

tion problem rather than in a demonstration of techniques as such.

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GEOLOGICAL SIGNIFICANCE OF THE MOONIE OIL FIELD DISCOVERY, QUEENSLAND, AUSTRALIA

The discovery of the first commercial oil field on the Continent of Australia has caused a reappraisal of the petroleum prospecting potential of all its sedimentary basins. The Moonie discovery marks the beginning of an oil-producing industry and has caused many preconceived ideas to be discarded. Geologically, Moonie is most significant for its contribution to the understanding of the structural and sedimentary history of the Surat Basin as related to the accumulation of petroleum.

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DEVONIAN GAS FIELDS IN BRITISH COLUMBIA: A PROBLEM IN CARBONATE PETROLOGY

Major gas fields in northeastern British Columbia occur in several types of carbonate porosity traps of Middle Devonian age. These traps consist of lenses or "patch reefs" in a shelf environment, barrier reef ridges at the shelf edge, and apparently of isolated bioherms in the adjacent basin. The reef limestones are primarily stromatoporoid rubble. These rocks apparently had high original porosity but, except where dolomitized, are now tightly cemented by calcite. As a result, production is now found only in the dolomitized rocks.

The process of dolomitization is controlled in part by original depositional environment, but is partly independent of original lithology. Exploration for these reservoirs, therefore, requires a study of both depositional environment and the cementation and dolomitization processes.

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ARAGONITE FORMATION BY MARINE BACTERIA

Investigations of the calcium and magnesium metabolism of marine deaminating bacteria have revealed that these organisms are capable of binding alkaline-earth elements on or in the cell wall-cell membrane complex. In actively metabolizing cells, both calcium and magnesium are taken up as a complex with amino acids and peptone. Accumulation of these elements during this phase, however, is low as compared with senescent cells. In the latter case, the accumulation of calcium is such that a given volume of cells will concentrate up to 100X the concentration in an equivalent volume of sea water. Magnesium concentration is considerably less and the element appears to be preferentially exchanged for calcium at this stage.

The nature of the binding force is under investigation but appears to be a type of weak adsorption or ion exchange. The bound calcium may be eluted from cells by washing with any isotonic fluid at pH's varying between 5 and 9.

Unwashed cells may be considered as small concentrated sources of calcium. When carbonate concentration becomes sufficiently high (from respired CO₂) and pH is at a minimum of 7.8 (from excretion of NH₃), calcium carbonate precipitation occurs as aragonite crystals with bacteria occupying the center of the crystal. It is surmised that bacteria may act as nuclei for precipitation in nature since the environ-

ment produced in static culture in the laboratory is similar to that produced in interstitial spaces of the upper sediments—only on a smaller scale. Examination of fine sediment particles from Florida Bay have revealed them to be largely calcified bacteria.

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DEVELOPMENT OF CLAY MINERAL ZONES DURING DELTAIC MIGRATION—SUBSURFACE RECENT SEDIMENTS OF THE EASTERN MISSISSIPPI DELTA AREA

Three clay mineral zones have been recognized in cores from Recent sediments of the eastern Mississippi Delta area. The clay mineral suite in each of these zones is apparently related to the position of the active Mississippi Delta as follows: (1) during the regressive St. Bernard subdelta phase, when the active delta was near the cored locations, the clay suite deposited there was richly montmorillonitic, reflecting the type of clay being carried by the ancestral Mississippi River; (2) when the site of active deltaic deposition shifted to the west of the cored locations (in this case down-current), local transgressive conditions developed in the eastern Delta area, and the clay included in the sediments deposited there was influenced more by local weathering conditions and by longshore drifting of clay from the more kaolinitic eastern Gulf province. These two factors probably combined to form the slightly more kaolinitic clay mineral suite which characterizes the two transgressive phases above and below the sediments of the St. Bernard subdelta.

Comparison of St. Bernard subdelta clays with modern Mississippi River clays indicates that the clay mineral suite carried by the river has become less montmorillonitic within the past few thousand years. The possibility exists, therefore, that the various ancient Mississippi River subdeltas may be characterized by distinctive clay mineral suites.

The highly montmorillonitic clay carried by the St. Bernard phase of the Mississippi River affected, to a limited degree, an area to the east outside of the actual subdelta. This wider distribution, which was probably brought about by oceanic, wind, and tidal currents, extends across some environmental boundaries and has allowed the Recent section of the Mississippi Sound to be subdivided and correlated chronologically with the St. Bernard subdelta section approximately 40 miles away.

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GEOLOGY AND PETROLEUM EXPLORATION, WESTERN ARCTIC ISLANDS

The Queen Elizabeth Islands of the Canadian Arctic Archipelago are considered most favorable for petroleum exploration. The main structural feature is the Parry Island fold belt extending from west-central Melville Island east across Bathurst and Cornwallis Islands and thence northeasterly. The strata within the fold belt are a conformable sequence of Ordovician to Upper Devonian beds. The age of folding is placed as Hercynian. South of the Parry Island fold belt, the Ordovician—Upper Devonian succession is essentially a gentle north-dipping homocline broken by the north-south-trending Boothia Arch on which movement occurred in late Silurian or early Devonian time (Caledonian). North of the fold belt, the Sverdrup Basin is a conformable sequence of Pennsylvanian to Tertiary strata. The sedimentary axis of the basin

extends from northern Melville Island northeasterly through the Ringnes Islands to Axel Heiberg Island—the deepest part of the basin. Tertiary tectonics produced north to northeasterly trending structures in the eastern part of the Sverdrup Basin. In the remaining part of the basin folding was less intense. Along the sedimentary axis of the basin are piercement domes and diapiric folds.

The Winter Harbour anticline was chosen as the location for the first well in the Arctic Islands because of its accessibility as well as favorable geology. In a normal season, ships could reach Winter Harbour from the east through Lancaster Sound. The structure is a large gentle fold on the southern side of the Parry Island fold belt. The primary objective was the Read Bay-Allen Bay reef carbonates of Silurian-Ordovician age.

Dome *et al.* Winter Harbour No. 1 was spudded September 10, 1961, and abandoned April 7, 1962, at depth of 12,543 feet. It drilled continuously throughout the winter without any serious difficulty. The section drilled consisted of an upper unit, 7,874 feet thick, of non-marine sandstone, siltstone and shale of Upper and Middle Devonian age. This was followed by 3,730 feet of Devonian-Silurian marine shale. The remaining 939 feet was Silurian and possibly Ordovician non-porous dolomite and anhydrite. The marine shale sequence represents, in part, the off-reef shale facies of the main objective, the Read Bay-Allen Bay carbonates. Although good reservoir beds were not encountered, the information obtained will assist greatly in future exploration of the Arctic Islands.

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CYCLICITY IN PERMIAN EVAPORITES OF WESTERN OKLAHOMA

Four major evaporite cycles are widely present in Lower and Middle Permian strata of western Oklahoma, interstratified with clastic sediments in a sequence 4,000 feet thick. Named in ascending order the Wellington, Cimarron, Blaine (including salt beds that underlie and overlie it in subsurface), and Cloud Chief, they consist almost exclusively of anhydrite and rock salt. Thin beds of dolomite also are present, but potassium salts have not been found. The cycles diminish in thickness upward, as the maximum thickness of the lower two is 1,000 feet, the next younger 600 feet, and the youngest 100 feet.

The uppermost or Cloud Chief evaporites consist only of massive anhydrite, whereas each of the three lower cycles is divisible into individual subcycles, some of them traceable over a region covering more than 15,000 square miles. A single cycle of anhydrite overlain by salt characterizes each of these major units. Dolomite-anhydrite couplets in the 150-foot thickness of the Blaine also are outstanding for their demonstrable continuity and persistence.

Continuous cores of nearly pure rock salt 150 feet thick in the lower part of the Cimarron evaporites likewise show pronounced cyclical development, which is reflected in the isomorphous potassium of the halite, in the range of 100 to 400 ppm. Low potassium values in the lower part of each cycle contrast with high values in the upper part, producing geochemical discontinuities at the boundaries between successive cycles.

Also arranged in cycles are the clastic sediments of the framework that contains the cyclic evaporites. Particularly conspicuous are the interbedded brownish red and gray-green shales of the Flowerpot, Blaine, and

Dog Creek Formations. Investigations of boron thus far suggest a marine environment for the shales, and in one area the highest shale values (250 ppm boron) are associated with as much as 4.5 per cent copper.

Cyclicality in the Permian evaporites of Oklahoma are related to cyclical changes in environment during the progressive sinking of a sedimentary basin. Roles are doubtless played by tectonism and climate, in forming the basin itself as well as in producing the aridity necessary for the precipitation of evaporites, but eustatic change in level of the sea must also have been a prominent factor during Early Permian time, when continental glaciation in the southern hemisphere was repeatedly raising and lowering the sea.

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FIELD RESULTS OBTAINED WITH THE VIBROSEIS® METHOD

The VIBROSEIS® method has been used by Seismograph Service Corporation and its subsidiaries in field operations for about two years. Three U.S.A. crews are currently operating. Much of the domestic work has been for clients who wanted to see what the method would do in certain problem areas, either for planning further exploration programs or for evaluation before committing themselves for foreign contracts.

Field operations were commenced in Libya in the fall of 1961 and have continued there since that time. Crews have also operated or are operating in Ireland, France, Belgium, and England. Field results from some of these countries are illustrated together with a discussion of field techniques employed, quality of records and production figures. The paper is illustrated by examples of records obtained in different areas and under different surface and geological conditions.

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PHOTO GEOLOGY AND GEOPHYSICS

There are many ways in which surface geology can be useful to geophysics, not only as an aid to structural interpretation, but in refining the accuracy and improving the efficiency of geophysical methods. That the vast majority of geophysical work has been accomplished in relative ignorance of the surface geology is an established fact. Many specific examples of misinterpretation and waste can be attributed to a lack of consideration of surface geology. Because of this historical lack of surface geologic consideration, there is a large reservoir of data which can be high-graded and refined very inexpensively. Photogeology is by far the most rapid, effective and inexpensive way to do surface geology.

Possibly the geophysical tool most critically affected by the surface geology is gravity. From Newton's First Inverse-Square Law it follows that density changes closest to the gravimeter, affect it most critically. Four practical ways in which gravity data can be refined by coordination with photogeology are cited, along with slides to demonstrate the problems. Inexpensive coordination procedures are described. In many areas they represent an easy improvement and an effective prospecting program.

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