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Naturally Fractured Tight Gas Reservoir Detection Optimization

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CONTRACT INFORMATION

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Period of Performance: September 30, 1993 - March 31, 1997

Schedule and Milestones

Program Schedule	**FY 1994**				**FY 1995**				**FY 1996**				**FY 1997**	
Field	Q_1	Q_2	Q_3	Q_4	Q_1	Q_2	Q_3	Q_4	Q_1	Q_2	Q_3	Q_4	Q_1	Q_2
Task 1 - Site Selection Remote Sensing Imagery High Resolution Aeromagnetics Field Studies Structural Studies														
Task 2 - Field Test Plan														
Task 3 - 3-D Multicomponent Shear wave Acquisition Processing Interpretation														
Task 4 - Project Summary														

OBJECTIVES

The objectives of the fracture detection optimization program are to 1) Develop and optimize an integrated exploration approach utilizing advanced remote sensing imagery, high-resolution aeromagnetics, stratigraphic mapping and dynamic tectonic modeling that will reliably predict fracture prone areas and 2) Demonstrate application of 3-D multicomponent seismic array for siting wells within the selected fracture prone area to target naturally fracture tight gas reservoirs.

BACKGROUND INFORMATION

Natural fracture intensity and diversity of orientation is a requirement for commercial production from the vast store house of natural gas held in tight gas reservoirs. Identifying and defining the location of fractured reservoirs with advanced seismic technologies such as shear wave birefringence has shown promise (Martin and others, 1987). Unfortunately, its high cost constrains the use of these technologies for exploration and reconnaissance mapping. Surface seismic fracture detection technologies however, maybe cost effectively applied in regions where fractures are already known to exist. Current geologic models for locating open fracture systems are qualitative (Lorenz and others, 1991) and as such too speculative to justify the expense commitment of using advanced seismic methods to verify their location and characteristics. Quantification of fracture characterization is possible by improving and correct application of existing geological and geophysical techniques.

Prediction of subsurface fractures will be accomplished by integrating and optimizing existing fracture detection tools. The research concept being pursued in this project is that fractures are generated by multiply reactivated basement faults. Structural warps associated by basement faults both fracture the overlying rocks and establishes regions of low stress settings allowing dilation of the natural fracture system. Therefore the development of an exploration strategy designed to identify these important but frequently subtle basement features is critical to locating fractured regions in advance of drilling. Infield development of the predicted fractured area can be most cost effectively accomplished by targeting fracture systems utilizing advanced seismic fracture detection technologies such as 3-D multicomponent shear wave surveys.

PROJECT DESCRIPTION

A field demonstration site will be located in the Piceance Basin, northwestern Colorado. The Piceance Basin is an ideal area for the project due to 1) the wealth of subsurface fracture data collected at the MWX site, critical for calibration of the project fracture detection methodology 2) high drilling activity targeting tight gas reservoirs and support by the industry for optimizing fracture detection technology 3) widespread distribution of tight gas reservoirs within the basin that could be accessed by successful deployment of the technologies developed under this project.

An aggressive technical program involving a multi-disciplinary approach to meet the challenge of optimizing fracture detection technologies is the project foundation. Data acquisition, compilation, interpretation and synthesis as displayed on figure 1 is the first project phase. The key element in the first phase is determining the relationship of permeability anisotropy orientation to basement structures. Permeability anisotropy can be established through iso-production contouring of wells producing from fractured tight gas reservoirs. The presence and orientation of basement features has been determined by utilizing advanced basement imaging tools. Establishment of the relationship to known favorable permeability fairways to mappable basement features will provide an exploration analog for the identification of undrilled basement structures and associated fractured tight gas reservoirs. A 3-D muticomponent shear wave program will be acquired, processed and interpreted over the area predicted to be fractured. Barrett Resources will drill and complete wells targeted by the seismic shoot. Well testing and reservoir simulation of historical production trends will determine reservoir permeability and thereby verify if wells drilled under this project have encountered better permeability than wells drilled without the benefit of integrated fracture detection technologies. An economic analysis will be performed to determine if the economic benefits of the fracture detection technologies are offset by increased gas reserves.

RESULTS

A rigorous approach to structural analysis has been undertaken to successfully determine basement features controlling shallow structural development. To provide a foundation for structural interpretation, a high resolution aeromagnetic survey was acquired and processed over the southern basin (figure 2). To minimize interpretation subjectivity and establish credibility of interpreted features, basement features were also interpreted utilizing 400 line miles of seismic surveys, and utilizing Landsat Thematic Mapper (TM) and Side Looking Airborne Radar (SLAR) imagery for the basin and surrounding areas.

Spatially detailed aeromagnetic maps were used to interpret zones of basement structure. Basement structures, some verified by seismic profiles, corresponded to steep magnetic gradients and linear trending contours. Utilizing this technique, first order and second order basement features have been located on the reduced-to-pole total field magnetic intensity contour map (figure 3). The most prominent features include an interpreted paleobasement high in the east central portion of the basin flanked on the east and west by northwest trending faults NW3 and NW4 and on the north and south by EW3 and EW2 respectively interpreted as east - west trending faults. Seismic coverage (figure 4) has confirmed the basement high which has caused truncation of the Paleozoic section. At basement level, structural lineament NW4 is formed by low angle thrust faults that typically terminate within the Manços shale. Mild warping and draping of the sediments occurs along the fault termination boundaries.

Coincident features to the identified first and second order northwest lineaments have been mapped through linear feature analysis of TM imagery. These lineaments are a composite of individual linear features as interpreted from Landsat Thematic Mapper imagery. Northwest-trending linear features were contoured with respect to frequency of occurrence. Imagery lineaments are defined as zones of aligned and concentrated linear features, which are linear elements interpreted directly from imagery. Figure 5 presents lineaments interpreted from NW-trending linear features in the southern portion of the basin. Note on figure 5 the close correlation of lineaments as interpreted from imagery to basement faults as interpreted from aeromagnetics. This close correlation and further calibration from seismic lines establishes interpreted NW lineament features as significant structural lineaments. Analysis of the E-W trending features is in progress. Preliminary interpretation of E-W structural elements suggests lateral movement along fault zones. Stratigraphic interpretation indicates the NW4 structural element acted as a basin hingeline during Cretaceous deposition.

Structurally Aligned Reservoir Compartmentalization

The best production from Cameo coals and overlying tight gas sands of the Piceance Basin has been established in the Rulison, Parachute and Grand Valley Fields. Iso-production contouring of these three fields has been performed separately on the coal and tight gas sand as part of an effort to determine geologic controls on gas production. The strong NW trend of the production contouring from both intervals implies a common event causing permeability anisotropy. The close proximity and alignment of northwest trending basement faults (figure 6) to the production anisotropy is interpreted as being fracture controlled. Fractures have been generated by basement faults causing the northwest aligned production trend. A region of high stress occurring within close proximity to the structural lineament causes closure of the fracture system and results in a no-flow boundary. Gas migrating southward out of the gas-centered basin became trapped along the no flow boundary causing an overpressuring along the northwest flanks of the basin hingeline NW4. Southwest of the hingeline, the Cretaceous reservoirs are gas saturated and underpressured because the hingeline has isolated water recharge from the Northeastern basin elevated outcrop from the southwestern basin. High fracture permeability and overpressuring conditions are responsible for better reservoir performance observed at Rulison field when compared to other fields producing from Cameo coals and overlying tight gas sands. Since the favorable reservoir properties at the Rulison Field are associated with the basin hingeline, similar reservoir compartments are likely to exist northwest and southeast of the Rulison field along the basin hingeline.

CONCLUSIONS

Fractured production anisotropy in Piceance Basin Mesaverde Group gas reservoirs are controlled by basement fault trends. These basement faults and associated fracture permeability trends can be accurately located using an integration and optimization of remote sensing imagery, high resolution aeromagnetics, stratigraphic mapping and dynamic tectonic modeling. Although some of the basement-related fracture trends have been drilled, the majority of the fracture prone area's identified in the southern Piceance Basin by this project, not yet drilled, represent significant exploration targets.

FUTURE WORK

An area interpreted to be underlain by natural fractures will be selected by June 1995 as the site for field demonstration of the 3-D multicomponent shear wave program. The 3-D shear wave survey will be calibrated with a multicomponent VSP survey in the central portion of the test site. The VSP survey will provide critical information on shear wave attenuation and fracture orientation, thereby serving as an aide in designing the 3-D shear wave survey. Preliminary 3-D shear wave survey design calls for a 4.45 mi^2 array which at average targeted depths of 4,000 - 6,000 feet would yield a 3-D portrait of 2 mi^2 when wave migration is considered. Survey acquisition is planned for early 1996. Data processing and interpretation will locate zones of maximum fracture intensity within fluvial sections of the Mesaverde Group. Barrett Resources will drill wells to encounter the fractured zones as interpreted from the seismic survey. The zones will be stimulated and production tested. Permeability of the completed interval and gas reserve forecasts will be determined through reservoir simulation and production history matching. A comparison of reserves will be made between wells drilled with and without utilization of the fracture detection technology. An economic analyses will determine relative benefits of the fracture detection technology and associated higher costs.

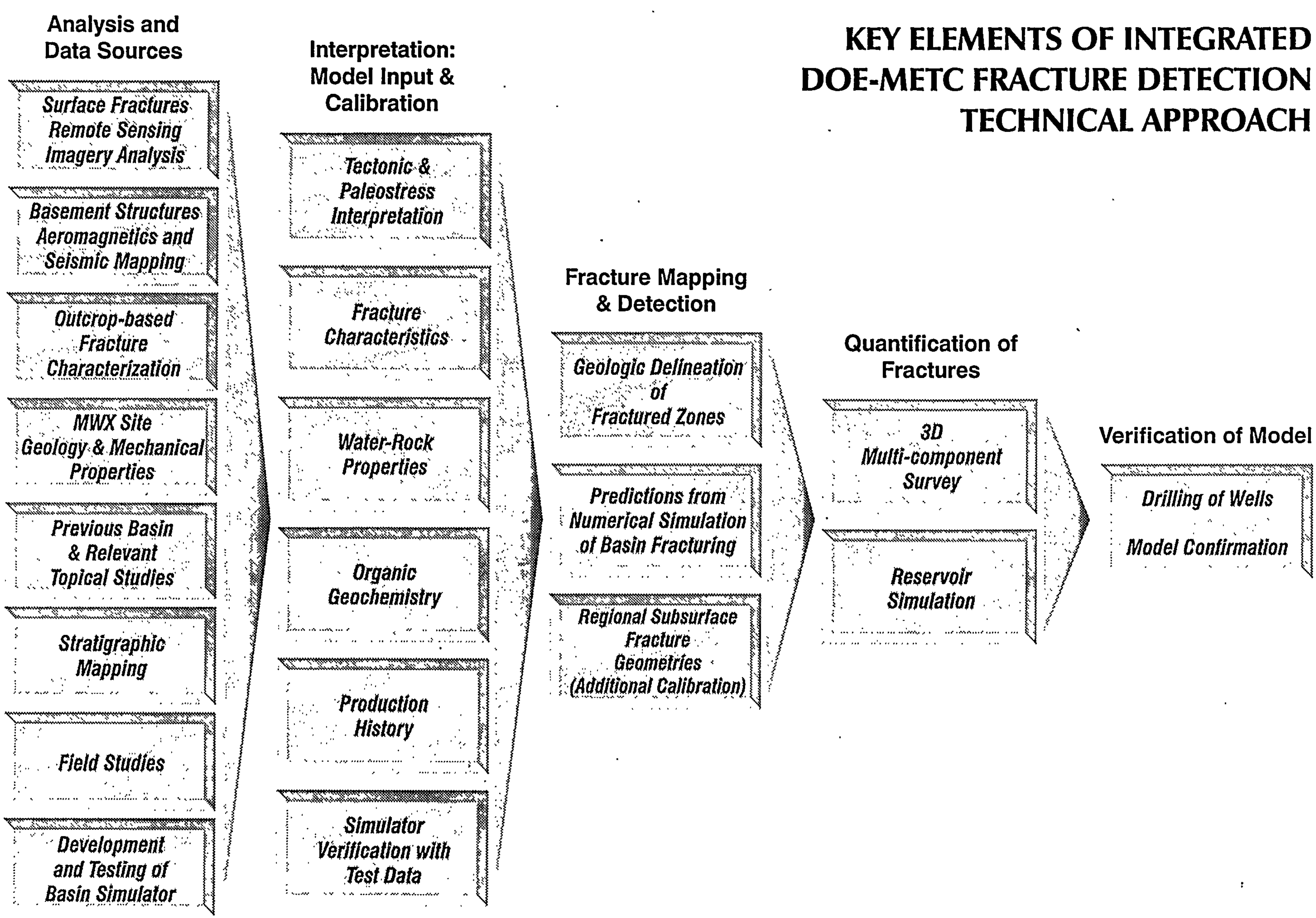
REFERENCES

Lorenz, J., Teufel, L., and Teufel, N., 1991, Regional Fractures I: A mechanism for the formation of regional fractures at depth in flat-lying reservoirs, American Association of Petroleum Geologists Bulletin, 75, 1714-1737.

Martin, M.A. and Davis, T.L., 1987, Shear-Wave Birefringence: A New Tool for Evaluating Fractured Reservoirs, *Geophysics: The Leading Edge of Exploration*, Oct. 22-28.

FIGURE 1

KEY ELEMENTS OF INTEGRATED DOE-METC FRACTURE DETECTION TECHNICAL APPROACH



AEROMAGNETIC SURVEY AREA AND SEISMIC GRID, PICEANCE BASIN

FIGURE 2

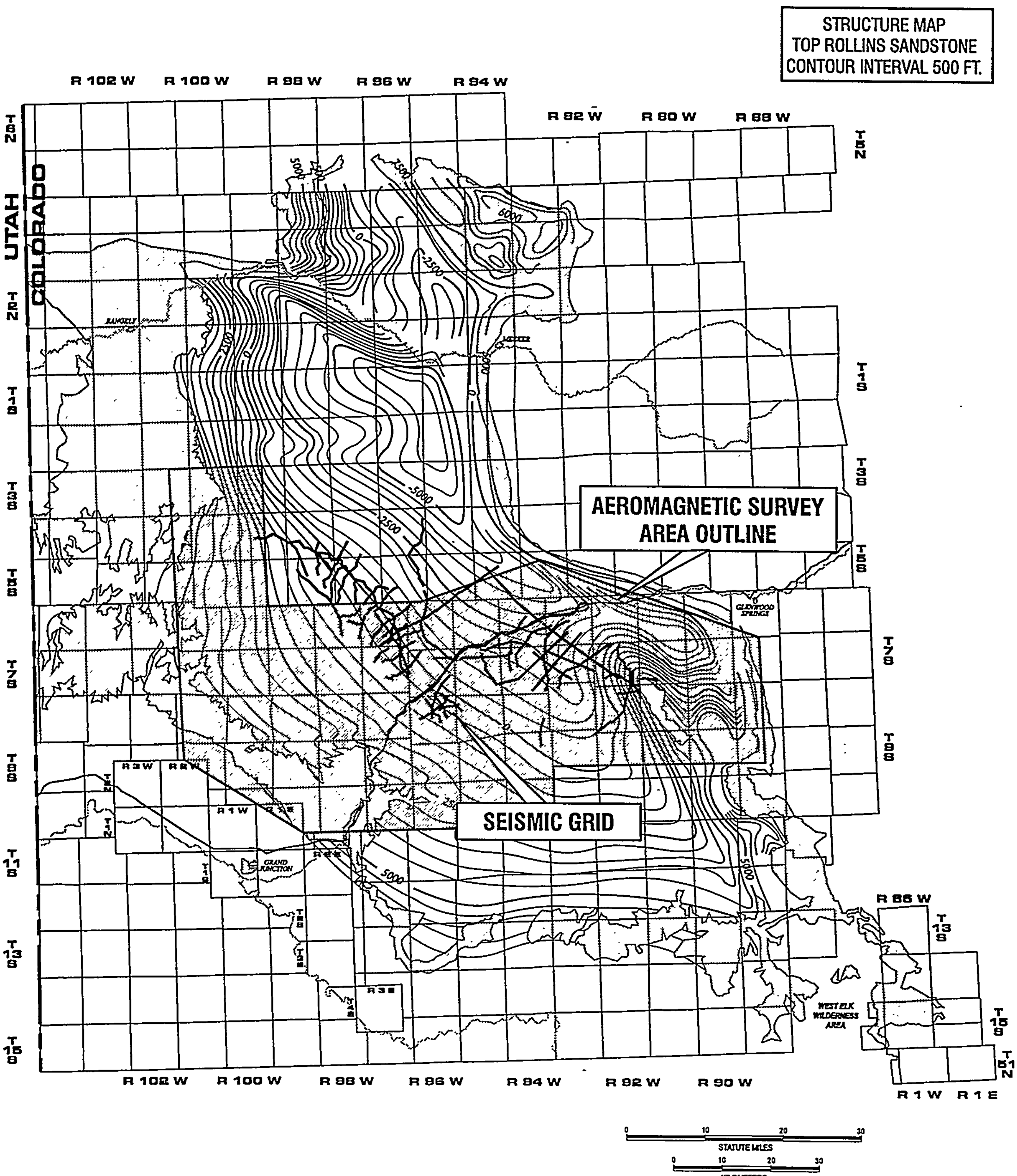


FIGURE 3

REGIONAL HIGH-RESOLUTION REDUCED-TO-POLE TOTAL FIELD MAGNETIC INTENSITY

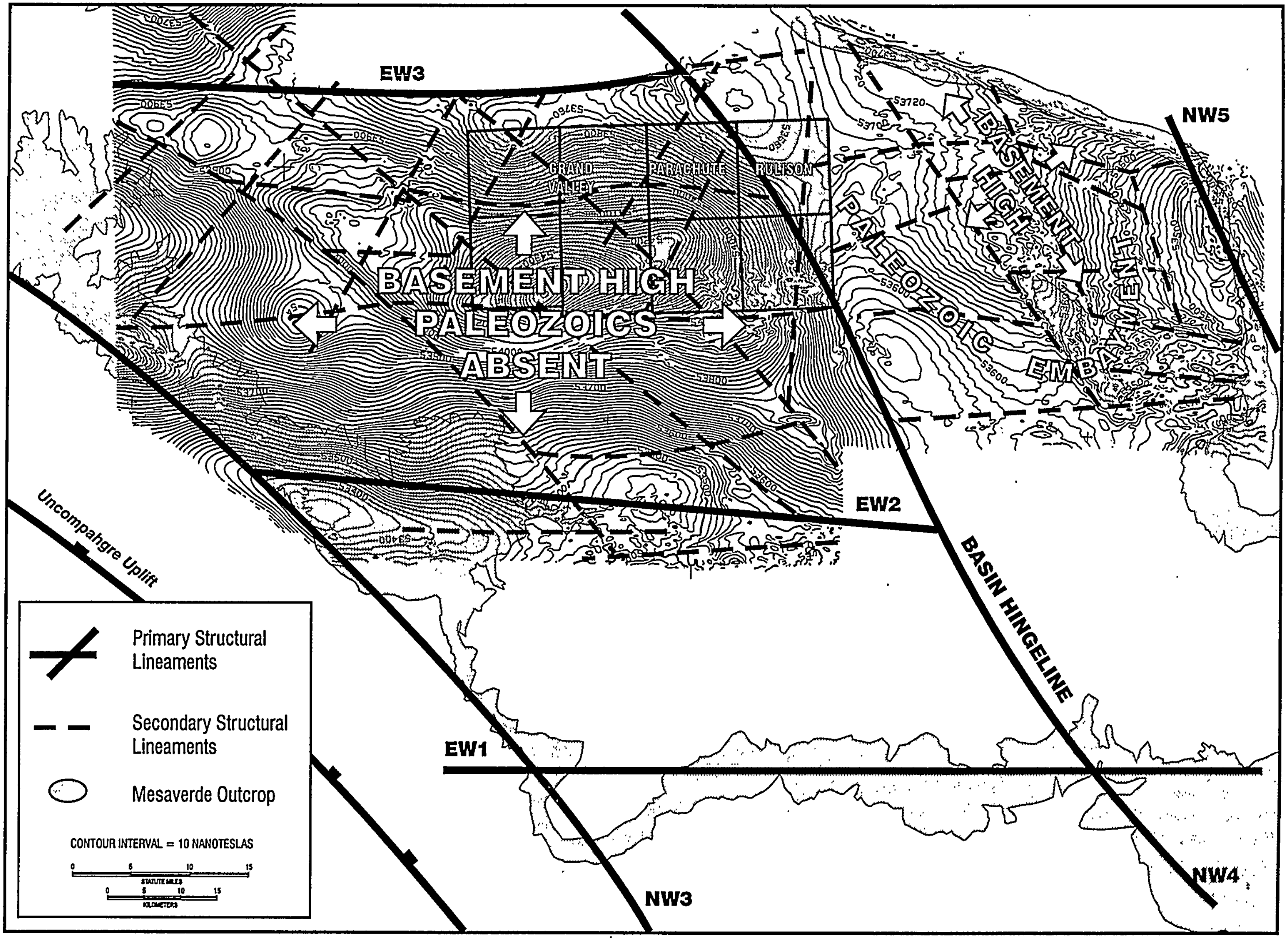


FIGURE 4

BASEMENT FAULTS INTERPRETED FROM SEISMIC

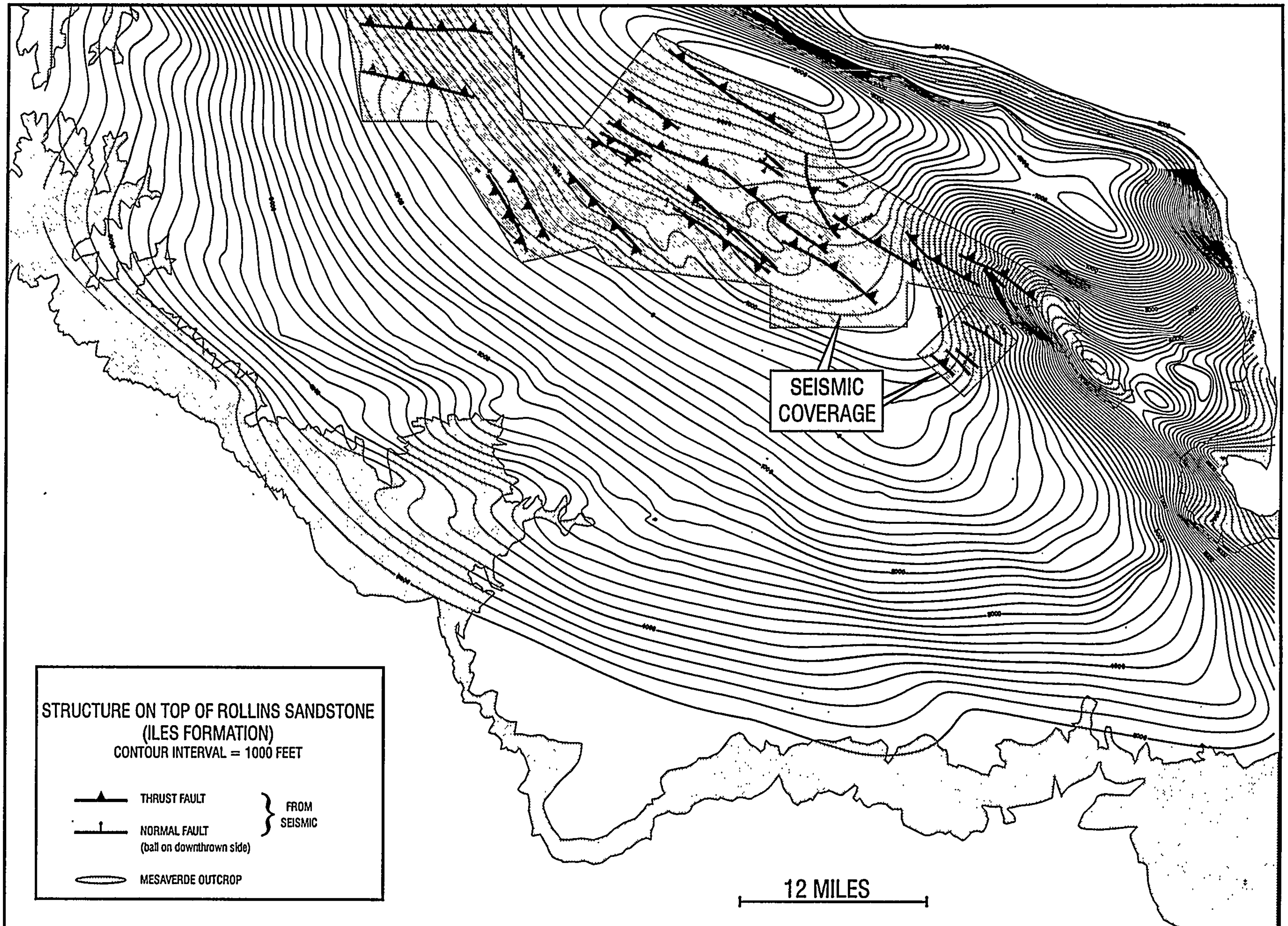


FIGURE 5

LINEAR FEATURE ANALYSIS - NW TRENDING INTERVAL
CONTOURED LINEAR FEATURE FREQUENCY

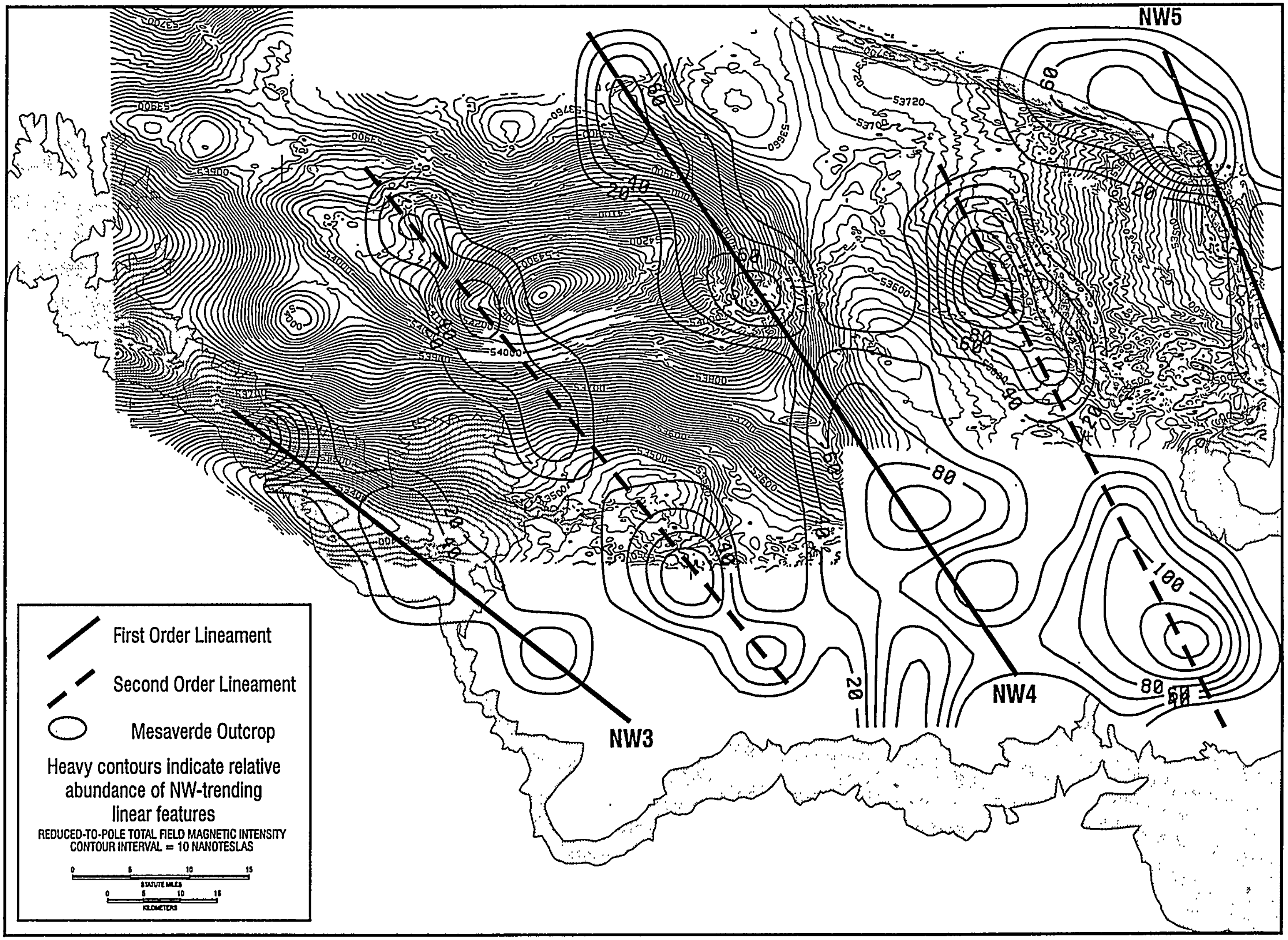
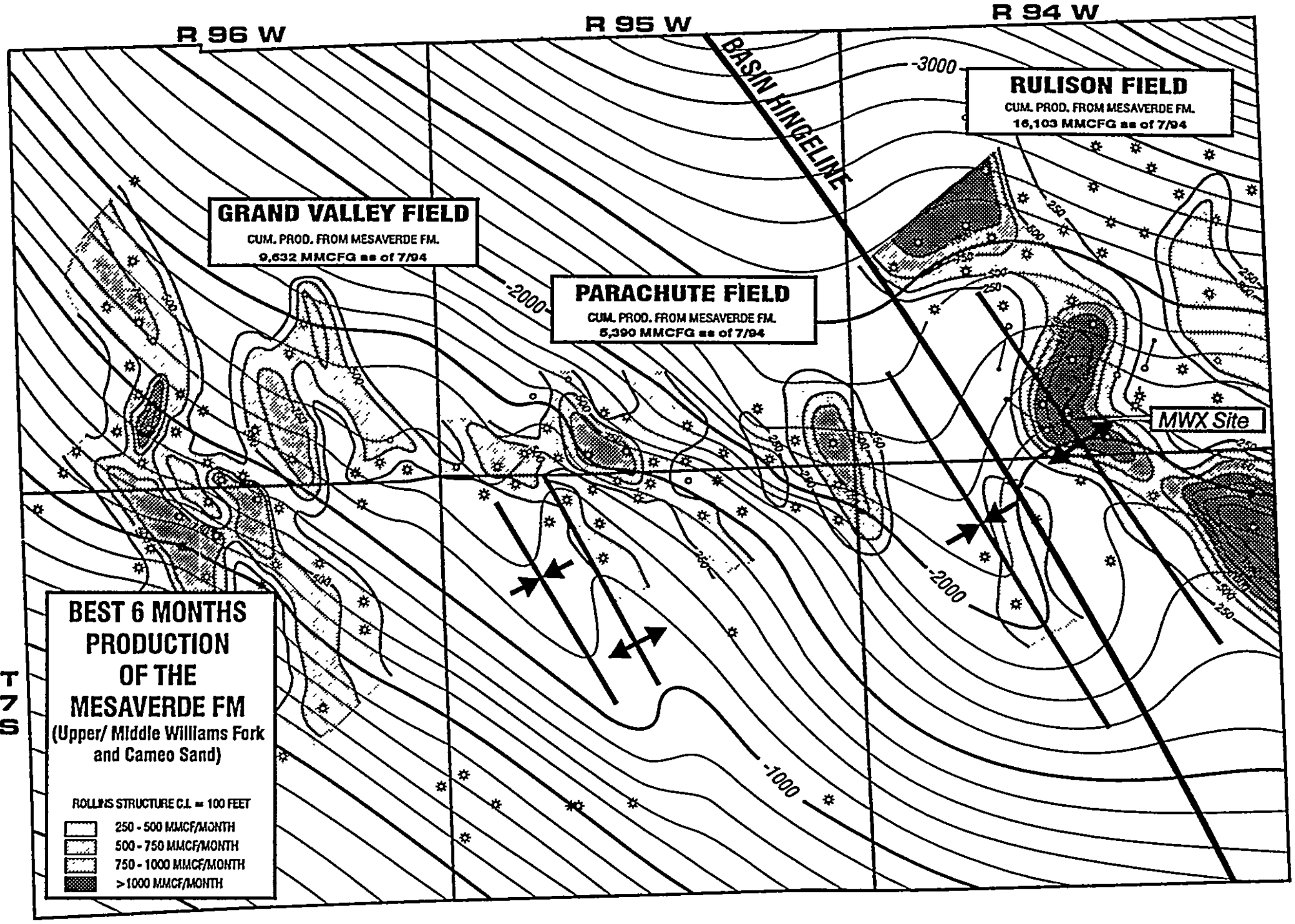
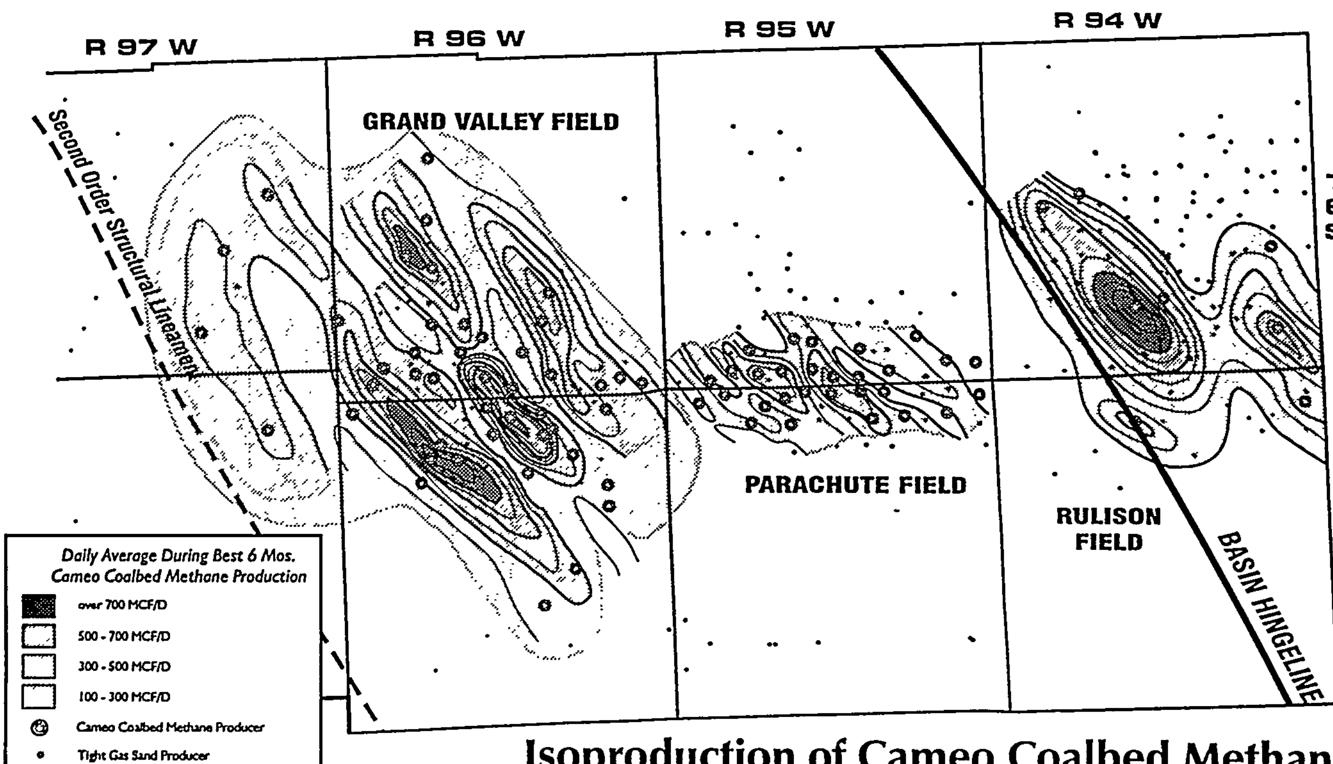


FIGURE 6

RELATIONSHIP BETWEEN STRUCTURE AND PRODUCTION

Grand Valley, Parachute and Rulison Fields, Piceance Basin





Isoproduction of Cameo Coalbed Methane