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AN ANALYSIS OF THE STRUCTURAL PARAMETERS THAT INFLUENCE
GAS PRODUCTION FROM THE DEVONIAN SHALE

Annual Progress Report for 1978-1979

By

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Work Performed Under Contract No. EY-76-C-05-5194

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U. S. DEPARTMENT OF ENERGY

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THAT INFLUENCE GAS PRODUCTION FROM THE DEVONIAN SHALE

1978 - 1979

ANNUAL PROGRESS REPORT

CONTRACT DE-AC21-76MC05194
Formerly EY-76-C-05-5194

SUBMITTED BY

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DEPARTMENT OF GEOLOGY AND GEOGRAPHY
WEST VIRGINIA UNIVERSITY

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RESEARCH ASSOCIATES

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PREFACE TO VOLUMES I AND II

This report is written to document progress made during the third year of our study for the Eastern Gas Shales (EGSP) Project, and it is organized to meet the needs of readers who have a variety of interests in the project. The first portion of Volume I includes the Executive Summary which gives a general overview highlighting the progress made over this contract year. The second portion of Volume I includes task reports written by the specific task investigators, and it is written primarily for scientists interested in a technical overview of the third years' work. Volume II of the report consists of appendices of data compiled by the principal investigators. The appendices serve as a data bank for work accomplished during fiscal 1978-1979. These data can be used by other scientists with the permission of the principal investigator responsible for the specific compilation.

PERSONNEL

Robert C. Shumaker, Project Director

REGIONAL STRUCTURE TASK

Robert C. Shumaker, Principal Investigator

SURFACE STRUCTURE TASK

Russell L. Wheeler, Task Director *
Jeanette M. Dixon, Principal Investigator
Thomas H. Wilson, Principal Investigator

SURFACE FRACTURES TASK

Brian R. Long, Principal Investigator *
Mark A. Evans, Principal Investigator
Kevin D. Lee, Principal Investigator

PRODUCTION TASK

Jane Negus de Wys, Principal Investigator

HYDROLOGY TASK

Henry W. Rauch, Task Director
Robert R. Beebe, Principal Investigator *

GEOPHYSICAL TASK

Richard T. Williams, Task Director
Keith G. Kirk, Principal Investigator *
James E. Ruotsala, Principal Investigator

GEOLOGIC DRAFTING SPECIALISTS

Philip E. Haring *
Patricia P. Stockdale
John G. Wright

SECRETARY

Jean A. Toren

Other major contributions to our project were made by:

Jean Cheng	Statistics
David Kutner	Structure
Dr. John Renton	Geochemistry
William Schaefer	Production

* No longer attached to project.

AN ANALYSIS OF THE STRUCTURAL PARAMETERS
THAT INFLUENCE GAS PRODUCTION FROM THE DEVONIAN SHALE

1978 - 1979

ANNUAL PROGRESS REPORT

VOLUME 1

EXECUTIVE SUMMARY AND TASK REPORTS

VOLUME I

PART I

EXECUTIVE SUMMARY - BACKGROUND AND PROGRESS 1978-1979

ROBERT C. SHUMAKER

INTRODUCTION

This report presents the scientific progress of our efforts toward understanding shale gas production from the Devonian shale within the project area (Figure 1). We consider that two major advances toward understanding the nature of Devonian shale production have occurred during fiscal 1978-1979: one relates shale gas production to structural position along basement flexures, and the other relates gas production to the geochemistry of the shale.

It is not only interesting but important to note that while both advances were directly dependent upon certain equipment and at least one person funded thru the DOE's EGSP program, neither research project was directly funded under our contract. The work was accomplished under West Virginia University funding. We have always had the encouragement of DOE/METC's scientific management to pursue ideas that could not be directly funded, and in this case the results have been significant to our contractual objectives. The senior author feels that it is important to point out the value of this latitude in research within a university. Too often the criticism is made that university research is not goal oriented. It is essential to a research program that it not be too goal oriented demanding contract deliverables, and that latitude and flexibility are not sacrificed to restrictive contractual obligations. The kiss of death to successful research is very often excessive managerial regulation specified by non-scientific personnel. Mutual trust, flexibility, combined with a tolerance of failure in university-governmental research is essential if true scientific progress is anticipated.

PURPOSE OF THE STUDY

The specific objectives of our contract are given in the section entitled Objectives found within the Task Report section of this Volume. In general, the purpose of our research under the EGSP program is to analyze structural parameters of local and regional geology that influence Devonian shale gas production within the contract area (Figure 1). Our project was designed in 1976, initiated in early 1977, and it became fully staffed for significant work in 1978. Our efforts thus far have been channeled toward defining the structural parameters that influence shale gas production, but we are to develop, in conjunction with other contractors, techniques or rationales for shale gas (fracture porosity) exploration. We are just entering the "results" phase of the project which will permit us to characterize the shale and thus assist the exploratory phases of the EGSP program.

A second goal of the EGSP program at West Virginia University is to provide support for geologists and geophysicists who are studying to obtain advanced degrees in the mineral industry sciences.

Figure 1. Contract area

METHODS OF APPROACH AND ORGANIZATION

We are attacking the problem of locating fracture zones within the Devonian shale along several avenues: thru our remote sensing studies, subsurface and surface geologic studies, thru geochemical, geophysical, and hydrologic studies. Our attack is broad and yet it is integrated into one work contract. Our method of approach to attain the contractual objectives is thru organization of our efforts into several tasks: one group is compiling the regional structure; a second is studying surface fractures and subsurface fractures found in oriented shale cores. A third group is studying shale gas production in detail where reliable production data is available. A fourth study group is investigating surface structures which would have production potential if found in the subsurface, and a fifth group is studying ground water-lineament-gas production (hydrology) interrelationships. These five study groups, that is: regional structure, fractures, surface structures, production, and hydrologic studies are supported under the EGSP Resource Inventory Tasks.

Another of our study groups, the geophysical task, is carried under the EGSP Shale Characterization Task. Our geophysical task is to develop inexpensive seismic and resistivity techniques which can locate shallow fracture zones.

In essence, the first two tasks, regional structure and fracture studies, are designed to provide a regional or basin structure framework for the entire project. The surface structure studies seek to document, by analytical field work, those details of structure which are either similar to structure producing gas or those structures which we feel are prospective for shale gas production. The production studies will seek out and study those gas fields where detailed well production records are available that permit thorough analysis and documentation of the geologic parameters that influence gas production from the shale. The geophysical studies are charged with the task of developing inexpensive geophysical techniques that can locate shallow fracture zones of high permeability. We have coordinated our studies so that most of the task groups are working in specific shale gas producing areas where we have reliable production data (Cottageville, Midway-Extra, and the Big Sandy fields - Figure 1).

The attention of all study groups focuses on fracture porosity within the shale: its origin, distribution, and methods of locating zones of more intense fracturing. It is important to realize that even though each study group is carried as a Resource Inventory Task or the Characterization Task, each group has the additional and longer ranged goal of defining parameters that would be useful in exploring for potentially productive fracture porosity in the shale. Often overlooked is this latter goal of developing a method or rationale for selecting areas for

drilling shale gas wells that have a higher than normal potential for shale gas production. It is further emphasized that our basic research approach applies to many other DOE projects such as the Tight Sands Project, Methane Drainage Project, mine hazards, underground coal gasification, etc. Indeed, any project which deals with fractured rocks will be interested and derive benefits from our work on fractures and gas production from fractured shale.

MAJOR ACCOMPLISHMENTS 1978-1979

Because we have completed two years of research effort at full staff levels, we are now completing discrete segments of research that lead to obtaining the objectives of the contract.

Specific relationships between shale gas production and both local and regional structures are now apparent, and we can specifically characterize structural aspects of the shale gas production. Based on this characterization we have developed empirical exploration rationales for the West Virginia portion of our contract area. These major accomplishments for this year are briefly reported in the Noteworthy Accomplishments below, but for the details of specific accomplishments the reader is referred to the individual task reports (Part II of this Volume).

Over the long term it is difficult to evaluate what is or will be most significant from this year's effort. Within shale characterization, we now have a far better understanding of the nature of relationship between surface and subsurface fracturing. We know that it is highly speculative to estimate subsurface fracture trends from surface trends (Long, ref. 1). We continue to document a relationship, albeit nebulous, between low-altitude photo linears, ground water production, ground water quality, and shale gas production (Beebe, ref. 2). The results obtained by Beebe (ref. 2) at Midway-Extra (Figure 2) are similar to those found by Jones and Rauch (ref. 3). We know much more about subsurface fracturing of the Devonian shale thru our study of oriented cores (Evans, ref. 4 & 5), and we have determined that cross-strike structural discontinuities are zones of more intense fracturing that extend at depth to the shale (Dixon and Wilson, ref. 6). We have found that the maximum gas production in the two shale gas fields (Figure 2) studied thus far follows the syncline and certain flanks of basement folds (Shumaker, ref. 7). Furthermore, we have found that the highest productive areas of the Big Sandy gas field coincide with shale that can be characterized geochemically (Negus-de Wys, ref. 8).

All of these new understandings have significance in relationship to characterization, but the last three, that is, empirical relationships between: (1) low-altitude photo linears and production, (2) structural position and production, and (3) shale geochemistry and production, should have an immense impact on the EGSP exploration program. The author suggests that individuals interested in these subjects should read the articles referenced for significant details.

Figure 2. Structure Contours on Top of the Berea Sandstone

Noteworthy accomplishments during 1978-1979 include:

1. Documentation of the geologic parameters that affect shale gas production from the Midway-Extra field (Figure 1). The significant variable that controls production is geologic structure. Producing wells of this field are off-structure, following the synclinal trough and western flank of the Midway anticline (Schaefer, ref. 9).
2. Reinterpretation of the Cottageville field production data (de Wys and Shumaker, ref. 10) supports the Midway-Extra model that production increases off structure, and that the very highest producing wells occur above a mapped basement fault (Shumaker, ref. 7).
3. Detailed structural analysis of Berea sand suggests that a major basement fault connects these two fields (Figure 2).
4. Chemical analysis of well sample cuttings within the Big Sandy field of eastern Kentucky indicates that the Devonian shale can be characterized, and that there is a direct relationship between the distribution of geochemical elements or minerals and production from the shale (Negus-de Wys, ref. 8).
5. A hydrologic study of the area in and around the Midway-Extra field (Figure 1) has been completed. Preliminary analyses suggest a positive association among the density of low-altitude photo lineaments of a particular trend, ground water well productivity, ground water quality, and shale gas productivity.
6. Surface fracture studies in eastern Kentucky in and around the Big Sandy gas field show very complex fracture patterns and that the patterns differ greatly from one lithology to the next. Coal face cleats have the simplest pattern, and within the field they show a swing from a cross-strike Appalachian trend to a trend parallel to the adjacent Pine Mountain thrust. The significance of this change in trend is not known, but the higher gas yield may relate to the diverse fracture pattern of that area. This surface fracture study (Long, ref. 1) will be integrated with our on-going subsurface geologic and production study of the Big Sandy gas field (Negus-de Wys, ref. 8).
7. In areas of limited outcrop it has been difficult to determine joint intensity which will permit geologists to determine if lineaments represent zones of more intense fracturing. A method of determining joint intensity was developed this past year (Dixon, ref. 11), and it was applied with positive results to Petersburg and Parsons lineaments (Figure 1) (Dixon and Wilson, ref. 6).
8. Fractures in 13 oriented shale cores were described and analyzed (Figure 1). Fractures within the shale cores are divisible into two

broad categories as either natural and induced fractures. Results of analyses support a tectonic origin for the fractures and the concept of the fracture facies (Shumaker, ref. 12) associated with commercial production from the shales. This documentation of core fractures is fundamental to characterization of the shale reservoir permeability and production, and it is essential for understanding the extent of a permeable fracture facies.

9. Major accomplishments in the geophysical studies include the isolation and correction of major electronic design flaws within the equipment, the writing of computer programs for plotting seismic data, the preliminary shooting of one line in the Cottageville field, and the re-shooting of Test Site 11.

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1. Long, Brian R., "Regional Survey of Surface Fractures in Eastern Kentucky," 1979, Masters thesis, West Virginia University, Morgantown, W. Va.
2. Becbe, Robert R., "A Study of Hydrogeologic Trends In Exploration for Devonian Shale Gas in the Midway-Extra Gas Field of Putnam County, West Virginia," 1979, Masters thesis, West Virginia University, Morgantown, W. Va.
3. Jones, D. Scott and Henry W. Rauch, "A Hydrologic Study of Water Well Yields and Ground-water Quality Related to Stratigraphic and Structural Settings in Western Jackson County, West Virginia," January 1978, DOE-Morgantown Energy Technology Center UGR File No. 107, Morgantown, W. Va., 24 p.
4. Evans, Mark A., "Fracture Density and Orientation Study of the Reel Energy #3 D/K Core from Mason County, West Virginia," December 1978, DOE-Morgantown Energy Technology Center UGR File No. 052, 48 p.
5. Evans, Mark A., "Fracture Density and Orientation Study of the MERC #1 Core from Monongalia County, West Virginia," June 1979, West Virginia University, Department of Geology and Geography, Devonian Shale Program, Morgantown, W. Va.
6. Dixon, Jeanette M. and Thomas H. Wilson, "The Parsons Cross Strike Structural Discontinuity as an Exploration Area for Fractured Gas Reservoirs," October 1979, Proceedings Third Eastern Gas Shales Symposium, METC/SP-79/6.

7. Shumaker, Robert C., et al., "Parameters of Geologic Structure which Affect Devonian Gas Shale Production in West Virginia and Eastern Kentucky - a Progress Report 1978-1979," October 1979, Proceedings Third Eastern Gas Shales Symposium, METC/SP-79/6.
8. Negus-de Wys, Jane and John J. Renton, "Inorganic Geochemical Studies of Eastern Kentucky Gas Field(s) and Comparison with Gas Production," October 1979, Proceedings Third Eastern Gas Shales Symposium, METC/SP-79/6.
9. Schaefer, William W., "Geology and Producing Characteristics of the Devonian Brown Shale Midway-Extra Field, Putnam County, West Virginia," 1979, Masters thesis, West Virginia University, Department of Geology and Geography, Morgantown, W. Va.
10. de Wys, Jane Negus and Robert C. Shumaker, "Pilot Study of Gas Production Analysis Methods Applied to the Cottageville Field," February 1978, DOE-Morgantown Energy Technology Center UGR File No. 101, 45 p.
11. Dixon, Jeanette M., "A Method to Identify Zones of Intense Jointing with Application to the Parsons Lineaments, West Virginia," April 1979, DOE-Morgantown Energy Technology Center UGR File No. 169, 46 p.
12. Shumaker, Robert C., "Porous Fracture Facies in the Devonian Shales of Eastern Kentucky and West Virginia," June 1978, DOE-Morgantown Energy Technology Center UGR File No. 099, 10 p.

PROBLEMS

Two problem areas have developed in our program over the past year. The first and most significant lies within our geophysical task effort, and the second relates to mounting a multi-spectral camera within the University aircraft.

Our seismic work is behind schedule because of instrumentation problems. When we purchased the Bison reflection seismic system nearly three years ago it was with the expressed purpose of using this portable model as a basic unit for building and developing a low-cost, high-frequency seismic system. We considered that a low-cost and high-frequency system was the only one that would be practical for locating fracture zones in a marginally economic venture such as exploration for Devonian shale gas. We have been successful in this endeavor to the extent of redesigning the system, shooting two test sites (Figure 1) and obtaining chart recordings of the data by the end of the second year. Hand copies of strip-chart plots were satisfactory so long as our interest centered on a few test sites that required short seismic spreads. Last fall we moved to the Cottageville field where longer lines were to be shot and much more data recorded. We started to use the Bison digital recorder to store our data. This digital recorder is an integral part of the purchased system. After a major effort to shoot our first long line at Cottageville we found, to our dismay, that the recorder was not

functioning properly. At that point we were on the edge of winter; so we decided to correct the problem during the winter and to reshoot the line in the spring. We spent most of the winter months shuffling the equipment back and forth to the Bison company. By early spring it was apparent that Bison either would not or could not make the necessary repairs to their own equipment. We redesigned the equipment and by early summer we had redrilled shot and phone holes, and we re-shot the line at Cottageville. We found, again to our dismay, that the firing mechanism for the Bison was malfunctioning, giving us a variable start-time for each shot point. Datuming each shot was impossible with this malfunction. Again after protracted discussions and shuttling of equipment back and forth to the Bison company, we redesigned and built a start system ourselves. At this point, we felt that the fracture anomaly seen on the strip-chart seismic record at Wetzel County (Test site 11 - Figure 1) was in doubt, and that the anomaly might be related to a delayed start time or malfunction in the equipment. We have returned to Wetzel County to re-shoot that line to verify the chart-plotted data. Seemingly, we have corrected the equipment problems, and we are finally collecting seismic data on digital tape.

While awaiting resolution of the equipment problems we designed, wrote, and tested a program for computer display digitally recorded seismic data. We successfully test-plotted our first undatumed line at Cottageville, but correlation of coherent seismic events is impossible. The quality of that seismic data is good, and we are encouraged by the high frequency (high resolution) recorded by the Bison system when compared with commercially recorded data. However, the recording system cannot sample the data in sufficient detail to characterize the entire record. In addition, there are insurmountable problems in recording near surface data in the reflection mode. We feel that recording a narrow time-slice of high-frequency shallow data is the most feasible approach to isolating a fracture zone with our seismic system.

The second problem area - that of mounting the multi-spectral camera in the University airplane - presents several problems that are not easily resolved. During the past year we searched, without success, for a West Virginia state aircraft that would readily accept the particular equipment we have on loan from NASA. We have purchased a kit for conversion of the University aircraft, but the cost of installation of that kit and the camera has risen astronomically. In addition, we have not been able to locate an installation contractor who is situated nearby. We may have to abandon our plans for mounting the multi-spectral camera in the University aircraft to attain our own imagery over selected sites of geological interest.

EDUCATION

All six principal investigators have made satisfactory progress toward obtaining advanced degrees in Geology at West Virginia University. Three of our former principal investigators are now employed in energy-related industry or governmental work. This fall, all principal investigators

working on the project and employed by DOE under this grant are enrolled half-time in graduate studies leading toward advanced degrees in Geology. In addition, several graduate students have been supported in part on an hourly pay basis for their part-time work on the project.

It is difficult to estimate the long term benefits that other University students will derive from DOE support. Clearly the use of equipment purchased with DOE funds will have a significant effect on future research.

EQUIPMENT

During the third year of the project the following major piece of equipment has been purchased:

Nikon SCB Labophote Microscope with Objective 4X, 10X, 40X, 100X and with Nikon PFM camera and Manual.

FINANCES

The responsibility for financial accounting for this grant lies with the comptroller of West Virginia University. Detailed financial reports are forwarded to DOE by the comptroller's office as separate reports.

PUBLICATIONS

Listed below are the titles of articles published during 1978-1979 which report the results of our research efforts.

We are including a copy of each manuscript written over the past year in the Appendices (see appropriate appendix by task title).

Titles of articles published in fiscal year 1978-1979

Beebe, Robert R., "A Study of Hydrogeologic Trends in Exploration for Devonian Shale Gas in the Midway-Extra Gas Field of Putnam County, West Virginia," 1979, Masters thesis, West Virginia University, Department of Geology and Geography, Morgantown, W. Va.

Berger, Philip S., "Extension Structures in the Central Appalachians," January 1979, Masters thesis, West Virginia University, Department of Geology and Geography, Morgantown, W. Va. (DOE-METC UGR File No. 159)

de Wys (see Negus-de Wys) "Eastern Kentucky Gas Field: Structural-Stratigraphic Cross Sections and Potential Production Patterns."

de Wys (see Negus-de Wys) "Trend Analysis of Gas Production in the Cottageville Field."

Dixon, Jeanette M., "A Method to Identify Zones of Intense Jointing with Application to the Parsons Lineament, West Virginia," Southeastern Section of Geological Society of America, Blacksburg, Virginia, April 25-28, 1979. (DOE-METC UGR File No. 169, 46 p.)

Dixon, Jeanette M., "Field Techniques for Measuring Joint Intensity," September 1979, West Virginia University, Department of Geology and Geography, Devonian Shale Program, Morgantown, W. Va.

Dixon, Jeanette M., R. L. Wheeler, Sally M. Holland, Byron R. Kulander, "Style Elements, Intensity, and Relative Ages of Joints on a Detached Anticline," 14th Annual Northeast Section of the Geological Society of America Meeting, Hershey, Pa., Abs. Vol. 11, No. 1, January 1979.

Evans, Mark A., "Fracture Density and Orientation Study of the MERC #1 Core from Monongalia County, West Virginia," June 1979, West Virginia University, Department of Geology and Geography, Devonian Shale Program, Morgantown, W. Va.

Jones, D. Scott and Dr. Henry W. Rauch, "Lineaments and Ground-water Quality as Exploration Tools for Ground Water and Gas in the Cottageville Area of Western West Virginia," October 1978, DOE-Morgantown Energy Technology Center, Morgantown, W. Va., METC/SP-78/6 Vol. 1.

Lee, Kevin D., "Fractures from Devonian Shale Outcrops Along the Pine Mountain Thrust," May 1979, West Virginia University, Department of Geology and Geography, Devonian Shale Program, Morgantown, W. Va.

Long, Brian R., "Regional Survey of Surface Fractures in Eastern Kentucky," June, 1979, Masters thesis West Virginia University, Department of Geology and Geography, Devonian Shale Program, Morgantown, W. Va.

Negus-de Wys, Jane, and R. C. Shumaker, "Eastern Kentucky Gas Field: Structural-Stratigraphic Cross Sections and Potential Production Patterns," October 1978, DOE-Morgantown Energy Technology Center, Morgantown, W. Va., METC/SP-78/6 Vol. 1.

Negus-de Wys, Jane, and R. C. Shumaker, "Relations of Gas Occurrence to Geologic Parameters in Eastern Kentucky Gas Fields," AAPG Annual Convention, Houston, Texas, April 1979.

Ms. Negus-de Wys chaired a session on Natural Gas Habitats at this AAPG Annual Meeting.

- Negus-de Wys, Jane, and R. C. Shumaker, "Trend Analysis of Gas Production in the Cottageville Field," October 1978, DOE-Morgantown Energy Technology Center, Morgantown, W. Va., METC/SP-78/6 Vol. 1.
- Nuckols, III, E. B., "Exploration Parameters Derived from Historical Devonian Shale Production in Western West Virginia," October 1978, DOE-Morgantown Energy Technology Center, Morgantown, W. Va., METC/SP-78/6 Vol. 1.
- Ruotsala, James E., "Seismic Modeling," 10th Annual Appalachian Petroleum Geology Symposium, March 1979, Lakeview Country Club, Morgantown, W. Va. (Abstract - oral presentation.)
- Shumaker, Robert C., et al., "Parameters of Geologic Structure Which Affect Devonian Gas Shale Production in West Virginia and Eastern Kentucky - a Progress Report 1978-1979," Proceedings 3rd Eastern Gas Shales Symposium, October 1979, US/DOE-Morgantown Energy Technology Center, Morgantown, W. Va., METC/SP-79/6.
- Wilson, Thomas H., "Bedding Orientation Contours of Middle Devonian Shales Exposed in the Middle Mountain Syncline, Valley and Ridge Province, West Virginia," July 1979, West Virginia University, Department of Geology and Geography, Devonian Shale Program, Morgantown, W. Va.

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PART II

PRINCIPAL INVESTIGATORS' REPORTS

ON

RESOURCE INVENTORY TASKS

AND

SHALE CHARACTERIZATION TASKS

OBJECTIVES

The general objective of our project under contract DE-AC21-76MC05194 (formerly EY-76-C-05-5194) is to study the structural parameters of the Devonian shales that affect gas production in eastern Kentucky and West Virginia.

To that end our program is specifically designed to:

- 1.) Collect, compile, and analyze geologic data to construct regional structure maps of eastern Kentucky and West Virginia.
- 2.) Determine if structural types and styles affect production, and determine if minor structures as mapped in outcrop could influence production characteristics.
- 3.) Determine if shallow seismic surveys can detect near-surface faults and fracture zones, and if such structures can be detected, to further determine how fractures relate to both production from the shale and to lineations observed on remotely sensed data.
- 4.) Determine if a relationship exists between ground water movement and shale gas productivity.

Through the integration of our work with others it is our ultimate goal to discover if relationships exist between Devonian shale gas production and geologic structure. If such a relationship is established, we will attempt to develop a method or methods for selecting favorable sites to drill shale wells that have a greater potential for gas production than the norm for that region.

DELIVERABLE ITEMS

Certain items listed below are to be delivered in subsequent contract years and where appropriate several items may be delivered in the same report.

<u>ITEM</u>	<u>STATUS</u>
1. Geologic cross sections thru the eastern Kentucky gas field - 3 southwest-northeast 4 southeast-northwest	Complete
2. Isopach maps for the eastern Kentucky gas field area using ~300 wells of the: a. Bedford-Berea b. Cleveland-Undifferentiated Chagrin (?), black and gray intertonguing shales c. Chagrin-Three Lick d. Upper Huron e. Middle Huron f. Lower Huron	Complete
3. Map showing net thickness of Devonian shale sediments that have a Gamma Ray reading greater than 20 API units for the eastern Kentucky gas field area.	in progress
4. Structure contour map on the top of the Devonian Ohio black shale and base of the Huron shale for the eastern Kentucky gas field area using ~ 300 wells.	Complete
5. Preliminary initial open flow map based on 4750 gas wells in the eastern Kentucky gas field.	Complete
6. Structure contour maps of at least one reflection horizon in areas of resistivity and seismic surveys.	in progress
7. Brief report on seismic test site III, the Warfield fault, which should at least include a geologic cross section, complementary seismic section, shot point map, and subsurface structure or seismic time map on an identifiable seismic event. The report should identify seismic characteristics of the fault zone.	in progress
8. Summary report concerning the development of a petite seismic system and its application to exploration for shallow zones of fracture porosity emphasizing the recognition of porosity within the Devonian shale.	in progress

<u>ITEM</u>	<u>STATUS</u>
9. Regional maps showing core well locations: natural fracture orientation, mineralized fracture orientation, induced fracture orientation, in-situ stress direction, and trend of slickenside fractures (including slick direction and plunge) as determined from core analyses.	in progress
10. Individual reports on cored wells discussing relationship of fractures to local structural geology and gas production where data is available.	in progress
11. Report on the nature and origin of surface fractures in eastern Kentucky. Fracture maps showing orientation of surface fractures by lithology: sand, shale, limestone, and coal.	Complete
12. Map showing orientation of fractures above and below the Devonian shale of the Pine Mountain thrust.	Complete - open file
13. Preliminary report comparing the fractures mapped at the surface in the Pine Mountain thrust area and as compared to fractures logged in eastern Kentucky shale cores.	Complete - open file
14. A description of the characterization, interpretation and westward extension of at least one cross-strike structural discontinuity (CSD) in West Virginia.	in progress
15. A description of the development and methodology of intensity measurement for systematic joint systems and a discussion of outcrop joint system correlation with photolineament, CSD and subsurface structure patterns.	in progress
16. A report on the amount of bed-parallel extension faulting and fracturing in surface folds, including an assessment of the significance of these structural features in Devonian shale gas production.	Complete - open file
17. A model of shale fracture origin in specific areas of West Virginia and eastern Kentucky based on outcrop and core analysis. The model will include a statistical analysis of fracture and slickenside orientation data from cores.	research in progress
18. A report on the feasibility of using ground water occurrence and yield data as a tool for gas exploration based on data from the Midway-Extra gas field area. Also included will be a discussion on the correlation of ground-water yield and lineaments.	Complete

<u>ITEM</u>	<u>STATUS</u>
19. Maps of initial open flow characteristics related to various geologic conditions in the eastern Kentucky gas field analyses.	research in progress
20. A map of eastern Kentucky and West Virginia showing areas which have a high probability of Devonian shale gas production.	research in progress
21. A report of the structural characteristics of the surficial geologic units occurring in the eastern Kentucky gas field and in selected areas that do not have hydrocarbon production adjacent to it.	research in progress
22. A report on the correlation of geology, lineaments, fracturing, and oil and gas production.	research in progress

SCHEDULE OF MILESTONES

<u>MILESTONE</u>	<u>STATUS</u>
1. Complete deliverable item 1 - cross sections 1-15-79.	Delivered - open file
2. Complete deliverable item 2 - isopach maps 300 pts. 9-15-79.	Delivered - open file
3. Maps of API 20 units as described in deliverable item 3 9-30-79.	in progress
4. Structure maps for Top of the Ohio shale and base of Huron using 300 pts. 7-15-79.	Complete
5. Complete computer generated SYMAP contour of initial open flows for eastern Kentucky gas field 9-30-79.	Complete
6. Pattern recognition study of eastern Kentucky initial open flow maps. Initiated 12-15-78 Completed 1-15-79	Complete
7. Initiate trend analysis of initial open flow data for eastern Kentucky 2-15-79.	Complete
8. Complete brief report on shallow seismic and resistivity surveys of a selected area of known faulting including geologic cross sections, subsurface structure map on at least one identifiable seismic event - Milestone 7 1-15-79.	Delayed
9. Complete analysis of seismic and resistivity survey of Cottageville field outlining areas on seismic lines that indicate fracture porosity near the surface, and if possible, within the shale. Include also structure and isopach maps of key units shown on the seismic lines 5-30-79.	in progress
10. Complete report on the design, development, and use of a high sensitivity shallow seismic tool and the results of this tool's use in a shallow producing area. Milestone 8 9-30-79.	in progress
11. Complete a report on the use of resistivity equipment and interpret the results of resistivity surveys in selected ground water area 9-30-79.	Complete
12. Initiate study of seismic shear waves to detect the position and trend of shallow zones of subsurface fracture porosity 10-1-78.	Complete

<u>MILESTONE</u>	<u>STATUS</u>
13. Complete brief report on feasibility of using a seismic refraction survey to detect any velocity anomaly associated with shallow fracture porosity, 1-15-79.	in progress
14. Design field procedure and obtain equipment to implement study described in Milestone 13, 2-1-79.	in progress
15. Initiate field testing of Method designed in Milestone 14 - at suitable test site, 6-1-79.	in progress
16. Brief report on results of velocity anomalies associated with shallow fracture zones described in Milestone 13, 9-30-79.	in progress
17. Maps showing trends of surface fractures for the eastern Kentucky portion of contract area including a differentiation of fracture domains and fracture orientation by lithology, 12-30-78.	Complete
18. Report on the nature and origin of surface fractures in eastern Kentucky, 9-30-79.	Complete
19. Initiate study of remote sensing data around cored wells to determine lineament patterns, 12-1-78.	in progress
20. Complete analysis outline in Milestone 19, 2-1-79.	Complete
21. Initiate remote sensing study of eastern Kentucky to determine lineament patterns, 2-1-79.	in progress
22. Complete analysis as described in Milestone 21, 5-1-79.	in progress
23. Initiate study of fracture data from Pine Mountain thrust area, 10-1-78.	Complete
24. Complete analysis of data described in Milestone 25 with results plotted in map form by both lithology and fracture domain. Also analyze fracture data to rate variation with distance above and below the Pine Mountain thrust, 2-1-79.	Complete
25. Initiate fracture study of Lincoln County cores, 10-1-78.	Complete
26. Complete Milestone 25, 12-1-78.	Complete
27. Develop methods of bedding orientation analysis to 1) serve as a tool in mapping the structures present in the poorly exposed, mechanically incompetent black shales, and 2) provide an objective sampling rationale for the analysis of fracture orientation and spacing data collected in CSD's. Final report - 7-1-79.	Complete

<u>MILESTONE</u>	<u>STATUS</u>
28. Manuscript reporting results of an investigation of the Parsons lineament, to determine whether some Middle and Upper Devonian clastic rocks are more intensely fractured in the lineament than elsewhere, 1-1-79.	Complete
29. Map the Middle Devonian shales exposed in an area of the eastern outcrop belt where these shales are intersected by the Parsons CSD to examine any structural relationships to the CSD. Final report 9-1-79.	Complete
30. Contour maps of measures of joint intensity in an area containing part of the Parsons lineament, 12-1-78.	Complete
31. Report describing the field technique developed to rapidly estimate the surface area of systematic joints per unit volume of rock in a given locality, and evaluation of operator variability. Due 9-30-79.	Complete
32. Collect fracture data in the Middle Devonian black shales exposed in the eastern outcrop belt where these shales are intersected by the Parsons cross-strike structural discontinuity. Examine differences in fracture orientation and spacing. Relate these differences to the various structural elements present (i.e., folding, faulting, the CSD). Determine which differences (if any) can only be explained by the CSD. Final report 11-1-79.	Complete

Science Applications, Inc. (SAI) is providing technical support to DOE/METC by coordinating and reporting of certain EGSP technical work areas; therefore, it is necessary to incorporate the following provision into this contract (DE-AC21-76MC05194 - formerly EY-76-C-05-5194).

The work to be performed under this contract is subject to monitoring by W. George Fingleton from the Morgantown office of Science Applications, Inc., or such other persons as designated in writing by the Contracting Officer. The designated individual's responsibility will be to assist the DOE/METC Technical Project Officer (TPO) in coordinating with the Contractor for purposes of administering the detailed technical aspects of this contract. The SAI representative does not have the authority to make any commitments or authorize any changes which affect the contract price, terms, or conditions; any such changes shall be referred to the Contracting Officer for action.

All nonconfidential data generated will be submitted for computer storage to DOE/EGSP.

3.1 Work Package 2100-2-1 REGIONAL STRUCTURE STUDIES

Robert C. Shumaker

3.1.1 Current status of work and scheduled deliverables

We have compiled data on the structural tops for the Huron and Corniferous formations from drillers' logs for eastern Kentucky. Approximately 4500 wells have been abstracted.

We have constructed a detailed regional structure map on Top of the Berea sandstone for the area between the Cottageville and Midway-Extra fields of West Virginia (Figure 1). We have found a basement fault that is expressed as a low relief monoclinial flexure that connects the two fields, and presumably this trend has shale gas exploration potential. In our detailed analysis of these two fields we have found that the production relationship to structure is very similar. The detailed analysis of these relationships are given in "Parameters of Geologic Structure Which Affect Devonian Gas Shale Production in West Virginia and Eastern Kentucky - a Progress Report 1978-1979," Shumaker, et al. (Proceedings volume Joint EGSP-ES/AAPG Symposium, October 1979) and "Geology and Producing Characteristics of the Devonian Brown Shale Midway-Extra Field, Putnam County, West Virginia," W. W. Schaefer (Masters thesis 1979, West Virginia University).

3.1.2 Problem areas and suggested improvements

None.

3.1.3 Work plan for fiscal year 1979-1980

During the upcoming year we will initiate and complete a detailed structural map on two horizons along the east flank of the large Warfield anticline in the area of fracture domain changes as outlined by Kulander.

We will start to compile final versions of regional structure maps for the project area. These maps will be compiled on a base scale of 1:500,000 so that a complete picture of the basin can be had. This complete picture is required if we are to form a basis for regional comparison with other shale parameters.

* * * * *

3.1 Work Package 3200-5-1 PRODUCTION STUDIES

J. Negus-de Wys

This report considers work completed under:

- 3.1 Work Package 2100-1-1 CROSS SECTIONS,
- 3.2 Work Package 2100-1-2 ISOPACH MAPS,
- 3.3 Work Package 2100-2-1 STRUCTURE CONTOUR MAPS, and
- 3.4 Work Package 3200-4-1 OIL AND GAS MAPS

Work completed under these tasks is reported and summarized in the three papers to be given at the Lakeview meetings in October.

Copies of the Lithology Studies paper and Geochemistry Studies paper accompany this report.

A copy of the Introduction, Figures, and Conclusions of the Plate Tectonics paper is included. This paper relates the structural setting and sequence to gas occurrence (open flow data) and possible fracture trends.

Well cuttings from thirteen wells in the Eastern Kentucky Gas Field were studied under a binocular scope. Descriptions and cross sections were constructed. The shale was divided into black, brown, gray, and green. Lithofacies maps were drawn, and are suggestive of different source directions for the different lithologies. Fracture indicators were noted and contoured. The resultant configuration compares strikingly with the density contours of high producing wells. Density of high producing wells related most closely to 1) fracture frequency, 2) brown shale lithology, and 3) the Middle Huron stratigraphic unit. The complex intertonguing of siltier units of shale with less silty but highly organic facies may be a factor in gas production, and contribute to a "fracture facies."

A bentonite is observed to occur at the base of the Cleveland and is referred to as the "Big Sandy" Bentonite. Basinal subsidence appears to have increased following both the Tioga (below the Huron) and the "Big Sandy" bentonites.

Geochemistry was studied from the same well cuttings. Elemental and mineralic analyses are presented for the state of present research. The Si/Al is one of the best indicators or predictors of density of high producing wells. However, other elements also show an excellent match. The mineralic data is useful in paleogeographic and paleoenvironmental reconstructions. Computer-drawn maps are presented as examples of how these analyses may be used.

It has been proposed to continue work on this promising approach to gas field analysis and exploration. With further proposed analysis of the data it is anticipated that structural prediction may be possible, as well as areas of greatest gas accumulation.

3.1 Work Package 3200-5-1 PRODUCTION STUDIESJ. Negus-de Wys

continued -

In the third paper, which is to be presented orally, the structural trends and development in the field area are related to present plate tectonics concepts. Open flow trends are then compared with these structural features. A 3-D computer-drawn map of the open flow data in the center of the field shows the striking northeast-southwest trend of high production. It is planned to use this mapping method for later map predictions of the geochemical data, if the necessary funding is provided.

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As this report is being prepared for submission, word has been received of funding approval.

3.1 Work Package 2100-1-1 SEISMIC

James E. Ruotsala

3.1.1 Current status of work and scheduled deliverables

The past year has been a time of continuing development of a seismic reflection system based on the Bison, Inc., model 1580 seismograph and re-evaluation of project goals and past performance with respect to the geophysical tasks.

On the positive side, the University has demonstrated a commitment to continuing geophysical research in the addition of a geophysicist at the assistant professor level to the Department of Geology and Geography in March of this year. In addition, technical support for geophysical research has been greatly increased by a senior-level electronics technician hired through the College of Arts and Sciences Technical Services Staff in August.

One half mile (about 100 traces) of reflection seismic data was recorded by Keith Kirk in the Cottageville gas field in the spring of 1979. These data were transcribed to nine-track tape and plotted. The data were observed to suffer from a severe time correction problem due to the large uncertainty of the starting time (zero-time) for each 6 trace record. A circuit purchased from Bison, Inc., was used to start the seismograph on the arrival of the direct event from the shot to a geophone above the shot (the "uphole phone"). This circuit has never worked properly, and it is not a satisfactory way to determine zero-time even if it does work. The best way to establish zero-time is at the initiation of the explosion, the falling edge of the current pulse through the blasting cap. An Electrical Engineering graduate student was hired to build the necessary hardware late last spring, but it wasn't until we hired our own technician that the unit was built.

Although the Cottageville data are uninterpretable as a seismic section, it is littered with reflections, recognizable geologically on some of the 6 trace records. Figure 3 shows a comparison of commercially available VIBROSEIS* data (recorded by Geophysical Services, Incorporated) and the West Virginia University data, both from the Cottageville gas field. The WVU data is severely aliased at 1 kHz, indicating significant signal energy up to perhaps 3kHz. The resolution of the WVU data is an order of magnitude better than the GSI VIBROSEIS data.

On the negative side, reexamination of the data from the Pricetown underground coal gasification site (Wetzel County) shows that the

* Trade mark of Conoco, Inc.

3.1 Work Package 2100-1-1 SEISMIC - continuedJ. E. Ruotsala3.1.1 Current status of work and scheduled deliverables - continued

data and the interpretation are faulty. Those data and the interpretation were published in last year's Annual Report by Keith G. Kirk. A new interpretation of that data is appended to this report. The implication of this discovery is that no seismic reflection profile has yet been acquired, and no deliverables or milestones requiring such data have been completed.

3.1.2 Problem areas and suggested improvements

Performance of the geophysical tasks under this project has been hampered by a lack of support personnel, both professional and technical. Within the past year substantial improvements have been made in this area with the addition of a geophysicist and a technician to the Department. However, other serious problems remain.

The problems presently contemplated can be roughly separated into two groups: those related to data acquisition, and those related to data analysis. Problems related to data acquisition are discussed in this paragraph. It is well known that the amplitude of a seismic pulse will diminish in proportion to the distance it travels, simply because its energy is distributed on a hemispherical surface whose radius is the distance traveled. This is a purely geometrical effect. In fact the amplitude diminishes even more rapidly with absorption by earth materials, and as it is partially reflected at subsurface acoustic impedance changes. Because of this effect a reflection seismograph must be able to record both large and small amplitude signals. This property is measured in terms of the system's dynamic range. The dynamic range of the Dison seismograph is less than 48 decibels (dB), meaning that it can never record two signals whose amplitude ratio exceeds 256:1. But the situation is even worse because some part of the dynamic range must be reserved to record the signal wave form, at least 24 dB, so that reflection events must have amplitude ratios less than 16:1 to be properly recorded. This is a minimal situation: it would not be excessive to reserve the entire 48 dB range for the wave form. The amplitude of a reflection event is directly proportional to the reflection coefficient of the interface from which it originates. Since the range of reflection coefficients is at least 8:1, one needs 18 dB of dynamic range reserved to recover reflection events from reflectors within an adequate range of reflection coefficients. A further reservation must be made to allow for the less-than-optimum operating conditions encountered in practice, leaving less than 6 dB (2:1) for the geometric effect. In applications of the seismic reflection method, the system dynamic

3.1 Work Package 2100-1-1 SEISMIC - continued

J. E. Ruotsala

3.1.2 Problem areas and suggested improvements - continued

range limits the range of depths that can be investigated. There are other considerations, and in practice the depth range is somewhat site-dependent. Experiments at the Pricetown site indicate that adequate data may be obtained at depths from 350 to 1000 feet, although that is an estimate, yet to be confirmed.

The second class of problems relates to data analysis. The detection of fracture zones, and the presence of gas in the pore-space by seismic methods depends on the detection of reduced acoustic velocity, or a characteristic change in the wave form of the seismic pulse within the target area. Either of these will require the most sophisticated methods of seismic data processing. Since March, much time has been spent evaluating the West Virginia computing network (WNET) in anticipation of the data processing which will be required when the seismograph is ready for use. The results of that evaluation are very discouraging. WNET is an antiquated system, organized primarily for administrative record keeping. It is entirely inadequate, under present operating policies, for the computations necessary in the analysis of even small seismic data sets. While a "major" system up-grade is presently underway, the changes presently contemplated are of little consequence in applications requiring large calculations and graphic data display. The new plotter has been made available to this project on an experimental basis, and has been tested using data from the Cottageville gas field. It is of an old design, and obsolete in geophysical terms. Also, when it is fully implemented the cost of using it will be very high, perhaps \$20,000 for the plotting charges alone to process a seismic line from Cottageville, based on rates currently contemplated by WNET. That amount exceeds the purchase price of the plotter, and the supplies necessary to operate it.

3.1.3 Work plan for fiscal year 1979-1980

After modifications are made to the input amplifiers of the Bison seismograph and several minor repairs are complete, the system will be field tested at the Pricetown II site (Wetzel County). Work at Pricetown is tentatively scheduled for October 13. Judgment will be made at that time on the capabilities of our current equipment. This will determine what work will be done at Cottageville. The field work at Cottageville (reflection survey, if feasible; refraction survey, if shown feasible by the model studies) will probably begin next spring. The problem of data processing will be further studied in anticipation of data being collected from the Pricetown test site and Cottageville.

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TWO WAY TRAVEL TIME
(seconds)

GSI data

there are two reflection
events between 0.490 to
0.550 seconds

WVU data

there are at least 5 reflection
events between 0.490 to 0.550 seconds

Figure 3

3.1 Work Package 2100-2-2 STRUCTURE STUDIESThomas H. Wilson

3.1.1 Current status of work and scheduled deliverables

1. A three phase study of surface structures in Middle and Upper shales in the Middle Mountain syncline of the Valley and Ridge Province, Pendleton County, West Virginia, has been completed. The study included the following: 1) detailed mapping of the Middle Mountain syncline, 2) an analysis of bedding orientation contours of the syncline, and 3) a study of the orientations and spacings of systematic joints in the shales of the syncline. The studies were designed to characterize the Parsons cross-strike structural discontinuity in the Valley and Ridge Province in terms of observable structure.
2. Fifty five additional gravity stations were occupied in Pendleton County, Tucker County, Randolph County, and Grant County, West Virginia. These stations will be used in later gravity modeling of balanced cross sections along the length of the Parsons structural lineament.
3. Gravity modelling of existing cross sections has begun.
4. An analysis of the USGS's aeromagnetic data of West Virginia has been initiated.

3.1.2 Problem areas and suggested improvements

None.

3.1.3 Work plan for fiscal year 1979-1980

- 1.) Balanced cross sections will be constructed through the Appalachian Plateau along the length of the Parsons structural lineament.
- 2.) The gravitational fields of these cross sections will be modeled and compared with the gravity survey of Byron Kulander and Stuart Dean.
- 3.) Second vertical derivatives of the magnetic intensity data will be calculated for West Virginia.
- 4.) Write final report on project.

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3.1 Work Package 2100-2-2 STRUCTURE STUDIES

Jeanette M. Dixon

3.1.1 Current status of work and scheduled deliverables

Parsons Lineament Fracture Study, Tucker County, West Virginia: From October, 1978, through April, 1979, analyses of joint data gathered in Tucker County were completed. The results were published as a deliverable and are on file under the title "A Method of Measuring Joint Intensity with Application to the Parsons Lineament."

Petersburg Lineament Fracture Study, Grant and Pendleton Counties, West Virginia: In June, 1979, joint data was gathered along the Allegheny Front to determine: (1) if rocks in the Petersburg Lineament are more intensely fractured, and (2) how the Lineament affects rocks with depth. Analysis of data has been completed and will be published in the final report in January, 1980.

Westward Extensions of Lineaments Study: Pennsylvanian rocks in Taylor, Barbour, and bordering counties were examined to determine whether or not the Parsons and the Petersburg Lineaments extended westward onto the Plateau. Results of this study will be published in the final report in January, 1980.

Coal Cleat Intensity Study: Two coal seams in a roadcut on Route 48, Monongalia County, West Virginia, were examined to determine: (1) if differences in cleat intensities could be measured and (2) what affect an overlying stream channel has on cleat intensities. Being able to detect variations in cleating intensity may be useful in mine roof falls, pillar strength, and other mining problems. Results of this study will be published in the final report in January, 1980.

Operator Variance Study: Four operators measured three outcrops for joint intensity in order to determine how much, if any, variation in measurements would exist between operators. The results of this study will be published as a deliverable item October, 1979.

3.1.2 Problem areas and suggested improvements

None.

3.1.3 Work plan for fiscal year 1979-1980

Complete the final report due September, 1980.

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3.1 Work Package 2200-1-2 FRACTURE DENSITY AND ORIENTATION

Mark A. Evans

3.1.1 Current status of work and scheduled deliverables

Examination of thirteen oriented Devonian shale cores from the Appalachian Plateau revealed considerable deformation at depth in the form of fracturing and shearing. The core wells are located in Mason County, WV; Monongalia County, WV; Jackson County, WV; Wetzel County, WV; two from Lincoln County, WV; Allegheny County, PA; Carroll County, OH; Washington County, OH; Wise County, VA; Perry County, KY; Johnson County, KY; and Martin County, KY. Fracture frequency and orientation measurements were made on the fractures in each core. Fractures were differentiated (when possible) into core-induced fractures, unmineralized natural fractures, mineralized natural fractures, slickensided fractures, and slickenlines.

Core-induced fracture orientations exhibit an extreme consistency with depth in a particular core. They are also quite consistent regionally in that they all generally have a northeast trend. This consistency indicates the presence of a stress or rock fabric anisotropy which in turn may be related to an east to northeast trending maximum in-situ compressive stress (Sbar and Sykes, 1973).

One natural fracture trend found in most of the cores studied is orthogonal to the Appalachian trend and swing with that trend into the Southern Appalachians. These fractures probably formed as extension fractures under tectonic compressive stresses. Another natural fracture set found in most of the cores parallels the core induced fractures and probably formed in relation to the same stress or fabric anisotropy. Other, less prevalent, natural fracture sets also exist but show relationship only to local structures.

The presence of slickensides in most cores studied is evidence for slip plane and decollement movement in the Plateau. Decollement movement was found to have occurred in Allegheny County, PA; Monongalia County, WV; Wetzel County, WV; Lincoln County, WV; Wise County, VA; and possibly in Johnson County, KY; Martin County, KY; and Perry County, KY. Most displacement can be related to Alleghenian deformation.

Fracture frequency between cores revealed the existence of several fracture facies. These fracture facies are generally stratigraphically controlled. Natural fracture facies are the Marcellus Shale, Tully Limestone, Genesee Shale, West Falls Formation, and Lower Huron Member of the Ohio Shale. Slickenside fracture facies are usually decollement zones and include the Marcellus Shale, Tully Limestone, Genesee Shale, West Falls Formation, base of the Java Formation, and Lower Huron and Cleveland Members of the Ohio Shale.

3.1 Work Package 2200-1-2 FRACTURE DENSITY AND ORIENTATIONM.A. Evans

3.1.1 Current status of work and scheduled deliverables - continued

A small slip plane was found to exist near the base of the Lower Huron in nearly all cores which included this unit. Throughout most of the Plateau, displacement along this slip plane has a general northeast-southwest trend.

Dramatic differences in fracture patterns were found between two adjacent core wells in Lincoln County, WV. The wells are located over the Rome Trough and may have been under the influence of two different stress fields when fracturing occurred. This is consistent with the findings of Kulander and Dean (1978) who found chaotic fracturing in coals over a Rome Trough basement fault zone.

A core from a well located near a possible basement fault in Allegheny County, PA, exhibits a wide variety of fracture patterns that do not seem to be related to structures in that area. This anomolous fracture pattern is also consistent with the findings of Kulander and Dean (1978).

A final report on the fractures in the thirteen cores is nearly complete. A first draft is finished and drafting of illustrations has begun.

Kulander, B. R., and Dean, S. L., 1979, ms, Rome Trough Relationship to Fracture Domains, Regional Stress History and Décollement Structures: (in review for Proc. of the Southeast Section Geol. Soc. of America Symposium on Western Limits of Detachment and Related Structures in the Appalachian Foreland).

Sbar, M. L. and Sykes, L. R., 1973, Contemporary Compressive Stress and Seismicity in Eastern North America: an Example of Intro-Plate Tectoncs: Geol. Society of America Bull., v. 84, p. 1861-1882.

3.1.2 Problem areas and suggested improvements

No problems.

3.1.3 Work plan for fiscal year 1979-1980

Complete final report on fracturing in oriented Devonian shale cores from the Appalachian Plateau as well as complete drafting of illustrations. Two or more detailed reports on core fractures are also planned.

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3.1 Work Package 2200-1-2 FRACTURE STUDIES

Kevin D. Lee

3.1.1 Current status of work and scheduled deliverables

A report entitled "Fractures from Devonian Shale Outcrops Along the Pine Mountain Thrust" was completed using data collected during the summer of 1978.

More field work was done in the spring of 1979 at Jenkins, Kentucky, on joint occurrence in the thrust zone of Pine Mountain at the base of the Devonian shale. A postulated theory as a result of my field work is that joint occurrence in the thrust plane is derived from a combination of regional compression and local shearing.

The summer of 1979 was spent at Kentucky-West Virginia Gas Company in Prestonsburg, KY, recording structural tops from drillers' logs in the Big Sandy gas fields of eastern Kentucky. Approximately 4,500 drillers' logs were recorded. Work is now proceeding on three structure contour maps to be constructed from those drillers' logs.

3.1.2 Problem areas and suggested improvements

Finding a quicker way to get reimbursed for field expenses would be a blessing.

3.1.3 Work plan for fiscal year 1979-1980

Finish my maps by January 1, 1980, and complete my thesis by June 30, 1980.

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3.2 Work Package 3200-2-3 SUBSURFACE GEOLOGYHenry W. Rauch

Subtask - Identify 3 areas in which to conduct ground water studies.

3.1.1 Current status of work and scheduled deliverables

Ground-water studies have been initiated and completed in two areas: the Cottageville area of Jackson County, West Virginia (see Annual Report for 1978 for results), and the Midway-Extra area of northern Putnam County, West Virginia (see the second Volume of this 1979 Annual Report for results).

3.1.2 Problem areas and suggested improvements

Our only problem is that METC-DOE failed to extend us continued support for fiscal year 1980, making it impossible to select a third area for a third ground water study.

3.1.3 Work plan for fiscal year 1980

No work is planned under U.S. government sponsorship. Instead, private funding has been arranged to carry on our research.

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3.2 Work package 3200-2-3 SURFACE RESISTIVITYH. W. Rauch

Subtask - Conduct resistivity surveys over ground water study areas (defined under 3200-1-2).

3.2.1 Current status of work and scheduled deliverables

As was emphasized in previous reports, including that for fiscal year 1979, less stress has been put on resistivity surveying in favor of other more fruitful research aspects. Resistivity survey results have been accordingly included under other tasks: 3200-5-1 and 3200-5-3.

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3.3 Work Package 3200-5-1 STRUCTURE/PRODUCTION CORRELATIONH. W. Rauch

Subtask - Correlate all data and attempt to establish a relationship between geologic features, lineaments, fractures, ground water, and oil and gas production.

3.3.1 Current status of work and scheduled deliverables

All work has been completed for the second ground-water study area - the Midway-Extra area of Putnam County, West Virginia. The final project report consists of Robert Beebe's M.S. thesis and a paper authored by Beebe and Rauch for the 3rd EGSP conference at Lakeview, Morgantown, West Virginia; copies of both are included in the second volume of this report.

3.3.2 Problem areas and suggested improvements

None. See task 3200-1-2 report above.

3.3.3 Work plan for fiscal year 1980

See report for task 3200-1-2 above.

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3.4 Work Package 3200-5-3 LINEAMENT/STRUCTURE CORRELATIONH. W. Rauch

Correlate fractures and lineaments derived from photo analysis with results of ground water tests to determine if any relationship exists between ground water production and the occurrence of lineaments.

3.4.1 Current status of work and scheduled deliverables

See report for task 3200-5-1 above.

3.4.2 Problem areas and suggested improvements

None. See task 3200-1-2 report above.

3.4.3 Work plan for fiscal year 1980

See report for task 3200-1-2 above.

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