Core Slabbing For Reservoir Analysis

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To achieve maximum recovery from an oil field, especially when using supplemental recovery methods, the nature of the reservoir must be known in the greatest detail possible. In the past, several large reservoirs have been subjected to waterflooding under the assumption that they were "blanket" accumulations. When later detailed geologic analyses have been forced by a multitude of operational problems, the reservoirs were found to possess significant lateral discontinuity and/or marked permeability variations, requiring radical changes in the injection patterns. It is therefore important to reinforce the analysis of petrophysical and volumetric parameters of a reservoir with a sound geologic interpretation of the productive interval. This can best be accomplished by detailed examination of cores followed by careful correlation with well logs. Most of the following discussion will center on carbonate areas based partly on the author's experience in the Permian Basin, but also on the fact that carbonate reservoirs exhibit more complex porosity — permeability relationships than do sandstone reservoirs.

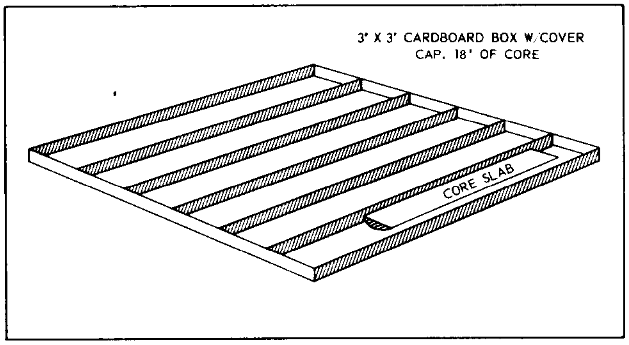

FIGURE 1

SLABBED CORE BOX

Cores are slabbed simply by cutting a 3/4-inch thick vertical slice from top to bottom. The remnants are stored for possible special analyses based on interpretation of the slabs. The slabbed core is marked and placed in cardboard boxes which hold up to 18 feet (Fig. 1). The boxes can then be conveniently laid out on the floor or a long table for examination. The slabs are swabbed with mineral oil to bring out the natural features, leaving a strip along one side for observation of porosity and testing with acid (Fig. 2).

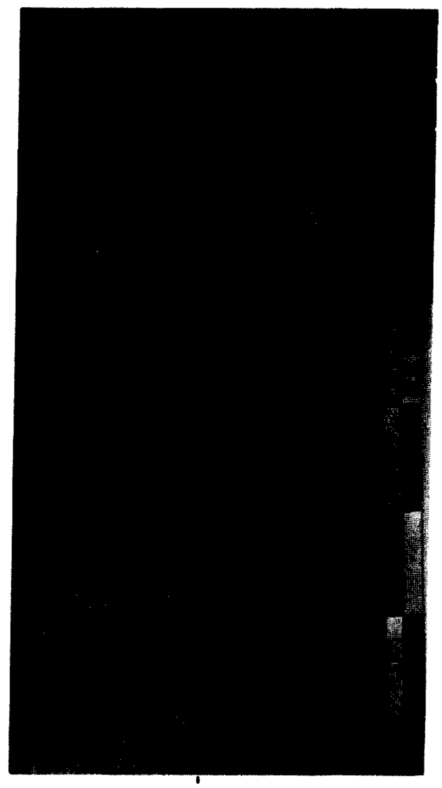

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FIGURE 2

SLABBED CORE PREPARED FOR EXAMINATION

In the course of recent progress in relating the features in ancient sedimentary rocks to those of recent depositional environments, it has been observed that megascopic features such as bedding, burrowing, and prelithification deformation, which can only be seen in cores, are important indicators of depositional environments. The original conditions of deposition control to a substantial degree the type and distribution

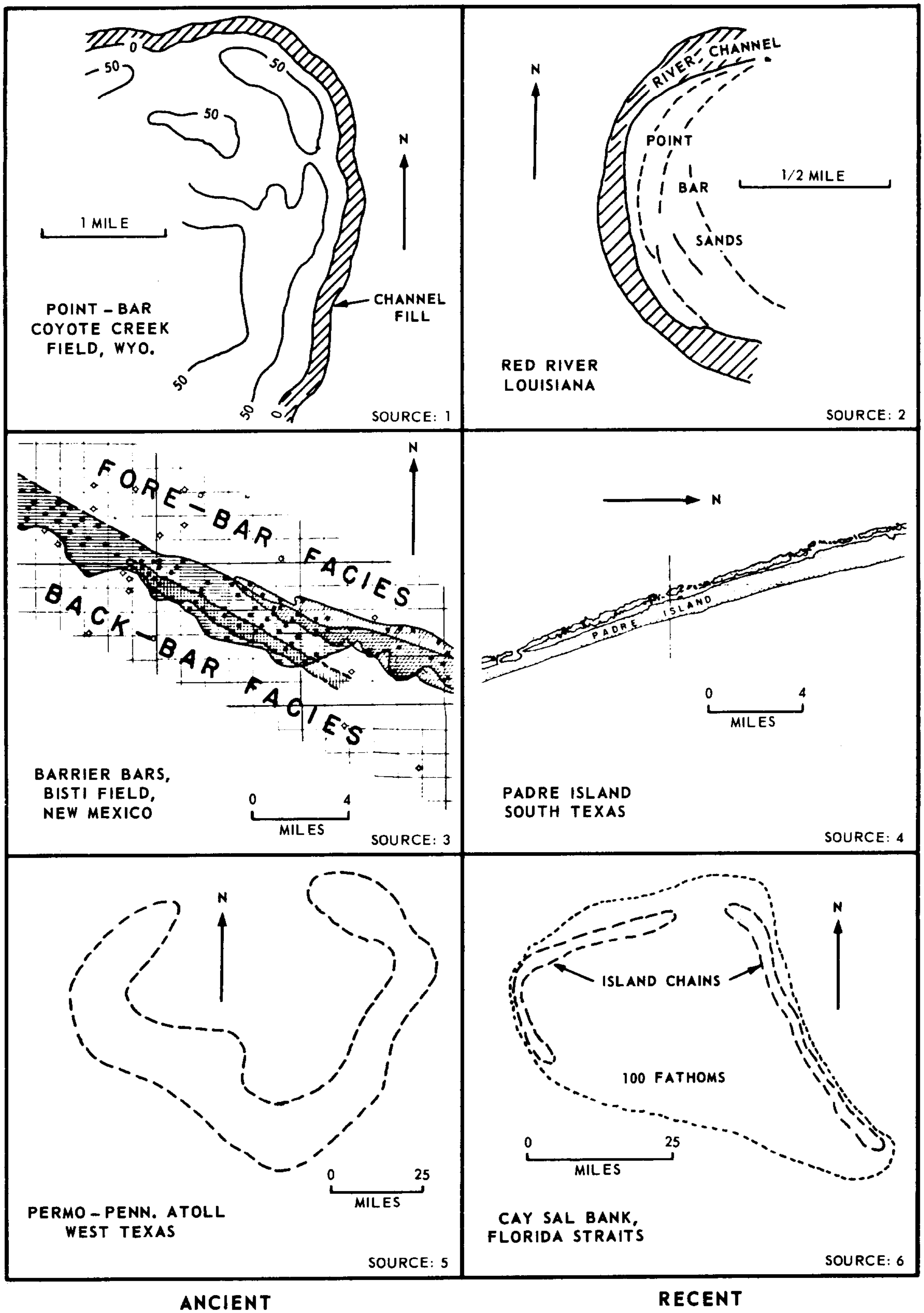

FIGURE 3

COMPARISON OF RESERVOIRS WITH RECENT SEDIMENTARY ENVIRONMENTS of porosity that ultimately occupies the lithified sediment. However, the ultimate shape of the sedimentary body may be altered by erosion and reworking under different environments, and porosity patterns normally associated with the particular sediment type may be greatly altered by the diagenetic effects of compaction, cementation, solution, and dolomitization. However, diagenetic effects on the potential reservoir rock often fail to completely override the original porosity patterns and will occasionally even enhance them or create porosity in a sediment that would otherwise be ultimately nonporous. In spite of the post-depositional changes that might be imposed upon sediments, reservoir geometry frequently conforms to the configuration associated with modern analogs of similar depositional environments (Fig. 3).

Porosity may occur in a variety of forms, especially in carbonate rocks. Basically the following pore types have been commonly observed; interparticle, intercrystalline, intraparticle, leached particle, and fracture (Fig. 4). Only interparticle and intercrystalline porosity are consistently permeable. Sandstone reservoirs are developed almost solely by interparticle porosity. However, carbonates may contain all of the listed varieties in various combinations. Carbonate sands may also possess mostly interparticle porosity, but often they become completely cemented, by virtue of their high initial permeability to solutions supersaturated with respect to calcium carbonate and/or sulfate. Intraparticle porosity is the primary pore network of skeletal remains such as the interior chambers of fusulinids and gastropods. Leached particle porosity is the "moldic" pore network remaining after fossils, pellets, oolites, or other grains have been dissolved. It may develop in muddy sediments or coarse mud-free sands. Fracture porosity may originate either by tectonic deformation or by dessication and slumping during subaerial exposure before complete lithification. In the latter case, permeability may be greatly enhanced by the leaching effects of ground water. Intercrystalline porosity is basically similar to interparticle porosity with respect to pore geometry. However, it is a secondary feature which most commonly develops as a result of dolomitization, and frequently occurs in a rock that was originally nonpermeable muddy sediment. When intraparticle and leached particle porosity occur to the exclusion of other types, the rock is for all practical purposes nonpermeable. This is frequently the case and in estimating net pay, it should be determined whether or not these more conspicuous pore types are accompanied by adequate interparticle and/or intercrystalline porosity. Occasionally intercrystalline porosity may be so fine as to be almost chalky in texture. Under these conditions, permeability may be very low.

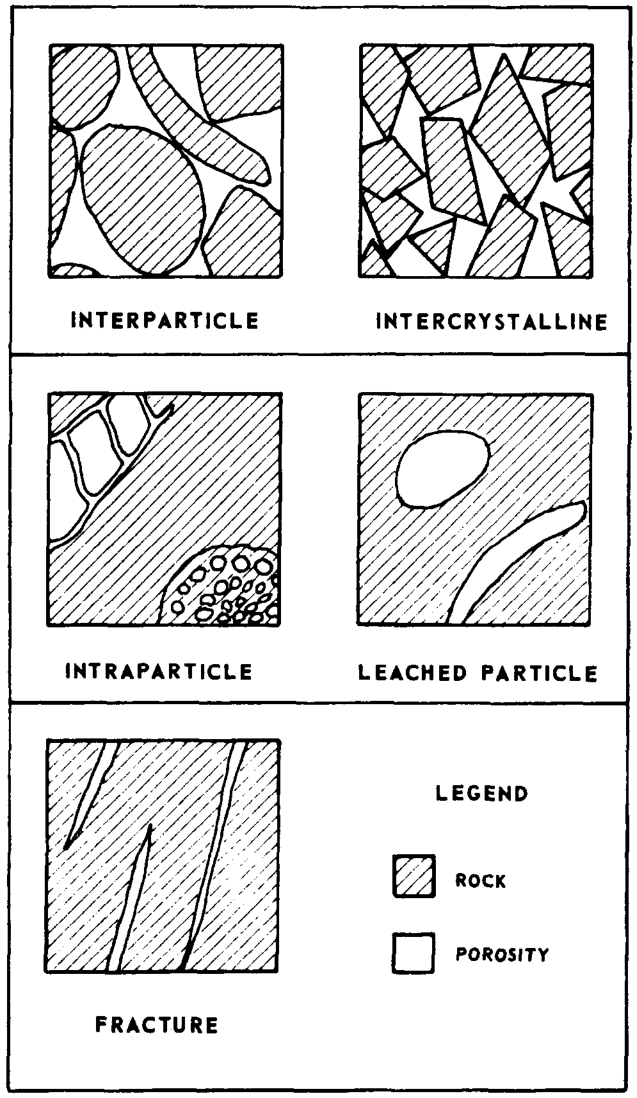

FIGURE 4

POROSITY TYPES

A subsurface example of complex porosity development is the Henshaw Wolfcamp field in Eddy County, New Mexico. Porosity is developed in five different carbonate sediment types, with average values between six and nine per cent. They consist of (1) fine-grained skeletal sand with mostly leached fossil and intrafossil porosity, (2) oolite sand with leached particle (oomoldic) porosity, (3) slightly fractured carbonate mud with, patchy occurrences of skeletal debris, (4) carbonate mud with patchy extremely fine intercrystalline porosity, and (5) muddy to grainy rock with patchy intercrystalline porosity in dolomite. The only one of these rock types that is economically productive is the slightly fractured muddy sediment, which also possesses the lowest average porosity of six per cent. Although the core analysis produced very erratic permeability values, these intervals are highly permeable by virtue of the connected leached fracture system.

Another example of permeability variations within a reservoir occurs within the Wasson San Andres field, in Gaines and Yoakum Counties, Texas. The San Andres reservoir is 200-300 feet of thin-bedded porous dolomite which had been under flood for about four years. A geologic study was undertaken in 1966 to aid in planning an expanded injection system. The interval of highest productivity consists of poorly sorted carbonate sand with interparticle, intercrystalline and leached fossil porosity. Porosity values range between 10 and 20 per cent and permeability from 10 to 50 millidarcies. In the same reservoir is very fine crystalline rock with similar porosity but with permeability seldom over five millidarcies. Recognition of this rock in cores as a distinctive sediment made possible an estimate of its regional extent. Wells containing both of these zones were equipped with downhole flow regulators to insure adequate injection rates into the less permeable rock. Core examination also revealed zones with porosity of up to ten per cent with no measurable permeability. These were carbonate muds with only leached fossil porosity, and were scattered throughout the reservoir. In addition to identification of distinct porous types, the core study revealed the reservoir to be much more thin-bedded and discontinuous in terms of permeable rock than was previously suspected. The peripheral flood pattern in use at the time would ultimately have recovered only a small fraction of the secondary oil reserves.

It is seldom economically feasible to core every well in a field, and in old fields being considered for their secondary recovery potential, the available core data is often meager and may be entirely lacking. However, in new fields some cores should be obtained as soon as possible after discovery in order to determine the nature of the productive rock and to provide a basis for more effective development of the field. This early approach also establishes a foundation of knowledge which is vital to the efficient design of later waterfloods. In old fields being subjected to supplemental recovery operations, a sparsity of reservoir rock data may be partly made up during the re-drilling, deepening, and infilling operations that are often necessary.

The potential complexity of porosity development and distribution in hydrocarbon reservoirs demands that all available data be carefully scrutinized to insure maximum recovery of the enclosed fluids. The great strides made recently in the interpretation of modern sedimentary environments have led to greater understanding of the ancient sites of deposition and their relationships to the occurrence of hydrocarbons. Further, in addition to improving the resolution of regional interpretation, it is now possible to apply these relationships to the scale of individual fields. Therefore, to cover the many facets of porosity development and distribution, especially in carbonates, a "slabbed-core view" of the reservoir must be considered an essential part of an adequate geologic analysis. By thorough examination of the slabbed core, the sequence of deposition and associated vertical distribution of permeable porosity can be determined. Relating the permeable zones to depositional environment, and both to log response, will yield the best possible fieldwide interpretation of reservoir geometry.

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