Morrow Series Study
of the
Las Animas Arch Region
Morrow Series of the Las Animas Arch Region

Overview

GeoDigital Information's Morrow Series study is designed to enhance both exploration and development efforts that are directed at Morrow reservoirs. These reservoirs occur within transgressive valley-fill sequences at multiple stratigraphic horizons. GDI has created an extensive sequence-stratigraphic framework that documents ten intervals of valley-fill deposits. The mapping of these intervals is essential in the exploration for Morrow-age reservoirs.

The Morrow study represents six man-years of geologic research which affords explorationists significant time savings in assimilating data and developing exploration strategies. The study area covers 16,500 square miles in southeastern Colorado, western Kansas, and the northern Oklahoma Panhandle. It spans Cheyenne, Prowers, Baca, and portions of Kit Carson, Lincoln, Kiowa, and Bent counties in Colorado; all of Wallace Greeley, Hamilton, Stanton, Morton, and portions of Sherman counties in Kansas; and portions of Cimarron and Texas counties in Oklahoma.

Correlations of 5,039 wells were made by defining six regional markers from the top of the Mississippian to the top of the Pennsylvanian Marmaton. Morrow valley-fill sequences are defined with, up to, 14 additional sub-regional correlation markers in 3,039 wells. Landsat imagery is included in the study to delineate paleostructures that affected Morrow drainage patterns and facies distributions.

Morrow depositional models and lithofacies reservoir potential are determined through the integration of core, thinsection, log analyses, and engineering data. Five representative field studies are incorporated with a focus on Morrow reservoir characteristics, trap types, and deliverability.

The Morrow study contains descriptions of 72 cores including 25 Union Pacific Resources proprietary cores and 11 Amoco Production proprietary cores that are essential for understanding the geologic history in this region.

The study components include an extensive summary text and figures, maps and cross sections, two volumes containing core and thinsection descriptions integrated with core-to-log comparisons, and four volumes of stratigraphic data appendices. These components provide the client with a presentation format that is concise and readily useable.

Database

| 5039 | Study Wells |
| 6    | Regional Stratigraphic Markers Correlated |
| 14   | Internal Morrow Markers Correlated |
| 72   | Cores Described |
| 395  | Thinsections |
Maps

Regional Maps (1 : 240,000)
12 Isopach Maps
1 Structure Map Top of Morrow
1 Penetration Map of Study Wells
1 Composite Map of Landsat Imagery, Valley Trends, and Interpreted Basement Blocks

Field Maps (1 : 36,000)
7 Isopach Maps
7 Net Sandstone Maps
7 Net Porous Sandstone (>10%) Maps
4 Structure Maps

Cross Sections

10 Regional Stratigraphic Sections
17 Field Cross Sections

Field Studies

Sorrento, Mt. Pearl, Stockholm SW, Kinsler, and McClave Fields

Report Contents


CORE DESCRIPTIONS - This appendix contain descriptions of 72 cores from southeast Colorado, southwest Kansas, and northwest Oklahoma.

STRATIGRAPHIC DATA - This section contains the stratigraphic data (20 formation tops, stratigraphic markers, and net sandstone values) and isopach values, as well as information on well name, operator, location, API number, completion date, datum, and production status for the 5039 study wells.

MAPS AND CROSS SECTIONS - This appendix contains fifteen regional maps at a scale of 1 : 240,000 and 25 field maps at a scale of 1 : 36,000. This includes isopach maps, structure maps, net sandstone maps, and a study well map.
Morrow Series of the Las Animas Arch
Morrow Series
of the
Las Animas Arch

Study
Table of Contents
# TABLE OF CONTENTS

Table of Contents ........................................................................................................ i  
List of Figures .............................................................................................................  vi  
List of Plates .............................................................................................................  xiii  
List of Tables .............................................................................................................  xiv  
List of Cross Sections ............................................................................................. xvi  
List of Maps ............................................................................................................. xvii  
Acknowledgements .................................................................................................. xviii  

## Summary

Summary ..................................................................................................................... S-1  
Approach .................................................................................................................. S-3  
Major Findings ......................................................................................................... S-4  
Tectonic Setting ....................................................................................................... S-4  
Depositional Setting and Environments ................................................................ S-4  
Sequence Stratigraphy ........................................................................................... S-5  
Petrography ............................................................................................................... S-5  
Petrophysics ............................................................................................................. S-6  
Field Studies ........................................................................................................... S-6  
Exploration Recommendations ............................................................................. S-6  
Engineering Recommendations .......................................................................... S-7  

## Chapter 1

Introduction .............................................................................................................. 1-1  
Methodology & Control ......................................................................................... 1-2  
Report Format ........................................................................................................ 1-3  

## Chapter 2

Tectonic and Depositional Setting ......................................................................... 2-1  
Tectonic Setting ...................................................................................................... 2-2  
Depositional Setting ............................................................................................... 2-4  
Sea-Level Fluctuations and Depositional Cycles .................................................. 2-5  

## Chapter 3

Regional Stratigraphic Framework .................................................................... 3-1  
Stratigraphic Picks ................................................................................................. 3-2  
Desmoinesian Series ............................................................................................. 3-3  
Marmaton Group .................................................................................................. 3-3  
Cherokee Group .................................................................................................... 3-3  
Atokan Series ........................................................................................................ 3-4  
Upper Atoka .......................................................................................................... 3-5  
Lower Atoka .......................................................................................................... 3-5  
Morrow Series ...................................................................................................... 3-6  


Chapter 8

Sequence Stratigraphy ................................................................. 8-1
Evolution of Stratigraphic Concepts .............................................. 8-2
Morrowan Stratigraphy ................................................................. 8-3

Chapter 9

Valley-Fill Systems ................................................................. 9-1
Definition and General Characteristics ......................................... 9-2
Phases of Valley-Fill Development ............................................... 9-3
Variations in Valley-Fill Systems ................................................. 9-4
Other Valley-Fill Systems ........................................................... 9-4
Texas Gulf Coast ................................................................. 9-4
Muddy Sandstone, Powder River Basin ....................................... 9-5
Criteria for Recognition of Valley-Fill Systems ............................... 9-5

Chapter 10

Morrow Sequence Stratigraphy .................................................. 10-1
Introduction ........................................................................ 10-2
Morrow Group .................................................................... 10-3
Lower Morrow ................................................................ 10-3
Upper Morrow ................................................................ 10-3
Definition of Valley-Fill Sequences ............................................ 10-4
Valley-Fill Sequences .............................................................. 10-5
U903-U953U .................................................................... 10-5
U803-853U .................................................................... 10-6
U703-U753U .................................................................... 10-6
U603-U653U .................................................................... 10-6
U701-U751U and U702-U752U ................................................ 10-7
U601-U651U and U602-U652U ................................................ 10-7
U401-U451U, U402-U452U, and U403-U453U ...................... 10-8
0351-U361U .................................................................... 10-8
U201-U301U and U202-U302U ................................................ 10-9
U101-U151U, U102-U152U, and U103-U153U ...................... 10-9
MRRW-U051U, MRRW-U052U, and MRRW-U053U ............. 10-10

Chapter 11

Petrography ........................................................................ 11-1
Introduction .................................................................. 11-2
Previous Work ................................................................. 11-2
Composition of Sandstones ....................................................... 11-4
Potential Reservoir Types ......................................................... 11-5
Nonreservoir Lithofacies ........................................................ 11-7
Porosity ........................................................................ 11-7
Diagenesis ..................................................................... 11-8
Observed Diagenetic Sequence ............................................... 11-8
Model for Diagenesis .............................................................. 11-9
Burial History of the Study Area ........................................ 11-10
Reservoir Quality .............................................................. 11-11
Provenance of Sandstones .................................................. 11-12
  Information from Framework Grains .................................... 11-12
Potential Source Areas ....................................................... 11-14
Conclusions ................................................................. 11-15

Chapter 12

Field Studies ................................................................. 12-1
Introduction ................................................................. 12-2
Petrophysical Methods ...................................................... 12-2
Data Preparation ............................................................. 12-3
Determination of Shale Volume and Effective Porosity ............ 12-4
Lithology Determinations ................................................. 12-4
Fluid Saturations ............................................................. 12-5
Effects of Mineralogy on Logs ............................................ 12-6

Sorrento/Mt. Pearl Fields ..................................................... 12-SMP1
History ............................................................... 12-SMP2
Geologic Setting ............................................................. 12-SMP2
Petrography ................................................................. 12-SMP5
Engineering Considerations .............................................. 12-SMP7
Reservoir Simulation Study of Alternative Schemes for Depletion of Thin Oil Columns Common to Morrow Oil Reservoirs .... 12-SMP9

Stockholm Field .............................................................. 12-S1
History ............................................................... 12-S2
Geologic Setting ............................................................. 12-S3
Petrography ................................................................. 12-S5
Petrophysics ................................................................. 12-S6
Production Characteristics .............................................. 12-S7
Reservoir Performance and Secondary Recovery Efforts ......... 12-S8

McClave Field ................................................................. 12-M1
History ............................................................... 12-M2
Geologic Setting ............................................................. 12-M3
Petrophysics ................................................................. 12-M5
Engineering Considerations .............................................. 12-M6
  Completion Methods .................................................... 12-M6
  Production Problems .................................................. 12-M7
  Hydraulic Fracturing .................................................... 12-M7
Pressure Transient Test Analyses ..................................... 12-M8

Kinsler Field ................................................................. 12-K1
History ............................................................... 12-K2
Geologic Setting ............................................................. 12-K2
Petrography ................................................................. 12-K4
Engineering Considerations .............................................. 12-K6
  Acid Susceptibility Tests ............................................. 12-K7
### Chapter 13

Exploration Recommendations ............................................................. 13-1  
Introduction ...................................................................................... 13-2  
Las Animas Arch Province ................................................................. 13-4  
Stockholm Province .......................................................................... 13-7  
Hugoton Embayment Province ........................................................... 13-10  
Morrow Hinge Province .................................................................... 13-12  
Apishapa Uplift .............................................................................. 13-15  
Summary ......................................................................................... 13-17

### Chapter 14

Engineering Recommendations ........................................................... 14-1  
Exploration Well Program ................................................................. 14-2  
Drilling ............................................................................................... 14-2  
Coring ............................................................................................... 14-2  
Openhole Logging ............................................................................ 14-3  
Drillstem Testing ............................................................................ 14-4  
Pressure Transient Testing of Oil Wells .......................................... 14-4  
Handling Production Problems in Morrow Reservoirs ............... 14-4  
Effects of Drilling and Completion Fluids on Clays and Cements ... 14-4  
Formation Fluids and Production .................................................. 14-6  
Water Flooding .............................................................................. 14-6  
Ideas for Optimizing Test and Production ....................................... 14-7  
Horizontal Well Technology ............................................................ 14-7  
Drillstem Testing ............................................................................ 14-8  
Pressure Transient Testing of Oil Wells .......................................... 14-9  
Reservoir Drive Mechanisms .......................................................... 14-9  
Reservoir Simulation .................................................................... 14-10

### Bibliography

Bibliography ...................................................................................... B-1  
Bibliography ...................................................................................... B-2
LIST OF FIGURES

Summary
S.1 Study area with significant Morrow fields
S.2 Composite map of Morrow valley trends
S.3 Location of grid of regional cross sections
S.4 Schematic diagram of upper Morrow correlations
S.5 Morrow depositional models: A) lowstand, B) highstand conditions
S.6 Association of Morrow valleys with basement block margins
S.7 Late Paleozoic structural features

Chapter 1  Introduction
1.1 Structural features in study area
1.2 Morrow penetration map
1.3 Morrow field locations
1.4 Regional cross section locations
1.5 Described core and thin section locations
1.6 Type log from Sorrento/Mt Pearl Fields showing Morrowan stratigraphic picks
1.7 Schematic Morrowan depositional models

Chapter 2  Tectonic and Depositional Setting
2.1 Present-day structural features in study and adjacent areas
2.2 Reconstructions of Mississippian and early Pennsylvanian plate positions
2.3 Structural features associated with the collision of the African and South American plates with the North American plate
2.4 Effects of basement blocks on Muddy Sandstone depositional patterns in the Powder River Basin

Chapter 3  Stratigraphy
3.1 Type log, Baca County, Colorado
3.2 Regional dip-oriented cross section B-B' showing general northward thinning and southeastward thickening of mapped intervals
3.3 General Marmaton log characteristics in the Las Animas Arch area
3.4 Log showing three carbonate/marine shale intervals within the Marmaton Group
3.5 Cross-section showing Cherokee Group characteristics and regional pick variations
3.6 Cross sections showing variations in the Cherokee Group interval: A) Thinning across the Las Animas Arch and B) Thickening into the Hugoton Embayment
3.7 Lower and upper Atoka log characteristics
3.8 Cross section illustrating time-transgressive nature of the upper Atoka marker
3.9 Cross section showing nature of upper Atoka interval in the Las Animas Arch area
3.10 Total Morrow isopach map
3.11 Cross section of upper Morrow valley-fill sandstone and flanking strata
3.12 Log characteristics of the lower Morrow interval in the central portion of the study area
3.13 Log characteristics of lower Morrow interval in the Hugoton Embayment and Anadarko Basin

Chapter 4 Landsat Imagery

4.1 Relationship of surface linear features to basement faults; Modified from Shurr (1982)
4.2 Late Paleozoic structural features associated with plate collision
4.3 Linear features observed on Landsat imagery
4.4 Structural provinces and their relationship to linear features
4.5 Structure on top of Morrow with basement blocks delineated
4.6 Interpreted boundaries of fault-bounded basement blocks inferred from Landsat linear features
4.7 Relationship of lineaments to geophysical surveys, Morrow valley trends, and fault-bounded basement blocks
4.8 Relationship of basement blocks to isopach values

Chapter 5 Lithofacies

5.1 Schematic block diagram showing depositional relationships of A) fluvial and B) marine Lithofacies
5.2 Core-to-log comparison of Dark Gray Thinly-Laminated Shale Lithofacies
5.3 Core-to-log comparison of Shaly Carbonate Lithofacies
5.4 Core-to-log comparison of Skeletal Wackestone to Grainstone Lithofacies
5.5 Core-to-log comparison of Interlaminated to Bioturbated Sandstone and Shale Lithofacies
5.6 Core-to-log comparison of Cross-Bedded Fossiliferous Sandstone Lithofacies
5.7 Core-to-log comparison of Cross-Bedded Sandstone with Shale Drapes Lithofacies
5.8 Core-to-log comparison of Conglomerate to Conglomeratic Sandstone Lithofacies
5.9 Core-to-log comparison of Coarse-Grained Cross-Bedded Sandstone Lithofacies
5.10 Core-to-log comparison of Fine-Grained Ripple-Laminated Sandstone Lithofacies
5.11 Core-to-log comparison of Gray-Green Mudstone Lithofacies
5.12 Core-to-log comparison of Dark Gray Carbonaceous Mudstone Lithofacies
5.13 Core-to-log comparison of Coal Lithofacies

Chapter 6 Petrophysical Facies

6.1 Characteristic log responses of the Marine Shale Petrophysical Facies
6.2 Characteristic log responses of the Marine Calcareous Mudstone Petrophysical Facies
6.3 Characteristic log responses of Marine Limestone Petrophysical Facies
6.4 Characteristic log responses of the Marine Sandy Mudstone Petrophysical Facies
6.5 Characteristic log responses of the Estuarine Sandstone Petrophysical Facies
6.6 Characteristic log responses of the Sandstone Petrophysical Facies
6.7 Characteristic log responses of the Fluvial Mudstone, Siltstone and Shale Petrophysical Facies
6.8 Characteristic log responses of the Coal Petrophysical Facies
6.9 Distribution of petrophysical facies in A) low sea level stillstand and B) high sea level stillstand depositional models
Chapter 7  Depositional Environments

7.1 Schematic depositional models for A) low sea level stillstand and B) high sea level stillstand
7.2 Valley-fill (fluvial) depositional model
7.3 Core-to-log comparison of valley-fill fluvial facies
7.4 Variations in valley-fill fluvial channel sequences
7.5 Core-to-log comparison of valley-fill floodplain facies
7.6 Valley-fill (estuarine) depositional model
7.7 Core-to-log comparison of valley-fill estuarine facies
7.8 Tidal channel point bar depositional model
7.9 Core-to-log comparison of tidal channel point bar facies
7.10 Shoreface depositional models for A) low-energy and B) high-energy conditions
7.11 Core-to-log comparison of low-energy Shoreface facies
7.12 Core-to-log comparison of moderate- to high-energy shoreface facies
7.13 Marine depositional model
7.14 Core-to-log comparison of marine carbonate facies

Chapter 8  Sequence Stratigraphy

8.1 Schematic representation of sequence units and terminology
8.2 Schematic model of sequence development phase one: sea level drop and stillstand
8.3 Schematic model of sequence development phase two: initial transgression
8.4 Schematic model of sequence development phase three: continued transgression
8.5 Schematic model of sequence development phase four: late stage transgression
8.6 Schematic model of sequence development phase five: maximum transgression and high stillstand

Chapter 9  Valley-Fill Systems

9.1 Schematic valley profiles and fill characteristics of a fluvial system with stable baselevel
9.2 Schematic fluvial system with fluctuating baselevel
9.3 Longitudinal profiles of streams showing location and characteristics of valley-fill deposits under different depositional conditions
9.4 Stacked Brazos river point bars
9.5 Isopach and cross sections of fluvial-fill in Corpus Christi Bay, Texas
9.6 Location of valley-fill facies in Matagorda Bay, Texas
9.7 Relationship of basement block-bounded blocks and position of Muddy Sandstone valley-fill sequences
9.8 Stages of valley development in a Muddy Sandstone hydrocarbon field
9.9 Representative Morrow valley-fill facies sequence

Chapter 10  Morrow Sequence Stratigraphy

10.1 Map of study area showing geographic distribution of the five correlation classes
10.2 Schematic regional Morrow Group cross section showing stratigraphic relationship of valley-fill sequences
10.3 Core-to-log correlation illustrating valley-fill sequence picks and their relationship to sequence Stratigraphy
10.4 Block diagram illustrating relationships between sequence Stratigraphy terminology and valley-fill sequences
10.5 Relationships between correlations in the five classes of RPI stratigraphy
10.6 Cross Section showing 0903-U953U valley-fill sequence
10.7 Map of U903-U953U valley trends
10.8 Cross section showing U803-U853U valley-fill sequence 10.9 Map of U803-U853U valley trends
10.10 Cross section showing U703-U753U valley-fill sequence
10.11 Map of U703-U753U valley trends
10.12 Cross section showing U603-U653U valley-fill sequence
10.13 Map of U603-U653U valley trends
10.14 Cross section showing U701-U751U valley-fill sequence
10.15 Map of U701-U751U and U702-U752U valley trends
10.16 Cross section showing U601-U651U valley-fill sequence
10.17 Map of U601-U651U and U602-U652U valley trends
10.18 Cross section showing U401-U501U valley-fill sequence
10.19 Type log showing the U403-U453U valley-fill sequence
10.21 Cross section showing 0351-U361U valley-fill sequence
10.22 Map of U351-U361U valley trends
10.23 Cross section showing U201-U301U valley-fill sequence
10.24 Map of U201-U301U and U202-U302U valley trends
10.25 Cross section showing U101-U151U valley-fill sequence
10.26 Map of U101-U151U, U102-U152U, and U103-U153U valley trends
10.27 Type log showing the MRRW-U052U valley-fill sequence
10.28 Map of MRRW-U051U, MRRW-U052U, and MRRW-U053U valley trends

Chapter 11 Petrography

11.1 Location of thinsection samples
11.2 Ternary diagram of Morrowan sandstones
11.3 Ternary diagram of relative proportions of clay, cement and porosity in the various sandstone facies
11.4 Burial history curves for Morrow strata in the A) Sorrento/Mt Pearl Field area, B) Stockholm Field area, and C) Hugoton Embayment
11.5 Regional distribution of volcanic rock fragments 11.6 Map showing potential source areas
11.6 Potential source areas for Morrow sandstones

Chapter 12 Field Studies

12.1 Location of the five fields selected for detailed study
12.2 Comparison of core measurements and computed log results
12.3 Matrix identification plot; modified from Schlumberger (1987)
Sorrento/Mt Pearl Fields (SMP)

12.SMP1 Penetration map of Sorrento/Mt Pearl Field area showing location of described cores and cross section locations
12.SMP2 Type log from the Sorrento Field area
12.SMP3 Type log from the Mt Pearl Field area
12.SMP4 Top Morrow structure map showing sandstone distribution
12.SMP5 Structural cross section across Sorrento/Mt Pearl Field area showing oil-water contacts
12.SMP6 Schematic cross section showing stratigraphic relationships in Sorrento/Mt Pearl Field area
12.SMP7 Isopach of U401-U501U valley-fill sequence in the Sorrento/Mt Pearl field area
12.SMP8 Net sandstone isopach of U401-U501U valley showing distribution of porous (>10%) sandstone
12.SMP9 Isopach map of the 0201-U301U valley-fill sequence in Sorrento/Mt Pearl Field area
12.SMP10 Net sandstone isopach of 0201-U301U valley showing distribution of porous (>10%) sandstone
12.SMP11 Cross Section B-B' showing stratigraphic relationships in Sorrento Field
12.SMP12 Cross Section D-D' showing stratigraphic relationships in Mt Pearl Field
12.SMP13 Cross Section F-F' showing stratigraphic relationships in Mt Pearl Field
12.SMP14 Simulation of production rates and ratios for selected Sorrento/Mt Pearl Field area wells
12.SMP15 Simulation of production rates and ratios for Mull Unit and Mt Pearl Unit
12.SMP16 Oil production and oil production decline for various depletion schemes in Sorrento and Mt Pearl fields
12.SMP17 Gas/oil ratio for various depletion schemes in Sorrento and Mt Pearl fields (rate MCF/day and cumulative MCF)
12.SMP18 Water/oil ratio, water production rate (STB/day) and cumulative water production (STB) for various depletion schemes
12.SMP19 Gas injection rates (MCF/day) and cumulative gas production (MCF) for various depletion schemes in Sorrento and Mt Pearl Fields
12.SMP20 Reservoir pressure decline for various depletion schemes in Sorrento and Mt Pearl Fields

Stockholm Field SW (S)

12.S1 Type log for Stockholm SW Field
12.S2 Penetration map showing location of described cores and cross sections for Stockholm SW Field
12.S3 Top Morrow structure map of Stockholm SW Field with distribution of U202-U302 and U702-U752U valley-fill sandstones
12.S4 Structural cross sections along the valley axis in Stockholm SW Field
| 12.S5 | Schematic cross section showing valley-fill sequences in Stockholm SW Field |
| 12.S6 | Isopach map of the U702-U752U valley-fill sequence in Stockholm SW Field |
| 12.S7 | Net sandstone isopach of the U702-U752U valley-fill sequence in Stockholm SW Field showing the distribution of porous (>10%) sandstone |
| 12.S8 | Isopach map of the U202-U302U valley-fill sequence in Stockholm SW Field |
| 12.S9 | Net sandstone isopach map of the U202-U302U valley-fill sequence in Stockholm SW Field showing the distribution of porous (>10%) sandstone |
| 12.S10 | Cross section B-B’ showing stratigraphic relationships in the northern part of Stockholm SW Field |
| 12.S11 | Cross section C-C’ showing stratigraphic relationships in the central part of Stockholm SW Field |
| 12.S12 | Map showing a plan for water flooding of the Stockholm Field Unit |

**McClave Field (M)**

| 12.M1 | Penetration map of McClave Field showing location of described cores and cross sections |
| 12.M2 | Type log for the central part of McClave Field |
| 12.M3 | Type log for the northern part of McClave Field |
| 12.M4 | Top Morrow structure map in the McClave Field area showing the distribution of sandstone in the major valley-fill sequences |
| 12.M5 | Schematic cross section showing relationship of valley-fill sequences in main portion of McClave Field |
| 12.M6 | Schematic cross section showing relationship of valley-fill sequences in the northern portion of McClave Field |
| 12.M7 | Isopach map of the U401-U501U valley-fill sequence |
| 12.M8 | Net sandstone isopach map of the U401-U501U valley-fill sequence in McClave Field showing the distribution of porous (>10%) sandstone |
| 12.M9 | Isopach map of the U351-U361U valley-fill sequence in McClave Field |
| 12.M10 | Isopach map of the U101-U151U valley-fill sequence in McClave Field |
| 12.M11 | Net sandstone isopach map of the 0101-U151U valley-fill sequence in McClave Field showing the distribution of porous (>10%) sandstone |
| 12.M12 | Cross section C-C' showing stratigraphic relationships in McClave Field |
| 12.M13 | Cross section D-D' showing stratigraphic relationships in McClave Field |
| 12.M14 | Structural cross-section along the McClave valley axis |
| 12.M15 | Comparison of the log responses of two gas producing wells in McClave Field |
| 12.M16 | Monthly gas production rates from McClave Field |
12.M17 Semi-log plot of adjusted pressure vs. effective time function and type curve plot for Semmens No 1 DST
12.M18 Semi-log plot of adjusted pressure vs. effective time function and type curve plot for Temple "D" No. 1 DST with monthly gas production for 1978-1988
12.M19 Semi-log plot of adjusted pressure vs. effective time function and type curve plot for Rowe "A" No. 1 DST with monthly gas production for 1981-1988
12.M21 Semi-log plot of adjusted pressure vs. effective time function and type curve plot for Temple "A" No. 1 DST with monthly gas production for 1978-1988
12.M22 Semi-log plot of adjusted pressure vs. adjusted Horner time function and type curve plot for Humphrey-Wollert No. 1 DST with monthly gas production from 1975-1988

Kinsler Field (K)
12.K1 Penetration map showing location of described cores and cross sections
12.K2 Schematic cross section showing stratigraphic relationships of Kinsler Field valley-fill sequences
12.K3 Type log of Kinsler Field area
12.K4 Top Morrow structure map in the Kinsler Field area showing the distribution of sandstone in the U103-U153U valley-fill sequence
12.K5 Isopach map of the 0103-U153U valley-fill sequence in Kinsler Field area
12.K6 Net sandstone isopach of the U103-U153U valley-fill sequence in the Kinsler Field area showing the distribution of porous (>101) sandstone
12.K7 Cross section K-K' showing stratigraphic relationships in the Kinsler Field area
12.K8 Structural cross section across Kinsler Field showing gas-oil contacts
12.K9 Decline curves for five Kinsler Field wells
12.K10 Acid susceptibility of iron-rich carbonates in the Hayward No. 1 well

Chapter 13 Exploration Recommendations
13.1 Structural provinces defined on the basis of Landsat imagery features
13.2 Distribution of Morrow oil and gas fields within the five structural provinces
13.3 Schematic regional Morrow cross section showing general stratigraphic relationships of incised valley-fill sequences
13.4 Composite map of upper Morrow valley trends
13.5 Regional distribution of Morrow oil and gas production and shows
13.6 Exploration recommendations of the Las Animas Arch Province
13.7  Exploration recommendations of the Stockholm Province
13.8  Maps showing A) upper Morrow and B) lower Morrow penetrations
13.9  Exploration recommendations of the Hugoton Province
13.10 Exploration recommendations of the Morrow Hingeline Province
13.11 Exploration recommendations of the Apishapa Province

Chapter 14   Engineering Recommendations

14.1  Schematic medium-radius horizontal wellbore penetrating a reservoir
LIST OF PLATES

Chapter 5  Lithofacies

5.1 Core and thinsection photomicrographs of the Dark-Gray Thinly Laminated Shale Lithofacies
5.2 Core and thinsection photomicrographs of the Shaly Packstone Lithofacies
5.3 Core photographs of the Skeletal Wackestone to Grainstone Lithofacies
5.4 Thinsection photomicrographs of the Skeletal Wackestone to Grainstone Lithofacies
5.5 Core photographs and thinsection photomicrographs of the Interlaminated to Bioturbated Sandstone to Shale Lithofacies
5.6 More core photographs and thinsection photomicrographs of the Interlaminated to Bioturbated Sandstone to Shale Lithofacies
5.7 Core photographs and thinsection photomicrographs of the Cross-Bedded Fossiliferous Sandstone Lithofacies
5.8 Core photographs and thinsection photomicrographs of the Cross-Bedded Sandstone with Shale Drapes Lithofacies
5.9 Core photographs and thinsection photomicrographs of the Conglomerate to Conglomeratic Sandstone Lithofacies
5.10 Core photographs of the Coarse-Grained Cross-Bedded Sandstone Lithofacies
5.11 Thinsection photomicrographs of the Coarse-Grained Cross-Bedded Sandstone Lithofacies
5.12 Core photographs and thinsection photomicrographs of the Fine-Grained Ripple-Laminated Sandstone Lithofacies
5.13 Core photographs and thinsection photomicrographs of the Gray-Green Mudstone and the Dark-Gray Lithofacies
5.14 Core photographs of the Coal Lithofacies

Chapter 11  Petrography

11.1 Examples of feldspar alteration
11.2 Examples of non-quartz grain types
11.3 Examples of clays
11.4 Examples of cements I
11.5 Examples of cements II
11.6 Examples of porosity I
11.7 Examples of porosity II
11.8 Examples of porosity III
LIST OF TABLES

Chapter 1   Introduction

1.1   Significant Morrow fields, discovery dates and cumulative productions
1.2   Generalized correlation chart

Chapter 5   Lithofacies

5.1   List of the 12 major lithofacies observed in core
5.2   Summary of lithofacies present in each described cored interval
5.3   Characteristics of the Dark-Gray Thinly Laminated Shale Lithofacies
5.4   Characteristics of the Shaly Carbonate Lithofacies
5.5   Characteristics of the Skeletal Wackestone to Grainstone Lithofacies
5.6   Characteristics of the Interlaminated to Bioturbated Sandstone to Shale Lithofacies
5.7   Characteristics of the Cross-Bedded Fossiliferous Sandstone Lithofacies
5.8   Characteristics of the Cross-Bedded Sandstone with Shale Drapes Lithofacies
5.9   Characteristics of the Conglomerate to Conglomeratic Sandstone Lithofacies
5.10  Characteristics of the Coarse-Grained Cross-Bedded Sandstone Lithofacies
5.11  Characteristics of the Fine-Grained Ripple-Laminated Sandstone Lithofacies
5.12  Characteristics of the Gray-Green Mudstone Lithofacies
5.13  Characteristics of the Dark-Gray Carbonaceous Mudstone Lithofacies
5.14  Characteristics of the Coal Lithofacies

Chapter 6   Petrophysical Facies

6.1   Relationship between petrophysical facies and lithofacies
6.2   Summary of log responses of the various petrophysical facies
6.2   Characteristic log responses of the eight petrophysical facies

Chapter 7   Depositional Environments

7.1   Depositional environments observed in cored intervals

Chapter 10   Morrow Sequence Stratigraphy

10.1  Correlation chart for the three detailed classes of upper Morrow stratigraphy

Chapter 11   Petrography

11.1  Summary of thinsection samples
11.2  X-ray diffraction traces of Morrow interstitial clays
11.3  Comparison of potential reservoir lithofacies
11.4 Characteristics of non-reservoir lithofacies types
11.5 Sequence of diagenetic events in Morrowan deposits
11.6 Values used to construct burial history curves

Chapter 12 Field Studies

12.1 Log analysis parameters for selected Morrowan fields
12.SMP1 Characteristics of Sorrento and Mt Pearl fields
12.SMP2 Sorrento and Mt Pearl Field area wells examined petrographically
12.SMP3 Summary of Sorrento/Mt Pearl field properties
12.SMP4 Reservoir properties used in reservoir simulation
12.SMP5 Results of reservoir simulation
12.S1 Characteristics of Stockholm SW Field
12.S2 Stockholm SW Field area wells examined petrographically
12.M1 Characteristics of McClave Field
12.M2 McClave Field Study summary of well test analysis results
12.M3 McClave Field well test analyses
12.M4 McClave Field test data
12.K1 Characteristics of Kinsler Field
12.K2 Kinsler Field area wells examined petrographically

Chapter 13 Exploration Recommendations

13.1 Oil and gas fields producing from various GDI stratigraphic intervals
13.2 Major producing intervals in significant Morton County, Kansas oil and gas fields
LIST OF CROSS SECTIONS

Regional Cross Sections
  Vertical Scales: 1"=100' and 1"=40'
  A-A'
  B-B'
  B"-B"
  B"-B"
  C-C'
  C"-C"
  W-W'
  X-X'
  Y-Y'
  Z-Z'

Sorrento/Mt Pearl Field Area Cross Sections
  Vertical Scale: 1"=40'
  A-A'
  A"-A"
  A"-A"
  B-B'
  C-C'
  D-D'
  E-E'
  F-F'
  Log-Derived Lithology - East
  Log-Derived Lithology - West
  Core to Log Comparisons

Stockholm Field Area Cross Sections
  Vertical Scale: 1"=40'
  A-A'
  A"-A"
  B-B'
  C-C'
  D-D'

McClave Field Area Cross Sections
  Vertical Scale: 1"=40'
  A-A'
  B-B'
  C-C'
  D-D'
  E-E'

Kinsler Field Area Cross Sections
  Vertical Scale: 1"=40"
  A-A'
  B-B'
  C-C'
LIST OF MAPS

Regional Maps (1:240,000)
- Marmaton Isopach
- Cherokee Isopach
- Upper Atoka Isopach
- Lower Atoka Isopach
- Total Atoka Isopach
- Upper Morrow Isopach
- Total Morrow Isopach
- Top Morrow Structure
- Penetration of Study Wells
- Composite of Landsat Imagery, Valley Trends and Interpreted Basement Blocks
- 0101-U151U, U102-U152U, U103-U153U Isopach
- U201-U301U, U202-U302U Isopach
- U601-U651U, U602-U652U Isopach
- U701-U751U, U702-U752U Isopach

Sorrento/Mt Pearl Field Area Maps (1:36,000)
- 0401-U501U Isopach
- U401-U501U Net Sandstone Isopach
- U401-U501U Net Porous (>10%) Sandstone Isopach
- U201-U301U Isopach
- U201-U301U Net Sandstone Isopach
- U201-U301U Net Porous (>10%) Sandstone Isopach
- Top Morrow Structure

Stockholm SW Field Area Maps (1:24,000)
- U702-U752U Isopach
- U702-U752U Net Sandstone Isopach
- U702-U752U Net Porous (>10%) Sandstone Isopach
- U202-U302U Isopach
- U202-U302U Net Sandstone Isopach
- U202-U302U Net Porous (>10%) Sandstone Isopach
- Top Morrow Structure

McClave Field Area Maps (1:48,000)
- U401-U501U Isopach
- U401-U501U Net Sandstone Isopach
- 0401-U501U Net Porous (>10%) Sandstone. Isopach
- U101-U151U Isopach
- U101-U151U Net Sandstone Isopach
- U101-U151U Net Porous (>10%) Sandstone Isopach
- Top Morrow Structure

Kinsler Field Area Maps (1:36,000)
- U103-U153U Isopach
- U103-U153U Net Sandstone Isopach
- 0103-U153U Net Porous (>10%) Sandstone Isopach
- Top Morrow Structure
Morrow Series
of the
Las Animas Arch

Selected Figures from the Study
Figure 1.7. Schematic Morrow depositional models. A) Low sea level stillstand. B) High sea level stillstand. These depositional models are discussed in detail in Chapter 7 (Depositional Environments). The effect of sea-level fluctuations on stratigraphic sequences is outlined in Chapter 8 (Sequence Stratigraphy).
Figure 12.M15. Comparison of logs from two gas-producing wells in McClave Field showing the effect of invasion of drilling fluid on log response. Invaded drilling fluid masks the log response in the Semmens 1 well. Semmens 1 well had an IP of 973 MCFD; Humphrey-Wollert 1 well had an IP of 572 MCFD.
Figure 2.2. Reconstructions of A) Mississippian and B) Early Pennsylvanian plate relationships.
Figure 10.19. Type-log for the U403-U453U valley-fill sequence. The U403-U453U valley-fill sequence is well-developed and is productive in the Taloga Field area of Morton County, Kansas.
Example of a Core Description


LOG DEPTH = CORE DEPTH + *
*CORED INTERVAL CLOSELY APPROXIMATES LOG INTERVAL; MISSING CORE PROHIBITS ACCURATE ADJUSTMENT

SEDIMENTARY TEXTURES AND STRUCTURES

CARBONATES

CLASTICS

GN, PK, WK, MOST EVAP

G, C, M, F, VF, CLAY

COMPOSITION ELECTRIC RESISTIVITY (md)

PERM.

INTERPRETED DEPOSITIONAL ENVIRONMENT

NOTES

PLANAR/ANASTOMOTIC, CARBONACEOUS DEBRIS, STICKS, CHERT CLASTS

MOSTLY STRUCTURELESS WITH DISSEMINATED ORGANOIDS AND CHARCOAL, ABUNDANT PYRITE

CROSSBEDDED TO CONFORTED FLAT BEDS, CHARCOAL DEBRIS, FRAGMENTED CARBONACEOUS DEBRIS, YELLOW HALOS AROUND PYRITE

COARSE TO PEBBLE Sized SANDSTONE CLASTS, LOOSLY BEDDED

MATRIX SUPPORTED SHALE CLASTS

DISSEMINATED CARBONACEOUS DEBRIS ALONG FORESETS, SWELLING CLAYS

CORE MISSING

CORE MISSING

CORE MISSING

CORE MISSING

CORE MISSING

POORLY SORTED SHALE CLASTS