McElroy Field: Development of a Dolomite Reservoir, Permian Basin of West Texas*

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INTRODUCTION

McElroy Field, located in West Texas along the boundary between Crane and Upton Counties, lies along the eastern edge of the Central Basin Platform. Production is from the Permian-age Grayburg Formation, a thick sequence of anhydritic dolostones and siltstones. These sediments have undergone a complex history of sedimentation and diagenesis that ultimately controlled the relative productivity of the reservoir.

The structure of the reservoir in McElroy Field is a north-south trending asymmetrical anticline with a steep east flank and gently-dipping west flank (Fig. 1). A stratigraphic permeability barrier defines the western boundary of the field, whereas the eastern edge of the reservoir is limited by a gradual reduction of permeability coupled with an increase in water saturation.

Wells in McElroy Field range in depth from 3,000 to 4,100 ft and produce from a gross section that averages 275 ft in thickness. Average reservoir porosity is 14 percent, with permeability ranging from 0.01 to 2000 md. Reservoir energy is provided by a solution gas-drive mechanism. Total areal extent of the field is in excess of 50 square miles, of which a 35 square mile portion is 100 percent Chevron owned and

operated (Fig. 2). Discovery of the field in 1926 has been followed by continuous development that now
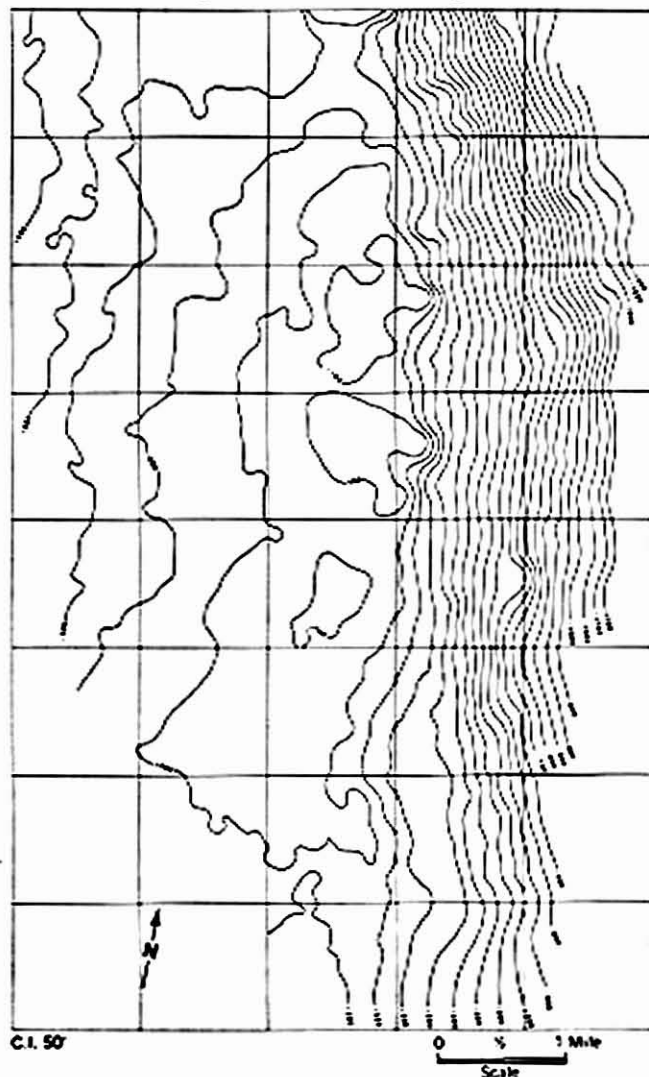

Figure 1. Structure map of a marker within the upper portion of the Grayburg Formation over the McElroy Field illustrates the strongly asymmetrical nature of the anticline. The map reflects values that are related to a sea-level datum. Geologic data indicate the timing of the folding is post-Grayburg Permian in age.

includes more than 1800 wells. Secondary recovery processing of the reservoir began in 1960. Current plans include large-scale alteration of the water–flooding program as well as polymer and pilot CO_2 injection projects.

STRATIGRAPHY AND FACIES

Stratigraphic relations within McElroy Field have been discussed by Longacre (1980, 1983) and Harris and others (1984). Prior to deposition of the Grayburg Formation, a regression exposed the under-lying San Andres carbonate platform. During subse-quent reflooding of the platform, a shallowing upward sequence of Grayburg carbonate shelf deposits accumulated (Figs. 3 and 4). Open-shelf deposits at the base of the sequence are dolowackestones and packstones that are commonly burrowed mixtures of peloids and fusulinids. The overlying shallow-shelf facies is formed of burrowed dolowackestones and packstones containing pelecypods and peloids. The capping regressive portion of the sequence comprises

shallow-water shelf to intertidal sediments of the upper Grayburg, which form the main portion of the reservoir. These sediments are heterogeneous and contain a variety of lithologies: intraclast, fusulinid, and ooid dolograinstones are interbedded with dolo-mudstones, burrowed dolowackestones, and minor quartz silt (Fig. 5). The upper Grayburg deposits along with the overlying supratidal anhydrites, siltstones, and tidal-flat dolomites of the Queen Formation, which form the seal for the reservoir, prograded from west to east across the field.

Intercrystalline porosity is common in all reservoir dolostones. Other porosity types are also important: intergranular porosity occurs in dolograinstones, moldic porosity formed after the solution of pelecypods and fusulinids is common in dolowackestones and packstones, and vugular and fracture porosity are present in portions of the field. Shallow-water shelf deposits are homogeneous, unstratified, bioturbated dolowackestones and packstones. Vertical continuity within this zone is
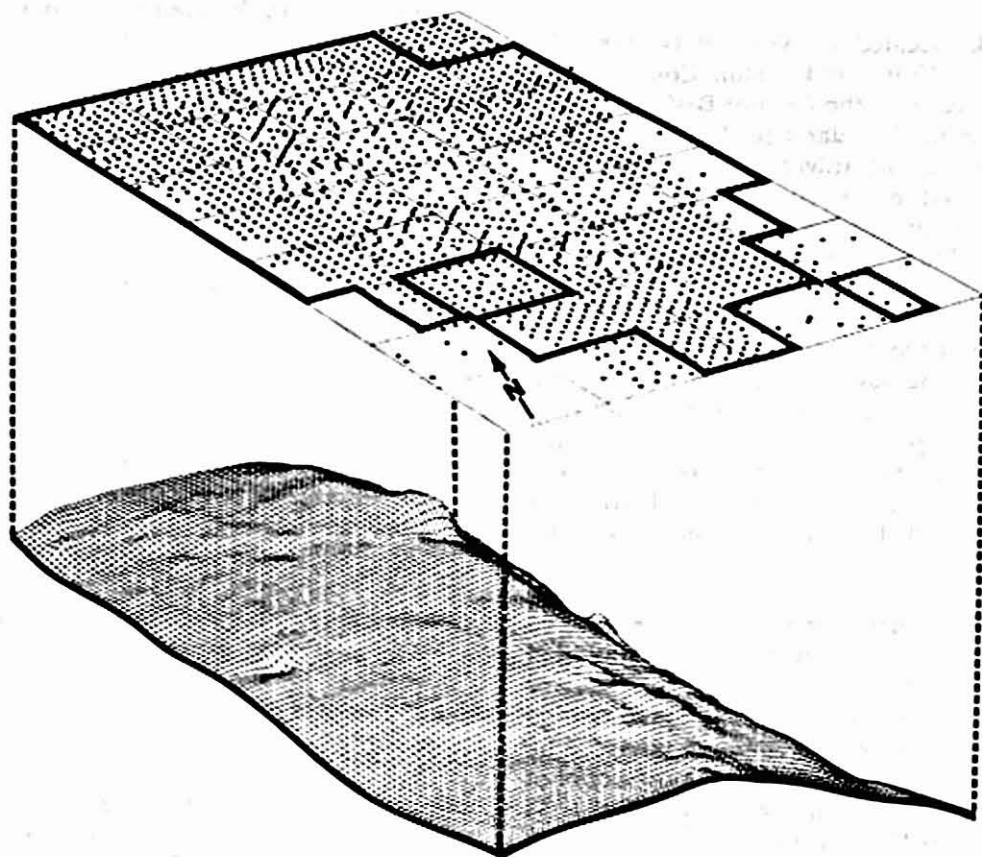

Figure 2. Mesh perspective structure map of an upper Grayburg marker, overlain by a map of well locations in McElroy Field. Since 1926, more than 1800 wells have been drilled in the field. Development of the reservoir has been through patterned drilling to influence the success of waterflooding. Different patterns have been employed to exploit varying reservoir quality - sunflower patterns in the central portion of the field and nine-spot patterns on both the eastern and western flanks. Approximately 1350 producing wells are supported by 450 water injection wells.
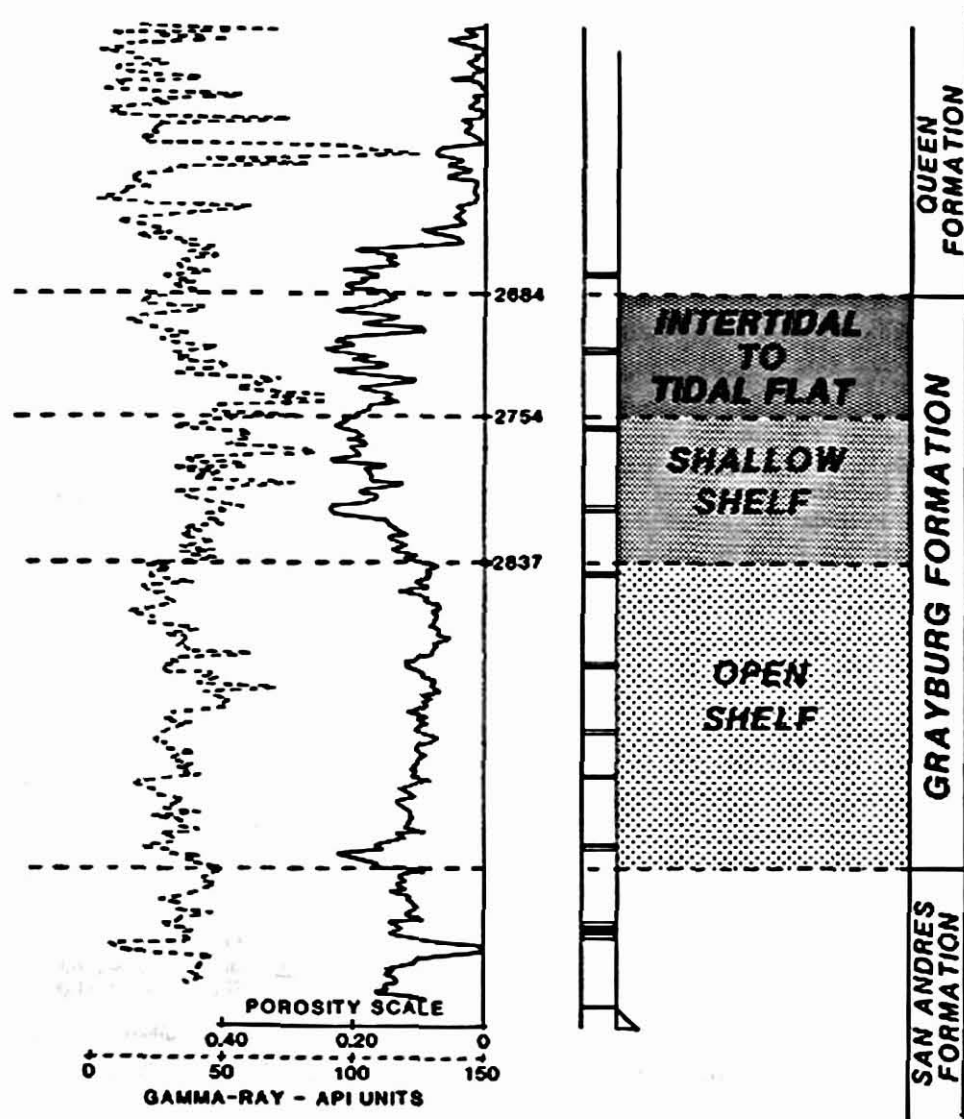
Figure 3. Type log of well J. T. McElroy 1026 from the central part of McElroy Field illustrates typical Gamma Ray and Neutron log responses. Porosity values have been corrected to core-equivalent values over the reservoir interval. The facies within the Grayburg have been defined by study of both conventional core and wireline logs. Well-bore diagram illustrates perforated intervals.

good, despite localized nonporous zones due to sulphate cementation. The best porosity and permeability occur in the overlying shallow-water shelf and intertidal lithofacies. These deposits are stratified and show abrupt lithological variation vertically and horizontally. Accompanying this variation are changes in porosity and permeability. Dolograinstones and dolopackstones of this facies are porous in the central portion of the field and nonporous on the flanks.

RESERVOIR DEVELOPMENT

Oil/water production and reservoir pressure conform to the development and orientation of permeability within the pay interval. Recovery varies between the central and flanking areas of the field: highest recoveries in the central portion of the field reflect favorable reservoir quality which has influenced the success of both primary and secondary processes, whereas poorer reservoir performance in the flanking areas of the field is related to decreased reservoir quality (Fig. 6). Cumulative-production data indicate that maximum production has been from wells in the central portion of the field that are situated along the crest of the structure. Reservoir zones thin toward the eastern flank of the field and pinchout to the west (Fig. 7). Interbedded nonporous
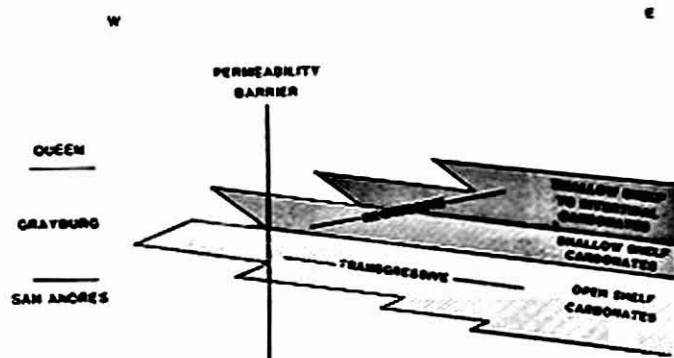
Figure 4. Schematic stratigraphic cross section through McElroy Field. Dolostones of the Grayburg Formation include open-shelf deposits formed during a transgression of the previously-exposed San Andres shelf and overlying shallow-water shelf and intertidal regressive deposits. Continued regression resulted in evaporitic deposits forming both updip and overlying seals. The updip permeability barrier that defines the western edge of the field is due to evaporite plugging of porosity in dolomites as well as to tight bedded evaporites.

zones separate the reservoir vertically throughout the entire field and make correlation of pay zones and prediction of continuity between wells difficult.

Production is complicated locally by larger-scale permeability patterns. After the beginning of the waterflood in 1960, abnormally high water production could be traced to direct communication between injection and producing wells. Communication is through either natural fractures, diagenetic channels or induced fractures formed during treatments to stimulate production, and over injection.

Plans for continued development of the reservoir focus on improving the current waterflood by careful evaluation of reservoir continuity using geological models and reservoir engineering data. Further study of the orientation and magnitude of permeability channels is necessary to aid remedial work intended to direct more injected water into unswept zones. Treatments with polymer have been used to modify the fluid injection profiles of water injection wells. Increasing the volume of injected water into the "tighter" zones is intended to provide waterflood support in portions of the field where poor vertical sweep efficiency has made the flood ineffective.

Recovering the most oil possible from large reservoirs like McElroy Field using better enhanced recovery techniques is vital to most operators in the Permian Basin. CO_2 injected into the relatively tight dolostones of the Grayburg will reach portions of the reservoir not processed during waterflooding. Equally important during future development is the continued application of geological and diagenetic models to concentrate efforts of reservoir engineers on areas where reservoir continuity is established.

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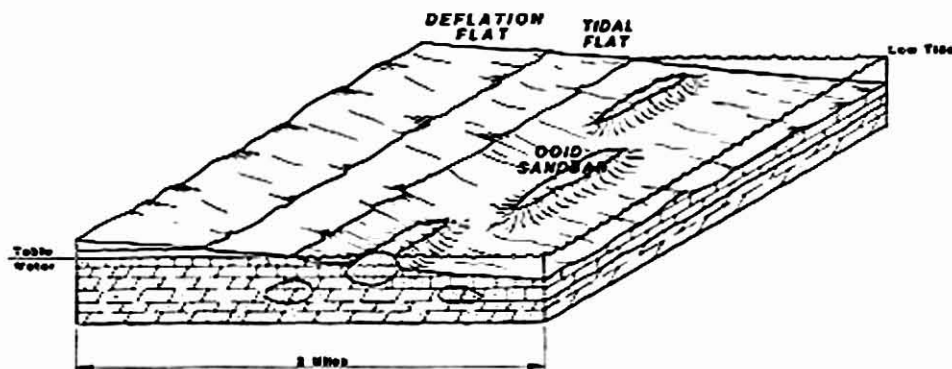

Figure 5. Schematic block diagram illustrating the variable depositional environments present in McElroy Field during deposition of the shallow-water shelf to intertidal sediments. Discontinuous carbonate grainstones are some of the most porous portions of the shallow-water shelf to intertidal facies. These are interpreted to have formed as sand bars on the shallow-water marine shelf. Dolomitization within the thick Grayburg interval most likely occurred during more than one phase of diagenesis.

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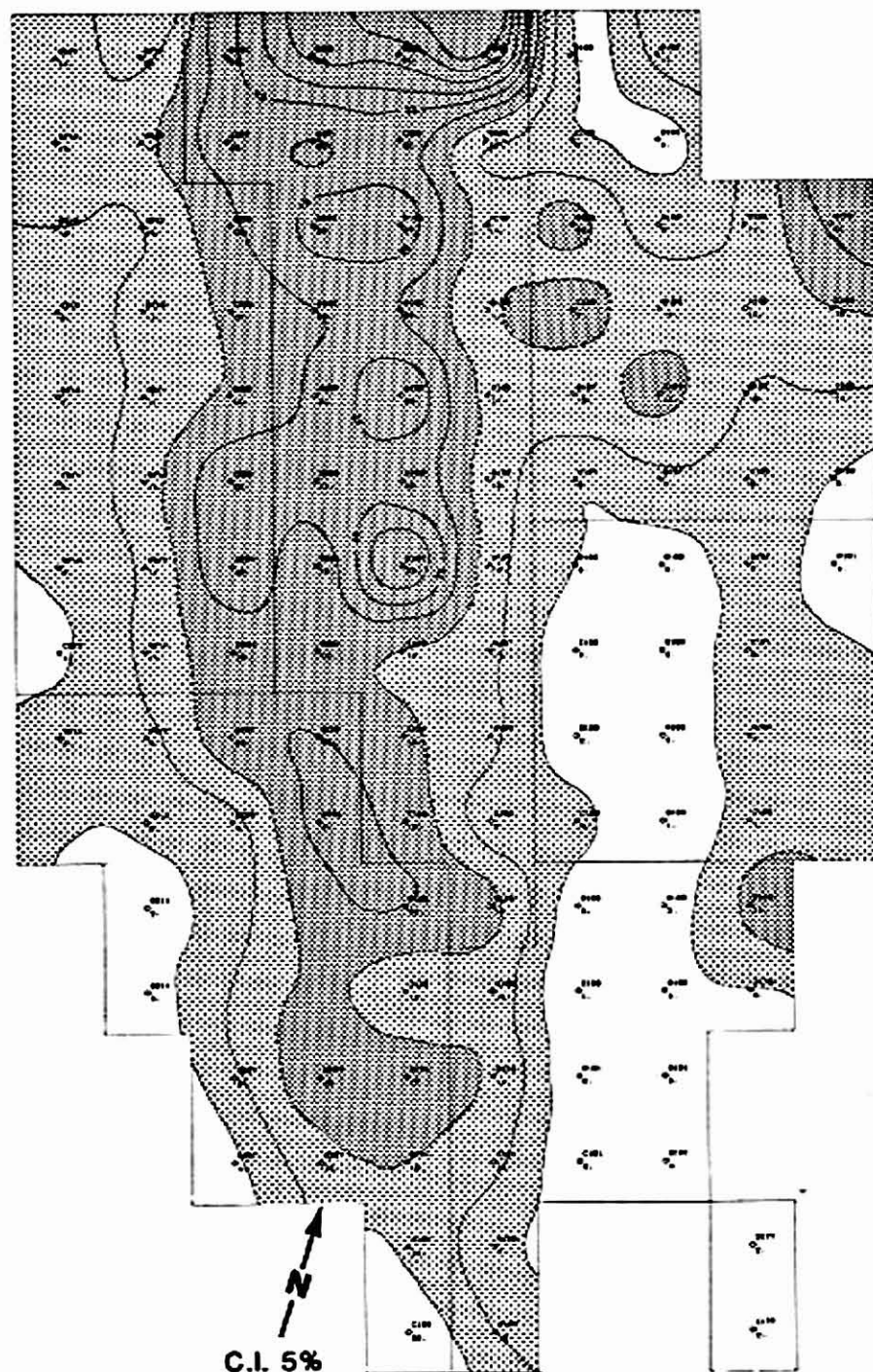
Recovery Factors

Highest

Intermediate

Lowest

Figure 6. Recovery-factor map for McElroy Field illustrating varying recovery between central and flanking areas. Highest recoveries correspond to portions of the field where favorable reservoir quality has influenced the success of primary and secondary processes. Poor reservoir performance is related to decreased reservoir quality.

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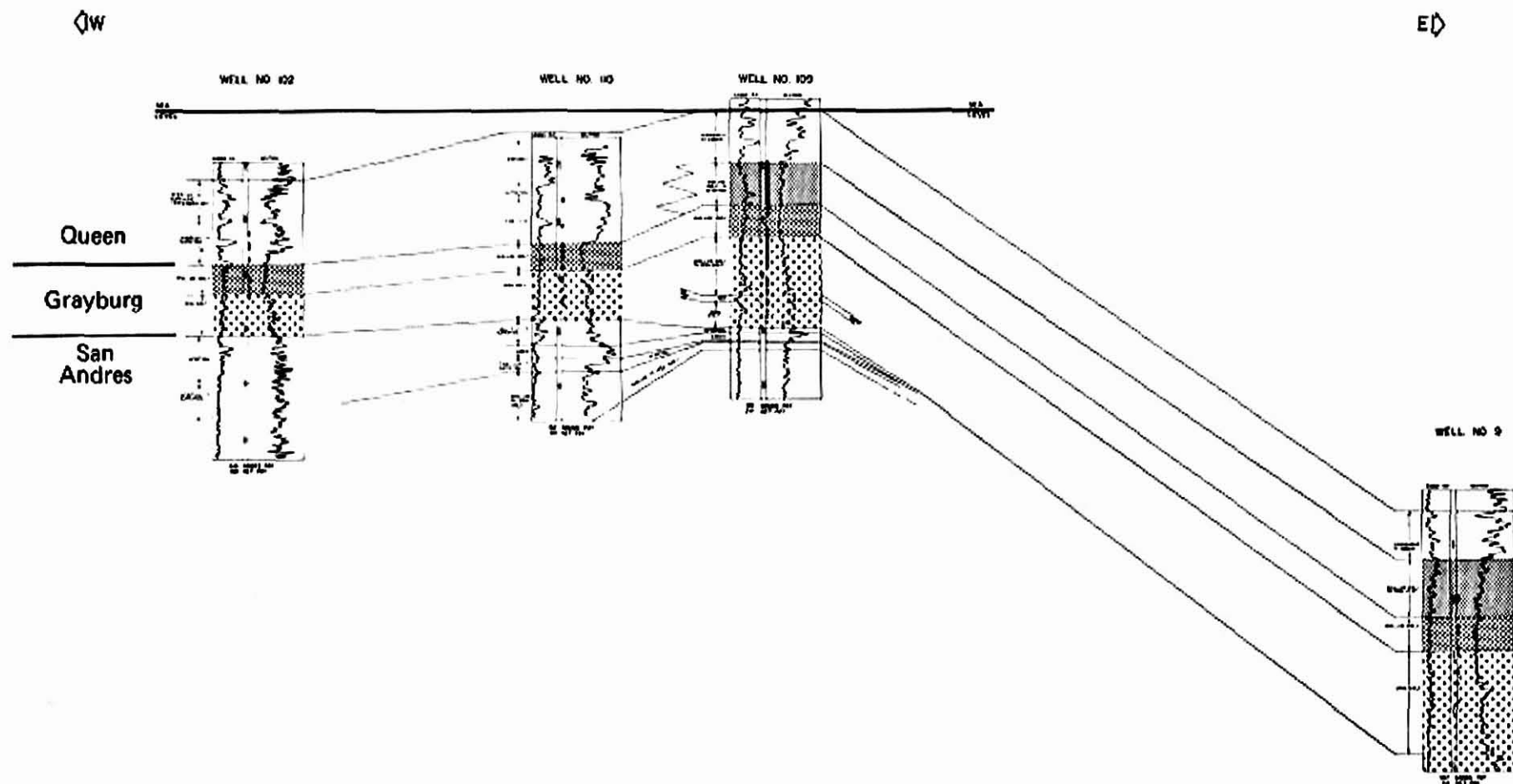

Figure 7. Structural cross section from west to east across McElroy Field. The asymmetry of the anticline and the vertical and horizontal relations of depositional facies are shown. Black vertical bars along the depth track of each well illustrate intervals with permeability greater than 1 md., thus illustrating the relative continuity of the pay section from well to well. The open-shelf facies thins to the west of the 109 well, and the thin reef interval is localized to that well only. The overlying shallow-water shelf facies are uniformly thick across the cross section. Shallow-water shelf to intertidal deposits found in the 109 well extend to the east but are not present in wells to the west. The terrigenous to sabkha facies that caps the entire sequence is much thicker in the more westerly wells where the shallow-water shelf to intertidal deposits are lacking. Log variation between wells reflects lithological changes that control the development of porosity within depositional facies.