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**GEOLOGICAL AND PETROPHYSICAL CHARACTERIZATION
OF THE FERRON SANDSTONE FOR 3-D SIMULATION OF A
FLUVIAL-DELTAIC RESERVOIR**

(Contract No. DE-AC22-93BC14896)

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**DELIVERABLE 1.4.4
FERRON SANDSTONE LITHOFACIES & 2 1996
CASE-STUDY AREAS
EMERY & SEVIER COUNTIES, UTAH**

Submitted by

Utah Geological Survey
Salt Lake City, Utah 84109
January 4, 1996

Contract Date: September 29, 1993
Anticipated Completion Date: September 29, 1996
Government Award (fiscal year): \$ 633,650
Program Manager: Thomas C. Chidsey, Jr.
Principal Investigator: M. Lee Allison

Contracting Officer's Representative

Robert Lemmon
U.S. Department of Energy
Bartlesville Project Office
P.O. Box 1398
Bartlesville, OK 74005

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LITHOFACIES AND CASE-STUDY SITE SELECTION

The types of dominantly sandstone lithofacies that characterize the Cretaceous Ferron Sandstone reservoir types were tentatively identified before the project began. These reservoir types were defined and mapped at the regional scale and are the subject of the detailed, highly focused case studies. The purpose of conducting detailed case-study analysis is to develop a comprehensive, interdisciplinary, and quantitative characterization of fluvial-deltaic reservoirs which will allow realistic inter-well and reservoir-scale modeling to be used for improved oil-field development in actual reservoirs world-wide. The resulting benefits and value may: (1) **increase recoverable reserves** by identifying untapped compartments created by reservoir heterogeneity, (2) **reduce development costs** by more efficiently siting infill drilling locations, (3) **increase deliverability** by exploiting the reservoir along optimal fluid-flow paths, (4) **enhance the application of new technologies**, such as horizontal drilling, by identifying optimal drilling directions to maximize fluid-flow, and (5) **identify reservoir trends** for field extension drilling.

Methods

Various geologic studies of the Ferron Sandstone (Anderson, 1991a, 1991b; Barton and Tyler, 1991; Cotter, 1971, 1975a, 1975b, 1976; Gardner, 1991; Ryer, 1981a, 1981b, 1982a, 1982b, 1983, 1991) were reviewed to compile a list of locations and types of lithofacies in the Ferron Sandstone to be examined in greater detail as part of the subsequent case studies. Preliminary regional interpretations were also used to help select the type and location of lithofacies for case studies. Potential case-study sites were delineated during several reconnaissance field trips by the geologic team.

Results

Two case-study sites were selected for the project: **Ivie Creek** and **Willow Springs Wash**, in the central and southern parts respectively of the project study area (Figure 1).

Ivie Creek site -- The Ivie Creek site was selected to examine the abrupt facies changes in the lower Ferron delta-front sandstones or parasequence sets in outcrops north of Ivie Creek, east of the mouth of Ivie Creek Canyon. Access to the area is excellent because of the close proximity to Interstate 70 (I-70). Field trips to the this area, as part of technology transfer activities, will be easily conducted.

The Ferron Sandstone in the Ivie Creek case-study area consists of two regional scale parasequence sets, the Ferron No. 1 and No. 2 sandstones (Kf-1 and Kf-2). Locally, each parasequence set is divided into three mappable, coarsening-upward, stratigraphic sequences (a, b, and c) which may or may not represent parasequences.

The lowest sequence in the Kf-1 is the Kf-1a and represents a river-dominated delta deposit which changes from proximal to distal (where the sandstone pinches out) or east to west across the Ivie Creek area. These changes can be documented at two locations along the outcrop belt. Of particular interest is the interrelationship among high-angle foreset beds (clinoforms), hummocky cross bedding, and planar-laminated sandstones. The clinoforms, which accumulated on the prograding delta front, are prominently displayed on the north side of Ivie Creek.

Figure 1. Location map of the Ferron Sandstone study area (outcrop belt is cross-hatched) showing detailed case-study sites (outlined by heavy dashed lines).

Assuming a lobate shape for the deposits, the subsurface pinch-out location of these deposits has been approximated. A core-hole drilling program in the Ivie Creek area was chosen to help characterize the sequence from proximal to beyond the pinch-out.

The Kf-1b sequence laps onto the more distal parts of the Kf-1a sequence in the western part of the case-study area and represents the distal portion of another delta lobe, probably originating from the southwest. This sequence includes a channel sandstone body, lenticular in cross section, deposited by a northwesterly flowing stream.

The Kf-1c sequence, the uppermost, is continuous across the entire Ivie Creek area and represents a wave-modified delta. The sequence is capped by unidirectional, trough-cross-bedded sandstone. The Kf-1c contains loading features near the mouth of Ivie Creek and thickens to the north as the Kf-1a pinches out.

Above the cross-bedded sandstone are 10 to 15 feet (3-6 m) of bay-fill deposits. These deposits consist of carbonaceous mudstone; thin, rippled-to-bioturbated sandstone and siltstone; fossiliferous mudstone to sandstone; oyster coquina; and ash-rich coal. The uppermost carbonaceous mudstone or ash-rich coal is the sub-A coal zone. A flooding surface has been identified at the top of the sub-A. The boundary with the overlying Kf-2 parasequence set is drawn at this flooding surface.

The Kf-2 parasequence set represents a wave-modified depositional environment. The lowest sequence of the Kf-2 parasequence set is the Kf-2a. The Kf-2a begins as interbedded sand and shale in a prodelta to lower shoreface environment. These deposits are thin, typically less than 10 feet (3 m) thick. They are overlain by a 0.5-to 1-foot-(0.2-0.3-m-) zone of highly carbonaceous to coaly sandstone which grades into 20 to 30 feet (6-9 m) of very-fine-grained, silty, and slightly carbonaceous sandstone. The unit is intensely bioturbated and was deposited in the middle-shoreface environment.

The Kf-2b sequence consists of horizontally bedded, silty sandstone at the base and unidirectional, trough-cross-bedded sandstone toward the top. In a road cut along I-70 this unit displays trough sets which become horizontally bedded in a downdip direction. These deposits are interpreted as mouth-bar deposits.

The Kf-2c sequence is separated from the underlying Kf-2b sequence by a siltstone to shale interval which varies in thickness across the case-study area. Generally the entire unit fines from west to east. In the east, the Kf-2c is interpreted as a bay-fill sequence (although it is devoid of fossils). At the top of the sequence is a thin, medium-grained carbonaceous sandstone which may represent the migration of a beach (foreshore deposits) across the bay fill prior to capping by coastal-plain deposits and deposition of the overlying A coal.

Deposition of sandstones in the Kf-1 parasequence set was from the south to southeast, whereas the general coarsening of the Kf-2 parasequence set to the west suggests that this unit was deposited from west to east. The Kf-2 contains more and cleaner sand, indicating a more wave-modified environment of deposition.

Reservoir modeling will be conducted on data collected from and geological interpretations of both the Kf-1 and Kf-2 parasequence sets in the Ivie Creek case-study area. Reservoir modeling will concentrate on: (1) variations in fluid flow between the parasequence types, (2) the amount of communication between each parasequence set, and (3) the effects the various bounding surfaces within parasequences would have on fluid flow in these units. Recommendations will be made on how bounding surfaces can be identified from core and well-log data and, ultimately, how such features should be considered in field development and secondary or enhanced oil recovery programs.

Willow Springs Wash site -- The Willow Springs Wash site is the largest of the two case-study areas. It covers an area 3.5 miles (5.6 km) long and 4 miles (6.4 km) wide (Figure 1). The site was selected because of the excellent three-dimensional aspect of exposures in the Willow Springs Wash and Indian Canyon areas. The focus of the work at this site will be parasequences of the Kf-1 delta-front. No reservoir simulations will be conducted on data collected from the Willow Springs Wash area. However, the architectural elements interpreted from the outcrops will be incorporated into the overall reservoir model for the Ferron Sandstone.

The Ferron Sandstone in Indian Canyon of the Willow Springs Wash area consists of excellent exposures of the Kf-1 parasequence set. The set is divided into five mappable stratigraphic sequences (a through e). Three are considered parasequences. The parasequences are displayed in a forward-stepping arrangement similar to many delta-front reservoirs. The transgressive (or "flooding") surfaces that separate the parasequences are overlain, at least in part, by mudstone units that may act as permeability barriers between sandstone bodies. Rocks in these sequences contain prodeltaic; lower, middle, and upper shoreface; foreshore; and fluvial-dominated delta-front deposits.

The Kf-1a through 1c represent non-deltaic coastal deposits; in contrast, the Kf-1d represents deposits from a subdelta of a river-dominated deltaic complex. Paleocurrent measurements on large-scale, trough-cross-stratification in the delta-front sandstone at the top of the Kf-1d indicate flow to the north. Several distributary channels cut the Kf-1d in this area. Paleocurrent measurement taken from these channels indicate north to northeast flow. A bay-fill sequence caps the top of the Kf-1 parasequence set.

The Kf-2 parasequence set in Indian Canyon of the Willow Springs Wash case-study area is thin and consists coastal-plain deposits containing little sandstone.

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