detail for the particular stage of exploration and production. The type and amount of data required for a proper reservoir description are diverse, from several disciplines, and depend upon the stage of the reservoir's exploration and production cycle. The cycle is viewed as a continuous series of overlapping stages from discovery, through appraisal, planning, development, and reservoir management. The concepts and data needed to define and exploit reservoirs become more complex and quantitative as the production becomes more mature. Concepts, data, and models developed during the production phases, when reapplied to exploration, provide important guides to the explorationists for evaluating trapping elements, seals, reservoir quality, and risks in basin and wildcat evaluation.

When one looks at the question "When is a reservoir description needed?" the answer is simple. The need starts once a discovery is made and the discovery is being appraised as to the best estimates of hydrocarbon in place, recoverable reserves, and production rates. As a field or reservoir goes through its typical cycle of discovery, appraisal, planning, development, and reservoir management, a more complete description is both necessary and possible.

A critical first step in the reservoir description process is recognizing any correlative reservoir subzones or layers and any intervening dense, impermeable, or low-permeability strata. Knowledge of the depositional/diagenetic processes controlling reservoir and nonreservoir rock is essential to determine one's ability and degree of confidence in correlating these units. Seismic sequence, lithologic, and fluid analyses, and well-documented outcrop studies can add significantly in establishing interwell correlations. Recognizing and mapping all vertical or horizontal fluid-flow barriers, as well as theif zones or zones of unusual permeability contrast and faults, are critically important to all recovery processes. Flow-test data dovetailed with knowledge of the reservoir and nonreservoir framework based on geology/geophysics provide the best reservoir description of continuity/discontinuity.

Structural and stratigraphic maps, cross sections, and fence-and-block diagrams convey the three-dimensional geometry, distribution, and continuity of the reservoir, nonreservoir, and aquifer. A variety of computer programs aid in preparing these illustrations. Isopach maps without the accompanying detail correlation sections have been the pitfall of many projects. Net-pay isopach maps drawn to provide the basis for determining hydrocarbons in place have tricked many petroleum engineers into believing a reservoir is more continuous, more homogeneous, and less stratified than it actually is.

The importance of discontinuous shale barriers of limited areal extent on coning and the drainage of oil from a gas-invaded area illustrate the need to include shale dimensions in many types of recovery calculations and predictions.

The recognition, selection, and description of reservoir units or layers, and the communication of this picture to the petroleum engineers are fundamental contributions and responsibilities of the geologists/geophysicists. A coordinated data-acquisition program can greatly improve the probabilities of correct assessments in discovery, appraisal, planning, development, and reservoir management.

A good reservoir description designed to answer key reservoir performance questions is a fundamental tool. The incremental well costs to obtain adequate data for a reservoir description are very small compared with its value in improved recovery. The time to complete a reservoir description is before significant expenditures are planned and spent. Mathematical models and simulation of reservoir performance that do not have a realistic reservoir rock–fluid description are interesting, but are expensive exercises that potentially lead to inappropriate or incorrect management decisions.

In exploration ventures, detailed reservoir-description studies made during the production stages provide the critical data needed by the explorationist to estimate reservoir and seal quality from seismic, well logs, and samples.

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Laramide Basin Subsidence and Basement Uplift in Rocky Mountain Foreland of Wyoming

The basement-cored ranges of the Rocky Mountain foreland have attracted geologists' attention since the time of early exploration of the western United States and have been the subject of numerous structural studies since early in this century. Until the advent of hydrocarbon exploration, however, the basins got little attention. Even today, our knowledge of the uplifts far exceeds that concerning basin genesis. The most recent work shows that uplift of the ranges and subsidence of the basins are intimately related and suggests that viewing the subsidence-uplift couple as the unit of deformation in the foreland is most likely to lead to a better understanding of the timing and kinematics of the Laramide orogeny.

The Wind River Range in western Wyoming is an excellent natural laboratory for studying a Laramide uplift. A COCORP seismic profile provides geometric control, and tectogenic sediments record the history of uplift and erosion. The stratigraphy and provenance of these sediments indicate a complex Laramide and later tectonic history for the range and identify the timing and position of individual faulting events. These events are (1) main uplift of the range by motion on the Wind River fault and the formation of an erosion surface of low relief (Late Cretaceous through early Eocene), (2) elevation of this erosion surface as much as 3,000 ft (914 m) by motion on imbricates and associated tear faults in the hanging wall of the Wind River fault (end of early Eocene), (3) collapse of the tip of the Wind River fault into sedimentary fill of the Green River basin (between middle Eocene and late Oligocene), (4) uplift of the crest of the range by nearly 3,000 ft (914 m) forming the highest peaks in the Wyoming foreland (late Oligocene), and (5) collapse of the southern part of the range along normal faults (Neogene).

Basin modeling in two distinctly different structural settings points to several driving mechanisms for subsidence in Laramide basins. Subsidence of the northern Green River basin was a flexural response to sediment loading and the intracrustal and topographic loads imposed by uplift of the adjacent Wind River Range. In contrast, the Hanna basin subsided when a rigid crustal block rotated downward as the Rawlins uplift was raised on the other end. Both flexure and rigid block rotation likely are operative to varying degrees in most Laramide basins.

A schematic cross section through central Wyoming suggests that deep basins, where both rotation and tectonic loading are important, support structurally low ranges. Where rotation is not an important component of subsidence, basins support structurally high ranges. Furthermore, because basin subsidence and basement uplift are genetically linked, both indicate the timing of Laramide deformation.

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Pore Throats to Plate Margins: An Integrated Approach to Basin Analysis

The basin analysis approach to modeling sedimentary basins affords the opportunity to view ore deposits or accumulations of fossil fuels in the context of the evolution of the entire basin. Integration of data from diverse specialties is now widely practiced, and the multidisciplinary approach to the study of basins has greatly enhanced our ability to understand and to predict the occurrence and distribution of economically important commodities.

A significant outgrowth of the basin analysis technique is a more rigorous testing of scientific paradigms. Feedback from diverse specialties provides numerous constraints so that no conclusion can be drawn about one aspect of a basin's history without affecting the interpretation of other aspects. Thus, when a conclusion from one line of evidence is at variance with a conclusion drawn from several other lines of evidence, it is necessary to challenge the assumptions that led to the different conclusions. Challenging such assumptions usually involves examining cherished theories or paradigms. Our general reluctance to discard prevailing theories reflects our heavy reliance on useful rules of thumb; without them we could not begin to interpret the geologic past. This reluctance to relinquish useful theories is more easily overcome when several lines of evidence point us toward new concepts that have exciting implications of their own. Basin analysis, by its very nature, pushes us toward new perspectives and thus serves to promote new discoveries in geoscience.

A case study in the San Juan basin of New Mexico serves as an example of the basin analysis approach to a geologic problem and serves to illustrate that sometimes answers to questions that were never posed are the most significant (and surprising) outcome of the basin-analysis approach. The original goal of the San Juan basin study was to develop a genetic model for sandstone-type uranium deposits in the Jurassic Morrison Formation. Tectonic, geophysical, sedimentologic, petro-

graphic, hydrologic, and geochemical (organic and inorganic) studies were drawn together so that mineralization could be evaluated as one diagenetic event in the context of the entire depositional, structural, and diagenetic framework. The result was not only a model for uranium mineralization but also the development of several new concepts, many of them unrelated to the original problem. Spin-offs from the original study include significant advances in fields as diverse as hydrology, coal geology, saline, alkaline-lake geochemistry, and clay mineralogy. It was possible to document, for instance, that authigenic illite formed at near-surface conditions in the absence of the elevated temperatures commonly thought to be required. This finding limits the use of illite as a geothermometer and makes it of considerable interest in petroleum geology.

The integrative nature of the basin analysis approach allows a synoptic rather than a myopic view of specific geology problems. The approach can be applied to any geologic problem and will continue to lead us away from current paradigms as multiple lines of evidence force us to question our most cherished beliefs. Most certainly we will continue to learn surprising answers to questions we forgot to ask.

AAPG RESEARCH CONFERENCE

Petroleum Potential of Sedimentary Basins—Methods, Techniques, and Approaches
Leesburg, Virginia
April 26-29, 1988

NAHUM SCHNEIDERMANN[1] and CHARLES MASTERS[2]
Co-Conveners

The conference, held at the Xerox training center, was convened with the idea of bringing together workers in basin assessment through geological analogy, workers doing computer modeling by deterministic approaches, geologic statisticians, and representatives of exploration management. The conference was attended by 103 invited participants, 40 of whom represented 17 countries outside the United States. This international group represented 14 major oil companies, nine national oil companies, five national geological surveys and laboratories, and 13 research institutes and laboratories.

The conference was based on topical keynote addresses covering (1) basin development, classification, and play identification, (2) source rock occurrence and maturation, (3) oil generation, migration, and retention, (4) deterministic modeling of basin processes, and (5) statistical and analog methods of assessing petroleum occurrence by prospect, by play, and by basin. Free-form discussion was planned for and successfully encouraged both in conference and leisure time. In the program conclusion, three senior exploration management officials expressed their perspectives on the conference developments followed by spirited discussion from the conference audience. Details of some of the conference topics are as follows.

Source Rock Occurrence and Maturation. Various speakers clearly brought out the importance of recognizing and quantifying the geologic, biologic, and chemical controls on the occurrence of petroleum and its precursor rocks. Prolific source rocks were demonstrated to be unevenly distributed around the world and through geologic time; methods were presented to qualify the source rock potential by basin, considering richness, thickness, and stratigraphic distribution, to arrive at measured evaluations of the possible basin charge. These kinds of regional understandings are extremely important to basin petroleum evaluations and provide the context for play and prospect assessment.

Oil Generation, Migration, and Retention. Although much is now understood about these three essential elements in oil occurrence equations, clearly much remains to be learned. In general, the geochemists confirm an oil generating ability in nature far in excess of our ability to map its path or place limits to its migration. Continued efforts to quantify the physico-chemical aspects of oil maturation and expulsion are necessary to improve our deterministic predictions of fluid amounts and composition and of the timing of migration. Possible mechanisms of primary migration are generally known, but we do not understand which of these mechanisms was dominant in a particular geologic environment. We know the broad geologic parameters that control the secondary migration and sealing of the fluid flow. Random fracturing and other hydrodynamic windows in seals, however, introduce unpredictable avenues of vertical migration that can be recognized by biomarker determinations and/or pressure anomalies; the modeling of such migration pathways is not now possible. Migration losses are also beyond the realm of direct deterministic quantification.

Deterministic Modeling of Basin Processes. The physico-chemical modeling of certain basin processes was shown to be satisfactorily conducted in either two or three dimensions over time. The exercise is valuable in forcing rigor of data development but it suffers from the axiom, first expressed by G. K. Gilbert, that a given geologic configuration can be achieved by more than one sequence of processes. Furthermore, and more importantly, as an assessment procedure, modeling is limited by our inability to physically control the migration and reservoir/entrapment variables. Statistical means were demonstrated to circumvent the random character of migration paths and character of reservoir development in order to predict charge volume in undrilled prospects.

Statistical and Analog Methods of Assessing Petroleum Occurrence by Prospect, by Play, and by Basin. The varied presentations suggest that there is no unique way to conduct the exercises. Rather, there are many ways depending on the purpose and data available to the assessor. In all modes of assessment, the investigator is trying to use, statistically, the experience gained under analog conditions to demonstrate the probability of petroleum occurrence. The exercise is valid to the extent that the analogs are rational. Some highly sophisticated systems of assessment develop statistical measures of analog element validity. Though the basic exploration/assessment element in everyone's mind is the play, there is little in the way of systematic understanding of what is meant by a play nor little actually published in the way of play models. The significance of precision in play understanding lies in assigning risks to elements of the proposed play extensions. The assignment of risk, a major part of assessment methodology, remains difficult. Because no

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