tions. Groundwater in coastal sands and the alluvium of rivers was used during early settlement but the main growth in usage for irrigation has occurred in the last two decades. The Burdekin delta and the Hunter River Valley are examples. In the Murray-Darling River system interest in groundwater was intensified by waterlogging and soil salinization following intensive irrigation of the riverine plains. Water is supplied from the surface, although recent investigations have shown that many areas contain valuable groundwater resources. In the Perth basin, ground and surface water are being used for expanding urban and industrial developments. Groundwater sources now are incorporated into the existing system. Development of new mineral fields in northwest Australia has depended on availability of large quantities of water. Only groundwater has been able to provide the quantities needed.

To meet the increasing demands for water in Australia from new groundwater sources, the main requirement is for groundwater to be economically, socially, environmentally, and regionally managed.

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ARTIFICIAL RECHARGE OF GROUNDWATER IN BURDEKIN DELTA, AUSTRALIA

Aquifers underlying the 500-sq km onshore part of the Burdekin delta are among the most prolific in Australia. Annual production of groundwater is mainly for irrigation and is in excess of 300 x 10^6cu m. Aquifer thickness ranges from zero, where the river crosses a bedrock bar, to 100 m. Mean annual natural recharge has been estimated at 210 x 10^6 cu m, partly supplied by seasonal rains and partly by the Burdekin River which has a mean annual flow of 10 x 10^9 cu m and yet is ephemeral. The seasonal pattern of recharge and pronounced variations in recharge year by year cause major fluctuations in the water table. Intensive pumping has accentuated water-level fluctuations and in 1971, at the end of a dry period, the water table at one point was 5 m below sea level in an aquifer with a mean transmissivity of the order of 5,000 sq m/d. The short-term problem in the delta is severe fluctuation of groundwater levels and the long-term danger is saline intrusion.

Local water boards have been established to build and operate recharge works—the first such substantive program in Australia. Water is pumped from the river into a system of natural and artificial channels and increasing rates of recharge have been achieved. Pumpage for artificial recharge now is approaching 100 x 10^6 cu m/a. Suspended clay in the recharge water precludes recharge through bores without expensive pretreatment.

Since commencement of artificial recharge the system has had sharply declining recharge rates particularly in the constructed facilities, and in 1971 the Australian Water Resources Council initiated a group of research projects: (1) numerical modelling of the groundwater system, which will provide a basis for design and management of the expanding artificial-recharge program; (2) detailed study of unsaturated flow below the recharge pits, including the effects of low-permeability layers on and below the floor of the pits; (3) the role of the sediment load in the recharge waters in the reduction of recharge rates; and (4) study of the biota of the warm recharge waters and their effect in limiting recharge.

Other studies are in progress on tritium dating of the groundwater to assist in definition of the flow system and on the heterogeneity of the materials around the recharge pits.

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GEOLOGIC ASPECTS OF URANIUM RESOURCES OF JAPAN

Uranium minerals are widespread in Japan and are present in various geologic environments. Significant concentrations of the element, however, are limited to dissemination in Tertiary sedimentary rocks of small basins. These sedimentary rocks unconformably overlie Cretaceous to Paleogene granitic rocks.

The major sources of the uranium of the deposits are believed to be intergranular material and micas of the underlying granitic rocks. The average uranium content of the major granitic bodies in Japan ranges from 1.5 to 5.7 ppm, but in the vicinity of uranium concentration, can be as high as 11 ppm or more.

The uranium in the rocks probably was leached by circulating groundwater containing HCO_3^- ion. Waters within granitic masses contain up to 8.5 ppb uranium whereas the content in average groundwater is less than 0.05 ppb. The element was transported as uranyl bicarbonate complex and deposited under reducing conditions or was adsorbed in clays and other material.

The primary ore minerals of the Tono mine are uraninite and coffinite, but the major form of uranium concentration here seems to be adsorption in montmorillonite and other materials. Recently, interesting and unique deposits of the element, such as a very close association with zeolite and concentration in traps between reverse faults and the basement granite, were found in this mine.

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SUBMARINE PHOSPHORITE DEPOSITS OF CHATHAM RISE NEAR NEW ZEALAND

Phosphorite nodule deposits, with estimated total reserves in excess of 200 x 10^6 tons, are present at an average depth of 350 m on the crest of Chatham Rise. The rise is a broad submarine ridge about 130 km wide and 800 km long extending eastward from Banks Peninsula on the east coast of the South Island, New Zealand, to slightly beyond the Chatham Islands. Preliminary investigations based on exploratory dredging in 1968 by Global Marine Inc. suggest that 65 x 10^6 tons of the phosphorite deposits are concentrated sufficiently to be of economic interest. These more concentrated deposits are mainly in an area of about 4,600 sq km centered 560 km from the South Island.

The phosphate content of nodules ranges from 18.6 to 25.4% P_2O_5, averaging 21.5%. Satisfactory superphosphate can be made from the nodules after they are calcined to reduce their high calcite level. The reactivity of the nodules on the Hoffman and Breen phosphate ore solubility scale is a high 10. Pot trials with rye grass by the New Zealand Fertiliser Manufacturers' Research Assoc. Inc. confirmed the agronomic availability of the phosphate suggesting that finely ground Chatham Rise phosphorite also may have value as a direct-application fertilizer.

The deposits have considerable potential value for the agriculturally based economy of New Zealand, where per capita superphosphate consumption is the highest in the world. Current annual consumption of phosphate rock, wholly imported, is about 1,300,000 tons, increasing annually by about 10% during the past 20 years.

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PETROLEUM FIELDS WITH RESERVOIRS OF VOLCANIC ROCKS, JAPAN

As 5 of 11 major oil and gas fields found during the last 15 years in Japan have volcanic-rock reservoirs, they have become an important objective in exploration for petroleum in Japan.

Japanese oil and gas fields have been found mainly in Neogene sedimentary basins developed on the Japan Sea coast along the northern half of Honshu. The basin, associated with volcanic activities, began its depression in the early Miocene, but it continued to subside through the Neogene and Quaternary.

Volcanic-rock reservoirs are present in the formations deposited during middle Miocene and early Pliocene times. They are composed of liparitic, dacitic and/or andesitic lava, agglomerate, and tuff breccia. Intergranular pores are the main cause for the porosity, but many fractures and vugs which may provide additional porosity are known.

Volcanic-rock reservoirs have a rough resemblance to carbonate-rock reservoirs in that fractures and vugs are predominant, formation resistivity is higher than surrounding formations, and the shapes of volcanic-rock masses commonly show reeflike forms. However, the decisive difference between them is that whereas carbonate rocks may be source rocks as well as reservoir rocks, the volcanic rocks are not source rocks. Therefore it is important that, in searching for petroleum in volcanic-rock reservoirs, source rocks must be confirmed close by.

Each volcanic-rock reservoir has been found to have its own pore continuity. Some reservoirs have good pore continuity but others do not. For development of these fields, the difficulty is in determining the location and magnitude of the lava bodies which have good porosity.

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SEDIMENTARY BASINS AND PETROLEUM PROSPECTS OF ONSHORE AND OFFSHORE NEW ZEALAND

Petroleum prospects are virtually restricted to basins formed after the Early Cretaceous Rangitata orogeny. Basin sedimentary rocks are mainly Cenozoic, but some thick marine Cretaceous sequences fill the Northland and East Coast basins of the North Island; thinner, mainly terrestrial Cretaceous deposits are present in some areas in the northwest and southeast of the South Island. Subsiding epicontinental basins are offshore relatively close to land on the west coast, near 40°S, and the southeast coast, from 44° southward. Along the east coast of the North Island the late Cenozoic fold belt, which extends offshore about 100 km, comprises an extremely thick and continuous marine sequence of Aptian to Pleistocene age. Major areas of submarine rises and plateaus around New Zealand are foundered continental blocks with only thin or no sediment cover. Between these, several younger underdeformed sedimentary basins are below water more than 2,000 m deep and are filled with sedimentary deposits several kilometers thick.

Throughout New Zealand sedimentary rocks are commonly of a sand-shale facies with only minor carbonate rocks, mainly in the Oligocene, locally also in the Paleocene-Eocene, Miocene, and Plio-Pleistocene. Along the west side of both islands and east and south of the South Island, the characteristic assemblage is of the shale-sandstone-coal type. Potential reservoirs generally are in sandstones near the base of the sedimentary sequence (Late Cretaceous to early Tertiary), in an environment that was transitional between shallow-marine and nearshore deltaic to estuarine-brackish and nonmarine (sandstones in coal measures). Locally, reservoirs may be in limestones. Many unconformities, pinchouts, onlaps, and lateral facies changes throughout the Cenozoic sequence may have created favorable conditions for extensive stratigraphic traps, but exploration has been concentrated on structural traps.

Production has been obtained only in the Taranaki basin, both on- and offshore, with proved recoverable reserves of about 6 trillion cu ft of gas and 200 million bbl of condensate. Except for a minute percentage produced from Pliocene sandstones, all of the production is contained in the Eocene Kapuni Formation. Good shows in wells, and also surface seepages, are known from the east coast of the North Island and the west coast of the South Island. In Northland one recent well had strong gas shows, but over 9,000-ft thick allochthonous olistostrome deposits make this a particularly difficult area to explore. In general, the prospects are good for further discoveries, mainly offshore, and also on some land areas. The total area of prospective basins on land covers nearly 50,000 sq mi, whereas offshore the area, to an arbitrary depth limit of about 1,000 m, is roughly 100,000 sq mi. Only 10 wells have been drilled offshore, of which three established the large Maui gas field and one noncommercial well which tested oil at a rate of 600 bbl/d was abandoned.

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DRILLING AT SUMMIT OF KILAUEA VOLCANO

No abstract available.

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GEOTHERMAL POTENTIAL OF SOUTHWESTERN UNITED STATES

The area comprises the states of California, Nevada, Utah, Colorado, New Mexico, and Arizona, and includes the following geologic provinces: the Colorado Plateau, Basin and Range, Sierra Nevada and Southern California batholiths, Great Valley and Coast Ranges of California.

This area is considered favorable for geothermal prospecting because of the presence of many hot springs, Tertiary and especially Quaternary volcanism, and faulting of both block and rift type.

The Geysers field, the largest geothermal field in the world as well as the only commercially producing