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# APPLICATIONS OF ADVANCED PETROLEUM PRODUCTION TECHNOLOGY AND WATER ALTERNATING GAS INJECTION FOR ENHANCED OIL RECOVERY - MATTOON OIL FIELD, ILLINOIS

COOPERATIVE AGREEMENT NUMBER DE-FC22-93BC14955

AMERICAN OIL RECOVERY, INC.

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Date of Report: May 24, 1993

Award Date: December 29, 1992

Anticipated Completion Date: December 31, 1994

Government Award for Current Year: $ 702,091.00

Program Manager: Michael R. Baroni

Principal Investigator: Michael R. Baroni

Technical Project Officer: Gene Pauling

Reporting Period: FIRST QUARTER 1993



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## DISCLAIMER



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# APPLICATIONS OF ADVANCED PETROLEUM PRODUCTION TECHNOLOGY AND WATER ALTERNATING GAS INJECTION FOR ENHANCED OIL RECOVERY - MATTOON OIL FIELD, ILLINOIS

U.S. DEPARTMENT OF ENERGY CONTRACT DE-FC22-93BC14955
QUARTERLY TECHNICAL PROGRESS REPORT -
1ST QUARTER, 1993

## PHASE I - PLANNING AND ANALYSIS

"Phase I activities are designed to provide sufficient theoretical and applied data prior to field implementation of the WAG in Phase II"

## I. OBJECTIVES

For work during the first quarter of 1993, American Oil Recovery, Inc. targeted completion of the following specific objectives:

- Convene meetings of Mattoon Project subcontractors in order to plan and coordinate Project activities. Confirm organizational arrangements and plans for implementation of Mattoon Project.
- Complete most work on detailed analysis of reservoir geology of productive leases in the Mattoon Project.
- Identify first Facies Defined Subunit for initial injectivity testing to be commenced near the beginning of the second quarter.
- Identify additional Facies Defined Subunits for injectivity testing and characterization during the second and third quarters.
- Award subcontract to the Illinois State Geological Survey and commence work on preparation of a geostatistical model (STRATAMODEL) of more than 100 wells on 1,000 acres within the Mattoon Project Area.
- Obtain oil samples from wells in the identified Facies Subunit for reservoir rock, fluid, and $CO_2$ compatibility testing by the Illinois State Geological Survey.
- Design $CO_2$ injection pumps and injection monitoring equipment configuration. Obtain bids for required pumps and diesel motor.

## II. SUMMARY OF TECHNICAL PROGRESS

Organizational meetings were held on January 8, February 19, and March 19, 1993 to discuss geology, reservoir engineering, field procedures, and various financial matters related to the Mattoon Project. Meeting participants included representatives from American Oil Recovery, Inc., Prairie Project Services, Sigma Consultants, Bretagne G.P., Metro Petroleum Company, and Covington Oil and Gas Partnership. Such meetings will be continued as appropriate on a monthly basis.

Very substantial progress was made during the first quarter in developing an understanding of reservoir geology. Through the analysis of more than 150 geophysical logs, drillers logs, and lithologic logs, by American Oil Recovery, Inc. and its subcontractors, work is nearing completion on ten stratigraphic cross sections, a detailed structure map on the top of the Cypress Formation, an isopach map of five separate sandstone reservoirs (A, B, C, D, E) within the Cypress Formation (primarily sandstone and shale). In addition, a three dimensional model of the project geology (fence diagram) is more than eighty percent complete. Task 1.1.5, review of existing core data, will be completed during the second quarter. Our analyses indicate the Cypress Formation contains five distinct intervals of fluvial-deltaic sand deposition, which we have identified in ascending order as A, B, C, D, and E. A more detailed description and disgrams of these facies is contained in Appendix A. B and C sand Facies are the principal oil-producing reservoirs. They are more or less continuous throughout the project area, and have been extensively developed by both primary production and water flooding.

A, D, and E Sand Facies are thinner and are relatively discontinuous. They have been bypassed or only partly developed in the Project area. We have identified six Facies Defined Subunits in the A, D, and E facies that are candidates for $CO_2$ injectivity tests and characterization during Phase I.

American Oil Recovery, Inc. selected one of these Subunits, the Pinnell A, for initial injectivity tests and characterization work during the second quarter.

A contract has been signed with the Illinois State Geological Survey to prepare a computer-generated geologic model of the Cypress Formation, utilizing the STRATAMODEL program. This analysis will include geologic data from more than 100 wells within an area of approximately 1,000 acres. This work is now approximately 80 percent complete. Results will be analyzed and discussed in our second quarterly report.

Oil and gas samples from the Metro Petroleum No. 3W Pinnell Unit (Pinnell Facies Defined Subunit) have been supplied to the Illinois State Geological Survey for characterization of response to $CO_2$ injection. Additional core tests will be completed on Cypress Formation cores upon completion of an infill well. Results of these characterization tests will be presented in the 2nd and 3rd Quarterly Reports.

In order to insure efficient and timely injection of $CO_2$, American Oil Recovery, Inc. has designed and constructed a trailer-mounted $CO_2$ injection system consisting of a 350 psi 10HP electric-powered booster pump and a diesel-powered triplex main injection pump (pressure to 1500 psi). An adjoining "doghouse" (separately portable) contains a pressure and injection-rate monitoring console, and pressure driven safety cut-off switches for both high and low pressure. This system is capable of an injection rate of as much as 200 tons of $CO_2$ per twelve hour day, depending upon reservoir porosity and permeability.

## TABLE 1

## 1.1 RESERVOIR GEOLOGY - COMPLETION STATUS

| Task Number | Description | Percent Complete |
|---|---|---|
| 1.1.1 | Prepare detailed stratigraphic cross sections. | 90 |
| 1.1.2 | Prepare a detailed structure map. | 88 |
| 1.1.3 | Prepare a detailed isopach map. | 90 |
| 1.1.4 | Prepare a detailed lithofacies map. | 89 |
| 1.1.5 | Review existing core data (porosity, permeability, saturations). | 10 |
| 1.1.6 | Prepare a 3-D reservior geologic description (fence diagram) for the demonstration area in the Mattoon Field from the geologic model, and petrophysical data. | 1 |

## TABLE 2

## 1.2 GEOSTATISTICAL MODELLING - COMPLETION STATUS

| Task Number | Description | Percent Complete |
|---|---|---|
| 1.2.1 | A sedimentologic and stratigraphic analysis based on the logs of the wells in the Cypress Formation will be performed. | 17 |
| 1.2.2 | A geostatistical study will be performed using STRATAMODEL to determine the proportion of lithofacies of sandstone and shale for 106 wells in an area of approximately 1,000 acres. Then simulations of the lithofacies in the Cypress Formation will be done, based on the results of the STRATAMODEL simulation. | 52 |
| 1.2.3 | The results of the above analysis will be utilized in the reservoir management, selection of FDWS, and project monitoring. | 0 |
| 1.2.4 | Determine optimum spatial arrangement of existing or proposed injectors and procedures for maximum oil recovery from the Cypress FDWS. | 0 |

## TABLE 3

## 1.3 LABORATORY TESTING - COMPLETION STATUS

| Task Number | Description | Percent Complete |
|---|---|---|
| 1.3.1 | Run core tests on cores recovered from newly drilled well (Task 1.4.5). Determine porosity, permeability, response to $CO_2$ injection, and other characteristics necessary for the field demonstration. | 0 |
| 1.3.2 | Determine minimum miscibility pressure and reservoir rock and fluid compatibilities for the proposed demonstration. | 0 |

## TABLE 4

## 1.4 FIELD DESIGN - COMPLETION STATUS

| Task Number | Description | Percent Complete |
|---|---|---|
| 1.4.1 | Plan completion and production practices to be followed in field demonstration. Plan location and core points for characterization well in the Cypress FDWS. | 0 |
| 1.4.2 | Based on reservoir geology and engineering studies, select FDWS for field demonstration and target wells to be included. | 0 |
| 1.4.3 | Determine surface facilities upgrade requirements for installation of the demonstration project. | 4 |
| 1.4.4 | Solicit bids for project installation by contacting potential contractors and service firms. | 25 |
| 1.4.5 | Drill one new well within confines of selected FDWS. Core well through through Cypress interval, send to commercial laboratory for testing; log well; run pressure and production tests; and complete well. | 0 |
| 1.4.6 | Environmental information collection: If necessary, this task involves the collection of environmental information specified in "Information Requirements for National Environmental Policy Act." This detailed site and project specific information may be used as the basis for site specific NEPA documents to be prepared by DOE. | 0 |

## TABLE 5

## 1.5 FIELD TESTING - COMPLETION STATUS

| Task Number | Description | Percent Complete |
|---|---|---|
| 1.5.1 | Select FDWS for $CO_2$ stimulation tests | 0 |
| 1.5.2 | Rework as many as three wells for injection testing. | 0 |
| 1.5.3 | Perform injectivity test of $CO_2$ in selected wells. At least, 12,000 tons of $CO_2$ will be utilized. | 0 |
| 1.5.4 | Perform temperature survey in selected injection wells to test geostatistical model results. | 0 |
| 1.5.5 | Perform reservoir interference testing between wells with $CO_2$ to test geostatistical model results. | 0 |

## APPENDIX A

### Preliminary Results of Reservoir Geology Analysis

The base of the Cypress Formation is defined by a marine limestone about five feet thick. Subsequently deltaic mud and fine silt interbedded with generally fine-grained sand of the Cypress Formation subsequently accumulated to a total thickness of approximately one hundred feet. This total thickness of interbedded deltaic shale and sand was subsequently covered by thick marine limestone of a transgressive marine environment (Barlow Limestone), terminating deltaic conditions.

Within the area of study in the Mattoon Field, five deltaic sand bodies (A, B, C, D, E) are defined by well data.

### A Sand

The A Sand (Figure 1) is located a few feet above the basal marine limestone and is typically thin (0-10 feet) and moderately to strongly calcareous. The sand has low to moderate porosity and permeability. It is extensively developed only in the southwestern part of the Mattoon Project area. An atypical development of the A Sand occurs on the Pinnell lease, where it is ten feet thick, and has fair porosity and permeability. The A Sand is also present in two areas along the western margin of the Uphoff and Seaman leases. Elsewhere, throughout more than 60 percent of the project area, this sand is absent.

The A Sand, as well as other clastic units within the Cypress Formation of the Mattoon Field, consist of fine grained sand with substantial interstitial silt and clay, indicating a relatively low energy level depositional environment - i.e. sluggishly flowing distributory streams.

### B Sand

The B Sand (Figure 2) occurs as a blanket deposit throughout most of the Project area, with the exception of a limited area in the northern half of the Uphoff lease, and elsewhere in a few other small shale-out areas. This is a delta-fringe type sand, formed on a delta-strand plain. The sand typically has fair permeability, and attains a thickness of more than twenty-five feet at one location in the southwestern part of the project area. However, in essentially all of the project area it is less than fifteen feet thick, and is commonly less than ten feet thick.

### C Sand

Our reservoir geologic mapping indicates that the C Sand (Figure 3) occurs as two thick (20-25 feet) southward trending sand bodies consisting of distributary channel-fill and overbark deposits –one lying parallel to the eastern margin of the Mattoon Project area, and a second channel-fill deposit extending across the western one-third of the area. Available evidence suggests the strand line was located only a few feet below the elevation of these channels, since the channels appear not to be deeply incised into adjacent interdistributary delta clay deposits. These deposits grade laterally into delta strand plain sand deposits which are much thinner and occur in the central part of the project area. The C Sand is entirely replaced by delta-strand plain silt and clay on the northern part of the Uphoff lease.

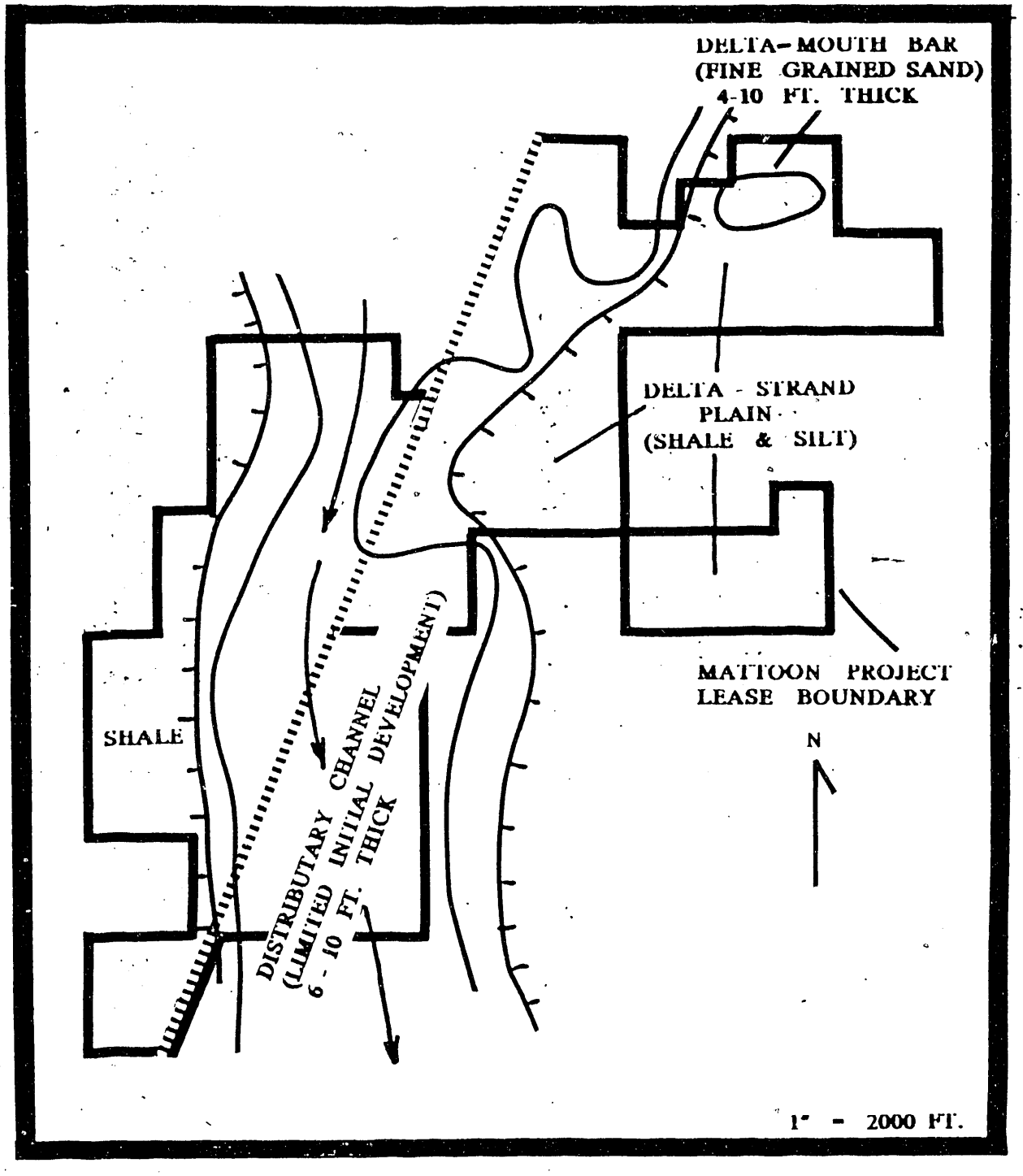


FIGURE 1 A SAND. INITIAL CYPRESS DELTA FORMATION, WEAKLY DEVELOPED DISTRIBUTARY CHANNEL SAND AND SILT ADJACENT TO DELTA-STRAND PLAIN. SANDS COMMONLY VERY CALCAREOUS.

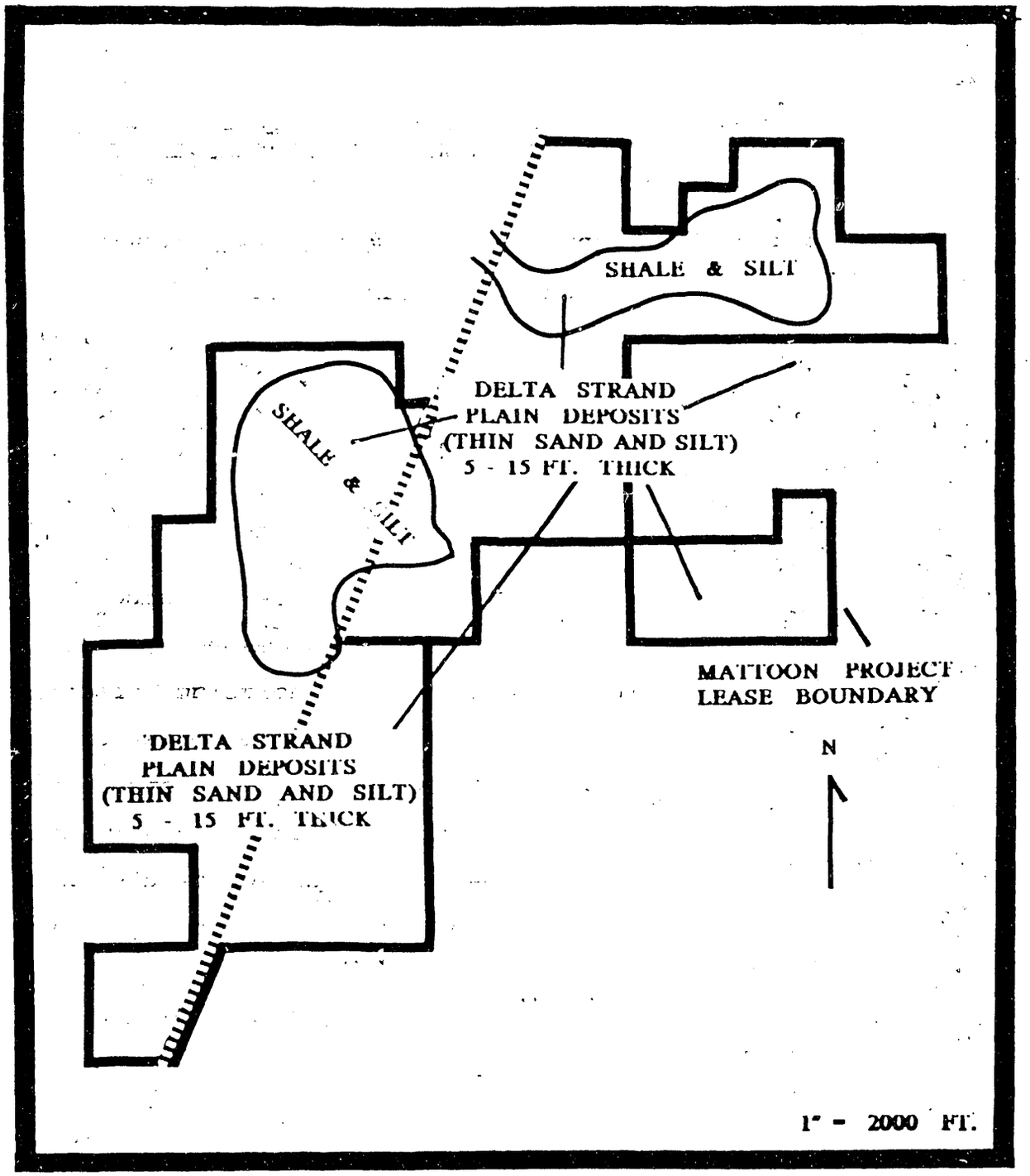


FIGURE 2. B SAND. INITIAL EXTENSIVE SAND DEVELOPMENT OF THE CYPRESS DELTA "BLANKET" SAND AND SILT (STRAND PLAIN DEPOSITS) COVER MOST OF MATTOON PROJECT AREA.

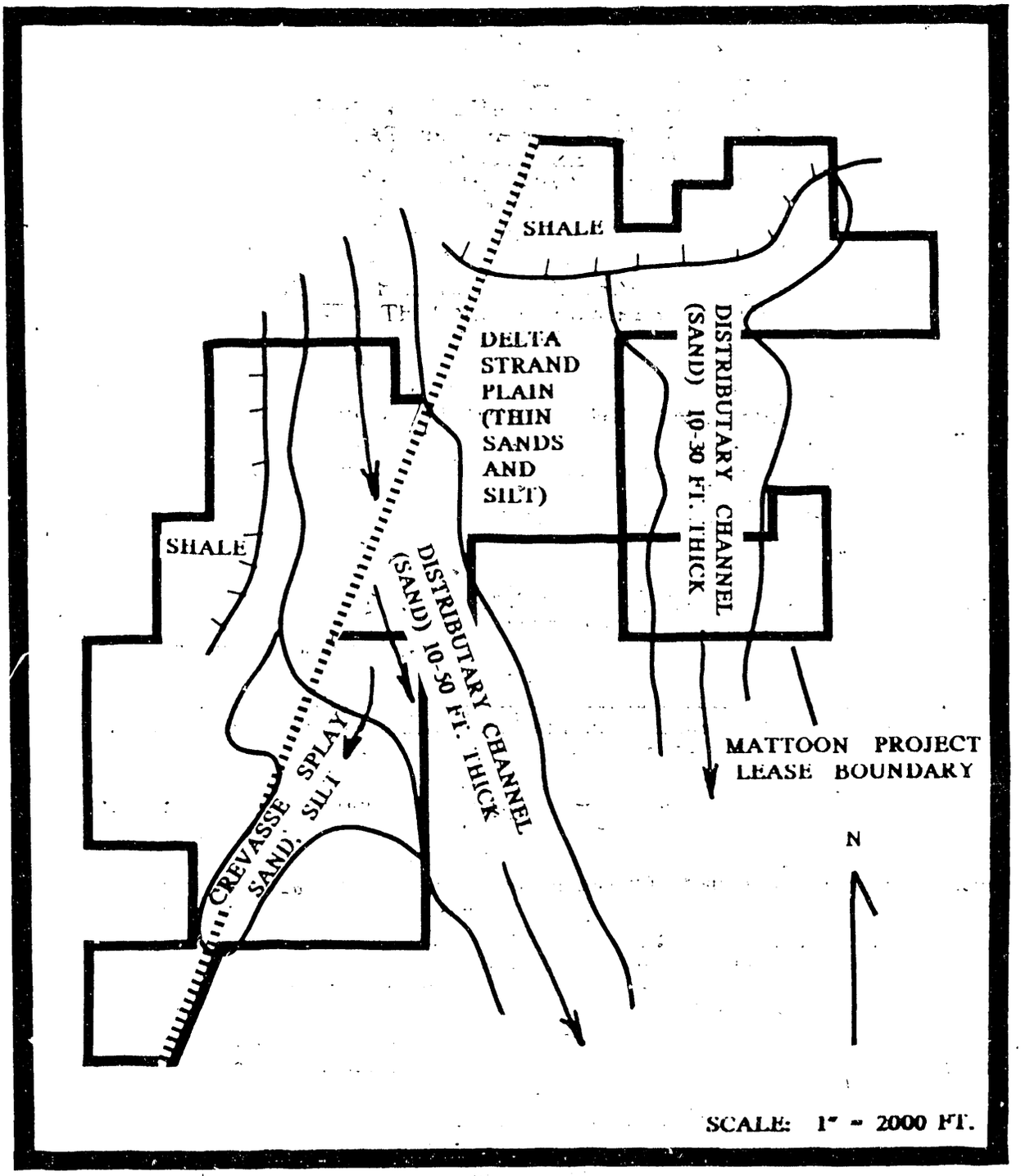


FIGURE 3. C SAND. STRONGLY DEVELOPED DELTA DISTRIBUTARY CHANNELS (MIDDLE CYPRESS). CHANNELS STRONGLY INCISED INTO DELTA-STRAND PLAIN.

**D Sand**

The D Sand (Figure 4) contains a single southward-trending sand body (5 - 15 feet thick) which is a weakly developed distributary channel that lies along the eastern boundary of the project area and slightly to the east of a previously described distributary channel in the overlying C Sandstone. A second extensive sand development in the D Sand horizon occurs in the southwestern part of the project area. This sand body is evidenced to be a distributary channel of limited extent. Two additional limited isolated developments of the D Sand occur in the central part of the Seaman lease, and extending westward from the Pinnell lease (outside of project area). The D Sand is generally less well developed than other sands of the Cypress Formation in the Mattoon Project area.

**E Sand**

The E Sand (Figure 5) is thin but relatively extensive in the eastern part of the project area, and in the southwestern part. A moderately extensive development also occurs along the western boundary of the Seaman leases, and extending beneath the Ashland leases. The sand is thin (generally less that ten feet thick) but has fair porosity and permeability. A thick development of the sand (14+ feeth thick) is also present at the extreme southwestern margin of the area but is structurally low in relation to the producing areas of the Mattoon Field.

This sand represents the terminal phase of distributary channel development in the Cypress Formation, and was completely covered by a marine advance (rise in strand line) which resulted in deposits of a thick, regionally extensive marine limestone (Barlow Limestone)

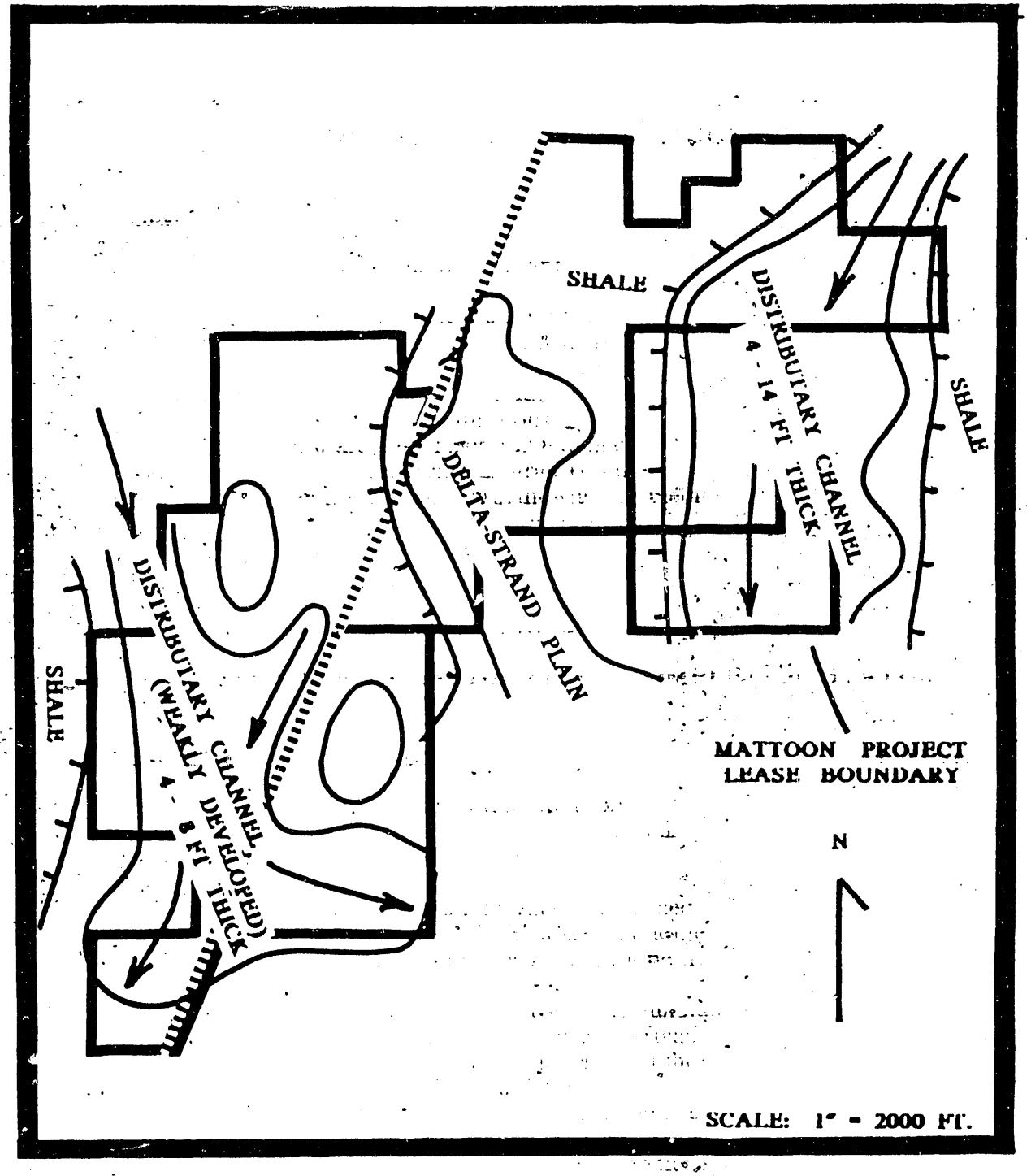


FIGURE 4 D SAND. LATE DELTA CYCLE DISTRIBUTARY SAND DEVELOPMENT.

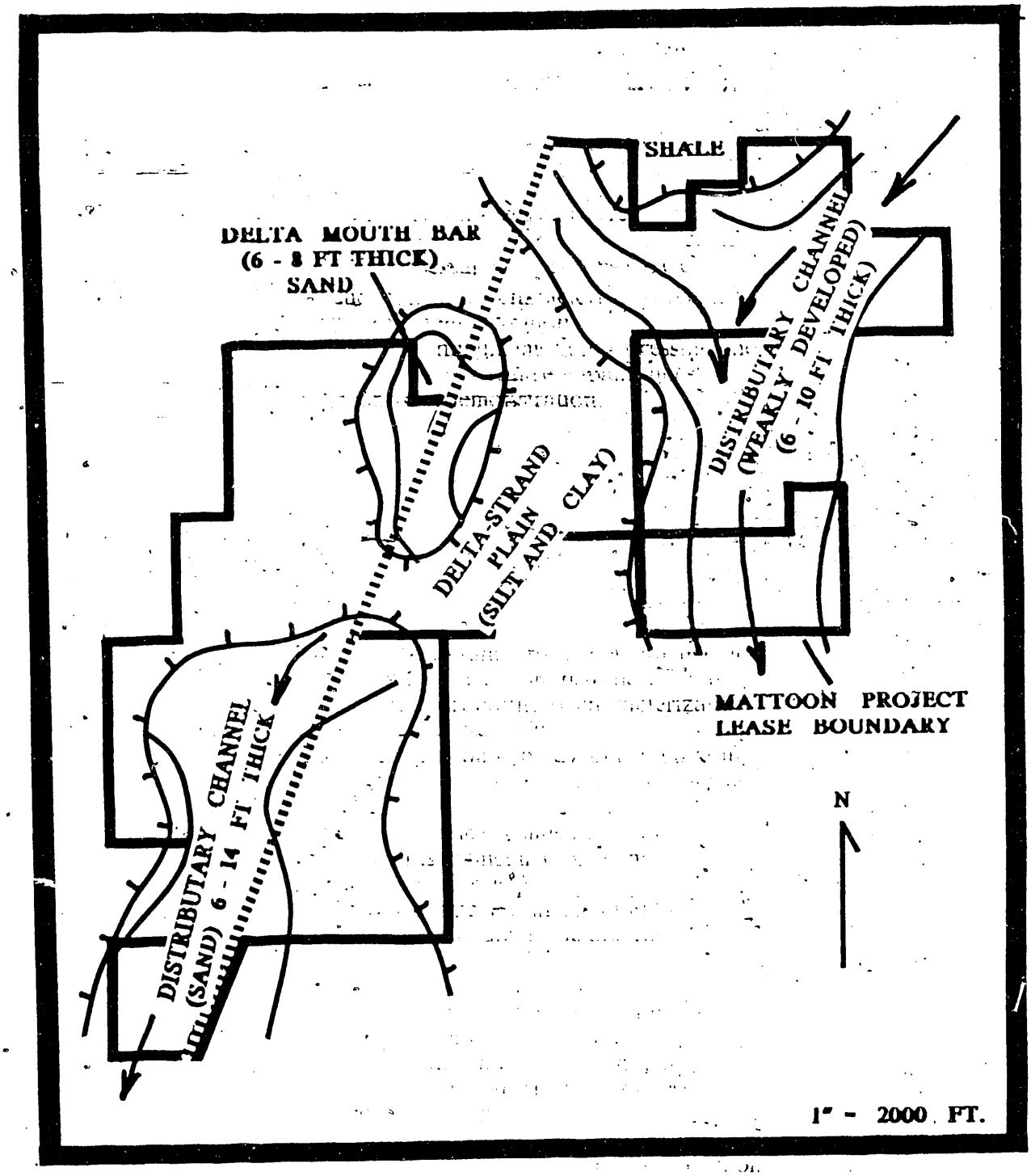


FIGURE 5 E SAND. TERMINAL PHASE OF CYPRESS DELTA. CHANNEL FILL SANDSTONE SLIGHTLY INCISED INTO ADJACENT STRAND PLAIN DEPOSITS.