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University Lands Advanced Recovery Initiative

Annual Report

June 1996–June 1997

Bureau of Economic Geology

The University of Texas at Austin

Noel Tyler, Director

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Introduction

Hydrocarbon production from West Texas lands held by The University of Texas System has been in decline since the 1960's (fig. 1). Nonetheless, analysis of resources on University Lands indicates that of the 7,252 million stock tank barrels (MMSTB) of original oil in place, only 1,679 MMSTB has been recovered since production was established early in this century, and only 150 MMSTB of reserves exists. Unless advanced development practices are applied to University Lands fields, some 5,423 MMSTB will therefore remain unrecovered in existing fields. Importantly, 2,140 MMSTB of this resource, nearly one-third the original oil in place, is mobile oil that can be recovered using standard drilling and completion practices, provided that well bores and completion intervals are geologically targeted to access this unrecovered resource (fig. 2).

The goal of the University Lands Advanced Recovery Initiative is to characterize selected University Lands reservoirs to aid operators in geologically targeting the remaining hydrocarbon resource to stem the decline in University Lands production. This project is funded by The University of Texas (U.T.) System and by matching funds from operators of University Lands fields chosen for site-specific studies. The agreement between the Bureau of Economic Geology and the U.T. System was finalized on July 29, 1996.

Three individual site-specific projects have been initiated in the first year of the project (1) Fuhrman-Mascho Block 10 Unit, a San Andres–Grayburg carbonate and sandstone reservoir in Andrews County operated by Arrow Operating Company, (2) University Waddell Devonian field, a Devonian chert reservoir in Crane County operated by Pennzoil, and (3) North McElroy Grayburg field, a Grayburg carbonate reservoir in Crane and Upton Counties newly acquired by Apache Corporation (fig. 3). Fuhrman-Mascho and University Waddell fields have recovery efficiencies significantly below that of comparable fields within the same geologically based play. McElroy field, although producing at an efficiency above play average, contains an enormous 232 million barrels of unrecovered mobile oil (table 1).

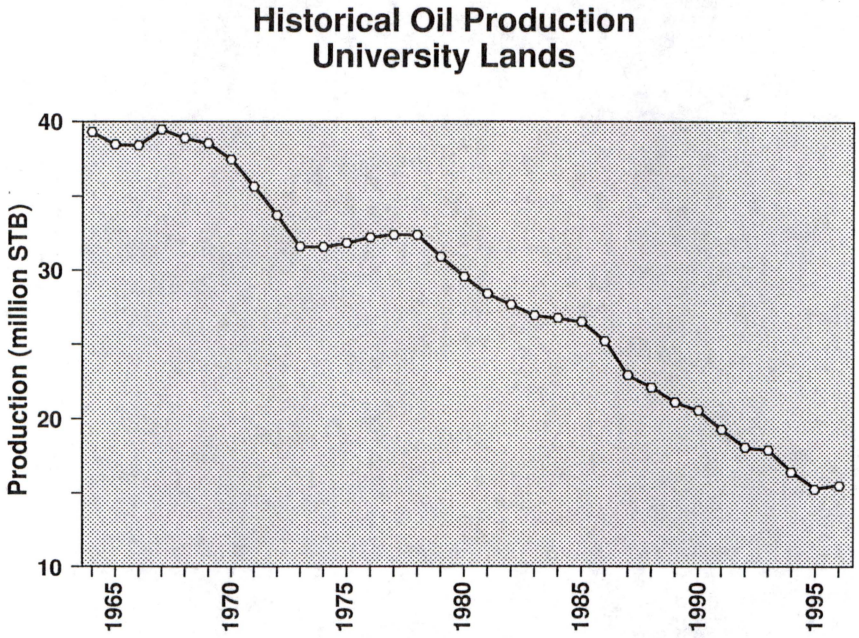

Figure 1. Annual oil production from University Lands. Annual production has declined from nearly 40 MMSTB/yr in the mid 1960's to approximately 15 MMSTB/yr.

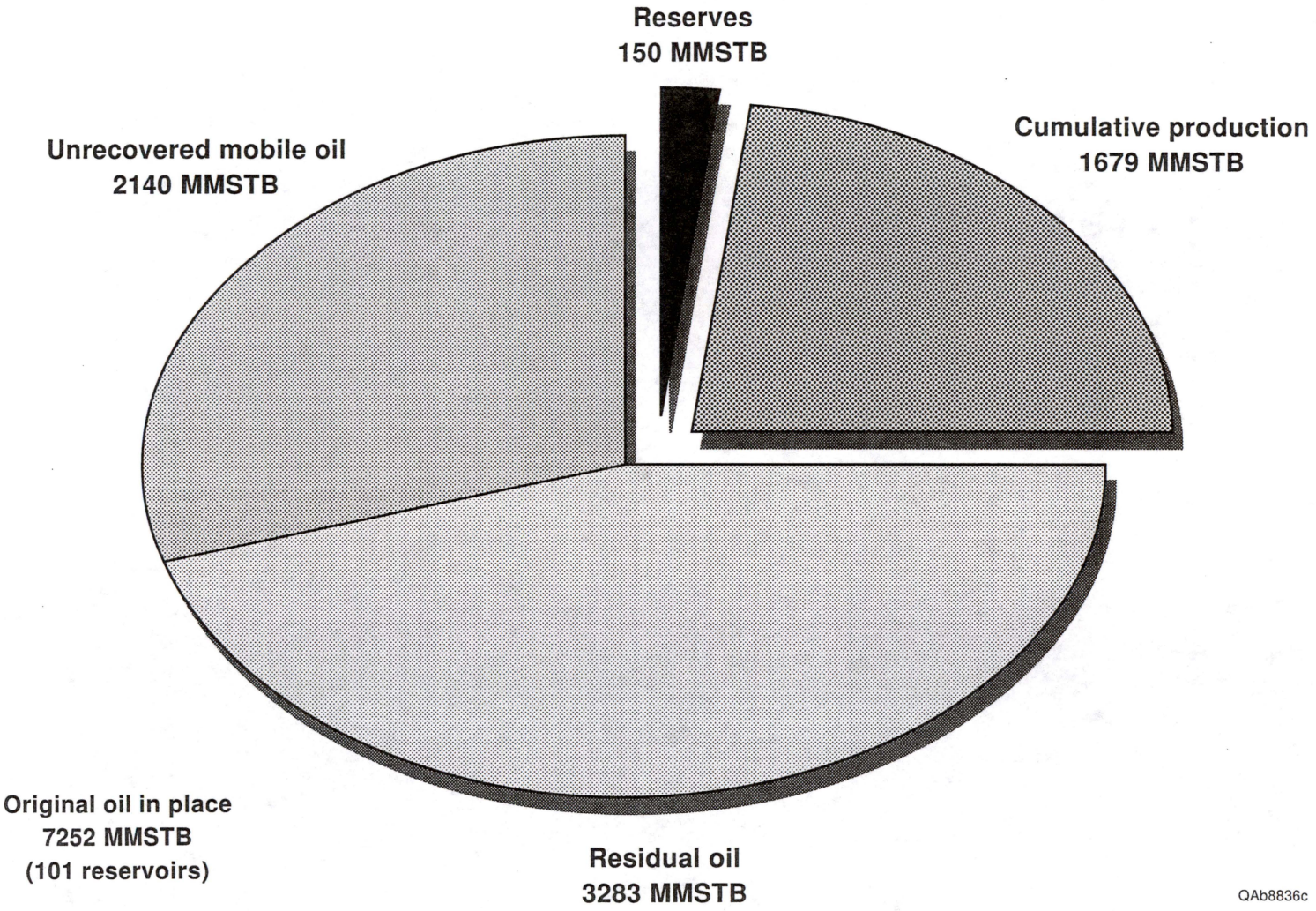

Figure 2. Distribution of the oil resource base on University Lands. Nearly one-third of the original oil in place is mobile oil that will remain unrecovered by currently deployed development programs.

University Lands Blocks and Fields Targeted for Recovery Optimization

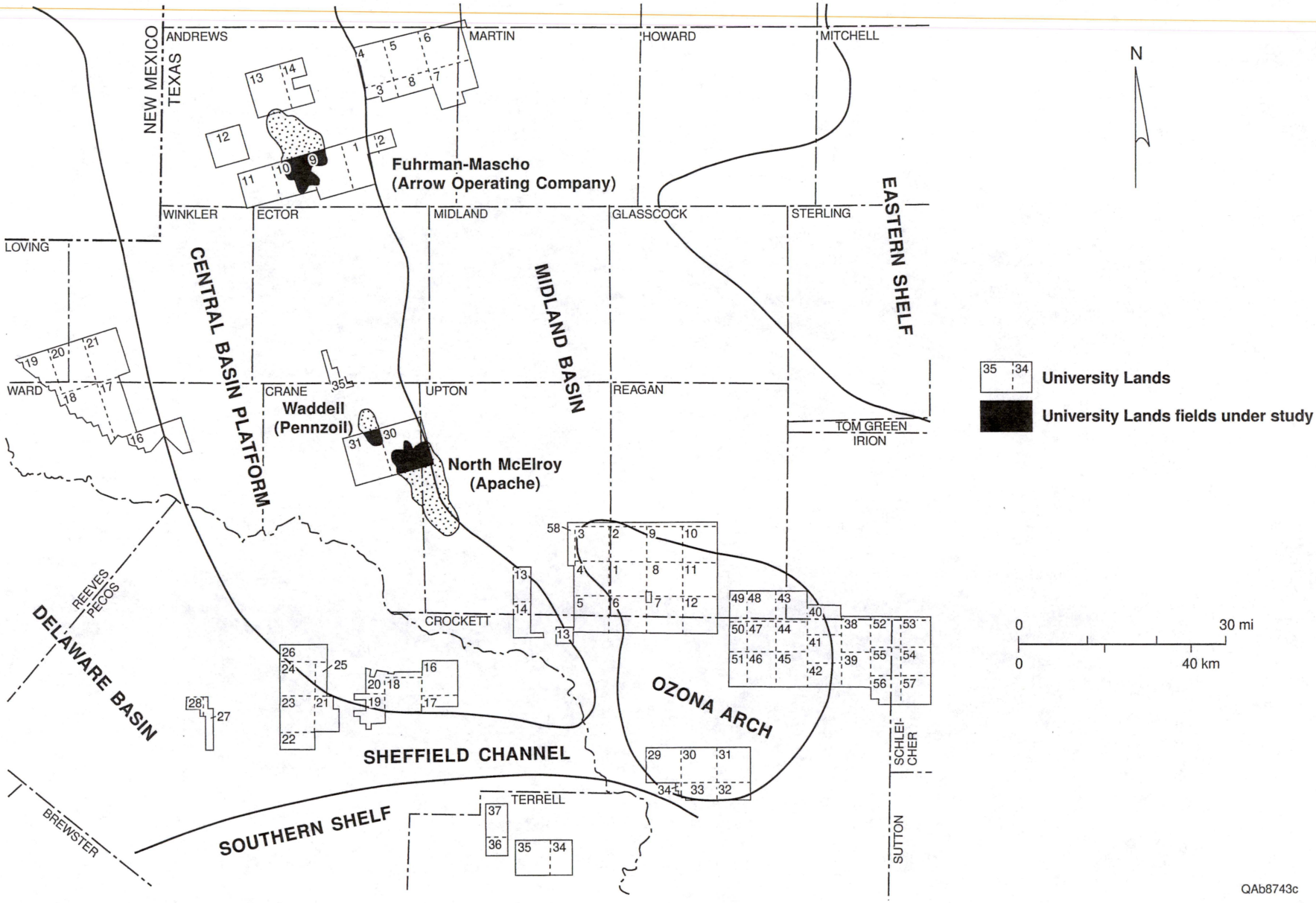

Figure 3. Location map for three site-specific reservoir-characterization studies on University Lands in West Texas.

Table 1. Oil volumes in the State Lands fields targeted for advanced reservoir-characterization studies.

Volumetrics of targeted fields

	Original oil in place (MMbbl)	Recovery efficiency		Remaining mobil oil (Mmbbl)
		Reservoir	Play average	
Fuhrman-Mascho (San Andres–Grayburg)	203	13.4	24	47.7
McElroy (Grayburg)	685	26	21	232
University Waddell (Devonian)	66	30	35	17

Unrecovered mobile oil is the principal target for increasing production from University Lands reservoirs. In mature fields it occurs in (1) deeper pools that are below the total depths of wells, (2) compartments that are either not contacted by a well bore or are contacted at a location that does not allow for efficient drainage, (3) zones that are bypassed because the well bore has not been opened (perforated) in the appropriate depth interval, or (4) parts of the reservoir that have been inefficiently swept by waterflooding because of poor waterflood program design (fig. 4). Conventional drilling, completion, and enhanced recovery technologies can access most of this remaining mobile oil resource, provided those technologies are targeted using advanced geologic interpretations. This is the primary goal of the University Lands Advanced Recovery Initiative.

Fuhrman-Mascho Block 10 Unit

Stephen C. Ruppel, Principal Scientist

Arrow Operating Company began a 50-well infill drilling program and welcomed the University Lands Advanced Recovery Initiative study as a means of fully assessing the opportunities afforded by this development program. Indeed, one of the earliest cooperative activities following initiation of the project in January 1997 was to core one of these infill wells to provide data for calibrating wireline logs.

Stratigraphic relationships in Fuhrman-Mascho field indicate that the reservoir comprises three flow-unit regimes, each with distinct geological, engineering, and field-development significance. Flow Regime 1 constitutes the lower Grayburg, a succession of generally nonporous carbonates and highly continuous, permeable siltstones at the top of the reservoir. This interval has contributed most of the production to date and is highly floodable. Flow Regime 2 consists of the underlying upper San Andres, a succession of shallow-water carbonates with scattered and very discontinuous porosity. Because permeability development is highly variable, this zone is a relatively poor candidate for waterflood and may act as a baffle between Regimes 1 and 3 in many parts of the field. Untapped compartments in Flow Regime 2 may be targets for infill wells. Flow

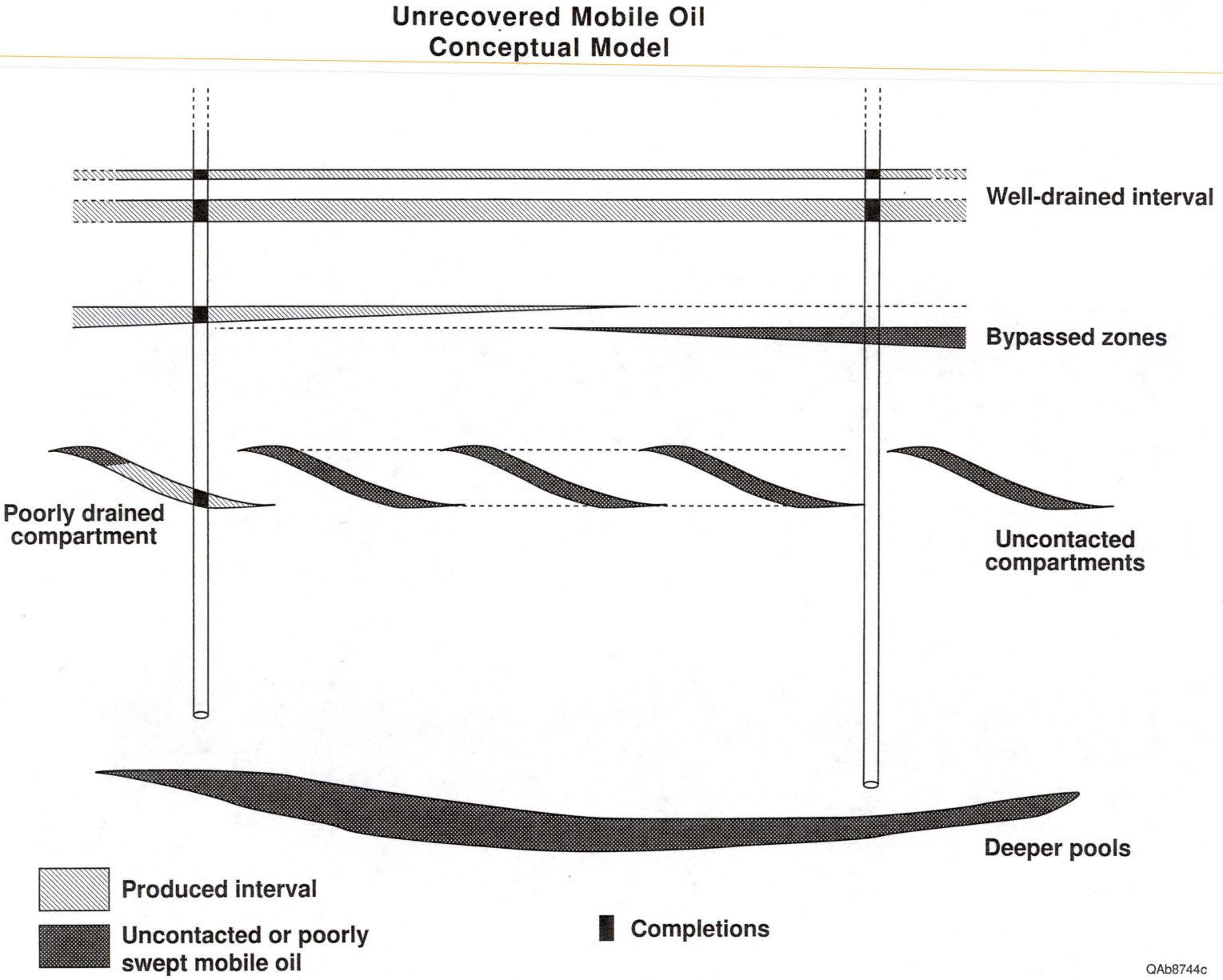

Figure 4. Conceptual diagram illustrating common forms of reservoir heterogeneity that can contribute to inefficient recovery.

Regime 3 consists of a highly continuous porosity zone developed in deeper water carbonates beneath an unconformity at the top of the lower San Andres. Although permeability is variable in this zone, its continuity makes it an excellent candidate for waterflood (fig. 5).

Facies changes in Flow Regime 2 from north to south across University Lands Block 10 suggest that the potential for production from this unit may actually increase in the structurally low parts of the field. This is because permeable rocks are more abundant to the south in the structurally low southern parts of Block 10. Indeed, the oil–water contact defined by Arrow drilling in Fuhrman-Mascho field is approximately 150 ft deeper than that defined in the adjacent Emma field (also on University Lands). This indicates that additional oil production potential may exist deep in Emma field (fig. 6).

These findings suggest the presence of new potential in deeper and structurally low parts of many University Lands San Andres–Grayburg reservoirs on the Central Basin Platform, including Emma, Triple N, Goldsmith North, Shafter Lake, Shafter Lake North, Penwell, and Jordan, as well as many smaller fields. These relationships have been communicated to operators currently working in the area of Jordan and Penwell fields, who are already beginning a study to determine the potential for more drilling.

University Waddell Devonian Field

Roger Barnaby, Principal Scientist

University Waddell Devonian field is operated by Pennzoil, who agreed to a cooperative field study in January 1997. Production is from a Devonian reservoir that is currently being waterflooded. Pennzoil is actively drilling a total of four infill wells and welcomes this cooperative study as a means of delineating bypassed oil, identifying recompletion opportunities in currently active production and injection wells, assessing methods for modifying the waterflood pattern and, possibly, evaluating a miscible nitrogen or carbon dioxide gas displacement program.

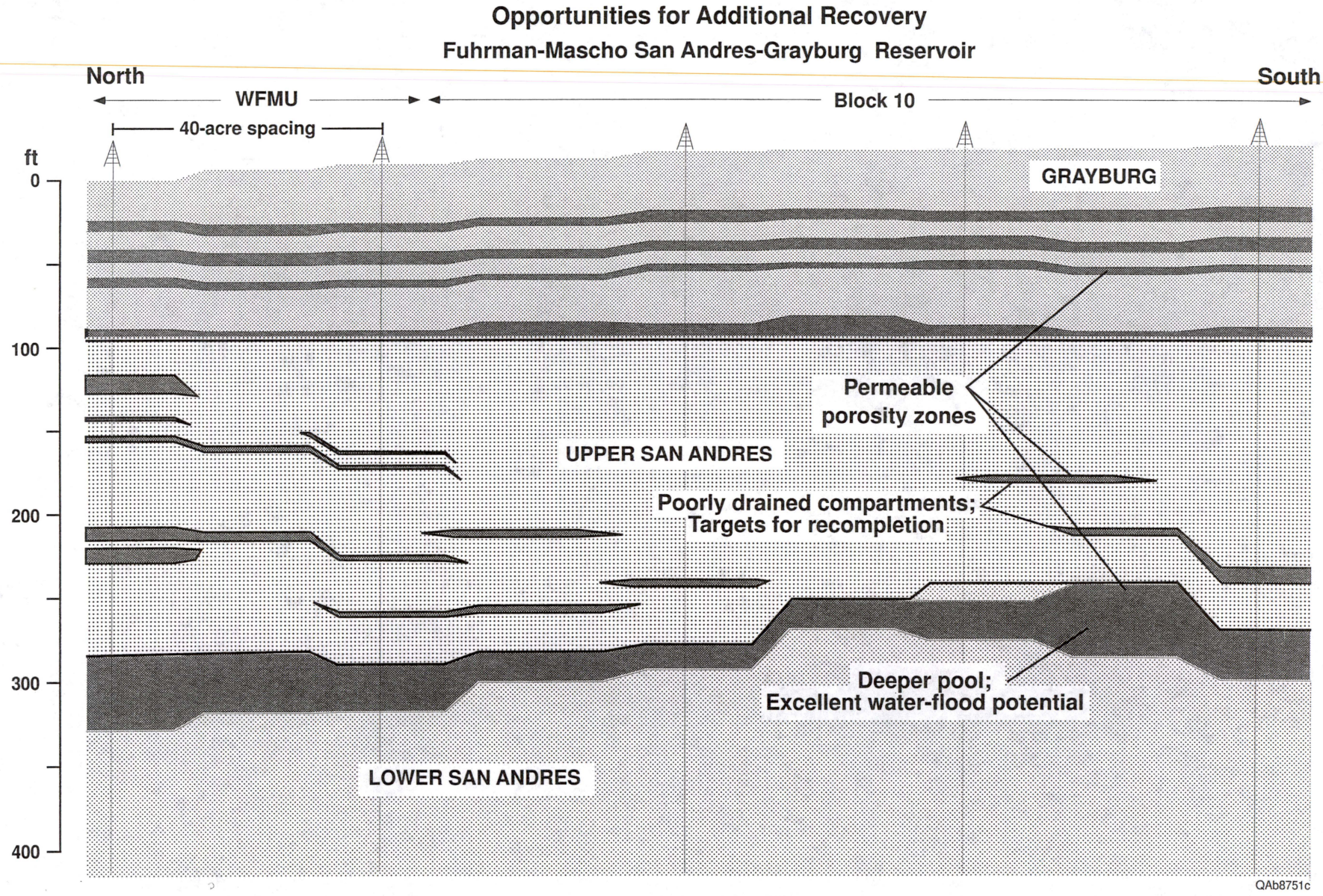

Figure 5. Cross section illustrating the stratigraphy of the reservoir at Fuhrman-Mascho field. Cumulative production to date is primarily from the porous and permeable siltstones in the Grayburg Formation. Poorly drained and uncontacted porous and permeable reservoir compartments in the upper San Andres Formation are targets for infill drilling and laterally continuous porous, and permeable parts of the lower San Andres Formation are a candidate for water-flood production.

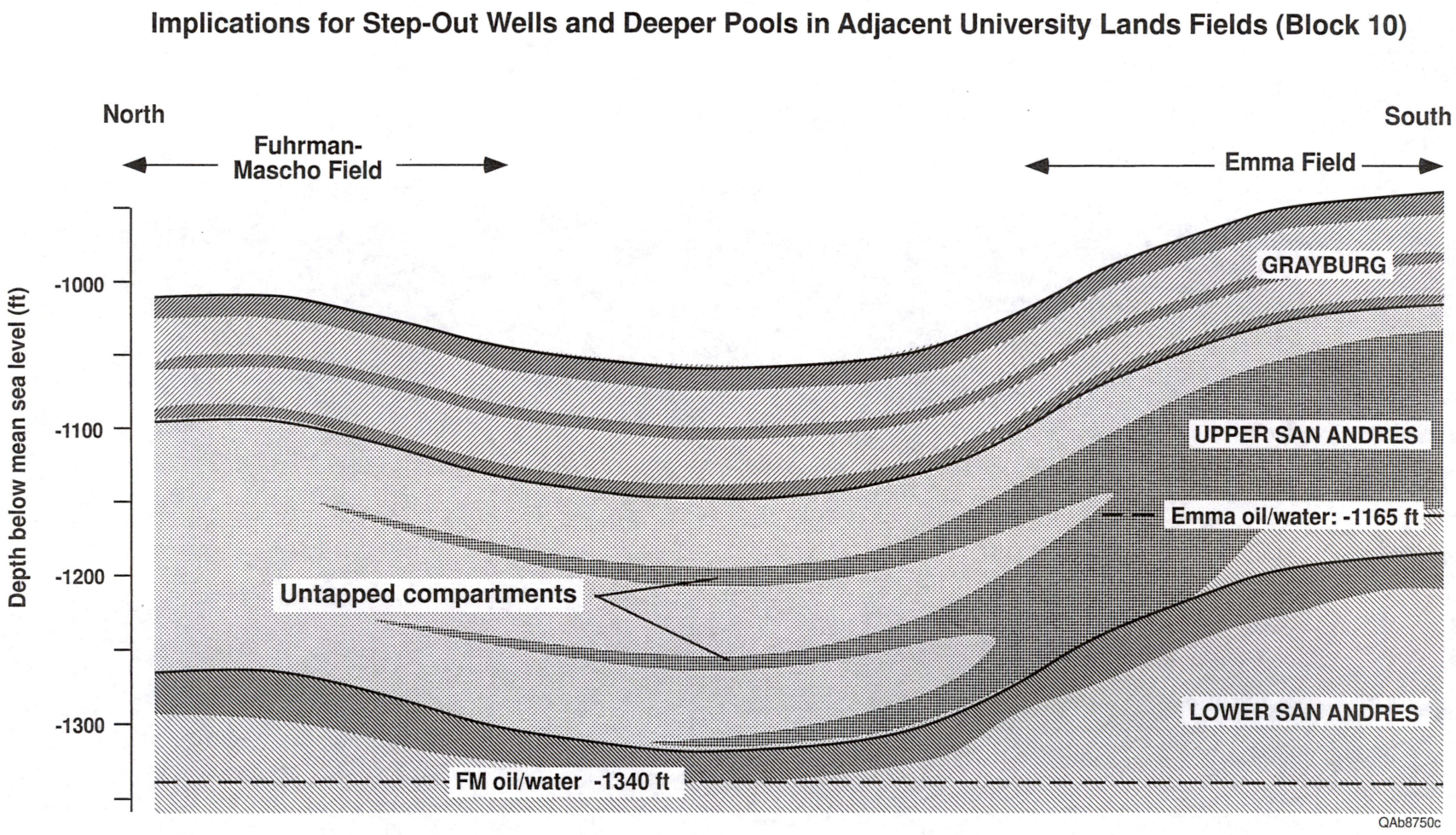

Figure 6. The discovery of an oil–water contact at Fuhrman-Masco field that is 150 ft lower than the oil–water contact at neighboring Emma field suggests the possibility of untapped reservoir compartments in structurally low positions on University Lands.

Reservoir zones in this field are dominated by laminated to massive cherts with abundant sponge spicule molds and attendant good reservoir quality. This facies is highly heterogeneous both laterally and vertically, with some key zones clearly not connecting between well bores. Sorting and sedimentary structures indicate that cherts accumulated as high-energy deposits in submarine channels feeding distal submarine-fan complexes.

Gamma-ray response is attenuated throughout the chert and limestone reservoir interval because of the paucity of interbedded siliciclastic rocks. Careful correlation of low amplitude gamma-ray inflections can be used to establish a much more accurate reservoir framework than can be done by correlating log-derived porosity.

Detailed correlation of gamma-ray logs is crucial to accurately correlating productive reservoir zones at Waddell field. Such correlations demonstrate that among various wells, completed zones in wells previously thought to be in communication are actually isolated reservoir compartments. This lateral and vertical discontinuity of reservoir zones resulted in inefficient waterflood sweep. Moreover, in most wells, some zones of high porosity remain untested (fig. 7). Detailed correlation and mapping of these heterogeneous porous units will provide a geologically targeted development strategy of recompletions, infill drilling, and waterflood injection to maximize hydrocarbon recovery.

North McElroy Grayburg Field

Charles Kerans, Principal Scientist

This field, recently acquired by Apache Corporation, produces oil from a platform carbonate reservoir in the Grayburg Formation. As the new operator of this property, Apache welcomes this cooperative study to identify opportunities for new production strategies. The final agreement for this cooperative study was signed on July 1, 1997.

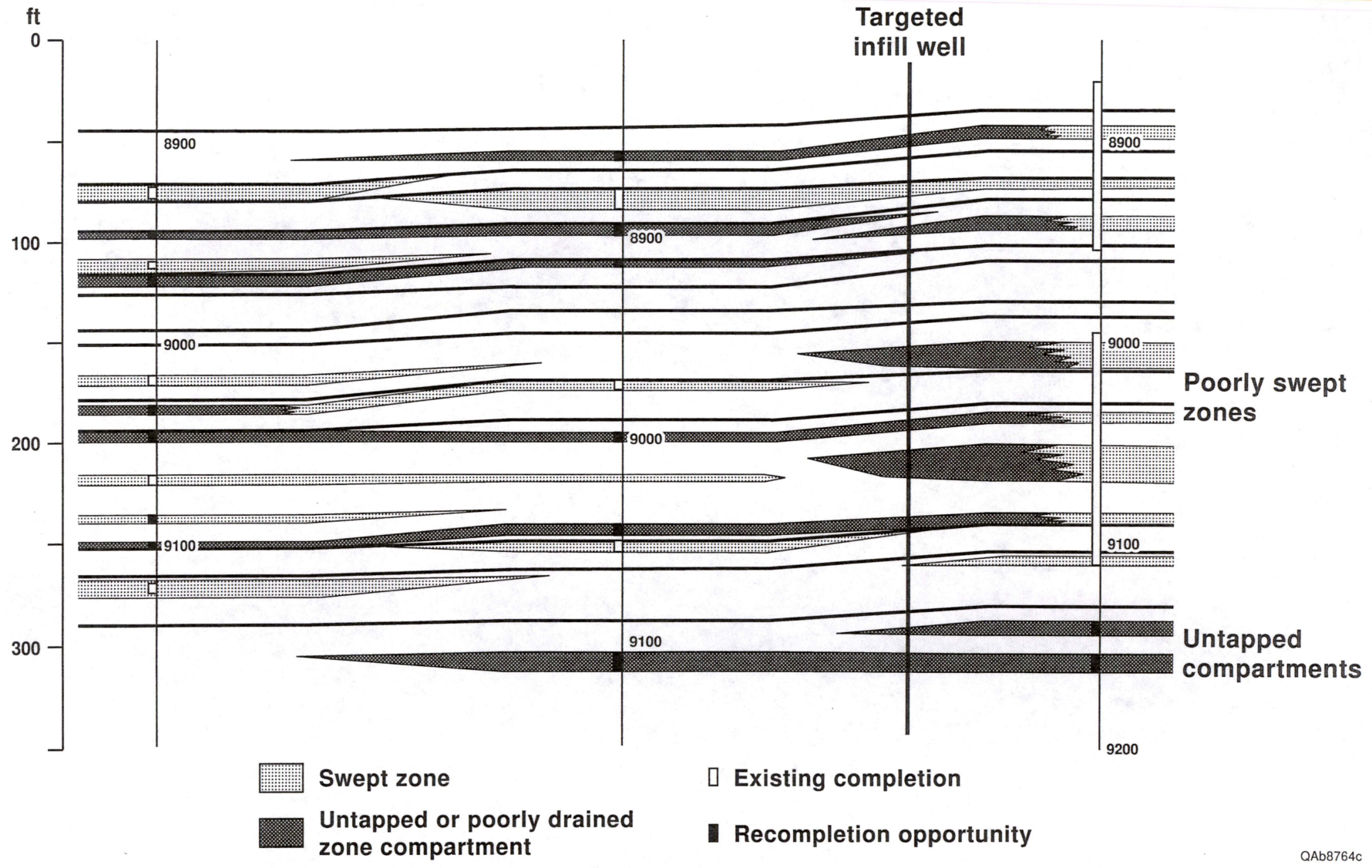

Figure 7. Cross section illustrating the stratigraphy of the reservoir at University Waddell field. Laterally discontinuous porous and permeable zones contain remaining mobile oil in both poorly swept parts of the reservoir and untapped reservoir compartments.

Operator Contributions

The following operator contributions have been made to support cooperative University Lands reservoir characterizations studies. The total dollar values of these contributions are summarized in table 2.

Fuhrman-Mascho Block 10 Unit

* Arrow has drilled 53 wells, 17 of which are on University Lands Block 10.
* A 460-ft continuous core from well no. 124 was taken at Bureau recommendation.
* Additional well logs, including acoustic, formation imaging, spectral gamma ray, and others, have been acquired on the basis of Bureau recommendations.
* Paper copies of new well logs and many old logs have been provided to the Bureau.
* Logs from new wells have been digitized, and the digital files have been provided to the Bureau.
* Various other types of data, including completion reports and production data, have been copied and provided to the Bureau.

University Waddell Devonian field

* A digital log data base containing digitized log data and core-plug porosity and permeability has been provided to the Bureau.
* A digitized production and injection data base has been provided to the Bureau.
* A digitized well-completion-history data base has been provided to the Bureau.
* Papers copies of digitized logs, a base map containing well location and production status, and interpreted (ELAN) log suites from key wells have been contributed to the joint study.
* Pennzoil has agreed to run a formation imaging log in planned lease-line wells.

Table 2. Operator agreement matching funds.

Operator	Committed	To date (4/1/97)
ARROW*	$618,000	$198,783
PENNZOIL**	$122,300	$121,500
APACHE***	$404,500	Project starting
TOTAL	$1,144,800	

Ratio of UT system to operator match = 1:1.54

*Cores, wireline logging, log digitizing, data copying, staff time
**Digital logs, digital data base
***Numerical modeling, log digitizing, 3-D seismic survey