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STRUCTURAL EVOLUTION OF MESOZOIC AND CENOZOIC BASINS IN WESTERN NORTH AMERICA

The North American segment of the Circum-Pacific east of the Aleutian Trench is distinguished from adjoining segments by the absence of an oceanic trench and the lack of recorded seismicity with focal depths exceeding 70 km. The continental margin seaward of the North American cordillera incorporates a series of irregularly distributed sedimentary basins of late Mesozoic and Cenozoic age. The structural development of these basins was determined by progressive, episodic subsidence accompanied by interbasin uplift.

The tectonic history, structural style, and distribution of the basins demonstrate the presence of a composite system of mobile vertical stress fields which has endured over the past 140 m.y. A superimposed horizontal stress field of uncertain duration is expressed tectonically by strike-slip faults and related structures. These data are incompatible with hypotheses of overriding lithospheric plates and their corollaries as currently proposed.

Basin development was initiated in late Mesozoic time, with the differentiation of the continental shelf into discrete basins of localized subsidence. Progressive deepening, migration, and reorientation of the basin axes, and local reversals of vertical movement combined to produce the present composite basins. Commonly structural relief of 20-30 km is developed on the steeper flanks and most basins contain sedimentary thicknesses in excess of 10 km. Internal structures, including basin-margin compressional features, reflect the dominant vertical stress system. Second-order drag folds are well developed in association with strike-slip fault systems.

The primary vertical tectonic forces which created these basins are still active, as evidenced by earthquake, geodetic, and geomorphic data.

A total of 21 billion bbl of oil and 37 trillion cu ft of gas has been discovered in seven of the 36 basins described. A practical understanding of the structural style and framework of these prime target areas is critical to the realization of the energy potential of the relatively untested basins of this province.

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OUTLINE OF PHANEROZOIC HISTORY OF AUSTRALIA AND SURROUNDING OCEANIC REGION

The Tasman orogenic zone has been accreted onto the eastern side of a Precambrian shield. A series of transitional to postorogenic basins has been superimposed.

The Tasman orogenic zone, which was mobile from the Cambrian to Early Cretaceous, underwent progressive but stepwise cratonization with culminations or orogenesis in the Early Ordovician, Middle Devonian, Early Permian, and Early Cretaceous. Relicts of this orogenic zone crop out in New Zealand and New Caledonia, and are inferred in the foundered continental blocks of the Queensland Plateau, Lord Howe Rise, Norfolk Ridge, and the Campbell Plateau. The Tasman orogenic zone, which differs considerably from the classic model, can be explained as an active plate boundary between a Paleopacific-oceanic plate and a continental plate. Mountain building has been of a modest scale and no great crustal thicknesses have been developed.

The sediment filling the various basins is mainly clastic and, in the early and middle Paleozoic at least, had a dominant southerly source. Antarctica must have been a significant contributor, and probably remained so even in the Permian and early Mesozoic when parts of the Eastern Highlands were elevated. In the early Paleozoic, carbonate rocks are more abundant in the north of the continent.

Fragmentation of this part of Gondwanaland commenced in the west in the Late Jurassic to Early Cretaceous with the formation of the Wharton basin. In the east, the Tasman Sea started to form in the Late Cretaceous. Although an incipient rift formed across southern Australia in the middle Mesozoic, new seafloor formation and northward motion of Australia away from Antarctica did not commence until the Paleocene. Eastward accretion of oceanic crust took place in the Eocene and Oligocene (the Coral Sea and the South Fiji basin). Some phases of plate convergence occurred in this time interval resulting in overthrusts of oceanic crust. Relocation of the Pacific plate boundary inside the Melanesian arcs resulted in some of the sea floor, formed during extension, being consumed from the Miocene onward. Folding and uplift in the island of New Guinea also took place in the later Tertiary and Quaternary.

The continental shelf and thick sediment accumulations in marginal basins have formed as a response to rifting.

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EFFECT OF SUBSURFACE WASTE-DISPOSAL PRACTICE ON GROUNDWATER RESOURCES IN HAWAIIAN ISLANDS

Geologic and hydrologic framework (K. J. Takasaki).—Groundwater in Hawaii is present as basal water, as dike-impounded water, and as perched water. Basal water, the fresher part of it forming a lens-shaped body floating on saline groundwater, is in dike-free volcanic rocks and in sedimentary rocks. Dike-impounded water is confined to volcanic rocks in eruptive zones. Perched water is present in all rocks and at all altitudes.

Most recharge to groundwater is in the wet interior mountains. Therefore, the main areas of recharge are upgradient from developed areas where most wastes are disposed of in the subsurface. This natural deterrent, by position of the recharge area, so far has kept much of the groundwater in its pristine quality state. Deterioration of the groundwater will increase as land developments encroach toward the recharge areas—the degree will depend greatly on the waste-disposal practices.

Most natural discharge of groundwater is along the shore, downgradient from disposal wells. The contamination of the beaches rather than of the water supply is the main concern regarding subsurface disposal of wastes in the low areas under present conditions.

Hydraulic, geochemical, and monitoring aspects of liquid-waste injection under Ghyben-Herzberg equilibrium conditions (F. L. Peterson).—The success of injection operations depends primarily on injection capacity and fate of the injected waste. To evaluate these factors properly an understanding must be obtained of local hydrogeologic conditions, hydrodynamics of injection under Ghyben-Herzberg lens conditions, and possible chemical and biologic effects. Hawaiian hydrogeology is understood fairly well, and where adequate information is not available, it usually is possible to collect these data by careful field investigation. Considerable information is available from other parts of the world on the hydrodynamics of waste-water injection. However, much of this information is not directly applicable to injection in the Hawaiian environment. Particularly troublesome are the complications caused by the extreme heterogeneity of Hawaiian receiving formations and Ghyben-Herzberg lens effects. Likewise, because chemical and biologic reactions depend on the nature of the injected waste, the receiving waters, and the receiving formations, many of the data collected elsewhere are not applicable in Hawaii.

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## HEAVY MINERAL SAND MINING IN AUSTRALIA

The history of the industry from its inception in 1934 at Byron Bay to the present-day projects at Eneabba is outlined. A brief description of the geologic environment and the exploration methods employed indicates how the commercial deposits are located and evaluated.

Mining methods and equipment used in the industry today including restoration of mined areas are discussed. General description of techniques and equipment used to separate the constituent minerals of the mine concentrate including transport, packaging of the finished products, and the quality control are given.

The unusual problems associated with mining in an area of high land-use demand are described as are those associated with establishing infrastructure in such remote areas as Eneabba. The contribution to the economy of the communities involved also is discussed.

The discussion of marketing includes the features associated with commodities of which Australia is practically the sole supplier (rutile and zircon), and the situation in which the competition is worldwide (ilmenite).

The many diverse uses of the products are discussed briefly as a background to the effects in the market on changing uses and changing demand.

The growing demand for the products, Australia's and the world's capacity to meet the demand, and the future of the industry are covered. The future of the individual minerals and their possible substitutes is discussed as a means of predicting the future of the heavy mineral sands industry in Australia.

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## RECENT KNOWLEDGE OF HYDROCARBON POTENTIALS IN SEDIMENTARY BASINS OF INDONESIA

Although the search for hydrocarbons in Indonesia was initiated about eight decades ago, exploration work is still at a high level.

Recent studies have resulted in a new understanding of the prolific Tertiary sedimentary basins and, especially, knowledge concerning offshore sedimentary basins has been updated significantly. More important, however, is the current knowledge on the mechanism of basin formation which seems to enhance the validity and applicability of the new global tectonics to the geology of Indonesia.

The Tertiary sedimentary basins in western Indonesia previously have been described as "idiogeosynclines," situated around the periphery of a supposed landmass of pre-Tertiary age (the Sunda Shelf). Recent exploration surveys and subsequent drilling have shown that the southern part of the Sunda Shelf actually consists of many sedimentary basins and intervening uplifts. Major faults are common throughout the area and clearly control the distribution and shapes of the basins. Block faulting appears to have broken up the periphery of the Sunda Shelf at the beginning of Tertiary time. The chief crude-oil production in western Indonesia is from the regressive and deeper transgressive sand series of Oligocene-Miocene age, except in East Kalimantan where producing zones range from Eocene to Pliocene age.

Prospects have changed considerably since oil and gas in economic amount have been proved within the interbedded limestone formation of Tertiary age and additional reserves are anticipated within stratigraphic traps.

Oil and gas discoveries within deltaic sandstones, notably in East Kalimantan, have upgraded significantly the onshore and offshore potentials of the area. Carbonate rocks are becoming a prime objective in the search for oil, especially in the East Java-Madura basinal area.

Although eastern Indonesia was chiefly the site of late Paleozoic and Mesozoic sedimentation, oil has been proved only within the strata of Tertiary age, notably in the Salawati basin. Of particular importance was the recognition of the tremendous potential that reefs, and in particular Tertiary reefs, possess as hydrocarbon reservoirs. A similar basin and environmental model is anticipated for the Bintuni basin.

Scientific cruises within the last five years have indicated the presence of several potential basinal areas between the Sunda Shelf and the Sahul Shelf.

The sedimentary basins in Indonesia can be classified into grabenlike basins, present foreland basins, and basins which are in front of the present magmatic arc.

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## GROUNDWATER POTENTIAL OF AREAS UNDERLAIN BY VOLCANICLASTIC ROCKS—EXAMPLES FROM INDONESIA

Many areas in Java, Indonesia, underlain by subrecent to recent volcaniclastic rocks support a dense population (more than 1,000 persons per sq km) and contain large reserves of groundwater. Three areas are typical: Yogyakarta in central Java, Bandung in west Java, and Nganjuk-Kertosono in east Java. The volcanic material is mostly of andesitic composition.

The Yogyakarta area is underlain by about 100 m of ash, sand, gravel, and coarser aggregate from the continuously active volcano Merapi. In the Bandung area, lavas and breccias from the ancient Sunda volcano are overlain by about 120 m of lahar from the volcano