Additive processes include the mechanical deposition of secondarily infiltered detritus; the precipitation of calcite in fibrous or bladed, turbid cavity linings; and precipitation of calcite in coarse, clear mosaics.

Subtractive processes involve removal of aragonite in solution and, during dolomitization, similar leaching of low-magnesium calcite.

Reconstitution includes (1) recrystallization or aragonite to calcite, and (2) reorganization of the unstable, high-magnesium calcite. This reorganization can go in two directions: to stable, low-magnesium calcite by the "purging" of excess magnesium (which is probably generally removed in solution); or to dolomite, by similar purging of excess calcium. In either process, attendant recrystallization leads to loss of microstructure and the obscuring of surface boundaries; if both framework and matrix are affected, they may blend into a homogeneous rock fabric which bears little resemblance to the original sediment.

The various diagenetic steps are illustrated by examples from the Permian Capitan reef, from the Triassic reefs of the Alps, and from the Cenozoic of Florida.

Cost of Finding Oil

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A plan is outlined for calculating the industry's cost of finding oil in an area. This is possible by an exhaustive examination of published data from which finding expenditures are calculated. Total dollar expenditures are related to barrels found. Barrels found are current reserve estimates of reservoirs discovered, corrected for future revisions and secondary recovery changes.

Comparisons of finding costs are made for three areas covering most of the interior United States. The areas are Kansas and Oklahoma, the Illinois-Michigan basin area, and the Rocky Mountains.

In the period 1942 through 1957, the cost of the average barrel found in the Rocky Mountains was $0.41. This is comparable with $0.57 and $0.70 per net barrel for Kansas-Oklahoma and the Illinois-Michigan basin areas.

Costs of finding oil are increasing in most areas of the United States at a faster rate than development and producing costs; they are expected to increase in the future. To find more oil at less cost is the challenge to the petroleum geologist.

Techniques of Prediction with Applications to Petroleum Industry

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The art of soothsaying, although probably not the world's oldest profession, can certainly offer strong claims for being its second oldest. Non-scientific soothsaying is based largely on astute guesswork and ambiguous statement, whereas scientific soothsaying, or prediction, consists in trying to foretell as accurately as possible the future evolution of a material system in terms of a knowledge of its mechanism, its past history, and of the physical data on which its evolution depends.

According to the second law of thermodynamics, the evolution of any material system, when viewed in its entirety, must be unidirectional and irreversible; hence, incapable of repetition. However, the evolution of some systems can be resolved into cyclical and non-cyclical components—the swinging pendulum versus the falling weight of a clock, for example. If the mechanism is understood, the prediction of a cyclical phenomenon for limited periods of time can often be made with great precision.

The production of oil and gas, although slightly affected by a minor superposed seasonal cycle, is predominantly an example of a non-cyclical phenomenon. The number of oil or gas pools still to be discovered continuously diminishes; the mean depth and cost of wells continuously increase; and the production of power from uranium (and probably later from deuterium also) is well advanced on its inexorable ascendancy.

Current industry data suggest that the total initial quantity of crude oil (whether producible or not) accumulated in reservoirs in the United States, excluding Alaska, was of the order of 350–500 billion barrels, and that the initial reserves of natural gas were about 800–1,200 trillion cubic feet. American Petroleum Institute data indicate that since 1925 production of crude oil in the United States has lagged discovery and development by the nearly constant amount of 10–11 years. Discovery is thus a preview of production by approximately this period. The peak of discovery and development of crude oil occurred about 1952–1953, which suggests that the peak of production should occur 10–11 years later. The peak of estimated proved reserves, which should occur about halfway between the peaks of discovery and production, actually was reached late in 1957.

Comparable data for natural gas suggest that the peak of production should not be reached before 1970, or shortly thereafter.

Conservation of Oil and Gas and Its Relation to Exploration

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If this nation is to possess the domestic recoverable reserves of petroleum so vital to our future security and progress, improved conservation practices and increased exploratory efforts are essential. These two important phases of petroleum activity, frequently considered independent or competitive, are significantly interrelated.

The considerable progress in petroleum conservation during the last two decades presents an interesting record and one of which the industry can be proud; but, if in the future, the new miscible phase drive and thermal recovery processes are applied where feasible and the conventional but improved gas drive and water flood techniques adopted elsewhere, it would appear that the industry stands on the threshold of the greatest improvement in oil recovery in its entire history. Additionally, the flaring of gas well or casinghead gas can be reduced to an insignificant percentage of the total volume produced.

Such improved conservation can conceivably have negative as well as positive effects on exploration. The negative effects which have been suggested, if they become significant, can be minimized by wise regulation. On the positive side, such improved recovery can make additional funds available for exploration from the petroleum industry itself and attract more outside venture capital.

Experience with the new recovery techniques may convincingly demonstrate that wider spacing than presently practiced can be followed with greater rather than reduced ultimate recovery, thereby offsetting the present trend of rapidly rising development costs. But if this goal is to be attained, development wells must be located with regard to structural position and recovery mechanism involved rather than distance from property lines and offset obligations. Wells should be initially completed in a manner suitable for ultimate secondary recovery operations without redrilling or expensive reworking.

Proof of past economic waste, tolerated by the industry and ignored by some regulatory bodies on the assumption that they are precluded by statute from considering it, is found in many of the modern efficient pressure maintenance operations, wherein up to half of the wells are shut in, either because they are not needed or are improperly located and completed.

Survival of the domestic petroleum industry and preservation of national security require that the exploration-development geologist and the conservation reservoir engineer work together more closely in the future in order to attain maximum efficiency of recovery and minimize such economic waste. In this effort they will require and deserve the support and cooperation of management, landmen, attorneys, land and royalty owners, and legislative and regulatory bodies.