Final

BC/14896-14
DOE/BC/14896--14

**GEOLOGICAL AND PETROPHYSICAL
CHARACTERIZATION OF THE FERRON SANDSTONE
FOR 3-D SIMULATION
OF A FLUVIAL-DELTAIC RESERVOIR
(Contract No. DE-AC22-93BC14896)**

TECHNICAL PROGRESS REPORT

Submitted by

Utah Geological Survey
Salt Lake City, Utah 84114
October 1996

RECEIVED

APR 07 1997

OSTI

Contract Date: September 29, 1993
Anticipated Completion Date: September 29, 1996
Government Award (fiscal year): \$ 285,892
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

RECEIVED
USDOE/PETC
97 JAN 16 PM 2:50
ACQUISITION & ASSISTANCE DIV.

Reporting Period: July 1 - September 30, 1996

US/DOE Patent Clearance is not required prior to the publication of this document.

~~DISTRIBUTION~~ OF THIS DOCUMENT IS UNLIMITED

CLEARED BY
PATENT COUNSEL

MASTER

DISCLAIMER

**Portions of this document may be illegible
in electronic image products. Images are
produced from the best available original
document.**

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

(Contract No. DE-AC22-93BC14896)

Utah Geological Survey (UGS), Salt Lake City, Utah 84114

Submitted: January 1997

Contract Date: September 29, 1993

Anticipated Completion Date: August 29, 1997

Government Award (fiscal year): \$ 633,650

Principal Investigator: M. Lee Allison, UGS

Program Manager: Thomas C. Chidsey, Jr., UGS

Contracting Officer's Representative: Robert Lemmon, Bartlesville Project Office

Reporting Period: July 1 - September 30, 1996

PRELIMINARY DOCUMENT
DO NOT QUOTE OR DISTRIBUTE

Objective

The objective of this project is to develop a comprehensive, interdisciplinary, and quantitative characterization of a fluvial-deltaic reservoir which will allow realistic inter-well and reservoir-scale modeling to be constructed for improved oil-field development in similar reservoirs world-wide. The geological and petrophysical properties of the Cretaceous Ferron Sandstone in east-central Utah will be quantitatively determined. Both new and existing data will be integrated into a three-dimensional representation of spatial variations in porosity, storativity, and tensorial rock permeability at a scale appropriate for inter-well to regional-scale reservoir simulation. Results could improve reservoir management through proper infill and extension drilling strategies, reduction of economic risks, increased recovery from existing oil fields, and more reliable reserve calculations. Transfer of the project results to the petroleum industry is an integral component of the project.

Summary of Technical Progress

Four activities continued this quarter as part of the geological and petrophysical characterization of the fluvial-deltaic Ferron Sandstone in the Ivie Creek case-study area (Fig. 1): (1) petrophysical analyses, (2) geostatistics, (3) reservoir modeling, and (4) technology transfer.

Petrophysical Analyses

Petrophysical measurements were made on 87 Ferron Sandstone core plugs collected from the Ferron Sandstone No. 2-Ivie Creek parasequence set (Kf-2-Iv) during the 1995 field season and processed through Amoco Production Research's Geoscience Evaluation Module (GEM). The measurements consisted of: (1) saturated, dry, and grain densities, (2) effective and Boyle's Law porosities, (3) air permeability, (4) magnetic susceptibility, (5) qualitative and quantitative mineralogy, (6) compressional and shear wave velocities as a function of effective pressure, and (7) thin-section-image analysis. The specific details of the GEM procedures used are given by Sondergeld and Rai.¹⁻³ Velocities were measured using the pulse transmission technique of Schreiber, et al.⁴ and mineralogy was determined using a transmission infrared technique described by Griffiths and de Haseth.⁵

The major findings from preliminary analyses of these data are: (1) clay content has little effect on velocity but carbonate cementation increases velocity (via its reduction of porosity, not by directly increasing rigidity modulus), (2) a major source of velocity dispersion is the expansion that these outcropping rocks have undergone due to uplift and erosional exhumation, (3) only carbonate content has a significant effect on porosity from possible mineralogic controls, (4) porosity strongly controls permeability, with kaolinite content a much smaller influence where diagenetic kaolinite lines pores closing pore throats, and therefore decreasing permeability, (5) carbonate dissolution is a major control on Ivie Creek petrophysical patterns, and (6) the velocity structure is not representative. The porosity and permeability-structures still retain their original link to grain size, in spite of subsequent cementation and carbonate dissolution, so the applicability of fluid-flow modeling to deep exploration plays is not strongly impacted.

Ferron well logs from outside the Ivie Creek case-study area were analyzed for comparison of petrophysical responses to those observed in Ivie Creek core plugs and geophysical logs. The database search for all wells with both sonic and density logs of the Ferron identified 31 such wells. Twenty-four of these wells had accurate sonic and density logs with minimal gas effect. Velocities and densities for these wells were analyzed for velocity/porosity patterns which were compared the results to Ivie Creek data. A comparison was made of the discrete-core compressional velocity measurements to velocity and density measurements from geophysical logs from the Ivie Creek No. 3 core hole (Figs. 1 and 2). Agreement is generally good despite the different measurement techniques and the different measurement volumes.

Thin section were made from selected core plugs having varied lithology, lithofacies, and permeability values. All Ferron samples fall within a broad category of quartzo-feldspathic arenites, although they vary in the degree or amounts of grain types. Most sorting is moderate, with Kf-2-Iv shoreface sandstones (hummocky cross-stratified, horizontally bedded, or bioturbated) tending to be the "cleanest." This is to be expected given that the Kf-2-Iv are from wave-dominated (and reworked) sediments. The Ferron Sandstone No. 1 Ivie Creek parasequence set (Kf-1-Iv) samples

Fig. 1. Ivie Creek case-study area including location of the two- and three-dimensional model domains to be simulated. The approximate geometry of the intermediate-scale, two-dimensional domain is shaded and the detailed two-dimensional domain is a solid black line. Solid dots with associated numbers are locations of project core holes.

(A)

(B)

Fig. 2. Comparisons of geophysical log and continuous-core measurements, for both velocity and density, at the Ivie Creek No. 3 core hole (see Fig. 1 for location).

are typically "dirtier", contain more lithics and altered grains, and are more compact (probably due to rapid sedimentation from fluvial-dominated deltas).

Very little if any primary porosity remains in any of the samples. Almost all the porosity of any significance is secondary porosity controlled by the dissolution of carbonate phases (carbonate, dolomite, and possibly siderite). Where such secondary porosity is present, quartz and clay (kaolinite) cements largely remain with some interspersed minor carbonate and/or iron cement.

There appears to be a strong correlation between porosity and grain size in that the coarser grain sizes (generally fine to medium or coarse) tend to have more and larger pores. Coarser grained sandstones tend to be more quartz rich and are relatively "cleaner" with less matrix. Organic matter may form small-scale permeability barriers, and it is noted that coarser grained samples with better porosity generally contain less organic matter. Fine-grained samples tend to have more organic matter as well as more concavo-convex grain contacts resulting in reduced porosity.

Geostatistics

Geostatistical work this quarter was devoted to: (1) populating the Ferron Sandstone No. 1 Ivie Creek-a parasequence (Kf-1-Iv-a) with petrophysical data, and (2) investigating statistical relationships between geologic features and permeability data, and among various geologic features for the Kf-2-Iv in the Ivie Creek case-study area (Fig. 1). In order to run fluid-flow simulations for the three-dimensional facies model, the model must be populated with petrophysical data. The approach to be used requires that each lithofacies within the model be populated by the geometric mean of the permeability data. The geometric mean of the data is utilized in regions where fluid flow is neither parallel nor perpendicular to the strata. Plotting the permeability data for each facies on a log-normal plot show data spikes at about 2 millidarcies (md) and 0.5 md that corresponds to instrument limits. An approach to account for these values, is to model these low permeability values by extrapolating the log-normal trend observed in the higher permeability values (Fig. 3A).

Lithofacies panels (lithofacies, sedimentary structures, and grain sizes) for the Ivie Creek amphitheatre were used to generate a deterministic distribution of permeability. Each of three panels was discretized into 4 ft x 4 ft blocks and a number code was assigned for each attribute (for example clinoform proximal [CP] lithofacies = 2). These attribute values were loaded into the computer with accompanying spatial coordinates. The rules for assigning permeability values to each block were calculated from the transect data. Geometric mean permeability values were calculated for all known combinations of facies, sedimentary structures, and grain size.

Statistical analyses were calculated for the Kf-2-Iv. These included: (1) summary statistics (mean, median, and others) for each parasequence and lithofacies, (2) histograms, (3) cumulative probability plots, (4) relative percentage bar plots, and (5) cross plots. The Kf-2-Iv is a wave-modified, fluvial-deltaic system as compared to the Kf-1-Iv-a which is a fluvial-dominated system. This difference is reflected in the cumulative permeability plots that show much higher values for the Kf-2-Iv than for the Kf-1-Iv-a (Fig. 3B). The lithofacies identified within the permeability transect data range from lower shoreface to foreshore, mouth-bar, bay, and transgressive facies (Fig. 3C).

Each parasequence is characterized by a particular suite of lithofacies, grain sizes, and sedimentary structures as shown in the summary plots of Figure 4. The major lithofacies in the parasequences of the Kf-2-Iv is middle shoreface followed by distributary-mouth bar and lower

(A)

(B)

(C)

Fig. 3. Cumulative percent permeability plots from the Ferron Sandstone, Ivie Creek case-study area: (A) model data and raw data from the Kf-1-Iv-a parasequence, (B) raw data from the Kf-1-Iv-a parasequence and the a, b, c parasequences of the Kf-2-Iv, and (C) lithofacies versus permeability from the Kf-2-Iv. Abbreviations for lithofacies: CP - clinoform proximal, CM - clinoform medial, CD - clinoform distal, LSF - lower shoreface, MSF - middle shoreface, USF - upper shoreface, FOR - foreshore, DMB - distributary-mouth bar, DIB - distal-mouth bar, BAY - bay-fill, and TRA - transgressive.

Fig. 4. Statistical analyses of the Kf-2-Iv parasequence set as a whole and the three parasequences within it (a, b, and c), Ivie Creek case-study area: (A) histogram showing lithofacies distribution, (B) histogram showing grain-size distributions (megascopic observations), and (C) histogram showing relative frequency of sedimentary structures. Abbreviations for lithofacies: BAY - bay-fill, BHD - bay-head delta, BSH - backshore, COA - coastal plain, DIB - distal-mouth bar, DIC - distributary channel, DMB - distributary-mouth bar, FOR - foreshore, LSF - lower shoreface, MEB - meander belt, MSF - middle shoreface, PRO - prodelta, SWA - swamp, TRA - transgressive, and USF - upper shoreface. Abbreviations for sedimentary structures: CON - convoluted/contorted, FLA - flaser bedded, HOR - horizontally bedded, HUM - hummocky cross-stratified, IRR - irregularly laminated, RIP - ripple cross-laminated, TRO - trough-cross-stratified, and BIO - bioturbated.

Fig. 5. Sketch of an idealized clinoform geometry similar to those mapped within the Kf-1-Iv-a parasequence on cliffs found at the Ivie Creek case-study area.

A single, generic, model domain that encompasses up to four complete clinoforms in the Kf-1-Iv-a of the Ivie Creek amphitheatre will be created (Fig. 6). The model domain will be approximately 600 ft long with permeabilities distributed within the domain according to the rules inferred from work on the Ferron outcrop. Permeability and capillary pressure information will be gleaned from test results provided in the literature. This fine-grid model (for example, 1 ft by 0.2 ft grid block) is required to directly assess how capillary pressure effects might influence fluid flow across the bounding surfaces.

A sensitivity study will be used to explore the way that permeability variations associated with the sloping bounding surfaces included in the model domain might influence production strategies using the well configuration of Fig. 6A. Field-based constraints will be provided by additional detailed mapping, core plugging, and mini-permeability testing to be carried out next quarter. Different permeability distributions will be assigned to the bounding surfaces to determine how they influence reservoir production. Although most of the simulations will use a five-point differencing scheme, the relative merits of using a nine-point differencing scheme in simulating the sloping clinoform geometry will also be assessed.

Once the impact of different bounding surface types has been fully assessed, a simulation study will be used to explore the cost effectiveness of adding infill wells to enhance reservoir production (Figs. 6B and 6C). Although simulation results will be specific to the Kf-1-Iv-a outcrop, relationships will be developed that will help to estimate optimal well spacing in other geological environments where clinoform features are found with similar bounding surface geometries and petrophysical properties.

Task II - Two-Dimensional Intermediate-Scale Simulations. Task II differs from Task I in two important ways. First, the project studies will be expanded to assess more than just the possible impact of the bounding surfaces on reservoir production. This will be accomplished by developing a single, stochastic petrophysical model that includes variations in the petrophysical properties found within individual clinoforms. The stochastic model will be constrained by the detailed data collected at the Ivie Creek case-study site. Second, a larger grid-block size will be required (for example, 5 ft by 1 ft) because of working with a larger model domain (perhaps about 1000 ft long). As before, however, both primary production and water-flood scenarios will be simulated and the effectiveness of the homogenization method will be explored.

The petrophysical model to be simulated is based on the detailed clinoform/lithofacies maps constructed from photomosaics and geological mapping combined with the outcrop-based permeability data. In particular the focus will be on the medial-to-proximal lithofacies exposed in the cliff face at the Ivie Creek amphitheater (Fig. 7). The petrophysical model will include spatially varying permeability and porosity within both the bounding surfaces and the clinoform features. A stochastic approach has been developed to make the petrophysical assignments. A series of reservoir simulations will be run from primary production through water flood for different completion scenarios and infill strategies.

Task III - Three-Dimensional Reservoir Characterization and Simulation. The three-dimensional simulations of Task III will provide an opportunity to evaluate how the three-dimensional geometry of facies containing clinoform features might influence full-scale reservoir production. Although the two-dimensional model domains used in Tasks I and II will provide direct insight into the way that detailed variations in petrophysical properties might influence production,

Fig. 6. Sketch of the most detailed two-dimensional modeling domain showing a generic package of clinoforms with intervening bounding layers for a series of three-well configurations: (A) wells are isolated if bounding layers are impermeable, (B) well pairs communicate within a single clinoform, and (C) several wells communicate within a single clinoform.

Fig. 7. Sketch of intermediate-scale, two-dimensional modeling domain: (A) Kf-1-Iv-a parasequence as seen looking north at the cliff face with cut-out indicating medial-to-proximal facies within model, (B) well configuration for two-well production scenario, and (C) well configuration for three-well production scenario.

the impact of the three-dimensional geometry of clinoform sets cannot be assessed without using a full three-dimensional petrophysical model. Working in three dimensions, however, necessitates working with a larger grid block size (20 ft by 20 ft by 4 ft) in a representative model domain 2000 ft on a side. A single, carefully-selected production scenario (including both primary production and water flood) will be simulated using three different petrophysical models based on data collected for the Kf-1-Iv-a parasequence at the Ivie Creek amphitheatre; a homogeneous case (Fig. 8A), a simple layered case (Fig. 8B), and a more realistic heterogeneous case (Fig. 8C).

The most realistic petrophysical model is based on the gridded three-dimension facies model developed for a 2000 ft by 2000 ft region of the Kf-1-Iv-a at the Ivie Creek amphitheatre. Each petrophysical model used in the Task III simulations will be derived from the permeability and porosity values assigned to each facies type found within the gridded petrophysical domain. Thus, the homogeneous case will be parameterized using bulk averages of the permeability and porosity values assigned in the fully heterogeneous case. The simple layered case will be created using the values of permeability and porosity assigned in the full heterogeneous case at each of the production/injection wells to be included in the simulation. For example, once the synthetic wells are sampled from the three-dimensional petrophysical model, a series of layers containing lateral variations in petrophysical properties will be constructed while ignoring the potential implications of the sloping facies boundaries represented at the case-study site.

Task III will provide a basis for comparing the fluid-flow simulation results obtained using three different representations of the Kf-1-Iv-a petrophysical model. These results will help assess the value of using the three-dimensional geometry of clinoform features in predictive reservoir simulations.

Current Status of the Modeling Effort

During the quarter clinoform geometries of the Kf-1-Iv-a parasequence were incorporated in both two-dimensional and three-dimensional gridded model domains. In addition, the deterministic and stochastic routines needed to distribute permeability and porosity within the clinoform-based model domains have been developed and tested. Preliminary two- and three-dimensional fluid-flow simulations also demonstrate that the simulation tasks outlined are ready to proceed. It is anticipated that work performed during the coming quarter will yield significant progress towards completing these modeling tasks.

A key objective of the Ferron Sandstone project flow simulation studies is to incorporate outcrop-based geology and petrophysical properties into the flow models. The extent to which this can be done depends on the relative spatial scales of the flow model, the geological mapping, and the petrophysical data. If the flow modeling is done at a scale much smaller than that of the geological mapping then it is difficult to constrain the flow model using outcrop-derived architecture. Where flow modeling is done at a scale much larger than that of the geological and petrophysical data, averaged data are used. For example, a large flow model may be based on the spatial distribution of facies, each having specific petrophysical properties, rather than representing the more detailed depositional architecture.

Two-Dimensional Simulations (Tasks I and II). The two-dimensional flow simulations of the Ivie Creek amphitheater are done at a spatial scale near the scale of the outcrop mapping, and somewhat larger than the vertical spacing of outcrop permeability measurements. Because the scales of the

Fig. 8. Sketch of three-dimensional model domain showing: (A) homogeneous petrophysical model, (B) simple-layered model, and (C) full heterogeneous model. A hypothetical well pattern is shown on the top surface.

data and the flow simulations are so closely matched, the Ivie Creek case-study area provides an uncommon opportunity to examine how the architecture of delta-front deposits influences the spatial distribution of petrophysical properties and hence multiphase fluid flow in the subsurface.

Developing tools for integrating outcrop architecture into flow-simulation models was the focus of the quarter's activity. Several steps were required to convert the digitized line drawings of architecture provided by the project geologists into a grid that is used both to distribute petrophysical properties and for flow modeling. These include (in chronological order): (1) resolving gaps in the linework, (2) converting the linework to polygons, that is closed regions in space, (3) gridding polygonal regions to enable distribution of properties within individual polygons, and (4) merging individual polygons, with distributed properties, into a flow- simulation model (TETRAD-3D).

The basic architectural element of the Ivie Creek delta-front deposits is the clinoform (Fig. 5), a roughly sigmoidal shape representing an episode of deposition (and thus of delta-front progradation). At the distal end a clinoform laps onto previously deposited sediments (often older clinoforms). Proximally, a clinoform is truncated by either a younger clinoform or a parasequence boundary. Clinoforms are, therefore, closed regions of space. However, the linework obtained from the geologists included many clinoforms that were not completely enclosed. Lines often ended dangling in space, without terminating against another boundary (Fig. 9A). This was usually due to digitizing, although in some cases it was a result of geological uncertainty about the extent of a clinoform and its relationship to its neighbors. Digitizing problems were resolved manually by extending the line(s) enclosing a clinoform until it terminated against another clinoform, a parasequence boundary, or extended beyond the Ivie Creek case-study area (Fig. 9B). Geological uncertainties were resolved in consultation with project geologists. These linework boundaries were used to define clinoforms as unique polygons (in proper spatial positions) which could then be modeled as individual objects.

Once the boundaries of each clinoform are defined the clinoform must be gridded in order to assign petrophysical properties in the fluid-flow simulator. Petrophysical properties are then assigned to each grid block in the interior of a clinoform using a deterministic or stochastic approach. Figure 10B illustrates a gridded version of the clinoforms shown in Fig. 10A with the black grid blocks representing thin regions where the properties of bounding surfaces are specifically represented. Two computer programs were written to accomplish these tasks. The gridding program was designed to allow different gridding increments in the x and z directions.

Each computer program has been tested numerous times. The codes have been used to create a simple test model of a portion of the Ivie Creek amphitheater for preliminary flow simulations. A few flow simulations have now been run, but the results have not been closely examined and so are not presented here. The main effort during the next quarter will be in two areas: (1) populating clinoforms with petrophysical properties, and (2) performing and analyzing flow simulations.

Three-Dimensional Simulations (Task III). The detailed three-dimensional petrophysical model needed to study the Kf-1-Iv-a parasequence at the Ivie Creek amphitheatre was completed this quarter. Although the grid block size (20 ft by 20 ft by 4 ft thick) is much larger than those used in the two-dimensional simulations, it is still much smaller than what might be used in typical reservoir simulation studies. This block size was selected to provide insight into the way that lumped clinoform geometries might influence the interwell sweep efficiency of different oil production strategies. Preliminary three-dimensional simulations have been completed for a simple homogeneous case using TETRAD-3D. Full-scale simulations of both the homogeneous and

Fig. 9. Expanded view (not to scale) of some of the clinoforms mapped in the Kf-1-Iv-a parasequence at the Ivie Creek amphitheatre with: (A) gaps between lines marking clinoform boundaries shown by circles, and (B) closed polygons with each clinoform represented as a single closed form.

Fig. 10. Sample model domain showing: (A) closed polygons representing individual clinoforms and (B) digitized polygon set with bounding surfaces represented as black grid blocks having finite height and width.

heterogeneous petrophysical models are ready to begin.

Continuing Effort to Create Synthetic Clinoform-Like Objects. Previous quarterly reports have outlined the planned use of a stochastic code to generate packages of stacked clinoform-like objects that resemble the features mapped in the Kf-1-Iv-a parasequence at the Ivie Creek amphitheatre. The modeled result is being improved by integrating a new set of "soft" rules based on geological inferences. This is an empirical approach where the algorithm will be modified to produce new versions of the clinoform packages that more closely approximate the geometry of the clinoform packages mapped in outcrop. Over the past year a series of statistical measures have been developed that characterize the clinoform geometry mapped in the Ivie Creek photomosaics. These statistical measures will be used to constrain models of synthetic clinoform structures then populate the clinoforms with permeability and porosity values following the approach described above in Tasks I and II. The results of two-dimensional fluid-flow simulations performed on model domains containing the synthetic clinoform packages will be compared to simulation results obtained with the deterministic clinoform geometries identified in the field. This approach is expected to provide a basis for creating the synthetic two- and three-dimensional clinoform geometries needed to model oil production in reservoir systems where similar geological environments are encountered.

Summary

Now that the field-based information needed to begin the fluid-flow simulation tasks is available, a modeling strategy has been developed and implemented. Algorithms are in place to distribute permeability and porosity within clinoform geometries derived from either: (1) the field-based photomosaics, or (2) the stochastic code. The TETRAD-3D code is being used to perform preliminary fluid-flow simulations with both the two- and three-dimensional petrophysical models.

Technology Transfer

Project material was displayed at the Utah Geological Survey (UGS) booth during the American Association of Petroleum Geologists (AAPG) Rocky Mountain Section meeting held in Billings, Mont., July 28-31, 1996 and at a UGS co-sponsored symposium entitled the *Geology and Resources of the Paradox Basin* held in Durango, Colo., September 20-21, 1996. At the AAPG meeting, Ferron team members presented a paper describing reservoir analogs, facies prediction, and rules for reservoir modeling based on regional stratigraphic relationships.⁶ An abstract presenting the results of petrophysical analyses of Ferron core plugs from selected outcrop reservoir analogs was submitted for presentation at the 1997 AAPG Annual Convention in Dallas, Tex.

The UGS is preparing to present the final results of the project to both academia and industry. Field trips covering the regional stratigraphy and case-study areas will be conducted during the 1997 Geological Society of America (GSA) and 1998 AAPG annual national meetings. The field trip road logs and Ferron interpretations will be published in a two-volume GSA guidebook. A UGS co-sponsored short course presenting reservoir modeling and simulation results will also be offered during the AAPG meeting. The meetings will be held in Salt Lake City, Utah, October 19-22, 1997 (GSA) and May 20-23, 1998 (AAPG).

References

1. C. H. Sondergeld and C. S. Rai, *Geophysical Evaluation Module Operator's Manual*, Amoco Research Report T88-E-0033: non-pagenated (1988).
2. C. H. Sondergeld and C. S. Rai, A New Concept in Quantitative Core Characterization, *The Leading Edge*: 774-779 (July 1993).
3. C. H. Sondergeld and C. S. Rai, A New Exploration Tool: Quantitative Core Characterization, *PAGEOPH*, 141 (2/3/4): 249-268 (1993).
4. E. Schreiber, O. L. Anderson, and N. Soga, *Elastic Constants and Their Measurement*, McGraw-Hill, New York: 196 (1973).
5. P. R. Griffiths and J. A. de Haseth, *Fourier Transform Infrared Spectrometry*, John Wiley, New York: 656 (1986).
6. P. B. Anderson, T. A. Ryer, and T. C. Chidsey, Jr., Ferron Sandstone - Stratigraphy and Reservoir Analogs, East-Central Utah [abs.]: *Amer. Assoc. of Petrol. Geol. Bull.* 80 (6): 965 (1996).

NEXT QUARTER PLANNED ACTIVITIES

Activities planned for the next quarter include:

1. Continue plotting locations of measured sections, paleocurrent sites, and gamma-ray and mini-permeameter transects on base maps. Post paleocurrent rose diagrams on the digital base maps.
2. Complete graphical log displays of gamma-ray measurements taken from outcrops in the Ivie Creek case-study area.
3. Enter 1995 measured section data and core descriptions into the revised UGS database.
4. Continue petrophysical analysis of samples from the 1995 core-plugging program and evaluate geophysical logs from core-hole program.
5. Continue quantifying sedimentary and petrophysical data to develop statistical models.
6. Publish as a UGS contract report, the computer codes describing the method in intuitive terms and how to use the codes. Modify TETRAD, the modeling program provided by Mobil, to test the homogenization methods in real oil industry simulators. The modifications require the inclusion of full tensor permeabilities.
7. Complete production of cross sections and lithofacies maps from the Ivie Creek case-study area.
8. Continue to annotate digital photomosaics to be used in regional cross sections and correlations. Prepare a base map of the region, locating all measured sections and transects by their latitude and longitude.
9. Complete Willow Springs Wash cross sections, photomosaics, and lithofacies maps.
10. Populate clinoforms with petrophysical properties, perform and analyze flow simulations, and conduct full-scale simulations of both the homogeneous and heterogeneous petrophysical models.
11. Continued planning AAPG and GSA field trips and short course.