National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
White Sands Test Facility
P.O. Box 20
Las Cruces, NM 88004-0020

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DEC 17 2019

December 12, 2019

Reply to Attn of: RE-19-184

Mr. John Kieling
New Mexico Environmental Department
Hazardous Waste Bureau
2905 Rodeo Park Drive East, Building 1
Santa Fe, NM 87505

Subject: Response to Approval with Modifications for Site-wide Geophysical Survey Investigation Work Plan

NASA submitted the *Site-wide Geophysical Survey Investigation Work Plan* to the NMED Hazardous Waste Bureau on April 30, 2019. The NMED HWB approved the report with modifications on October 8, 2019. NASA is voluntarily proposing this work; it is not required by the Permit and has not been requested by NMED. In addition, this project is intended to address the entire site, and is not targeted to any specific area. The geophysics investigation will be non-intrusive; no drilling will be performed, and no groundwater or soil samples will be collected for analysis.

This submittal provides a cross-reference table as where the modifications to the Addendum are addressed as Enclosure 1, printed replacement pages as Enclosure 2, and electronic copies of the revised Addendum, redline-strikeout of the revised Addendum, and cross-reference table on CD-ROM as Enclosure 3.

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

If you have any questions or comments concerning this submittal, please contact Mike Zigmond of my staff at 575-524-5484.

Timothy J. Davis
Chief, Environmental Office

Enclosures

cc:
Mr. Gabriel Acevedo
Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Drive East, Building 1
Santa Fe, NM 87505

National Aeronautics and Space Administration

Site-wide Geophysical Survey Investigation Work Plan

April 2019

Updated December 2019

NM8800019434

NASA Johnson Space Center White Sands Test Facility

Site-wide Geophysical Survey Investigation Work Plan

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Timothy J. Davis
Chief, NASA Environmental Office

12/12/19
Date

National Aeronautics and Space Administration

Johnson Space Center
White Sands Test Facility
12600 NASA Road
Las Cruces, NM 88012
www.nasa.gov/centers/wstf

www.nasa.gov

Executive Summary

This IWP (investigation work plan) describes the approach for an iterative site-wide geophysical survey that will be performed to improve the conceptual bedrock model for WSTF (White Sands Test Facility), specifically with regard to site-wide lithologies, bedrock elevations, and the location and attitude of primary bedrock structures. The first step, and foundation of the project, is an airborne magnetic-gravity bedrock survey to be performed across the western half of WSTF. The study area is bounded on the east by the foothills of the SAM (San Andres Mountains) and on the west, north, and south by the WSTF site boundary. The investigation will also include the reprocessing and reinterpretation of select historical geophysical data, and a limited passive seismic survey in the vicinity of the WSTF plume area over a portion of the WBFZ (Western Boundary Fault Zone). Based on the results of the initial investigation, other geophysical techniques may be subsequently applied to provide additional resolution of WSTF bedrock lithology and structure. These may include more extensive passive seismic surveys, ground-based refraction and/or reflection surveys, and borehole geophysics.

In July and August of 2018, NASA (National Aeronautics and Space Administration) invited seven independent geophysical contractors to review historical WSTF geophysical surveys. Following the data review and site visits, the contractors provided recommendations on technologies that could potentially improve the definition of the site bedrock map to support future source area investigations, well placements, groundwater modeling, and other related studies at WSTF. Proposed geophysical methods for this IWP focus on the site-wide airborne magnetic-gravity survey. The design strategy for the survey is based on recommendations from the seven geophysical contractors. The objective of the airborne magnetic-gravity survey is to effectively improve site-wide resolution of the bedrock formation contacts, alluvial thicknesses, and bedrock structural features. The WSTF Environmental Contractor will manage the geophysical survey, while data collection, processing, and interpretation will be completed by an off-site geophysical subcontractor. The technical details relative to design of the airborne magnetic-gravity bedrock survey will be finalized based on recommendations of the geophysical subcontractor that is selected during the competitive procurement process.

Additional geophysical elements that will be used to refine the lithological and structural interpretation of the site comprise reprocessing of historical geophysical data (utilizing working raw project files where available), and performing a limited passive seismic survey over a portion of the WBFZ. Historical reprocessing and borehole geophysics will be applied where feasible following the airborne magnetic-gravity survey to refine the bedrock profile in specific areas. Passive seismic evaluations may be considered for other specific investigation sites or on a site-wide basis.

This IWP is being proposed voluntarily by NASA, and is not directly associated with a specific SWMU (Solid Waste Management Unit) or source area. The performance of the work will not affect any of NASA's current investigation, monitoring, or remediation activities required by the Permit or associated documents. The survey will be non-intrusive; no drilling will be performed, and no soil or groundwater samples will be collected for analysis. Following award of a contract for the airborne magnetic-gravity component of the geophysical survey to a qualified subcontractor, a study performance window will be established based on the logistical schedule of WSTF and adjacent installations, subcontractor schedule, and desired timing of the field survey. NASA expects that completing the full site-wide geophysical survey will require one to two years, including the preparatory period for the airborne survey through performance of the supplemental geophysical methods. The project start date will be determined during procurement negotiations with the successful subcontractor. NASA will provide project updates to the

NMED (New Mexico Environment Department) in the monthly Environmental Activity Reports and quarterly Periodic Monitoring Reports.

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List of Figures

List of Acronyms

ags	Above ground surface
ft	Feet/foot
gpm	Gallon per minute
IR	Investigation Report
IWP	Investigation Work Plan
JDMB	Jornada del Muerto Basin
mi	Mile(s)
MPITS	Mid-plume Interception Treatment System
NASA	National Aeronautics and Space Administration
NDMA	N-nitrosodimethylamine
NMED	New Mexico Environment Department
SAM	San Andres Mountains
SECO	Subsurface Exploration Company
STGT	Second TDRSS Ground Terminal
SWMU	Solid Waste Management Unit
TDRSS	Tracking and Data Relay Satellite Station
WBFZ	Western Boundary Fault Zone
WSMR	White Sands Missile Range
WSTF	White Sands Test Facility

1.0 Introduction

NASA (National Aeronautics and Space Administration) WSTF (White Sands Test Facility) is located at 12600 NASA Road in central Doña Ana County, New Mexico. The site is approximately 18 mi (miles) northeast of Las Cruces, New Mexico and 65 mi north of El Paso, Texas (Figure 1.1). WSTF has supported testing of space flight equipment and materials since 1964 and continues to operate as a field installation of the NASA Johnson Space Center. The WSTF U.S. EPA (Environmental Protection Agency) Facility Identification Number is NM8800019434. Historical operations at WSTF have resulted in a groundwater plume requiring extensive investigation activities and associated corrective actions.

NASA operates two groundwater remediation systems to extract contaminated groundwater, remediate it using air stripping and ultraviolet photolysis, and inject treated groundwater into the aquifer. Delineation of the boundaries of the groundwater contaminant plume and interception of contaminated water depend on the proper placement of groundwater monitoring, extraction, and injection wells. In addition, accurate conceptualization of the groundwater contaminant plume and the effects of groundwater remediation efforts depend on valid hydrogeologic inputs to the site-wide conceptual and numerical groundwater models.

Establishing the best conceptual model of the subsurface geology at WSTF is critical for effectively planning investigations, locating monitoring and extraction wells, and supporting input information for the numerical groundwater model. This IWP (investigation work plan) describes the approach for an iterative site-wide geophysical survey that will be performed to improve the conceptual bedrock model for WSTF, specifically with regard to site-wide lithologies, bedrock elevations, and the location and attitude of primary bedrock structures. The current bedrock map for WSTF is based on interpretations of historical geophysical surveys from the late 1980s through 1990s, calibrated with geologic logs from the multiple site wells installed as a part of environmental investigation and remediation projects. In addition, there are several areas where drilling data are limited and interpretation of subsurface geology based on historical geophysical survey is speculative. In order to better define and delineate the subsurface geological units and produce an updated top-of-bedrock and structural map as part of the groundwater investigation and remediation effort, NASA plans to conduct a site-wide geophysical survey. The site-wide survey will include an airborne magnetic-gravity survey that utilizes the latest geophysical investigative tools, data collection methods, and data processing software. NASA also plans to reprocess and reinterpret select historical geophysical data and perform a limited passive seismic survey. Depending on the results of this effort, NASA may initiate a more extensive passive seismic survey or perform borehole geophysical surveys at existing wells to better define structures in bedrock in specific areas.

1.1 Approach

This IWP describes the approach for the planned site-wide airborne magnetic-gravity bedrock survey and the supplemental geophysical methods that may be performed to help refine the interpretation. The airborne magnetic-gravity bedrock survey area, shown in Figure 1.2, is bounded on the east by the foothills of the SAM (San Andres Mountains) and on the west, north, and south by the WSTF site boundary. Two "No Fly" zones have been designated at WSTF by two tenants (the Goddard Space Flight Center and the United States Air Force). These zones are identified on the figure, and comprise the areas surrounding the Tracking and Data Relay Satellite Station (TDRSS) to the south and Second TDRSS Ground Terminal (STGT) to the north.

In July and August of 2018, NASA invited seven independent geophysical contractors from across the United States (selected on the basis of expertise) to perform a review of historical WSTF geophysical surveys and provide recommendations for future geophysical evaluations. In general, the geophysical contractors did not express confidence in the original 1988 seismic reflection survey data interpreted by

Reynolds (1988), primarily due to the fact that interpretations were primarily focused on drilling data in lieu of the low resolution seismic data.

During site visits, NASA geologists and geophysical subcontractor representatives also reviewed the gravity data presented by Maciejewski (1996). Although the geophysical contractors believed the data were valid, they remained uncertain as to the accuracy of the interpretation, since it was largely based on the 1988 Reynolds survey. Experts agreed it would be a prudent step to perform a new survey utilizing modern techniques, compare gathered data to well data that has been compiled since 1988, and produce a revised site-wide bedrock lithology and structural map for the site. The work proposed in this IWP is based on the recommendations provided by the seven geophysical contractors.

1.2 Objectives and General Scope of Site-Wide Geophysical Survey

The primary objective of the site-wide geophysical survey is to use the airborne magnetic-gravity method to enhance NASA's conceptual model of the WSTF bedrock surface, specifically with regard to the definition of bedrock lithological contacts, alluvial thicknesses on top of bedrock, and the attitude of significant structural features. The WSTF Environmental Contractor will manage and supervise the geophysical survey. Data collection, processing, and interpretation will be performed by an off-site geophysical subcontractor. The final design of the geophysical survey is subject to revisions, per the recommendations of the geophysical subcontractor ultimately awarded the contract; however, in order to provide a uniform basis for each contractor to construct a cost proposal, the technical requirements outlined in Section 4.0 (Scope) are presented. The investigation will also include the reprocessing and reinterpretation of select historical geophysical data, and a limited passive seismic survey in the vicinity of the WSTF plume area over a portion of the WBFZ (Western Boundary Fault Zone). Additional geophysical techniques may be subsequently performed to provide more resolution of WSTF bedrock lithology and structure. These may include more extensive passive seismic surveys, ground-based refraction and/or reflection surveys, and borehole geophysics. Evaluation of the results of the investigation and interaction with NMED will be used to establish the utility of future geophysical surveys at WSTF.

1.3 Magnetic Survey Description

Local variations in the earth's magnetic field can occur due to either differences in the permanent magnetization of materials, or differences in magnetic susceptibility. The subsurface bedrock lithologies at WSTF are anticipated to differ to a sufficient degree that lithologic contacts along near-vertical geologic features (contacts/faults) may be interpretable from magnetic anomalies or gradients. The following materials and their magnetic properties are expected:

- **Alluvial/colluvial overburden:** no permanent magnetization, low magnetic susceptibility; essentially, the overburden should be transparent.
- **Limestone:** no permanent magnetization, very low magnetic susceptibility; limestone should also be transparent.
- **Andesite:** high permanent magnetization due to thermoremnant magnetization of iron minerals, high susceptibility due to iron minerals.
- **Rhyolite:** moderate permanent magnetization due to thermoremnant magnetization of iron sparse minerals, low susceptibility due to general lack of iron minerals.
- **Flow-banded Rhyolite:** possibly different (to some unknown degree) from other rhyolite.

These differences in magnetic properties have the potential to allow for site-wide mapping of geologic contacts beneath the overburden using an airborne magnetic survey.

1.4 Gravity Survey Description

Local variations in the earth's gravitational field can result from lateral changes in the density or thickness of surficial alluvial overburden on top of bedrock. The alluvial overburden at WSTF generally has porosities between 25 to 40%, while the bedrock has less than 5% primary porosity with secondary porosity along permeable faults and fractures. For similar mineral grain densities, there should be a large difference in bulk density between overburden and bedrock. Gravity variations should be dominated by overburden thickness, which should make the WBFZ, consisting of a series of subparallel half-graben faults with significant displacement of the bedrock to depth, readily detectable. If there is a difference in density between the andesite, rhyolite, and flow-banded rhyolite on the fractured bedrock pediment, the contacts may also be subtly apparent in the gravity survey results. Highly permeable fault zones should create linear gravity anomalies, which would also assist in WSTF conceptual model enhancement.

1.5 Regulatory Requirements

The WSTF site-wide geophysical survey is not part of a specific solid waste management unit investigation or remediation effort required by the NMED (New Mexico Environment Department). The proposed survey will be performed at the discretion and risk of NASA to enhance the understanding the subsurface bedrock lithology and structure of the site. However, since information and data reported for the site-wide geophysical survey investigation will be used to enhance the understanding of the geologic conceptual model at WSTF, it will be applicable to periodic groundwater monitoring and contamination remediation and investigations regulated under the WSTF Hazardous Waste Permit.

1.6 Other Considerations

Revisions to the site-wide geophysical survey design for the IWP may be implemented based on developing logistical factors at WSTF, suggestions from potential vendors, and potential costs of the project. Problems with logistical issues at WSTF such as flight path approvals, data acquisition frequencies, safety, or security may affect the scope or schedule of the survey.

NASA recognizes that there are no guarantees that the initial investigation will enhance the existing interpretation of WSTF subsurface bedrock lithology and structure. Based on the data processing and interpretation from the site-wide airborne magnetic-gravity survey, additional geophysical methods may be applied to collect higher resolution geophysical data.

2.0 Background

2.1 Current Subsurface Bedrock and Structural Interpretation

WSTF bedrock lithology and structural maps have been developed based largely on the interpretation provided on the site-wide, seismic reflection survey performed by Reynolds in 1988 (Figure 2.1). As monitoring and remediation well boreholes at WSTF were subsequently drilled and lithological and geophysical logging performed, updates were made to the interpretation based on the new data points available. An integrated geophysical interpretation performed by Maciejewski in 1996 as part of a master's thesis at the University of Texas El Paso refined bedrock elevations and some of the major site faulting using 90 widely-spaced gravity data points (Figure 2.2). The results of the thesis were summarized in Volume 2, Chapter 4 of NASA's draft site-wide RCRA Facility Investigation report (NASA, 1996).

2.2 Impact of Bedrock Lithology and Structure on the Placement of Groundwater Wells

Monitoring and remediation wells at WSTF are designed and placed with specific objectives in mind, which include proximity to perceived bedrock drainage areas, bedrock structures, and areas with potentially elevated groundwater contaminant concentrations. Factors influencing the ability to install monitoring and remediation wells successfully to meet various project objectives include the bedrock lithology, depth to bedrock, and characteristics of individual structures or structural zones.

In the WSTF Mid-plume Area (Figure 1.2), typical groundwater yields in wells screened in a fractured bedrock aquifer are less than 5 gallons per minute. Structural flow zones with enhanced groundwater flow have been an important exploration target. The MPITS (Mid-plume Infiltration Treatment System) was located in an area indicated by focused seismic reflection surveys (e.g., SECO [Subsurface Exploration Co.], 2001a) to be structurally complex. The MPITS incorporates extraction wells with relatively higher production rates than are typical for the area. Targets for additional extraction well locations may be generated from an enhanced bedrock lithology and structure map.

At the Plume Front (Figure 1.2), extraction wells have been completed in the alluvial aquifer; however, there are indications that flow of groundwater contaminants may be enhanced along a specific section of the WBFZ near the southwest margin of WSTF. Previous focused seismic reflection surveys have been performed (e.g., SECO, 2001b). Despite this, delineation of the WBFZ in this area remains uncertain, and a refinement with enhanced resolution of lithology and structure would be highly beneficial to support NASA's ongoing efforts to continually improve operational efficiency of the Plume Front Treatment System. An enhanced site bedrock and structural map would provide a critical resource relative to the definition of individual fault blocks within the WBFZ and optimization of groundwater extraction and contaminant mass removal. This could directly impact the contaminant plume remediation efforts by reducing the remediation timeframe and associated cost.

2.3 Impact of Bedrock Lithology and Structural Interpretation on the Site Groundwater Flow Model

Bedrock lithology and structural interpretations will support future efforts to characterize fractured bedrock and remediate contaminated groundwater through inclusion in the WSTF site groundwater flow model. The model assigns aquifer properties based on the hydrogeological characteristics (affected by lithology and structure) within each individual model cell in order to predict future contaminant plume migration and the effectiveness of the remediation systems. It is critical that inputs to the model be as accurate as possible in order to minimize assumptions and the compounding effect of interpretive error. An enhanced bedrock lithology and structural interpretation would directly impact the quality and defensibility of the groundwater flow model predictions.

3.0 Site Conditions

WSTF encompasses an area of approximately 60,500 acres along the western flank of the southern SAM (Figure 1.2). The area proposed for the airborne magnetic-gravity survey covers approximately 20 square mi that corresponds to the majority of the western half of the WSTF property. This area is inclusive of all the property between the northern and southern site boundaries and includes the western SAM foothills, pediment slope, and JDMB (Jornada del Muerto Basin) west to the western site boundary. Two "No Fly" zones at WSTF comprise the areas surrounding the TDRSS and STGT facilities to the south and north, respectively.

3.1 Surface Topography

The flight lines for the airborne survey are proposed at an approximate altitude of 300 ft (feet) ags (above ground surface) for the majority of the survey where topography is gently inclined at between 2 to 10 degrees along the WSTF alluvial-covered pediment slope and JDMB. The ground surface is vegetated by relatively sparse scrub and brush, is relatively flat, and should not pose any difficulty for the aircraft to maintain a relatively uniform elevation ags across the flight paths. The low undulating foothills and shallow arroyos east of the WSTF industrialized areas and adjacent to the SAM provide the most varied of the survey topography encountered.

3.2 Subsurface Geology

A significant amount of geological and geophysical investigation has been performed at WSTF over the last 30 years. All pertinent information currently on file (investigation reports, topographic and geologic maps, historical geophysical surveys, and well lithologic and geophysical logs) will be made available to the geophysical subcontractor in order to assist with planning, processing, and interpreting site-wide geophysical survey data generated during this study.

3.3 Weather

The weather at WSTF is characterized by abundant sunshine, low humidity, slight rainfall, and large day-to-night temperature variance. Spring (March and April) is the driest time of the year with mild temperatures and dust storms caused by sustained winds. Summers (May through September) are characterized by clear hot days, progressing to warm cloudy weather with seasonal monsoon rains in July through September. Fall (October through November) is characterized by warm sunny days and cool nights with mild winds. Winters (November through February) are mild with clear sunny days and cold clear nights. The WSTF Environmental Contractor will coordinate with the subcontractor and surrounding entities: White Sands Missile Range; WSTF, the United States Air Force; Federal Aviation Administration; Las Cruces International Airport and any other local regulatory agencies to schedule the flights in conjunction with the weather and preference of the geophysical subcontractor accordingly.

4.0 Scope of Site-wide Geophysical Survey Activities

4.1 Airborne Magnetic-Gravity Survey Design

The gravity survey component accounts for the more bulky equipment requirements for the airborne survey, and is the primary factor requiring the use of a manned aircraft. The proposed airborne geophysical survey will be revised based on the expertise of the geophysical contractor selected during the competitive procurement process, with the intent of meeting project objectives at a lower cost or with enhanced results. The finalized design parameters for the survey will follow the detailed approach recommended by the geophysical subcontractor awarded the contract. In general, the planned airborne magnetic-gravity bedrock survey design parameters include the following elements.

- The survey will cover a rectangular area with dimensions of approximately 4 x 5 mi (Figure 1.2). This 20 square mi area covers the majority of the western half of WSTF, primarily across a gentle alluvial-covered pediment slope on the west side of the SAM into flat alluvial-covered terrain of the JDMB.
- Survey lines are anticipated to be positioned along east-west transects parallel to the long axis of the survey area, and oblique to the primary northwest-trending structures in the area characteristic of basin-range faulting (for example the WBFZ). The final orientation of the survey lines will be selected and justified by the geophysical contractor.

- The anticipated survey line spacing along east-west transects is approximately 200 ft across the entire area, representing up to 400 line mi of airborne data collection.
- Control survey lines are anticipated to be positioned perpendicular to survey lines in a north-south direction; because many geological features are in the east-west direction (for example Laramide structures that may extend into the northeastern corner of the survey area from Bear Canyon within the SAM). The final orientation of the control survey lines will be selected and justified by the geophysical subcontractor.
- The north-south transects may be arranged with a line spacing of approximately 200 ft. This data collection effort, representing up to an additional 400 line mi will provide grid data to establish more defensible 3-D bedrock and structural maps.
- The optimum altitude for successful data acquisition ranges between 265 and 400 ft ags. The elevation of the airborne flight lines are anticipated to be approximately 300 ft ags where feasible based on all available safety and security protocols.
- The sample acquisition frequency along each airborne survey line will be approximately 20 to 30 ft, or otherwise as suggested and justified by the geophysical subcontractor.

4.2 Airborne Magnetic-Gravity Survey Responsibilities

The geophysical subcontractor will be responsible for the following.

- Coordination of clearances required within restricted airspace, including White Sands Missile Range, NASA-WSTF, the United States Air Force, Federal Aviation Administration, Las Cruces International Airport and any other local regulatory agencies, and filing of the required flight plans.
- Provision of the field airborne magnetic-gravity survey equipment and instrumentation required to record the required geophysical data.
- Provision of qualified personnel necessary to prepare the instrumentation, perform the airborne survey, and collect the required geophysical survey data.
- Provision of the equipment and personnel required to download, process and interpret the data collected during the airborne survey.
- Submittal of a final airborne magnetic-gravity survey report with a summary of survey design, a description of the geophysical methods employed, data collection details, survey results, interpretation of the geophysical data generated, and further recommendations. A comprehensive bedrock map, with cross-sections along selected flight lines (where feasible), will also be included.

NASA and the WSTF Environmental Contractor will be responsible for the following.

- Obtain approval for the contractor aircraft to fly over WSTF and the adjacent tenant facilities.
- Provision of preparatory geological investigation reports, site historical geophysical data, geologic maps, and existing well logs to the geophysical contractor for the purposes of calibrating the geophysical survey.
- Provision of qualified field survey supervision for the duration of the field project.
- Provision of WSTF Environmental Contractor geological staff familiar with site geophysics to support the preparation and evaluation of field airborne magnetic-gravity survey data.

4.3 Airborne Magnetic-Gravity Survey Methods

The following procedures are anticipated when collecting the airborne magnetic-gravity measurements.

- Record first real time measurements from geophysical instrumentation mounted in the aircraft to produce magnetic-gravity data related to the ground surface below.
- Collect second real time measurements from navigation and mapping instruments associated with or carried by the aircraft.
- Compute a background response of each geophysical instrument using the second real time measurements to take account of its time varying altitude, and the time varying topography of the ground surface below.
- Adjust an operating or data processing condition of each geophysical instrument using the respective background response and the instrument's altitude to enhance the performance of that instrument.
- Adjust the geophysical data output for that instrument having reduced effects resulting from variations in altitude, attitude and topography.
- Subsequently process and interpret the geophysical data with the support of WSTF Environmental Contractor geological staff as necessary. Structural discontinuities such as faults, fractures and geological contacts may create lateral contrasts in density and magnetization of rocks, which generate gravity and magnetic signatures. Due to density and magnetic variations of the rocks, these structural discontinuities may be partly detected on the gravity image and partly on the magnetic image.
- In addition to creating the site-wide separate gravity and magnetic images, a combined image that integrates the two images using an image fusion technique will be generated if feasible for better interpretation of the acquired data.

5.0 Scope of Geophysical Reprocessing and Limited Passive Seismic Survey

The other elements of the geophysical investigation that will be applied to provide additional resolution to WSTF bedrock lithology and structure include the reprocessing and reinterpretation of select historical geophysical data and aerial photography, and a limited passive seismic survey in the vicinity of the WSTF plume area over a portion of the WBFZ. These geophysical elements will be applied to provide supplemental data to the airborne magnetic-gravity survey either to address deficiencies specific to individual investigation sites or to provide more optimal site-wide coverage. Other geophysical techniques may be subsequently performed to provide more resolution of WSTF bedrock lithology and structure. These may include more extensive passive seismic surveys, ground-based refraction and/or reflection surveys, and borehole geophysics.

Specific data are available from historical geophysical surveys performed and from borehole geophysics that can be used to address the "data gaps." Site-wide coverage can be provided by passive seismic surveys performed on the ground (also known as ambient noise surface wave tomography), which provides a cost-effective alternative to standard seismic reflection and refraction. A discussion of the methods to be used are provided below.

- Reprocessing and reinterpretation of historical geophysical data and aerial photography: This element will be applied where the detail for specific previously studied areas can potentially be improved, and added benefit could result from this evaluation. NASA will contract geophysical subcontractors in an attempt to reprocess and reinterpret seismic data from previous site-wide, Mid-plume, and/or Plume Front surveys, along with resistivity and refraction data from the 200 Area. The success of this action will depend on the availability of the raw historical data, the ability of subcontractors to perform reprocessing, and the associated cost. Several of the geophysical subcontractor representatives that visited WSTF expressed that it may be possible to extract additional detail from the historical survey results using modern data processing methods.

- Limited passive seismic survey: This element will be performed to investigate a specific area of the airborne survey. NASA plans to perform a limited passive survey over a portion of the WBFZ. The outcome of this survey will be used to decide whether to perform additional passive seismic survey work. Passive seismic nodes will be utilized in “rolling” grids, which will allow the data collection to extend progressively across the area of interest while efficiently managing the number of nodes. Passive seismic or ambient noise surface wave tomography uses natural low-frequency signals (0 to 10 hertz) to generate vertical profiles in the ground. The results would be used to supplement the alluvial depth isopach map and structural interpretations. Some of the geophysical contractors believed that the airborne magnetic-gravity survey may not require further refinement; however, the design of the limited passive seismic survey will be based on the site-wide results of the airborne survey.
- Other geophysical techniques – more extensive passive seismic surveys, ground-based refraction and/or reflection surveys, and borehole geophysics: These additional techniques will be evaluated following completion of the investigation. For the borehole geophysics, acoustic televiewer logging may be employed in new boreholes to verify fracturing indicated by the airborne and passive geophysical surveys. Synthetic seismographs may also be produced from the logging of new boreholes using density and sonic logs to calibrate any future seismic surveys. Existing cased holes cannot be used for these logging techniques.

6.0 Schedule

The schedule for conducting the site-wide geophysical survey, geophysical processing, and the limited passive seismic survey is tentative at this time. Following award of the contract for the airborne magnetic-gravity component of the geophysical survey to the subcontractor, all necessary permissions will be obtained to perform the fieldwork. Depending on the WSTF logistical schedule, subcontractor schedule, and desired timing of the field survey, a performance window will be established. Geophysical processing work and the limited passive seismic survey will be performed contemporaneously with the airborne geophysical survey to the best extent possible. The anticipated schedule below is dependent on the award date for the contract.

- Award of airborne magnetic-gravity survey contract purchase order – December 2019 (tentative).
- Preparatory period (3 months) – acquisition of permits and permissions, determination of airborne and geophysical equipment, and scheduling of the optimum performance window.
- Potential lag time between preparatory period and airborne field survey (3 months) – may be affected by timing of optimal conditions to perform field survey.
- Airborne field survey window (1 month) – to follow preparatory period and lag time (includes pre-flight protocol, flyovers, and post-flight protocol).
- Geophysical data reprocessing and performance of the limited passive seismic survey will be performed concurrently with the lag time between the preparatory period and the airborne field survey (6 months).
- Data evaluation and processing/report generation (3 months) – to follow airborne field survey, includes data evaluation, processing, interpretation, and subcontractor report preparation.

- Preparation of Site-wide Geophysical Survey IR (Investigation Report) for submittal to NMED (2 months).
- The anticipated duration for the site-wide geophysical survey investigation and submittal of the IR is 18 months. A Site-wide Geophysical Survey Investigation Report investigation report will be submitted to NMED by June 30, 2021.
- Other geophysical techniques – will be performed iteratively depending on the quality of the geophysical data generated for the site-wide geophysical survey and the magnitude of effort required (labor, materials, and cost). Other geophysical techniques may include more extensive passive seismic surveys, ground-based refraction and/or reflection surveys, and borehole geophysics.

7.0 References

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Figures

Figure 1.1 **WSTF Location Map**

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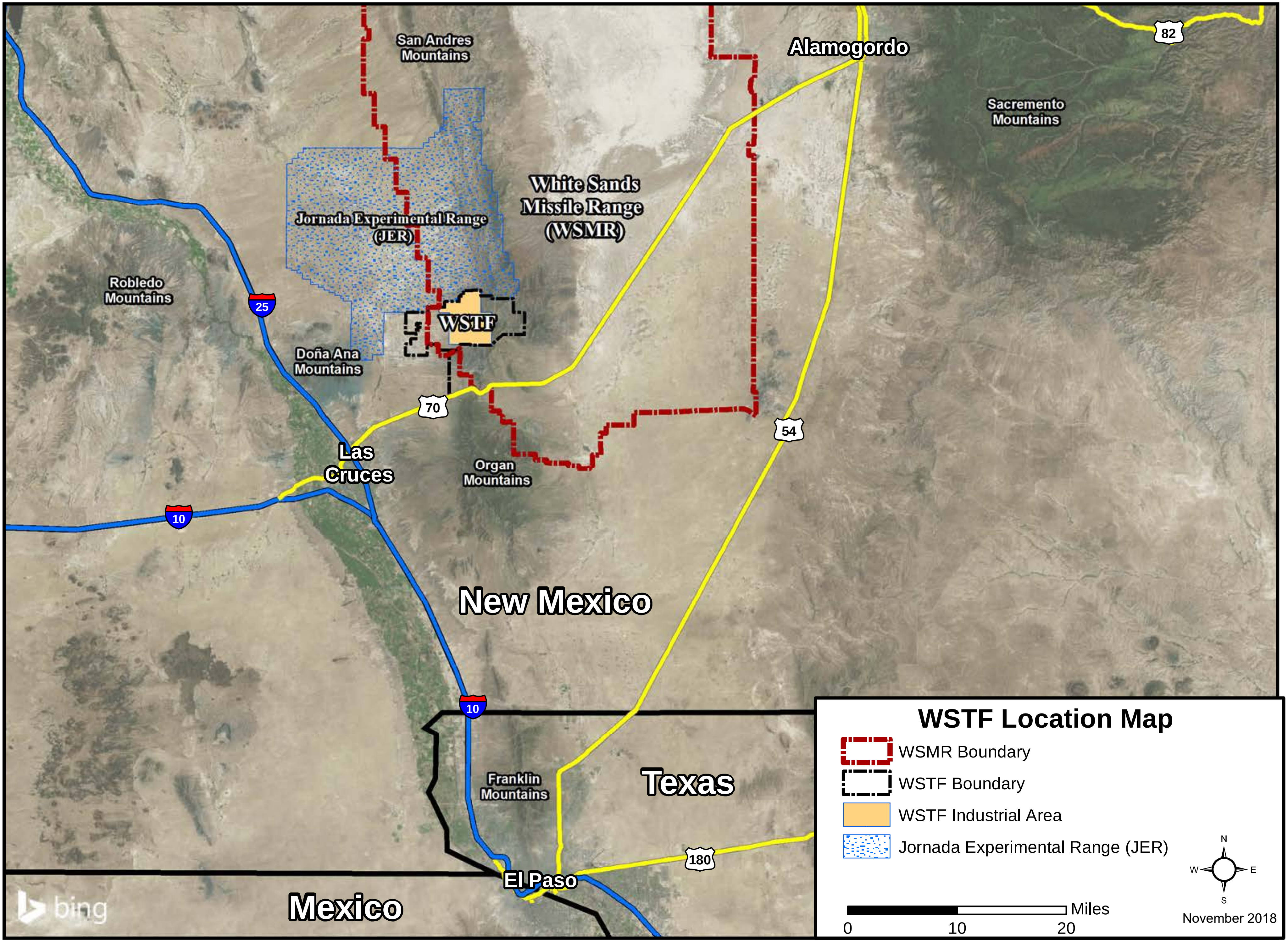
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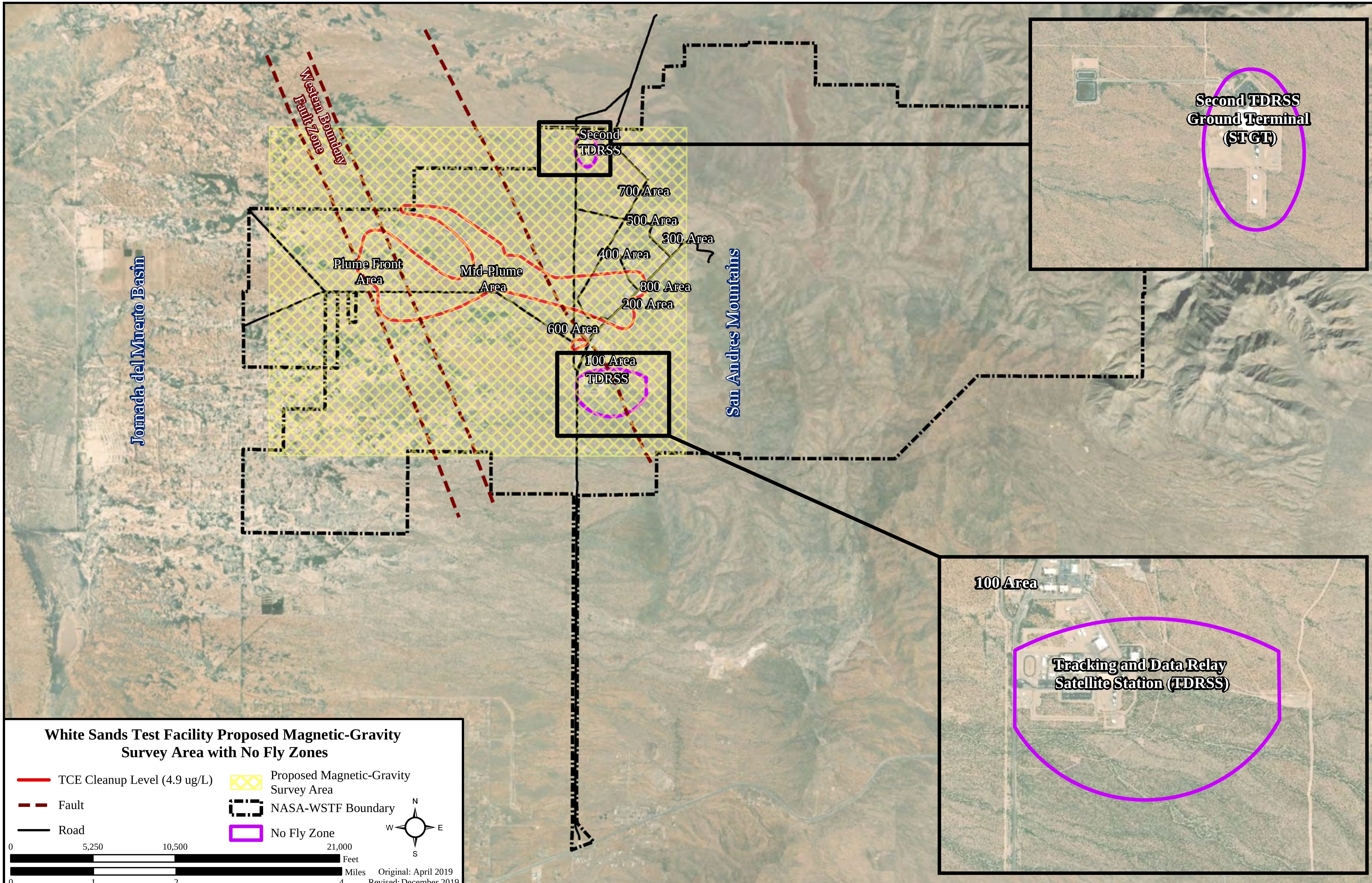
Robledo Mountains
25
WSTF
Doña Ana Mountains
70
54
Las Cruces
Organ Mountains
10
New Mexico
10
Franklin Mountains
Texas
180
El Paso
Mexico
bing
WSTF Location Map
WSMR Boundary
WSTF Boundary
WSTF Industrial Area
Jornada Experimental Range (JER)
N
W
E
S
Miles
0
10
20
November 2018

Figure 1.2 Proposed Site-wide Geophysical Survey Area

(SEE NEXT PAGE)



Second TDRSS
700 Area
500 Area
300 Area
400 Area
800 Area
200 Area
Plume Front Area
Mid-Plume Area
600 Area
100 Area
TDRSS
Western Boundary Fault Zone
Jornada del Muerto Basin
San Andres Mountains
Second TDRSS Ground Terminal (STGT)
100 Area
Tracking and Data Relay Satellite Station (TDRSS)
White Sands Test Facility Proposed Magnetic-Gravity Survey Area with No Fly Zones
TCE Cleanup Level (4.9 ug/L)
Fault
Road
Proposed Magnetic-Gravity Survey Area
NASA-WSTF Boundary
No Fly Zone
N
W
E
S
0
5,250
10,500
21,000
Feet
0
1
2
4
Miles
Original: April 2019
Revised: December 2019

Figure 2.1 WSTF Bedrock Structures – Reynolds Interpretation 1988

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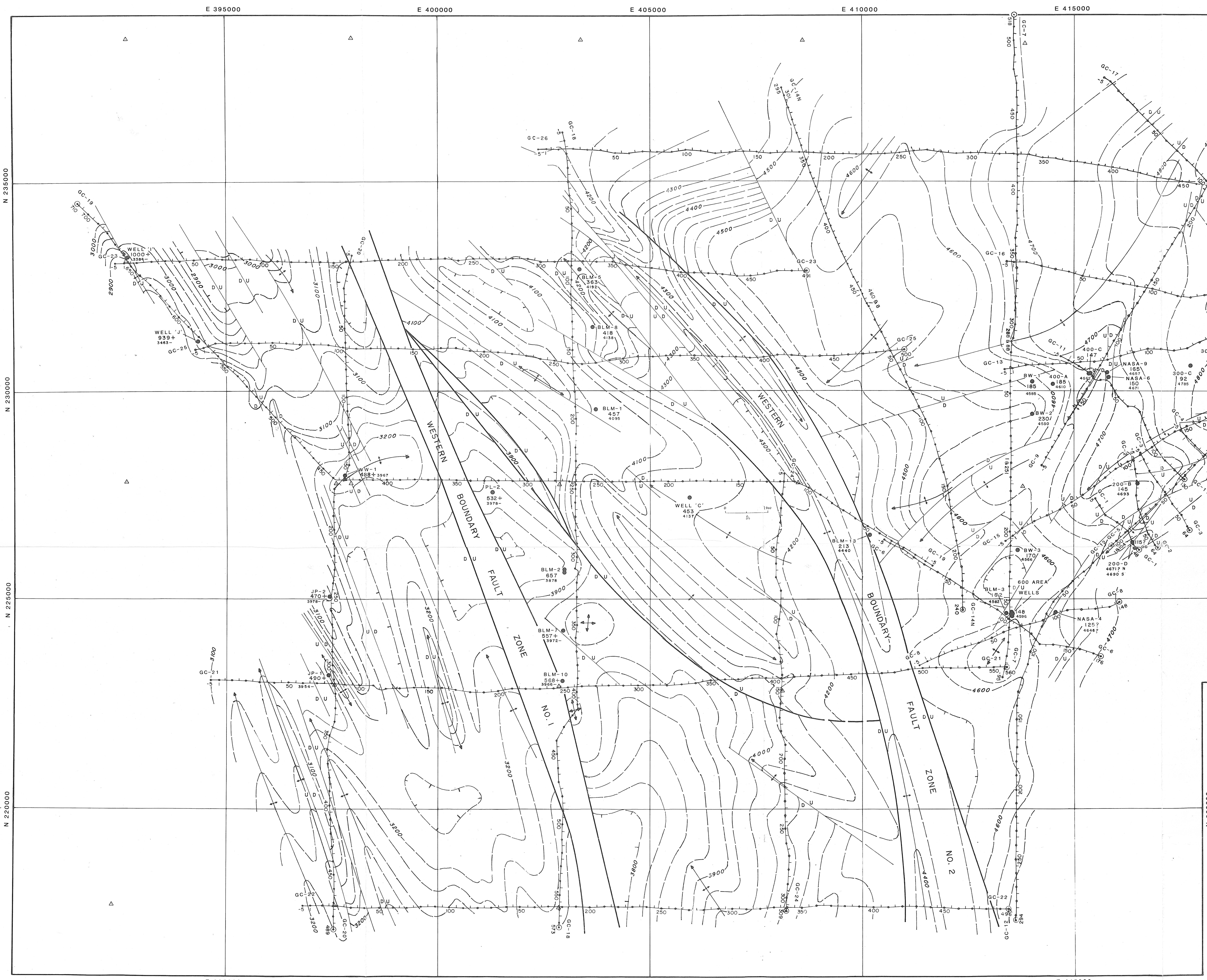


EXPLANATION

Seismic line location

BLM-5 363 4192 — Well location showing depth in feet to top of bedrock and elevation in feet on top of bedrock

U/D — Interpreted fault showing upthrown and downthrown sides (heavy lines mark major faults)

Interpreted anticline

Section corner

NASA

LYNDON B. JOHNSON FACILITY
Dona Ana County, New Mexico

REFLECTION SEISMIC SURVEY

STRUCTURE CONTOURS ON A SEISMIC HORIZON NEAR TOP OF BEDROCK (OR BASE SANTA FE GRP)

SCALE

0 500 1000 2000 3000 4000 FEET

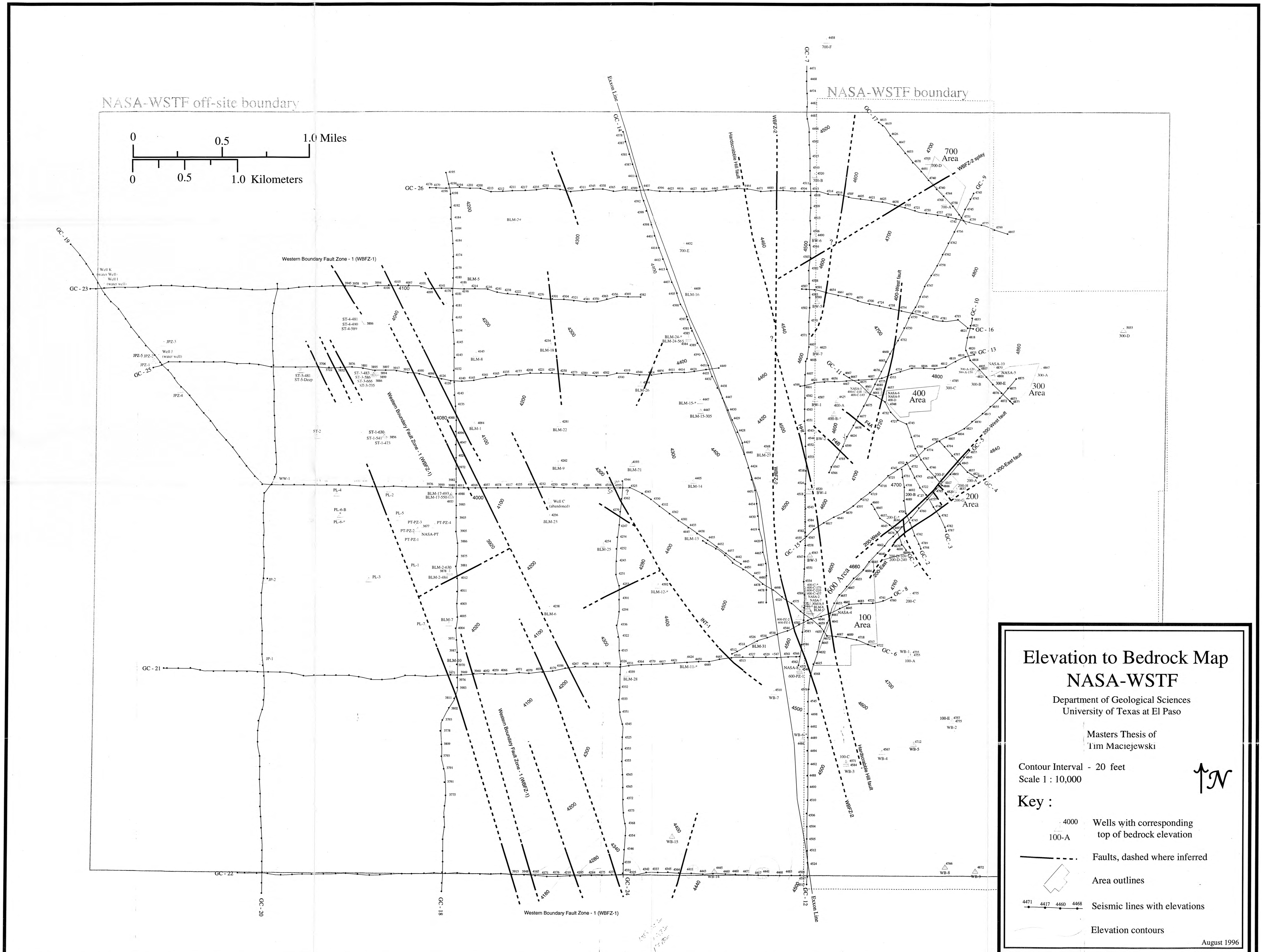
CONTOUR INTERVAL: 25 FEET
ELEVATIONS IN FEET ABOVE SEA LEVEL

JULY 26, 1989 — CHARLES B. REYNOLDS & ASSOC.

ENCLOSURE NO. 8

Figure 2.2 WSTF Elevation to Bedrock Map – Maciejewski Interpretation 1996

(SEE NEXT PAGE)



Enclosure No. 1

Comments for Approval with Modifications of the Geophysics Investigations Work Plan

NMED Comment Number	NMED Comments	NASA Revisions/Responses/Discussion
1. Section 1.2, Objectives and General Scope of Site-Wide Geophysical Survey, Page 2	**Permittee Statement:** "Additional geophysical techniques may be subsequently performed to provide more resolution of WSTF [White Sands Test Facility] bedrock lithology and structure. These may include more extensive passive seismic surveys, conventional refraction and/or reflection surveys and borehole geophysics" **NMED Comment:** The proposed geophysical survey investigation scope of work includes an airborne magnetic and gravity survey, a passive seismic survey in the vicinity of the WSTF plume front area, and reprocessing of select historical geophysical survey data, in lieu of conventional geophysical survey data collection methods. It is understood that the scope of work is based on the recommendations of prospective geophysical investigation contractors; however, the Permittee must ensure that geophysical methods used during the investigation yield data and information of sufficient quality to enhance the current subsurface geologic structural model at WSTF. This includes appropriate validation of collected data and any reprocessed data, which must be documented in the investigation report. If the results produced by the proposed primary investigation methods do not yield data and information that meet the Work Plan objectives, then the Permittee must use additional geophysical techniques. Revise the statement to indicate that additional geophysical techniques will be used to provide better resolution of WSTF bedrock lithology and structure, if the primary scope of work does not meet the objectives of the Work Plan. Revise the Work Plan accordingly, ensure that the revision is consistently made in all applicable sections of the Work Plan, and provide respective replacements pages.	NMED portrays the airborne magnetic-gravity and passive seismic surveys as "*in lieu of conventional geophysical survey data methods*". To the contrary, NASA is not suggesting that the proposed surveys are a substitute for any conventional geophysical method. The premise of the work plan is to employ a one-time airborne survey performed with the best available technology that is cost effective to meet the stated objective: improve the conceptual bedrock model for WSTF, specifically with regard site wide lithologies, bedrock elevations, and the location and attitude of primary bedrock structures over an approximate area of 20 square miles. In this matter, scale is important and the selected geophysical survey is appropriate to the scale. This would not be not the case for ground surveys. The airborne magnetic-gravity survey is a unique component of the Site-wide Geophysical Survey Investigation Work Plan. There are limited subcontractors who perform this type of geophysical survey and we have selected one of the leading providers through our competitive procurement process. The selected vendor offered two options, and we have selected the option with the tightest line traverse spacing and highest potential for effective processing of the data. Scale also speaks to the primary emphasis: valid hydrogeologic inputs to the conceptual site model. Bedrock structure can guide monitoring well and extraction well placement overall, and improvements to the conceptual ground water model can make for better model calibration and predictive capability. NASA's long-term emphasis is on plume remediation. The resolution of bedrock features at this scale is not expected to guide monitoring well placement at the SWMU scale. NASA does expect the airborne magnetic-gravity survey to minimally meet the objective of enhancing both (1) the understanding of subsurface bedrock lithology and structure, and (2) the site groundwater conceptual model. The measure of

NMED Comment Number	NMED Comments	NASA Revisions/Responses/Discussion
		improvement is expected to be in better relative bedrock relief and better delineation of the WBFZ, both validated through borehole data, relative to the current bedrock and structural interpretation in Section 2.1 of the work plan. NASA's extensive ground truth on site (bedrock tags with soil borings, boreholes, and previous seismic surveys) will be a key element in refining the processed airborne survey data. If these objectives are not minimally achieved, the same expertise that was brought to bear on the recommendation to perform the airborne survey, as well as on the recent recommendation not to perform electrical resistivity at the WSTF 600 Area Closure, will come to bear on whether other survey locations or methods can help. It is possible that the data itself will reveal strong limitations (contrast in rock properties, too much alluvium thickness) to any other types of survey. The chance of "better resolution of WSTF bedrock lithology and structure" may only pertain to very specific areas on site where bedrock structures and changing alluvial thicknesses are regional scale (WBFZ) or where existing ground truth on the ground is very limited to absent. For this reason the work plan uses the word "may" in the context of any further study. The best path forward after the airborne survey may not be additional geophysics. It might also be acceptance of the bedrock model as is. NASA added the final sentence to Section 1.2: "Evaluation of the results of the investigation and interaction with NMED will be used to establish the utility of future geophysical surveys at WSTF."
2. Section 1.5, Regulatory Requirements, Page 3	**Permittee Statement:** "The WSTF [White Sands Test Facility] site-wide geophysical survey is not part of a specific solid waste management unit investigation or remediation effort required by the NMED (New Mexico Environment	NASA concurs that the investigation results will be applicable to ongoing and future groundwater monitoring and contaminant remediation required by the WSTF Hazardous Waste Permit.

NMED Comment Number	NMED Comments	NASA Revisions/Responses/Discussion
	Department). The proposed survey will be performed at the discretion and risk of NASA [National Aeronautics and Space Administration] to enhance the understanding [of] the subsurface bedrock lithology and structure of the site." **NMED Comment:** An enhanced understanding of subsurface bedrock lithology and structure has implications related to the understanding of the groundwater aquifer at WSTF and is applicable to ongoing and future groundwater monitoring and contaminant remediation required by the WSTF Hazardous Waste Permit. Additionally, enhancement of the site-wide geologic conceptual model is applicable to understanding contaminant source zones and migration pathways at Solid Waste Management Units, Areas of Concern, and Closure activities regulated under the Facility Hazardous Waste Permit. NMED understands that the Permittee assumes any risk associated with the outcome of the final geophysical survey; however, following submittal of the investigation report and NMED review, NMED may direct the Permittee to complete additional investigation and/or provide additional information. Any further direction provided by NMED will be based on the investigation results and the quality of information and data collected and reported for the site-wide geophysical survey investigation. Revise the statement to also indicate that the information and data reported for the site-wide geophysical survey investigation will be used to enhance the understanding of the geologic conceptual model at WSTF and is applicable to continued periodic groundwater monitoring and contamination remediation and investigations regulated under the RCRA Permit. Revise the Work Plan accordingly and provide respective replacement pages.	As noted in the response to Comment 1, the resolution of bedrock features at the site-wide scale of the magnetic-gravity survey is not expected to guide monitoring well placement or reveal paths of migration at the SWMU scale. However, any new understanding of major subsurface features that underlie a given SWMU or its immediate area would certainly be utilized in work plans or interpretations of SWMU data. NASA added the final sentences to Section 1.5: "However, since information and data reported for the site-wide geophysical survey investigation will be used to enhance the understanding of the geologic conceptual model at WSTF, it will be applicable to periodic groundwater monitoring and contamination remediation and investigations regulated under the WSTF Hazardous Waste Permit."

Comments for Approval with Modifications of the Geophysics Investigations Work Plan

NMED Comment Number	NMED Comments	NASA Revisions/Responses/Discussion
3. Section 6.0, Schedule, Page 9	**Permittee Statement:** "The anticipated duration for site-wide geophysical survey investigation and submittal of the IR [Investigation Report] is 1 to 2 years." **NMED Comment:** Based on the Permittee's proposed anticipated investigation schedule, an investigation report documenting the site-wide geophysical survey must be submitted to NMED no later than June 30, 2021. If changes to the proposed project schedule have been made, update the Work Plan accordingly and provide an anticipated investigation report submittal due date and respective Work Plan replacement pages.	A Site-wide Geophysical Survey Investigation Report investigation report will be submitted to NMED by June 30, 2021. Section 6.0 of the Work Plan has been modified accordingly.
4. Section 7.0, References, Page 9	**NMED Comment**: For reference and retention in the WSTF administrative record, provide hardcopy and electronic copies of the following Work Plan reference documents with the response to NMED's modifications: a. Maciejewski, T.J. (1996). Integrated Geophysical Interpretation of Bedrock Geology, San Andreas Mountains, New Mexico. Unpublished master's thesis, University of Texas at El Paso, Texas. b. Reynolds, C.B. (1988). Final Report, Shallow Seismic Reflection Survey, NASA Lyndon B. Johnson Test Facility Area, Dona Ana County, New Mexico. Charles B. Reynolds & Associates, Consulting Geophysicists and Geologists. Albuquerque, NM. c. SECO. (2001). Final Report, Mid-Plume Area Seismic Reflection Study, NASA White Sands Test	Hardcopy and electronic copies of four references included in the Work Plan are provided. These copies provide the text, tables and figures for each reference.

NMED Comment Number	NMED Comments	NASA Revisions/Responses/Discussion
	Facility, Dona Ana County, New Mexico. Subsurface Exploration Company, Pasadena, CA.	

INTEGRATED GEOPHYSICAL INTERPRETATION
OF BEDROCK GEOLOGY, SAN ANDRES
MOUNTAINS, NEW MEXICO

BY

TIMOTHY J. MACIEJEWSKI

INTEGRATED GEOPHYSICAL INTERPRETATION OF BEDROCK GEOLOGY, SAN ANDRES MOUNTAINS, NEW MEXICO

by

Timothy J. Maciejewski, B.S.

THESIS

Presented to the Faculty of the Graduate School of

The University of Texas at El Paso

in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE

Department of Geological Sciences

UNIVERSITY OF TEXAS AT EL PASO

December, 1996

INTEGRATED GEOPHYSICAL INTERPRETATION OF BEDROCK GEOLOGY, SAN ANDRES MOUNTAINS, NEW MEXICO

TIMOTHY J. MACIEJEWSKI

Department of Geological Sciences

APPROVED:

Kate C. Miller

Dr. K. C. Miller, Chair

G R Keller

Dr. G. R. Keller

Dr. G. C. Ohlmacher

John W

Dr. J. Walton

Associate Vice President for Research
and Graduate Studies

ACKNOWLEDGEMENTS

The list of people who have helped me in one way or another with this thesis is long and distinguished. The primary help came from my committee chairman, Dr. Kate Miller, who thought of me when NASA approached her with the project, and whose knowledge of the ProMax system made the synthetic seismograms possible. Dr. Greg Ohlmacher assisted me with geologic interpretations. Mike Jacobs and Geoff Giles at the NASA–WSTF were very helpful in providing me with all of the data used in this project. Dr. Randy Keller provided me the financial means to get through my undergraduate and graduate degrees. I would also like to thank all of the nameless people who put up with me when I was first learning the UNIX system. Don Roberts and later Carlos Montana kept the UNIX system operating. Alex Duran read, laughed at, and corrected my first attempts at this thesis; and I want to thank Michael and Julie Whitelaw for just being friends.

A special thanks goes to my wife, Diana, for putting up with my coming home late, and working so that I could finish my degree.

This study was partially supported by the NASA–WSTF, New Mexico, and the NASA funded Pan American Center for Earth and Environmental Studies. I would also like to thank the Society of Exploration Geophysicists for giving me a scholarship which helped with tuition payments.

This thesis was submitted to committee on August 21, 1996.

ABSTRACT

During the 1960's and 70's, hazardous materials were released onto the ground surface at the National Aeronautics and Space Administration – White Sands Test Facility (NASA–WSTF) northeast of Las Cruces, New Mexico. Currently, NASA is seeking to identify and classify the nature and extent of the geologic units that influence migration of the hazardous constituents released at this facility. This thesis is part of this effort, and focuses on mapping the top of bedrock and any features contained within the bedrock and overlying alluvium which may influence groundwater flow in the vicinity of the facility.

Approximately 42 miles (67.6 km) of shallow seismic reflection data, well log information from over 80 wells, and a local gravity survey, were used to produce a new top of bedrock map. Several features on this map may affect groundwater flow. Remotely sensed data were used to examine the bedrock lithology and drainage patterns. There are three major faults crossing NNW across the facility, two of which combine to form the eastern boundary fault for the Jornada basin. There are two types of bedrock encountered through drilling on the NASA–WSTF, Tertiary andesite to the west and Paleozoic marine deposits to the east. Gravity modeling shows that the eastern basin boundary fault juxtaposes Paleozoic marine deposits against Tertiary volcanics. This fault has around 7900 ft (2400 m) of displacement. This same model also constrained the Western Boundary Fault Zone–1 to around 1700 ft (517 m) of down to the west displacement, producing a maximum alluvial thickness in the Jornada basin of 2600 ft (790 m).

Several minor faults and natural paleo–topographic features combine to produce two paleochannels trending westward away from the San Andres Mountains. Groundwater may be funnelled into these depressions by natural bedrock topography and faults, and channeled off to the west along with the contaminants.

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INTRODUCTION

Since the establishment of the National Aeronautic Space Administration White Sand Test Facility (NASA–WSTF) in 1964, there have been few studies of the local geology. Questions still remain about the location and displacement of faults within the Jornada basin. It is these faults that control the location and type of bedrock beneath the NASA–WSTF. The top of bedrock controls the flow direction of the groundwater and the type of bedrock could significantly effect the rate of groundwater flow through the bedrock.

Site–specific hydrologic processes are important at the NASA–WSTF as propellants and solvents have been either accidently or purposely disposed of on the surface of the ground and stored in leaking underground storage tanks (LUSTS) over a number of years. Ground surface contamination and dumping has caused a plume of contaminants to enter and be carried along with the groundwater. NASA is now required to characterize the hydrologic cycle through the NASA–WSTF, in order to model the contaminant plumes through time. This model is part of a report from NASA to the Environmental Protection Agency (EPA) as part of a Resource Conservation Recovery Act (RCRA) Facility Investigation/Corrective Measure Study (RFI/CMS). This becomes important when one considers that the third–most populous city in New Mexico, Las Cruces, is less then 18 miles (29.0 km) to the southwest of the NASA–WSTF (Figure 1). This thesis combines additional local data and regional geologic information in order to present a more detailed picture of geology which may affect the hydrologic flow under the site. A subset of these results were used by the NASA–WSTF in their report to the EPA early in 1996.

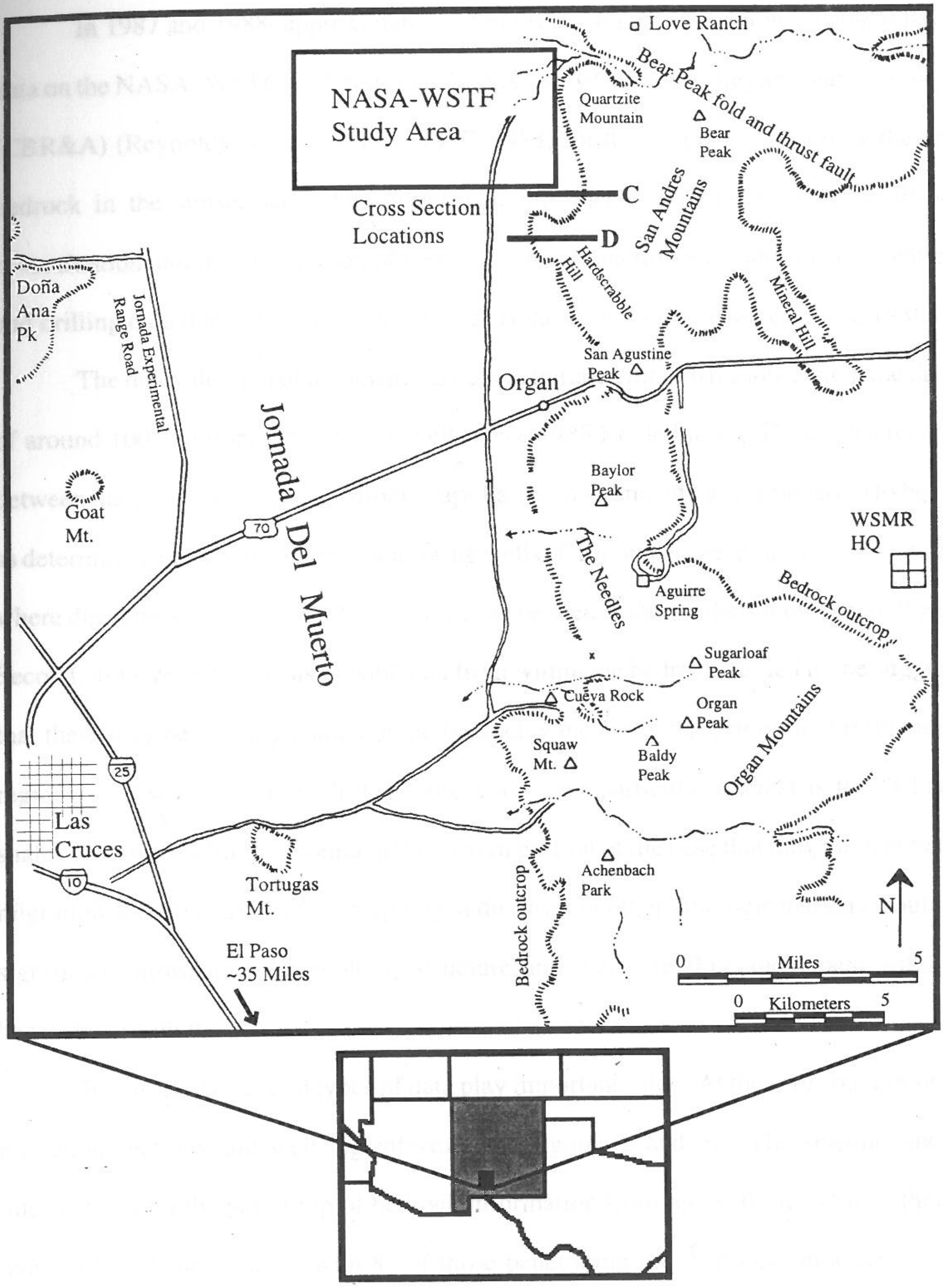


Figure 1. Index map showing the NASA White Sands Test Facility which is located 18 miles (29 km) northeast of Las Cruces, New Mexico on the western slopes of the southern San Andres Mountains (modified from Seager, 1991). The lines labeled C and D correspond to the locations of Seager's C and D cross sections.

In 1987 and 1988, approximately 42 miles (67.6 km) of shallow seismic reflection data on the NASA–WSTF were acquired for NASA by Charles B. Reynolds and Associates (CBR&A) (Reynolds and Associates, 1987, 1988) for the purpose of mapping the top of bedrock in the subsurface. The purpose of this thesis is to present the results of a re–evaluation and reinterpretation of these data in conjunction with additional geophysical and drilling data that have accumulated since acquisition of the seismic data in 1988.

The re–evaluation of the seismic data was initiated for two reasons. First, the drilling of around 100 additional monitoring wells since 1988 has led to significant discrepancies between the 1988 elevation to bedrock maps based on seismic data and elevation to bedrock as determined by the more recent monitoring wells. Differences are greatest in off–site areas where discrepancies of over 300 ft (94.1 m) can be seen in the southernmost part of the base. Second, more recent analysis of well data from within the bedrock has led to the suggestion that there may be lithologic units in the bedrock which may have important influences on regional and site–specific hydrologic processes. Of particular interest is the "Charlene shale", a Paleozoic horizon found in the eastern portion of the base that may prevent vertical migration of fluids. Subsurface mapping of this layer or other lithologic markers would give significant information on geologic structure and therefore fluid movement within the bedrock beneath the site.

In this thesis, several types of data play important roles. At the forefront are seismic reflection sections and well log information (Figures 2 and 3). The seismic lines are interpreted with the aid of top of bedrock information from the well logs. Since there are over 140 wells on the base with 88 of those penetrating into bedrock, an accurate top of bedrock map is insured. Seismic data, top of bedrock map, and well information are used to

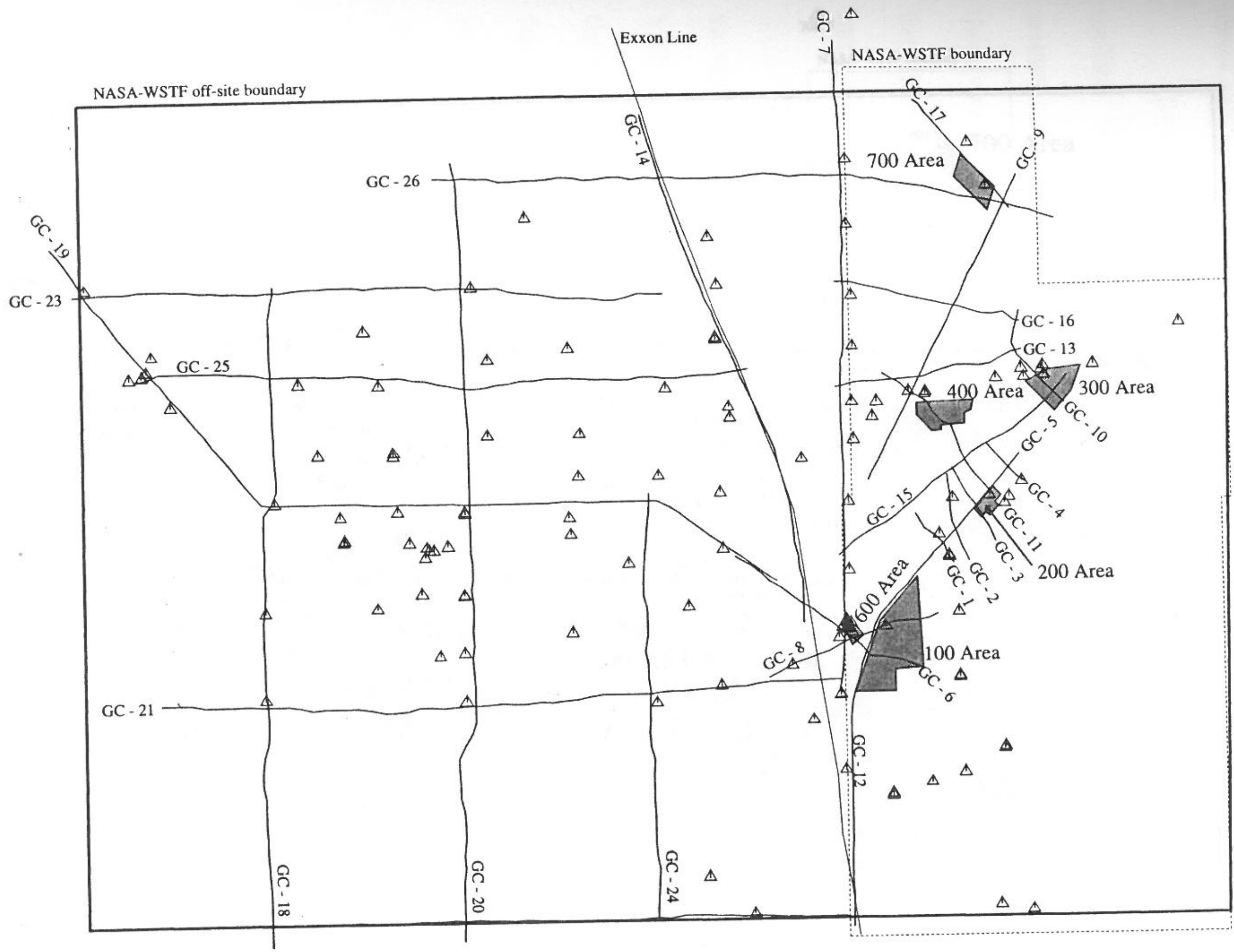


Figure 2. NASA-WSTF with location of Geoscience Consultants seismic lines (GC-1 through GC-26), contamination source areas (Area 100, 200, 300, 400, 600, and 700), and monitoring wells (△). The Exxon line location was obtained from Keller et al. (1986).

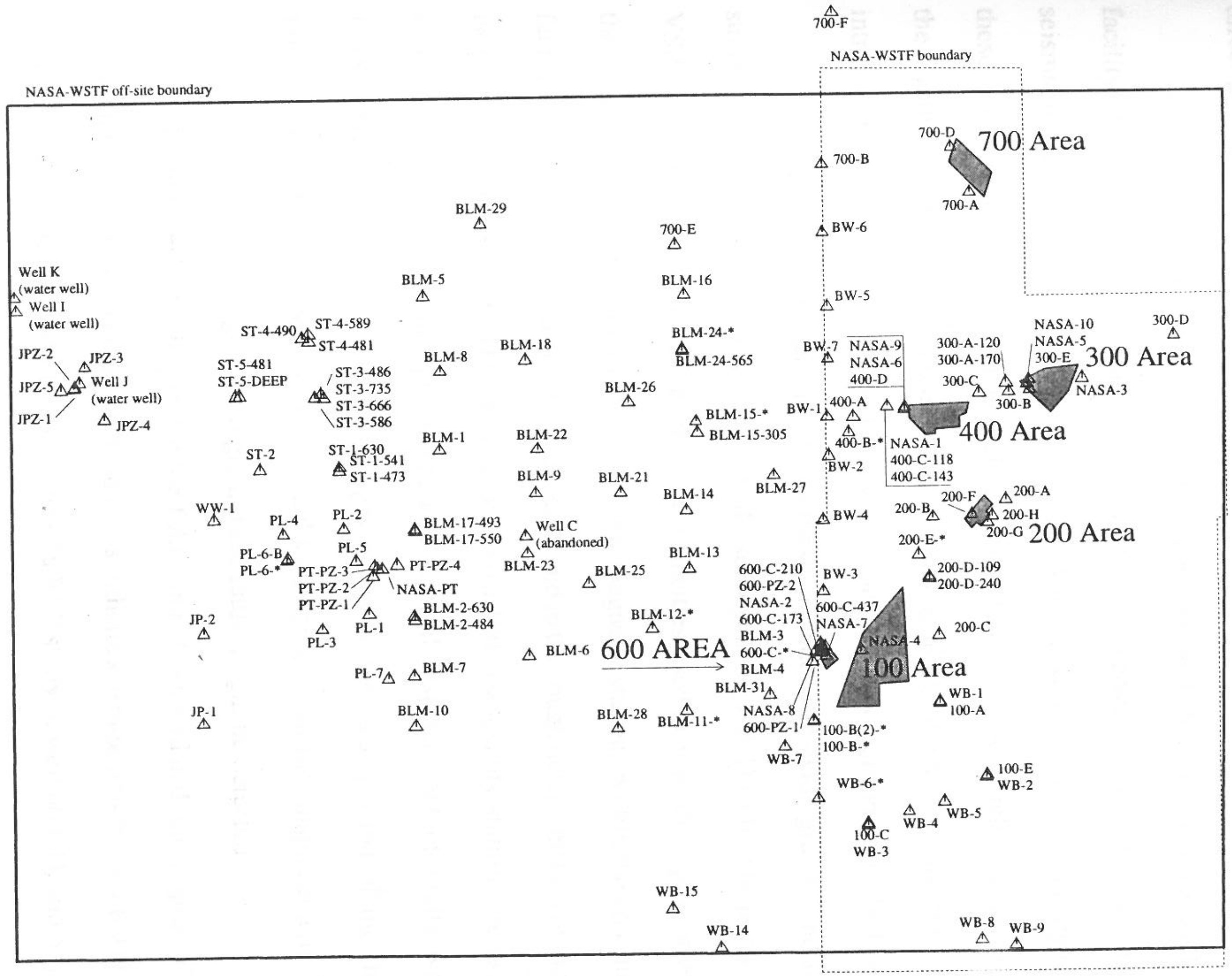


Figure 3. Water well and monitoring well locations throughout the NASA White Sands Test Facility region. There are over 140 wells, 88 of which penetrate some type of bedrock.

interpret the locations of faults, paleochannels, and any other structures which may inhibit or direct groundwater flow.

Synthetic seismograms were generated from well logs from three wells on the facility. This effort had two main goals. The first is to ensure an accurate tie between the seismic reflection sections and the top of bedrock in the wells. Sonic and density logs from these wells will be used to generate a reflection coefficient series, which in turn will generate the synthetic reflection sections. The second goal is to explore the possibility of intra–bedrock mapping on a shale layer within the Paleozoic portion of the bedrock.

New data collected as part of this thesis includes site–wide gravity and magnetic surveys, and a Vertical Seismic Profile (VSP) survey in the 600–D well. The purpose of the VSP was to provide a means of checking the velocities used in time–to–depth conversion of the seismic data. Collection of almost 85 new magnetic stations within the confines of the facility aid in the placement of very large faults and in the rough determination of the alluvial isopact and bedrock type. The addition of almost 100 new gravity stations are used in the determination of horizontal placement and vertical displacement of faults within the NASA–WSTF. Thematic Mapper images comprise the final portion of the thesis. A possibility exists that some of the buried faults may produce surface displacement. Through side looking radar imaging of the region, these faults might be detected.

In this thesis, I will present the following: 1) an updated and improved bedrock elevation map, 2) an alluvial isopach map, 3) synthetic seismograms based on well log data from from three wells in the site, 4) results of a VSP study in well 600–D, and 5) produce a complete Bouguer gravity map and magnetic intensity map based on surveys conducted during the re–evaluating period.

REGIONAL GEOLOGY

Geologic History

During latest Precambrian time, rifting and continental drift gave birth to the proto–continent of North America around 650 – 500 Ma. The rifted continental margins of interest are the Cordilleran in the west and Ouachita in the east. Throughout Early Paleozoic time both of the new continental edges accumulated thick shelf sediment. Continued passive subsidence along these margins may have allowed the margins to become connected around the southern end of a stable cratonic arch (Dickinson 1981). The southern portion of New Mexico was at the very southern tip of the this arch (Figure 4). Due to this stability of the arch and the passive tectonism during this time, the craton was eroded leaving a wide areal expanse having very little relief (Seager, 1981). Localized deposition history of central New Mexico can be seen in the stratigraphy (Figures 5 and 6).

In Late Cambrian to Early Devonian time, seas transgressed ENE across the southern tip of the arch depositing marine sediments unconformably upon the eroded Precambrian and Cambrian rocks of southern New Mexico (Seager, 1981). In the Late Paleozoic, southern New Mexico buckled under the stress produced by the Permo–Carboniferous Ouachita orogeny. Under the present day NASA–WSTF, this tectonism produced a downwarped area. At the beginning of the Permian, continued subsidence of this basin allowed shallow marine waters teeming with life to invade the region (Seager, 1981). The creatures produced mounds which were preserved in the sand and clay of the Panther Seep formation (Kottlowski, 1994).

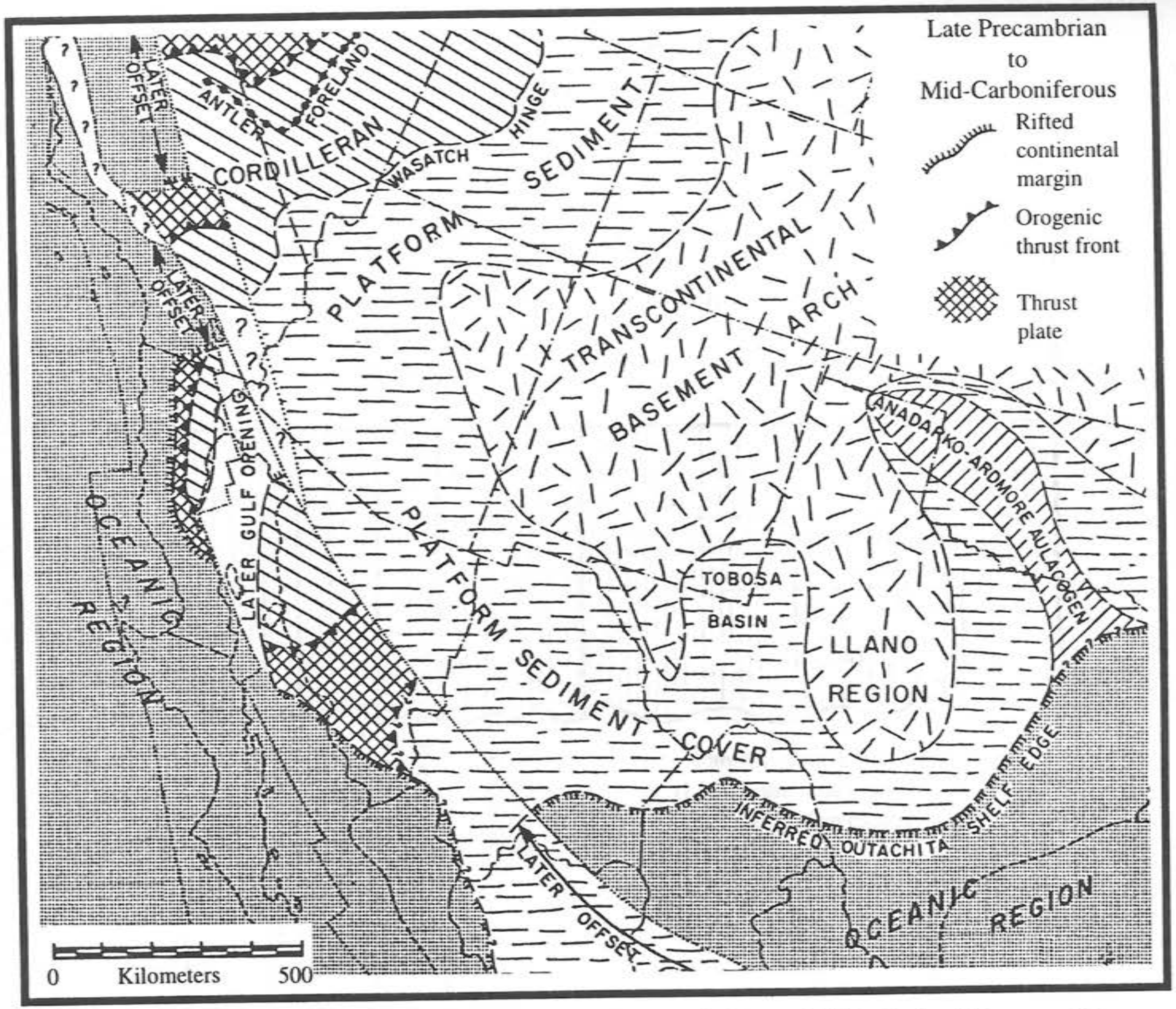


Figure 4. Paleotectonics of Southern North America during the Late Precambrian to Mid-Carboniferous. The southernmost portion of New Mexico is located on the stable basement arch, with thick platform sediment being deposited to the south. Modified from Dickinson (1981).

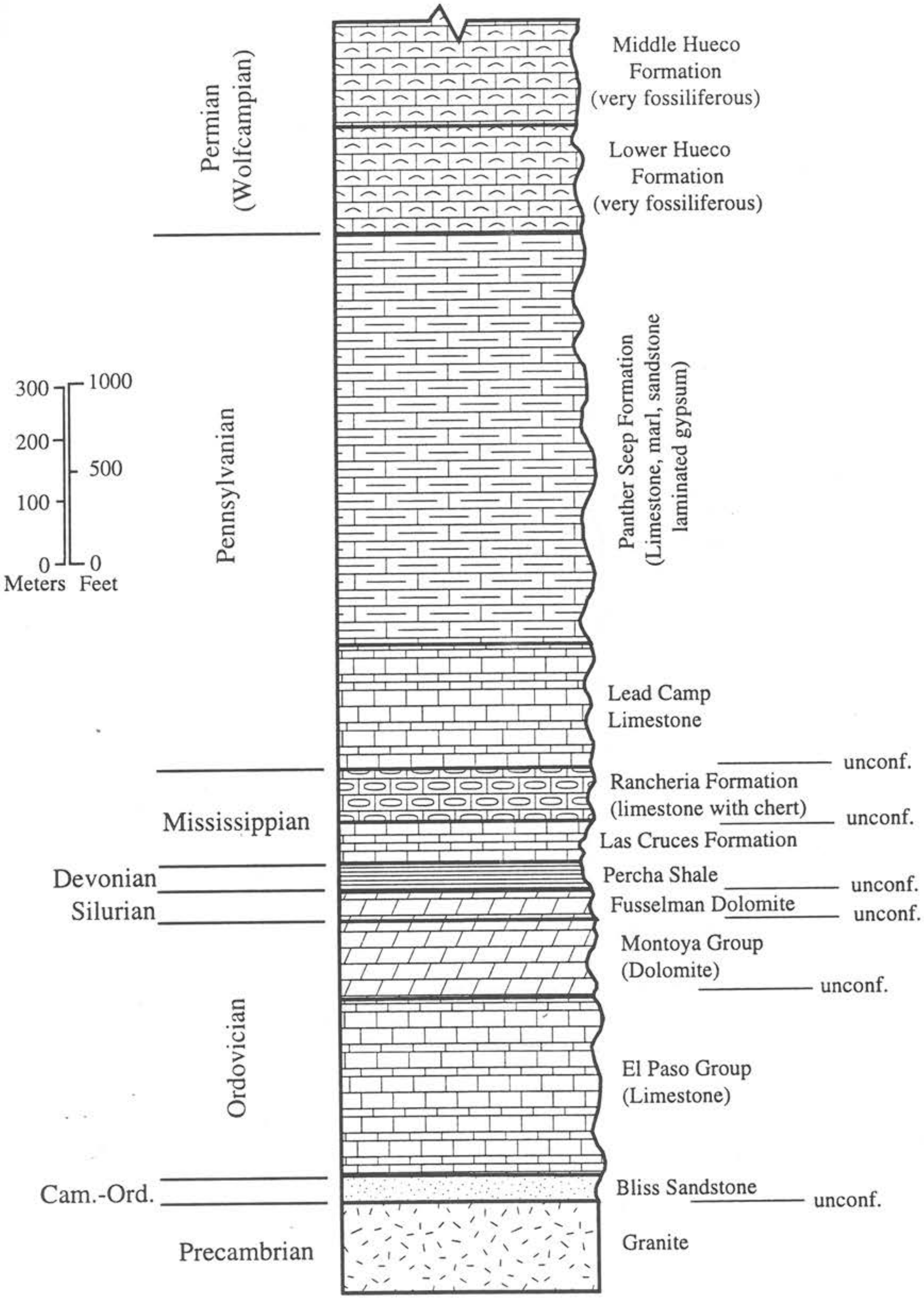


Figure 5. Stratigraphic column for the San Andres Mountains. Modified from Seager (1981).

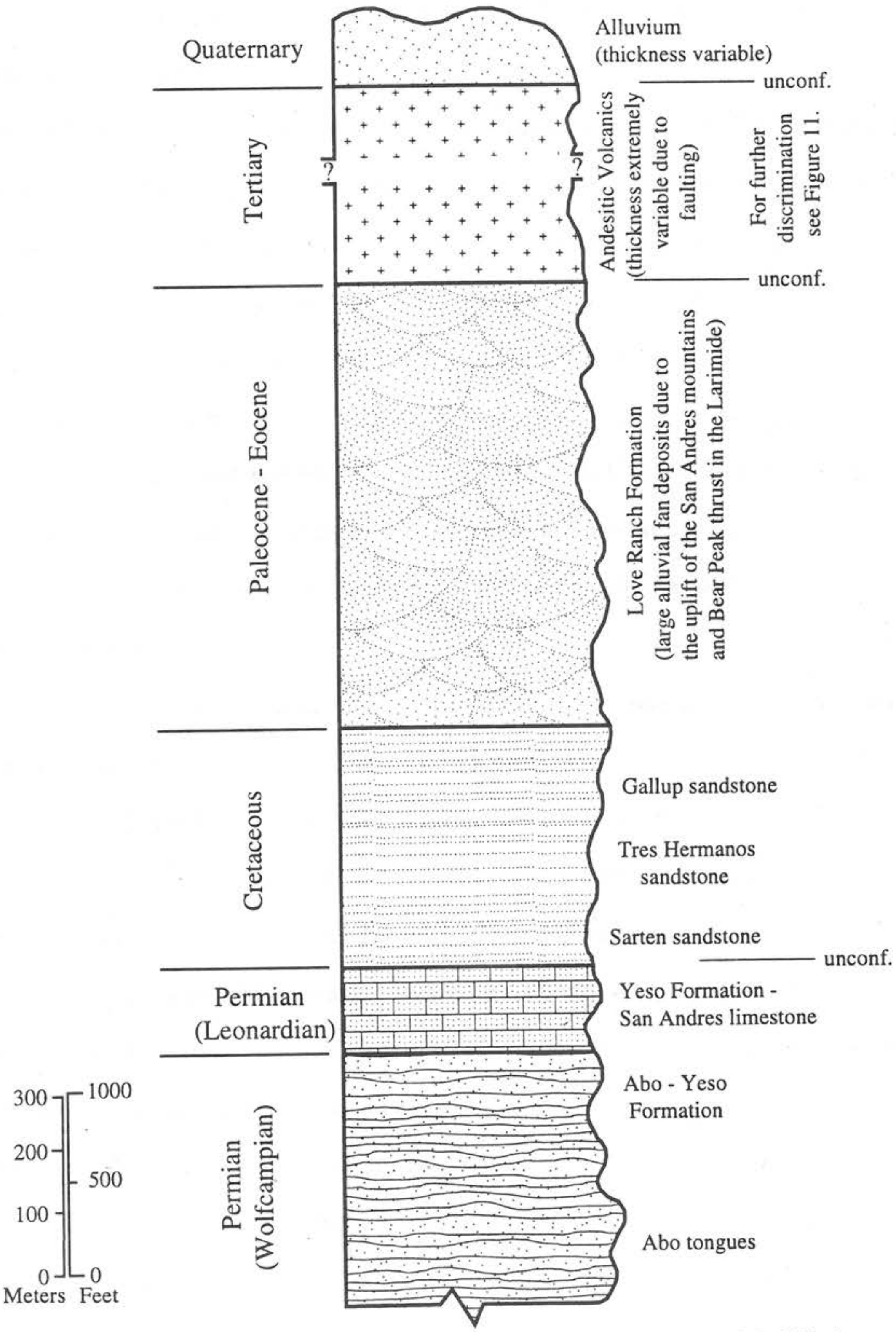


Figure 6. Stratigraphic column for the San Andres Mountains. Modified from Seager, 1981.

In the Early Permian, stresses from the Ouachita collision caused intraplate deformation and uplift of the Ancestral Rocky Mountains (Dickinson, 1981). This uplift of northern New Mexico, Colorado, and Utah produced a huge surplus of clastic sediment. This sediment draped across south central New Mexico forming the Abo Formation. The rising sea during this time competed with the increased sediment load resulting in a fluctuating shoreline which crossed the San Andres region several times (Seager, 1981).

At first, Tertiary and Jurassic sediments seemed curiously absent from the San Andres region. During these time periods, important changes were taking place in plate tectonics which reflected the breakup of Pangea. Along the Cordilleran margin, subduction of the sea floor brought arc magmatism and exotic terranes to the Pacific Coast. In the Ouachita region, rifting was opening the Gulf of Mexico and the modern Atlantic Ocean (Dickinson, 1981).

The abundance of sediment in the Late Cretaceous seas hints at further tectonic instability for the region (Seager, 1981). Due to shallowing of the subducting Farallon plate beneath the Cordilleran, contractional deformation swept across the region. The deformation associated with the Laramide orogeny lasted until Late Oligocene. Since the Laramide tectonic features of southern New Mexico are overlain by Rio Grande Rift (RGR) features and post–Laramide volcanism, mapping Laramide deformation is difficult. There are two main Laramide structures which influence the NASA–WSTF region. First is the large block uplift of the San Andres–Organ Mountains; the second is the large Bear Peak thrust in the southern San Andres Mountains. The movement of the thrust was not along one fault, but rather along a zone of west–northwest trending reverse faults dipping around 60° northwards (Seager et al., 1986). This thrust exhibits 5000 to 10,000 ft (1524 to 3000 m) of vertical displacement, juxtaposing Precambrian rock against the Hueco formation of Permian age (Seager, 1981). An oil industry seismic reflection profile crosses the WSTF (Keller et al., 1986; Adams et al., 1994). It crosses structural grain in a strike position relative to the Basin and Range structures, but in a dip position relative to Laramide thrusting. The profile shows flat lying Paleozoic strata overthrust by Precambrian rock at the Bear Peak thrust.

Great thicknesses of offloaded sediments from the recently uplifted Laramide mountains and Bear Peak thrust filled the Jornada Valley. More the 2000 ft (610 m) of boulder conglomerates and interbedded red sandstones, shales, and mudstones of the Love Ranch Formation overlie the older marine deposits with a pronounced erosional unconformity (Seager, 1981). Just to the south in the Organ Mountains, the conglomeratic red beds of the Love Ranch Formation are resting unconformably upon steeply dipping Pennsylvanian and Permian limestones (Kottlowski, 1994). These sediments represent a complex set of alluvial fan deposits recording the uplift of the adjacent mountain ranges.

Waning compressional stresses gave way to arc magmatism and prominent extensional tectonics in the Oligocene, due to the steepening of the subducting slab, beneath the west coast (Dickinson, 1981). The Organ volcanic center, which now outcrops as the Organ spires in the Organ Mountains, is the likely source of most of the volcanic rocks (andesite) in the region. The estimated thickness of volcanic debris around the Organ Mountains is thought to be around 2 miles (3.2 km) (Seager et al., 1986).

The last major tectonic event that deformed the region was the Rio Grande Rift in which tectonism began about 30 Ma and is presently continuing at a slow rate. The RGR consists of a series of well–defined, asymmetrical grabens extending from Colorado to

Chihuahua Mexico. In the NASA–WSTF region, it is expressed itself as a complex 61 mile (100 km) wide zone of normal faulting which formed several grabens (Seager and Morgan, 1979; Keller, et al., 1990). The RGR may have been a bi–product of an upwelling asthenosphere producing significant thinning of the crust. Regional seismic refraction profiling and gravity studies (Sinno et al., 1986; DeAngelo, 1988; Daggett et al., 1986) show that the crust is 28 – 30 km thick.

Quaternary tectonics produced minor faults that parallel the major basin boundary faults. These faults downdrop the top of the Tertiary volcanics about a kilometer down in the center of the basin. There are three main subdivisions of the Quaternary alluvium. The oldest is the basal alluvium, which is mostly alluvial fan deposits and pediment gravels (Camp Rice Formation) from the late Pliocene (Hawley, 1975). The intermediate unit is made of several generations of alluvial fans from the late Pleistocene. The youngest or modern unit is the unconsolidated arroyo–channel deposits and canyon fill, as well as the alluvial fans. These sediments are mostly Holocene in age, but may range up to 15,000 years old (Seager, 1981).

Geographical and Structural Settings

The NASA–WSTF (Figure 1) lies within the RGR physiographic province which has formed during Late Oligocene time in response to extensional tectonic forces (Seager, 1981). The NASA–WSTF (Figure 1) region is characterized by north–south trending fault–bounded mountain ranges and intermontane basins. The San Andres and Organ Mountains and the adjacent Jornada basin, in which the NASA–WSTF is located, are the local manifestation of these province wide features. In addition, Laramide thrusting and compressional tectonic features have been mapped adjacent to the northern portion of the study area within the Bear Peak fold and thrust belt. Deformation related to the Laramide compression and the RGR extension may also influence bedrock structure beneath the NASA–WSTF.

During the RGR, the east side of the San Andres Mountains are bounded by the Tularosa and Hueco basins which are RGR grabens. The west side of the mountain range experienced rift faulting to form the Jornada basin. Two faults in the NASA–WSTF region, the Hardscrabble Hill fault and WBFZ–2, comprise the majority of displacement on the eastern basin boundary fault for the Jornada basin. The Hardscrabble Hill fault juxtaposes extrusive Tertiary andesite next to Paleozoic marine deposits, while a third fault, WBFZ–1, downdrops the alluvium into the basin (Figure 7).

On two cross sections (Figure 1, 8) from Seager (1981), present the structural and stratigraphic framework for the region. Over 9 different periods of erosion and subsequent deposition affected the San Andres region. Seager mapped in the Hardscrabble Hill fault as having unknown displacement, and through gravity interpretation, placed the eastern basin boundary fault for the Jornada basin just west of Hardscrabble Hill. The total displacements on both the WBFZ–2 and Hardscrabble Hill faults remain uncertain.

Structurally, the NASA–WSTF region can be divided into three zones: the Jornada basin to the west, the pediment slope of the San Andres Mountains to the east, and a transition zone in the middle (Figure 7). The WBFZ–1 and eastern basin boundary fault form the boundaries between these regions. The pediment area consists of a thin veneer (0 to 200 ft (0 to 61 m)) of coalescing alluvial fan deposits overlying faulted bedrock. The alluvium in the transition zone is 350 – 750 ft (107–229 m) thick, and exceeds 2000 ft (610 m) west of the

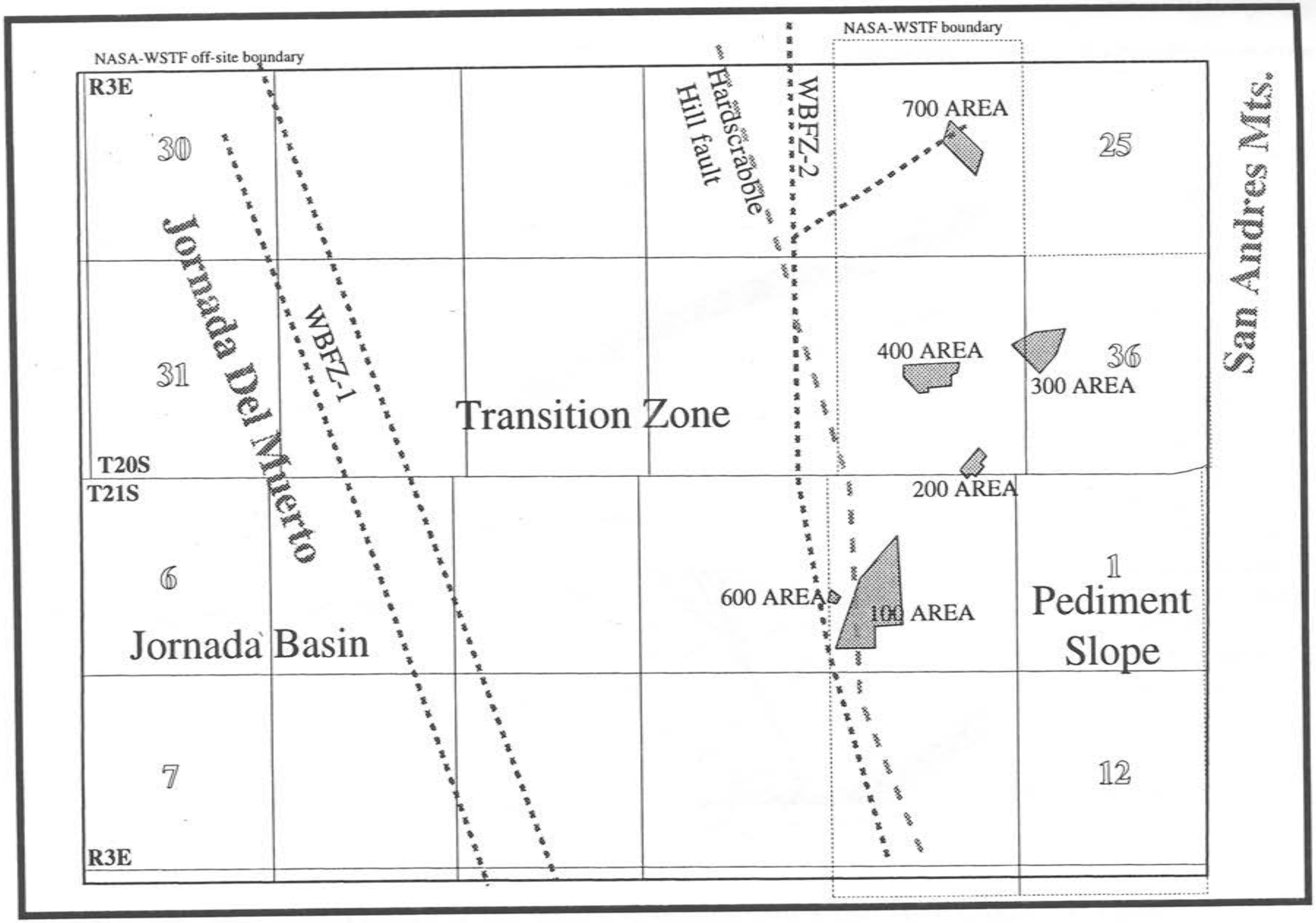


Figure 7. Regional structures at the NASA-WSTF study area. The site can be divided into three main regions: Pediment Slope, Transition Zone, and Jornada Basin.

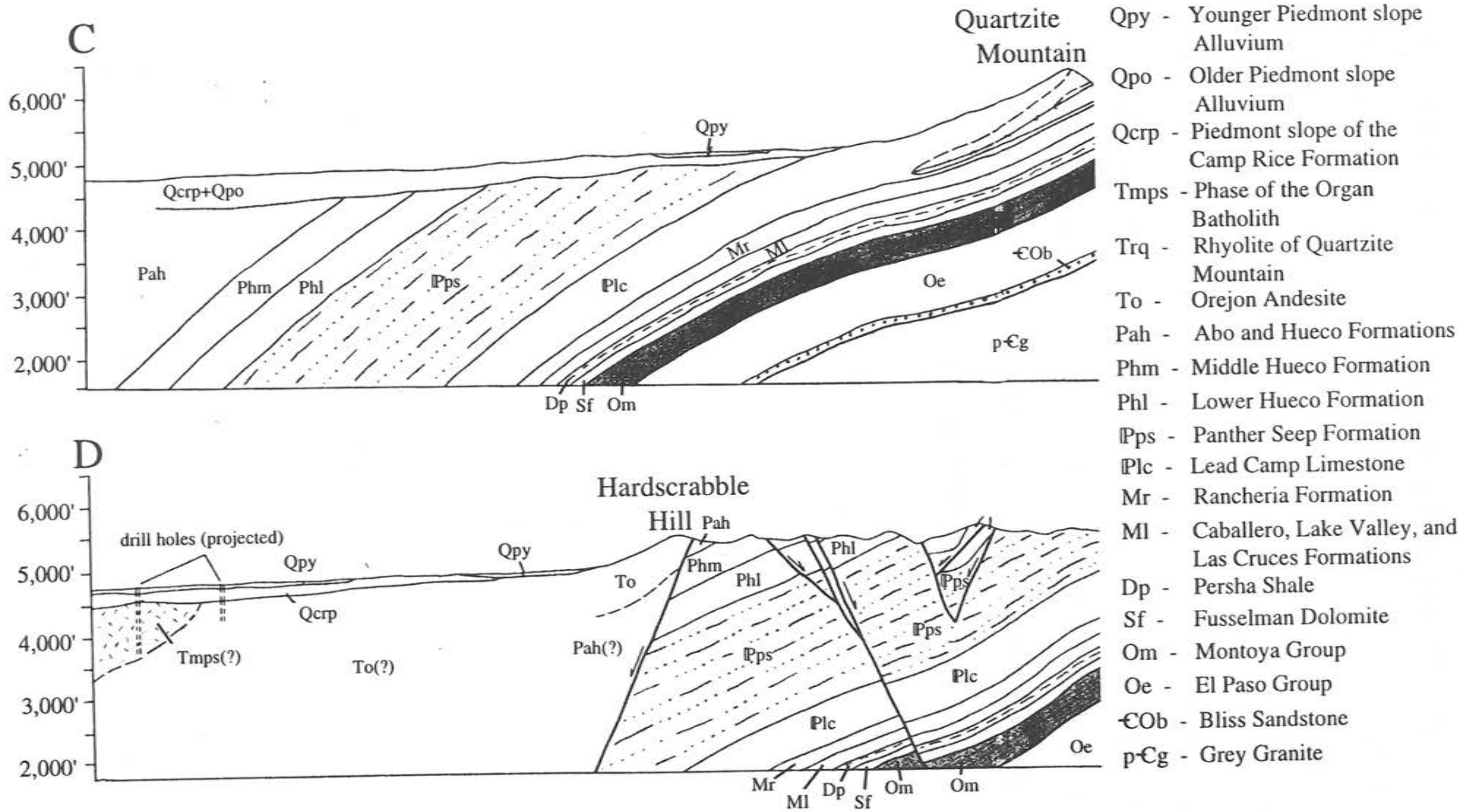


Figure 8. Cross sections of the Jornada basin and San Andres Mountains from Seager (1981), located of Figure 1. Displacement along the Hardscrabble Hill fault on the D cross section is unknown and trend direction is also unknown once it is covered by alluvium. The fault may pass through the C cross section, but is not recognized due to the alluvial cover.

WBFZ–1. In the vicinity of the Jornada basin, gravity studies (Daggett et al., 1986, Gilmer et al., 1986, and Decker et al., 1975) combined with P–wave delay studies (Harder et al., 1986) suggest that Quaternary basin fill in the Jornada basin may reach as much as 3,500 feet (1,067 m) in thickness. Cenozoic fill, which includes the pre–rift Love Ranch Formation and the Tertiary volcanics, may reach as much as 10,000 feet (3050 m) thick.

Bedrock units below the alluvium consist of Paleozoic limestones, sandstones, siltstones, and shales as well as Tertiary intrusive and extrusive volcanic rocks (Kottlowski, 1956; Kottlowski et al., 1994; Summers et al., 1968). Presently, only the eastern most portion of the NASA–WSTF has exposed bedrock (Figure 9).

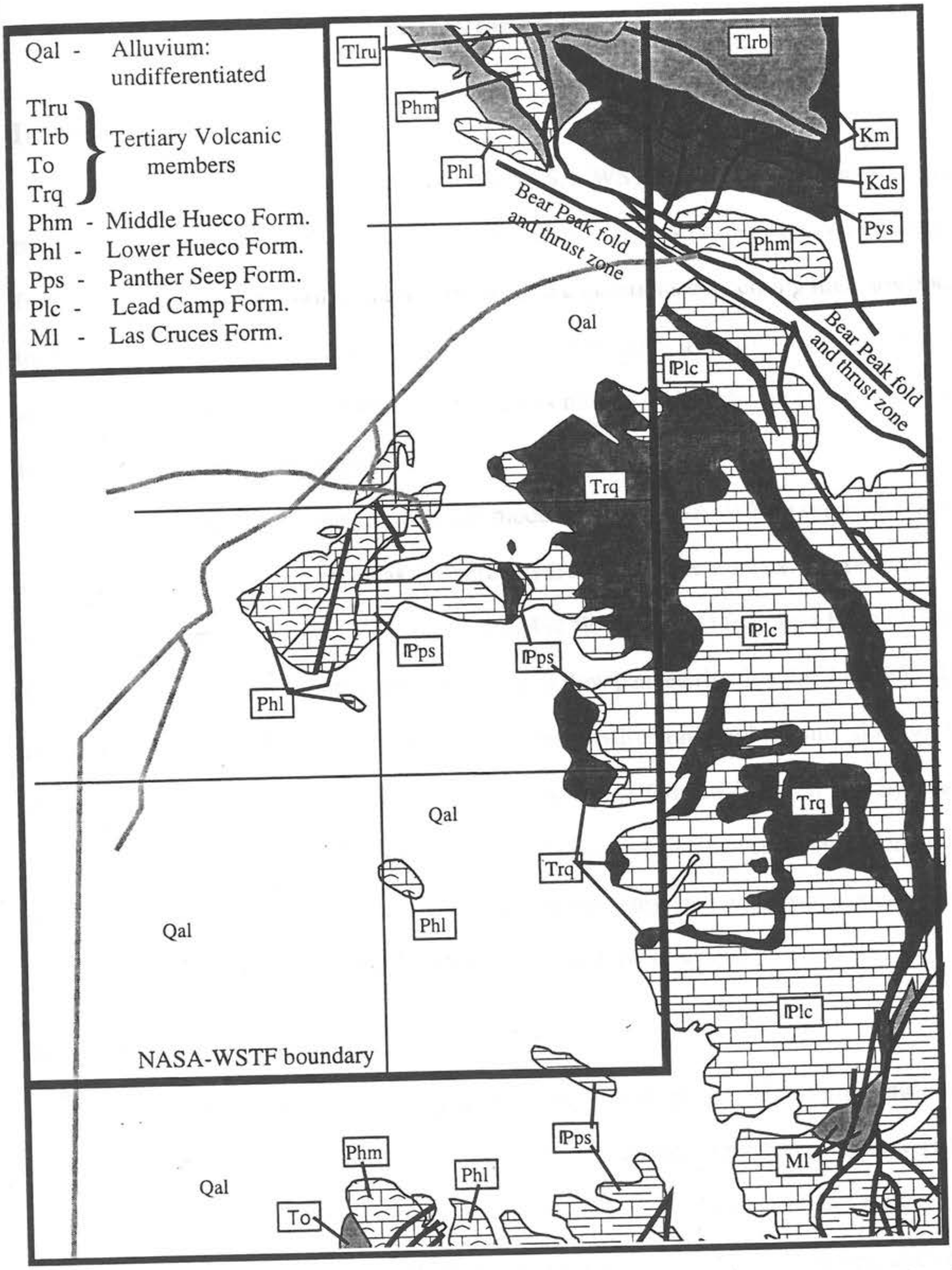


Figure 9. Bedrock outcrops in the eastern-most portion of the NASA-WSTF. Bedrock consists of both Paleozoic section and Tertiary volcanics. The Bear Peak thrust crosses over the NE corner of the facility. Modified from Seager, 1981.

HYDROLOGY

Introduction

Hydrology studies are underway at the NASA–WSTF because of contamination of the site. The natural groundwater movement is in the process of carrying contamination from the facility into the Jornada basin. Some of the questions concerning this movement include: where are the contaminants migrating? How does the difference between the alluvium and different types of bedrock affect this motion? How do the faults within the bedrock influence the fluid migration?

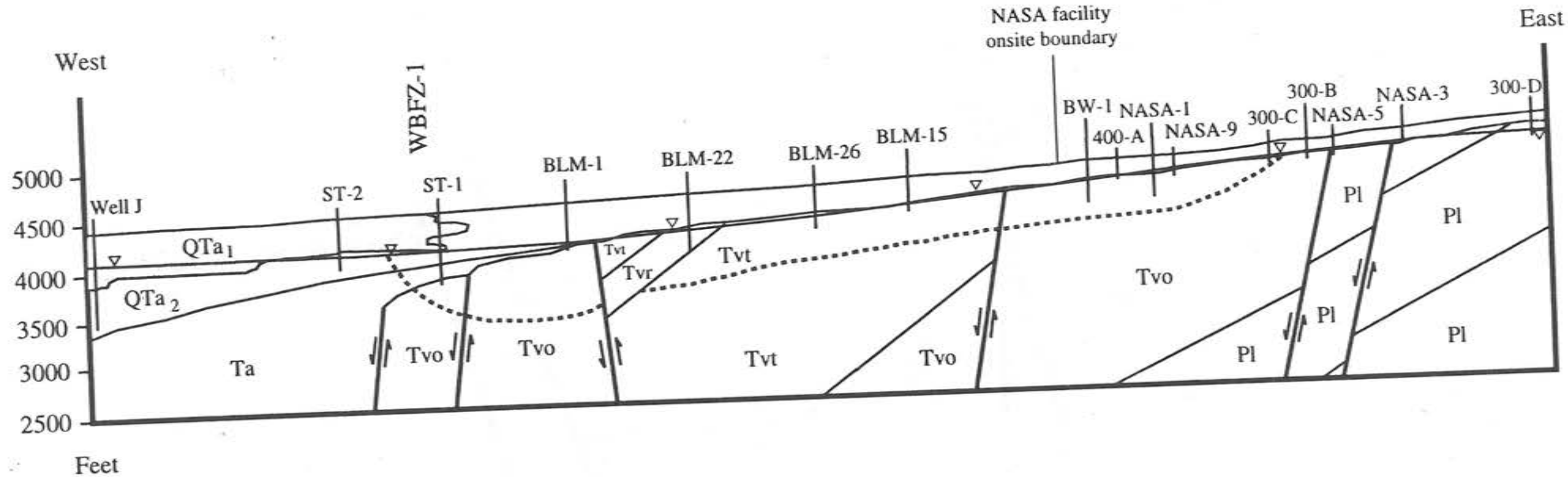
For fluid migration, the groundwater model for the NASA–WSTF suggests that the type of bedrock is not as important as its overall hydrologic characteristics. Therefor the site was classified into three distinct hydrostratigraphic flow units: 1) fractured bedrock (both Paleozoic and Tertiary), 2) porous alluvium, and 3) flow banded rhyolite (GCL, 1995). The two types of bedrock were classified into one hydrostratigraphic unit due to the interconnectiveness of their fault systems. It is the difference between the hydraulic conductivities of the porous alluvium and fractured bedrock that drives the need for a more accurate bedrock–alluvium contact map. Through this integrated geophysical study of the NASA–WSTF, an accurate bedrock elevation map will be produced.

Hydrologic Overview

The NASA–WSTF staff has been modeling the properties of the groundwater to fulfill requirements of a 3008(h) order by the Environmental Protection Agency (EPA) Region 4. An initial groundwater modeling report (GCL, 1995) provided background information on contaminant concentration, aquifer parameters, system stresses, and other factors which may influence the hydrological framework. The overall goal of that modeling effort was to produce a site specific three–dimensional (3–D) groundwater flow and contaminant transport model. Of importance to this model is the 3–D site–wide bedrock model (3DSWBM) which includes depth to bedrock. The GCL report states that this site is hydrologically complex, with the saturated units consisting of porous alluvium and several types of bedrock. From this information, Geoscience Consultants Ltd (GCL) produced a model showing the different bedrock types encountered through drilling, thickness of the alluvium, and possible vertical extent of the contamination (Figure 10) (GCL, 1995).

The main source of the groundwater is mountain–front recharge through fractures and fault zones exposed in bedrock outcrops. It is estimated that the San Andres Mountains provide 112 AFA/m (area feet annually per mile) of recharge into the Jornada basin, and that aquifer conditions range from confined to unconfined. It is believed that groundwater and contaminants move through the bedrock and intercept coarse–alluvial filled channels, and that it flows westward through these channels into the Jornada basin (GCL, 1995). A saturated alluvium isopach map suggests that groundwater flow concentrates into buried paleochannels (Figure 11).

Stratigraphic units are grouped into lithostratigraphic units on the basis of their petrology, geology, and stratigraphy on the NASA–WSTF (Figure 12). Lithostratigraphy is then used as the map units for the conceptual hydrogeologic model. According to the EPA, a hydrostratigraphic unit is "a sequence of geologic units delimited on the basis of their hydrologic properties", thus both Paleozoic bedrock and Tertiary volcanics were grouped into one unit (USEPA, 1992). The NASA–WSTF is broken down into three hydraulic units: porous alluvium, fractured bedrock, and flow–banded rhyolite.



▿ - Water table

Pl - Paleozoic Limestone (undifferentiated)
Tvo - Tertiary volcanics Orejon andesite
Tvt - Tertiary volcanics Ash flow tuff
Tvr - Tertiary volcanics flow-banded rhyolite
Ta - Tertiary (miocene) Alluvium
QTa- Quaternary/Tertiary Alluvium

Figure 10. An east-west hydrogeologic cross section of the bedrock and alluvium across the NASA-WSTF, as mapped by Geoscience Consultants LTD. (GCL) (1995). The dashed line represents the inferred vertical extent of the contamination.

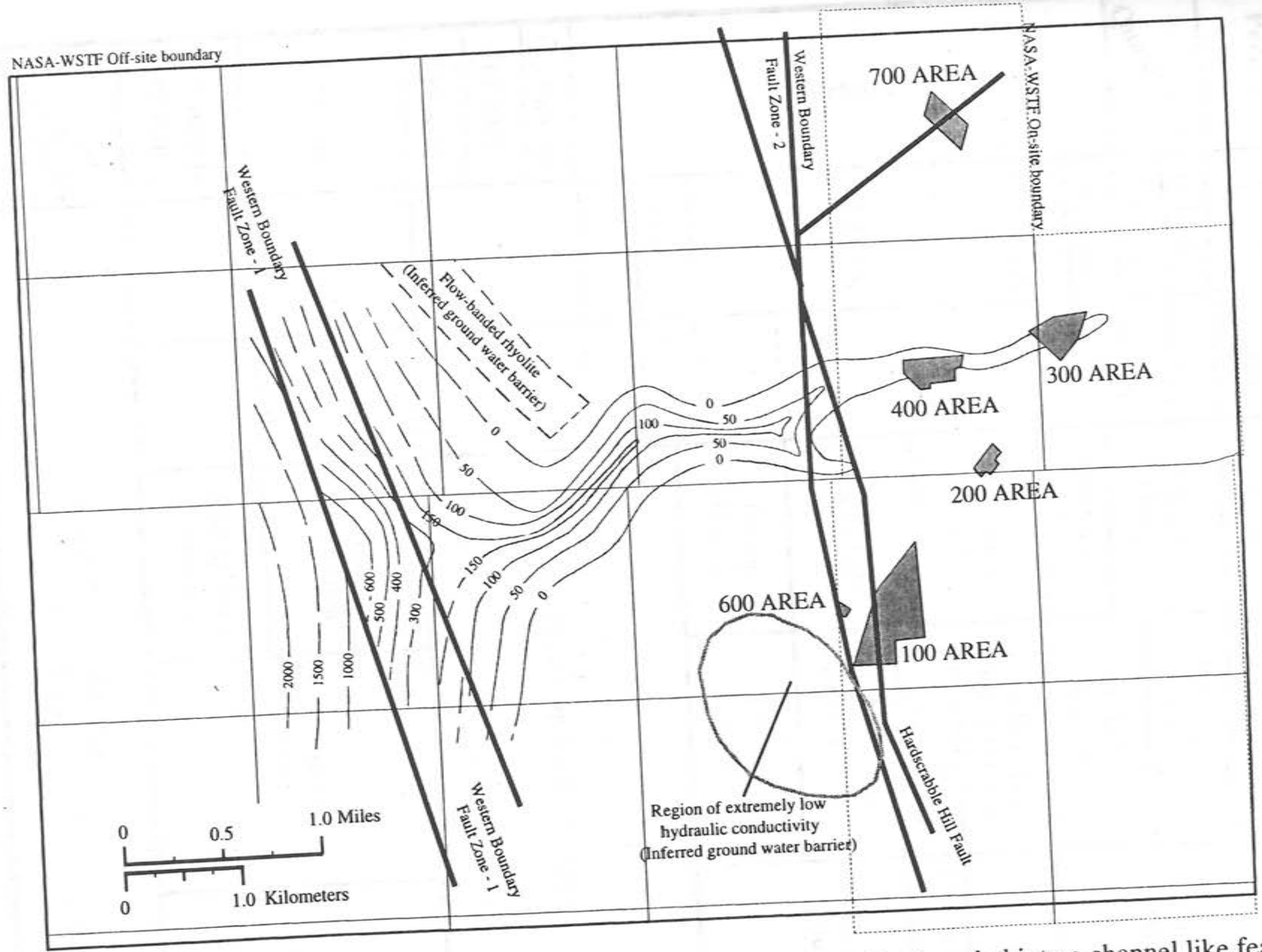


Figure 11. Isopach map of saturated alluvium. Notice how the water appears to be funneled into a channel like feature through the base and then continues off to the west. The ground water appears to flow around the inferred groundwater barriers. Modified from GCL (1995).

Period	Epoch	Age (Ma)	Stratigraphic Units	Lithostratigraphic Units (Map Units)	Hydrostratigraphic Units
Quaternary	Holocene	0.01	Santa Fe Group	Paleochannel Alluvium	Porous Alluvium
	Pleistocene	2.5		Jornada Basin Alluvium	
Tertiary	Pliocene	5.3	Hayner Ranch Formation		
	Miocene	23.7			
	Oligocene		Tuff of Cox Ranch	Ash-flow Tuff (interbedded facies)	
				Fractured Flow-banded Rhyolite	Fractured Flow-banded Rhyolite
			Cueva Tuff	Ash-flow Tuff (interbedded facies)	Fractured Bedrock
			Orejon Andesite	Fractured Andesite	
		34.5			
	Eocene	57.8	Not Present in the Study Area		
		66.4			
Cretaceous					
Jurassic					
Triassic		245			
Permian		294	Hueco Formation	Fractured Limestone	Fractured Bedrock
Pennsyl-vanian		320	Panther Seep Formation		
Mississippian and Older			Not Present in the Study Area above 1500 ft (amsl)		

Figure 12. Table of statigraphic, lithostratigraphic, and hydrostratigraphic units occurring on the NASA-WSTF. Notice only three hydrostratigraphic units are used to delineate the hydrologic structure of the site. Modified from GCL (1995).

These are treated as separate hydrologic units due to substantial differences in their groundwater flow velocities and hydraulic properties. The hydraulic properties of the lithostratigraphic units were determined through aquifer testing, geophysical logging, and analysis of cuttings and core samples. In the fractured bedrock unit, the hydraulic conductivity (K) ranges from 1×10^{-5} to 30 ft per day. In alluvium, it ranges from 0.8 to almost 100 ft per day based on pump tests.

Two hydrologic barriers are present on the NASA–WSTF (Figure 13). First is a flow–banded rhyolite. Groundwater flowing westward through the facility encounters this barrier and diverges to either the northwest or southwest and then continues to flow to the west. Since this barrier can only be seen through groundwater mapping, contamination charts, and well logs, and can not be distinguished on the seismic data, it will be only sparsely mentioned in the rest of this report. The second barrier is a region of extremely low hydraulic conductivity. This region is defined by 5 wells southwest of the 100 – 600 region (100–B, BLM–11, BLM–12, WB–6, and WB–7). These wells did not produce sufficient water to be completed as monitoring wells. All 5 wells have a hydraulic conductivity around 1×10^{-5} to 1×10^{-4} feet per day (GCL, 1995).

Contamination Source Areas

As stated earlier, this thesis was motivated by the contamination and clean–up efforts at the NASA–WSTF. Much of the chemical waste was generated during the construction and operation of the facility in the 1960's and 70's. Lack of knowledge about the chemical hazards at that time led to the introduction of 8 primary contaminants into the groundwater system; these are now considered to be potential human health and environmental threats by

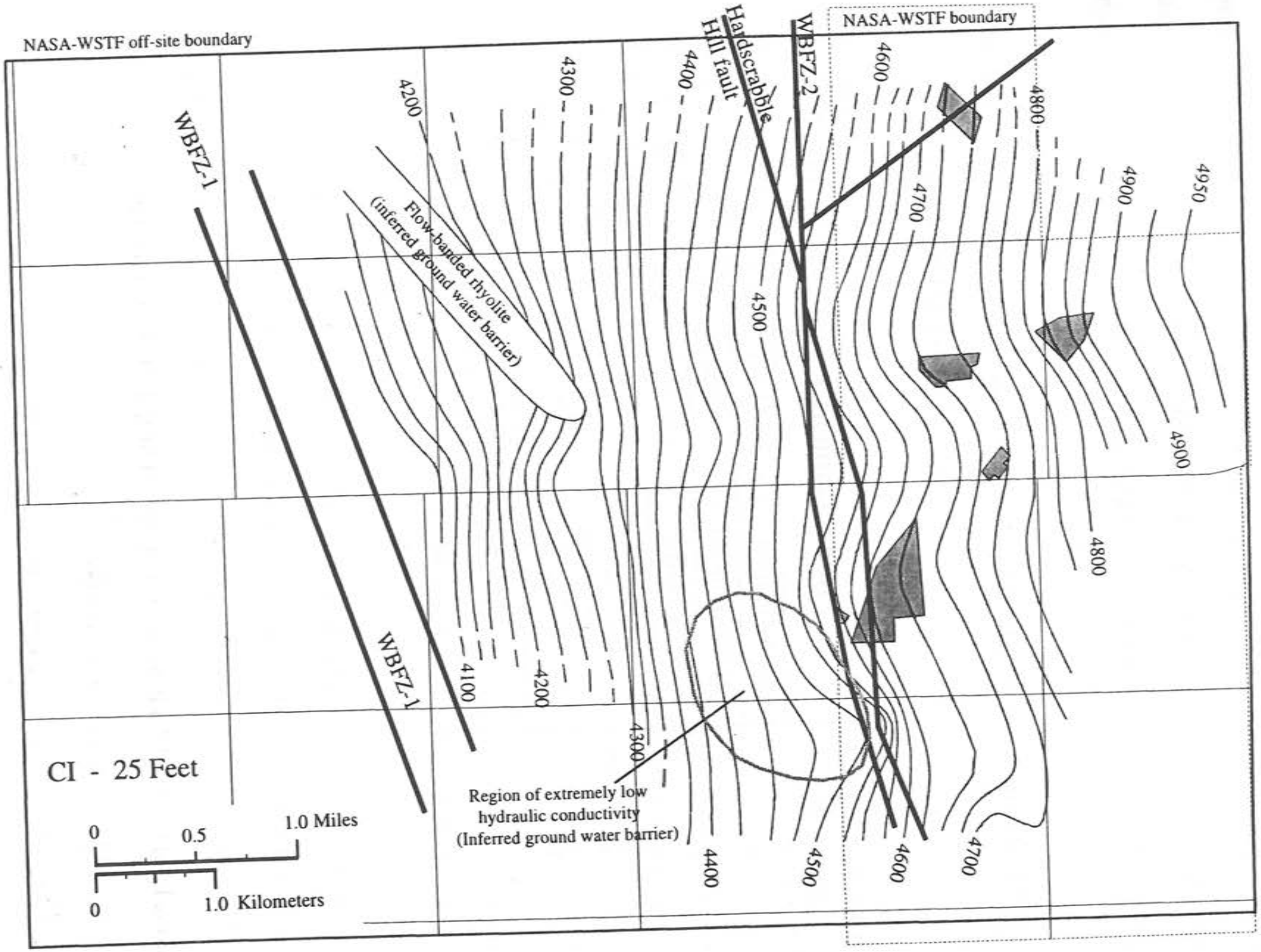


Figure 13. Elevation od water table at the NASA-WSTF. The northern inferred ground water barrier is a flow-banded rhyolite, and the southern inferred barrier is a region of low hydraulic conductivity as defined by well data.

federal and state drinking water standards. Seven of the major contaminants are volatile organic compounds, 5 chlorofluorocarbons and 2 chlorinated solvents, the other belongs to the nitrosamine class of organic compounds. The contaminant name, chemical name, and maximum concentrations within the groundwater are found in Table 1 (GCL, 1995).

Table 1 Contaminant name, chemical name, and maximum concentration recorded in the groundwater.

Name	Chemical Name	Concentration ppb (max)
Freon–113	1,1,2–Trichloro–1,2,2–trifluoroethane	2200
Freon–123A	1,2–Dichloro–1,1,2–trifluoroethane	20
Freon–123	2,2–Dichloro–1,1,1–trifluoroethane	1.0
Freon–11	Trichlorofluoromethane	1600
Freon–21	Dichlorofluoromethane	42
TCE	Trichloroethene	780
PCE	Tetrachloroethene	< 10
NDMA	N–Nitrosodimethylamine	27

Source areas for the contaminants lie on the alluvial pediment surface just west of the San Andres Mountains. The primary source is from infiltration of waste water on the NASA–WSTF alluvial surface (Figure 14). Discharge of test waters into the 300 – 400 area arroyos represent about 44% of all groundwater pumped by the WSTF. In total about 90 acre feet annually is the estimated recharge in the 300 – 400 area arroyos. Other point sources include the 100, 200, 600, and 700 area sewage lagoons and arroyos, but it is estimated that these sites contribute about 5 % of the total groundwater recharge of the site. They do not

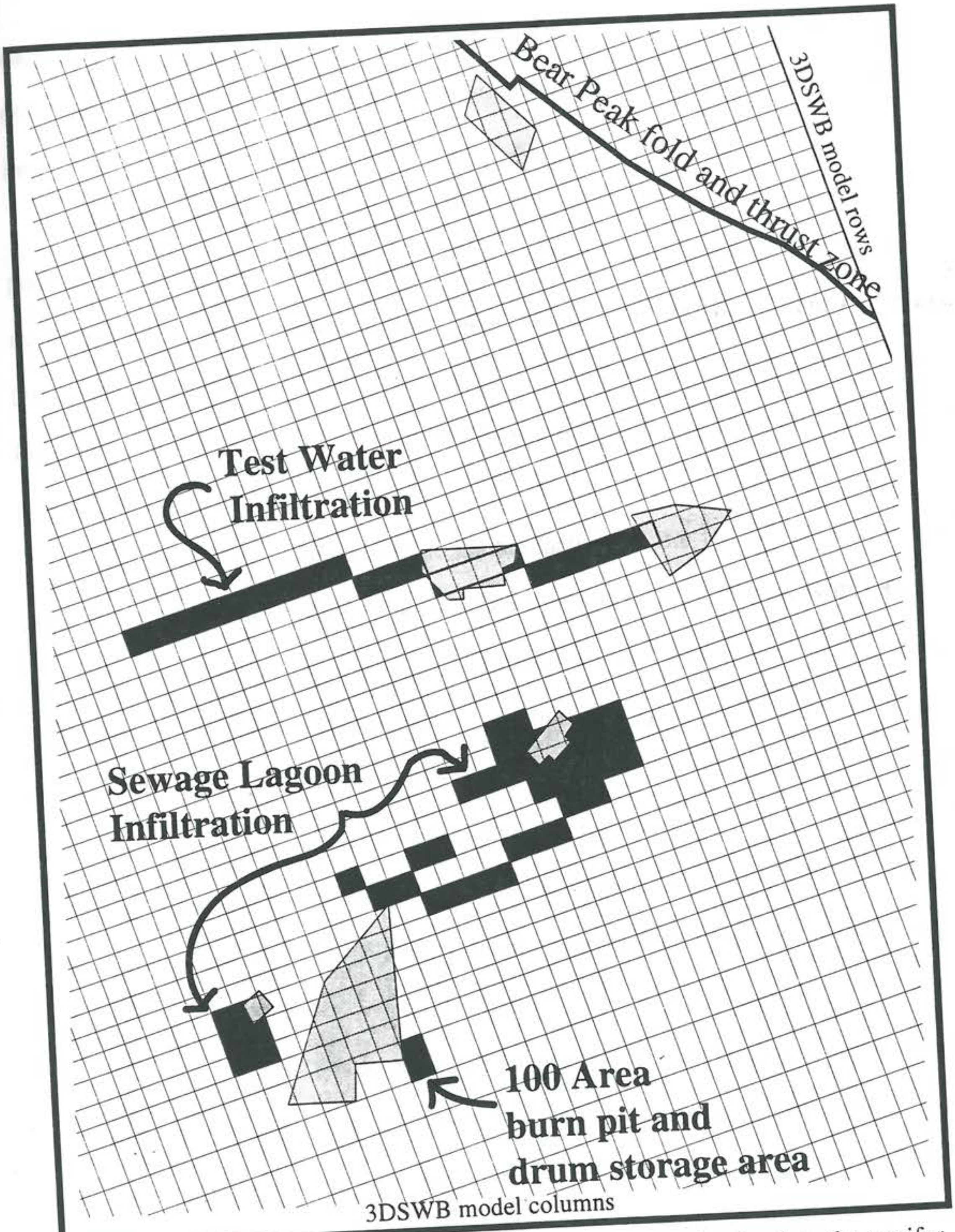


Figure 14. Location of water recharge and contaminant infiltration into the aquifer. It also shows a portion of the 3-D site wide bedrock model (3DSWBM) grid. Notice that blocks increase in size away from the source areas, and therefore diminish in importance. The black squares of the model grid are considered groundwater infiltration locations. Modified from GCL (1995).

significantly affect the flow of groundwater, but they are noted due to their contaminant potential. Over time, the chemical front has migrated several miles down gradient to the west into the thick alluvial deposits of the Jornada basin (GCL, 1995).

The source areas were primarily determined through work records from that time period. These areas were primarily broken down by building type and usage. The 100 area is mostly administrative buildings. The 200 area is for laboratories; the 300 and 400 areas are testing facilities for mock–up rockets and shuttle engines. Area 600 is for surface impoundment of waste from the other facilities, and the 700 area is the landfill for the site (Figure 7).

Numerous source areas for the contamination on the NASA–WSTF have been identified. These regions labeled the 100, 200, 300, 400, 600, and 700 areas are based upon historical use of the individual hazardous chemicals and plume distribution. Maps of chemical concentrations have been produced by GCL. Freon–113 concentrations were mapped to show the contaminant distribution (Figure 15). This figure will later be compared to the top of bedrock map produced through the reinterpretation of the seismic data. The following is a summary of how the contaminants were introduced into the hydrologic system, based on the NASA–WSTF groundwater modeling report to the EPA from GCL (1995).

The NASA–WSTF is actually broken into two portions (Figure 7). The onsite area was the original boundary of the NASA–WSTF, but when contamination was found, the offsite area was acquired in order to contain the contaminants within the NASA–WSTF boundary. The region is small, encompassing only 24 square miles, being 6 miles east–west and 4 miles north–south (9.7 by 6.4 km).

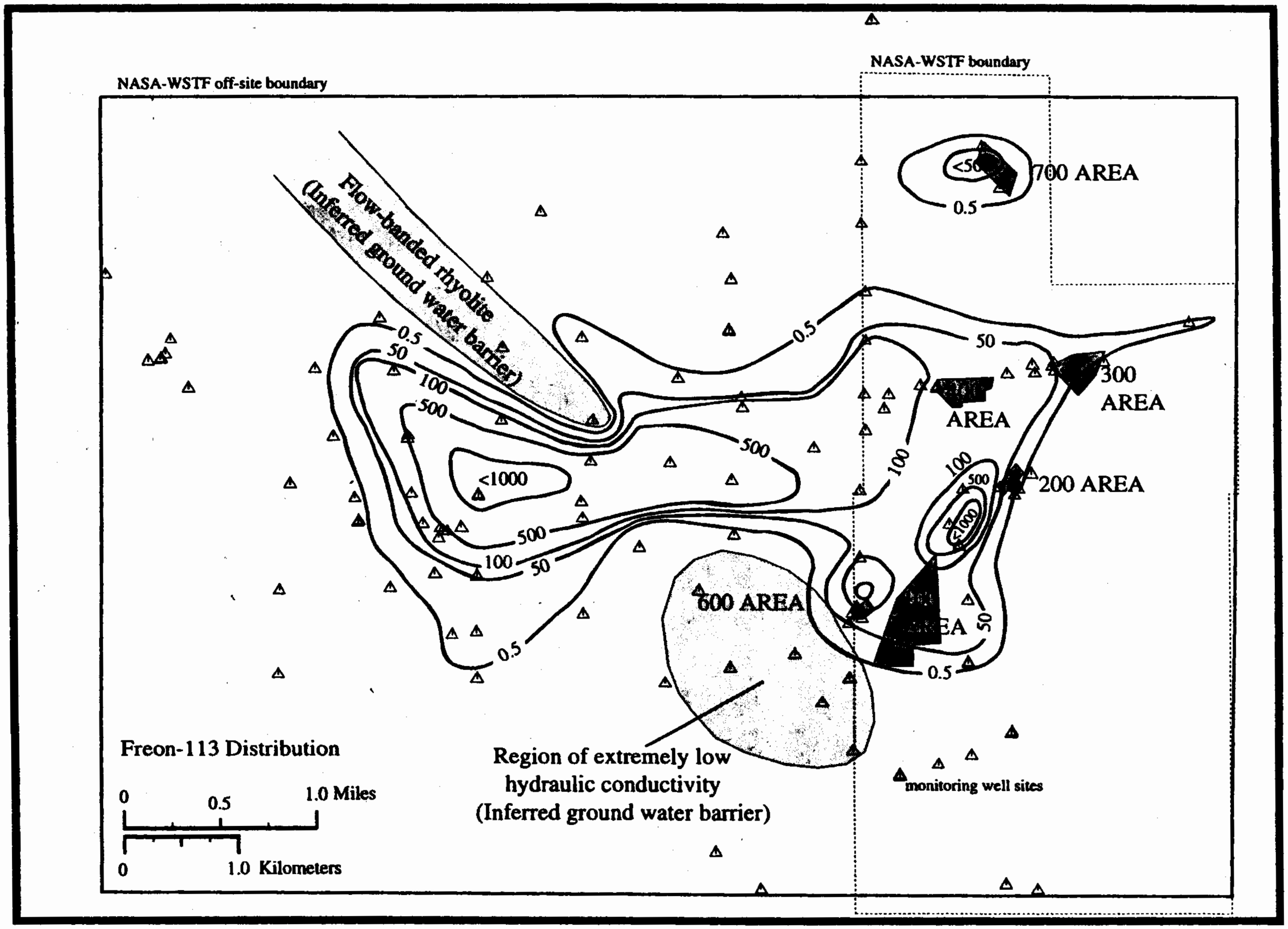


Figure 15. Distribution of Freon-113 on the NASA White Sands Test Facility. Modified from GCL (1995). The contaminants are contoured in parts per billion (PPB).

100 Area

As part of fire training exercises to contain chemical fires, waste chemicals were brought from the 200 area and ignited on a water surface. This was done so that the fire fighters could gain experience extinguishing a real chemical fire. The fire pit was unlined, consequently this is a minor source for Freon–11, Freon–21, and TCE. The actual amount and type of chemicals used in the fire training are unknown. Empty drums still remain east of the 100 area next to the fire pit.

200 Area

The 200 region was constructed in 1964 to help support projects for the Apollo and later space flights. Waste generated at the 200 area laboratories were disposed of in four ways: 1) placed in underground storage tanks, which later leaked, 2) piped directly into an adjacent arroyo, 3) used in fire training exercises in the 100 area, and 4) piped to surface impoundments in the 600 area. Several compounds were released sporadically from 1964 through the mid–1980's. The released waste probably ranged from a dilute aqueous–phase liquid to pure product, consisting of Freon–113, Freon–11. TCE was used as a high–grade cleaning solvent for above ground piping. It is believed that a leaking above ground storage tank and surface spills led to the introduction of TCE into the environment in the 200 area.

300–400 Areas

Propulsion tests during the late 1960s initially used Freon–11 then later Freon–113 as their primary propellent. These chemicals found their way into the environment in many ways. Spent and excess propellent, and emergency discharges were directed into the 300 – 400 area surface impoundments. These impoundments were allowed to drain into the arroyos next to the facilities. Also large volume discharges were "spills to grade" (ie. allowed to flow down gradient into the arroyos).

NDMA originates from the 300 – 400 areas. NDMA is assumed to be a natural bi–product of propulsion test firings using unsymmetrical dimethylhydrazine (UDMH). Its existence as an aqueous–phase liquid probably occurred from the mid 1960s through mid–1970s.

TCE was primarily used during the construction of the 300 and 400 areas in the mid–1960s. Miles of above ground fuel pipelines were cleaned with TCE prior to testing activities. The actual construction practices, volume of TCE, and disposal of said chemical are unknown.

600 Area

Since the waste in the 600 area was piped from the 200 area it consists of Freon–113, Freon–11, and TCE, identical to the 200 area. The 600 area impoundments were closed in 1986, and all residual waste was removed from the pond three years later in 1989.

700 Area

The plume beneath the 700 area is much smaller and separate from the main plume, and much lower in chemical concentrations. Small amounts of Freon–113, Freon–11, and TCE were found in soil–gas data.

Other Contaminants

Freon–21, Freon–123, and Freon–123A were not used during propulsion testing in the 300 and 400 areas nor in any other area at NASA–WSTF. Their occurrence is believed to have resulted from the transformation of Freon–113 to Freon–123 and Freon–123A, and Freon–11 to Freon–21.

Tetrachloroethene (PCE) is not known to have been used as a solvent at NASA–WSTF. Its occurrence is believed to be related to PCE impurities found within the TCE used during construction and cleaning activities at the facility. As a result, wherever TCE contamination took place, there were also traces of PCE.

Modeling Methods

The computer packages being used to model the groundwater flow conditions include MODFLOW (a U.S. Geological Survey 3–D finite–difference groundwater model) and PATH3D (a particle tracking module for MODFLOW), both of which use MTD3 (a 3–D numerical code used for mass transport). These two programs were used to simulate groundwater flow and contaminant transport in both alluvium and fractured bedrock in the three–dimensional site wide bedrock model (3DSWBM). In order to input data into these programs, the NASA–WSTF was discretized into blocks or cells in both horizontal and vertical directions (Figure 14). The finest horizontal cell spacing, 300x300 ft, is used where hydrologic or chemical changes are the greatest, i.e. near the contamination source points. The maximum grid size, 1000x1000 ft, is used at the model edges were there is no contamination (GCL, 1995).

Vertically the 3DSWBM contains 14 layers ranging in thickness from 100 ft near the surface to 250 ft at the bottom of the model (Figure 16). Each layer represents a horizontal slice of the NASA–WSTF. The upper 11 layers are each 100 ft thick, while layers 12, 13 and 14 are 150 ft, 150ft, and 250 ft thick respectively. The reason for the increase in thickness is

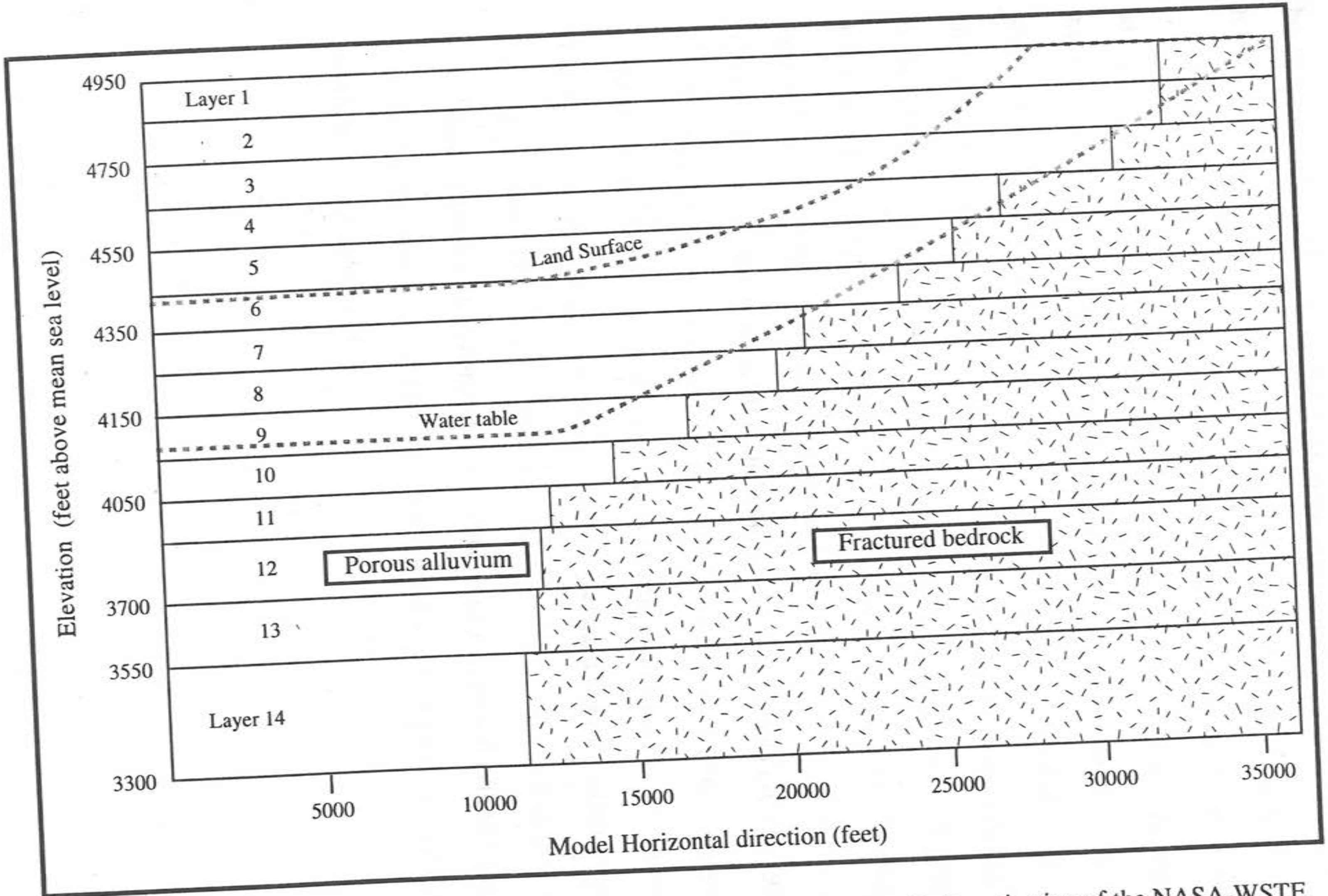


Figure 16. Vertical cross section of the 3-D site wide bedrock model (3DSWBM) grid discretization of the NASA-WSTF. This model breaks the site into 85,500 individual cells used by the computer programs to calculate the hydrologic model. Modified from GCL (1995).

because there are rapid changes in the lithology, contamination concentration, and water levels across the uppermost layers. There are a total of 85,000 cells in the model domain.

The boundary conditions vary across the model. Constant–head cells were placed along the eastern boundary of all of the layers to represent inflow from the San Andres Mountains. A constant–head cell is one where the head in that cell remains constant, but the groundwater into and out of this cell varies. No–flow cells were placed along the northern and southern boundaries of the model. These represent areas where water can flow parallel to the boundary, but not across it. The western edge of the model is lined with general head boundaries (GHB). GHB provides a means to correct for a changing head. This was used to take into consideration the change in head through time of the Jornada basin. From 1963 to 1993 the change in head was –2.4 ft in the north to –3.6 ft in the south (GCL, 1995).

The model takes into consideration vertical and horizontal changes in the hydraulic conductivity across the NASA–WSTF. This is especially important for the paleochannels. The model also uses storage coefficients, specific yield and porosity information obtained from pump tests. Other factors used to predict the flow of the contamination include retardation, dispersion, diffusion, and decay of the contaminants within the groundwater. but this information was obtained through outside reports from individuals who are experts within these particular fields.

BEDROCK INTERPRETATION FROM SEISMIC RECORDS AND WELL DATA

Mapping Methods

A primary focus of this thesis was to produce a bedrock elevation map (Enclosure 1) based on the re–interpretation of 42 miles of seismic lines acquired by CBR&A on the NASA–WSTF, combined with information on lithology and depth to bedrock from over 70 wells (Figure 3 and Appendix B). A simplified map (Enclosure 1) shows that bedrock dips to the west and that two major NW trending fault zones cross the site, in addition, many minor faults are delineated by the data. This map represents a simplified view of the bedrock structure, where many smaller faults with displacements in the range of 10 to 20 ft (3.1 to 6.1 m) were not included on the final map, but were interpreted on the seismic records (Enclosures 2 – 26). Of these smaller faults, many are placed on more detailed maps in the description of individual areas later in this chapter. The reasons for the simplified presentation is two fold. First, the placement of many small faults on the map will obscure the primary structural features, and secondly, the overall effect on fluid flow due to small–offset faults is probably small.

Because seismic data is plotted in time not depth, any interpretation of depth to bedrock will depend on the velocity–to–depth function. For this study, Table 2 was used to convert travel time down to the bedrock horizon on the seismic record to depth. Table 2 is consistent with the large number of wells on the site and thus ensures that the time–depth conversion is accurate when interpolating between wells and the seismic profiles.

Once an accurate time–to–depth conversion table was created, every well, where feasible, was projected onto the seismic lines. Wells that were fault separated from a nearby seismic line were not projected onto the line. Wells more than 500 ft (150 m) away from a seismic line were only used with extreme care. Since the seismic data is of poor quality, well information provided an invaluable source of information. The reinterpretation would be impossible with the seismic data alone. In many places on the seismograms, faults would have been missed or misplaced.

Table 2. Depth to velocity conversion table.

Depth (ft)	Velocity (ft/s)
0 – 12	1,200
12 – 50	4,000
50 – 100	5,000
100 – 200	6,000
>200	6,200

Seismic Interpretation

Surface wave propagation anomalies combined with the top of bedrock reflector displacement were used in locating faults. Large surface waves which were processed into the seismic lines actually assisted in the placement of the faults. Where there were two faults close together, the surface wave energy produced a dead zone on the seismogram. This dead zone manifests itself as an area of no reflectors, or reduced amplitude: GC–13, SP–70 (Enclosure 13). Where only a single fault is involved, the surface energy appears to get trapped within the fault. This produced a series of larger than normal reflectors beneath the fault which attenuate rapidly on both sides of the fault: GC–10, SP–30 (Enclosure 11). For some faults, only displacement along the top of bedrock reflector could be seen, surface waves were not altered by the fault.

The displacement of most of the faults is down to the west, however, the dips on these faults are poorly constrained. This is due to 2 factors: 1) the source produced a large amount of surface wave energy rather than directing the energy downwards into the ground, and 2) the data processing routines attenuated all signals whose dip was greater then 20°. As a result, fault dips could not be traced reliably below the bedrock surface. Given that the most recent deformation in the region is extension associated with the RGR, most of the faults are probable steeply dipping normal faults. A few of the faults "appear" to have a steep dip, but the data is not reliable enough for an accurate determination.

Some of the bedrock in the 200 area is too shallow for the seismic data to image. The dominant frequency (f) on the seismic records is around 50 Hz. Using an average velocity of 3,400 ft/s (1,036 m/s) for the upper 50 ft (15.2 m) of alluvium, the wavelength (λ) is 68 ft (20.7 m). Under ideal conditions, the alluvial/bedrock contact should be imaged at $\frac{1}{2}\lambda$. This would place the minimum resolvability depth at 34 ft (10 m) deep. Consequently there was no top of bedrock reflection returned in the 200 area where the bedrock was shallower than 34 ft (10 m) in depth. Contours in this area are based entirely on well data.

At times, knowing the depth to bedrock in a well is more preferable than knowing the elevation of the bedrock. But when describing displacement along faults, knowing the elevation is more useful than knowing the depth. Since multiple measurements are needed for this section, Appendix B contains the elevation of the bedrock/alluvium contact, and also the depth to the bedrock alluvial contact for all of the wells which encountered bedrock. The surface elevation of NASA–WSTF was contoured from well tops and seismic line survey locations (Figure 17).

Bedrock Composition

Two types of bedrock dominate the NASA–WSTF: Paleozoic marine deposits consisting of limestone, sandstone, and shale; and Tertiary volcanics (Orejon andesite). The distribution of bedrock lithologies was mapped while drilling on the onsite area (Figure 18). The bedrock in the offsite area is comprised entirely of Tertiary volcanics, consisting mainly of andesite (extrusive volcanic ash–flow tuff and a few intrusions) (Figures 5 and 6). The change in bedrock composition across the site is related in part to the basin boundary faults. East of this fault the majority of the bedrock is mainly Paleozoic strata, whereas the west is comprised entirely of andesite. In places the change from Paleozoic strata to Tertiary andesite seems to produce a change in the signal, but this change is not imaged on all of the seismic lines which cross the basin boundary fault.

A small, thin tongue of andesite extending eastward between the 300–400 areas and 700 area lying unconformably upon tilted Paleozoic strata. Although the andesite–Paleozoic contact could not be imaged in the seismic data, two wells in this area give a general thickness for the tongue. In the 700 area, well 700–A encounters andesite bedrock at an elevation of 4759 ft (1451 m), but after 57 ft (17.4 m) of andesite, Paleozoic strata were encountered. The 300–E well encounters andesite at 4830 ft (1472 m) in depth. After 75 ft (22.9 m) of andesite the bedrock changed to limestone for 30 ft (9.1 m). The bedrock changed to andesite for another 25 ft (7.6 m) before returning to Paleozoic strata. This second layer of andesite is

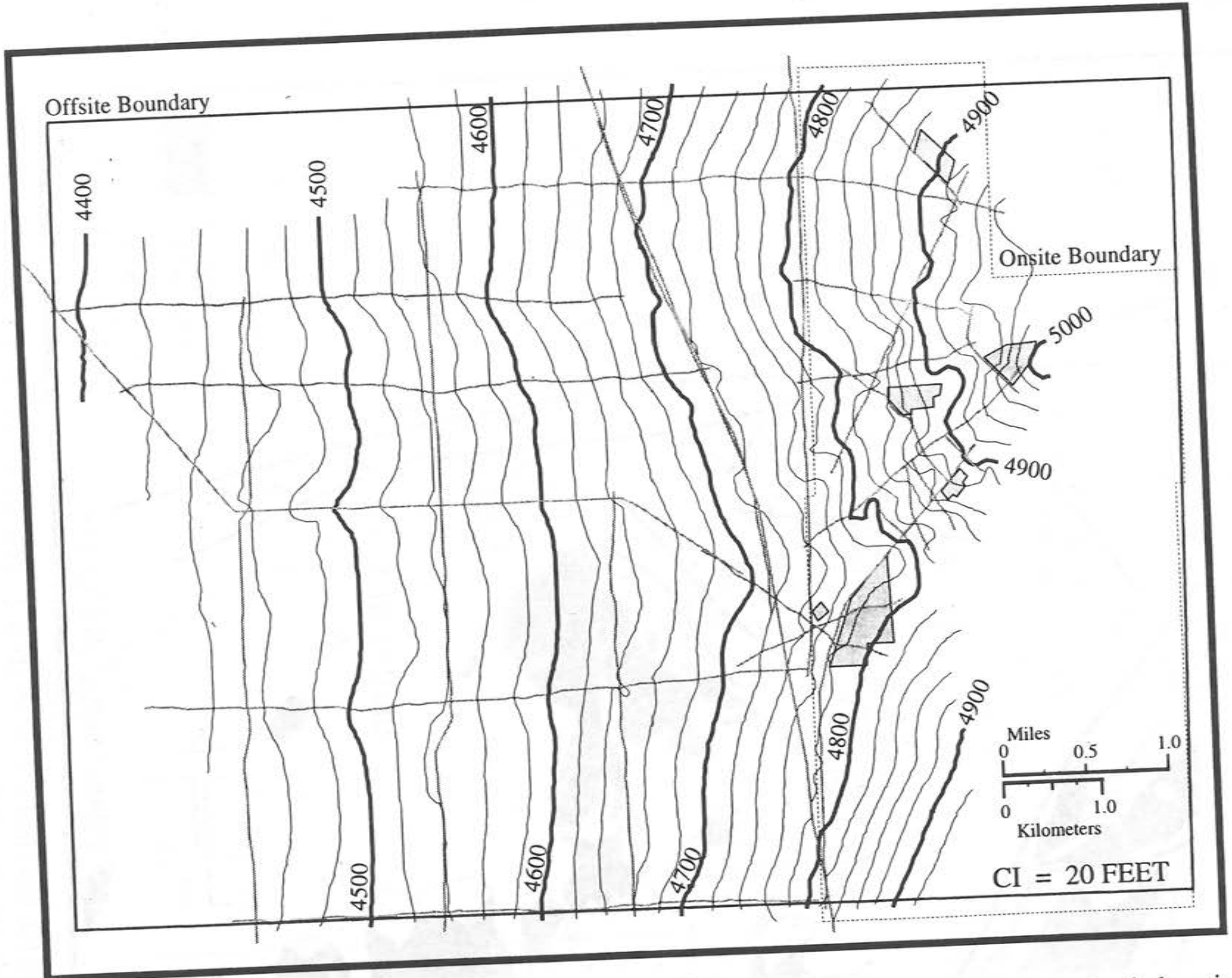


Figure 17. Elevation map of the NASA-WSTF, contoured from top of well information and seismic locations. There is over 600 ft of surface relief across the facility.

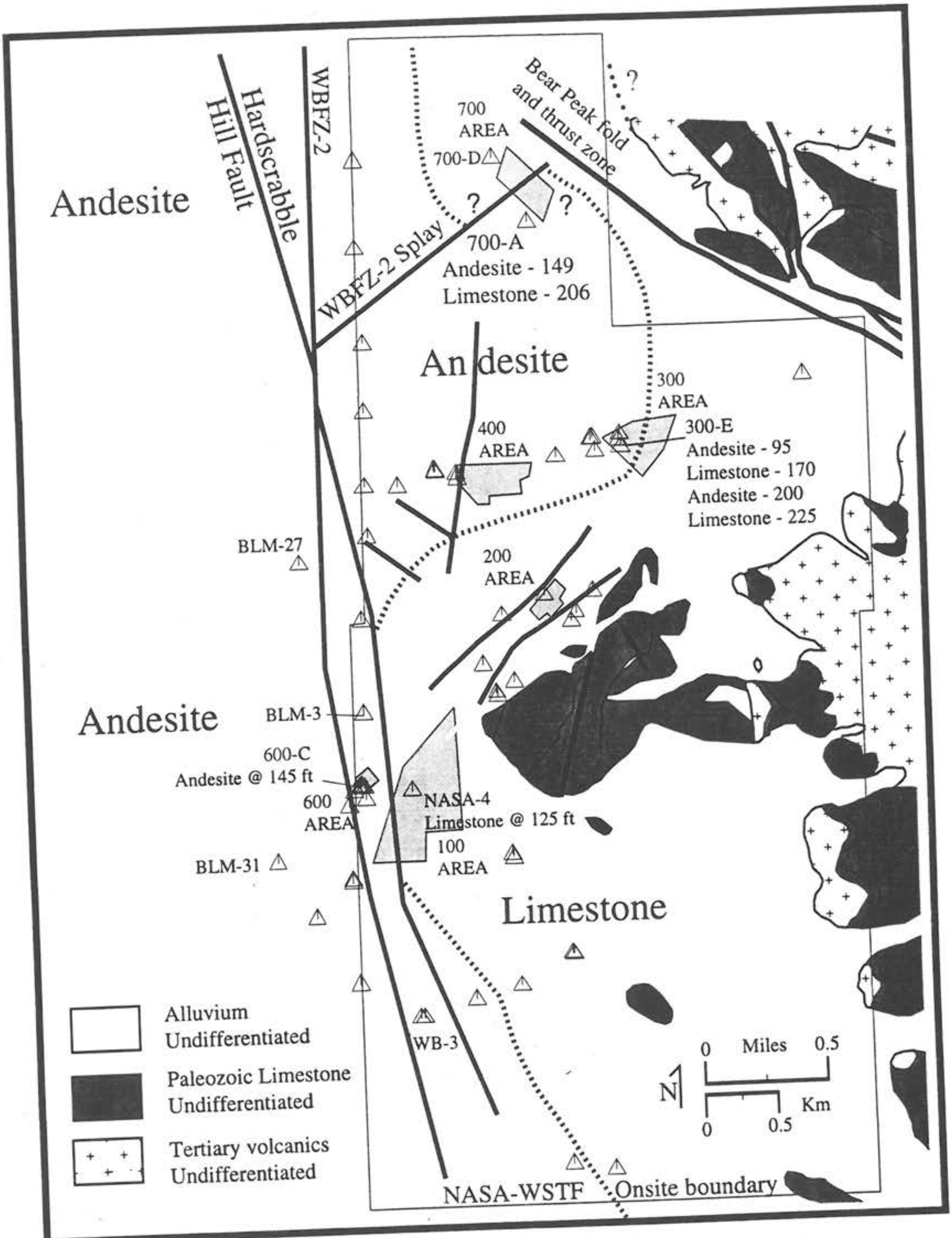


Figure 18. Bedrock type for the onsite area. The Hardscrabble Hill fault did not completely juxtapose limestone against andesite, there is a little andesite left on the eastern side of the fault. Two wells penetrate the andesite and bottom out in Paleozoic rock: 300-E and 700-A. The dashed line represents the interpreted andesite tongue boundary. Modified from Seager (1981).

probably a sill intruded into the Paleozoic bedrock. With the lack of data outside the main region of interest, the extent of the andesite is unclear.

Since the boundaries of the tongue of andesite were not imaged on the seismic data, well information was used to interpret the sides. The northern boundary became problematic when considering bedrock elevation. In well 700–A the bedrock is 4759 ft (1451 m) with the upper 57 ft of bedrock being andesite. Well 700–D lies to the NW across the WBFZ–2 splay. Its bedrock elevation is 55 ft (16.7 m) lower then the 700–A well, but it contained no andesite. One possible scenario for removal of the andesite from the western side of the fault includes reactivation of an older fault. The older fault may have had left lateral strike–slip or reverse movement. After a period of erosion which removed the andesite, the fault underwent normal separation dropping the bedrock down to the west. Another possible cause for the observed andesite geometry might be large paleotopographic relief at the time of the andesite deposition.

Major Faults

Three major faults have been identified on the NASA–WSTF (Enclosure 1): 1) Western Boundary Fault Zone 1 (WBFZ–1) which is the westernmost fault zone and trends NNW through the NASA–WSTF offsite area, 2) Western Boundary Fault Zone 2 (WBFZ–2) which is a fault zone that trends NNW through the center of the facility, and 3) Hardscrabble Hill fault which parallels the WBFZ–2. A combination of the Hardscrabble Hill fault and the WBFZ–2 appear to constitute the eastern basin boundary fault for the Jornada basin.

Western Boundary Fault Zone 1 (WBFZ–1)

The WBFZ–1 consists of multiple normal fault segments, that drop the bedrock surface down to the west into the Jornada basin (Enclosure 1). The total displacement on the fault zone can not be estimated from the seismic, but exceeds 1700 ft (518 m), based well data. Three wells in this region fall along an east–west line not more then 4000 ft (1219 m) long, but their bedrock surface differs by more then 1700 ft (518 m) in elevation. well BLM–17 lies east of the fault zone with a bedrock elevation of 3988 ft (1215 m). NASA–PT is located in the fault zone with a bedrock elevation of 3679 ft (1121 m), and well PL–6–* never encountered bedrock, penetrating 2000 ft (610 m) of alluvium, placing the bedrock below 2280 ft (695 m) in elevation. Gravity modeling, discussed in chapter 6 suggests that the maximum thickness of alluvial fill is 2600 ft (800 m).

Hardscrabble Hill fault

The Hardscrabble Hill fault cuts through the middle of the NASA–WSTF, and may represent an extension of the Hardscrabble Hill fault as mapped by Seager (1981) in an outcrop 1.2 miles (2 km) to the south (Enclosure 1). Since this fault juxtaposes andesite against Paleozoic section, a character change is evident on some of the seismograms. This manifests itself as either a dead zone or truncated reflectors. The fault is visible on seismic lines GC–6, 8, 12, 15, and less clearly on GC–26 (see Enclosures 2 – 26 for seismograms). Even though this fault has over 1000 ft (305 m) of throw based on Seager's outcrop mapping and well log data, it does not have any bedrock surface relief, as seen on the seismic data. Based on this, the Hardscrabble Hill fault is assumed to be older then the other faults on the NASA–WSTF. The total displacement of this fault is unknown, but through gravity modeling, this fault along with the WBFZ–2 combine for around 7900 ft (2400 m) of vertical movement.

The change in bedrock from Paleozoic rock to andesite, across this fault is also documented by wells in the 100 and 600 areas. Well NASA–4 on the eastern side of the fault encounters bedrock at 125 ft (38.1 m) penetrating 50 ft (15.2 m) of Paleozoics thereafter. Well 600–C–437 on the western side of the fault encounters bedrock at 145 ft (44.2 m) and penetrates 355 ft (108.2 m) of andesite thereafter. A little further to the west, well BLM–31 encounters bedrock at 200 ft (60.9 m) and penetrates over 500 ft (152.4 m) of andesite.

Western Boundary Fault Zone 2 (WBFZ–2)

Sub–parallel to the Hardscrabble Hill fault is the WBFZ–2 (Enclosure 1). This fault drops the bedrock surface from 14 ft (4.3 m) to 220 ft (67 m) in depth on the pediment slope, down to 280 ft (85.3 m) to 500 ft (152 m) in depth in the transition zone. Displacement on the fault ranges from 40 ft (12.2 m) in the 600 area, to around 80 ft (24.4 m) near well BLM–27. WBFZ–2 is easily seen on seismic lines GC–6, 8, 12, and less clearly on GC–26 (see Enclosures 2 – 27 for seismograms). To the north, the displacement of the WBFZ–2 beyond well BLM–27 decreases noticeably. This may be due to a second fault which either splays off of, or intersects the WBFZ–2, compensating for the difference in displacement. The splay probably trends NE–SW, passing through the 700 area, and intersects the WBFZ–2 just west of GC–16. It has an average displacement of 40 ft (12.2 m) down to the northwest.

200–East and 200–West Faults

Two northeast trending faults (200–East and 200–West) dominate the bedrock topography in the 200 area (Enclosure 1). The main eastern fault (200–East) has a vertical displacement between 20 and 60 ft (6.1 and 18.3 m), and the western fault (200–West) has a vertical displacement of 40 to 100 ft (12.2 to 30.5 m), depending on internal block faulting. Both faults trend NE and parallel one another.

The 200–East fault is located SE of the 200–G and 200–H wells and raises the bedrock up to an elevation of 4835 ft (1474 m). This fault can be seen on seismic lines GC–1, 2 and 3. From this location, limestone bedrock outcrops on the surface a few hundred feet to the SE. ENE of GC–3, there is no additional data to trace the fault.

Fault 200–West lies just NW of well 200–F and trends parallel to GC–5,12. This fault is imaged on GC–1, 2, 3, 4, and 11. Northeast of GC–4 this fault can no longer be traced. The maximum vertical displacement along the fault is 100 ft (30.5 m) and is down to the NW found next to well 200–F. The 200–West fault may have a left–lateral strike–slip component as discussed below in the 200 area portion of this chapter. Both 200–East and 200–West faults extend towards the 100 area, where the 200–East fault either curves around to the south, eventually trending in a SSW direction, or is truncated by another fault which trends in a southeasterly direction (Figure 19). Fault 200–West may either be truncated by another fault, or continue on towards the 600 area. If the 200–West fault does trend into the 600 area, this could give the contaminants a direct path from the 200 area into the 600 area.

The close proximity of the faults to each other and possible strike–slip motion on the faults has caused the bedrock between the two faults to fracture in a block–like fashion. This causes the faults to have variable offset, depending on the internal block structure between the faults.

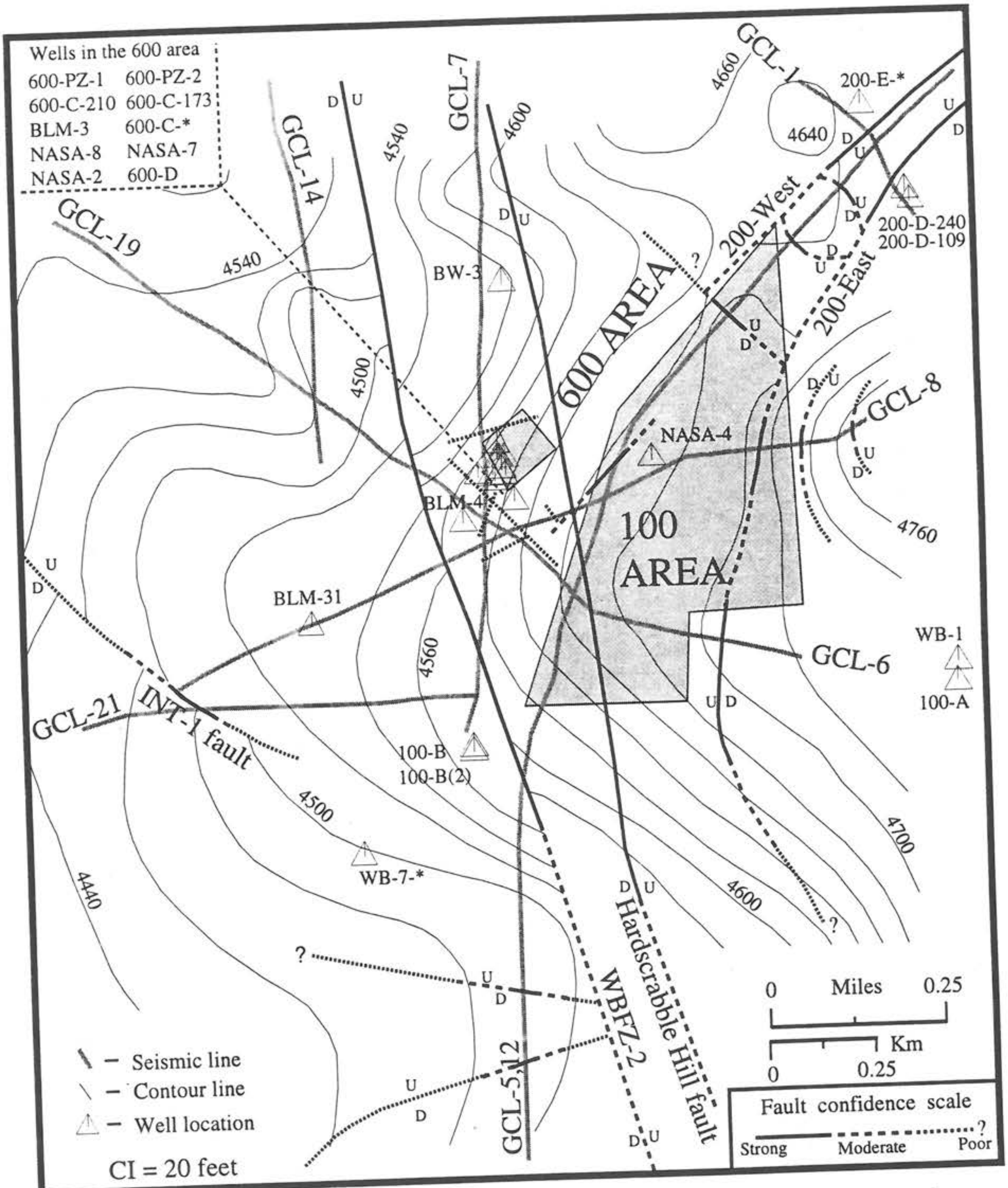


Figure 19. Elevation of the bedrock in the100 and 600 areas. The major features include the Hardscrabble Hill fault and the Western Boundary Fault Zone 2 (WBFZ-2). The SW boundary of both 200-East and 200-West are unknown as they can not be traced with the existing dataset.

Detailed Structure of the Onsite Areas

The structure of the bedrock in the onsite area is important to know because these are the sources of the contamination at the NASA–WSTF. The location of paleochannels, dip of bedrock surface, and faults control possible contamination pathways. Since the minor faults only offset the bedrock 10 to 20 ft (3.0 to 6.1 m), they were not taken into consideration while contouring the top of bedrock map (Enclosure 1). Consequently, even though all of the faults are placed on the regional maps within this chapter, only the larger of them affect the contouring.

100 Area

The 100 area is dominated by sloping bedrock, dropping from east to west, towards the 600 area. The bedrock under the 100 area is cut by one main and several minor faults (Figure 19). The major fault across the area is the Hardscrabble Hill fault. The minor faults have between 10 to 30 ft (3.1 to 9.3 m) of displacement on them. The effects of the faulting on the bedrock surface water flow is probably minimal. The effect that the Hardscrabble Hill fault might have on the groundwater flowing through the bedrock is unknown and not accounted for in the current groundwater model.

The bedrock beneath the 100 area ranges from 67 ft (20.4 m) in the east to 160 ft (48.8 m) in the SW. This gives a corresponding bedrock elevations of 4730 ft (1442 m) in the east and around 4620 ft (1408 m) in the SW. Only one well is located within the 100 area, NASA–4. There the depth to Paleozoic bedrock in the NASA–4 well is 125 ft (38.1 m).

200 Area

The 200 area is the most complex of the six areas examined. It is dominated by two northeast trending faults: 200–East and 200–West (Figure 20). The region between these two northeast trending faults is faulted in a northwesterly direction, creating block–like structures between the two main faults. The shallowest bedrock on site is found at a depth of 17 ft (5.1 m) in the 200–F well based on log data, producing a small structural high. Wells 200–G and 200–H have depths to bedrock of 55 ft (16.8 m) and 74 ft (22.5 m) respectively. The bedrock under the 200–F well is 4847 ft (1477 m) in elevation and 4753 ft (1449 m) and 4746 ft (1447 m) under the 200–G and 200–H wells. Consequently, there is probably at least one small fault lying between well 200–F and the wells 200–G and 200–H, down dropping the bedrock to the southeast.

Northeast of well 200–F, are two smaller internal faults (internal meaning between the 200–West and 200–East faults), which places the bedrock at 65 ft (19.8 m) below the surface, or 4746 ft (1447 m) in elevation. Immediately to the NW of well 200–F is the 200–West fault which displaces the bedrock 100 ft (30.5 m) down to the NW. During the Rio Grande Rift σ_2 was N–S and σ_3 was E–W. This could have set up a stress regime that may have produced a left–lateral strike slip motion along NE trending faults (Figure 21). Such motion along the 200–West fault could also have forced fault 200–S1, north of well 200–E, to thrust up to the north. However the determination as tó whether the fault is a small thrust or a normal is still questionable since the fault dip can not be determined.

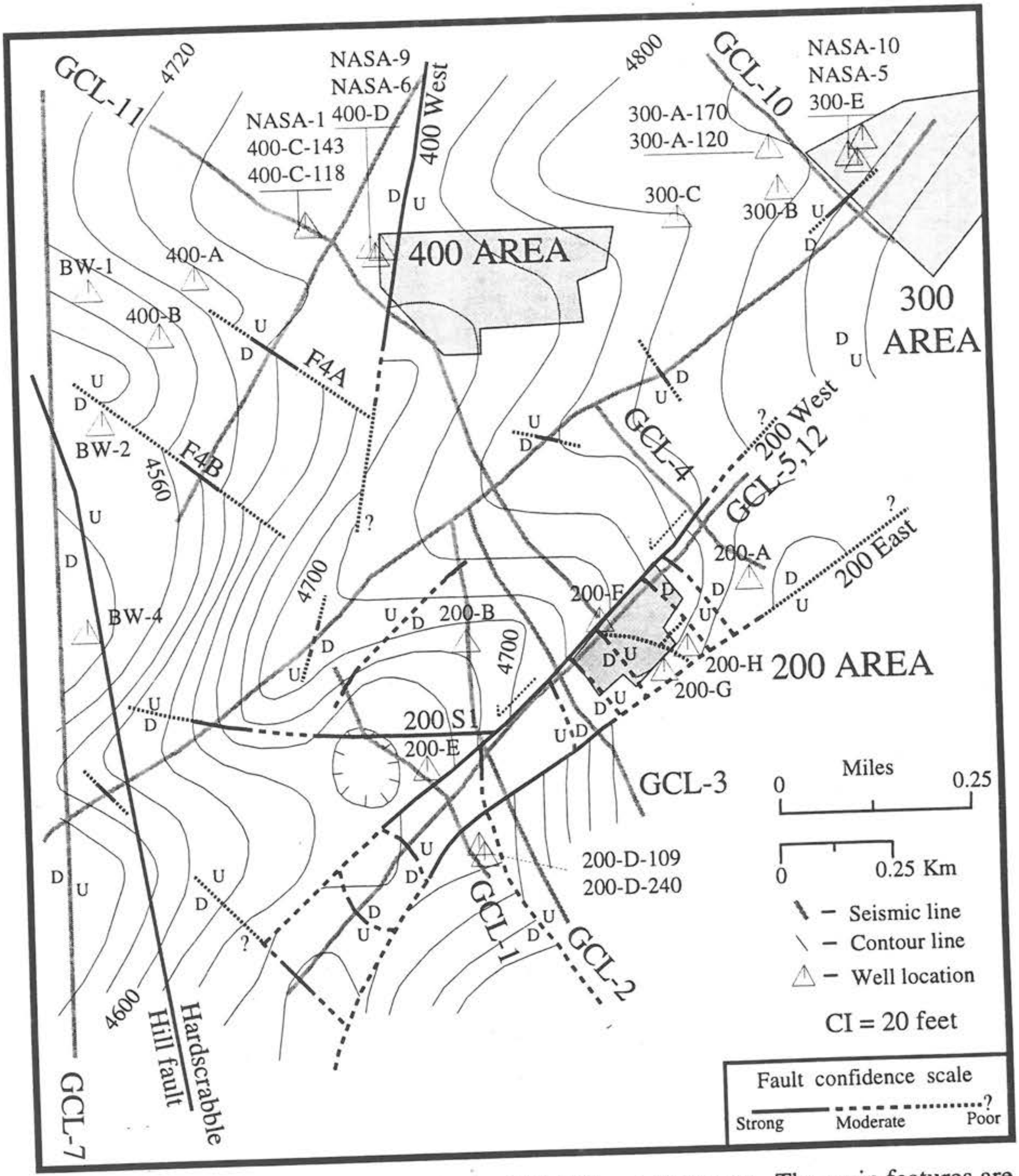
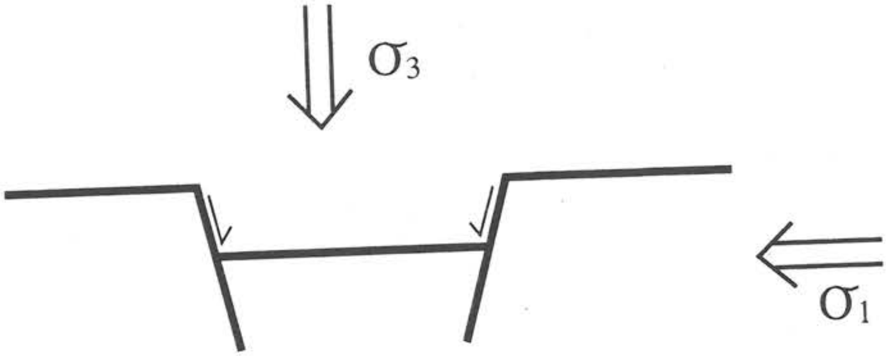
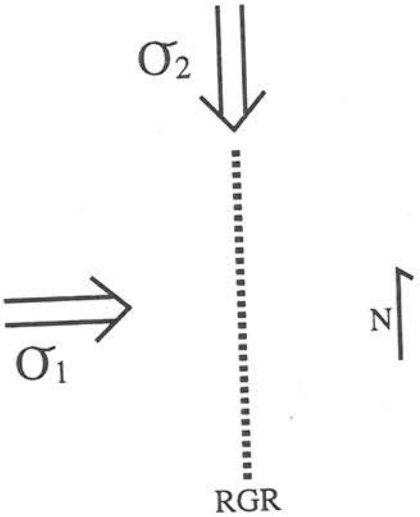


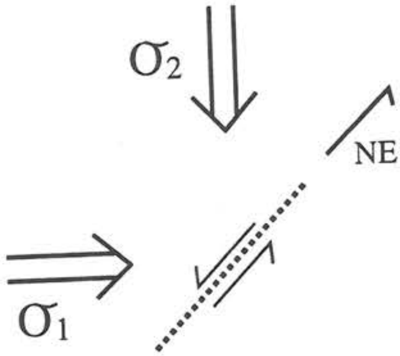
Figure 20. Elevation of the bedrock in the 200, 300 and 400 areas. The main features are the two paleochannels, and the highly faulted bedrock beneath the 200 area. The 200-west fault has over 100 ft of throw near the 200-F well, and has a possible left-lateral strike-slip component in its displacement.



A. Stress regime during extensional faulting.



B. Stresses on a RGR normal fault, assuming a roughly N-S trend for the fault



C. The resulting stresses could produce left-lateral strike-slip motion

Figure 21. Assuming a roughly N-S trend for RGR normal faulting in the San Andres region, the regional stresses could cause left-lateral strike-slip motion on a NE trending fault, or a right-lateral strike-slip motion on a NW trending fault.

300 Area

The bedrock beneath the 300 area is relatively featureless compared to the other areas. Only one small fault extends into the area (Figure 22). This fault has at most 15 ft (4.6 m) of displacement, down to the SE. There are 3 wells this area, 300–E, NASA–5, and NASA–10. The depth to the bedrock from these wells range from 100 ft (30.5 m) to 135 ft (41.2 m), the corresponding elevations range from 4820 ft (1470 m) to 4860 ft (1481 m). Based on the top of bedrock contour mapping, a paleochannel is incised into the bedrock surface sloping from ENE to WSW, through the northwest portion of the 300 area.

400 Area

The main feature of the 400 area is a N–S trending fault, 400–West, which passes just west of the area (Figure 21). This fault has 60 ft (18.3 m) of down to the west displacement. The depth to the bedrock in this region ranges from 92 ft (28.0 m) in well 300–C, just east of the 400 area, to 165 ft (50.3 m) in the NASA–9 well. The corresponding elevations range from 4765 ft (1452 m) in the east to 4657 ft (1419 m) in the west. There are 3 wells in the 400 area: NASA–9, NASA–6, and 400–D. The depth to the bedrock from these wells range from 145 ft (44.2 m) to 165 ft (50.3 m). The channel that passes near the 300 region extends SW through the 400 area. The bedrock surface dips to the southwest beneath the 400 area

600 Area

The bedrock below the 600 area is criss–crossed with faults, including two major and at least six minor faults that offset the bedrock (Figure 19). The Hardscrabble Hill fault is located directly east of the 600 area. The second major fault, WBFZ–2, lies to the west of the 600 region. To the south lie five smaller faults having an average displacement of 15 ft (4.5

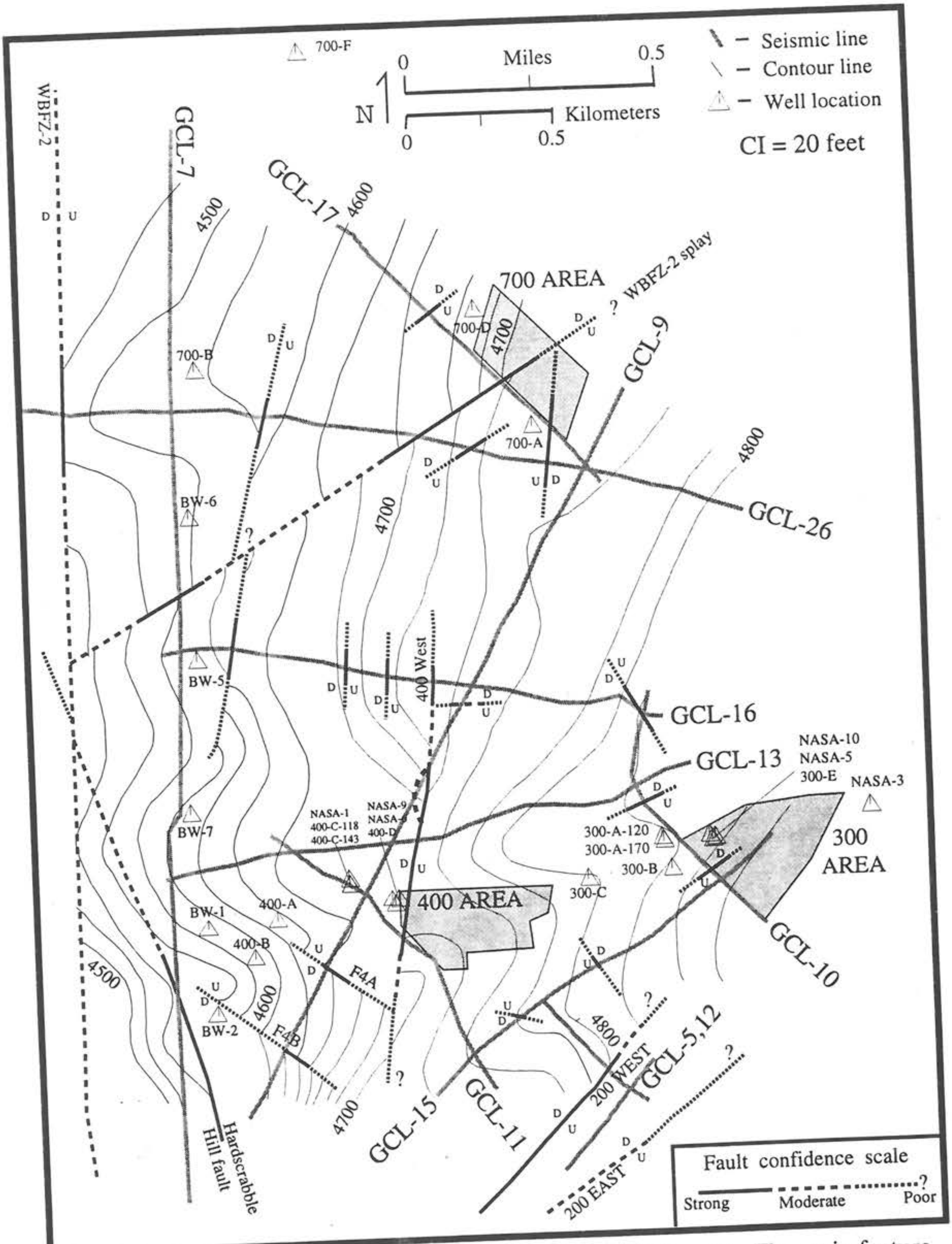


Figure 22. Elevation of the bedrock in the 300, 400 and 700 areas. The main feature is the splay of the WBFZ-2 trending northeast through the middle of the 700 area.

m). There are 12 wells in or around the 600 region with a depth to bedrock from 137 ft (41.8 m) in the 600–PZ–2 well to 162 ft (49.4 m) in the BLM–3 well. The bedrock dips to the NW and has an elevation from 4600 ft (1402 m) to 4620 ft (1408 m).

700 Area

Area 700 is dominated by a large northeast trending fault (Figure 21). This fault might be a splay of the WBFZ–2. The WBFZ–2 splay cuts through the 700 area displacing the bedrock down to the northwest. There are three other smaller faults around the 700 area. Again these faults are not on the regional structure map (Enclosure 1) due to the fact that their displacements are minimal at 10 to 20 ft (3.0 to 6.1 m). Two wells, 700–A and 700–D, aid in the interpretation of the seismic data which places the bedrock at 149 ft (45.4 m) and 180 ft (54.9 m) in depth or 4,759 ft (1,451 m) and 4,705 ft (1,434 m) respectively. The discrepancies between the two wells can be accounted for through displacement on the WBFZ–2 splay.

Paleochannels

The bedrock topography map points to two possible paleochannels in the bedrock which cross through the on–site area (Figure 23). The first originates just north of the 200 area. This channel is primarily structurally controlled. Its southern boundary is produced by the 200–West fault. There may be another fault controlling the NW side of the channel, but the data is too sparse in that region to be conclusive. The blocks between the 200–East and 200–West faults dips very shallowly towards the west and directs the flow of the water into the main portion of the channel. A combination of the faulting and natural bedrock surface features have produced a small bedrock depression near the 200–E–* well. The bedrock

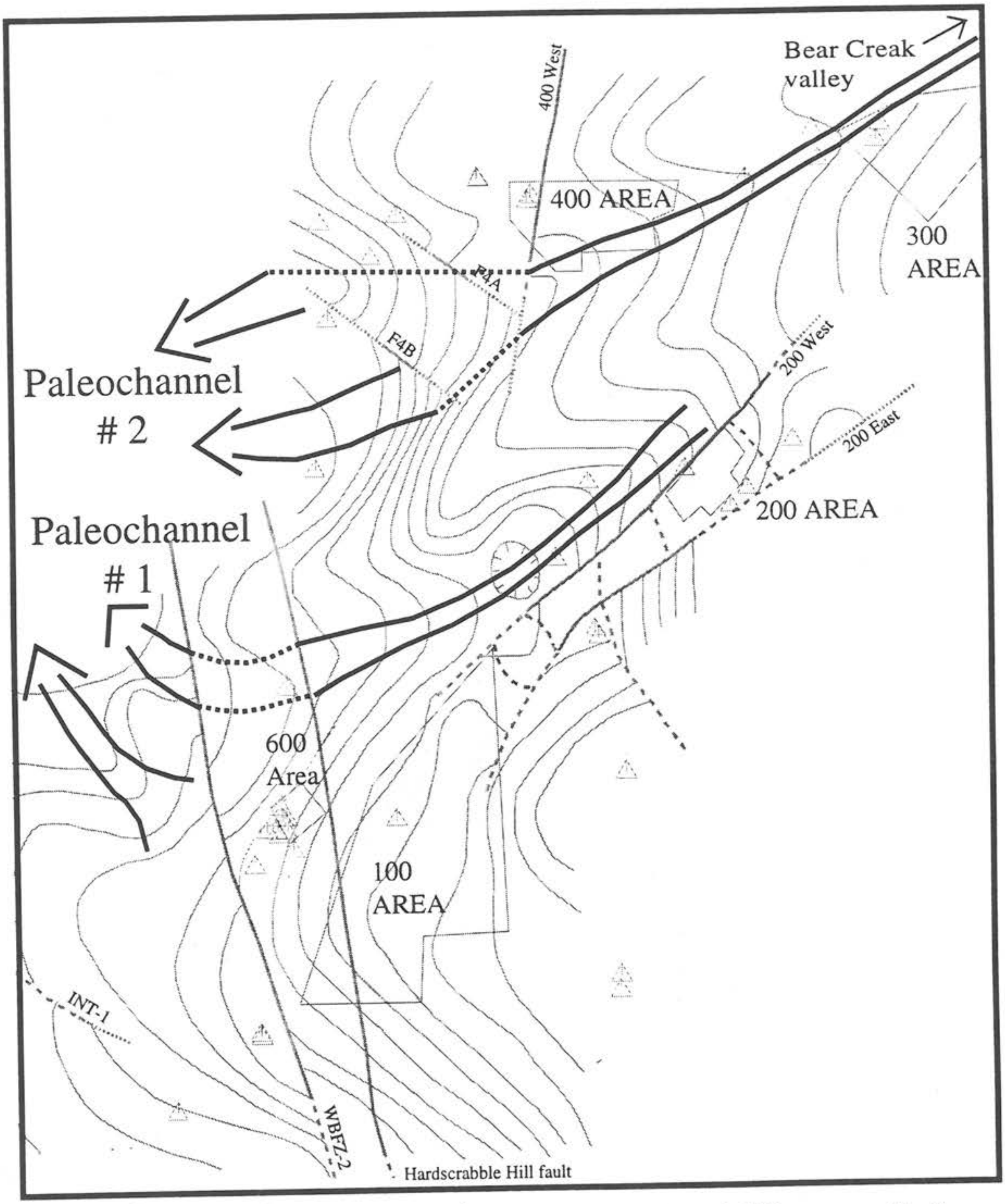


Figure 23. Elevation map of the 100, 200, 300, 400 and 600 areas with the direction of the paleochannels superimposed. The first originates in the 200 area where it trends in a southwest direction. North of the 600 area it turns northwest. The second originates in the Bear Creek Valley, northeast of the 300 area. The two later join together and trend in a westerly direction.

channel extends down to the SW, towards the 600 area. Due to the highly faulted nature of the bedrock between the 200 and 600 areas, the channel appears to be broken by faults. Northwest of the 600 area, the channel is diverted to the northwest.

The second channel originates in the Bear Creek valley NE of the 300 region. The channel passes north of the 300 area and south of the 400 area trending in a WSW direction. Immediately southwest of the 400 area the channel is broken by three, down to the west faults: 400–West, F4A, and F4B. These faults lead to a broadening of the channel and cause it to turn slightly such that it is trending in a westerly direction. Since the first paleochannel turned to the NW, it intersects the second channel east of well BLM–21. The two channels combine and continue off in a westerly direction, eventually encountering the WBFZ–1 where the channel intersects the Jornada basin.

When the location of the Freon contamination plume and paleochannels are compared (Figure 24), a correlation between the two appears to exist. The paleochannels funnel water into them and provides a lower hydraulic conductivity, allowing the water to be funnelled to the west (GCL, 1995). Consequently a majority of the groundwater may be flowing along the surface of the bedrock carrying the contamination to the west in the Jornada basin.

A combination of contamination concentration maps and groundwater velocities suggests that the groundwater flow is concentrated in the paleochannels. The velocity of the groundwater in the channel alluvium is 2 ft/day, while for the basin alluvium it is 0.002 – 0.15 ft/day and for the bedrock it is 0.001 – 0.2 ft/day. The high fluid flow in the bedrock may be attributed to assumed porous flow in the faults (GCL, 1995). Since groundwater takes the

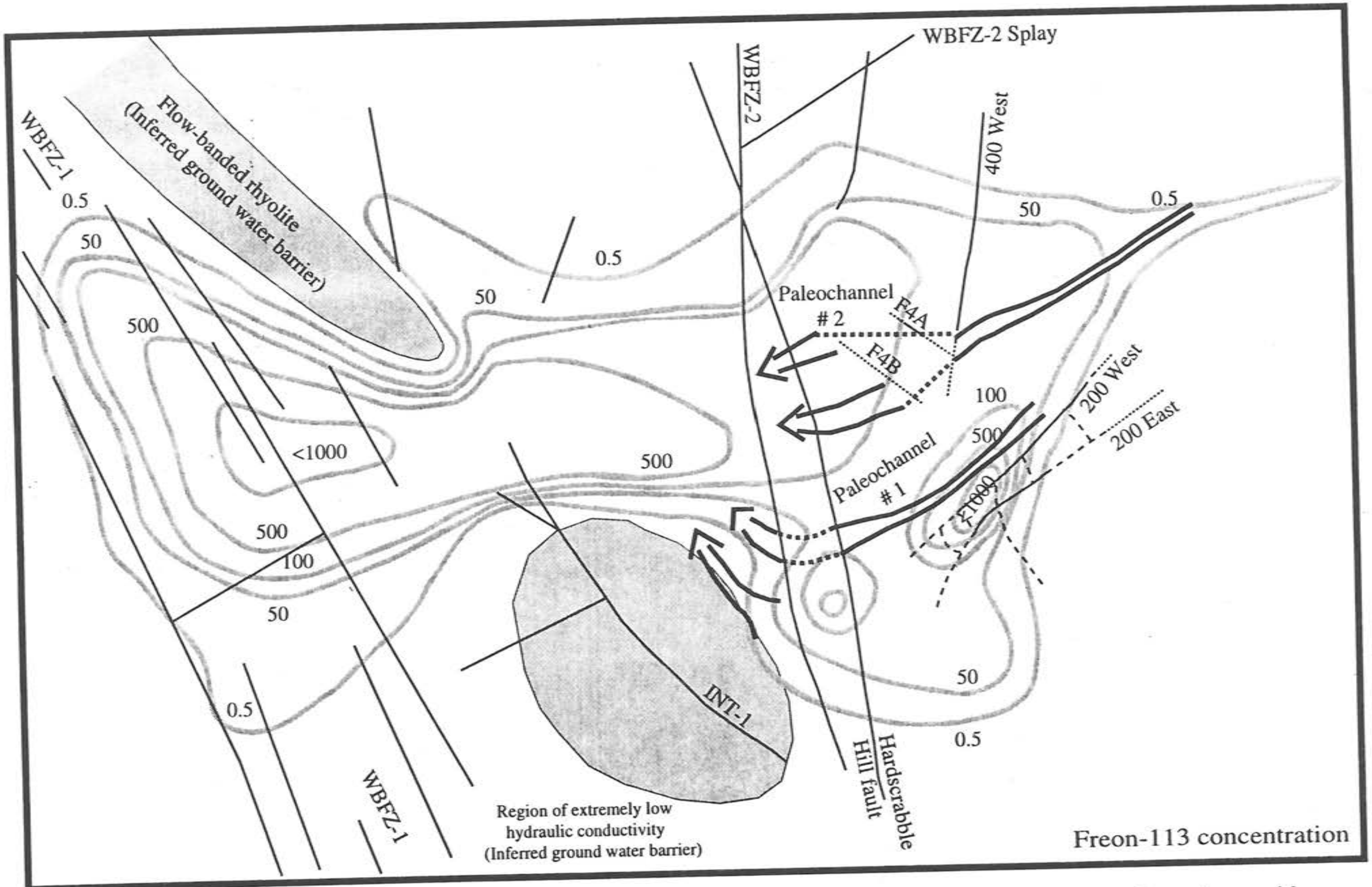


Figure 24. Bedrock channels and major faults overlying the Freon-113 contamination plume. The paleochannels provide a zone of higher hydraulic conductivity. The ground water and contaminants seem to concentrate within the channels.

path of least resistance, it flows off of the top of bedrock into the channels. A minor amount of groundwater also recharges the bedrock water supply through the fault system.

Bedrock Features of the Offsite Region

The main feature of the off site region is the presence of a depression in the bedrock surface near well BLM–21 (Enclosure 1). This depression is produced through a combination of faulting and paleo–topographic features. The paleo–topographic feature is a probable extension of the paleochannels which pass through the on site areas. The channel is confined to the north and to the south by tectonic features. Directly south of the channel is a small structural high, possibly a small thrust associated with compression due strike–slip movement along INT–1, associated with Rio Grande Rift faulting.

To the NW of the paleochannel lies a flow–banded rhyolitic dike or flow, interpreted from the well log and contamination plume data (GCL, 1995). The dike is only seen in two wells; BLM–8 and BLM–22. Well BLM–22 encounters the rhyolite at 325 ft (99 m) in depth and did not exit the unit until 255 ft (78 m) later. The rhyolite dike may have an effect on groundwater flow due to the compositional difference between it and the andesite. However the seismic records show little to no bedrock relief associated with this feature. Since groundwater contamination has not been detected in either of the wells in the rhyolitic dike, it is assumed to be a groundwater barrier (GCL, 1995).

An intermediate displacement fault, INT–1 trends in a northwest direction west of the 600 area and is located about half way between the WBFZ–1 and WBFZ–2 (Enclosure 1). This fault is the western boundary of the structural high, immediately west of the 600 area. On the northern end on the fault, there is a small thrust–like feature, probably caused by a strike–slip motion. This thrust feature lifts the bedrock slightly, producing a constriction of a paleochannel near well BLM–21, as it flows off the the west. This fault can be seen on GC–19, 21, and 25. The small bedrock high can be seen best on seismic lines GC–19 SP–115 through 128 (see Enclosures 2 – 26 for seismograms).

Depth to Bedrock

Elevation to bedrock, depth to bedrock, topography decrease to the west. Thus, an alluvial isopach map (Figure 25) helps to highlight a few of the bedrock features stand out better, especially the paleochannel #1. The alluvial isopach map was produced by contouring depth to bedrock at every fifth seismic trace and at every well which encountered bedrock. Paleochannel #1 can be seen coming out of the 200 area where it trends into the 600 area. The bedrock high, which causes the channel to turn to the northwest, shown up as a thin area extending to the west, west of the 600 area. In this particular mapping procedure, the second paleochannel is not as evident.

The depth to bedrock in the Jornada basin is also quite evident. The dark region to the west of the WBFZ–1 corresponds to the thick basin deposits. The anomalous high on the eastern portion of the map is partially due to edge effects. Since there is no data in the region, the gridding program fits a smooth surface so that it can contour the region.

Implications of Bedrock Map for Site Geology and Hydrology

This study provides considerable detail about the structures beneath the NASA–WSTF. Structurally, the NASA–WSTF region can be divided into three zones: the Jornada basin to the west, the pediment slope of the San Andres Mountains to the east, and a transition zone in the middle, each separated by a RGR fault zone (Figure 26). This cross

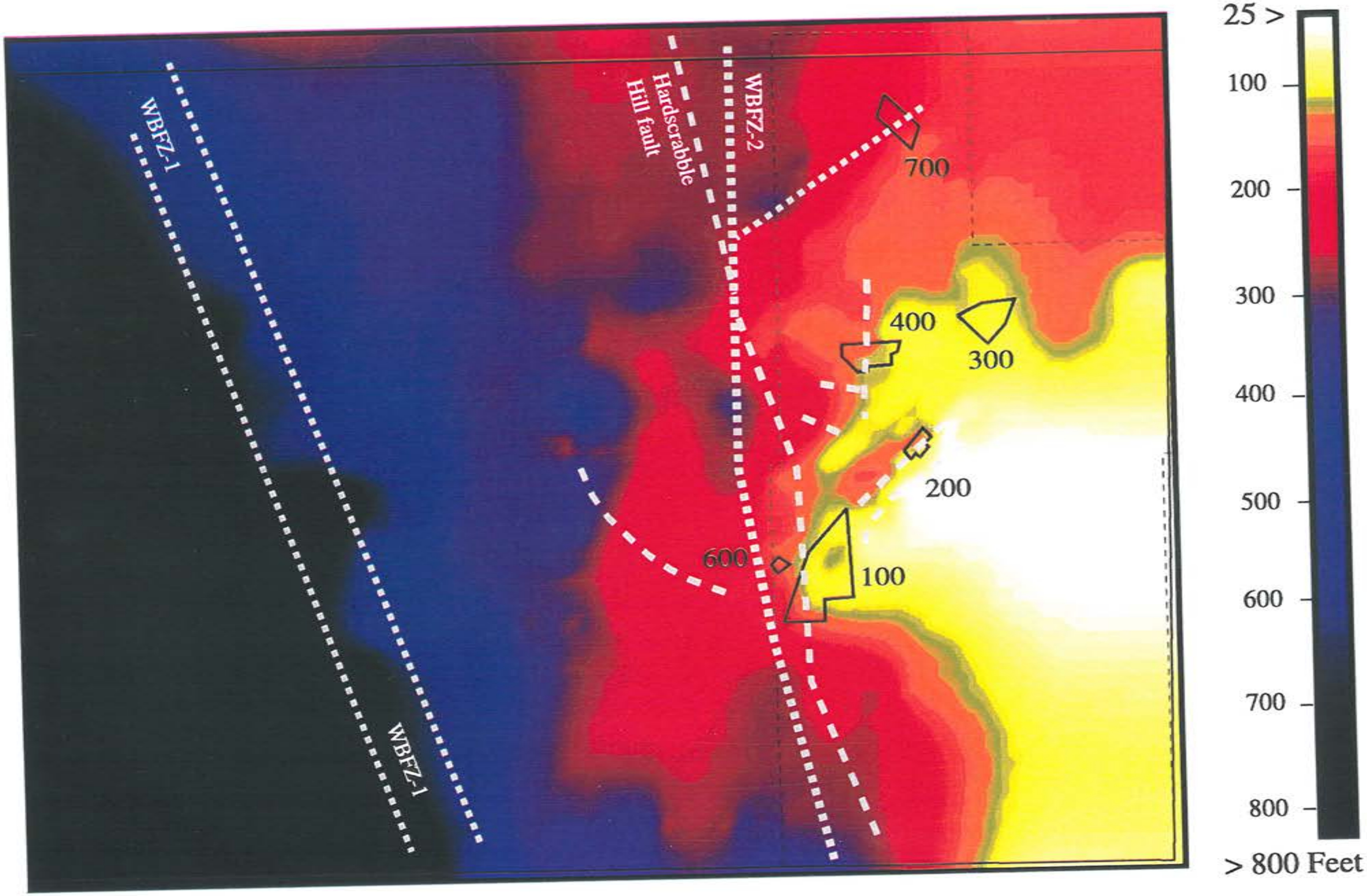


Figure 25. Alluvial isopach map. By plotting the thickness of the alluvium, the paleo-channel in the 200 area stands out better.

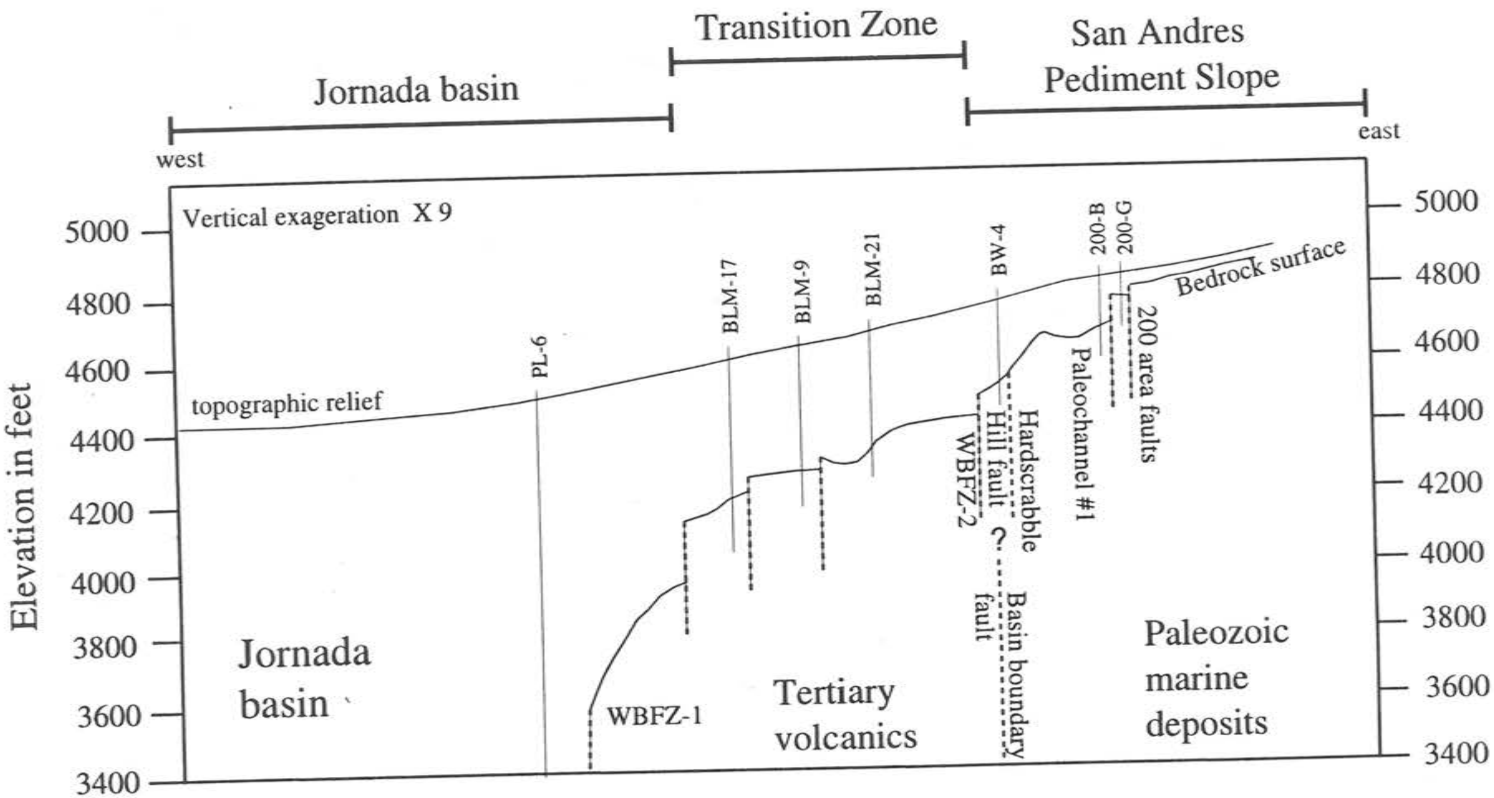


Figure 26. Cross section of the bedrock under the NASA-WSTF. The section is in the identical location as the gravity model, but emphasizes only the facility. The bedrock in this area can be divided into three main zones, each being separated by a RGR fault zone.

section of the NASA–WSTF covers the exact area as the gravity model, as seen in the gravity and magnetics chapter, but emphasizes the structures below the facility. Using a simple formula based on the elevation of the bedrock in two wells, NASA–3 and BLM–9, the average dip on the bedrock surface across the NASA–WSTF is 4–5° down to the west.

The surface of the bedrock varies dramatically, not only compositionally, but structurally. WBFZ–1 has at least 1700 ft (456 m) of displacement and provides the boundary between the Jornada basin and the transition zone. Through gravity modeling, the basin is thought to be around 2600 – 3100 ft (790 – 950 m) deep, with at least one well, PL–6–* penetrating 2000 ft (610 m) of alluvium (Figure 25). Upon crossing over the WBFZ–1 the bedrock drastically increases in elevation. The alluvium in the transition zone is 350 – 750 ft thick.

Most of the faults in the transition zone are probably the results of Rio Grande Rift extensional faulting. A small thrust–like feature on the northern end of fault INT–1 could be an area of localized compression associated with a strike–slip component in the movement along INT–1. Another feature of the transition zone is the flow–banded rhyolite. It trends NNW and terminates north of the thrust like feature. The origin and extent of the rhyolite is unknown (GCL, 1995).

A local high on the central block lies directly southwest of the 600 area. This bedrock high is a small plateau with a depth of approximately 200 ft (60.9 m), based on wells BLM–31 and 100–B, and is bound on three sides by faults. This region also corresponds to the zone of low hydraulic conductivity as seen in the hydrological section (Figure 15). The eastern boundary for the transition zone is the eastern basin boundary fault for the Jornada basin.

East of the basin boundary fault lies the pediment area. The pediment area consists of a thin veneer (0–200 ft) of coalescing alluvial fan deposits overlying faulted bedrock which consisted of mainly Paleozoic marine deposits, but a thin tongue of andesite is lying unconformably upon the Paleozoic rocks (Figure 18). Bedrock beneath the thin pediment alluvial surface is broken by many faults, most of which are probably Rio Grande Rift normal faults, but a few of them may exhibit a left–lateral strike slip motion.

Through gravity interpretation of the NASA–WSTF region, the basin boundary fault was placed through the middle of the base having at least 1.6 miles (2.5 km) of vertical displacement. WBFZ–2 and Hardscrabble Hill combine to form the basin boundary fault, but the total amount of displacement on either fault is unknown. Although through bedrock surface erosional features, it is believed that the Hardscrabble Hill fault is older than the WBFZ–2. This is suggested by the observation that the Hardscrabble Hill fault has no bedrock surface relief on either mapped bedrock outcrop nor imaged on the seismic data, and the WBFZ–2 has at least 40 ft of identifiable displacement.

Two paleochannels were delineated by the top of bedrock mapping. The first trends by the 300 and 400 areas, and the second goes by the 200 and 600 areas. The two join together in the offsite region and trend to the west. In the transition zone, the channel is constricted while flowing between the small structural high to the south and the rhyolite dike to the north. The channel eventually empties into the Jornada basin over the WBFZ–1. Since the paleochannels produce a zone of high hydraulic conductivity, the groundwater is probably funnelled into the channels (GCL, 1995).

The minor faults on the base have an influence on the groundwater system. A majority of the contamination seems to follow the paleochannel through the offsite portion of the NASA–WSTF (Figure 24). But in the onsite region, the contamination also may have followed the faults. This can be seen in the spreading of the contamination away from the paleochannels, especially where the contamination appears to flow upgradient to the regional groundwater flow (Figure 24). As of now, the flow of groundwater through faults has only been interpreted through contamination concentration maps, no actual measurements have been taken to determine the amount of water flowing through or across faults.

SEISMIC SIGNATURE OF THE BEDROCK

Log Information

Another aspect of the seismic interpretation was to examine the feasibility of mapping intra–bedrock reflectors within the existing seismic dataset. The original seismic survey was designed only to image top of bedrock. However, as NASA scientists became increasingly concerned about the vertical extent of contamination, the geometry of intra–bedrock horizons became more important. Of particular interest was a Paleozoic shale layer, informally named the Charlene shale. Drilling data suggests that this shale layer may be an aquatard. After penetrating this layer, the hydrologic conditions changed from being unconfined above the shale to confined below the shale layer. This was noted by an increase in well head below the shale unit. Downhole camera logs also show a significant upward component in the water flow through the well (Geoscience Consulting, LTD. 1995). The possible importance of the Charlene shale is that it could place a bounds on the bottom of the contamination plume in the eastern portion of the NASA–WSTF

Three wells, the 200–F, 200–G, and 600–D have sonic and density logs which were used to generate synthetic seismograms for comparison to the reflection data (Figure 27). Since the logs do not run the full length of the wells, synthetic seismograms were only produced for portions of the wells (Table 3). The 200–F and 200–G wells encountered Paleozoic strata, while well 600–D penetrates into the Tertiary volcanic portion of the bedrock. Thus, the synthetic seismograms from these wells should be representative of the two primary bedrock types located within the NASA–WSTF.

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Another aspect of the seismic interpretation was to examine the feasibility of mapping intra–bedrock reflectors within the existing seismic dataset. The original seismic survey was designed only to image top of bedrock. However, as NASA scientists became increasingly concerned about the vertical extent of contamination, the geometry of intra–bedrock horizons became more important. Of particular interest was a Paleozoic shale layer, informally named the Charlene shale. Drilling data suggests that this shale layer may be an aquatard. After penetrating this layer, the hydrologic conditions changed from being unconfined above the shale to confined below the shale layer. This was noted by an increase in well head below the shale unit. Downhole camera logs also show a significant upward component in the water flow through the well (Geoscience Consulting, LTD. 1995). The possible importance of the Charlene shale is that it could place a bounds on the bottom of the contamination plume in the eastern portion of the NASA–WSTF

Three wells, the 200–F, 200–G, and 600–D have sonic and density logs which were used to generate synthetic seismograms for comparison to the reflection data (Figure 27). Since the logs do not run the full length of the wells, synthetic seismograms were only produced for portions of the wells (Table 3). The 200–F and 200–G wells encountered Paleozoic strata, while well 600–D penetrates into the Tertiary volcanic portion of the bedrock. Thus, the synthetic seismograms from these wells should be representative of the two primary bedrock types located within the NASA–WSTF.

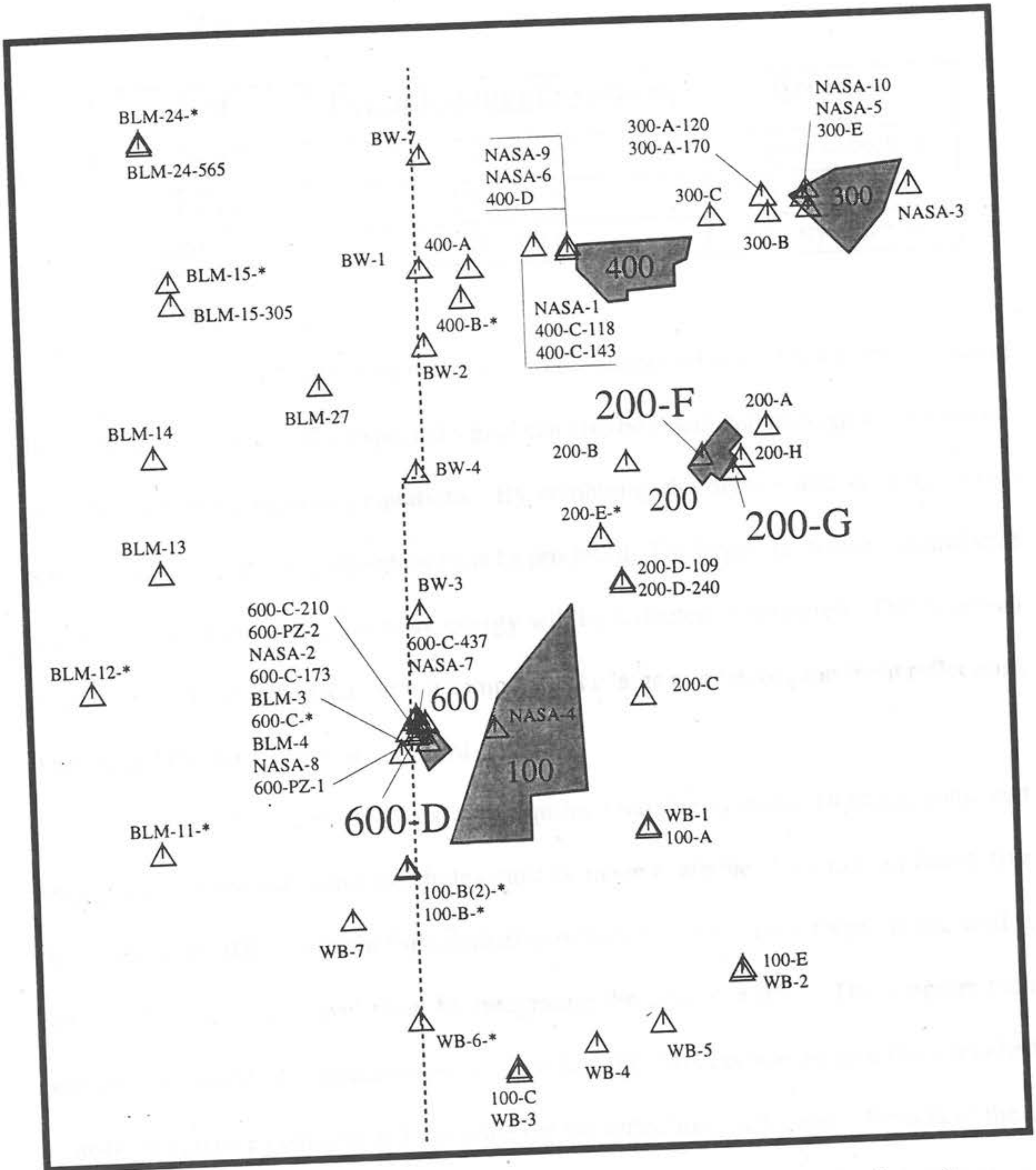

Figure 27. Location of the 200-F, 200-G and 600-D wells used in the density and velocity averages of the lithologies. These wells are also the locations of the synthetic seismograms used to tie the seismic signature to the formations. Wells 200-F and 200-G were completed in Paleozoic bedrock, while the 600-D well encounters Tertiary volcanics.

Table 3. Well log depth and bedrock type encountered for the three wells of interest.

Well	Depth Extent of Synthetic	Bedrock
200–F	130–590 ft	Paleozoic section
200–G	130–450 ft	Paleozoic section
600–D	200–700 ft	Tertiary andesite

Reflection seismograms represent records of energy reflected back to the surface of the earth due to a source. The expected signal can also be calculated through a combination of Snells law and Zoeppritz's equations. By combining the density and velocity of two geologic layers, an acoustic impedance can be produced. The larger the acoustic impedance is between two rock layers, the more energy will be reflected or refracted. The observed waveform received at the recorder is a composite of a large number of prominent reflections (Sheriff and Geldard, 1995; and Telford, 1990).

Creation of synthetic seismograms requires a number of steps. Digitized sonic and density logs for the individual boreholes must be made available to *Vsynth*, an Interactive Data Language (IDL) program for calculating reflection coefficients. Depth in the well is converted to two–way travel time, by integrating the sonic log data. The program then calculates a smoothed impedance curve. The last IDL process was to take the smoothed acoustic impedance contrasts and calculate out the reflection coefficients. Results of these steps are shown in Figures 28 and 29 for well 200–F, Figures 30 and 31 for well 200–G and Figures 32 and 33 for the 600–D well.

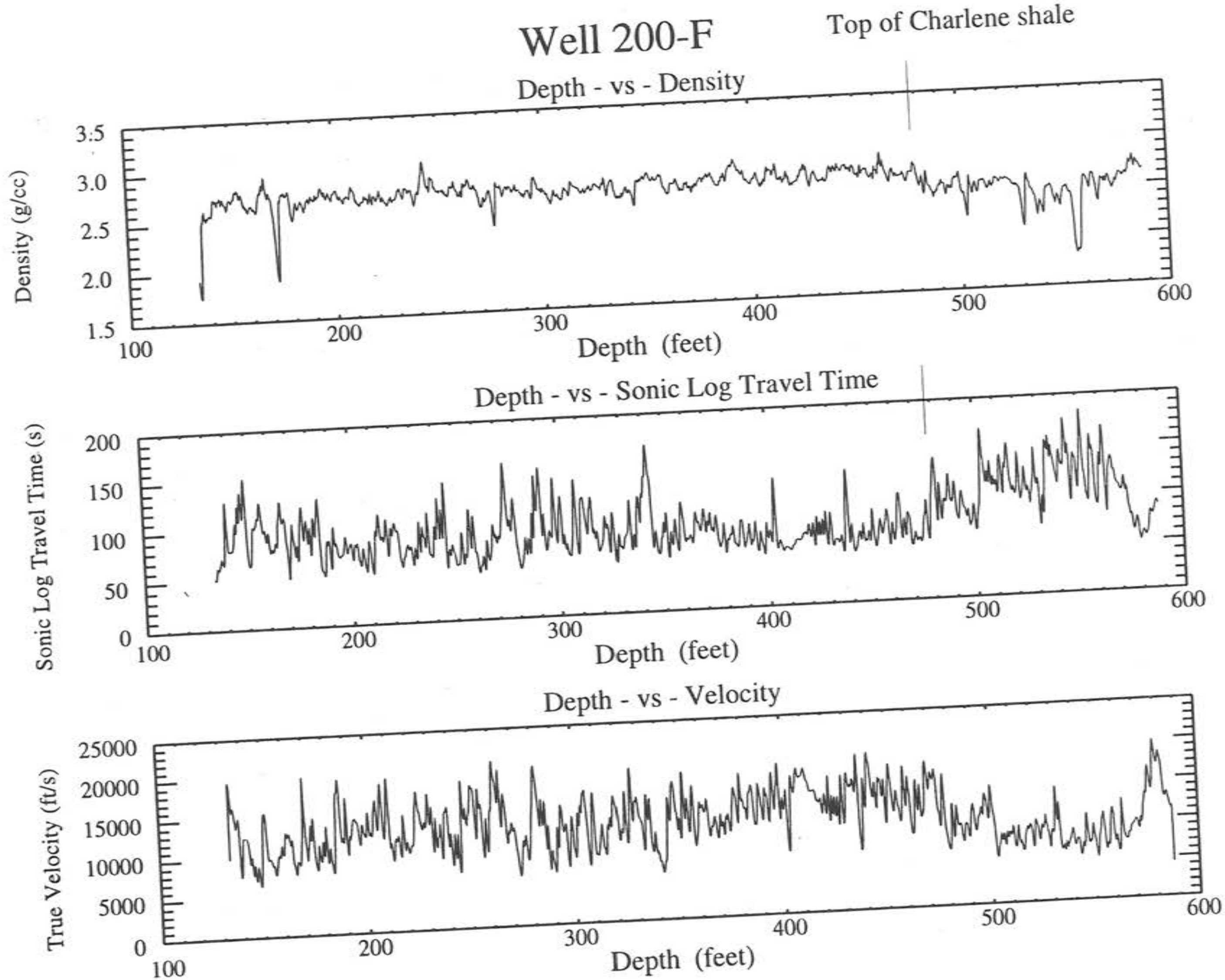

Figure 28. Density and sonic log data for the 200-F well.

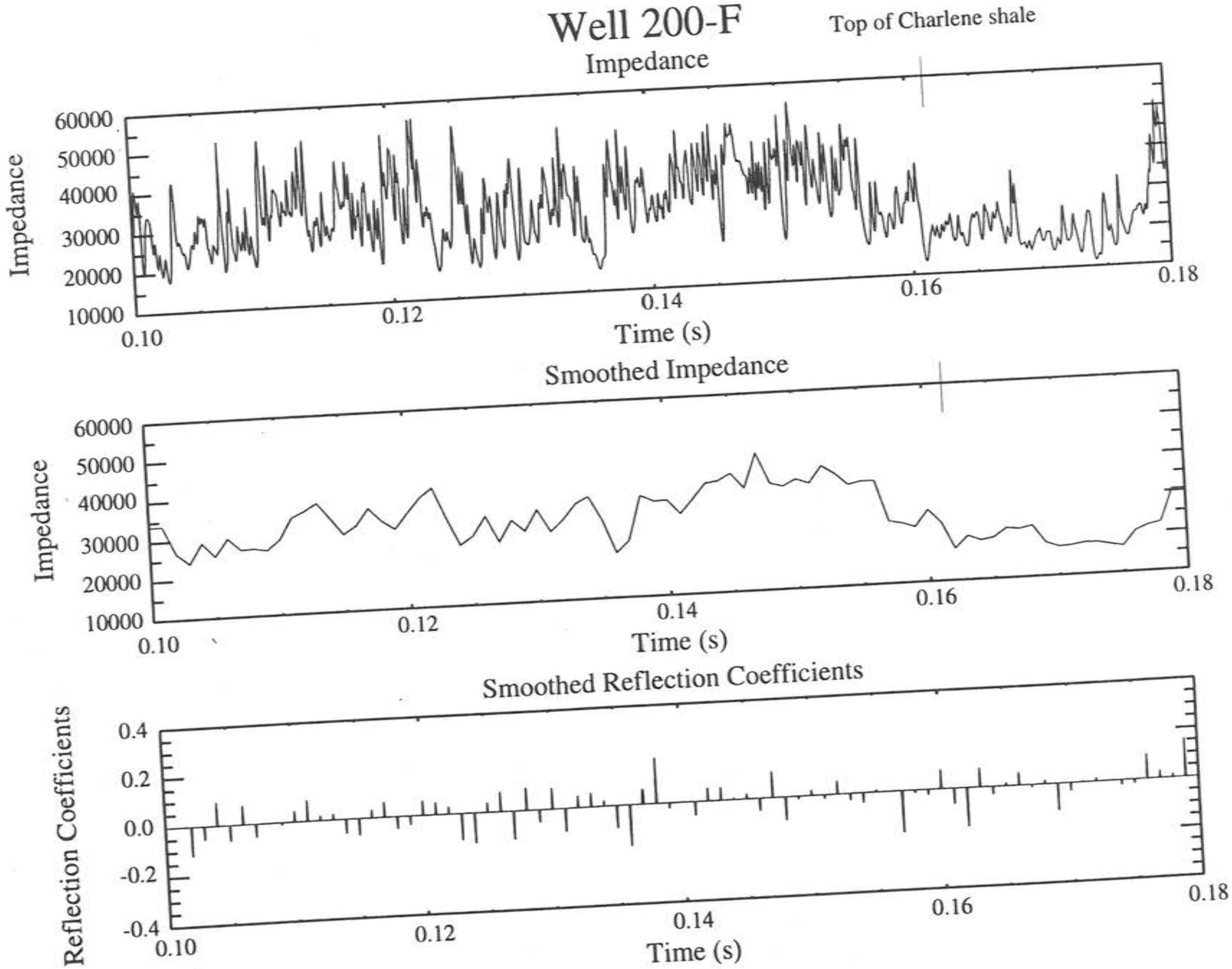

Figure 29. Impedance and reflection coefficients for well 200-F.

Well 200-G

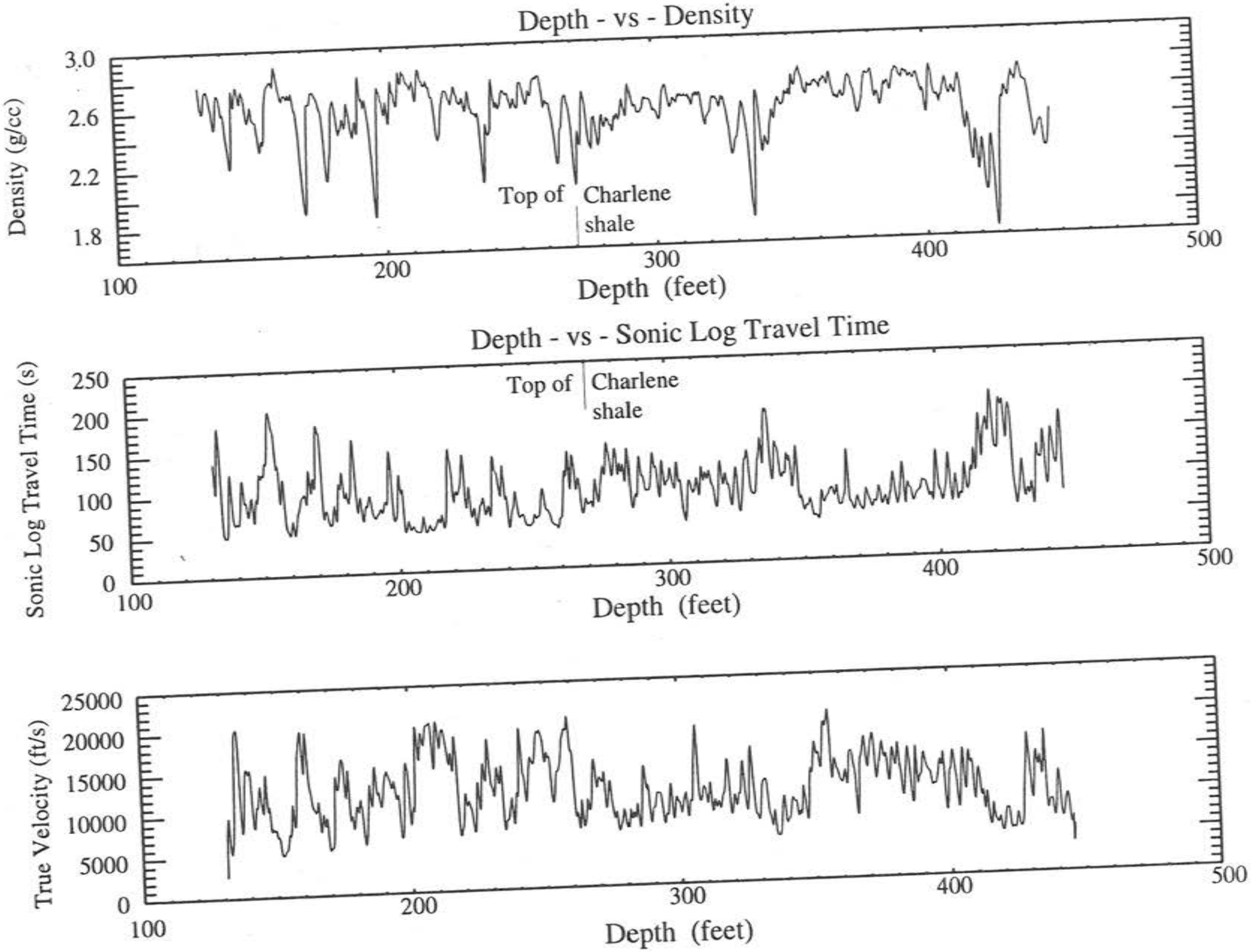

Figure 30. Density and sonic log data for the 200-G well.

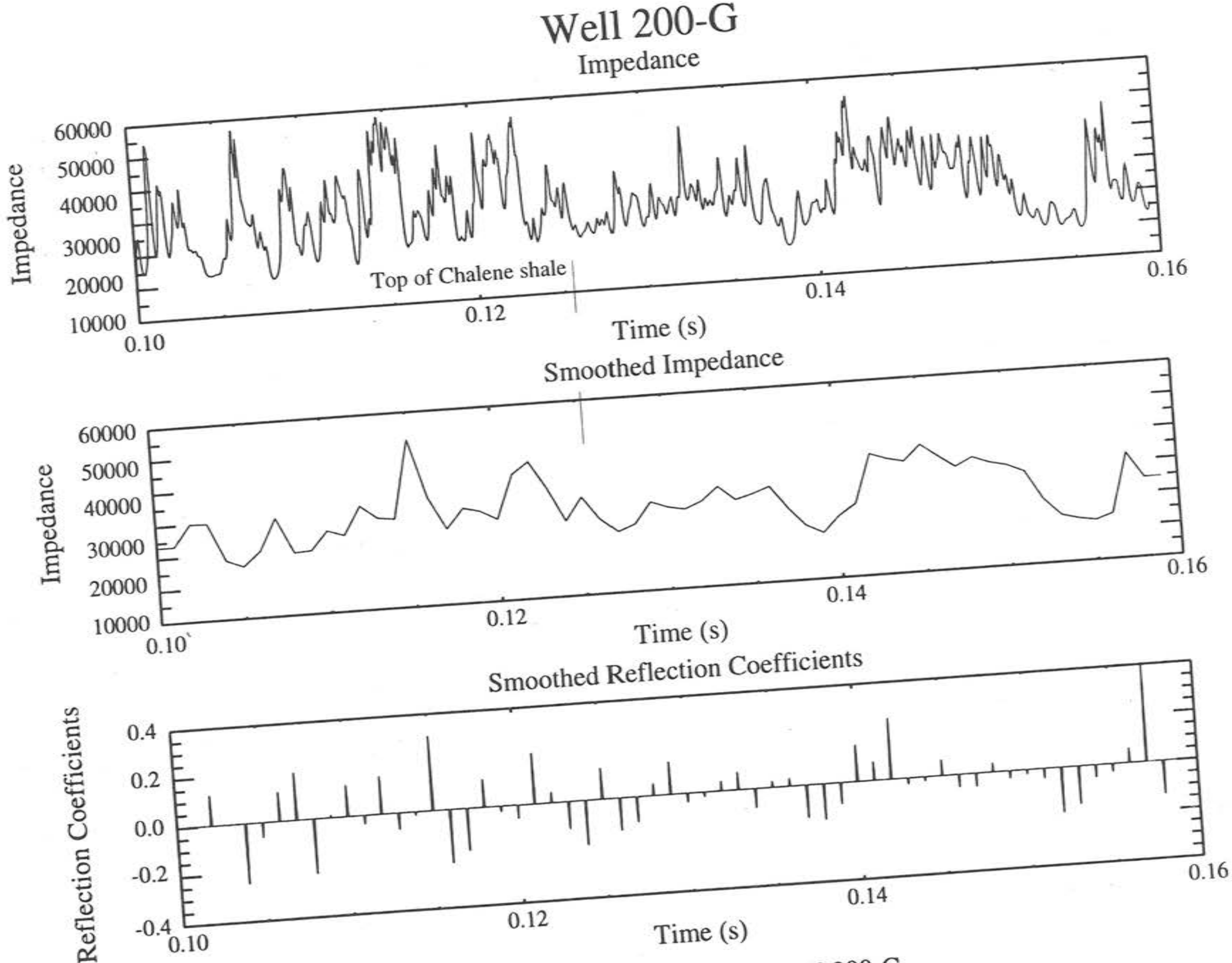

Figure 31. Impedance and reflection coefficients for well 200-G.

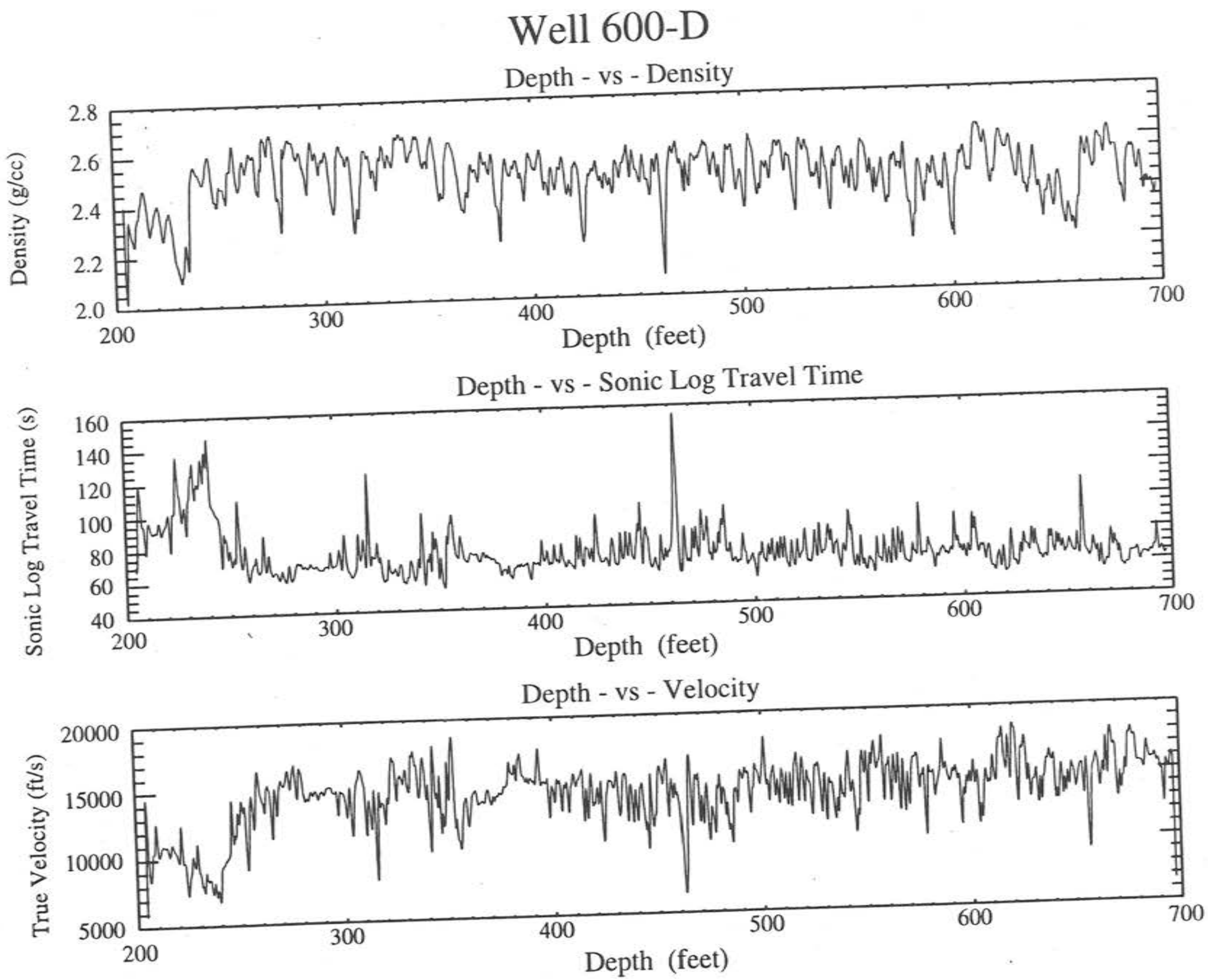

Figure 32. Density and sonic log data for the 600-D well.

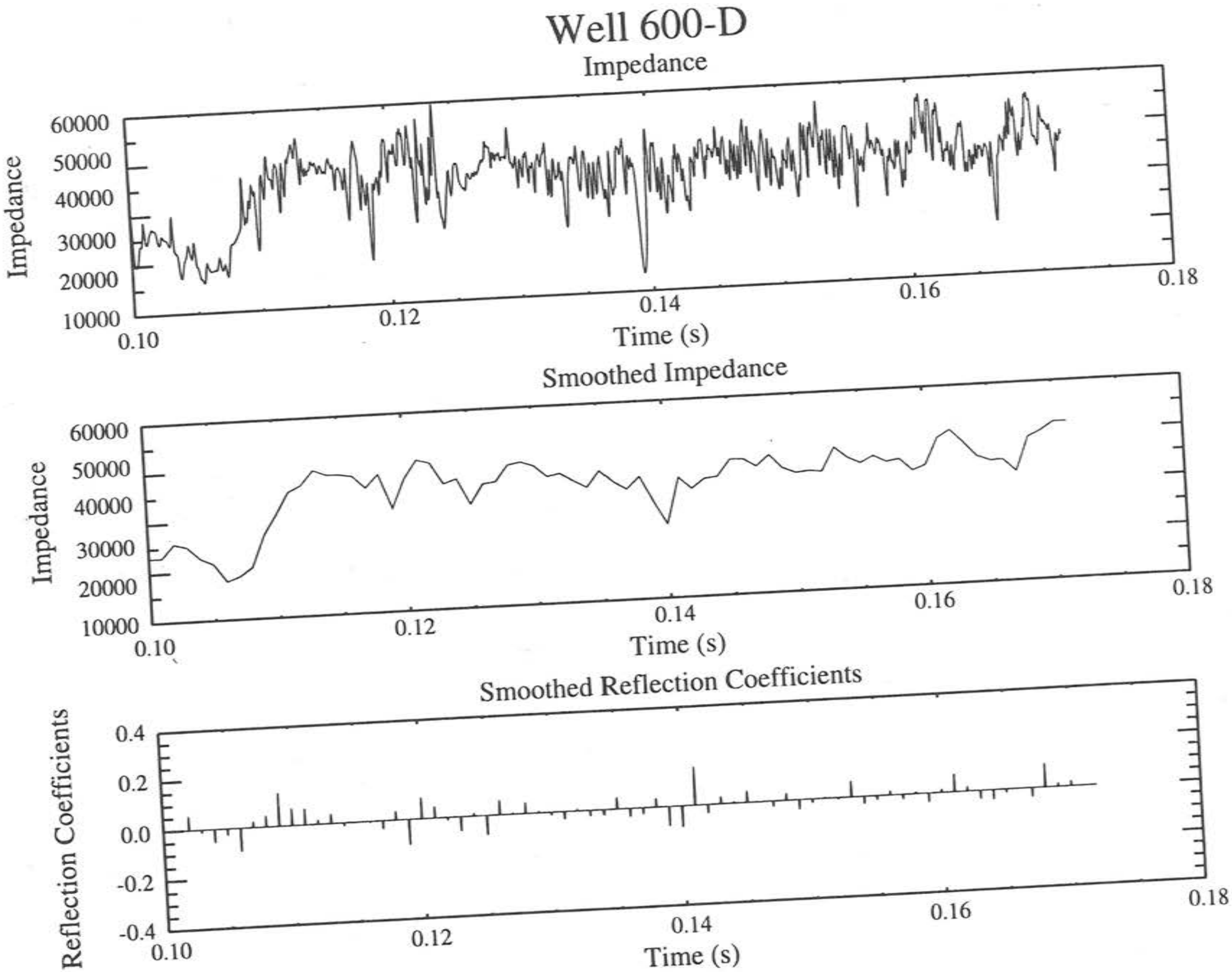

Figure 33. Impedance and reflection coefficients in for well 600-D.

The typical shallow reflection coefficient is $\approx$0.045 and a sandstone to limestone contact is on the order of 0.2 (Telford, 1990). The reflection coefficients within the Paleozoic bedrock are very high as seen in wells 200–F and 200–G (Figures 29 and 31), often greater then 0.1 and as high as 0.4. Conversely, the andesitic portion of the bedrock has only a few reflection coefficients as high as 0.1 as seen the 600–D well (Figure 33). The high reflection coefficients in the andesite could be due to localized fracturing, weathering associated with the movement of the groundwater, or volcanic flow boundaries within the sequence. They could also be due to velocity and density differences associated with different amounts of welding in the individual tuffaceous units.

Examination of the reflection coefficient series from these wells brings out features important to intra–bedrock mapping efforts. First, the velocity and density differences within the Paleozoic portion of the bedrock are high, thus make intra–bedrock mapping feasible. Secondly, the reflection signature of the Tertiary volcanics is significantly different than the Paleozoic section.

The last step in producing the synthetic seismograms was to filter the reflection coefficients. By applying several bandpass filters to the reflection coefficients, a filter panel of synthetics was generated (Figure 34). The bandpass filter 5–10–80–120 seemed to provide the best match to the seismic data. Thus, the reflection coefficients from all three wells were filtered using this bandpass filter: 200–F (Figure 35), 200–G (Figure 36), and 600–D (Figure 37).

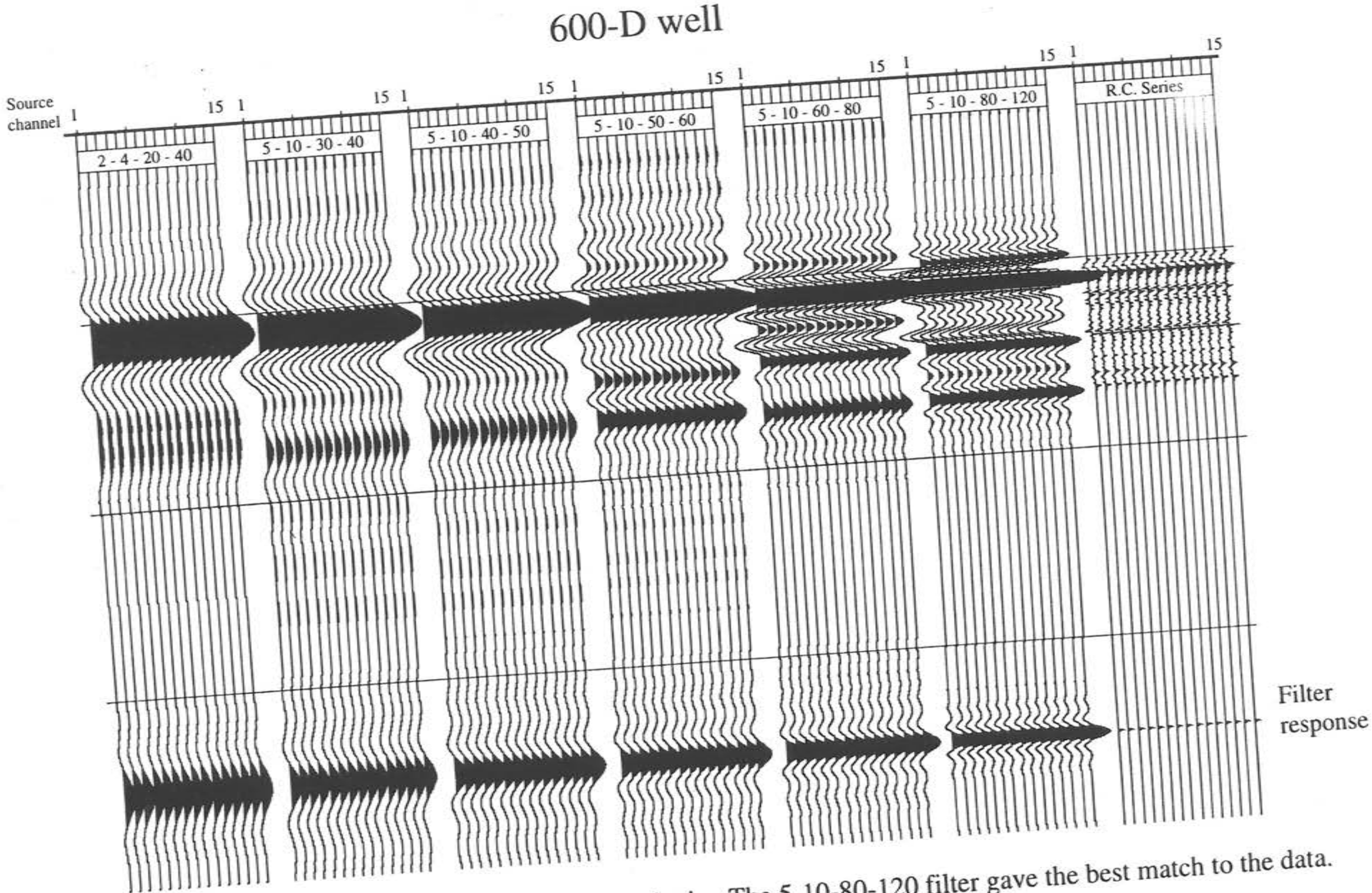

Figure 34. Example of filter panels for well 600-D synthetic. The 5-10-80-120 filter gave the best match to the data.

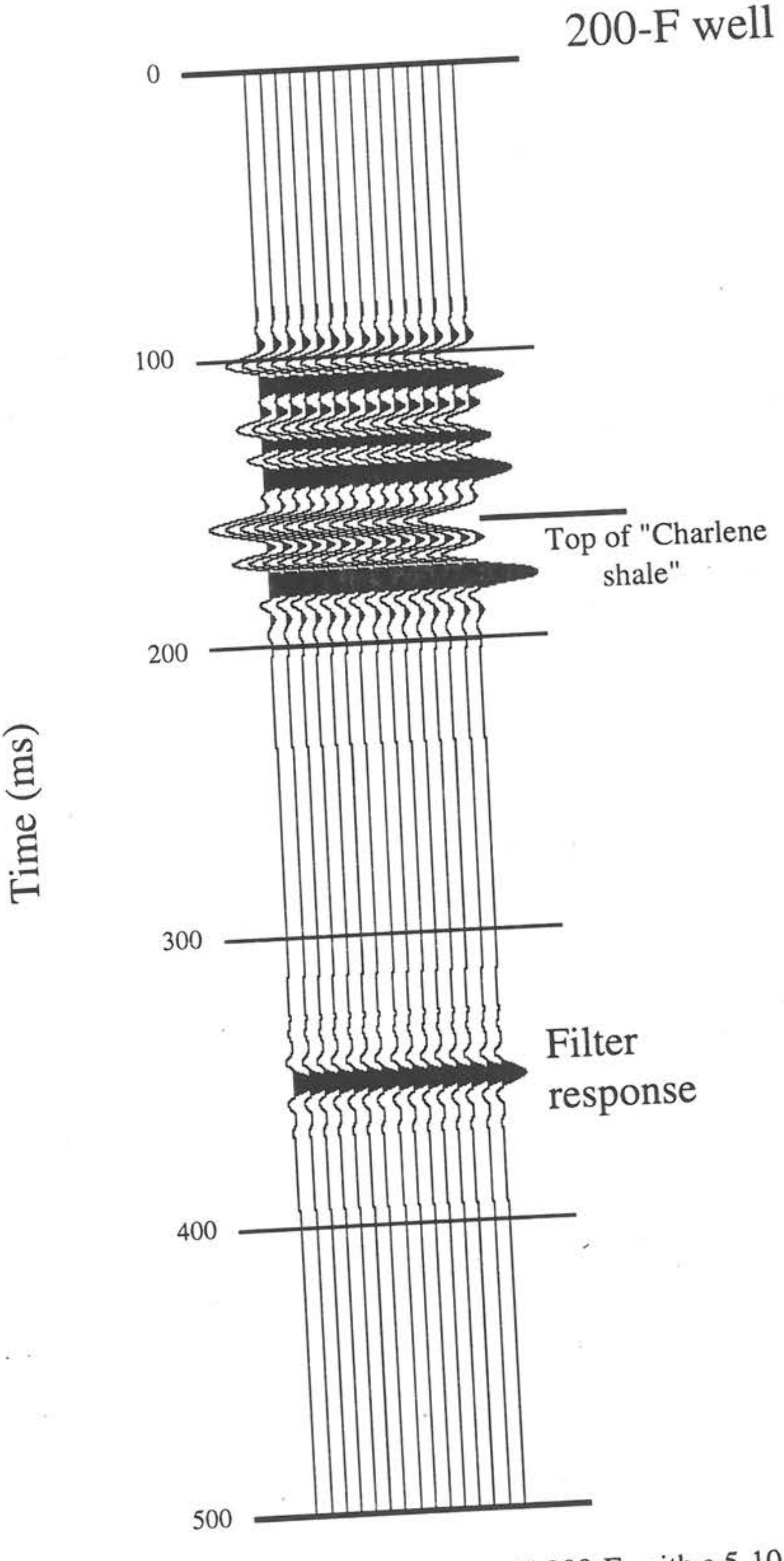

Figure 35. Synthetic seismogram from well 200-F, with a 5-10-80-120 bandpass filter applied.

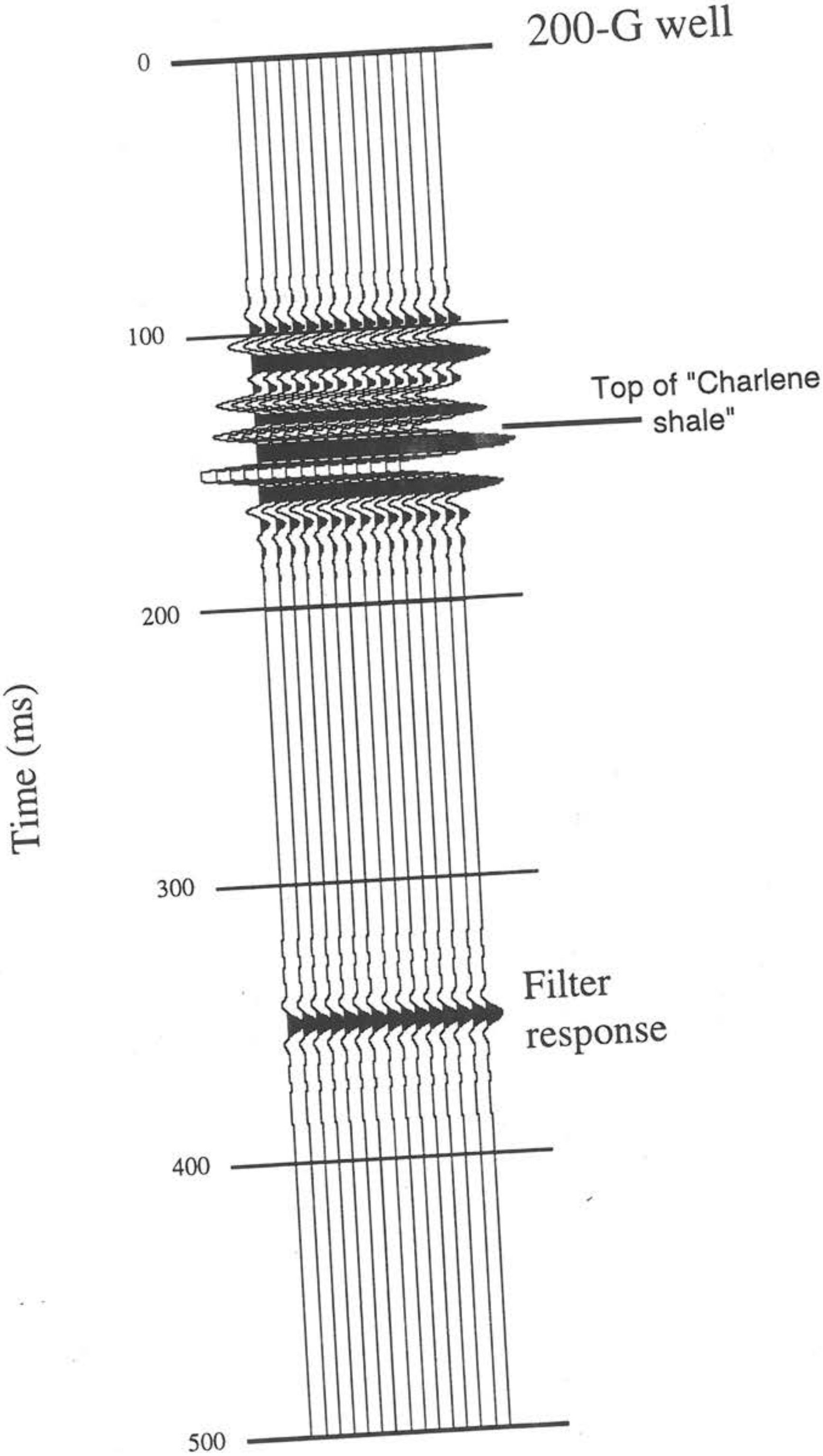

Figure 36. Synthetic seismogram from well 200-G, with a 5-10-80-120 bandpass filter applied.

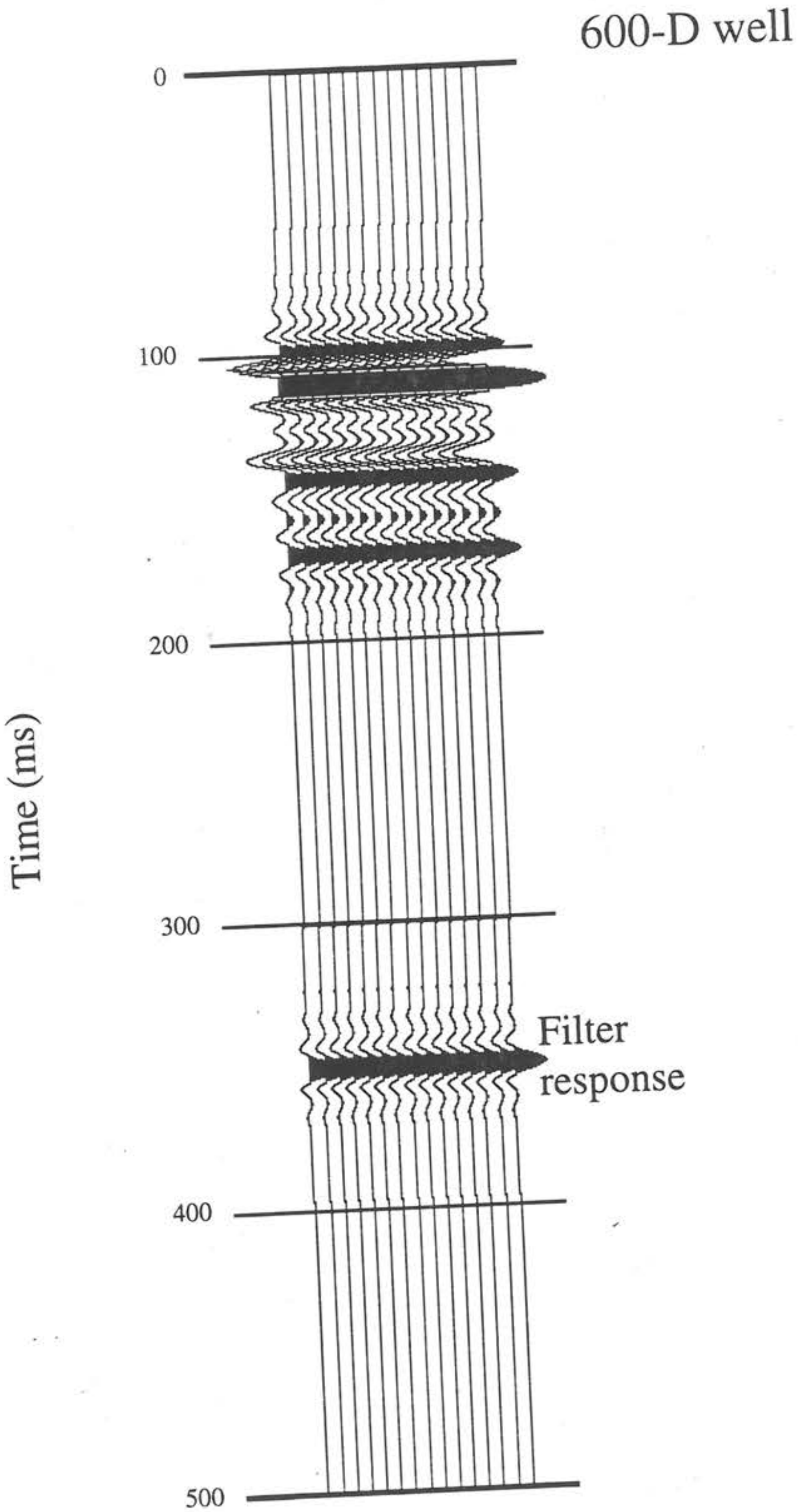

Figure 37. Synthetic seismogram from well 600-D, with a 5-10-80-120 bandpass filter applied.

Since the 200–F well is located at the end of GC–11, its synthetic was tied to the seismic data (Figure 38). At first, correlation between the synthetic and seismogram is apparent, but structural evidence suggests that this conclusion is unreliable. Outcrop information from Seager (1981), triangulation between wellbores on the top of the Charlene shale (200–G, 200–G, and 200–H), and dip measurements on well core from well 200–D (Geoscience Consultants. LTD, 1995) all point to a 30 – 35° northwest dip on the Paleozoic strata.

A comparison of raw shot records from GC–2 to synthetic shot gathers (Figure 39), shows that the horizons within the bedrock are probably not being imaged on the seismic data. The two reasons for this are: 1) the "soft" weight used to eliminate bouncing also appears to have produced large, unwanted surface waves. As a result, filters were applied in an attempt to suppress them during data acquisition and processing; 2) in addition, a velocity filter was applied to the recorded signal, which is the appropriate data processing procedure for reducing surface wave distortion of the signal (Charles B. Reynolds & Associates, 1987).

Charles B. Reynolds & Associates (1987) also indicates that a coherency filter which "enhances seismic events oriented at less than approximately 20° from the horizontal" was applied to the data. This is also an appropriate procedure since the sought after top of bedrock dips on average 4° to the west; unfortunately, the same filter would attenuate the Paleozoic intra–bedrock reflections dipping at 30 – 35°. Since the seismic survey was designed to image the bedrock surface and not intra–bedrock horizons, the acquisition parameters are not optimal for mapping intra–bedrock features such as the surface of the Charlene shale.

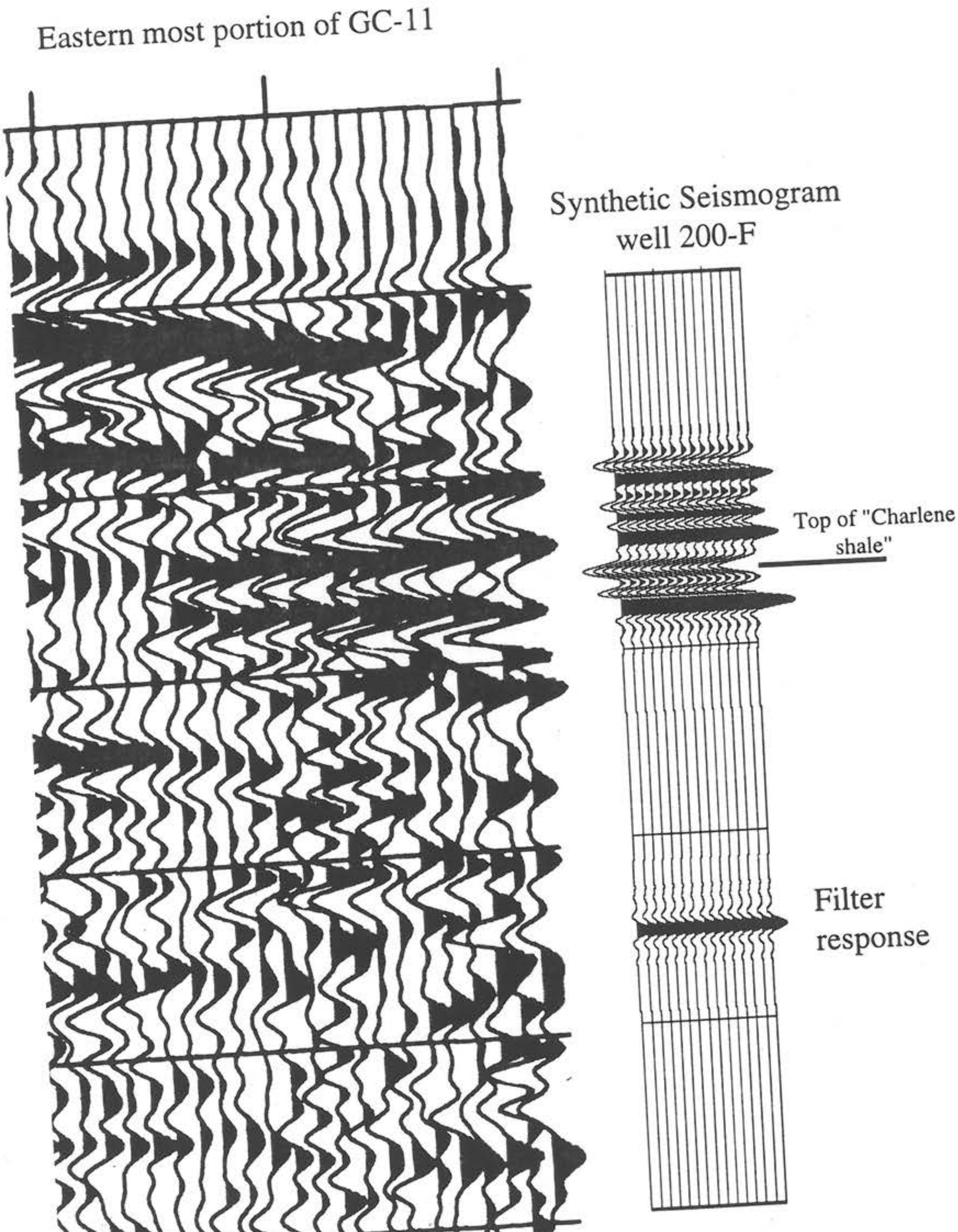

Figure 38. By comparing the synthetic seismogram from well 200-F to GC-11, correlation is apparent, but other evidence suggests otherwise. Outcrop mapping and well cores point to a 30-35 dip. This dip is not imaged in the seismic data

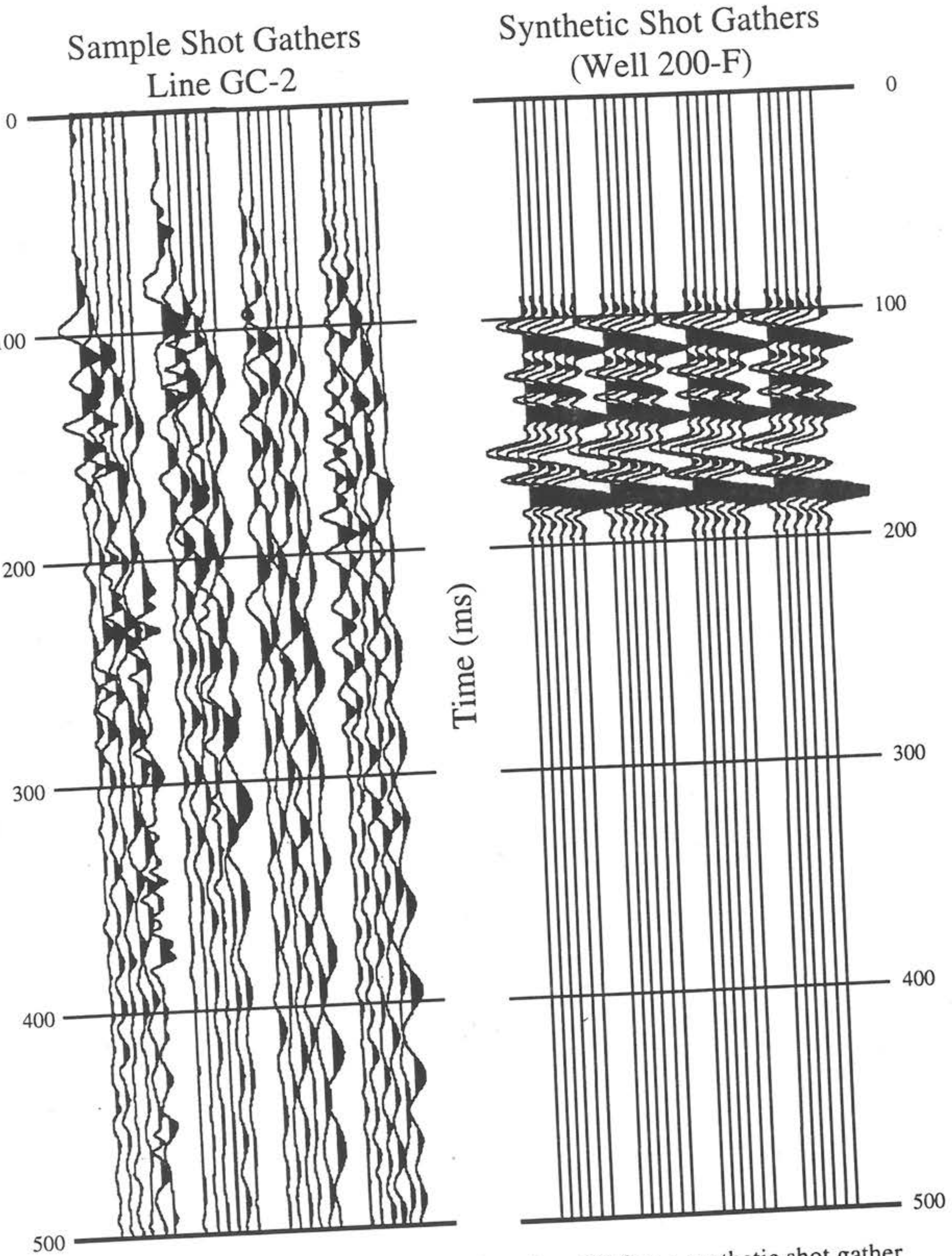

Figure 39. Comparison of raw shot record from line GC-2 to a synthetic shot gather from the 200-F well. Note that the raw shot records lacks reflected energy and are dominated by surface wave energy.

GRAVITY AND MAGNETICS

Introduction

As seen in the previous chapter, the quality of the seismic data is relatively poor; consequently, well information had to be used to find the bedrock/alluvial horizon on the seismograms. Where there are no wells, another method was needed to determine depth to bedrock. Gravity modeling provided the means to calculate this depth. Interpretation of the gravity should also aid in locating large faults (WBFZ–1 and the eastern basin boundary fault) and estimating their total vertical displacement. The gravity model will be constrained with known depth to bedrock locations and also rock density information obtained from well logs. The gravity in conjunction with a magnetic survey helps trace major lithological changes in the bedrock associated with the eastern basin boundary fault

Gravity Acquisition and Processing

The University of Texas at El Paso (UTEP) has been compiling a national gravity database for the past two decades. This database contains millions of gravity stations, which have been reduced to Bouguer anomaly values using correction processes outlined in Cordell et al. (1982). The parameters included in the data reduction include an average crustal density of 2.67 g/cc, datum at sea–level, and terrain corrections as described by Plouff (1977).

A search of the UTEP gravity database for the NASA–WSTF region yielded 5 data points within the site boundary, one of which was later eliminated because it was determined to be a bad point (Figure 40). The station in question was re–occupied during the gravity

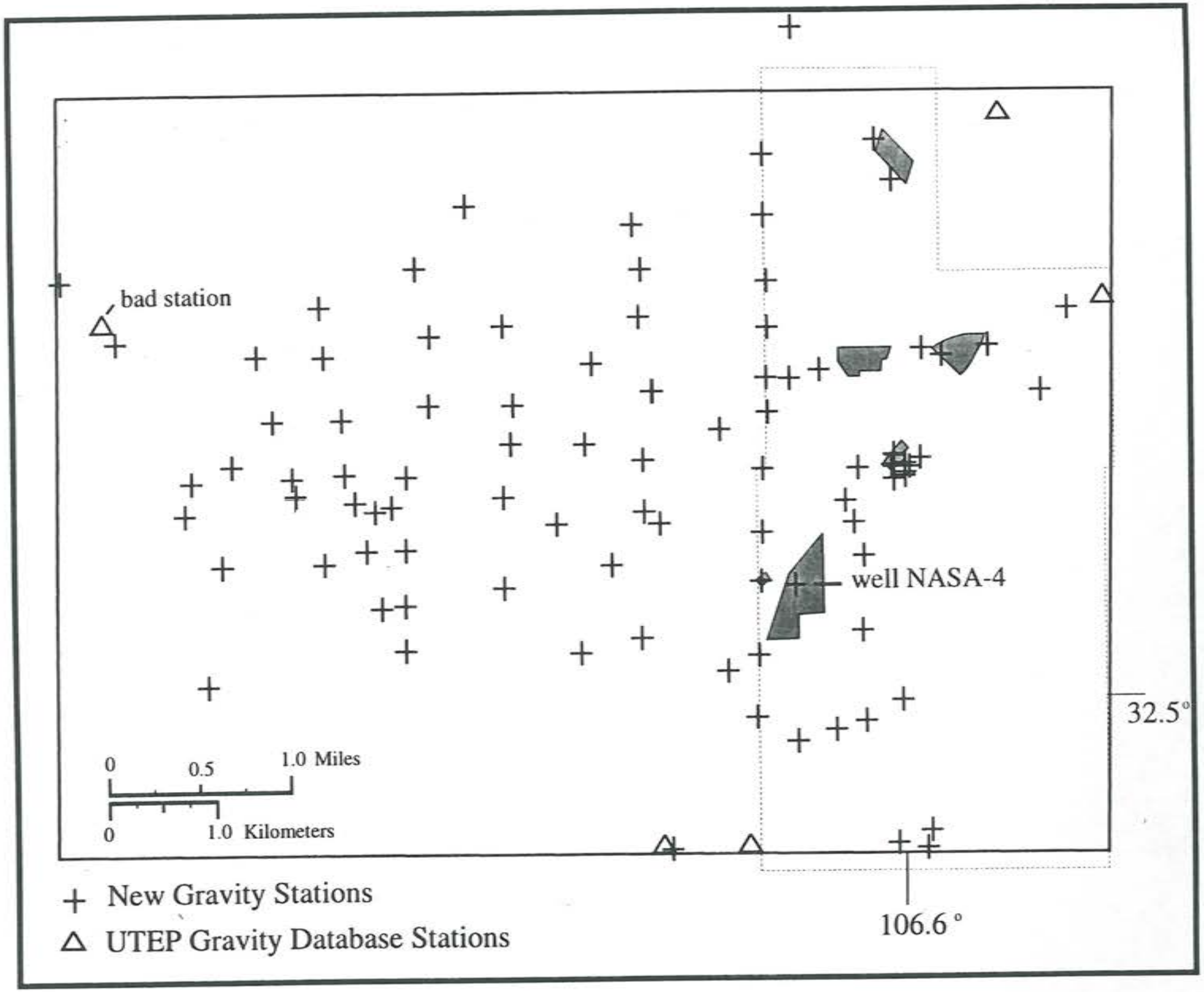

Figure 40. Locations of the old and new gravity stations within the perimeter of the NASA-WSTF. The lack of data within the UTEP database prompted the gravity study.

survey and the database value was 10 mGals off of the new reading. These gravity values range from –149 to –167 mGals and decrease from east to west across the site.

Since the gravity data was so sparse across the site, a small gravity survey of the NASA–WSTF was undertaken in order to obtain better coverage during the summer of 1995. A total of 95 new gravity locations were gathered in and around the base during this survey. Since most of the well sites had already been surveyed, their locations were used for the gravity survey. Well NASA–4 was established as the base station for the survey, and every new gravity station was tied to this point (Figure 40). NASA–4 was then tied to the closest national gravity base station, which is located 19.9 miles (32 km) to the southwest in Las Cruces. The tie between NASA–4 and Las Cruces was established by measuring the difference between gravity readings at the two stations ten times and then taking their average.

The survey was done using a Worden Gravimeter. At every location the dial reading, time, well name, and terrain differences were noted. The location and elevation of each station were later obtained through a database of well information provided by NASA–WSTF. The data was then reduced on a UNIX computing system using the UTEP program, *Gravreduce*. Given the information stated above along with the absolute gravity value of the base station as input, the program calculates the absolute gravity at all of the stations correcting for instrument drift, changes in gravity due to terrain, latitude, free air effect, and the Bouguer effect (Telford et al., 1990). An average crustal density of 2.67 g/cc along with a machine constant of 0.0943 dial units/mGal and inner terrain corrections for every station were used in the reduction of the gravity data. After correction, the new data were merged with the data obtained from the database. Two maps were produced from the reduced gravity data: 1) a Bouguer gravity map of the NASA–WSTF and 2) a more regional Bouguer gravity map.

NASA–WSTF Gravity Map

The first step in producing the local Bouguer gravity anomaly map was to search the database using the *GRAV* program, a home developed program from the UTEP Geological Sciences Department. *GRAV* consists of a series of steps used for processing and contouring gravity and magnetic data. This program uses the minimum curvature technique for gridding (Swain, 1976).

In order to reduce edge effects caused by the contouring algorithm when it encounters an open edge, an area larger than the area of interest was searched. The search area was from 32.43° to 32.56° latitude and –106.75° to –106.53° longitude. The 54 stations obtained by the search were combined with the 95 new stations from the survey, and reintroduced into *GRAV* for processing. The gravity data was gridded at a 400 m interval. This grid interval provided the best coverage for the region, a tighter coverage could not be used due to the sparseness of data outside of the NASA–WSTF. The grid was then unprojected and contoured.

The resulting Bouguer gravity was plotted using the *MAPPER* program, another UTEP program that projects and plots data. The gravity grid was used to generate a contour map with a 2 mGal contour interval (Figure 41). The Bouguer gravity decreases from –146 to –179 mGals trending from NE to SW across the site. Gravity modeling, discussed later in

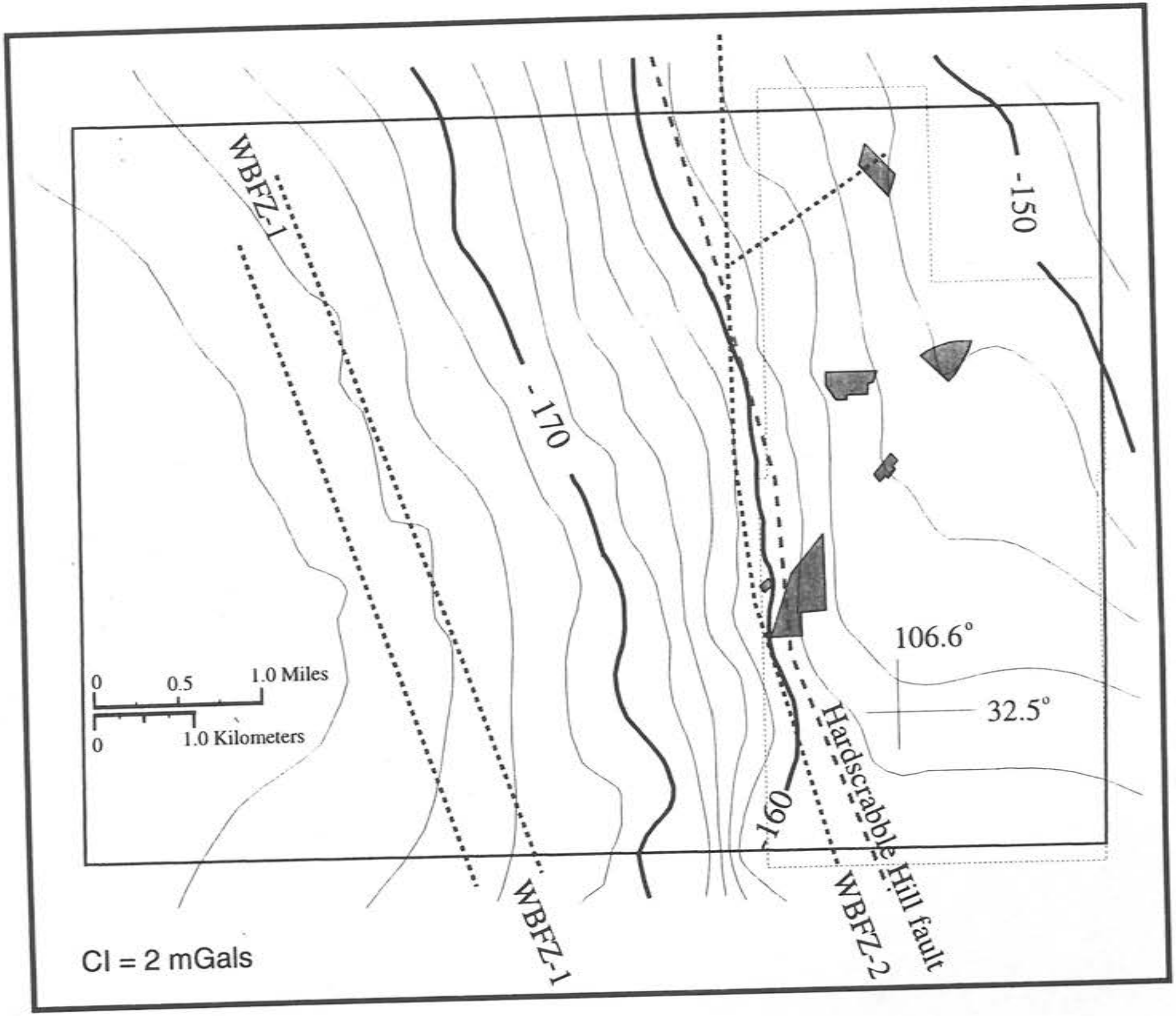

Figure 41. Contours of Bouguer gravity across the NASA-WSTF and the location of the major faults in the area, as imaged by seismic interpretation. The large gravity gradient, 5mGals/mile, produced by the eastern basin boundary fault, masks the gravity signatures of the smaller faults.

this section, shows that the gravity gradient is due to a combination of faulting which downdrops the basin to the west, and a lithologic change from Paleozoic section to Tertiary volcanics across the eastern basin boundary faults.

Regional Gravity Map

Using the UTEP gravity database, the region of 32° to 33° latitude and –107° to –106° longitude was searched for existing data. The 95 stations from the site survey were combined with over 2400 stations from the database. *GRAV* was used to grid the data at a 1000 m interval and then contour it at a 5 mGal interval (Figure 42).

A better sense for the bedrock structure can be obtained from this map. The San Andres Mountains are represented by the gravity highs trending north–south through the northeastern part of the map. The Jornada basin produces the gravity low directly to the west of the site. Assuming that changes in the gravity field can be associated with the changes in bedrock elevation, the lowest values of gravity may be associated with the deepest portions of the basin.

Magnetics

The UTEP database also contains airborne magnetic data. Unfortunately, the data only covers the western portion of the NASA–WSTF, leaving the eastern portion of the site uncovered. The magnetic database was searched for the same region as the gravity. The recovered data were plotted and contoured to produce a total intensity magnetic anomaly map (Figure 43). Even though only half of the facility is covered, a general decrease in the magnetic readings from north to south can be observed. Due to the lack of data, a magnetic

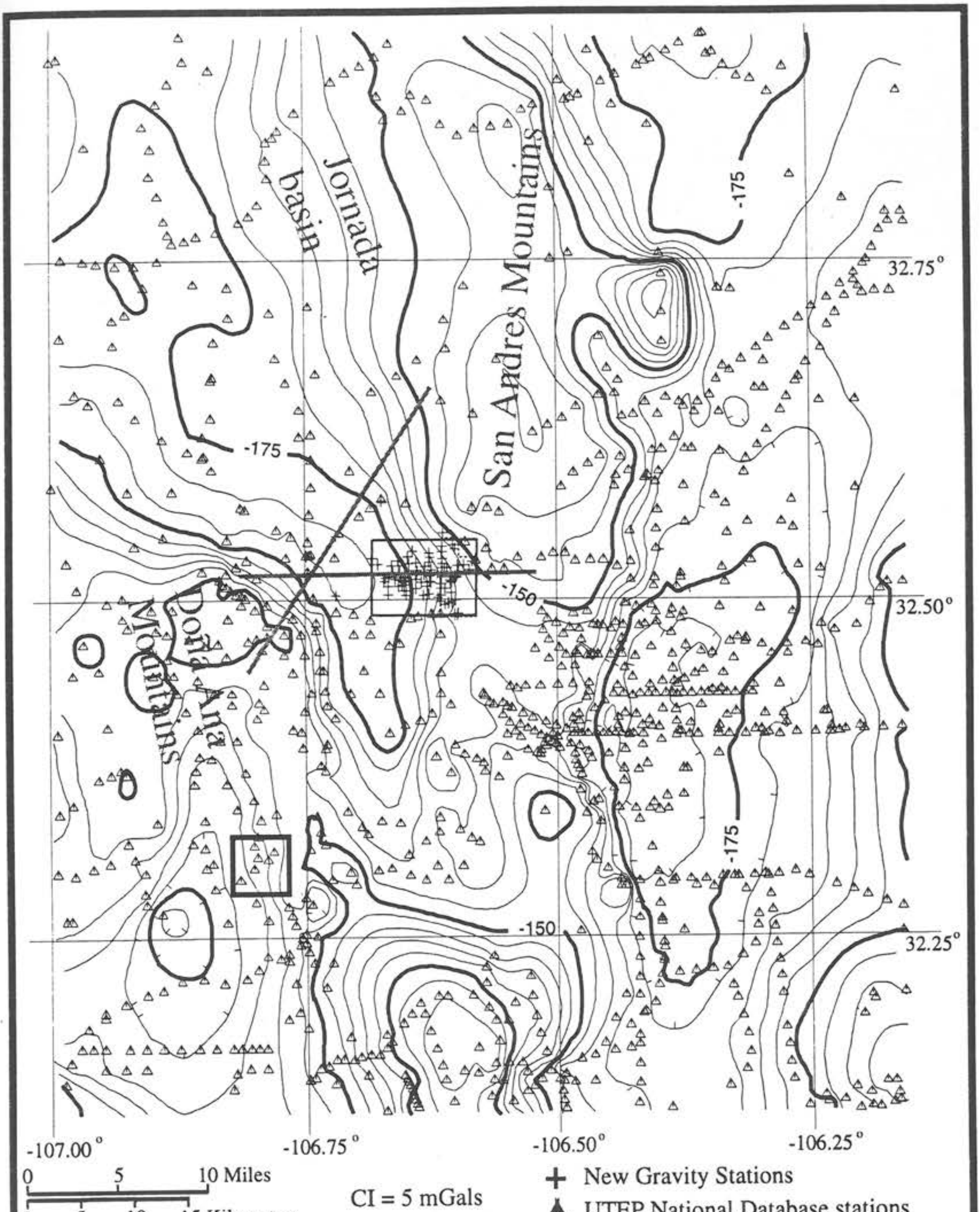

Figure 42. Regional gravity stations and contours. The small square in the southwestern portion of the map is the city of Las Cruces, New Mexico. The grey dashed lines represent the location of two gravity model cross sections. The east-west line is from this report and the NE-SW line is from Gilmer et al. (1986). Low gravity values in the northwest suggest deepening of the Jornada basin.

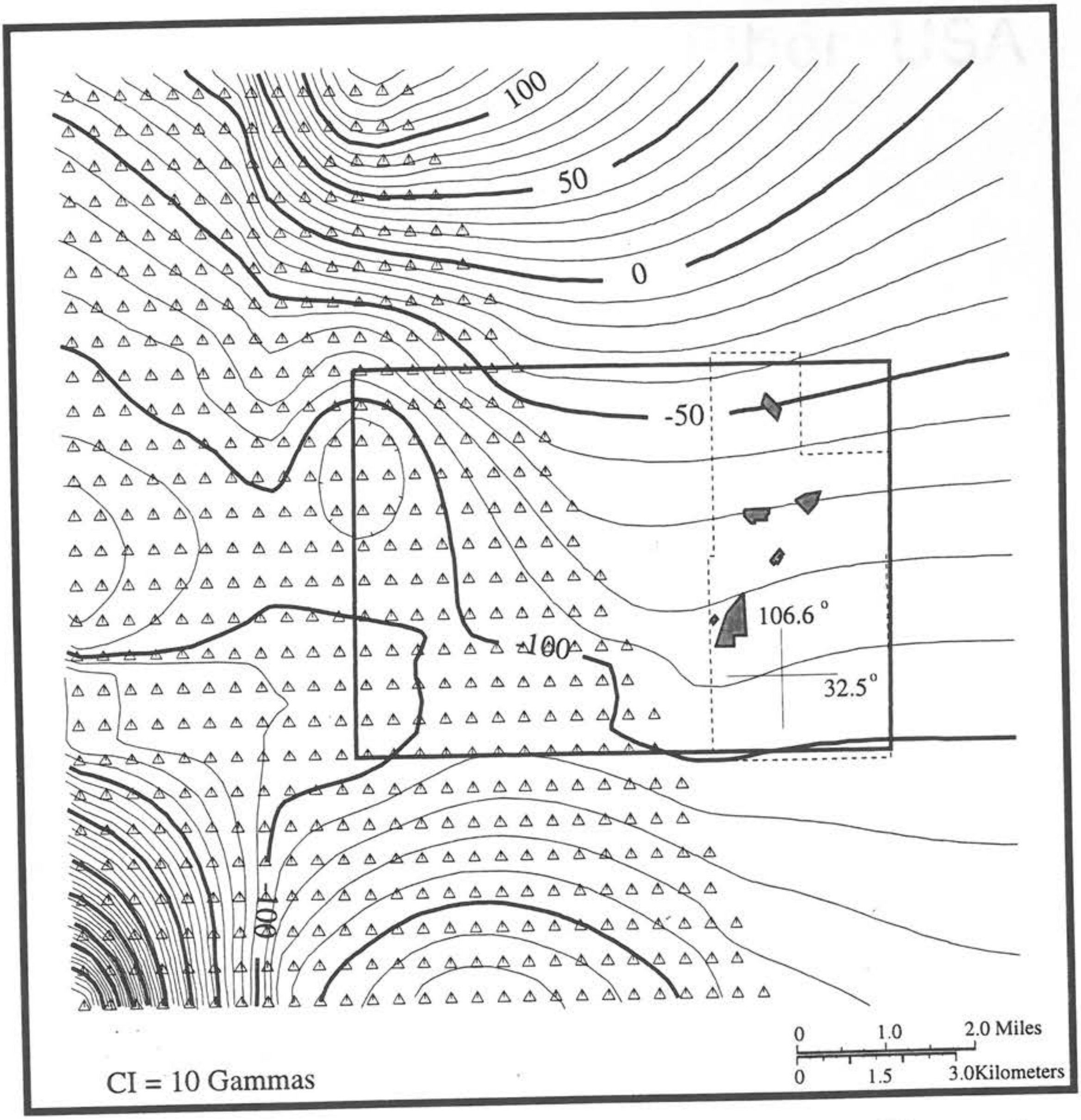

Figure 43. Magnetic data from the UTEP airborne magnetic database. The general decrease in intensity from north to south may be associated with the Bear Peak thrust.

survey was undertaken in conjunction with the gravity survey during the summer of 1995. The survey was done using a proton–precession magnetometer.

The data from the survey was first processed in Excel to compensate for the assumed linear drift caused by the solar radiation and instrument drift. It was then processed in exactly the same manner as the gravity data, producing a contour map of the relative magnetic intensity in the region (Figure 44). The differences between the two magnetic data sets can be accounted for by the differences in the survey heights. The ground survey is more susceptible to the effects of the underlying bedrock types and man–made anomalies. Hidden power lines and the effects of the radiating energy from buildings cause the magnetic data to fluctuate across the facility. The worst stations were deleted from the dataset before contouring, leaving only 85 stations within the perimeter of the base.

A gray–scale plot of the data suggests a general increase in the magnetic readings from east to west (Figure 45). This may be the result of the different rock types juxtaposed next to each other across the Hardscrabble Hill fault. Andesite should have a higher magnetic susceptibility than marine deposits; hence the higher magnetic readings to the west.

Gravity Modeling

An east–west trending gravity model that starts in the Doña Ana Mountains, crosses the Jornada basin and terminates 2.8 miles (4.6 km) east of the NASA–WSTF was constructed in an effort to constrain displacement along the eastern basin boundary fault, and also determine depth to bedrock on the eastern portion of the facility. The bedrock west of the WBFZ–1 can not be imaged with the present seismic data because of the quality of the data and the length of the seismograms, as a result, the displacement along the WBFZ–1 is

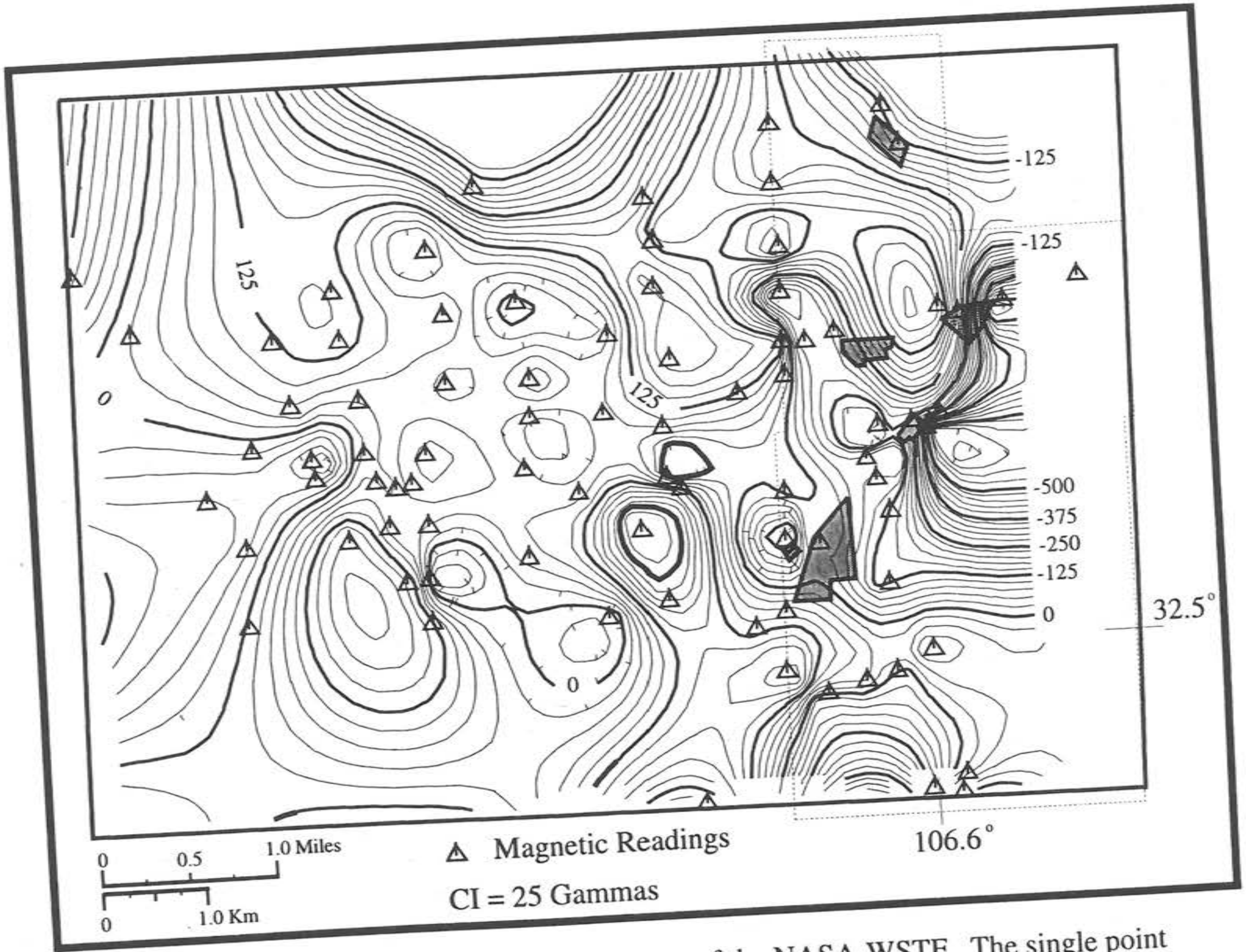

Figure 44. Magnetic readings from the 1995 survey of the NASA-WSTF. The single point anomalies are produced from the interference of power lines, metal culverts, or energy radiating from buildings. The two anomalies in the northern portion of the base were removed because they were produced from the gridding algorithm rather then actual data.

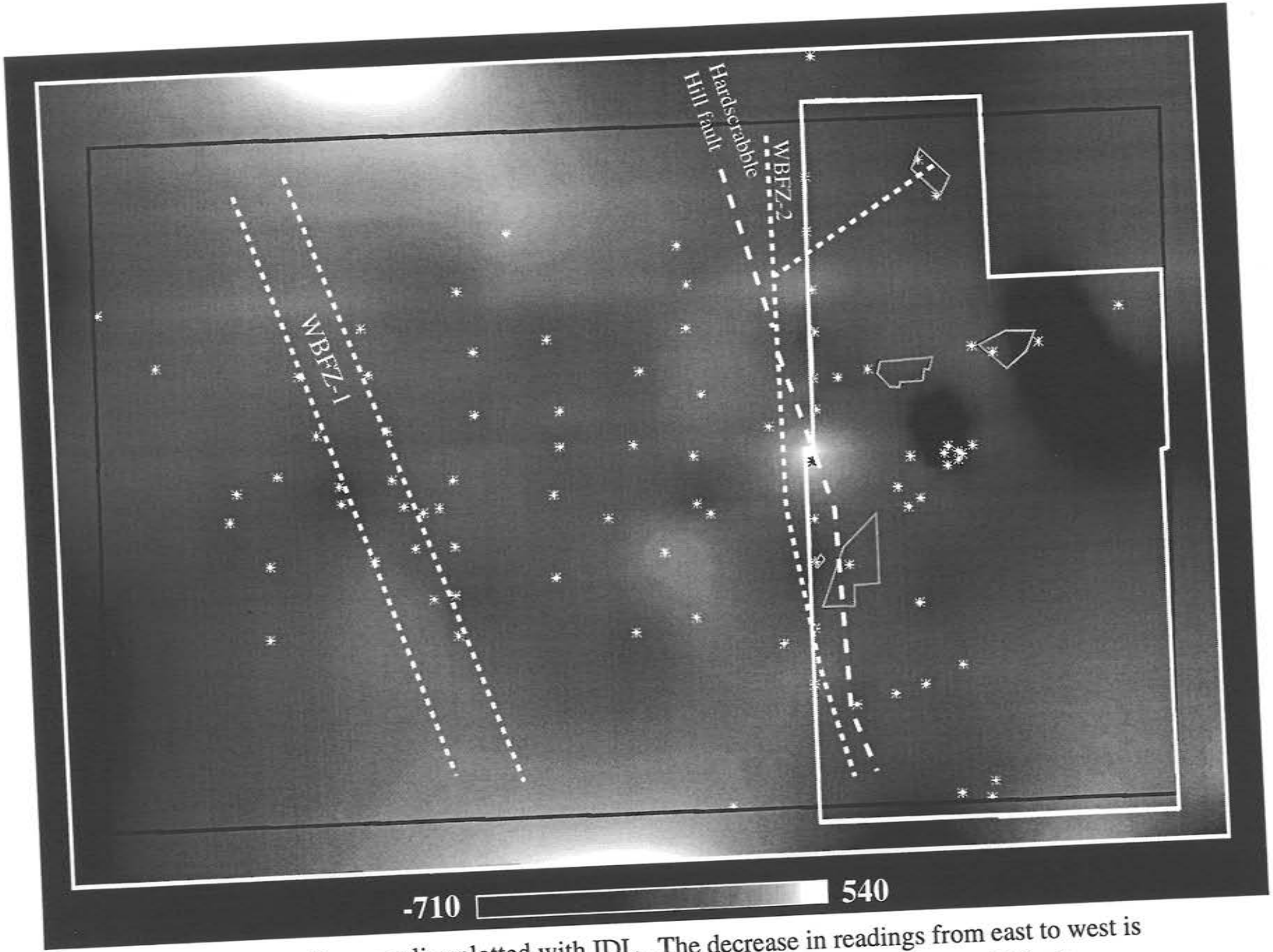

Figure 45. Local magnetic anomalies plotted with IDL. The decrease in readings from east to west is associated with the change in bedrock lithologies due to the Hardscrabble Hill fault.

unknown. The displacement along the eastern basin boundary fault is unclear also. Since this fault juxtaposes Tertiary volcanics against Paleozoic section, it should have a large displacement, but only 80 feet (24 m) of bedrock surface relief is evident.

The gravity model is a two–and–one–half dimensional cross section of the densities and calculated gravitational attraction of the beds, as described by Cady (1980). The model extends from (32.5173°N, –106.6820°W) in the Doña Ana Mountains to (32.5173°N, –106.5795°W) in the San Andres Mountains. Gravity values within 3050 ft (1000 m) normal to straight line between the two end points were used as the observed gravity within the model. A total of 96 gravity stations were used (Figure 46).

An initial gravity model was constructed based on the model of Gilmer et al. (1986) (Figure 47) and shallow bedrock constraints from this study. This model also crosses the Jornada basin, but trends N–S (Figure 42). Density values for the Paleozoic and andesite portions of the bedrock from density logs of three wells on the facility compare well with those reported by Gilmer et al. (1986). The average density for andesite in the 600–D well is 2.49 g/cc compared to 2.50 g/cc used by Gilmer et al. Paleozoic strata in wells 200–F and 200–G average 2.55 and 2.65 g/cc respectively compared to 2.60 g/cc used by Gilmer et al.

Using known surface geological maps and previous subsurface work, a cross section of the Jornada basin was constructed (Figure 45). Five separate bodies were used in the calculation of the observed gravity. The densities of the bodies are listed in Table 4. Since the Love Ranch Formation and the Precambrian granite were not observed in this study, their densities were obtained from Gilmer et. al. (1986). The density for the alluvial fill is an average density for loose, unconsolidated sediment.

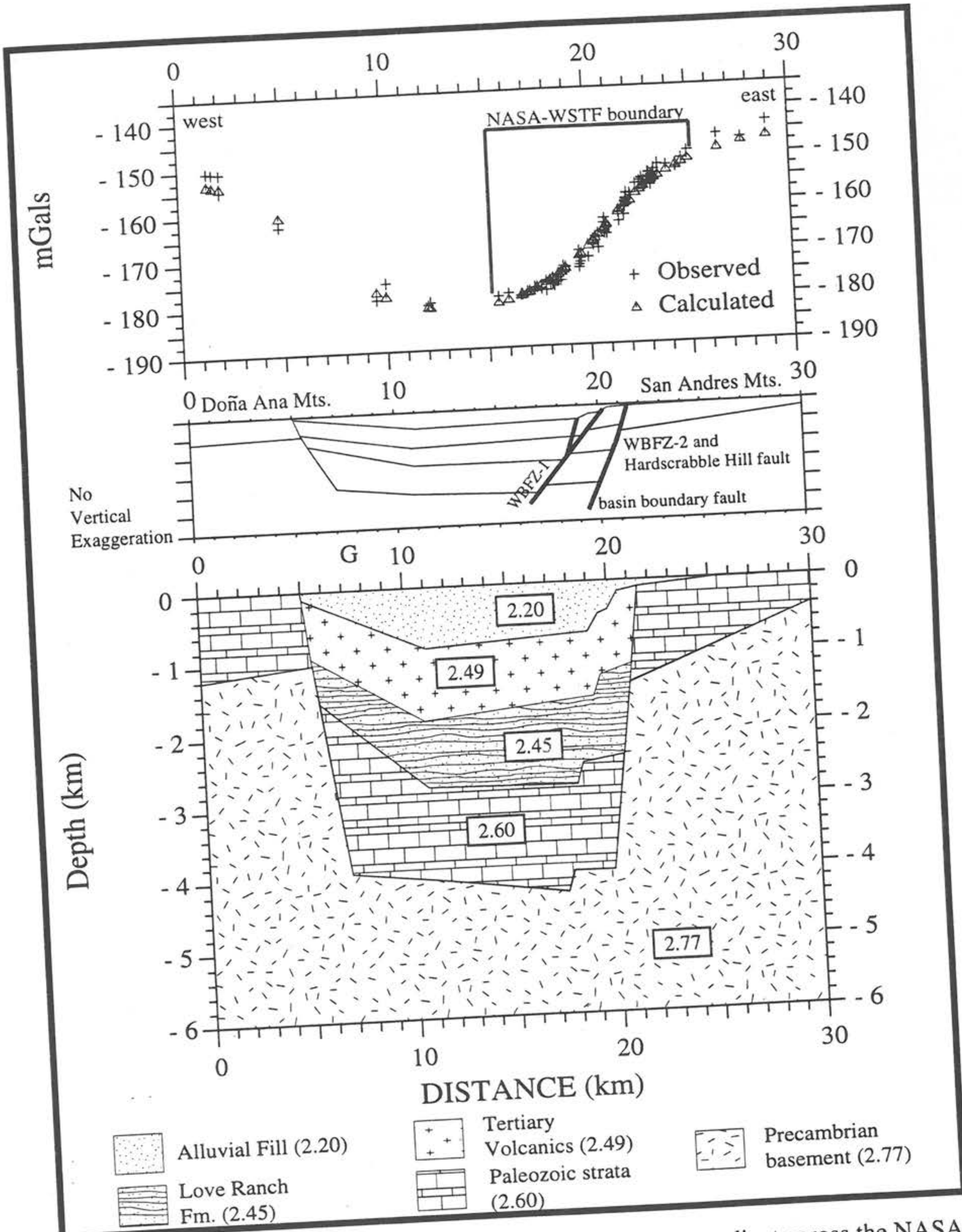

Figure 46 . Gravity modeling of the Jornada basin. The large gradient across the NASA-WSTF is associated with the large displacement on the basin boundary fault. The "G" represents the tie point to the gravity model of Gilmer et al. (1986).

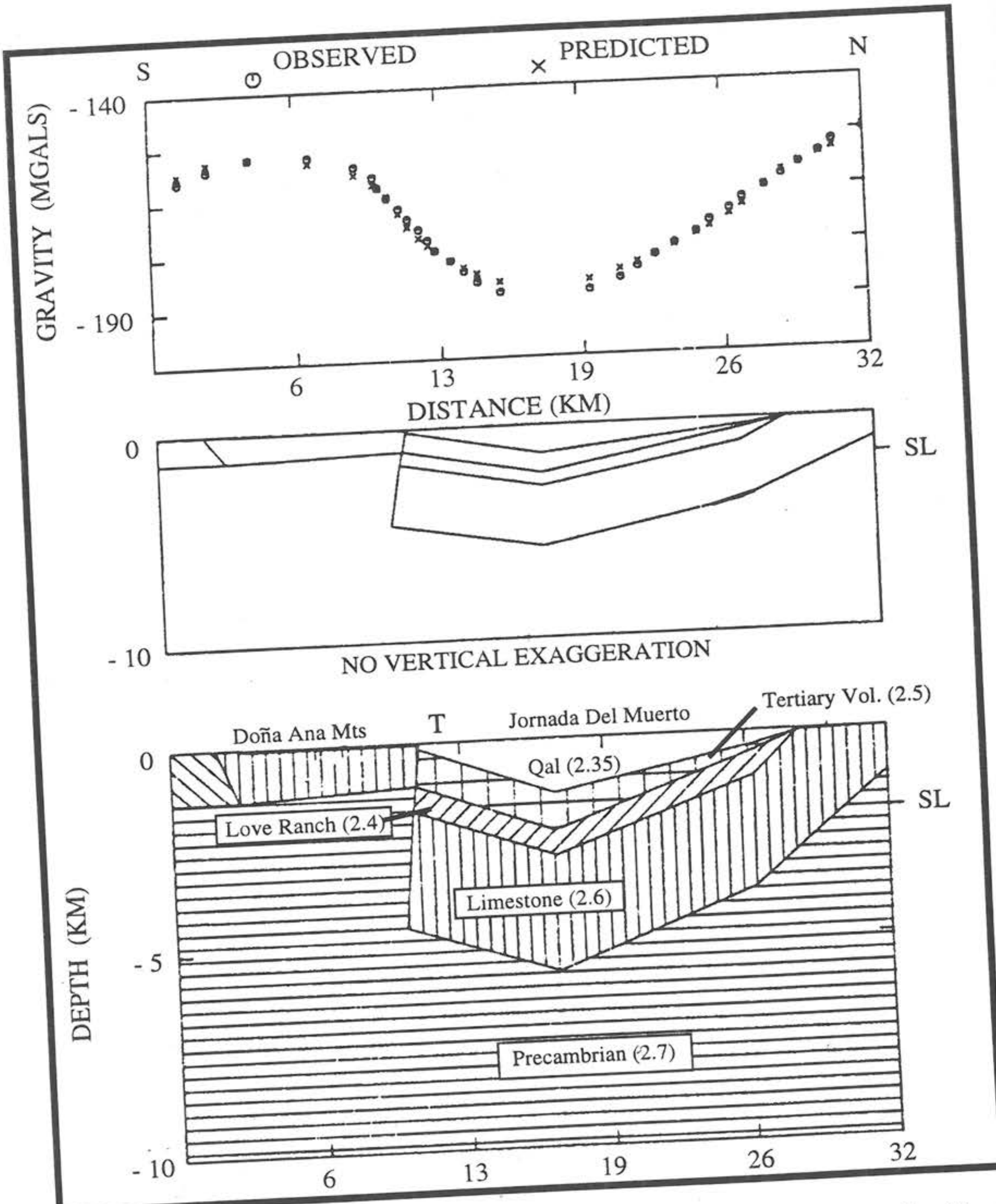

Figure 47. Gravity model of the Jornada basin by Gilmer et al. (1986). The densities used by Gilmer et al. agree with density logs within the NASA-WSTF. The differences between the two cross sections can be accounted for by the different trends of the cross sections. The "T" represents the tie point to the gravity model constructed in this study.

Table 4 Density of bedrock formations used for the gravity modelling.

Formation	Density (g/cc)
Alluvial Fill	2.20
Tertiary Volcanics	2.49
Love Ranch Formation	2.45
Paleozoic strata	2.60
Precambrian Granite	2.77

The top of bedrock is constrained by multiple wells. For the WBFZ–2, up to 80 feet (24 m) of displacement can be seen on the seismic lines (Figure 25). The Hardscrabble Hill fault is constrained by the NASA–4 and NASA–7 wells, near the location of the gravity model. Bedrock elevation and seismic line interpretation suggests that there is little or no bedrock surface relief across the Hardscrabble Hill fault. Westward, the top of bedrock is constrained up to the WBFZ–1. The bedrock drops off sharply at this location. Consequently, neither well log information nor seismic data constrain the top of bedrock thereafter.

Thicknesses of the individual layers is consistent with that reported by Seager (1981). The Love Ranch Formation is known to consist of more than 2000 ft (610 m) of complex alluvial–fan deposits. The thickness of the Tertiary volcanic rocks in the Organ Mountains is thought to exceed 10,000 ft (3000 m) in thickness. Since the Organ Mountains are 6 miles (9.33 km) away from the site, only 3300 ft (1000 m) of volcanics are interpreted below the NASA–WSTF through natural attrition of falling volcanic debris. Gilmer et al. also used 3300 ft (1000 m) as the maximum thickness for the volcanic unit.

Since some stations are located north and south of the profile, the observed gravity appears as a band. The calculated gravity was made such that it split this band down the middle. The maximum alluvial thickness in the Jornada basin was modeled to be 2600 ft (800 m). On NASA– WSTF there are two main features. The first is WBFZ–1, a series on normal faults displacing the bedrock down to the west, rather than one main fault. The total displacement along this fault zone is about 1600 – 1900 ft (490 – 580 m). The second main feature is the eastern basin boundary fault. The displacement on this fault system is at least 6400 ft (2000 m), but it is unclear which fault has the majority of the displacement, the WBFZ–2 or Hardscrabble Hill fault.

The Hardscrabble Hill fault may be an extension of the fault mapped by Seager (1981) across the Hardscrabble Hill to the south of the facility. This fault has at least 1000 ft (300 m) of displacement and represents where Paleozoic section is juxtaposed against Tertiary volcanics. An interesting feature of this fault is that it has no bedrock surface relief. The WBFZ–2 cuts across the Hardscrabble Hill fault and the displacement of this WBFZ–2 at the cross section location is 50 ft (15.2 m).

A Cenozoic fill thickness of 10,000 ft (3000 m) was modeled by Harder et al., (1986). Harder et al. obtained their depths through P–wave delay time modeling. Delay times are measured by comparing the time the P–wave took to arrive against a time calculated from an average earth model. Since a positive delay time was measured, a large low velocity body was present in the Jornada basin. By obtaining independent measurements for P–wave velocity within the basin, Harder et al. calculated a basin fill thickness of 10,000 ft (3000 m) NE of the Doña Ana mountains. In this thesis, a basin fill thickness of 9000 ft (2800 m) through gravity modeling. A difference of 1000 ft (300 m) which is less than 10%.

A comparison of this gravity model (Figure 46) and the gravity model from Gilmer et al., (Figure 47) shows a number of similarities. The thickness of the volcanic and alluvial layers, density of the layers, location of the western basin boundary fault, and total depth down to bedrock are all similar. Notable differences include the thickness of the Love Ranch Formation, total depth to granite, and placement of the eastern basin boundary fault. Since the Gilmer et al. model trends NE–SW and crosses over to the north side of the Bear Peak thrust whereas the model from this study stays to the south of the thrust, differences are to be expected.

During the initial stages of the gravity survey, the objectives were to aid in the placement of large faults and find the depth to bedrock on the western portion of the NASA–WSTF were the wells do not penetrate into bedrock. Gravity is useful, but neither of these could be achieved with a high degree of accuracy due to the presence of the basin boundary fault and the naturally ambiguous nature of gravity. The presence of this fault on the facility was known, but the amount of displacement on the fault was relatively unknown before the survey.

Due to the large gradient in the gravity field across the site (5 mGal/mile), the gravity signatures from the smaller faults are hard to distinguish. A 50 foot (15.2 m) displacement in the bedrock will only produce a 2 – 3 mGal anomaly. That small signal can not be seen in the 5 mGal/mile gradient of the Hardscrabble Hill fault anomaly. The WBFZ–1 has about 2000 ft (610 m) of displacement which should produce an 8 mGal signature. Unfortunately, this is superimposed upon the signature from the Hardscrabble Hill fault, making the two inseparable. The implications of this is that if the throw on one fault is reduced, the displacement on the other can be increased to match the observed gravity field.

The gravity model shows over 2000 ft (610 m) of Love Ranch deposits within the Jornada basin, but well data shows that no Love Ranch is present east of the eastern basin boundary fault. This suggests that the Jornada basin must have been partially open before the onset of Rio Grande Rift extension. The interaction between the Laramide uplift and thrusting, and Rio Grande Rift extension is complex and needs further study in this region.

Fault dips are also poorly constrained by the gravity, since a slight change in fault dip can be compensated for by changing the formation thicknesses and densities. For example a change in dip of 10% can be counterbalanced by changing the density by no more than 5%. This is a larger problem for steeply dipping faults, since a 5° variation has little effect on the calculated gravity. For shallow dipping faults, a change in the dip angle could dramatically alter the gravity signature. The dip on the basin boundary fault was modeled to be 75°, which would represent a high angle normal fault. Seager (1981) also inferred used a 75° dip of the Hardscrabble Hill fault just to the south of the base (Figure 19). Since neither the WBFZ–1 or WBFZ–2 outcrop on the surface, their dips are estimated through gravity modeling and seismic data. These two faults are probably Rio Grande Rift normal faults having a dip angle of 75° and 65–70° respectively. The exact dips of the faults are difficult to estimate, surface wave leakage on the seismic data and the large gravitational signature produced by the basin boundary fault prohibit a direct viewing of the dip. These angles were chosen for two reasons: 1) they are most likely high angle normal faults associated with Rio Grande Rift extension, and 2) a high angle makes the theoretical gravity fit the observed gravity.

Three main conclusions can be drawn from the gravity model. First, the WBFZ–1 displaces the bedrock 1800 to 2000 ft (547 to 608 m) down to the west. The maximum thickness of the alluvial sediments in the Jornada basin is around 2900 ft (900 m) thick. The other important interpretation from the gravity data are location and displacement of the main basin boundary fault. The displacement along the Hardscrabble Hill fault and the WBFZ–2 are unknown, but together they have 8000 ft (2500 m) of movement.

REMOTE SENSING

Purpose

Remote sensing provided another way of examining the regional geology. Since the ground is not covered by thick vegetation, plotting different bands of a LANDSAT Thematic Mapper (TM) image in various combinations enhances the different geologic units of the bedrock and alluvium. This is made possible by the different reflective properties of the sedimentary and igneous rocks that comprise the San Andres Mountains and Jornada basin. Also a side–looking radar image was examined in an attempt to see surface expression of the fault crossing the NASA–WSTF.

Introduction

Remote sensing is defined as collecting and interpreting information about a region without coming in physical contact with it (Sabins, 1987). This method of observation commonly employs electromagnetic energy (light, heat, and radio waves) to measure the characteristics of the region. The most common techniques being aerial photography and satellite imagery. LANDSAT Thematic Mapper data were used here to examine the NASA–WSTF and the surrounding region.

Thanks to NASA's development of the LANDSAT satellites, relatively inexpensive TM data are available for almost anywhere in the world. The data from the TM imagery have 30 m spatial resolution with 7 spectral bands, each of which covers a different portion of the spectrum (Table 5). The TM acquisition system is a cross–track scanner, scanning during both east–bound and west–bound sweeps. This reduces the scan rate and provides a longer dwell time producing better spatial and spectral resolution. The TM mirror sweeps east and west 7 times per second, and each band uses 16 detectors to input data, except band 6 which only uses 4 detectors. Bands 1–5 and 7 are in the visible light or reflected infrared and band 6 is in the thermal infrared (Sabins, 1987).

Table 5. Spectral bands of the TM images and their respective wavelengths.

Band	Wavelength (λ)
1	0.45 – 0.52 μm
2	0.52 – 0.60 μm
3	0.63 – 0.69 μm
4	0.76 – 0.70 μm
5	1.55 – 1.75 μm
6	10.40 – 12.50 μm
7	2.08 – 2.35 μm

The remote sensing technique of radar imaging was also used to examine this region. The side–looking radar data was examined, concentrating on the faults crossing the NASA–WSTF. Since the faults cutting through NASA–WSTF are large, they may have a surface expression which would be enhanced by the radar data. No signals were observed from either fault. This suggests that the WBFZ–1 and eastern boundary faults have no significant ground surface displacement.

Data Involved

Through the use of a dedicated UNIX terminal and PCIworks, the TM image was produced through a series of steps. Since the NASA–WSTF is on the seam of two scenes, the 7 bands of each image had to be merged together. First an empty database containing 11 channels was initialized, with the lower right being (–106.2°W, 32.1°N) and the upper left being (–107.0°W, 32.9°N). All 7 channels of the White Sands scene were dumped into this new database. The El Paso scene was a little harder to place in the database. A color matching look–up–table (LUT) was produced in PCIworks Imageworks. Because the band intensities of the two scenes were completely different, the LUT was used to match the color intensity between them. Also, ground control points (GCP) were collected through PCIworks GCPworks. The GCP are to ensure an accurate fit at the seam. The El Paso scene was incorporated into the new database with the aid of the LUT and GCP.

The next step was to overlay the digital elevation map (DEM) over the TM image and it was placed into channel 8. This also had GCP collected to ensure accurate placement of the DEM. The final step was to overlay the entire image with gravity. A gravity map was produced in IDL and saved in Tiff format. The Tiff file was broken down into its RGB intensities: red, blue, and green. Again GCP were collected and the gravity image was placed in channels 9 through 11.

Thematic Mapper Regional

Bands 3, 4, and 7 were used to create the regional TM false color image in PCIworks Imageworks. Band 3 is located in the red portion of the visible light spectrum and is important for discriminating vegetation types. Bands 4 and 7 are in the reflected infrared (IR) portion of the spectrum (Figure 48). Band 4 is useful for determining biomass, and band 7 is good for mapping hydrothermally altered rocks associated with mineral deposits (Sabins, 1987) . The vegetation is emphasized by combining the three bands together and placing band 7 in the red, band 3 in green, and band 4 in the blue. The proximity of Las

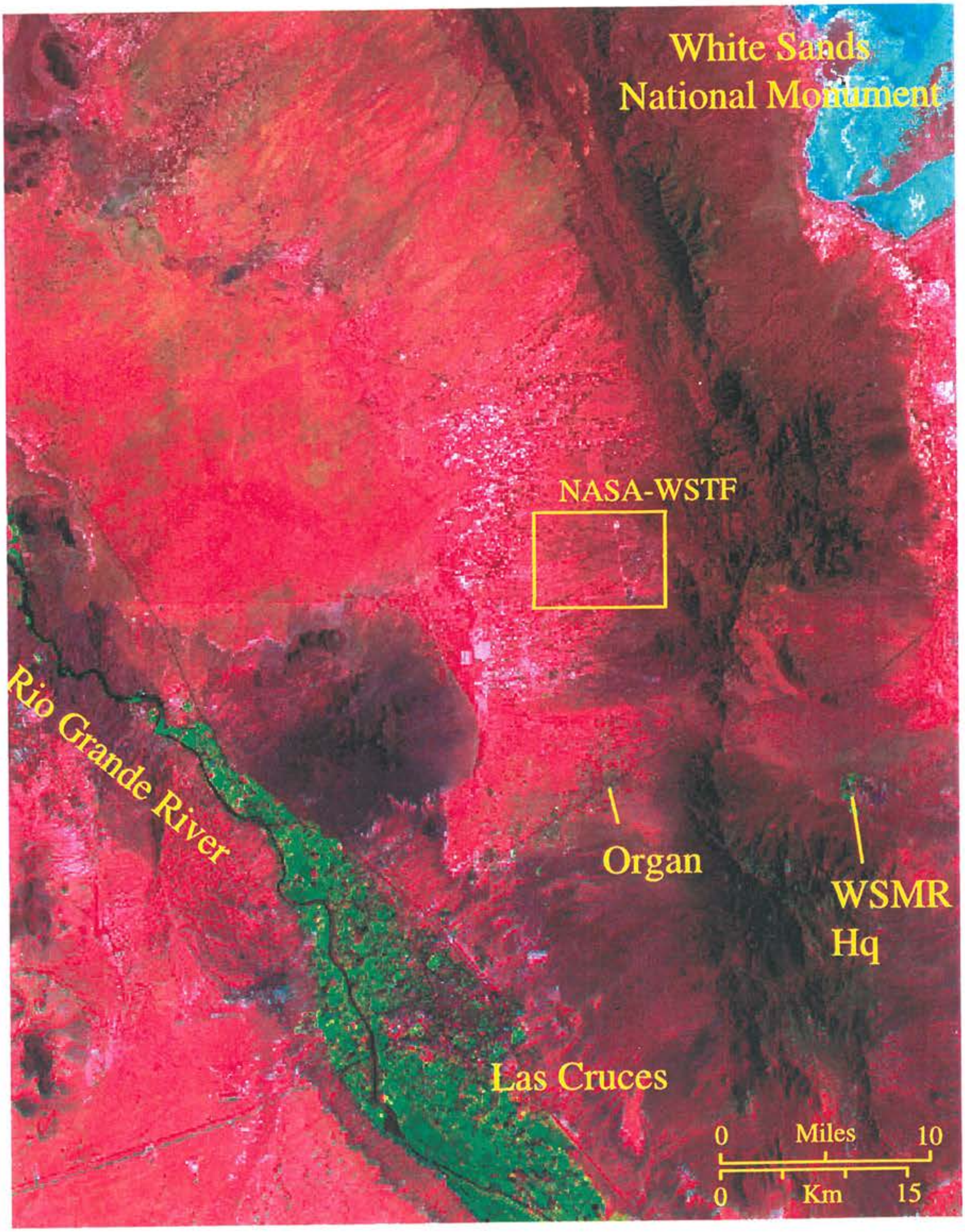

Figure 48. TM false color image of NASA-WSTF and surrounding region. Band 3 is green, band 4 is blue, and band 7 is red. This combination emphasizes the vegetation around Las Cruces and Organ, which is imaged as bright green. The blues in the NE corner are due to White Sands.

Cruces and Organ to NASA–WSTF can easily be seen by observing the vegetation associated with the towns and cultivated areas.

Using this color combination, vegetation is imaged as a bright green color. The light blue blob in the northeast is the white sand of White Sands National Park. Its blue color is due the dramatic color contrast and reflectance of the white gypsum sand.

Thematic Mapper Local

Bands 1, 5, and 7 were user for the local TM image (Figure 49). Band 1 is useful for distinguishing soil from vegetation and deciduous from coniferous plants. Band 5 is used for distinguishing between vegetation types (Sabins, 1987). For the false colors, bands 1 was imaged as blue, 5 as green, and 7 as red. The image also had a linear contrast stretch applied to all three bands to compensate for the brightness of the reflected light off of the white sand to the northeast. The different bands allow the different rock types to be emphasized. East of the NASA–WSTF the limestone is a dark red–brown color whereas the volcanics are a golden color. Also north of the Bear Peak thrust, individual layers of the Paleozoic marine deposits are imaged. These can be seen as roughly N–S brown and purple layers which are truncated by the thrust. South of the thrust the bedrock is purple and green. The green is from igneous bodies, such as the andesite and granite. The purple color correlates to the Paleozoic marine deposits. Man–made objects such the buildings on the base and the roads are imaged as purple. Upon closer examination of the image, local drainage patterns for the valley surface can be seen. The different colors in the alluvium may be related to compositional differences within the alluvium which correlate with the rock types in the adjacent mountains.

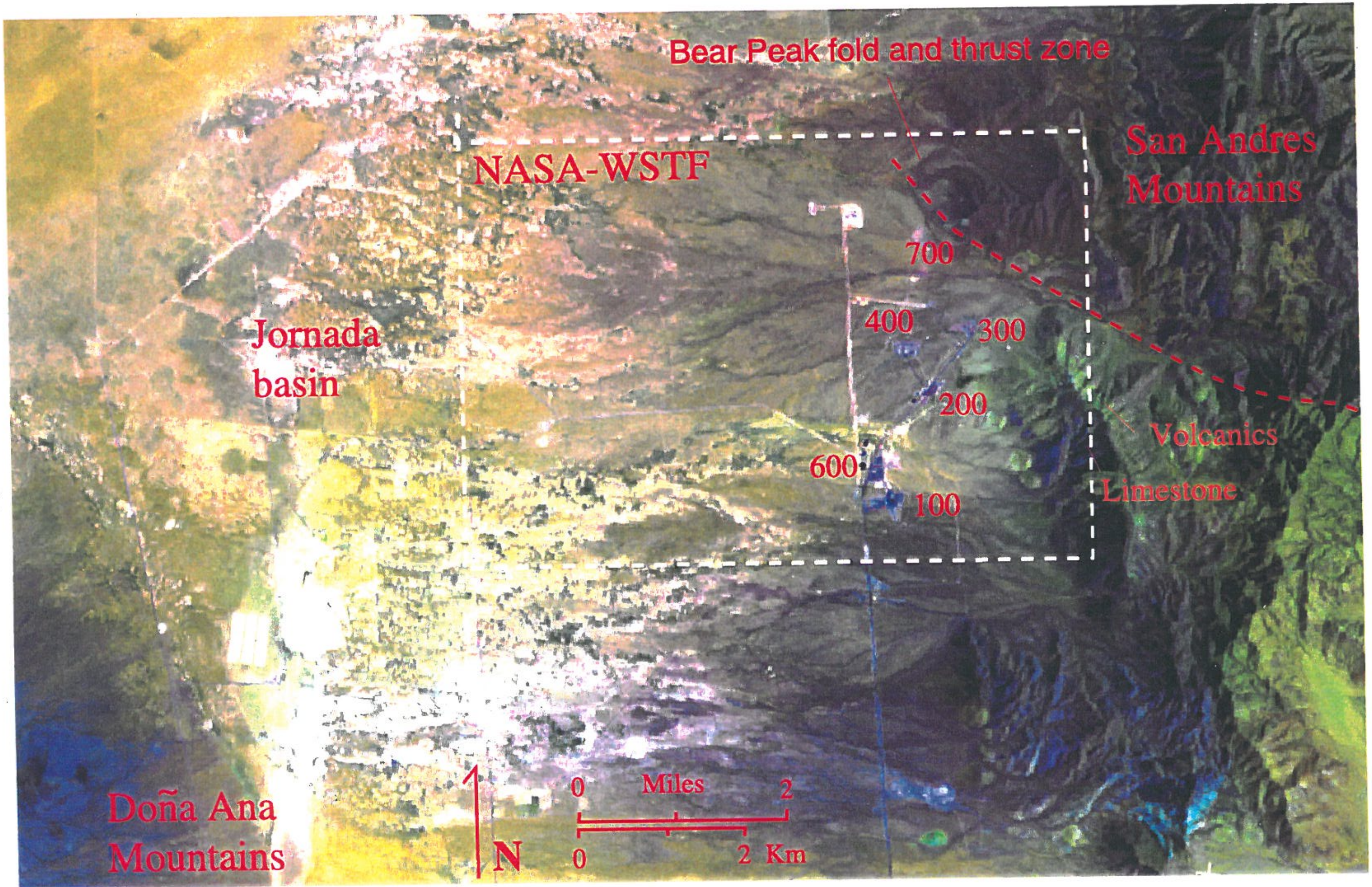

Figure 49. TM bands 1, 5, and 7 were used to create a false color image of the NASA-WSTF. These bands emphasize the different rock types in the mountains and the man-made objects on the base. Upon close examination, the image shows drainage patterns on the valley surface and changes in the composition of the alluvium.

Terrain Draped with Gravity

An interesting feature of the PCIworks program is the ability to drape a figure over the DEM data. As mentioned earlier, when the database for the PCI program was completed, it contained DEM data and a gravity image. The FLY routine within PCIworks takes the DEM data and projects it in two dimensions, such that it appears that one is looking at the terrain from the surface of the earth. A Bouguer anomaly intensity map for the same coordinates was produced in IDL and processed into the database. The image that was produced is looking in a NE direction across the Jornada basin, NASA–WSTF, and the western slopes of the San Andres Mountains (Figure 50). The different colors on the figure represent differences in the Bouguer gravity. There are two important color changes on the image. First is the change from blue to red in the middle of the figure. This represents the location of the basin boundary fault. Even though there is no change in topography associated with this fault, it is the major boundary fault for the Jornada basin. The second color change is from orange to yellow, which is the location of the Bear Peak fold and thrust zone.

Remote imaging of the NASA–WSTF provided an interesting way of examining large scale features. It provided a means to show the location of cultural areas, or vegetation, around the facility, it also provided a rough map to the different bedrock types in the San Andres Mountains. On a smaller scale, valley drainage patterns and changes in alluvial composition are noted. This small taste of remote sensing imagery suggests that this would be a very good tool to initiate a study of an area, or to provide a better way of presenting the data that is already known.

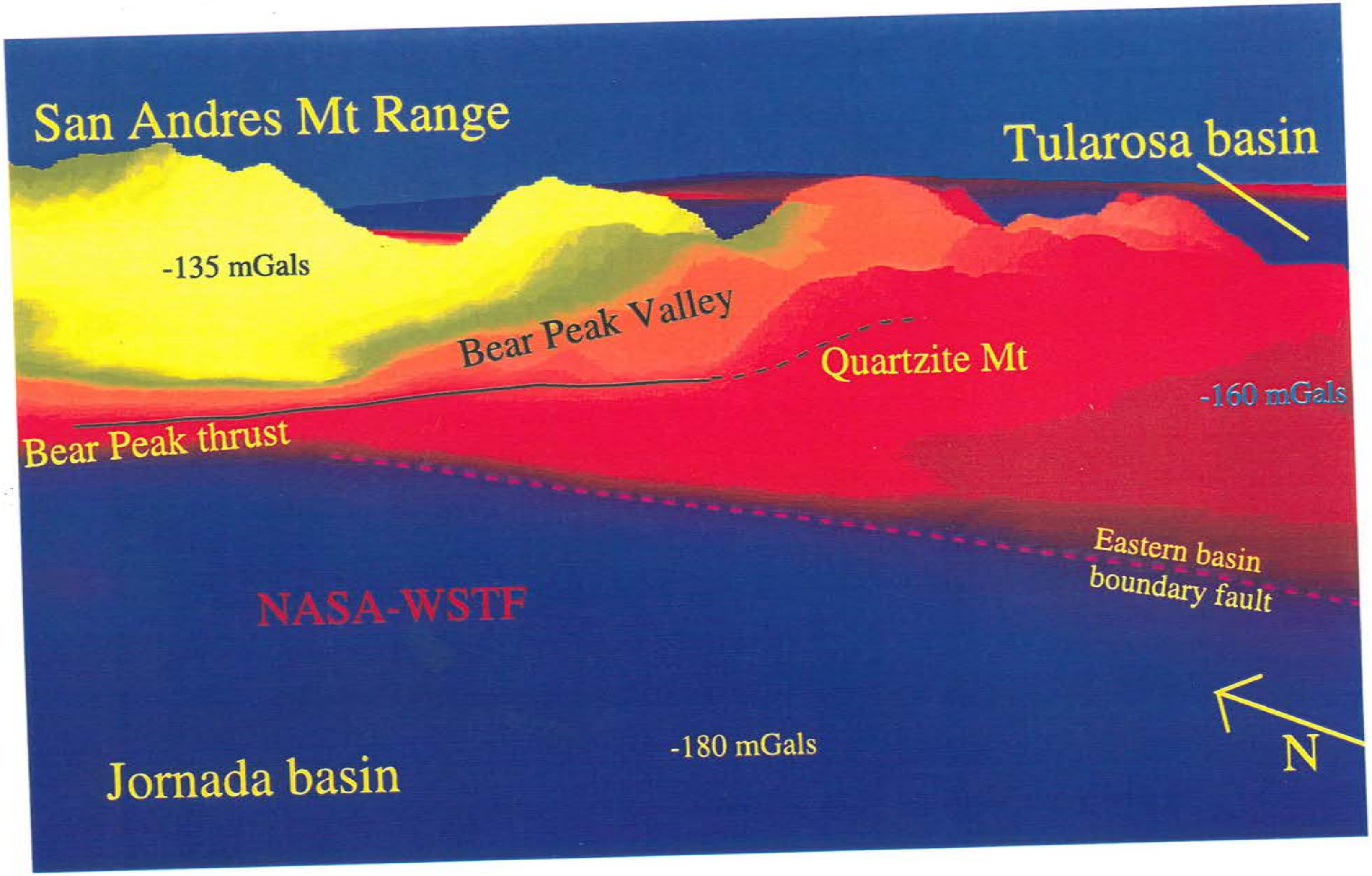

Figure 50. A 2-Dimentional view of the San Andres Mountains topography drapped with Bouguer gravity data. The dashed line for the Bear Peak thrust is where is dissapears behind Quartzite mountain.

CONCLUSIONS

By combining the results of the seismic re–interpretation, well log information, and a gravity survey, a final elevation to bedrock map was produced (Enclosure 1). On this map can be seen the two major north–northwest trending fault zones which divide the base into three distinctive bedrock regions: Jornada basin, Transition zone, and San Andres Mountains pediment. Another feature are the two paleochannels which trend westward across the base. It is believed that the paleochannels provide a region of low hydraulic conductivity, allowing the water to flow through it towards the west.

The Western Boundary Fault Zone 1 (WBFZ–1) trends through the western portion of the off site area. The fault zone is comprised of several down to the west normal faults with a total displacement over 1700 ft (517 m). The depth to bedrock west of the WBFZ–1 is greater than 2000 feet (610 m). Through gravity modeling, the maximum thickness of alluvium in the Jornada basin is around 2600 ft (790 m).

The other major fault zone on the base is the eastern basin boundary fault. This fault zone encompasses both the Western Boundary Fault Zone 2 (WBFZ–2) and the Hardscrabble Hill fault. The total displacement along these faults is calculated to be over 7900 ft (2400 m) through gravity modeling, but the total displacement along the individual faults is unknown.

Probably the most striking feature about the bedrock map is the location of two paleochannels trending westward through the base. The first originates in the 200 area trending southwest towards the 600 area. North of the 600 area the channel turns in a northwest direction. The second originates in the Bear Creek Valley and trends WNW by the

300 and 400 areas. Both of the channels eventually merge together and then trend in a westerly direction, eventually flowing over the WBFZ–1. It is believed that the groundwater either flows across the top of the bedrock until it encounters one of the paleochannels, or it may be funnelled into or out of the paleochannels by the smaller faults on the facility.

Through the production of synthetic seismograms in the 200–G and 200–F wells, it should be feasible to do intra–bedrock mapping on layers within the Paleozoic portion of the bedrock. Unfortunately, due to the processing of the seismic data to enhance the top of bedrock reflection, reflections from within the bedrock are severely attenuated.

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APPENDIX A: VERTICAL SEISMIC PROFILE

Introduction

The purpose of the Vertical Seismic Profile (VSP) was to double check the velocity information obtained during the earlier seismic survey. Production of a zero–offset VSP survey involves lowering sensors, usually hydrophones, down a well at equal increments of depth. A single location next to the well head was used for the introduction of a source impulse. Several source impulses were sent into the ground and stacked together for every 10 foot interval. This process attenuated much of the unwanted surface noise and enhanced first breaks. Since hydrophones do not discriminant motion direction, the entire wavetrain was recorded. This includes direct waves, reflection and refractions. Through the recording of the arrival time of the first breaks, the average velocity and interval velocities can be calculated. For a more complete description see Sheriff and Geldart (1995).

Data Acquisition

The original signal source was a weight drop on the back of a tractor. Unfortunately, the weight drop bounced producing a reverberation in the downgoing signal. The backup, a ten pound sledge hammer, was used instead. The sledge was applied forcefully to a steel plate resting on the surface of the ground roughly 7 ft (2 m) from the opening of the well. Multiple hammer blows were stacked together to reduce the signal to noise ratio and also to enhance the signals in the data. The recording device was a single hydrophone lowered down the well. A switch on the end of the hammer, triggered the recorder when the sledge struck the plate. The survey began at a depth of 210 ft (64 m) and ended at a possible depth of

880 ft (268 m). The total depth of the survey is questionable, this will be further discussed later.

On June 13, 1995 a VSP survey was conducted on well 600–D in the NASA–WSTF. Byrd Seismic Services from Miami, Arizona was contacted to conduct the survey for NASA. The equipment used for recording and processing the data was a Bison–2 9048, 16–bit system. The data was processed in the field during the time of acquisition. The signals were stacked and notch filters were applied for each depth interval within the Bison recorder. The final data was a hard copy from each station, and disks containing digital information. During the data acquisition, there may have been a problem with the survey. The tool seemed to get stuck when sliding down the well. Since the cord holding the hydrophones weighed more then the hydrophones themselves, it is feasible that the phones got stuck and the cord passed them by accounting for the strange velocities obtained.

Data Interpretation

The individual VSP traces were pieced together in ProMax (Figure 51). First breaks were picked by hand and transferred to a database. The database was then loaded into an Interactive Data Language (IDL) program which calculated the information in Table A–1. At first the calculations in the IDL program appeared to be incorrect, so a Fortran program was written to double check the information. The results from both programs were identical.

The results are questionable due to the fact that the interval velocities are inconsistent with each other and with velocities as measured in log data. They range from 3000 to over 100,000 ft/sec (900 to 30,500 m/s). The later half of the survey, 470 – 700 ft (143 – 213 m),

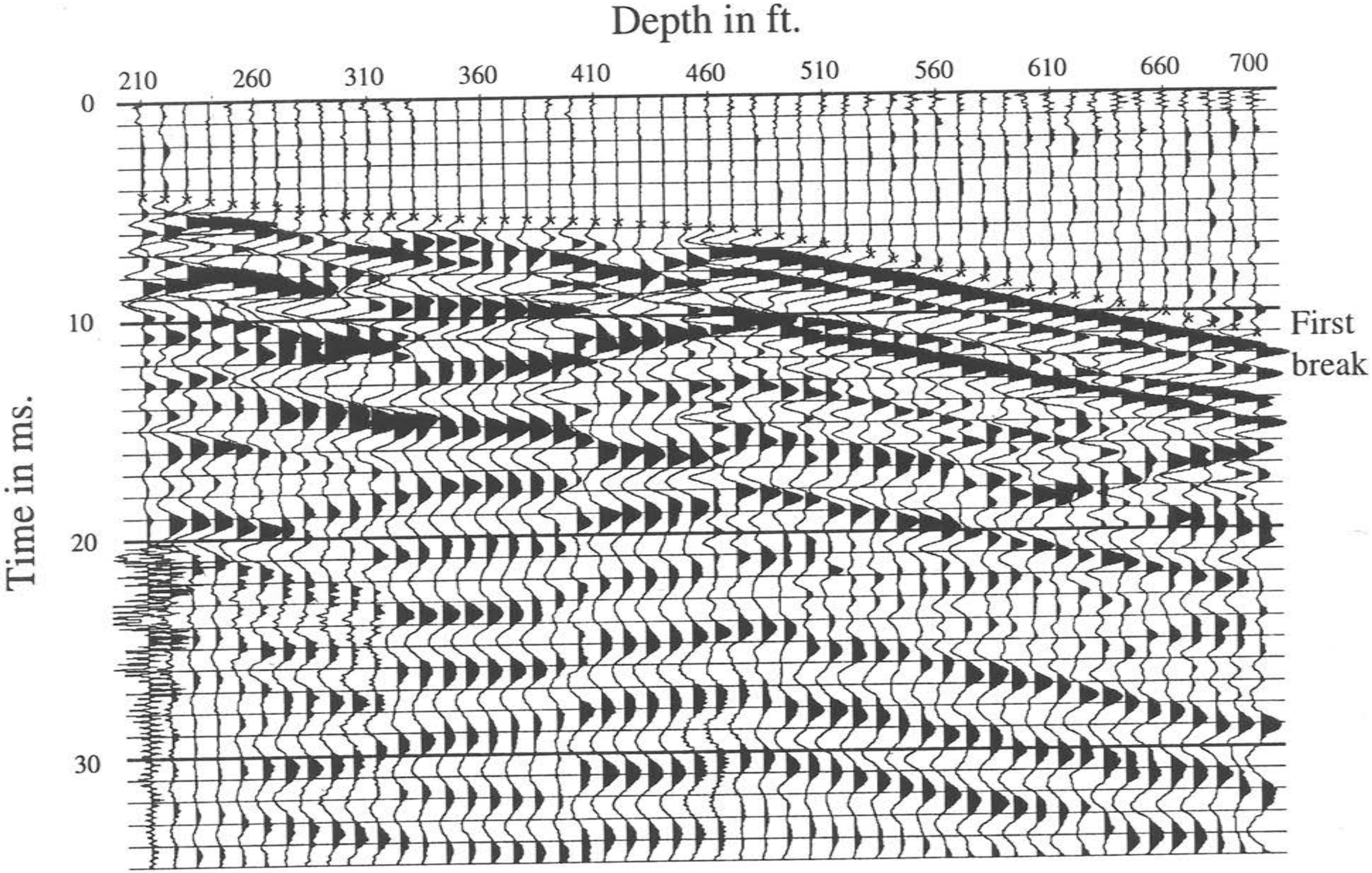

Figure 51. Vertical Seismic Profile (VSP) for well 600-D. A zero-offset survey produced through multiple hammer strikes stacked for 10 foot intervals, from 210 - 700 feet. Notice the inconsistent first breaks giving the anomalous velocity readings.

seems to have a good consistent first arrival, but the interval velocity averages about 4300 ft/s (1,310 m/s) which is very slow considering the average igneous velocity is between 15,800 – 21,100 ft/sec (4828 – 6437 m/s) (Telford, 1990). Also, the average velocity is decreasing with depth.

Some possible sources of error include the following. 1) Well 600–D is located on the eastern basin boundary fault, the bedrock may be fractured and/or altered to clays due to alteration associated with water transport along the faults. 2) The tool 'seemed' to get stuck several times going down the hole. If it was hung up on the swelling clays in the formation, its depth in the well would misjudge; thereby miscalculating the actual travel time to the instrument. 3) Human error: A wrong value could have been entered into the seismic recorder throwing the calibration of the instruments off.

The data, as it is now, can not be used to double check the velocities obtained through the seismic survey.

Table A–1. Time and Velocity information from the VSP survey on the 600–D well.

Depth (feet)	Time (ms)	Interval Time (ms)	Average Velocity (ft/s)	Interval Velocity (ft/s)
000	0.00	0.00	0	0
210	42.69	42.69	4919	4919
220	43.35	0.66	5075	15151
230	43.87	0.52	5243	19231
240	45.05	1.18	5327	8475
250	46.00	0.95	5435	10526
260	47.18	1.18	5511	8475
270	48.36	1.18	5583	8475
280	49.17	0.81	5695	12346
290	50.79	1.62	5710	6173
300	52.16	1.37	5752	7299
310	52.91	0.75	5859	13333
320	53.01	0.10	6037	100002
330	53.38	0.37	6182	27027
340	54.22	0.84	6271	11905
350	54.60	0.38	6410	26316
360	55.25	0.65	6516	15385
370	55.25	0.00	6697	++.
380	55.62	0.37	6832	27027
390	55.91	0.29	6975	34483
400	56.47	0.56	7083	17857
410	56.93	0.46	7202	21739
420	57.40	0.47	7317	21277
430	58.15	0.75	7395	13333
440	58.80	0.65	7483	15385
450	59.55	0.75	7557	13333

Table A–1 continued.

Depth (feet)	Time (ms)	Interval Time (ms)	Average Velocity (ft/sec)	Interval Velocity (ft/sec)
460	60.21	0.66	7640	15151
470	60.83	0.62	7726	16129
480	62.72	1.89	7653	5291
490	64.23	1.51	7629	6623
500	66.24	2.01	7548	4975
510	68.5	2.26	7445	4425
520	70.51	2.01	7375	4975
530	73.27	2.76	7234	3623
540	75.41	2.14	7161	4673
550	78.05	2.64	7047	3788
560	80.06	2.01	6995	4975
570	82.44	2.38	6914	4202
580	84.45	2.01	6868	4975
590	86.59	2.14	6814	4673
600	89.35	2.76	6715	3623
610	91.36	2.01	6677	4975
620	93.12	1.76	6658	5682
630	95.01	1.89	6631	5291
640	96.89	1.88	6605	5319
650	99.4	2.51	6539	3984
660	101.16	1.76	6524	5682
670	104.55	3.39	6408	2950
680	107.07	2.52	6351	3968
690	108.82	1.75	6341	5714
700	111.38	2.56	6285	3906

APPENDIX B: WELL LOCATION AND BEDROCK LITHOLOGY

°N Lat.	°W Long.	Elev. of Bedrock (ft)	Depth to Bedrock (ft)	Bedrock Type	Well Name
32.505	–106.603	4755.36	87.	Limestone	100–A–182
32.504	–106.614	4546.79	210.	Andesite	100–B–*
32.504	–106.614	4571.61	185.	Andesite	100–B(2)–*
32.497	–106.609	4584.82	232.	Andesite	100–C–365
32.500	–106.599	4756.99	144.	Limestone	100–E–261
32.518	–106.597	4821.27	70.	Limestone	200–A–*
32.517	–106.604	4692.77	145.	Limestone	200–B–240
32.514	–106.603	4775.68	35.	Limestone	200–C
32.513	–106.604	4670.79	115.	Limestone	200–D–109
32.513	–106.604	4690.25	95.	Limestone	200–D–240
32.515	–106.605	4668.36	150.	Limestone	200–E–*
32.517	–106.600	4863.00	17.	Limestone	200–F
32.517	–106.599	4808.13	55.	Limestone	200–G
32.517	–106.599	4820.36	74.	Limestone	200–H
32.526	–106.597	4796.67	115.	Andesite	300–A–120
32.526	–106.597	4809.28	102.	Andesite	300–A–170
32.525	–106.597	4821.92	110.	Andesite	300–B–166
32.525	–106.600	4785.27	92.	Andesite	300–C–128
32.529	–106.583	5033.71	75.	Limestone	300–D–153
32.525	–106.595	4832.00	95.	Andesite	300–E
32.524	–106.610	4625.09	170.	Andesite	400–A–151
32.524	–106.607	4658.74	150.	Andesite	400–C–118
32.524	–106.607	4661.55	147.	Andesite	400–C–143

°N Lat.	°W Long.	Elev. of Bedrock (ft)	Depth to Bedrock (ft)	Bedrock Type	Well Name
32.509	–106.613	4594.01	150.	Andesite	600–C–173
32.509	–106.613	4596.31	148.	Andesite	600–C–210
32.509	–106.613	4600.04	145.	Andesite	600–C–437
32.538	–106.600	4918.14	149.	Limestone	700–A–
32.540	–106.613	4520.89	285.	Andesite	700–B–510
32.541	–106.602	4705.28	180.	Limestone	700–D–186
32.535	–106.625	4432.77	285.	Andesite	700–E–458
32.550	–106.611	4458.62	305.	Andesite	700–F–455
32.522	–106.645	4094.67	457.	PLt	BLM–01–435
32.511	–106.648	3878.35	657.	Andesite	BLM–02–630
32.509	–106.614	4581.93	162.	Andesite	BLM–03–182
32.532	–106.646	4188.80	363.	FBR	BLM–05–527
32.509	–106.638	4238.36	350.	Andesite	BLM–06–488
32.527	–106.645	4143.33	413.	AFl Tuff	BLM–08–418
32.519	–106.637	4262.24	340.	AFw Tuff	BLM–09–419
32.505	–106.625	4424.05	253.	Andesite	BLM–11–*
32.510	–106.628	4392.61	255.	Andesite	BLM–12–*
32.514	–106.624	4445.98	220.	PLt	BLM–13–300
32.518	–106.624	4405.54	270.	AFw Tuff	BLM–14–327
32.524	–106.624	4447.60	255.	AFl Tuff	BLM–15–*
32.523	–106.623	4447.69	256.	AFw Tuff	BLM–15–305
32.532	–106.624	4409.07	307.	Andesite	BLM–16–*
32.517	–106.647	3988.13	550.	Andesite	BLM–17–493
32.517	–106.647	3953.24	585.	Andesite	BLM–17–550
32.528	–106.638	4234.84	375.	AFw Tuff	BLM–18–430
32.519	–106.630	4193.73	455.	PR	BLM–21–400

°N Lat.	°W Long.	Elev. of Bedrock (ft)	Depth to Bedrock (ft)	Bedrock Type	Well Name
32.522	−106.637	4281.84	325.	FBR	BLM–22–570
32.515	−106.638	4236.96	352.	PLt	BLM–23–431
32.528	−106.625	4385.84	328.	AFw Tuff	BLM–24–565
32.528	−106.624	4384.80	330.	VClast	BLM–24–Deep
32.513	−106.633	4254.42	365.	PR	BLM–25–455
32.525	−106.629	4354.97	310.	PLt	BLM–26–404
32.520	−106.617	4388.75	341.	PA	BLM–27–270
32.504	−106.631	4339.30	300.	Andesite	BLM–28
32.524	−106.612	4587.15	185.	Andesite	BW–1–268
32.521	−106.612	4544.18	234.	Andesite	BW–2–*
32.512	−106.613	4563.03	171.	Andesite	BW–3–180
32.517	−106.613	4520.75	230.	Andesite	BW–4
32.531	−106.612	4590.52	224.	Andesite	BW–5–295
32.536	−106.613	4490.23	325.	Andesite	BW–6–355
32.527	−106.612	4623.64	175.	Andesite	BW–7–211
32.526	−106.591	4867.42	143.	Limestone	NASA–03
32.509	−106.610	4645.74	125.	Limestone	NASA–04
32.526	−106.595	4800.53	125.	Limestone	NASA–05
32.524	−106.606	4671.03	150.	Andesite	NASA–06
32.509	−106.613	4602.23	145.	Andesite	NASA–07
32.508	−106.613	4611.35	140.	Andesite	NASA–08
32.524	−106.606	4657.23	165.	Andesite	NASA–09
32.526	−106.595	4835.48	100.	Andesite	NASA–10
32.514	−106.650	3677.79	845.	Andesite	NASA–PT–WL
32.515	−106.652	4412.63	100.	Andesite	PL–5
32.526	−106.654	3856.61	645.	Andesite	ST–1–630

°N Lat.	°W Long.	Elev. of Bedrock (ft)	Depth to Bedrock (ft)	Bedrock Type	Well Name
32.526	–106.655	3894.59	600.	Andesite	ST–3–586
32.525	–106.655	3899.36	595.	Andesite	ST–3–666
32.525	–106.655	3586.62	610.	Andesite	ST–3–735
32.529	–106.656	3886.16	605.	Tuff	ST–4–690
32.505	–106.603	4735.94	105.	Limestone	WB–01
32.500	–106.599	4775.00	126.	Limestone	WB–02
32.497	–106.610	4571.16	241.	Andesite	WB–03
32.498	–106.606	4567.78	277.	Andesite	WB–04
32.499	–106.603	4712.41	160.	Limestone	WB–05
32.499	–106.614	4486.34	289.	Andesite	WB–06–*
32.502	–106.616	4510.53	235.	Andesite	WB–07–*
32.490	–106.600	4766.68	195.	Andesite	WB–08
32.489	–106.597	4872.61	129.	Limestone	WB–09

Lithology Key:

AFl Tuff	Air Fall Tuff
AFw Tuff	Air Flow Tuff
FBR	Flow Banded Rhyolite
PR	Porphyritic Rhyolite
PLt	Porphyritic Latite
PA	Porphyritic Andesite
VClast	Volcano Clastics

Well Key

BLM	Bureau of Land Management well
BW	Boundary well
WB	West Bay well
PL	Public Land well
ST	State Land well

CURRICULUM VITAE

Timothy James Maciejewski, the son of Emmet and Janice Maciejewski, was born on January 22, 1970, in Bad Axe, Michigan. He graduated from Spring High School in 1988. He received his Bachelor of Science degree in geology from the University of Texas at El Paso, in December, 1993. He has presented oral presentations and posters at many regional and national meetings. He entered the Masters program at the University of Texas at El Paso in the spring of 1994. As of completion of this thesis he will be employed at the Chevron Production/Exploration Company in Midland, Texas.

Permanent Address:

Tim Maciejewski

P.O. Box 68257

El Paso, Tx 79968–9991

This thesis was typed by Tim Maciejewski

CURRICULUM VITAE

Timothy James Maciejewski, the son of Emmet and Janice Maciejewski, was born on January 22, 1970, in Bad Axe, Michigan. He graduated from Spring High School in 1988. He received his Bachelor of Science degree in geology from the University of Texas at El Paso, in December, 1993. He has presented oral presentations and posters at many regional and national meetings. He entered the Masters program at the University of Texas at El Paso in the spring of 1994. As of completion of this thesis he will be employed at the Chevron Production/Exploration Company in Midland, Texas.

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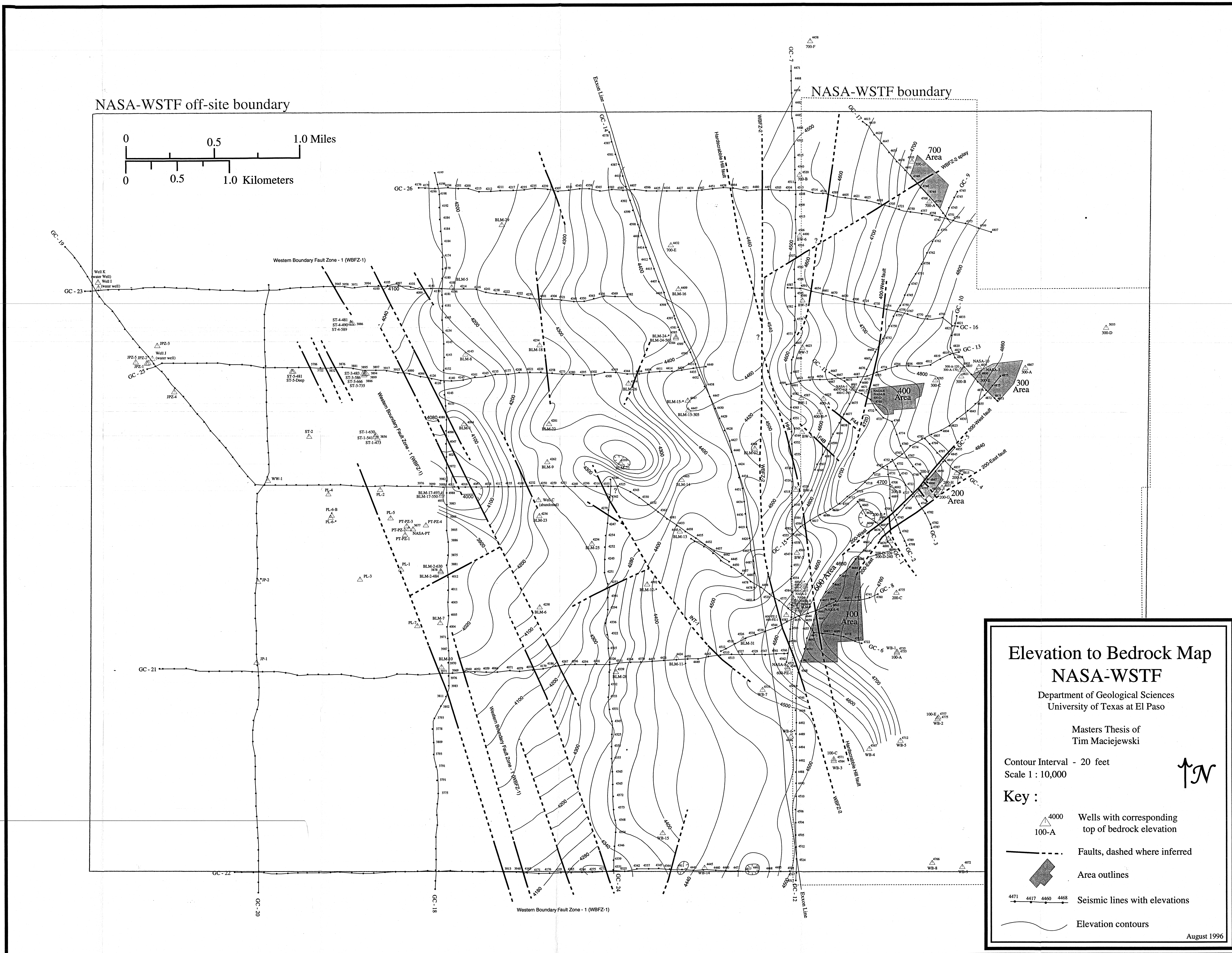
El Paso, Tx 79968–9991

This thesis was typed by Tim Maciejewski

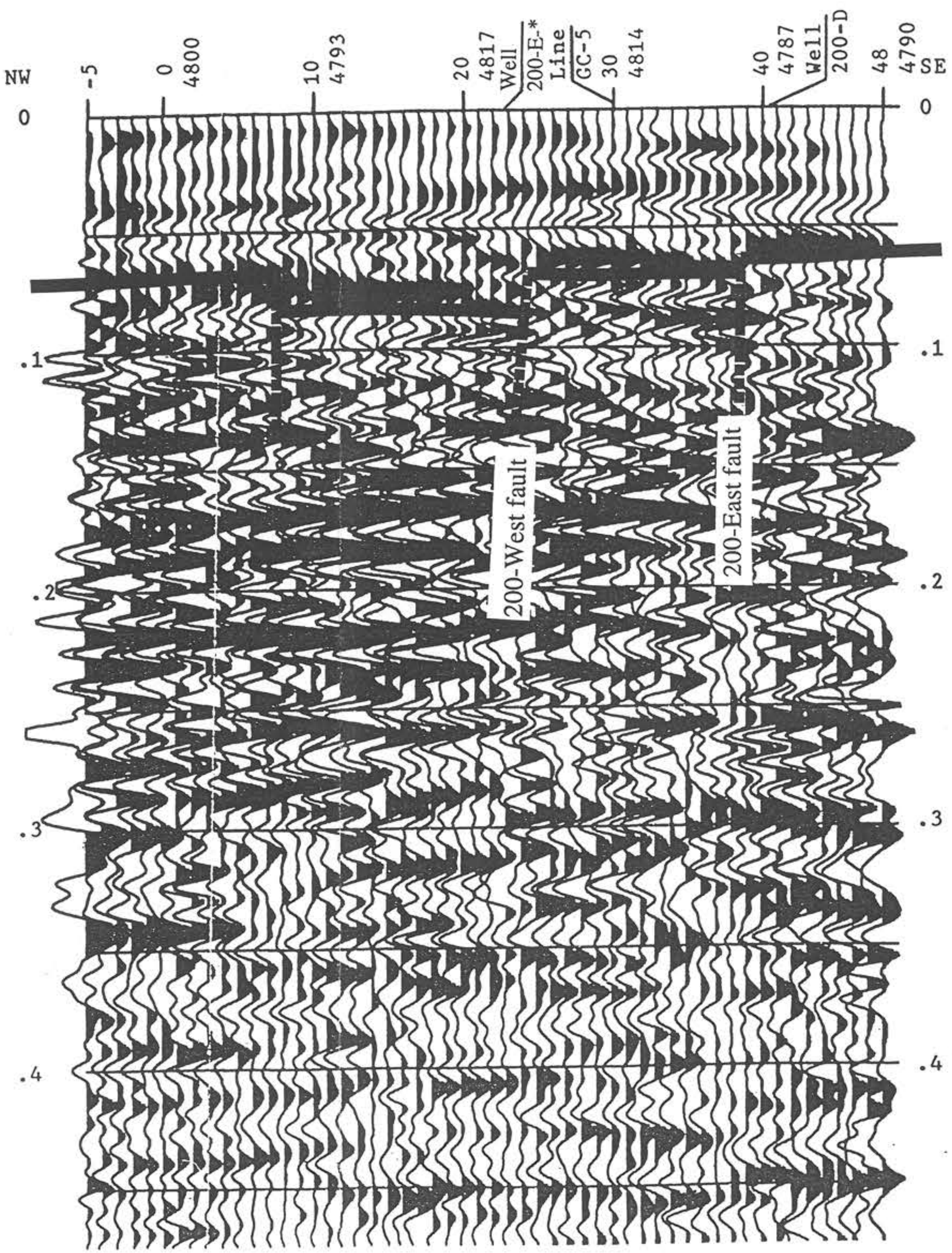
INTEGRATED GEOPHYSICAL INTERPRETATION OF BEDROCK GEOLOGY, SAN ANDRES MOUNTAINS, NEW MEXICO

BY

TIMOTHY J. MACIEJEWSKI



Enclosure No. 1



R40/R41: Well 200-D-109 ±35 FT SW

NASA

LINE GC-1 R1-R48

DONA ANA CO NM
600% CDP SECTION

RECORDING

RECORDED BY: CBR	DATE RECORDED: 02/04/87	INSTRUMENTS: EG&G ES1210F
GAIN MODE: FIXED	FIELD FILTER: OUT-80HZ	60HZ NOTCH FILTER: IN
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SPREAD

TYPE: END OVER	CDP FOLD: 6	NO OF GROUPS: 6
LINE DIR: NW-SE	NEAR GRP CTR: 66 FT	FAR GRP CTR: 394 FT
SEISES/GRP: 1 @ 66 FT INLINE	GROUP INTERVAL: 66FT	

ENERGY

SOURCE: 550 LB WT DRP	SP ARRAY: POINT	SP INTERVAL: 33 FT
SP OFFSET: 0	DROPS/SP: 1-3	

PROCESSING SEQUENCE

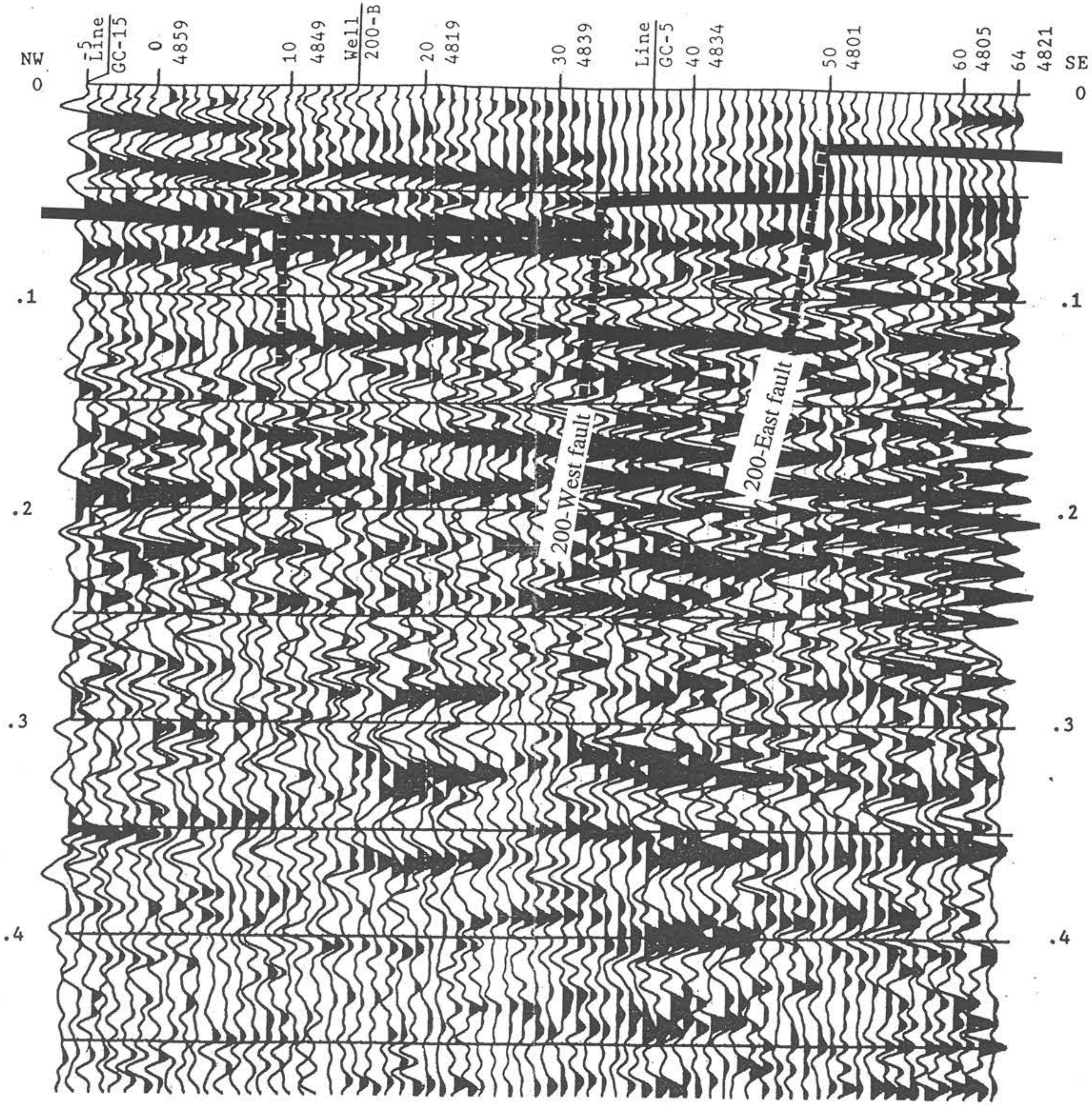
(1) TRANSCR	(2) DATA EDIT	(3) WX DTRM
(4) FANFIL	(5) TVDCON3 20 PTS	(6) STK 600%
(7) DTMCRN	(8) DIPFIL	(9) FIL 0-120 HZ
(10) TRC NORM	(11) PLOT VA/WT	(12)

PLOTTER DISPLAY

HORIZ SCALE: 33 FT/TR	POLARITY: POS	VERT SCALE: 15 IN/SEC
WX VEL.: 2200 FT/SEC	DATUM: SURFACE	CORRN VEL : 3700 FT/SEC

CHARLES B. REYNOLDS & ASSOC.

Enclosure No. 2



R15: Well 200-B ±85 FT NE

NASA

LINE GC-2 R1-R64

DONA ANA CO NM
600% CDP SECTION

RECORDING		
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SPREAD		
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LINE DIR: NW-SE	NEAR GRP CTR: 66 FT	FAR GRP CTR: 394 FT
SEISES/GRP: 1 @ 66 FT INLINE		GROUP INTERVAL: 66FT
ENERGY		
SOURCE: 550 LB WT DRP	SP ARRAY: POINT	SP INTERVAL: 33 FT
SP OFFSET: 0		DROPS/SP: 1-3
PROCESSING SEQUENCE		
(1) TRANSCR	(2) DATA EDIT	(3) WX DTRM
(4) FANFIL	(5) TVDCON3 20 PTS	(6) STK 600%
(7) DTMCRN	(8) DIPFIL	(9) FIL 0-120 HZ
(10) TRC NORM	(11) PLOT VA/WT	(12)
PLOTTER DISPLAY		
HORIZ SCALE: 33 FT/TR	POLARITY: POS	VERT SCALE: 15 IN/SEC
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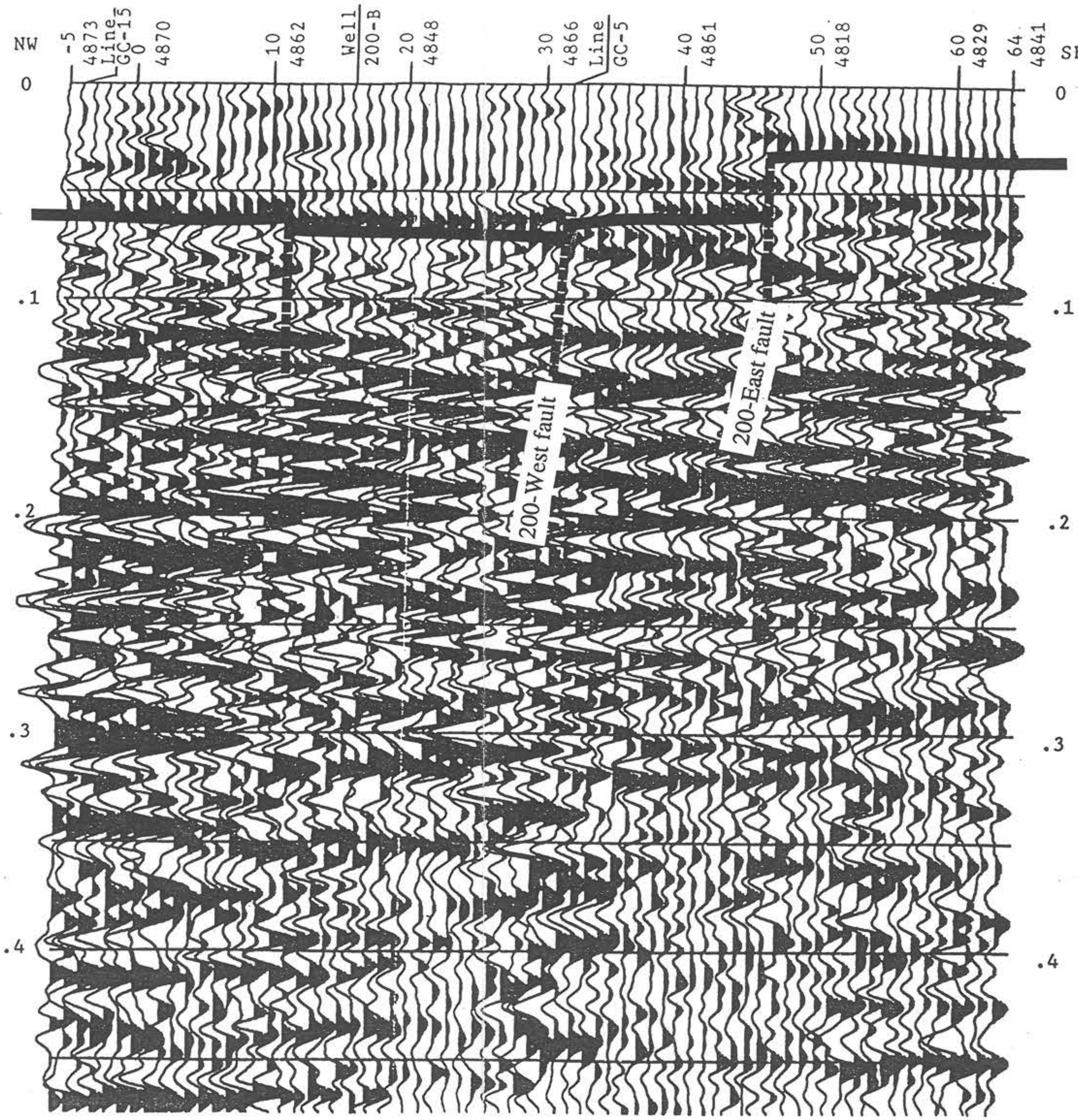
Enclosure No. 3



R16: Well 200-B ±440 FT SW

NASA

LINE GC-3 R1-R64

DONA ANA CO NM
600% CDP SECTION

RECORDING

RECORDED BY: CBR   DATE RECORDED: 02/08/87   INSTRUMENTS: EG&G ES1210F
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SPREAD

TYPE: END OVER   CDP FOLD: 6   NO OF GROUPS: 6
LINE DIR: NW-SE   NEAR GRP CTR: 66 FT   FAR GRP CTR: 394 FT
SEISES/GRP: 1 @ 66 FT INLINE   GROUP INTERVAL: 66FT

ENERGY

SOURCE: 550 LB WT DRP   SP ARRAY: POINT   SP INTERVAL: 33 FT
SP OFFSET: 0   DROPS/SP: 1-3

PROCESSING SEQUENCE

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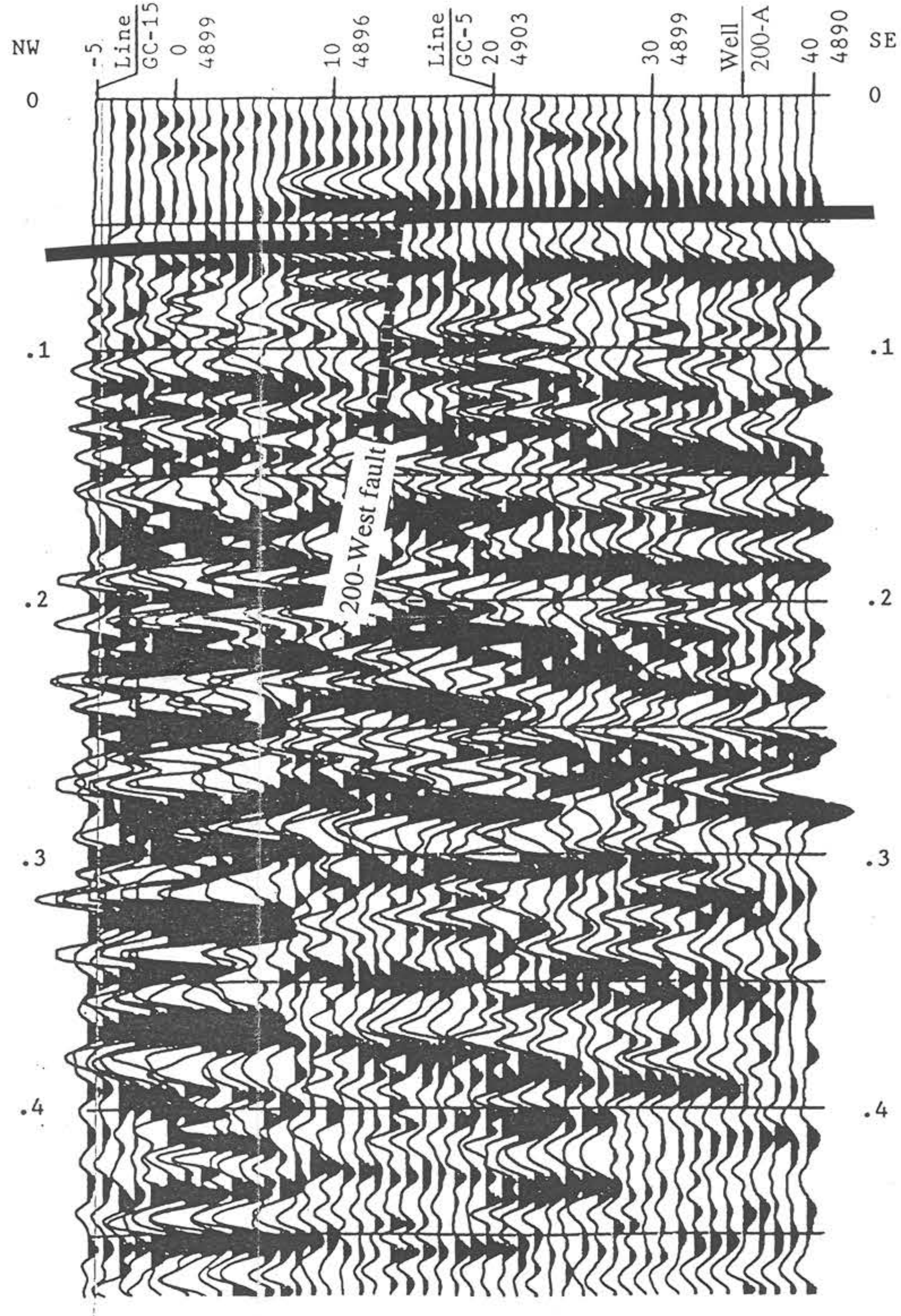
(4) FANFIL   (5) TVDCON3 20 PTS   (6) STK 600%
(7) DTMCRN   (8) DIPFIL   (9) FIL 0-120 HZ
(10) TRC NORM   (11) PLOT VA/WT   (12)

PLOTTER DISPLAY

HORIZ SCALE: 33 FT/TR   POLARITY: POS   VERT SCALE: 15 IN/SEC
WX VEL.: 2200 FT/SEC   DATUM: SURFACE   CORRN VEL : 3700 FT/SEC

CHARLES B. REYNOLDS & ASSOC.

Enclosure No. 4



NASA

LINE GC-4 R1-R40

DONA ANA CO NM
600% CDP SECTION

RECORDING

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SPREAD

TYPE: END OVER   CDP FOLD: 6   NO OF GROUPS: 6
LINE DIR: NW-SE   NEAR GRP CTR: 66 FT   FAR GRP CTR: 394 FT
SEISES/GRP: 1 @ 66 FT INLINE   GROUP INTERVAL: 66FT

ENERGY

SOURCE: 550 LB WT DRP   SP ARRAY: POINT   SP INTERVAL: 33 FT
SP OFFSET: 0   DROPS/SP: 1-3

PROCESSING SEQUENCE

(1) TRANSCR   (2) DATA EDIT   (3) WX DTRM
(4) FANFIL   (5) TVDCON3 20 PTS   (6) STK 600%
(7) DTMCRN   (8) DIPFIL   (9) FIL 0-120 HZ
(10) TRC NORM   (11) PLOT VA/WT   (12)

PLOTTER DISPLAY

HORIZ SCALE: 33 FT/TR   POLARITY: POS   VERT SCALE: 15 IN/SEC
WX VEL.: 2200 FT/SEC   DATUM: SURFACE   CORRN VEL : 3700 FT/SEC

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Enclosure No. 5

LINE GC-5 R1-R104 AND LINE GC-12 R1-R294

DONA ANA CO NM
600% CDP SECTION

RECORDING		
RECORDED BY: PRG	DATE RECORDED: 04/10/88	INSTRUMENTS: EG&G ES1210F
GAIN MODE: FIXED	FIELD FILTER: OUT-80HZ	60HZ NOTCH FILTER: IN
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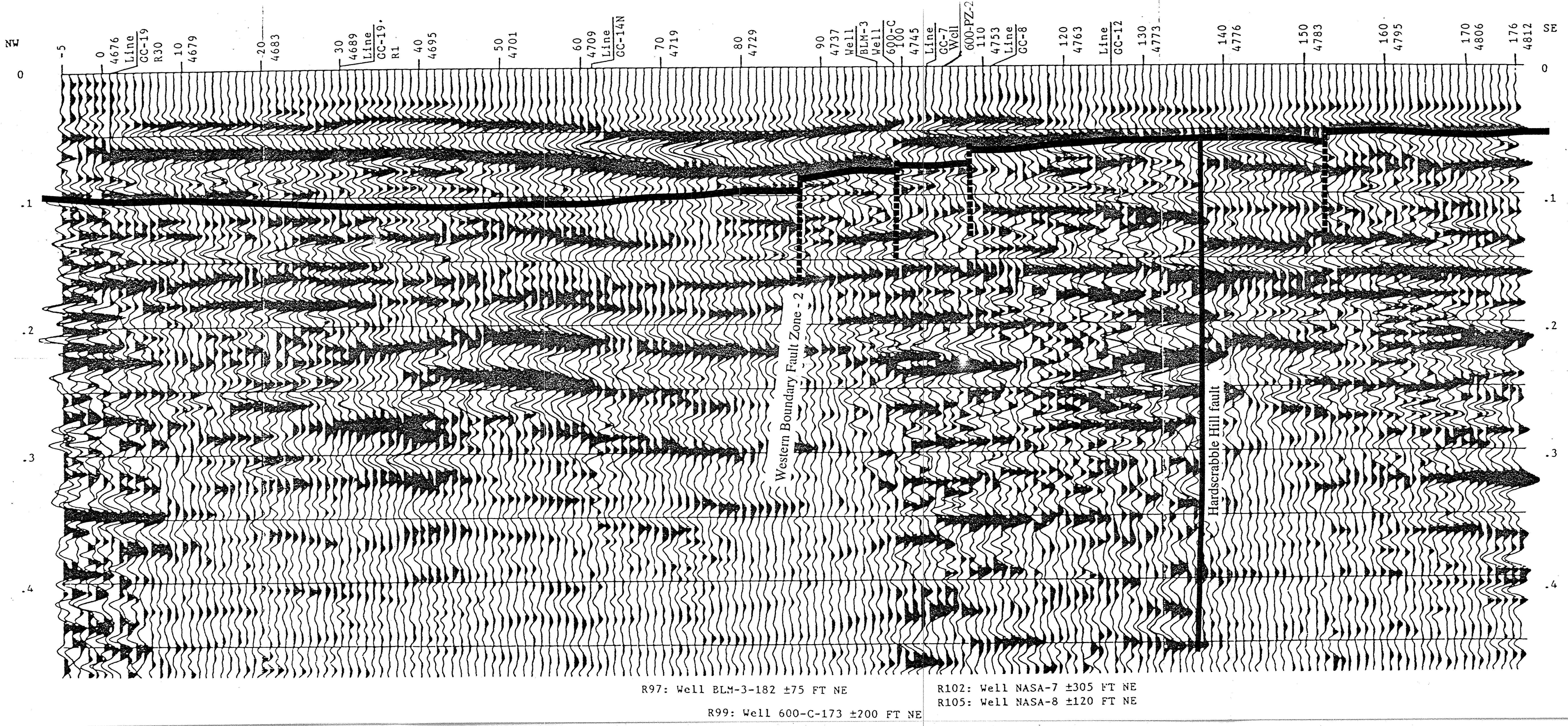
SPREAD		
TYPE: END OVER	CDP FOLD: 6	NO OF GROUPS: 6
LINE DIR: NE-S	NEAR GRP CTR: 66 FT	FAR GRP CTR: 394 FT
SEISES/GRP: 1 @ 66 FT INLINE	GROUP INTERVAL: 66FT	

ENERGY		
SOURCE: 550 LB WT DRP	SP ARRAY: POINT	SP INTERVAL: 33 FT
SP OFFSET: 0	DROPS/SP: 2-3	

PROCESSING SEQUENCE		
(1) TRANSCR	(2) DATA EDIT	(3) WX DTRM
(4) FANFIL	(5) TVDCON3 20 PTS	(6) STK 600%
(7) DTMCRN	(8) DIPFIL	(9) FIL 0-120 HZ
(10) TRC NORM	(11) PLOT VA/WT	(12)

PLOTTER DISPLAY		
HORIZ SCALE: 33 FT/TR	POLARITY: POS	VERT SCALE: 15 IN/SEC
WX VEL.: 2200/2300 F/S	DATUM: SURFACE	CORRN VEL : 3700 FT/SEC

Enclosure No. 6



NASA

LINE GC-6 R1-R176

DONA ANA CO NM
600% CDP SECTION

RECORDING

RECORDED BY: PRG   DATE RECORDED: 05/25/87   INSTRUMENTS: EG&G ES1210F
GAIN MODE: FIXED   FIELD FILTER: OUT-80HZ   60HZ NOTCH FILTER: IN
RECORD LENGTH: 0.5 SEC   SAMPLE RATE: 0.0005 SEC

SPREAD

TYPE: END OVER   CDP FOLD: 6   NO OF GROUPS: 6
LINE DIR: NW-SE   NEAR GRP CTR: 66 FT   FAR GRP CTR: 394 FT
SEISES/GRP: 1 @ 66 FT INLINE   GROUP INTERVAL: 66FT

ENERGY

SOURCE: 550 LB WT DRP   SP ARRAY: POINT   SP INTERVAL: 33 FT
SP OFFSET: 0   DROPS/SP: 2-5

PROCESSING SEQUENCE

(1) TRANSCR   (2) DATA EDIT   (3) WX DTRM
(4) FANFIL   (5) TVDCON3 20 PTS   (6) STK 600%
(7) DTMCRN   (8) DIPFIL   (9) FIL 0-120 HZ
(10) TRC NORM   (11) PLOT VA/WT   (12)

PLOTTER DISPLAY

HORIZ SCALE: 33 FT/TR   POLARITY: POS   VERT SCALE: 15 IN/SEC
WX VEL.: 1900 FT/SEC   DATUM: SURFACE   CORRN VEL : 3700 FT/SEC

CHARLES B. REYNOLDS & ASSOC.

Enclosure No. 7

R138: Well NASA-8 165 FT± E
R141/R142: Well BLM-3-182 90 FT± W
R144: Well 600-C-210 60 FT± E

R186/R187: Well BW-3 180 FT± E

R35: Well BW-2 530 FT± E

R60: Well BW-1 520 FT± E

NASA

LINE GC-7 R101-R250/R1-R88/R288-R518

DONA ANA CO NM
600% CDP SECTION

RECORDING

RECORDED BY: PRG DATE RECORDED: 04/28/89 INSTRUMENTS: EG&G ES...
GAIN MODE: FIXED FIELD FILTER: OUT-120HZ 60HZ NOTCH FILTER: IN
RECORD LENGTH: 0.5 SEC SAMPLE RATE: 0.0005 SEC

SPREAD

TYPE: END OVER CDP FOLD: 6 NO OF GROUPS: 6
LINE DIR: S-N NEAR GRP CTR: 66 FT FAR GRP CTR: 394 FT
SEISES/GRP: 1 @ 66 FT INLINE GROUP INTERVAL: 66FT

ENERGY

SOURCE: 550 LB WT DRP SP ARRAY: POINT SP INTERVAL: 33 FT
SP OFFSET: 0 DROPS/SP: 1-2

PROCESSING SEQUENCE

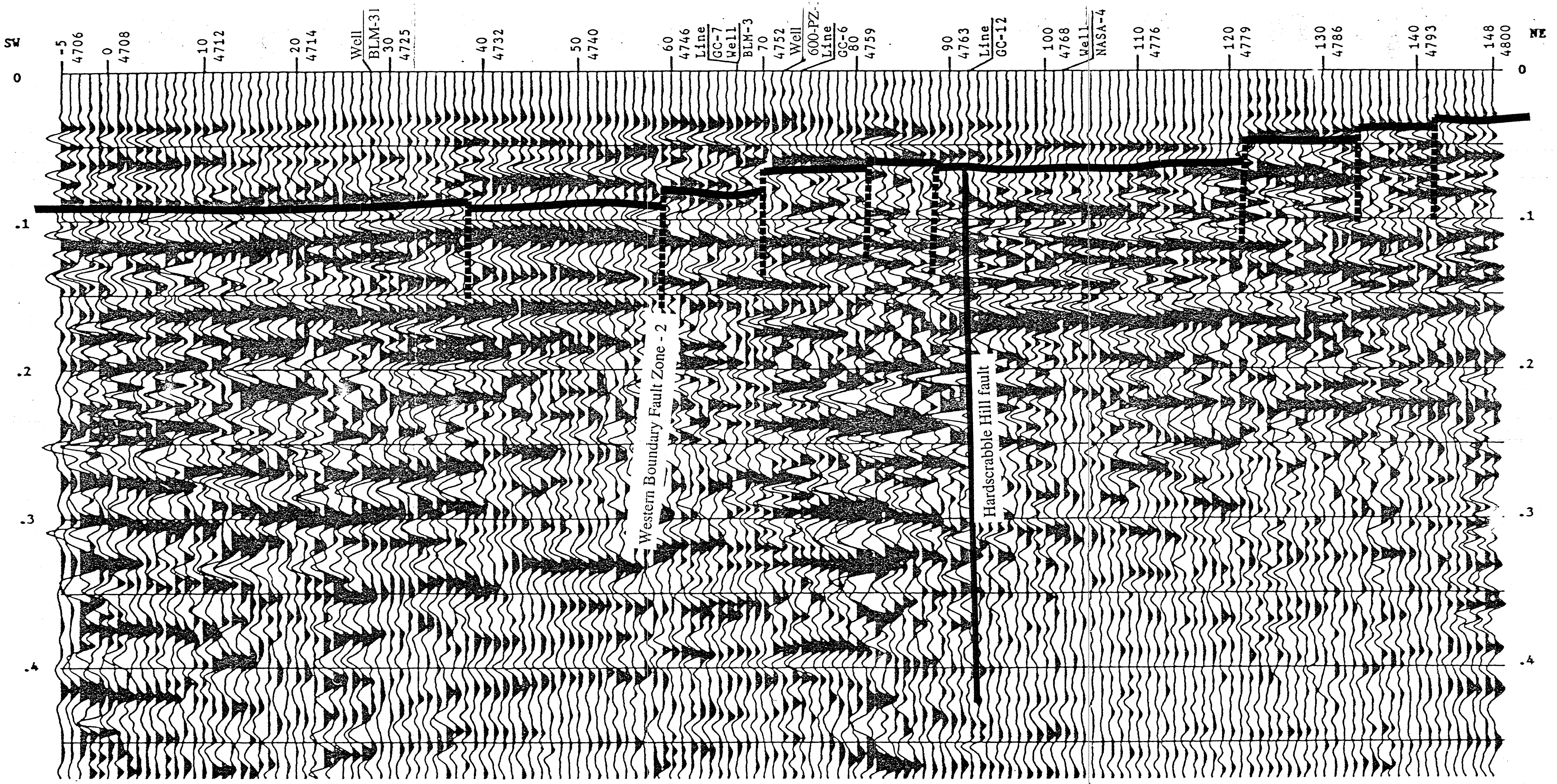
(1) TRANSCR (2) DATA EDIT (3) NX DTRM
(4) FANFIL (5) TVDCON3 20 PTS (6) STK 600% -
(7) DTMCRN (8) DIPFIL (9) FIL 0-80 HZ
(10) TRC NORM (11) PLOT VA/WT (12)

PLOTTER DISPLAY

HORIZ SCALE: 33 FT/TR POLARITY: POS VERT SCALE: 7.5 IN/SEC
NX VEL.: 2200 FT/SEC DATUM: SURFACE CORRN VEL : 3700 FT/SEC

CHARLES B. REYNOLDS & ASSOC.

Enclosure No. 8



R67: Well BLM-3-182 ±390 FT NW
R72: Well NASA-8 ±215 FT NW
R102: Well NASA-4 ±15 FT SE

NASA

LINE GC-8 R1-R148

DONA ANA CO NM
600% CDP SECTION

RECORDING

RECORDED BY: PRG DATE RECORDED: 05/22/87 INSTRUMENTS: EG&G ES1210F
GAIN MODE: FIXED FIELD FILTER: OUT-80HZ 60HZ NOTCH FILTER: IN
RECORD LENGTH: 0.5 SEC SAMPLE RATE: 0.0005 SEC

SPREAD

TYPE: END OVER CDP FOLD: 6 NO OF GROUPS: 6
LINE DIR: SW-NE NEAR GRP CTR: 66 FT FAR GRP CTR: 394 FT
SEISES/GRP: 1 @ 66 FT INLINE GROUP INTERVAL: 66FT

ENERGY

SOURCE: 550 LB WT DRP SP ARRAY: POINT SP INTERVAL: 33 FT
SP OFFSET: 0 DROPS/SP: 2-4

PROCESSING SEQUENCE

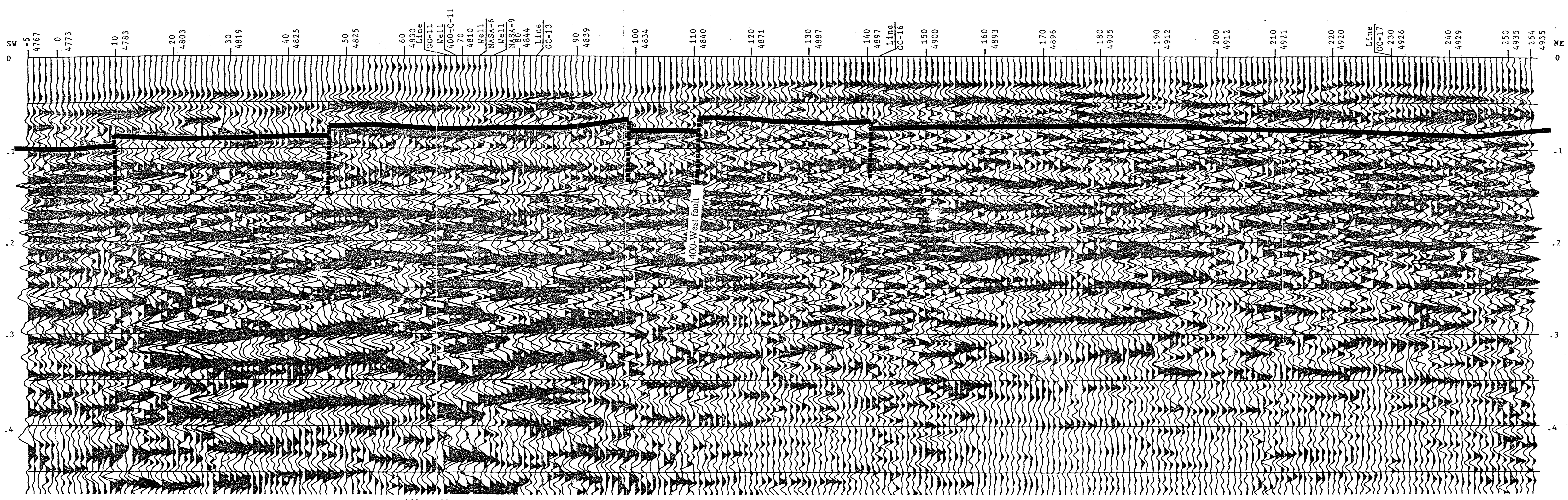
(1) TRANSCR (2) DATA EDIT (3) WX DTRM
(4) FANFIL (5) TVDCON3 20 PTS (6) STK 600%
(7) DTMCRN (8) DIPFIL (9) FIL 0-120 HZ
(10) TRC NORM (11) PLOT VA/WT (12)

PLOTTER DISPLAY

HORIZ SCALE: 33 FT/TR POLARITY: POS VERT SCALE: 15 IN/SEC
WX VEL.: 1900 FT/SEC DATUM: SURFACE CORRN VEL : 3700 FT/SEC

CHARLES B. REYNOLDS & ASSOC.

Enclosure No. 9



R69: Well 400-C-118 ±60 FT NW
R73: Well NASA-6 ±350 FT SE
R75/R76: Well NASA-9 ±290 FT SE

NASA

LINE GC-9 R1-R254

DONA ANA CO NM
600%-CDP SECTION

RECORDING		
RECORDED BY: PRG	DATE RECORDED: 07/24/88	INSTRUMENTS: EG&G ES1210F
GAIN MODE: FIXED	FIELD FILTER: OUT-120HZ	60HZ NOTCH FILTER: IN
RECORD LENGTH: 0.5 SEC	SAMPLE RATE: 0.0005 SEC	

SPREAD		
TYPE: END OVER	CDP FOLD: 6	NO OF GROUPS: 6
LINE DIR: SW-NE	NEAR GRP CTR: 66 FT	FAR GRP CTR: 394 FT
SEISES/GRP: 1 @ 66 FT INLINE	GROUP INTERVAL: 66FT	

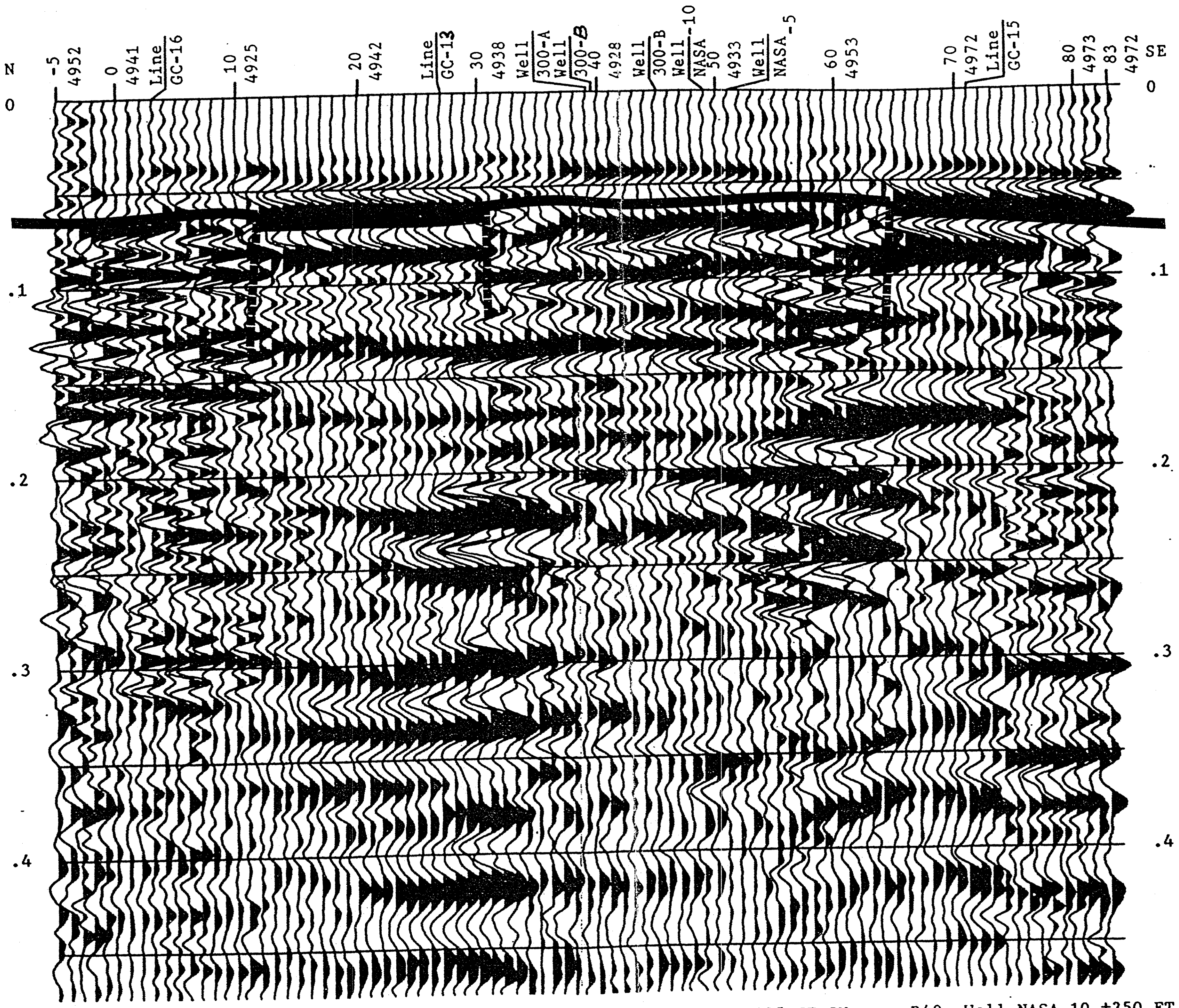
ENERGY		
SOURCE: 550 LB WT DRP	SP ARRAY: POINT	SP INTERVAL: 33 FT
SP OFFSET: 0	DROPS/SP: 1-3	

PROCESSING SEQUENCE		
(1) TRANSCR	(2) DATA EDIT	(3) WX DTRM
(4) FANFIL	(5) TVDCON3 20 PTS	(6) STK 600%
(7) DTMCRN	(8) DIPFIL	(9) FIL 0-120 HZ
(10) TRC NORM	(11) PLOT VA/WT	(12)

PLOTTER DISPLAY		
HORIZ SCALE: 33 FT/TR	POLARITY: POS	VERT SCALE: 15 IN/SEC
WX VEL.: 2000 FT/SEC	DATUM: SURFACE	CORRN VEL : 3700 FT/SEC

CHARLES B. REYNOLDS & ASSOC.

Enclosure No. 10



R39: Well 300-A-170 ±125 FT SW
R39/R40: Well 300-A-120 ±130 FT SW
R45: Well 300-B-166 ±255 FT SW
R49: Well NASA-10 ±250 FT NE
R51: Well NASA-5 ±175 FT NE

NASA

LINE GC-10 R1-R83

DONA ANA CO NM
600% CDP SECTION

RECORDING

RECORDED BY: CBR	DATE RECORDED: 04/19/87	INSTRUMENTS: EG&G ES1210F
GAIN MODE: FIXED	FIELD FILTER: OUT-80HZ	60HZ NOTCH FILTER: IN
RECORD LENGTH: 0.5 SEC		SAMPLE RATE: 0.0005 SEC

SPREAD

TYPE: END OVER	CDP FOLD: 6	NO OF GROUPS: 6
LINE DIR: N-SE	NEAR GRP CTR: 66 FT	FAR GRP CTR: 394 FT
SEISES/GRP: 1 @ 66 FT INLINE		GROUP INTERVAL: 66FT

ENERGY

SOURCE: 550 LB WT DRP	SP ARRAY: POINT	SP INTERVAL: 33 FT
SP OFFSET: 0		DROPS/SP: 1-3

PROCESSING SEQUENCE

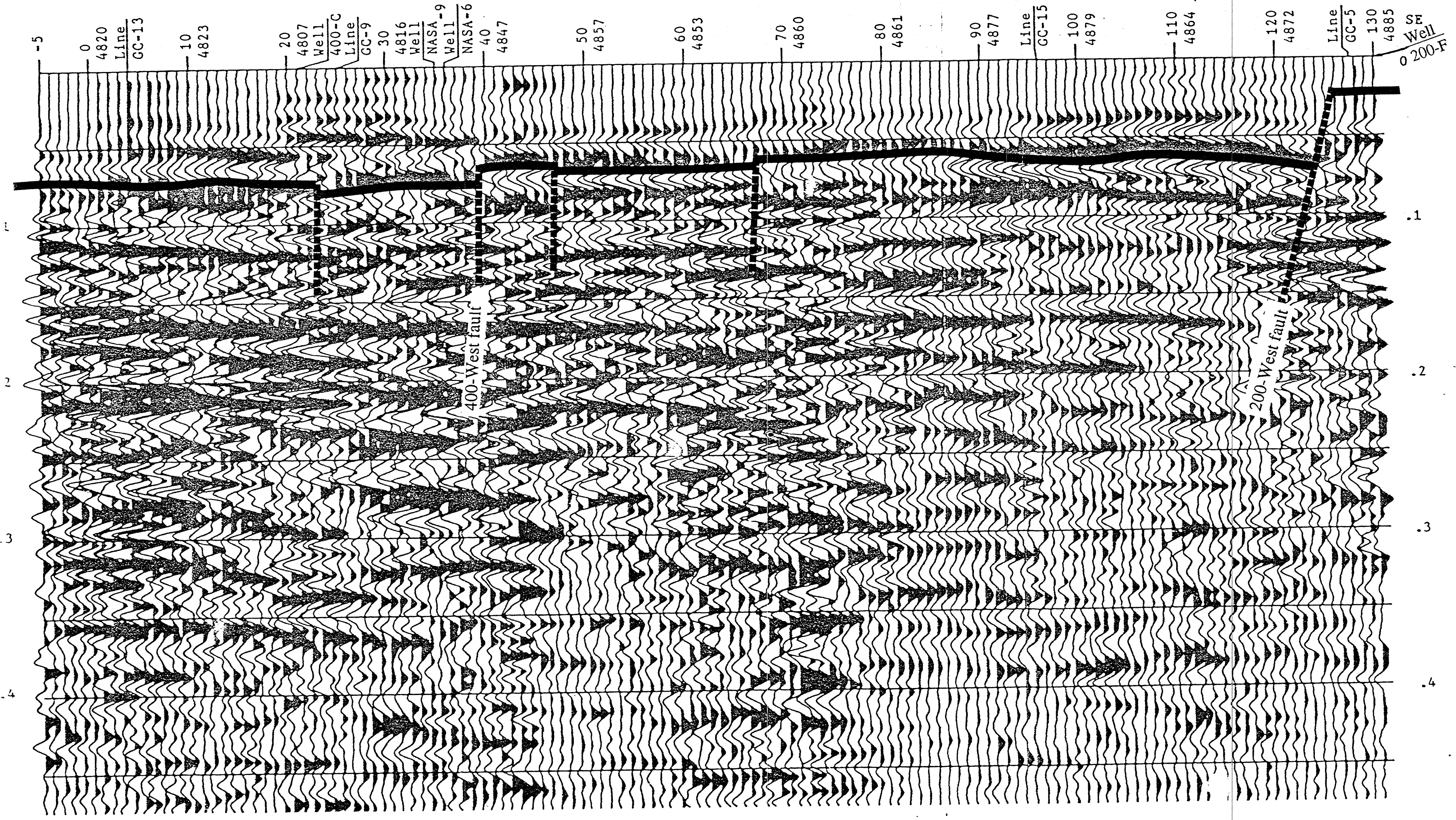
(1) TRANSCR	(2) DATA EDIT	(3) WX DTRM
(4) FANFIL	(5) TVDCON3 20 PTS	(6) STK 600%
(7) DTMCRN	(8) DIPFIL	(9) FIL 0-120 HZ
(10) TRC NORM	(11) PLOT VA/WT	(12)

PLOTTER DISPLAY

HORIZ SCALE: 33 FT/TR	POLARITY: POS	VERT SCALE: 15 IN/SEC
WX VEL.: 1800 FT/SEC	DATUM: SURFACE	CORRN VEL : 3700 FT/SEC

CHARLES B. REYNOLDS & ASSOC.

Enclosure No. 11



R21: Well 400-C-118 ±20 FT NE

R35: Well NASA-9 ±230 FT NE
R36: Well NASA-6 ±145 FT NE

NASA

LINE GC-11 R1-R130

DONA ANA CO NM
600% CDP SECTION

RECORDING

RECORDED BY: CBR	DATE RECORDED: 04/18/87	INSTRUMENTS: EG&G ES1210F
GAIN MODE: FIXED	FIELD FILTER: OUT-80HZ	60HZ NOTCH FILTER: IN
RECORD LENGTH: 0.5 SEC	SAMPLE RATE: 0.0005 SEC	

SPREAD

TYPE: END OVER	CDP FOLD: 6	NO OF GROUPS: 6
LINE DIR: NW-SE	NEAR GRP CTR: 66 FT	FAR GRP CTR: 394 FT
SEISES/GRP: 1 @ 66 FT INLINE	GROUP INTERVAL: 66FT	

ENERGY

SOURCE: 550 LB WT DRP	SP ARRAY: POINT	SP INTERVAL: 33 FT
SP OFFSET: 0	DROPS/SP: 1-2	

PROCESSING SEQUENCE

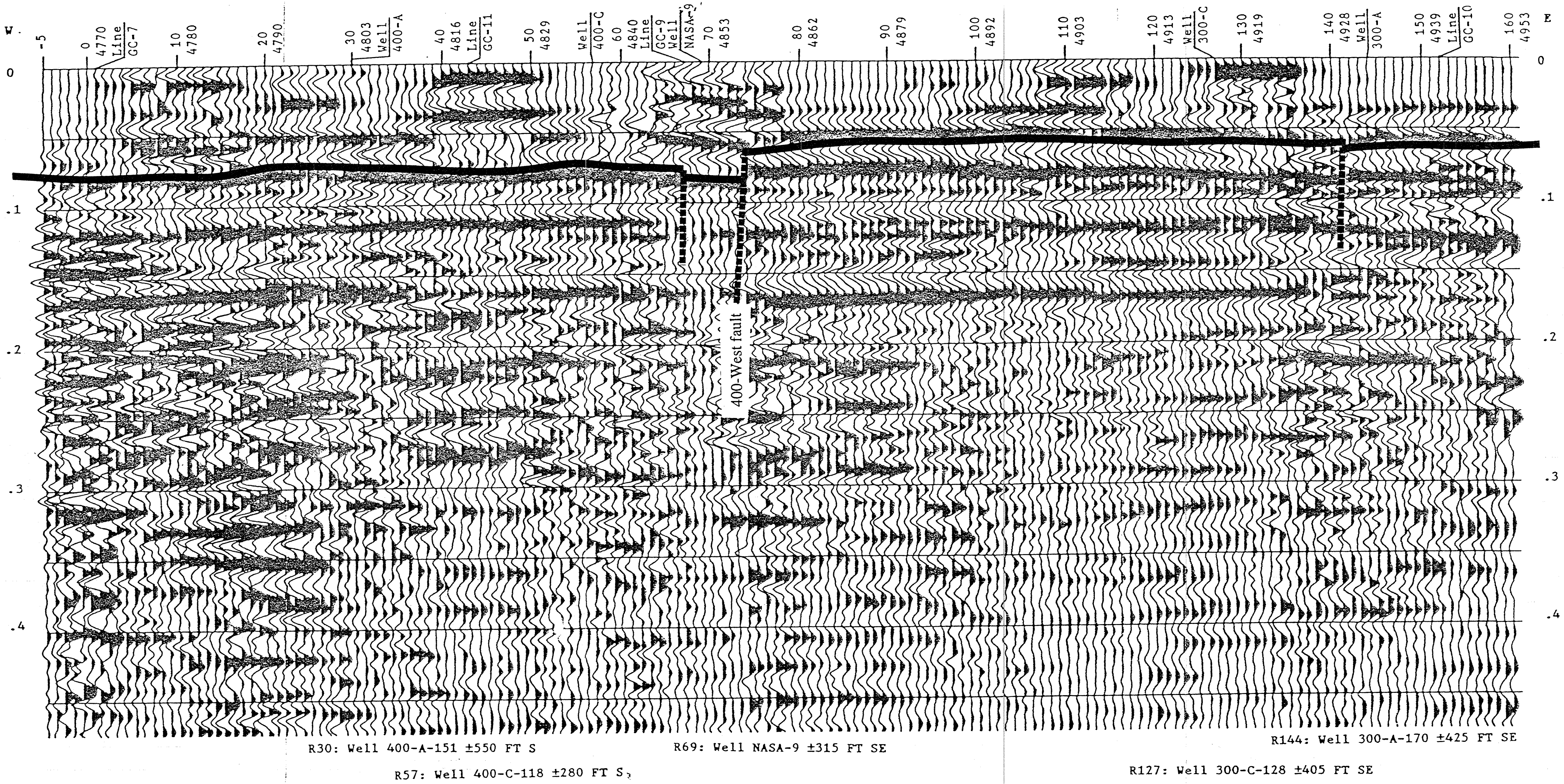
(1) TRANSCR	(2) DATA EDIT	(3) WX DTRM
(4) FANFIL	(5) TVDCON3 20 PTS	(6) STK 600%
(7) DTMCRN	(8) DIPFIL	(9) FIL 0-120 HZ
(10) TRC NORM	(11) PLOT VA/WT	(12)

PLOTTER DISPLAY

HORIZ SCALE: 33 FT/TR	POLARITY: POS	VERT SCALE: 15 IN/SEC
WX VEL.: 1800 FT/SEC	DATUM: SURFACE	CORRN VEL : 3700 FT/SEC

CHARLES B. REYNOLDS & ASSOC.

Enclosure No. 12



NASA

LINE GC-13 R1-R160

DONA ANA CO NM

600% CDP SECTION

RECORDING

RECORDED BY: CBR   DATE RECORDED: 03/14/87   INSTRUMENTS: EG&G ES1210F

GAIN MODE: FIXED   FIELD FILTER: OUT-80HZ   60HZ NOTCH FILTER: IN

RECORD LENGTH: 0.5 SEC   SAMPLE RATE: 0.0005 SEC

SPREAD

TYPE: END OVER   CDP FOLD: 6   NO OF GROUPS: 6

LINE DIR: W-E   NEAR GRP CTR: 66 FT   FAR GRP CTR: 394 FT

SEISES/GRP: 1 @ 66 FT INLINE   GROUP INTERVAL: 66FT

ENERGY

SOURCE: 550 LB WT DRP   SP ARRAY: POINT   SP INTERVAL: 33 FT

SP OFFSET: 0   DROPS/SP: 1-3

PROCESSING SEQUENCE

(1) TRANSCR	(2) DATA EDIT	(3) WX DTRM
(4) FANFIL	(5) TVDCON3 20 PTS	(6) STK 600%
(7) DTMCRN	(8) DIPFIL	(9) FIL 0-120 HZ
(10) TRC NORM	(11) PLOT VA/WT	(12)

PLOTTER DISPLAY

HORIZ SCALE: 33 FT/TR   POLARITY: POS   VERT SCALE: 15 IN/SEC

WX VEL.: 1800 FT/SEC   DATUM: SURFACE   CORRN VEL : 3700 FT/SEC

CHARLES B. REYNOLDS & ASSOC.

Enclosure No. 13

NASA

LINE GC-14N R301-R460/R8-R240

DONA ANA CO NM
600% CDP SECTION

RECORDING

RECORDED BY: PRG   DATE RECORDED: 04/28/89   INSTRUMENTS: EG&G ES1210F
GAIN MODE: FIXED   FIELD FILTER: OUT-120HZ   60HZ NOTCH FILTER: IN
RECORD LENGTH: 0.5 SEC   SAMPLE RATE: 0.0005 SEC

SPREAD

TYPE: END OVER   CDP FOLD: 6   NO OF GROUPS: 6
LINE DIR: NW-SE   NEAR GRP CTR: 66 FT   FAR GRP CTR: 394 FT
SEISES/GRP: 1 @ 66 FT INLINE   GROUP INTERVAL: 66FT

ENERGY

SOURCE: 550 LB WT DRP   SP ARRAY: POINT   SP INTERVAL: 33 FT
SP OFFSET: 0   DROPS/SP: 2-5

PROCESSING SEQUENCE

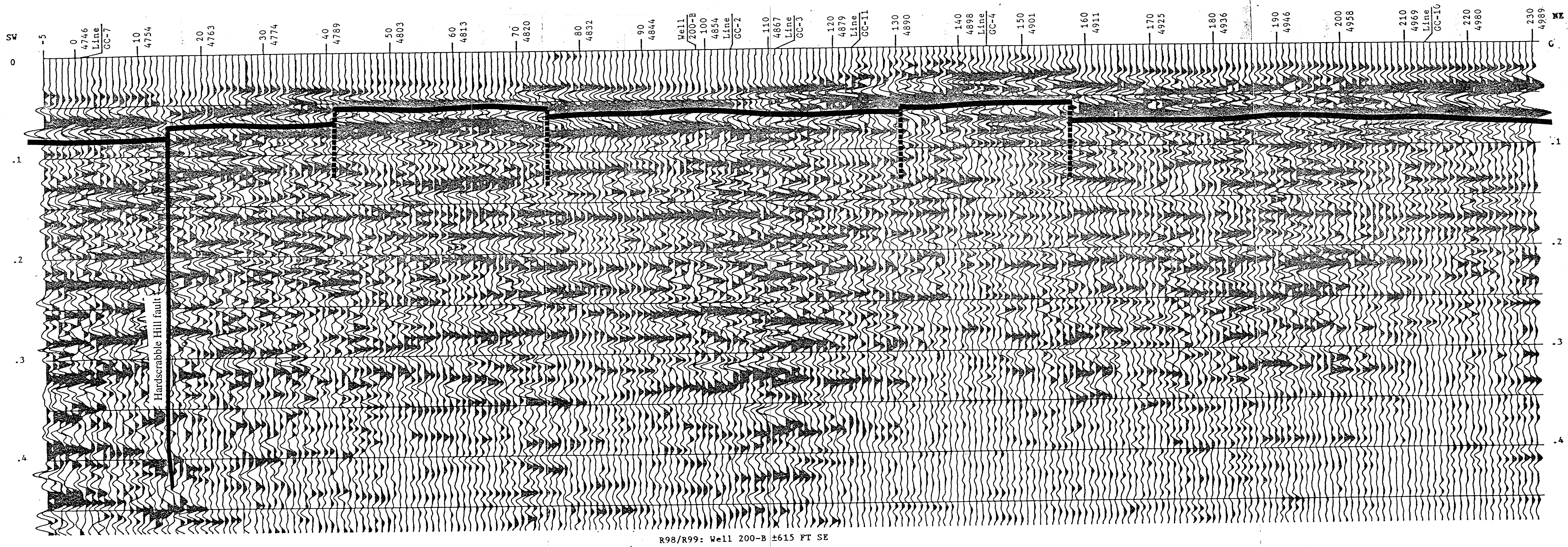
(1) TRANSCR   (2) DATA EDIT   (3) WX DTRM
(4) FANFIL   (5) TVDCON3 20 PTS   (6) STK 600%
(7) DTMCRN   (8) DIPFIL   (9) FIL 0-80 HZ
(10) TRC NORM   (11) PLOT VA/WT   (12)

PLOTTER DISPLAY

HORIZ SCALE: 33 FT/TR   POLARITY: POS   VERT SCALE: 7.5 IN/SEC
WX VEL.: 1900 FT/SEC   DATUM: SURFACE   CORRN VEL : 3700 FT/SEC

CHARLES B. REYNOLDS & ASSOC.

Enclosure No. 14



R98/R99: Well 200-B ±615 FT SE

NASA

LINE GC-15 R1-R230

DONA ANA CO NM

600% CDP SECTION

RECORDING

RECORDED BY: TBR   DATE RECORDED: 07/24/87   INSTRUMENTS: EG&G ES1210F

GAIN MODE: FIXED   FIELD FILTER: OUT-80HZ   60HZ NOTCH FILTER: IN

RECORD LENGTH: 0.5 SEC   SAMPLE RATE: 0.0005 SEC

SPREAD

TYPE: END OVER   CDP FOLD: 6   NO OF GROUPS: 6

LINE DIR: SW-NE   NEAR GRP CTR: 66 FT   FAR GRP CTR: 394 FT

SEISES/GRP: 1 @ 66 FT INLINE   GROUP INTERVAL: 66FT

ENERGY

SOURCE: 550 LB WT DRP   SP ARRAY: POINT   SP INTERVAL: 33 FT

SP OFFSET: 0   DROPS/SP: 2-3

PROCESSING SEQUENCE

(1) TRANSCR   (2) DATA EDIT   (3) WX DTRM

(4) FANFIL   (5) TVDCON3 20 PTS   (6) STK 600%

(7) DTMCRN   (8) DIPFIL   (9) FIL 0-120 HZ

(10) TRC NORM   (11) PLOT VA/WT   (12)

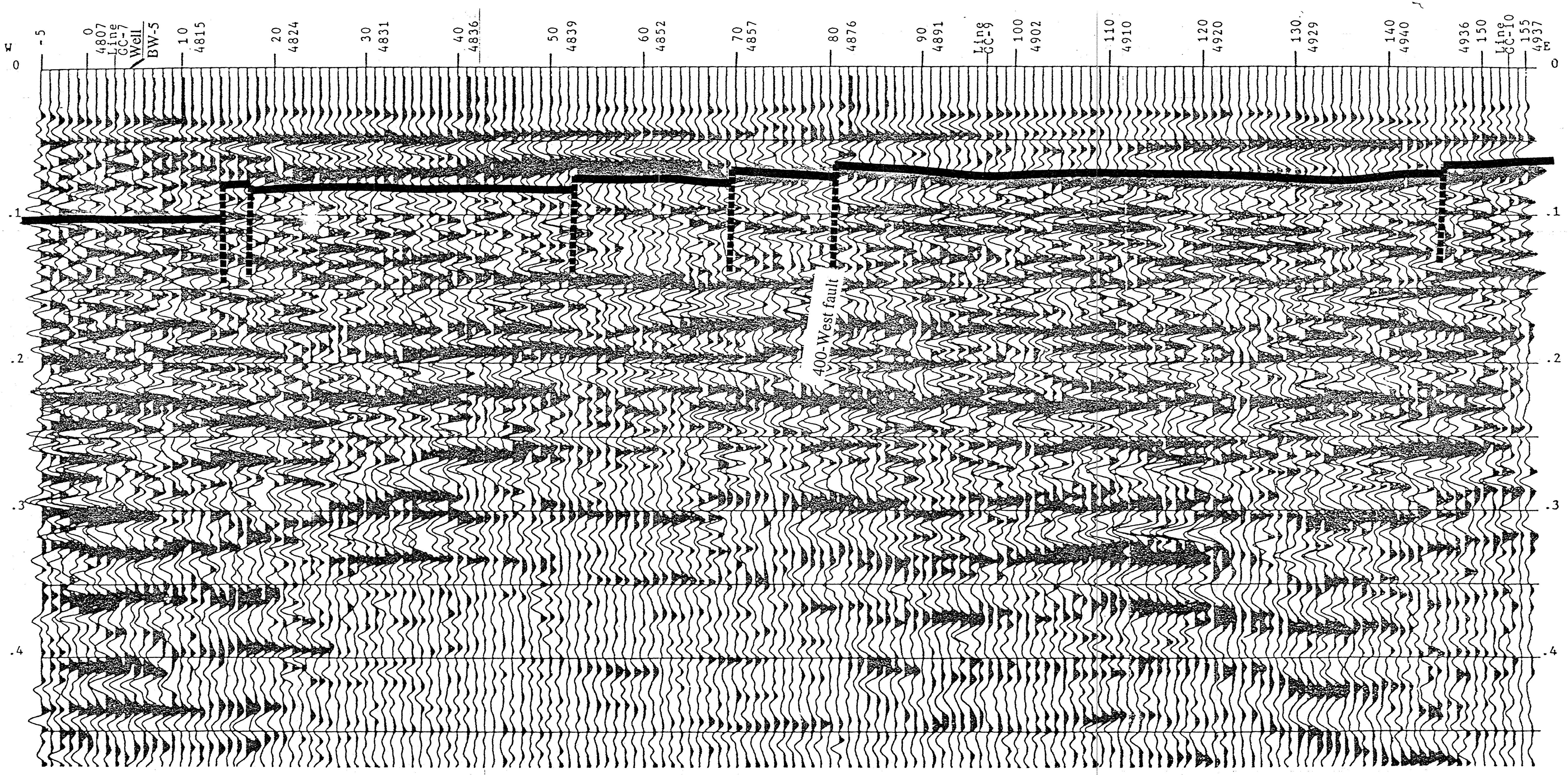
PLOTTER DISPLAY

HORIZ SCALE: 33 FT/TR   POLARITY: POS   VERT SCALE: 15 IN/SEC

WX VEL.: 1900 FT/SEC   DATUM: SURFACE   CORRN VEL : 3700 FT/SEC

CHARLES B. REYNOLDS & ASSOC.

Enclosure No. 15



NASA

LINE GC-16 R1-R155

DONA ANA CO NM
600% CDP SECTION

RECORDING

RECORDED BY: PRG   DATE RECORDED: 07/23/88   INSTRUMENTS: EG&G ES1210F
GAIN MODE: FIXED   FIELD FILTER: OUT-120HZ   60HZ NOTCH FILTER: IN
RECORD LENGTH: 0.5 SEC   SAMPLE RATE: 0.0005 SEC

SPREAD

TYPE: END OVER   CDP FOLD: 6   NO OF GROUPS: 6
LINE DIR: W-E   NEAR GRP CTR: 66 FT   FAR GRP CTR: 394 FT
SEISES/GRP: 1 @ 66 FT INLINE   GROUP INTERVAL: 66FT

ENERGY

SOURCE: 550 LB WT DRP   SP ARRAY: POINT   SP INTERVAL: 33 FT
SP OFFSET: 0   DROPS/SP: 1-2

PROCESSING SEQUENCE

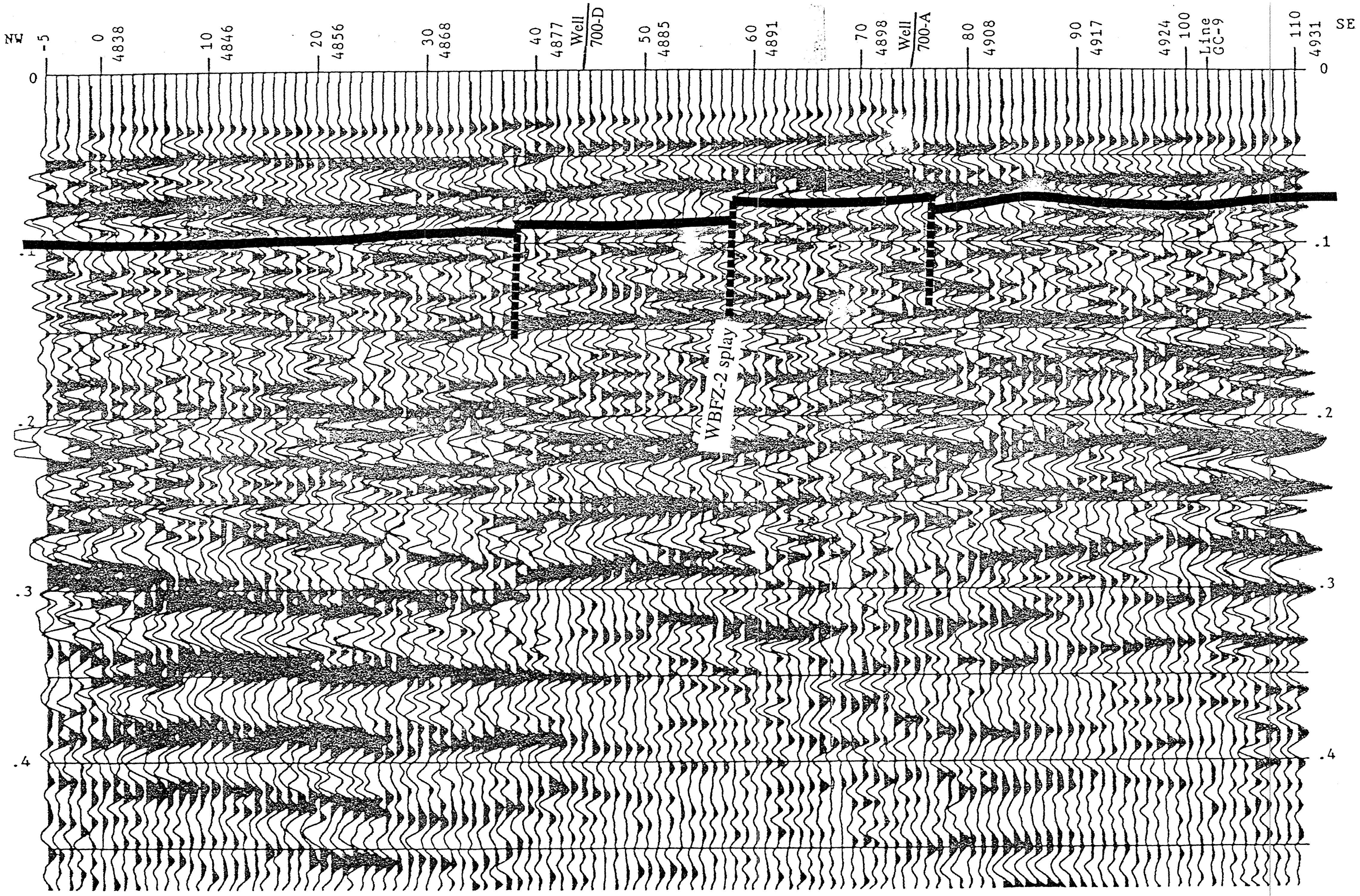
(1) TRANSCR	(2) DATA EDIT	(3) WX DTRM
(4) FANFIL	(5) TVDCON3 20 PTS	(6) STK 600%
(7) DTMCRN	(8) DIPFIL	(9) FIL 0-120 HZ
(10) TRC NORM	(11) PLOT VA/WT	(12)

PLOTTER DISPLAY

HORIZ SCALE: 33 FT/TR   POLARITY: POS   VERT SCALE: 15 IN/SEC
WX VEL.: 2300 FT/SEC   DATUM: SURFACE   CORRN VEL : 3700 FT/SEC

CHARLES B. REYNOLDS & ASSOC.

Enclosure No. 16



NASA

LINE GC-17 R1-R110

DONA ANA CO NM
600% CDP SECTION

RECORDING

RECORDED BY: PRG DATE RECORDED: 07/25/88 INSTRUMENTS: EG&G ES1210F
GAIN MODE: FIXED FIELD FILTER: OUT-120HZ 60HZ NOTCH FILTER: IN
RECORD LENGTH: 0.5 SEC SAMPLE RATE: 0.0005 SEC

SPREAD

TYPE: END OVER CDP FOLD: 6 NO OF GROUPS: 6
LINE DIR: NW-SE NEAR GRP CTR: 66 FT FAR GRP CTR: 394 FT
SEISES/GRP: 1 @ 66 FT INLINE GROUP INTERVAL: 66FT

ENERGY

SOURCE: 550 LB WT DRP SP ARRAY: POINT SP INTERVAL: 33 FT
SP OFFSET: 0 DROPS/SP: 1-2

PROCESSING SEQUENCE

(1) TRANSCR (2) DATA EDIT (3) WX DTRM
(4) FANFIL (5) TVDCON3 20 PTS (6) STK 600%
(7) DTMCRN (8) DIPFIL (9) FIL 0-120 HZ
(10) TRC NORM (11) PLOT VA/WT (12)

PLOTTER DISPLAY

HORIZ SCALE: 33 FT/TR POLARITY: POS VERT SCALE: 15 IN/SEC
WX VEL.: 2500 FT/SEC DATUM: SURFACE CORRN VEL : 3700 FT/SEC

CHARLES B. REYNOLDS & ASSOC.

Enclosure No. 17

GCL/NASA

LINE GC-18 R1-R573

600% CDP SECITON

RECORDING		
RECORDED BY: PRG	DATE RECORDED: 3/18/88	INSTRUMENTS: EG&G ES1210F
GAIN MODE: FIXED	FIELD FILTER: OUT-80HZ	60HZ NOTCH FILTER: IN
RECORD LENGTH: 0.5 SEC	SAMPLE RATE: 0.0005 SEC	

SPREAD		
TYPE: END OVER	CDP FOLD: 6	NO OF GROUPS: 6
LINE DIR: N-S	NEAR GRP CTR: 66 FT	FAR GRP CTR: 394 FT
SEISES/GRP: 1 @ 66 FT INLINE	GROUP INTERVAL: 66FT	

ENERGY		
SOURCE: 550 LB WT DRP	SP ARRAY: POINT	SP INTERVAL: 33 FT
SP OFFSET: 0	DROPS/SP: 2-6	

PROCESSING SEQUENCE		
(1) TRANSCR	(2) DATA EDIT	(3) WX DTRM
(4) FANFIL	(5) TVDCON3 20 PTS	(6) STK 600%
(7) DTMCRN	(8) DIPFIL	(9) FIL 0-120 HZ
(10) TRC NORM	(11) PLOT VA/WT	(12)

PLOTTER DISPLAY		
HORIZ SCALE: 33 FT/TR	POLARITY: POS	VERT SCALE: 15 IN/SEC
WX VEL.: 2100 FT/SEC	DATUM: SURFACE	CORRN VEL : 3700 FT/SEC

Enclosure No. 18

GCL/NASA

LINE GC-19 R1-R710

DONA ANA CO NM
600% CDP SECTION

RECORDING		
RECORDED BY: PRG	DATE RECORDED: 10/25/87	INSTRUMENTS: EG&G ES1210F
GAIN MODE: FIXED	FIELD FILTER: OUT-80HZ	60HZ NOTCH FILTER: IN
RECORD LENGTH: 1.0 SEC	SAMPLE RATE: 0.001 SEC	

SPREAD		
TYPE: END OVER	CDP FOLD: 6	NO OF GROUPS: 6
LINE DIR: E-W	NEAR GRP CTR: 66 FT	FAR GRP CTR: 394 FT
SEISES/GRP: 1 @ 66 FT INLINE	GROUP INTERVAL: 66FT	

ENERGY		
SOURCE: 550 LB WT DRP	SP ARRAY: POINT	SP INTERVAL: 33 FT
SP OFFSET: 0	DROPS/SP: 2-4	

PROCESSING SEQUENCE		
(1) TRANSCR	(2) DATA EDIT	(3) WX DTRM
(4) FANFIL	(5) TVDCON3 10 PTS	(6) STK 600%
(7) DIPFIL	(8) DTMCRN	(9) FIL 0-120HZ
(10) TRC NORM	(11) PLOT VA/WT	(12)

PLOTTER DISPLAY		
HORIZ SCALE: 33 FT/TR	POLARITY: POS	VERT SCALE: 7.5 IN/SEC
WX VEL.: 2400 FT/SEC	DATUM: SURFACE	CORRN VEL : 3700 FT/SEC

CHARLES B. REYNOLDS & ASSOC.

Enclosure No. 19

R307: Well JP-1-424 ±75 FT W

R250: Well JP-2-447 ±50 FT W

R159: Well WW-1-452 ±50 FT NW

NASA

LINE GC-20 R1-R489

DONA ANA CO NM
600% CDP SECTION

RECORDING

RECORDED BY: PRG DATE RECORDED: 03/17/88 INSTRUMENTS: EG&G ES1210F
GAIN MODE: FIXED FIELD FILTER: OUT-80HZ 60HZ NOTCH FILTER: IN
RECORD LENGTH: 1.0 SEC SAMPLE RATE: 0.001 SEC

SPREAD

TYPE: END OVER CDP FOLD: 6 NO OF GROUPS: 6
LINE DIR: N-S NEAR GRP CTR: 66 FT FAR GRP CTR: 394 FT
SEISES/GRP: 1 @ 66 FT INLINE GROUP INTERVAL: 66FT

ENERGY

SOURCE: 550 LB WT DRP SP ARRAY: POINT SP INTERVAL: 33 FT
SP OFFSET: 0 DROPS/SP: 2-3

PROCESSING SEQUENCE

(1) TRANSCR (2) DATA EDIT (3) WX DTRM
(4) FANFIL (5) TVDCON3 10 PTS (6) STK 600%
(7) DTMCRN (8) DIPFIL (9) FIL 0-120 HZ
(10) TRC NORM (11) PLOT VA/WT (12)

PLOTTER DISPLAY

HORIZ SCALE: 33 FT/TR POLARITY: POS VERT SCALE: 7.5 IN/SEC
WX VEL.: 2200 FT/SEC DATUM: SURFACE CORRN VEL : 3700 FT/SEC

CHARLES B. REYNOLDS & ASSOC.

Enclosure No. 20

NASA

LINE GC-21 R1-R560

DONA ANA CO NM
600% CDP SECTION

RECORDING

RECORDED BY: PRG   DATE RECORDED: 03/19/88   INSTRUMENTS: EG&G ES1210F
GAIN MODE: FIXED   FIELD FILTER: OUT-80HZ   60HZ NOTCH FILTER: IN
RECORD LENGTH: 1.0 SEC   SAMPLE RATE: 0.001 SEC

SPREAD

TYPE: END OVER   CDP FOLD: 6   NO OF GROUPS: 6
LINE DIR: W-E   NEAR GRP CTR: 66 FT   FAR GRP CTR: 394 FT
SEISES/GRP: 1 @ 66 FT INLINE   GROUP INTERVAL: 66FT

ENERGY

SOURCE: 550 LB WT DRP   SP ARRAY: POINT   SP INTERVAL: 33 FT
SP OFFSET: 0   DROPS/SP: 2-3

PROCESSING SEQUENCE

(1) TRANSCR   (2) DATA EDIT   (3) WX DTRM
(4) FANFIL   (5) TVDCON3 10 PTS   (6) STK 600%
(7) DTMCRN   (8) DIPFIL   (9) FIL 0-120 HZ
(10) TRC NORM   (11) PLOT VA/WT   (12)

PLOTTER DISPLAY

HORIZ SCALE: 33 FT/TR   POLARITY: POS   VERT SCALE: 7.5 IN/SEC
WX VEL.: 2200 FT/SEC   DATUM: SURFACE   CORRN VEL : 3700 FT/SEC

CHARLES B. REYNOLDS & ASSOC.

Enclosure No. 21

NASA

LINE GC-22 R1-R496

DONA ANA CO NM
600% CDP SECTION

RECORDING		
RECORDED BY: PRG	DATE RECORDED: 01/18/88	INSTRUMENTS: EG&G ES1210F
GAIN MODE: FIXED	FIELD FILTER: OUT-80HZ	60HZ NOTCH FILTER: IN
RECORD LENGTH: 1.0 SEC	SAMPLE RATE: 0.001 SEC	

SPREAD		
TYPE: END OVER	CDP FOLD: 6	NO OF GROUPS: 6
LINE DIR: W-E	NEAR GRP CTR: 66 FT	FAR GRP CTR: 394 FT
SEISES/GRP: 1 @ 66 FT INLINE	GROUP INTERVAL: 66FT	

ENERGY		
SOURCE: 550 LB WT DRP	SP ARRAY: POINT	SP INTERVAL: 33 FT
SP OFFSET: 0	DROPS/SP: 2-3	

PROCESSING SEQUENCE		
(1) TRANSCR	(2) DATA EDIT	(3) WX DTRM
(4) FANFIL	(5) TVDCON3 10 PTS	(6) STK 600%
(7) DTMCRN	(8) DIPFIL	(9) FIL 0-120 HZ
(10) TRC NORM	(11) PLOT VA/WT	(12)

PLOTTER DISPLAY		
HORIZ SCALE: 33 FT/TR	POLARITY: POS	VERT SCALE: 7.5 IN/SEC
WX VEL.: 2200 FT/SEC	DATUM: SURFACE	CORRN VEL : 3700 FT/SEC

CHARLES B. REYNOLDS & ASSOC.

Enclosure No. 22

NASA		
LINE GC-23 R1-R491		
DONA ANA CO NM		
600% CDP SECTION		
RECORDING		
RECORDED BY: PRG	DATE RECORDED: 02/14/86	INSTRUMENTS: EG&G ES1210F
GAIN MODE: FIXED	FIELD FILTER: OUT-80HZ	60HZ NOTCH FILTER: IN
RECORD LENGTH: 1.0 SEC	SAMPLE RATE: 0.001 SEC	
SPREAD		
TYPE: END OVER	CDP FOLD: 6	NO OF GROUPS: 6
LINE DIR: W-E	NEAR GRP CTR: 66 FT	FAR GRP CTR: 394 FT
SEISES/GRP: 1 @ 66 FT INLINE	GROUP INTERVAL: 66FT	
ENERGY		
SOURCE: 550 LB WT DRP	SP ARRAY: POINT	SP INTERVAL: 33 FT
SP OFFSET: 0	DROPS/SP: 2-3	
PROCESSING SEQUENCE		
(1) TRANSCR	(2) DATA EDIT	(3) WX DTRM
(4) FANFIL	(5) TVDCON3 10 PTS	(6) STK 600%
(7) DTMCRN	(8) DIPFIL	(9) FIL 0-120 HZ
(10) TRC NORM	(11) PLOT VA/WT	(12)
PLOTTER DISPLAY		
HORIZ SCALE: 33 FT/TR	POLARITY: POS	VERT SCALE: 7.5 IN/SEC
WX VEL.: 2200 FT/SEC	DATUM: SURFACE	CORRN VEL : 3700 FT/SEC
CHARLES B. REYNOLDS & ASSOC.		

Enclosure No. 23

NASA

LINE GC-24 R1-R309

DONA ANA CO NM
600% CDP SECTION

RECORDING		
RECORDED BY: PRG	DATE RECORDED: 04/08/88	INSTRUMENTS: EG&G ES1210F
GAIN MODE: FIXED	FIELD FILTER: OUT-80HZ	60HZ NOTCH FILTER: IN
RECORD LENGTH: 1.0 SEC	SAMPLE RATE: 0.001 SEC	
SPREAD		
TYPE: END OVER	CDP FOLD: 6	NO OF GROUPS: 6
LINE DIR: N-S	NEAR GRP CTR: 66 FT	FAR GRP CTR: 394 FT
SEISES/GRP: 1 @ 66 FT INLINE	GROUP INTERVAL: 66FT	
ENERGY		
SOURCE: 550 LB WT DRP	SP ARRAY: POINT	SP INTERVAL: 33 FT
SP OFFSET: 0	DROPS/SP: 1-3	
PROCESSING SEQUENCE		
(1) TRANSCR	(2) DATA EDIT	(3) WX DTRM
(4) FANFIL	(5) TVDCON3 10 PTS	(6) STK 600%
(7) DTMCRN	(8) DIPFIL	(9) FIL 0-120 HZ
(10) TRC NORM	(11) PLOT VA/WT	(12)
PLOTTER DISPLAY		
HORIZ SCALE: 33 FT/TR	POLARITY: POS	VERT SCALE: 7.5 IN/SEC
WX VEL.: 2200 FT/SEC	DATUM: SURFACE	CORRN VEL : 3700 FT/SEC

CHARLES B. REYNOLDS & ASSOC.

Enclosure No. 24

R0: Well 'J' ±175 FT NW

NASA

LINE GC-25 R1-R500

DONA ANA CO NM
600% CDP SECTION

RECORDING

RECORDED BY: PRG   DATE RECORDED: 06/01/88   INSTRUMENTS: EG&G ES1210F
GAIN MODE: FIXED   FIELD FILTER: OUT-80HZ   60HZ NOTCH FILTER: IN
RECORD LENGTH: 1.0 SEC   SAMPLE RATE: 0.001 SEC

SPREAD

TYPE: END OVER   CDP FOLD: 6   NO OF GROUPS: 6
LINE DIR: W-E   NEAR GRP CTR: 66 FT   FAR GRP CTR: 394 FT
SEISES/GRP: 1 @ 66 FT INLINE   GROUP INTERVAL: 66FT

ENERGY

SOURCE: 550 LB WT DRP   SP ARRAY: POINT   SP INTERVAL: 33 FT
SP OFFSET: 0   DROPS/SP: 2-4

PROCESSING SEQUENCE

(1) TRANSCR   (2) DATA EDIT   (3) WX DTRM
(4) FANFIL   (5) TVDCON3 10 PTS   (6) STK 600%
(7) DTMCRN   (8) DIPFIL   (9) FIL 0-120 HZ
(10) TRC NORM   (11) PLOT VA/WT   (12)

PLOTTER DISPLAY

HORIZ SCALE: 33 FT/TR   POLARITY: POS   VERT SCALE: 7.5 IN/SEC
WX VEL.: 2400 FT/SEC   DATUM: SURFACE   CORRN VEL : 3700 FT/SEC

CHARLES B. REYNOLDS & ASSOC.

Enclosure No. 25

NASA

LINE GC-26 R1-R511

DONA ANA CO NM
0.5 SEC 600% CDP SECTION

RECORDING

RECORDED BY: PRG   DATE RECORDED: 04/13/89   INSTRUMENTS: EG&G ES1210F
GAIN MODE: FIXED   FIELD FILTER: OUT-120HZ   60HZ NOTCH FILTER: IN
RECORD LENGTH: 1.0 SEC   SAMPLE RATE: 0.001 SEC

SPREAD

TYPE: END OVER   CDP FOLD: 6   NO OF GROUPS: 6
LINE DIR: W-E   NEAR GRP CTR: 66 FT   FAR GRP CTR: 394 FT
SEISES/GRP: 1 @ 00 FT INLINE   GROUP INTERVAL: 66FT

ENERGY

SOURCE: 550 LB WT DRP   SP ARRAY: POINT   SP INTERVAL: 33 FT
SP OFFSET: 0   DROPS/SP: 2-3

PROCESSING SEQUENCE

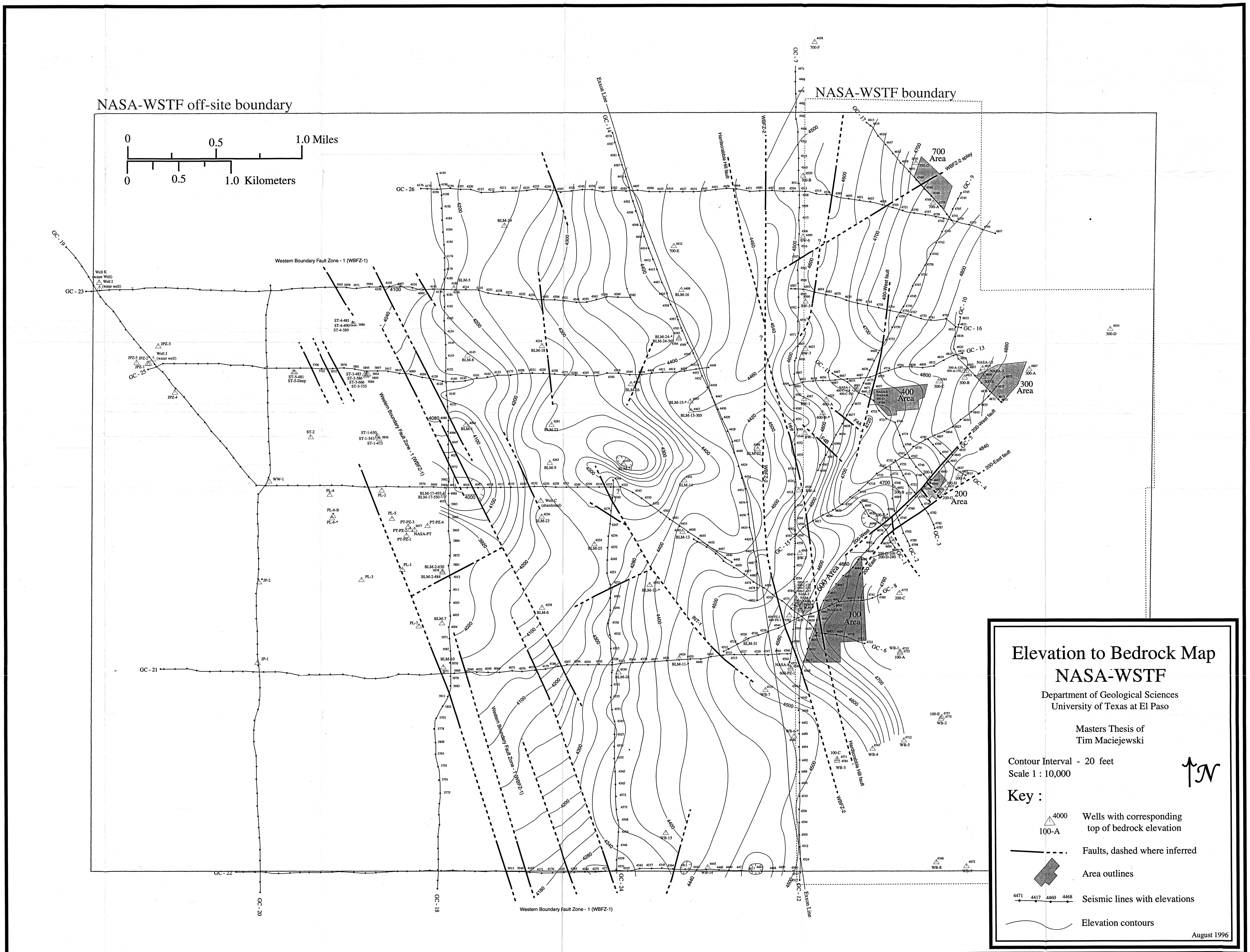
(1) TRANSCR   (2) REFRMT   (3) DATA EDIT
(4) WX DETERM   (5) FANFIL   (6) TVDCON3 30 MS
(7) STK 600%   (8) DIMORN   (9) DIPFIL
(10) FIL 0-80HZ   (11) TRC NORM   (12) PLOT VA/WT

PLOTTER DISPLAY

HORIZ SCALE: 33 FT/TRC   POLARITY: POS   VERT SCALE: 7.5 IN/SEC
WX VEL.: 2200 FT/SEC   DATUM: SURFACE   CORRN VEL : 3700 FT/SEC

CHARLES B. REYNOLDS & ASSOC.

Enclosure No. 26



Enclosure No. 1

Evaluation of Seismic Data for the NASA Johnson Space Center, White Sands Test Facility

Final Report
Date: October 1, 1995

By

Kate C. Miller
and
Tim Maciejewski

Department of Geological Sciences
University of Texas at El Paso

Submitted to:

NASA–Johnson Space Center
White Sands Test Facility
P. O. Drawer MM
Las Cruces, New Mexico 88004

Summary

During the contract period, early April 1995 through September 30, 1995, existing seismic data on the NASA White Sand Test Facility was re–evaluated and re–interpreted in conjunction with other geophysical and drilling data collected since acquisition of the seismic data in 1988. A new bedrock elevation map was generated, the feasiblity of mapping intra–bedrock reflectors was evaluated, and a gravity survey was conducted on the site.

The primary conclusions of this study are as follows:

1. Bedrock dips westward at 4 – 5° beneath the WSTF and is broken by three major northwest trending fault zones as well as numerous smaller fault zones. Two of the three major fault zones drop bedrock down to the west, resulting in a rapid increase in depth to bedrock west of these fault zones. Many minor faults also offset the bedrock.

2. Two bedrock channels are apparent on the map. The first originates from the valley east northeast of the 300 region and proceeds westward through the 300 and 400 areas. A second channel can be seen trending southwest near the 200 area, producing a low near the 200–E–* well. The second channel originates in the 200 area and goes through the 600 area. Near well BLM–21 both channels appear to converge and then continue off to the west.

3. Reliable mapping of intra–bedrock horizons is not feasible with the existing dataset. Synthetic seismograms based on well log data from the 200–F, 200–G, and 600–D wells indicates that horizons within bedrock should be seismically reflective. However, the seismic data to not image the 30 – 35° dips seen in adjacent bedrock outcrop, and the raw data appear to be dominated by surface wave energy that obscures reflected energy from within bedrock.

4. A modern seismic survey could be designed to image deeper bedrock layers. A source with deeper penetration that does not generate surface waves, combined with modern recording equipment that allows for greater offset and a greater number of recording groups on the ground should be able to image bedrock layers.

5. Two–dimensional forward modeling of the gravity survey acquired on site will help constrain the location and dip of many of the faults crossing the test facility, the geometry of the interface between the volcanic and Paleozoic rocks, and the thickness of Quaternary fill in the Jornada basin.

Introduction and Purpose

In 1987 and 1988, approximately 42 miles of shallow seismic reflection data on the NASA White Sand Test Facility were acquired for NASA by Charles B. Reynolds and Associates (CBR&A) (Reynolds and Associates, 1987, 1988) for the purpose of mapping the top of bedrock in the subsurface. The purpose of this report is to discuss the results of a re–evaluation and re–interpretation of these data in conjunction with the additional geophysical and drilling data that have accumulated since acquisition of the seismic data in 1988.

The re–evaluation of the seismic data was initiated for two reasons. First, the drilling of around 100 additional monitoring wells since 1988 has led to significant differences between the 1988 bedrock maps based on seismic data and bedrock as determined by the more recent monitoring wells. Differences are greatest in the off site area where discrepancies of over 300 feet can be seen in the southernmost part of line GC–24. Second, more recent analysis of well data from within the bedrock led to the suggestion that there may be lithologic units in the bedrock which may have important influences on regional and site–specific hydrologic processes. Of particular interest is the "Charlene shale", a Paleozoic horizon found in the 200 and 300 areas that may prevent vertical migration of fluids. Subsurface mapping of the Charlene shale or other lithologic marker would give significant information on geologic structure and therefore fluid movement within bedrock on the site.

In this report we present an updated and improved bedrock elevation map, seismic synthetics based on well log data from the 200 and 600 areas, a discussion of the shortcomings of the existing seismic data for structural interpretation of horizons from within bedrock, recommendations for appropriate seismic acquisition parameters for intra–bedrock structural mapping, and a complete bouguer gravity map based on a gravity survey conducted during the contract period.

Structural and Stratigraphic Setting

The NASA–WSTF (Figure 1) lies within the Basin and Range physiographic province which has formed during late Tertiary time in response to extensional tectonic forces. The region is characterized by north–south trending fault–bounded mountain ranges and intervening basins. The San Andres – Caballo Mountains and adjacent Jornada basin, in which the WSTF is located, are the local manifestation of these province–wide features. In addition, Laramide thrusting and compressional tectonic features have been mapped adjacent to the northern portion of the study area with the Bear Peak fold and thrust belt. Immediately north of the site, the Bear Peak thrust exhibits 5000 to 10,000 feet of displacement and places Precambrian rock over Hueco limestone of Wolfcampian age (Seager, 1981). Deformation related to the thrust may influence bedrock structure beneath the WSTF.

Structurally, the WSTF region can be divided into three zones: the Jornada basin to the west, the pediment slope of the San Andres mountains to the east, and a transition zone in the middle. Two major fault zones form the boundary zones for these regions. The fault zones strike north–northwest and are termed the Western Boundary Fault Zones 1 and 2 (WBFZ–1, WBFZ–2).

The pediment area consists of a thin veneer (0 to 200 feet) of coalescing alluvial fan deposits overlying faulted bedrock. The alluvium in the transition zone is 350 – 750 feet thick, and exceeds 1500 feet west of the WBFZ–1. Bedrock units below the alluvium consist of Paleozoic limestones, sandstones, siltstones, and shales as well as Tertiary intrusive and extrusive volcanic rocks (Seager, 1981).

Previous Geophysical Studies

A number of geophysical studies of a regional nature have been published for the southern Rio Grande rift, including the Jornada Basin region. Regional seismic refraction profiling (Sinno et al., 1986) show that the crust is 28–30 km thick. In the vicinity of the Jornada Basin, gravity studies Daggett et al., 1986, Gilmer et al., 1986) combined with P–wave delay studies (Harder et al., 1986) suggest that Quaternary basin fill in the Jornada basin may reach as much as 3500 feet in thickness. Cenozoic fill, which includes Tertiary Love Ranch Formation, may reach as much as 10,000 feet in thickness.

An oil industry seismic reflection profile crosses the WSTF (Keller et al., 1986). It crosses structural grain in a strike position relative to the Basin and Range structures, but in a dip position relative to Laramide thrusting. The profile shows flat lying Paleozoic strata overthrust by Precambrian rock at the Bear Peak thrust.

Seismic Interpretation of Bedrock Structure

The primary focus of this report is a new bedrock elevation map (Enclosure 51) based on the re–interpretation of 42 miles of seismic lines (Enclosures 1 – 50) acquired by CBR&A on the WSTF site combined with lithologic data from over 70 wells that encountered bedrock. The seismic data indicate that bedrock dips to the west and that three major northwest trending fault zones cross the site. In addition, many minor faults, particularly the beneath the 200 and 600 areas are delineated by the data. The bedrock elevation map presented in Enclosure 52 represents a simplified view of bedrock structure, where many smaller faults with displacements in the range of 10 to 40 feet were not placed on the map, but were placed on the interpreted seismic records (Enclosures 26 – 50). The reasons for the simplified presentation is two fold. First the placement of many small faults on the map obscures the primary structural features. Secondly, the overall effect on fluid flow due to small–offset faults is probably minimal.

Because seismic data is plotted in time not depth, any interpretation of depth to bedrock will depend on the velocity–depth function used to convert time to depth. For this study, the following table was used to convert travel time to the bedrock horizon on the seismic record to depth.

Thickness (ft)	Velocity (ft/s)
12	1200
38	4000
50	5000
100	6000
>200	6200

This function is consistent with the large number of wells on the site and thus ensures that the time–depth conversion is accurate when interpolating between wells along the seismic profiles. In the following paragraphs the primary structural features of the bedrock elevation map are discussed.

Major Fault Zones

Seismic and drilling data indicates that one major fault and two fault zones trending north–northwest divide the region into three distinct fault blocks. The faults contribute to westward deepening of the bedrock surface from the San Andres Mountains into the Jornada del Muerto valley. The first major fault cuts through the middle of the WSTF and may represent an extension of the Hardscrabble Hill fault, mapped by Seager (1981) in outcrop 2 km to the south.. It is visible on seismic lines, GC–6 at SP–135, GC–8 at SP–88, GC–12 at SP–77, GC–15 at SP–16, GC–7 at SP–15, and less clearly on GC–26 at SP–263. Even though this fault has over 700 feet of throw based on well data, it is not associated with any bedrock surface relief. Consequently this fault must be much older then the other faults on the site. The fault juxtaposes Pennsylvanian limestone to the east against Eocene andesite to the west. The throw on this fault is bounded by wells in the 600 area. Well NASA–4 on the eastern side of the fault hits bedrock at 125 feet penetrating 50 feet of limestone. Well 600–C–437 on the other side of the fault hits bedrock at 145 feet and penetrates 355 feet of andesite. A little further to the west, well BLM–31 hits bedrock at 200 feet and penetrates over 500 feet of andesite.

Sub–parallel to the Hardscrabble Hill fault is the Western Boundary Fault Zone 2 (WBFZ–2). This fault drops the bedrock surface from 14 to 220 feet in depth, down to 280 to 500 feet in depth. Because of the massive faulting in this region, displacement on the fault ranges from 40 feet in the 600 area, to around 80 feet near well BLM–27. WBFZ–2 is easily seen on GC–12 at SP–124, GC–8 at SP–58, GC–6 at SP–88, and less clearly on GC–26 at SP–295. Southward of the 600 area, WBFZ–2 exhibits increased displacement between well WB–3 and line GC–7. The displacement in the north, beyond well BLM–27 decreases noticeably. This may be due to a second fault which either branches off of, or intersects the WBFZ–2, compensating for the difference in displacement. This fault probably trends northeast, passing through the 700 area intersecting the WBFZ–2 just west of GC–16 having an average displacement of 40 feet down to the northwest.

A local high on the central block lies directly west of the 600 area. The high is a small plateau with a depth of approximately 200 feet, based on wells BLM–31 and 100–B, and is bounded on three sides by faults. This block is bounded to the east by the WBFZ–2 and to the west and south two smaller faults having displacements of 40 and 30 feet respectively

The third major faulted region is produced by the Western Boundary Fault Zone 1 (WBFZ–1) which trends north–northwest and is located in the western portion of the off site region. This fault zone consists of multiple down to the west normal faults that drop the bedrock surface down into the Jornada basin. The total displacement on all of these faults can not be estimated from the seismic due to short record length, but may exceed 1500 feet. Well PL–6–* penetrated 2000 feet of alluvium and never reached the bedrock. Interpretation of the gravity survey should place better constraints on the displacement across this fault zone. An interesting feature of this fault zone, is that even though the fault zone trends north – northwest, the individual faults appear to trend in a more northwesterly direction.

The 200 Area

The 200 area is dominated by two northeast trending faults. The region between these two northeast trending faults is also faulted in a northwestern direction, creating block–like structures between the two main faults. The main eastern fault (200–east) has a displacement of around 50 feet, and the western fault (200–west) has a displacement of 40 to 100 feet depending on the internal block faulting. The shallowest bedrock on site is found at a depth of 14 feet in the 200–F well. The depth to bedrock increases in all directions from this point. To the southeast there are two wells 200–G and 200–H with depths of 55 feet and 74 feet respectively. Consequently there must be a small fault running between well 200–F and the two wells 200–G and H down dropping the bedrock. The 200–east fault is located southeast of 200–G and 200–H and raises the bedrock up to a depth of 40 feet. Limestone bedrock outcrops on the surface a few hundred feet more to the southeast. To the northeast are two smaller internal faults, placing the bedrock at 65 feet. Fault 200–west dies out before it reaches line GC–10, but fault 200–east appears to continue to the northeast passing between wells NASA–3 and 300–D. Immediately to the northwest of well 200–F is the 200–west fault which drops the bedrock down 100 feet in depth. To the southwest the bedrock appears to be broken in many places between the two main faults.

There are two other features in the 200 region of importance. First is a fault running between GC–1 and GC–2 with about 70 feet of displacement. This fault is inferred from the top of bedrock data from two wells. Well 200–D on line GC–1 reached bedrock 115 feet deep whereas well 200–C on line GC–2 reached bedrock at 35 feet deep. Thus, a fault is needed to compensate for this difference. The second area of interest is near the 100 area. Both 200–east and 200–west faults propagate into the 100 area, where the 200–east fault then curves around to the south. Fault 200–west may either be truncated by another fault, or continue on into the 600 area. The data are inconclusive on this point.

The 600 Area

The bedrock below the 600 area is covered with criss–crossing faults including at lease two major and six minor faults that offset the bedrock. The depth to bedrock ranges from 110 feet to 165 feet across this region. One of the major faults is located directly east of the 600 area. This fault has no bedrock relief, but is inferred from the juxtaposition of 700 feet of andesite against limestone, as seen in well data. The second major fault lies directly to the west of the 600 region. This is a younger fault with approximately 40 feet of bedrock displacement down dropped to the west.

The 100, 300 and 700 Areas

Bedrock beneath the 100, 300 and 700 areas exhibit west dip and is virtually undisrupted by faults. A single northeast–trending fault crosses the 700 area and drops bedrock 40 – 50 ft down to the northwest. A few small offset faults were detected in these areas and are marked on the seismic records.

Other On Site Areas

Other important features in the on–site region include the presence of two channel–like structures. The first appears to originate from the valley east northeast of the 300 region. This channel proceeds westward through the 300 and 400 areas. Immediately west of the 400 area the channel is broken up by the presence of three down to the southwest faults. The faults lead to a broadening of the channel as it continues to the west. A second channel can be seen trending southwest near the 200 area, producing a low near the 200–E–* well. This second channel goes from the 200 area towards the 600 area, where turns to the northwest due to a structural high southwest of the 600 area. Near BLM–21 both channels appear to converge and then continue off to the west.

Off Site

The main feature of the off site region is the presence of a large low near well BLM–21. This low is produces through a combination of tectonic and paleo–topographic features. This low is an extension of the paleochannels which pass through the on site areas. The channel is confined to the north and to the south. Directly south of the channel is a small structural high, possibly a small thrust associated with compression due to localized faulting. To the northwest of the channel is a rhyolitic dike or flow interpreted from the well log data. The dike may have an effect on groundwater flow due to the compositional difference between it and the bedrock/alluvium contact. However the seismic records show little to no bedrock relief associated with this feature.

The bedrock drops off sharply at the WBFZ–1. The horizontal distance from BLM–17 to NASA–PT is approximately 1000 feet, but the bedrock drops over 300 feet in elevation to 3677 ft in the NASA–PT well. A couple thousand feet west of well NASA–PT is well PL–5 where the depth to bedrock exceeds 2000 feet. Unfortunately due to the surface wave noise in the seismograms, the actual depth to bedrock can not be determined from seismograms alone.

Synthetic Seismograms

Seismic reflection profiles are able to provide images of the subsurface because contrasts in acoustic impedance (the product of density and seismic velocity of rock) between geologic layers cause seismic source energy to be reflected back to the surface and recorded. The larger the acoustic impedance contrast between rock layers, the more "reflective" the processed seismic data will be and the more precisely the data can be used to map subsurface horizons. For a more detailed discussion of this process see Sheriff and Geldart (1995).

Well logs which measure velocity and density in the borehole are commonly used to generate synthetic seismograms which in turn can be used to estimate the reflectivity of rock layers and to directly correlate well log data to surface seismic profiles. Generation of a synthetic seismogram involves converting depth in the well to two way travel time using velocity measurements in the well, calculating reflection coefficients (a function of acoustic impedance) from the well data, and band-pass filtering the reflection coefficients to the same frequency band as the seismic data (e. g. Sheriff and Geldart 1995). Reflection coefficients exceeding 0.1 are considered to be large. Reflection coefficients in sedimentary rocks average ~ 0.05.

As part of this study, synthetic seismograms were generated from sonic and density logs in the 200–G and 600–D wells following the procedure just discussed. The 200–G well penetrates part of the Paleozoic sequence on site, whereas the 600–D well penetrates part of the Tertiary volcanic sequence. Thus, synthetic seismograms from these wells should be representative of the two primary bedrock types penetrated in the area. The resulting reflection coefficient series and synthetic seismograms are shown in Figures 2 – 4.

The synthetic seismograms demonstrate that the Paleozoic sequence are highly reflective, whereas the Tertiary volcanics are not. Reflection coefficients in the 200–G well are often greater than 0.1 and reach as much as 0.4. By contrast the 600–D well has only a few horizons with reflection coefficient as high as 0.1. These may be related to localized fracturing or volcanic flow boundaries within the sequence.

Two conclusions regarding acquisition and interpretation of surface seismic data can be drawn from these results. First, velocity and density contrasts between horizons within bedrock on site are sufficiently high to generate reliable reflections from within bedrock that can be directly correlated to well data. Second, the reflectivity character of the Paleozoic sequence is markedly different from that of the volcanics. This difference could be a useful tool for reliably interpreting bedrock types and geometry on seismic data on site.

Seismic Imaging of Intra–Bedrock Hydrologic Markers

The synthetic seismograms results suggest that horizons within bedrock are seismically reflective and that structural mapping of bedrock horizons can be done reliably on high quality seismic data. However, after extensive study of processed and unprocessed seismic records, it was concluded that the existing data were of insufficient quality to reliably map intra–bedrock horizons, but that a seismic survey could easily be designed to accomplish these goals. What follows is a technical discussion of why the data do not appear to image bedrock horizons and what it would take to acquire data that do image bedrock.

The primary evidence that the processed seismic records are not reliably imaging intra–bedrock horizons stems from the lack of correlation between outcrop and subsurface geology and the seismic data in the 200–area. Although an apparent correlation between the seismic and the well log synthetic can be made (Figure 5), the seismic data show almost no geologic dip. However, outcrop information (Seager, 1981), triangulation between wellbores on the top of the Charlene shale, and dip measurements on core in the 200–D well at 123 feet in depth all point to 30 – 35 degree northwest dip on the Paleozoic strata. The seismic records clearly demonstrate that the seismic data do not display dips of these magnitudes.

Examination of raw shot records from line GC–2 (Figure 2) suggests that reflecting horizons below the bedrock–alluvium interface are not being picked up in the seismic data. Two likely reasons for this are the large amount of surface wave energy in the data, and the fact that the survey acquisition parameters were designed for a shallow bedrock objective.

Seismic sources commonly generated surface waves in addition to the downgoing P–waves that lead to the desired reflected energy. Surface waves often have much higher amplitude than reflected waves and can completely obscure the reflected waves if care is not taken to suppress them during data acquisition and/or processing. The raw shot records obtained from CBR&A contain a great deal of surface wave energy (Figure x). Analysis of the seismic data processing procedures used by CBR&A (C. B. Reynolds and Associates, 1987) indicates that velocity filtering, the appropriate data processing procedure for suppressing surface waves was applied to the data. The CBR&A (1987) report also indicates that a coherency filter which "enhances seismic events oriented at less than approximately 20° from the horizontal" was applied to the data. This was also an appropriate procedure when the objective horizon was bedrock dipping at 2 – 5°. However, the coherency filter probably would have suppressed any bedrock reflections dipping at 30 – 35°, the anticipated dip of the Paleozoic strata. Complete reprocessing of the data, without a coherency filter, would be required to ascertain whether the data contain reflected energy from within bedrock.

Since the seismic survey was designed to image the bedrock surface, not deeper horizons, the acquisition parameters are not optimized for the intra–bedrock reflections. Acquisition parameters of greatest influence are source type and penetration, maximum spread offset, group interval and number of channels. A seismic survey designed to image intra–bedrock interfaces would include a higher energy source that generates less surface wave energy, larger offsets, smaller group interval, and a minimum of 24 to 60 channels on the ground. This sort of higher resolution survey would allow for better suppression of surface wave energy during both acquisition and processing, and thus better reflection imaging.

Gravity Survey

From July 1995 through August 1995 a gravity survey was conducted at the WSTF site. Since the locations and elevations of the 140+ monitoring wells on the base are known precisely, these sites were also used for gravity stations. The NASA–4 well located in the middle of the 100 area was used as a base station and all of the other gravity stations were tied to this base. The NASA–4 base station was then tied to Las Cruces. The new gravity data were then merged with existing data from the national gravity database at UTEP. The resulting complete bouguer gravity map (Enclosure 52) confirms the presence of NW–SE trending faults across the base. In the future, two–dimensional forward modeling of the data will help bound the location and dip of many of the faults crossing the test facility, along with placing the location of the bedrock within the western portion of the off site region.

Conclusions

The primary conclusions of this study are as follows:

1. Bedrock dips westward at 4 – 5° beneath the WSTF and is broken by three major northwest trending fault zones as well as numerous smaller fault zones. Two of the three major fault zones drop bedrock down to the west, resulting in a rapid

increase in depth to bedrock west of these fault zones. Many minor faults also offset the bedrock.

2. Two bedrock channels are apparent on the map. The first originates from the valley east northeast of the 300 region and proceeds westward through the 300 and 400 areas. A second channel can be seen trending southwest near the 200 area, producing a low near the 200–E–* well. The second channel originates in the 200 area and goes through the 600 area. Near well BLM–21 both channels appear to converge and then continue off to the west.

3. Reliable mapping of intra–bedrock horizons is not feasible with the existing dataset. Synthetic seismograms based on well log data from the 200–F, 200–G, and 600–D wells indicates that horizons within bedrock should be seismically reflective. However, the seismic data to not image the 30 – 35° dips seen in adjacent bedrock outcrop, and the raw data appear to be dominated by surface wave energy that obscures reflected energy from within bedrock.

4. A modern seismic survey could be designed to image deeper bedrock layers. A source with deeper penetration that does not generate surface waves, combined with modern recording equipment that allows for greater offset and a greater number of recording groups on the ground should be able to image bedrock layers.

5. Two–dimensional forward modeling of the gravity survey acquired on site will help constrain the location and dip of many of the faults crossing the test facility, the geometry of the interface between the volcanic and Paleozoic rocks, and the thickness of Quaternary fill in the Jornada basin.

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List Of Enclosures

Enclosure No. 39. Line GC–15, 0–120 Hz, interpreted
Enclosure No. 40. Line GC–16, 0–120 Hz, interpreted
Enclosure No. 41. Line GC–17, 0–120 Hz, interpreted
Enclosure No. 42. Line GC–18, 0–120 Hz, interpreted
Enclosure No. 43. Line GC–19, 0–120 Hz, interpreted
Enclosure No. 44. Line GC–20, 0–120 Hz, interpreted
Enclosure No. 45. Line GC–21, 0–120 Hz, interpreted
Enclosure No. 46. Line GC–22, 0–120 Hz, interpreted
Enclosure No. 47. Line GC–23, 0–120 Hz, interpreted
Enclosure No. 48. Line GC–24, 0–120 Hz, interpreted
Enclosure No. 49. Line GC–25, 0–120 Hz, interpreted
Enclosure No. 50. Line GC–26, 0–120 Hz, interpreted

Maps

Enclosure No. 51. Elevation of Bedrock map, contoured at 20 feet, Scale 1:10, 000
Enclosure No. 52. Gravity map, contoured at 2 mGals.

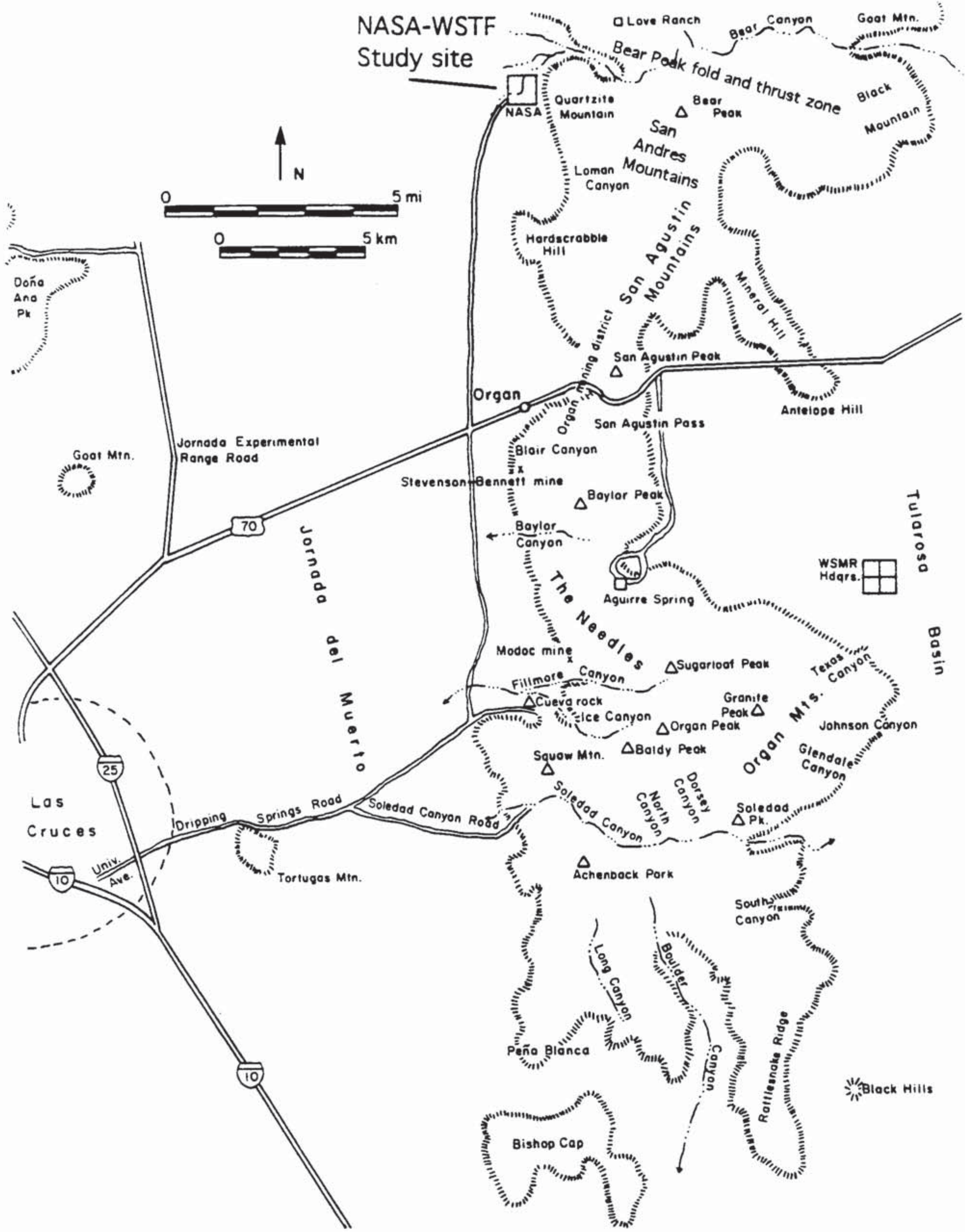


Figure 1. The NASA-White Sands Test Faciltiy is located 18 miles northeast of Las Cruces, New Mexico within the western slopes of the southern San Andres Mountains.

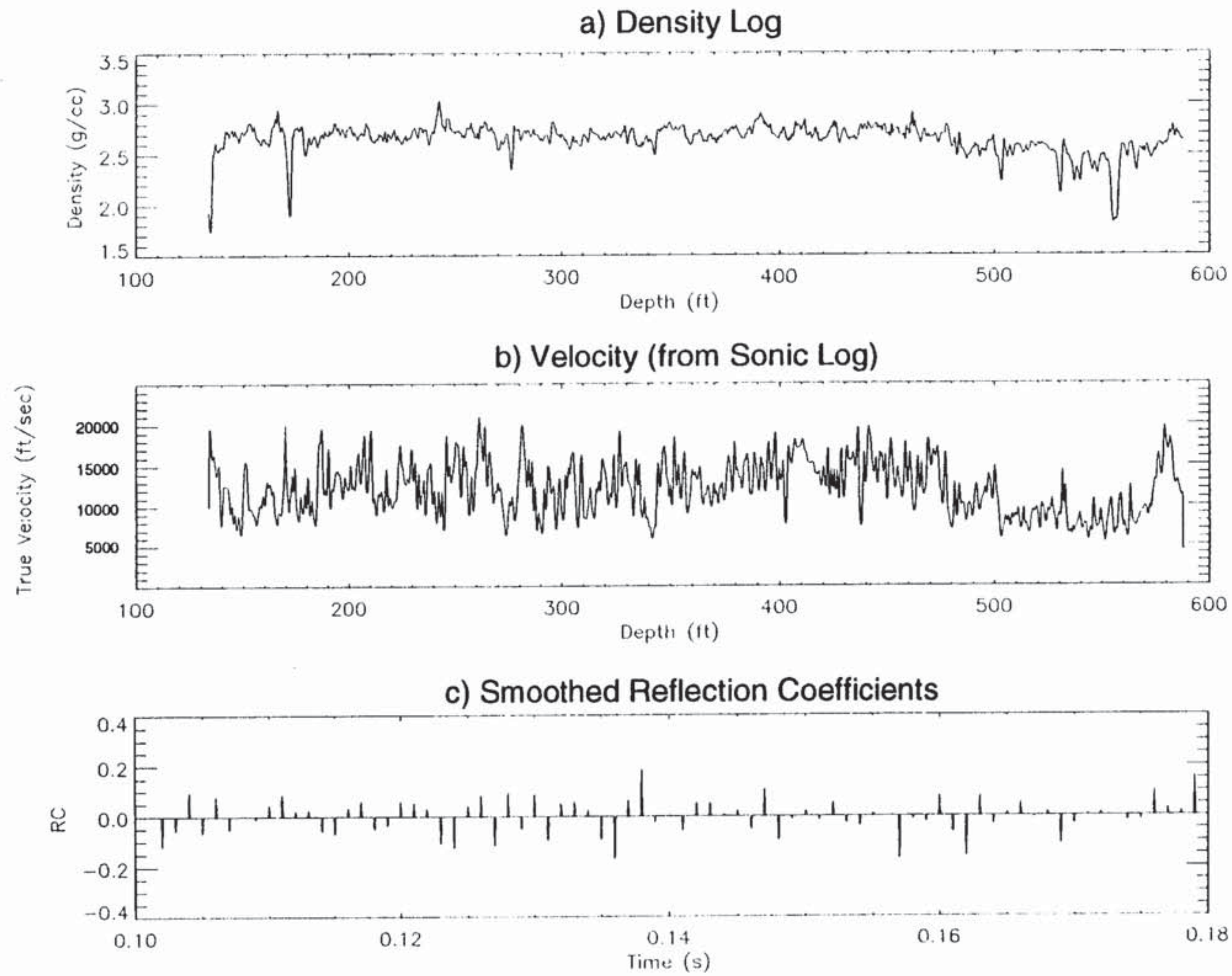


Figure 2a. Log data in depth and reflection coefficients in time for the 200-F well.

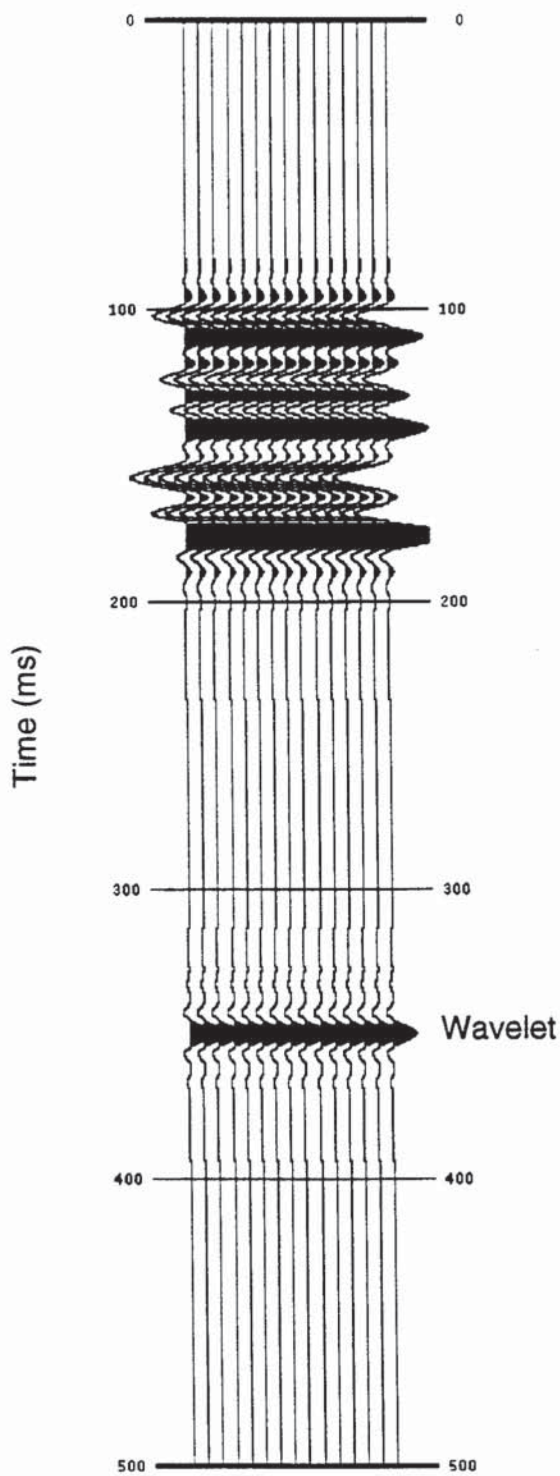


Figure 2b. Synthetic seismogram from the 200-F well.

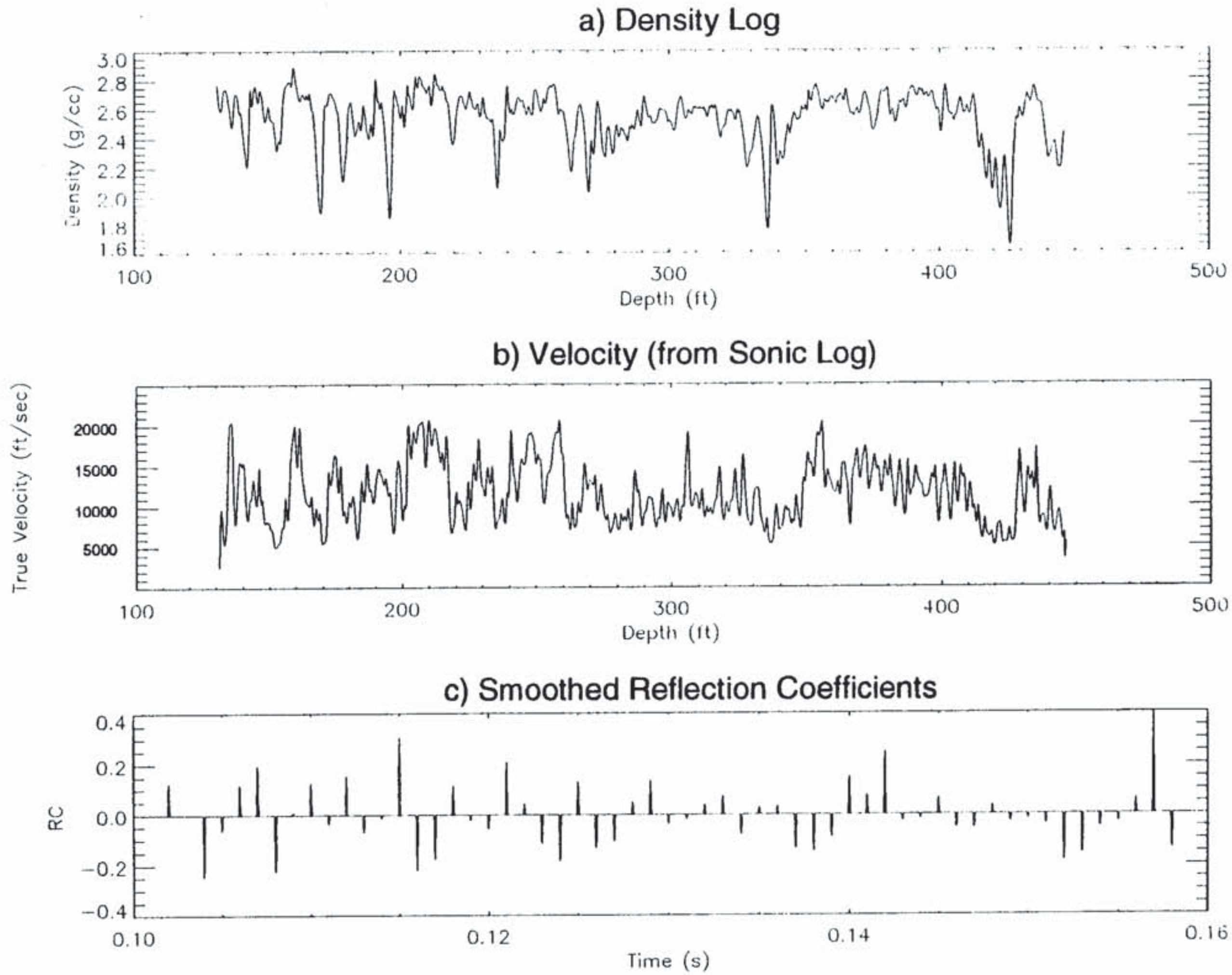


Figure 3a. Log data in depth and reflection coefficients in time for the 200-G well.

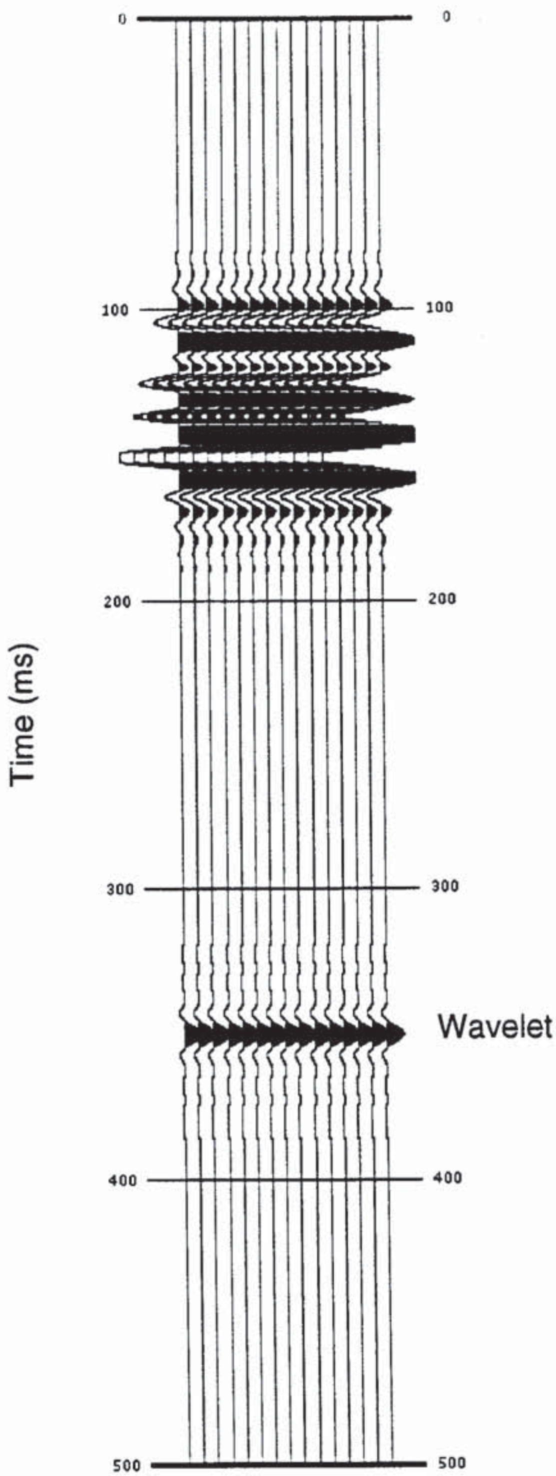


Figure 3b. Synthetic seismogram from the 200-G well.

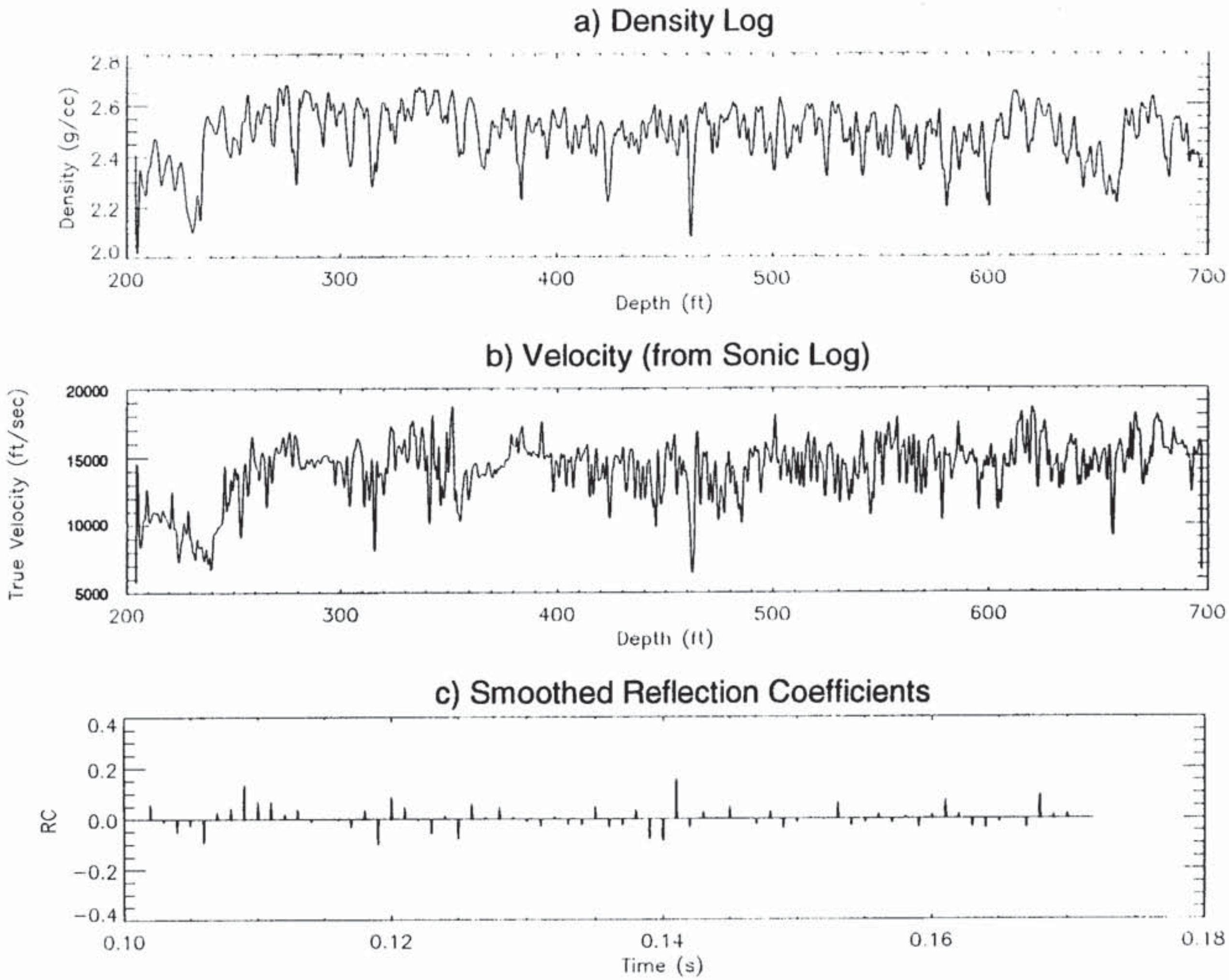


Figure 4a. Log data in depth and reflection coefficients in time for the 600-D well.

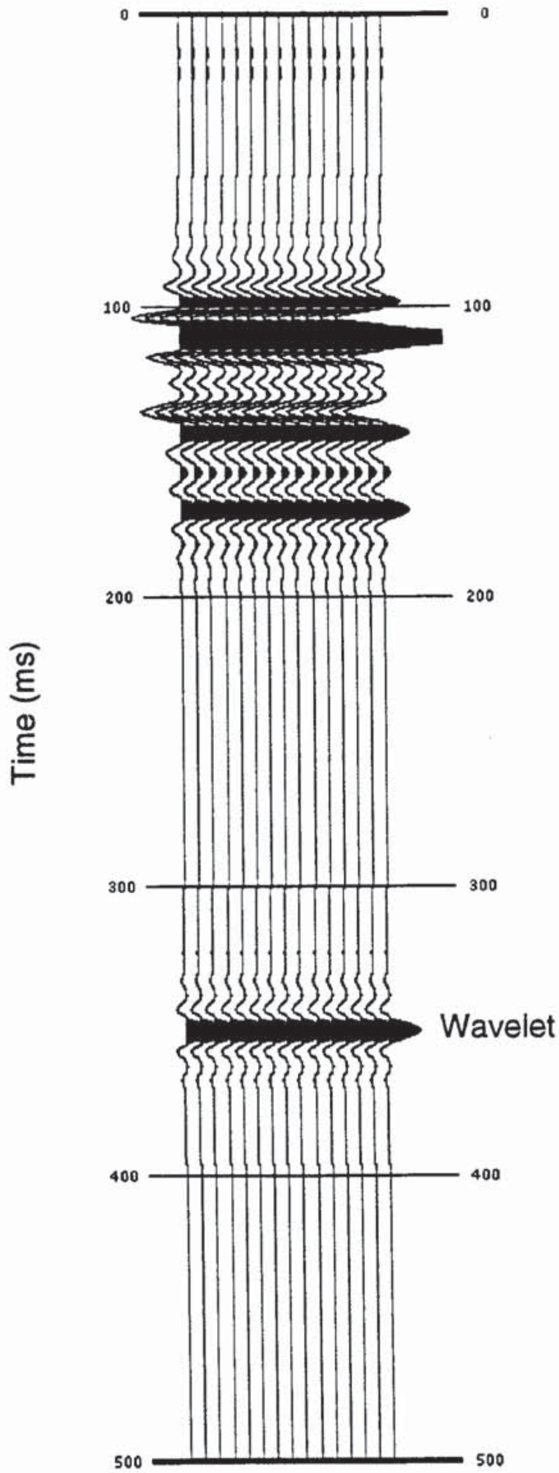


Figure 4b. Synthetic seismogram from the 600-D well.

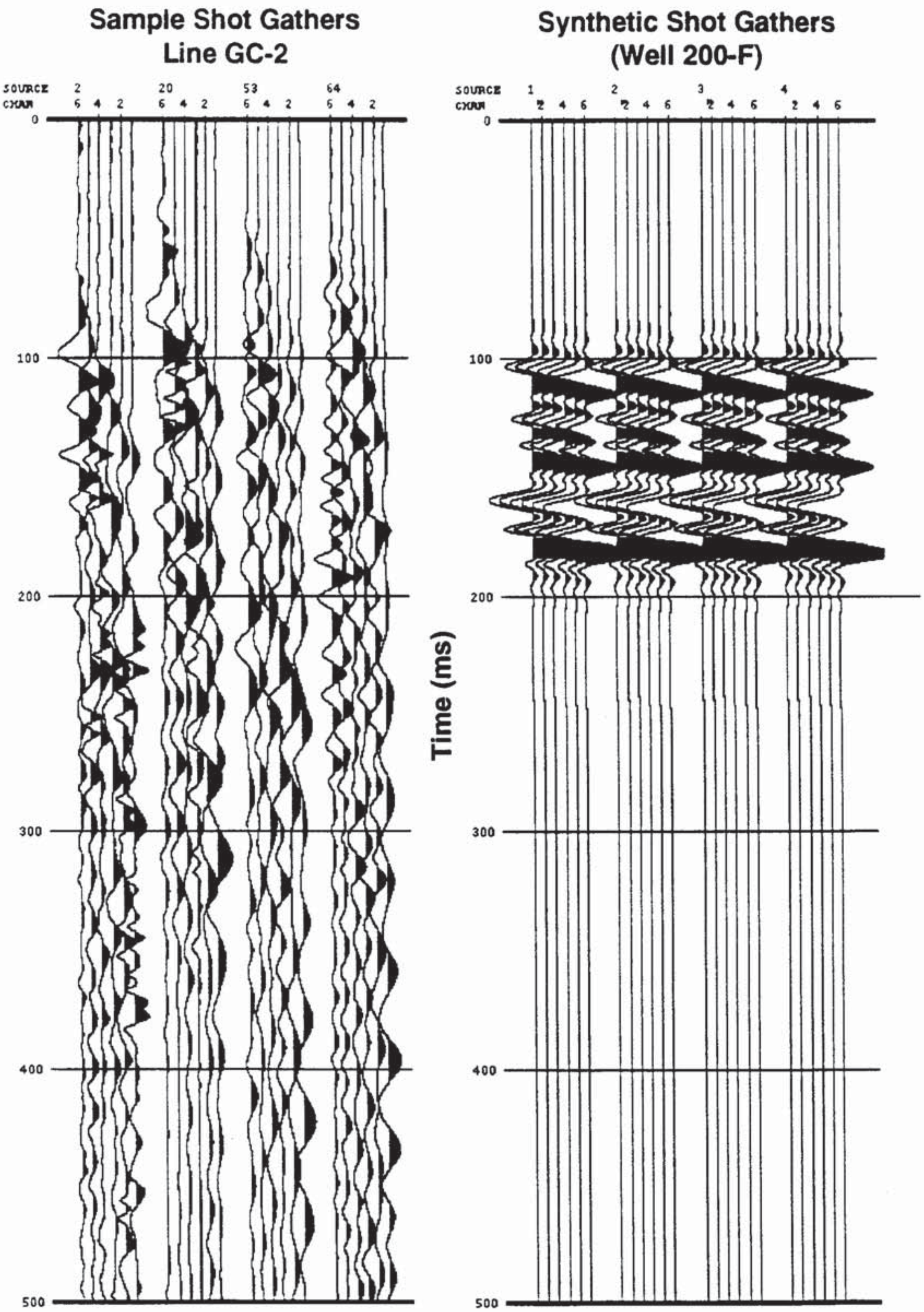
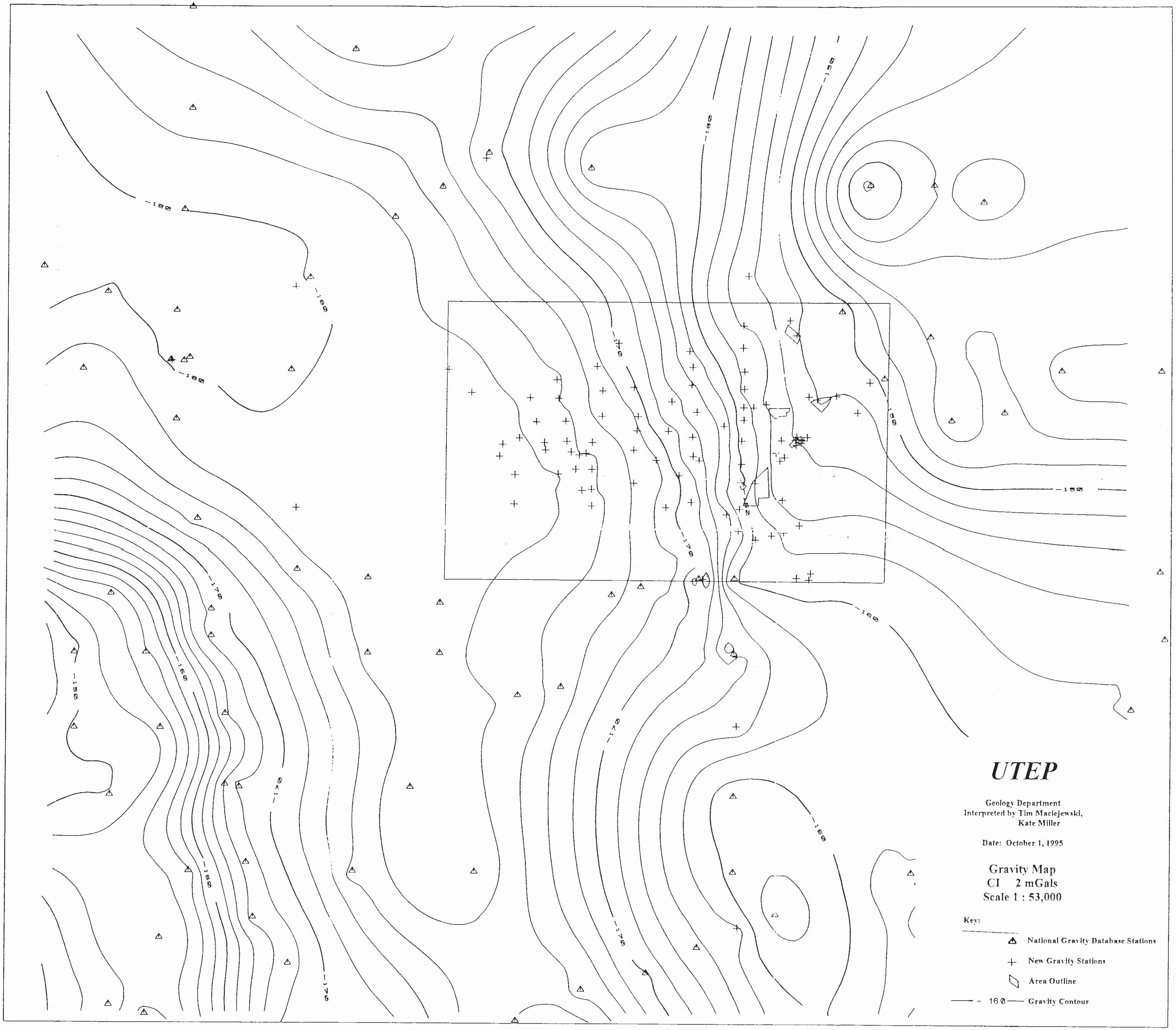


Figure 5. Comparison of raw shot records from line GC-2 to synthetic shot gathers based on log data from the 200-F well. Note that raw shot records lack reflected energy, but are dominated by surface wave energy.

ENCLOSURE NO. 51


UTEP
Geology Department
Interpreted by Tim Maciejewski,
Kate Miller
Date: October 1, 1995
Gravity Map
CI 2 mGals
Scale 1 : 53,000
Key:
National Gravity Database Stations
New Gravity Stations
Area Outline
160 Gravity Contour

Telephone (505) 881-4780

Charles B. Reynolds & Associates
Consulting Geophysicists and Geologists
4409 San Andres Avenue NE
Albuquerque, New Mexico 87110

December 30, 1988

FINAL REPORT
SHALLOW SEISMIC REFLECTION SURVEY
NASA LYNDON B. JOHNSON TEST FACILITY AREA
Dona Ana County, New Mexico

SUMMARY

During the period beginning in late February, 1987, and ending in late July, 1988, 25 shallow seismic reflection lines totalling 37.04 miles in length were recorded in the area of the NASA Lyndon B. Johnson Test Facility, Dona Ana County, New Mexico. The purpose of the survey was to attempt to trace the top of bedrock (or base of Santa Fe group) in the subsurface and especially to attempt to detect faults and other structural features which may influence groundwater movement.

Seismic and drilling evidence indicates that two major fault zones striking northwest to southeast, called the Western Boundary Fault Zones Nos. 1 and 2 (or WBF1 and WBF2) divide the area into three major fault blocks, deepening successively westward from the San Andres Mountains into the Jornada del Muerto Valley. The depth of the top of bedrock in the eastern fault block varies from about 100 to about 200 ft; in the central block it is about 350 to 750 ft and in the western block it is probably about 1,200 ft to about 1,500 ft.

Structural features in the eastern fault block generally trend northeast-southwest, and appear to be partly fault-controlled and enhanced by pre-Santa Fe grp erosion. Synclines in this area also seem to be buried stream valleys which may still be of importance in groundwater movement toward the southwest.

Structural features in the central block apparently trend northwesterly, with general southward deepening of the top of bedrock. A major cross fault, downthrown to the southwest, evidently cuts diagonally across the central block.

Structural features in the western block appear to strike north-northwest, with a general northward deepening of the top of bedrock suggested.

Telephone (505) 881-4780

Charles B. Reynolds & Associates
Consulting Geophysicists and Geologists
4409 San Andres Avenue NE
Albuquerque, New Mexico 87110 December 30, 1988

FINAL REPORT
SHALLOW SEISMIC REFLECTION SURVEY
NASA LYNDON B. JOHNSON TEST FACILITY AREA
Dona Ana County, New Mexico

Introduction - Twenty five shallow seismic reflection lines were recorded between early February, 1987, and late July, 1988, in the area of the NASA Lyndon B. Johnson Test Facility, about 25 miles northeast of Las Cruces, Dona Ana County, New Mexico. The location of the study area is shown on Figure 1. The seismic lines recorded are listed in Table I.

TABLE I

NASA SEISMIC LINES RECORDED FEBRUARY, 1987, THROUGH JULY, 1988

Line No.	No. of Profiles	Length in Miles
GC-1	48	0.3
GC-2	64	0.4
GC-3	64	0.4
GC-4	40	0.25
GC-5	104	0.65
GC-6	176	1.1
GC-7	309	1.93
GC-8	148	0.92
GC-9	111	0.69
GC-10	83	0.52
GC-11	130	0.81
GC-12	112	0.7
GC-13	160	1.0
GC-14N	240	1.5
GC-15	230	1.44
GC-16	155	0.97
GC-17	110	0.69
GC-18	413	2.58
GC-19	710	4.44
GC-20	321	2.01
GC-21	403	2.52
GC-22	496	3.1
GC-23	491	3.07
GC-24	309	1.93
GC-25	500	3.12
Totals	5,927	37.04

Where possible the lines were located along existing roads or trails, but in most cases it was necessary to work cross-country, with the attendant problems of difficult brush and deep arroyos.

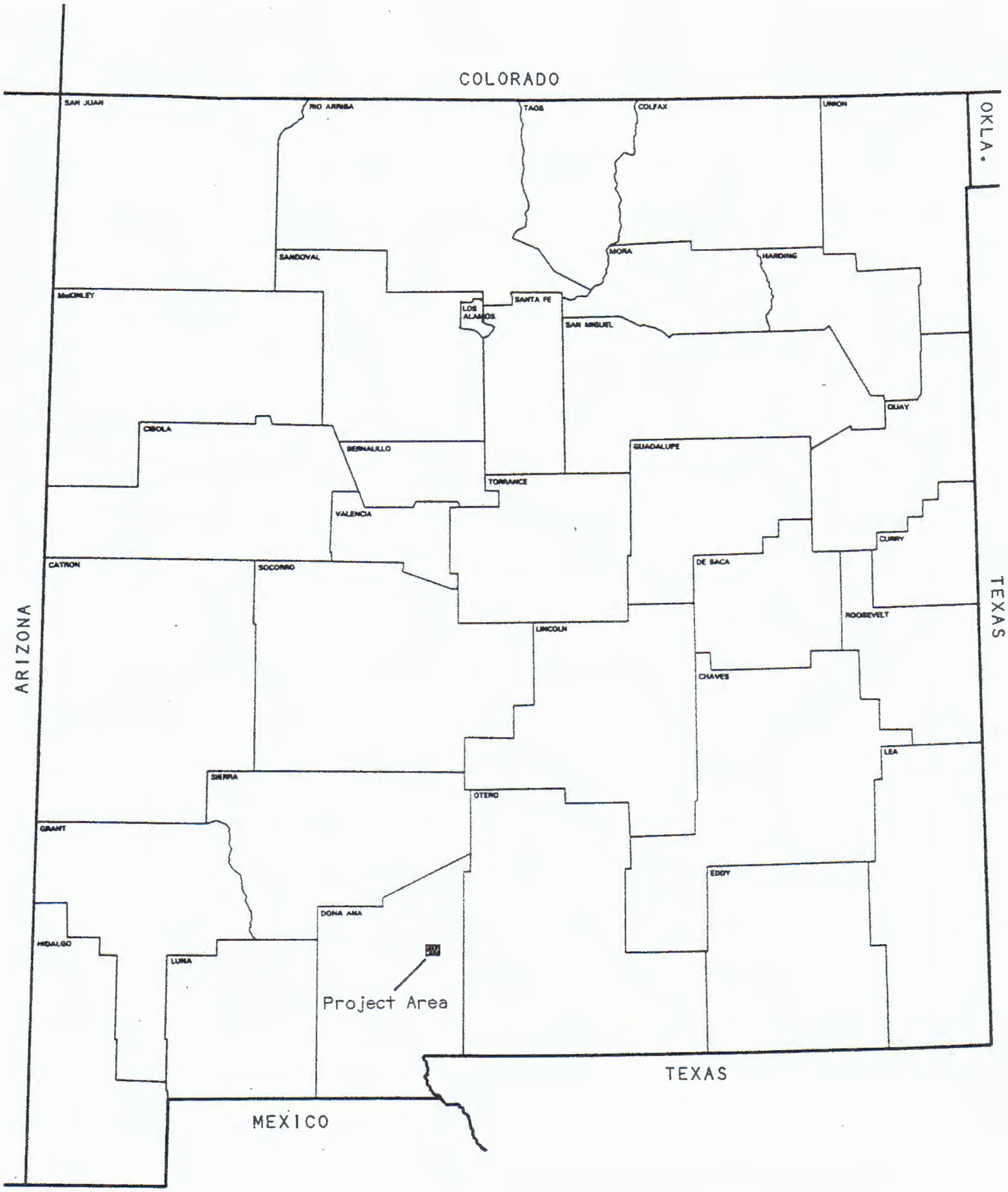


Figure 1. Project location map, Lyndon B. Johnson Test Facility Area. Dona Ana County, New Mexico.

December 30, 1988 Charles B. Reynolds & Assoc.

For the most part, the weather was good, although on occasion high winds or rain delayed the work.

The locations of the seismic lines are shown diagrammatically by Enclosure No. 1 (in pocket).

The main objective of the survey was to obtain a reflection from the top of bedrock (or base of the Santa Fe group) in order to investigate its depth, geometric form and geologic structure and especially to attempt to detect faults or other fracture zones which might influence fluid movements in the area. Because the top of bedrock is normally, in western alluvium-filled valleys, a good reflector of low-frequency seismic energy, it commonly produces a high-amplitude and high-quality reflection as seen on low-frequency seismic record sections.

Geologic Setting - The study area is about four miles north-south by about six miles east-west and is located at the eastern edge of the Jornada del Muerto, a major valley of southern New Mexico. The area begins at the western foothills of the San Andres Mountains and extends westward nearly to the center of the valley. In this distance the surface elevation decreases from about 5,000 ft near the mountains to about 4,400 ft in the valley. The surface soil is mostly sandy, and the surface is much cut by intermittent streams or arroyos of varying width and depth. The climate is a high desert type, with hot summers and cool to cold winters. Most of the precipitation (less than 10 inches per year) falls during summer thunderstorms, with some occurring as winter rain and snow. The vegetation is of the Upper Sonoran type, with bunchgrass, greasewood, mesquite and various cacti prominent. The principal economic use of the area prior to the establishment of the test facility was for the grazing of livestock, though there has been some mining in the mountains to the east and southeast.

Igneous and metamorphic rocks of Precambrian age crop out in the mountains east of the project area, as do largely marine strata of Cambrian through early Permian age. Continental redbeds with minor marine carbonates of middle and late Permian age are in turn overlain by marine shales, marine and non-marine sandstones and coals of Cretaceous age. Basal Tertiary non-marine sands and conglomerates overlie older rocks and are in turn overlain by acidic to intermediate volcanic strata and middle to late Tertiary unconsolidated silts, sands and gravels and Quaternary alluvium. Of particular importance in the project area are the Quaternary alluvium, the middle and upper Tertiary Santa Fe grp silts, sands and gravels, the middle Tertiary (Oligocene) Orejon andesites and the early Permian Hueco limestone.

From late Cambrian until mid-Permian time the area was part of a shallow, rather stable marine shelf on which were deposited limestones and shales with minor sandstones. In middle and late Permian time the region became a low floodplain on which red clays and sands were deposited. After a brief marine incursion in late Permian time, the area was probably largely emergent during the Triassic and Jurassic periods. During the Cretaceous the sea encroached on the region again, first from the southwest and then from the northeast, and a thick sequence of marine shales and sandstones and non-marine sandstones with some coal were deposited. At the end of the Cretaceous, during the great Laramide Revolution, the area was subjected to strong northeast-southwest crustal compression. The sea withdrew and fold and fault belts trending northwest-southeast developed, perhaps with significant mountain building. Explosive volcanism also began at this time, but reached its culmination during the Oligocene. Substantial local igneous intrusion also occurred during the latest Cretaceous and early to middle Tertiary.

In mid-Tertiary time the crustal compression which had affected the region earlier was replaced by crustal extension oriented approximately east-west. At this time (probably early Miocene) complex sets of normal or gravity faults developed and valleys, including the Jornada del Muerto, began to sink along these faults. At the same time, intervening mountain ranges, such as the San Andres Mountains, began to rise along the bounding fault sets and shed sediment into the valleys. This largely fault-controlled movement, whereby the valleys subside and the mountains rise, continues to the present time. Concurrently with the change from crustal compression to crustal extension, explosive volcanism was replaced by quieter basaltic volcanism.

Two major periods of tectonism followed by erosion have resulted in major angular unconformities. These are first, at the top of the Cretaceous and older strata and beneath the early Tertiary beds and the Orejon andesite, and second, above the Orejon and older beds and beneath the Santa Fe grp. Both of these unconformities, but especially the latter, are of great importance in hydrologic considerations in the study area.

The Permian Hueco limestone crops out along the eastern edge of the study area. To the west, Quaternary alluvium mantles Santa Fe grp, which in turn overlies Orejon andesite. The Hueco ls probably underlies the Orejon, but beds of late Permian or Cretaceous age may be present if preserved from post-Laramide erosion.

Reflection Method - The seismic system used is a single-vehicle operation specifically designed for shallow (generally, less than 3,000 ft of depth) reflection investigations. The seismic energy source is a patented bounceless "soft" weight of 550 lbs dropped 6-1/2 ft to the ground. The receiver array consists of six Mark Products G-21 10Hz gimbal-mounted self-orienting drag geophones attached to cables towed behind the seismic truck, with the geophones located at distances of 66, 131, 197, 262, 328 and 394 ft behind the impact point of the dropped weight. The output of each receiver is recorded separately.

The recording instruments are a multi-channel E.G.&G. Geometrics Nimbus ES1210F system with frequency filters and G724S digital recorder. Both analog and digital recordings are made at each drop point. The digital recordings were for one-half second with a sample rate of one-half millisecond and out-80 Hz filters on recording until Line GC-19, when a change was made to one second, 1 ms recording because of expected basinward deepening of bedrock. Notch filters (60 Hz) were used wherever power lines are near.

Drop points are chained 33 ft apart along the line being recorded, producing 160 recordings per mile and 600% common depth point stacking. One to seven drops have been made per position, with the average number of drops being about three for the later lines. After completion of recording, the lines were surveyed by surveyors contracted by the client.

The seismic data processing is carried out on IBM and Tandy PC computers using software written specifically for data recorded by this seismic system. Steps involved include transcription from field digital recordings to computer, reformatting to computer format, verification of data quality and editing, determination of the thickness of the surface low-velocity layer (weathering) and its velocity and that of the layer below by analysis of refraction returns, application of an F-K or velocity filter to remove refraction breaks as well as groundroll and airwave, time-variant deconvolution using three operators, 600% common depth point stacking, application of datum corrections (combined weathering and elevation corrections), use of a coherence filter which enhances seismic events dipping less than about 20 degrees in either direction, frequency filtering, trace normalization and variable area-wiggle trace plotting. A set of one-octave filter comparisons is made from time to time for selection of final frequency filters. Comparisons of different length deconvolution operators are also made; at this point it appears that 20 ms is the best operator length for the Lyndon Johnson Facility area.

Initially the datum or reference plane used for correction was a flat, horizontal plane at an elevation of 5,000 ft above mean sea level. A datum plane above the ground surface was selected to avoid losing any of the shallow reflection data. Later, however, as the survey developed westward (toward the valley), decreasing elevation made it apparent that the +5,000 ft datum was too high, causing the datum corrections to push a large part of the data off the bottom of the record sections. As a result all the lines were reprocessed and corrected to a surface datum.

The mean velocity of the low-velocity surface layer (weathering) as determined from refraction data for different lines varies from 1,800-2,200 ft/sec and the mean subweathering velocity is about 3,700 ft/sec (means of hundreds of determinations). These velocities both show a westward decrease, away from the mountains and toward the deep basin. The record sections included with this report have been corrected to a surface datum and frequency filtered with a 0-120 Hz bandpass filter, which is considered to make maximum use of the effect of the time-variant deconvolution. A second set of record sections was also made in a low-frequency (0-20Hz) version to try to enhance the reflection from the base of the Santa Fe grp, particularly in the deeper western sector where no wells reached the top of bedrock.

Results - Included with this report are the 600% stacked 0-120 Hz record sections for all the lines (Enclosures Nos. 2 through 25). Enclosures Nos. 26 through 49 are the low frequency versions (0-20z). The title blocks give details of the recording and processing parameters. For the primary purpose of the survey (recognition and tracing of the base of the Santa Fe grp or top of bedrock), most of the lines are considered to be of fair to excellent quality, because what is believed to be the base of Santa Fe grp reflection is generally of high amplitude and fairly continuous (in the deep western and south-central parts of the area, this is true only with the low-frequency version), although it is much faulted.

The top of bedrock (or base of Santa Fe grp) reflection varies considerably in different parts of the study area. This probably is a result of variation in the type of rock making up the top of bedrock. Along the extreme eastern margin of the area, the rock underlying the basal Santa Fe beds is the Permian Hueco limestone. Through most of the area the Orejon andesite underlies the basal Santa Fe, but the Orejon itself is highly variable in lithology. Welded tuffs, ash tuffs, flows and volcanic sediments are present, and it is likely that no single lithologic type is present at the top of the Orejon over a large area.

The top of bedrock reflection is best overall in the eastern major fault block, east of WBF2. Perhaps this is because here it is clearly an erosion surface, probably generally reduced to dense and competent erosion-resistent beds, which should be better reflectors than soft tuffs or loose sediments.

Interpretation - Also included with this report are copies of the record sections of the lines with the writer's interpretation. These interpreted record sections are Enclosures 50 through 73. The base of Santa Fe grp event, as traced by the author, is shown by horizontal to subhorizontal dark lines; interpreted faults cutting this reflection traverse are shown by dashed vertical to nearly vertical lines. Wells from which the base of Santa Fe grp depths were used are shown in the positions where they were used by vertical diagonally dashed lines.

Most of the faults shown appear to be vertical or high-angle normal faults. The most important possible exception is the WBF2 fault zone, which the data indicate could be a west-dipping listric fault zone (see Line GC-22, Enclosure No. 70).

Some measure of folding or flexing of the base of the Santa Fe grp seems to be evident. This folding is probably not due to regional compression, but more probably has been caused by local secondary compression, drag or differential settling produced by differing rates of subsidence of various fault blocks. There may also be some "inheritance" of previously-existing Laramide fold trends, most likely again by differential compaction or secondary movement.

Enclosure No. 74 is a map showing interpreted depth from surface to base of the Santa Fe grp (or top of bedrock). The depths are based on a seismic horizon tied to existing well control. The velocity function used for conversion of reflection times to depths is based on shallow refraction information, well ties in the area and on known velocities in other areas of similar lithologies and structural setting. This velocity function and a time-depth table derived from it are shown by Table II.

Faults considered to be of larger displacement or otherwise of importance are shown on the map by wider lines; faults believed to be less important are marked by narrower lines.

Well evidence clearly indicates the presence of two major fault zones (the Western Boundary Fault Zones Nos. 1 and 2, also referred to as WBF1 and WBF2), and the locations shown are interpreted from the seismic data. These fault zones appear likely to be northward continuations of faults mapped farther south by Seager (1981) and collectively called by him the Western Boundary Fault Zone. In general, the depth of the base of the Santa Fe grp east of WBF2 is about 100-200 ft. Between WBF2 and WBF1 its depth is of the order of 350-750 ft. West of WBF1, the depth of the base of Santa Fe grp is interpreted on the basis of apparent seismic correlation as seen on the low frequency record sectons (because no well here reached the top of bedrock) as perhaps being about 1,200-1,500 ft. WBF2 appears to have a displacement of about 200-400 ft, downthrown to the west. WBF1 is a much larger fault, being interpreted as having an average displacement of about 700 ft, also downthrown to the west. Together, the two faults apparently form a major part of the mechanism by which the valley to the west subsided as the mountains to the east rose.

Figure 2 is a block diagram showing the top of bedrock surface as contoured by computer. This illustration is included to show visually the form of the base of the Santa Fe grp in the study area. It is based on the elevation of that horizon at the locations of 32 important wells. Eight of these wells did not reach the top of bedrock, so the elevations used at these positions were taken from the seismic interpretation. Note that the three major fault blocks are clearly visible, as are the two major fault zones, which show as steepenings of contours in the western and central parts of the block diagram.

Also included in this report is a structure contour map with contours of equal elevation on the interpreted base of Santa Fe grp event (Enclosure No. 75). The scale here is also one inch equals 1000 ft, the contour interval is 25 ft, and the elevations are in feet above mean sea level. Well control points are shown as solid circles, with the elevation of the base of the Santa Fe noted in pertinent cases where the well reached that horizon.

The surface mapped (near base of Santa Fe grp) deepens to the west-southwest across the area. The general rate of dip in that

TABLE II
TIME-DEPTH TABLE

NASA LYNDON B. JOHNSON FACILITY AREA
DONA ANA COUNTY NEW MEXICO

Vave= 2850 + 17045 T2
Vave= 4600 + 6207 T2, T2> .1614689

DEPTHS IN FEET TIMES IN MILLISECONDS

DATUM = SURFACE

T2	Z	T2	Z	T2	Z	T2	Z
5	7	255	788	505	1953	755	3506
10	15	260	808	510	1980	760	3541
15	23	265	827	515	2008	765	3576
20	32	270	847	520	2035	770	3611
25	41	275	867	525	2063	775	3647
30	50	280	887	530	2091	780	3682
35	60	285	908	535	2119	785	3718
40	71	290	928	540	2147	790	3754
45	81	295	949	545	2175	795	3790
50	93	300	969	550	2204	800	3826
55	104	305	990	555	2232	805	3863
60	116	310	1011	560	2261	810	3899
65	129	315	1032	565	2290	815	3936
70	142	320	1054	570	2319	820	3973
75	155	325	1075	575	2349	825	4010
80	169	330	1097	580	2378	830	4047
85	183	335	1119	585	2408	835	4084
90	197	340	1141	590	2437	840	4122
95	212	345	1163	595	2467	845	4159
100	228	350	1185	600	2497	850	4197
105	244	355	1208	605	2527	855	4235
110	260	360	1230	610	2558	860	4273
115	277	365	1253	615	2588	865	4312
120	294	370	1276	620	2619	870	4350
125	311	375	1299	625	2650	875	4389
130	329	380	1322	630	2681	880	4427
135	348	385	1346	635	2712	885	4466
140	367	390	1369	640	2743	890	4505
145	386	395	1393	645	2775	895	4544
150	406	400	1417	650	2806	900	4584
155	426	405	1441	655	2838	905	4623
160	446	410	1465	660	2870	910	4663
165	464	415	1489	665	2902	915	4703
170	481	420	1513	670	2934	920	4743
175	498	425	1538	675	2967	925	4783
180	515	430	1563	680	2999	930	4823
185	532	435	1588	685	3032	935	4864
190	549	440	1613	690	3065	940	4904
195	567	445	1638	695	3098	945	4945
200	584	450	1663	700	3131	950	4986
205	602	455	1689	705	3164	955	5027
210	620	460	1715	710	3197	960	5068
215	638	465	1741	715	3231	965	5110
220	656	470	1767	720	3265	970	5151
225	675	475	1793	725	3299	975	5193
230	693	480	1819	730	3333	980	5235
235	712	485	1846	735	3367	985	5277
240	731	490	1872	740	3401	990	5319
245	750	495	1899	745	3436	995	5361
250	769	500	1926	750	3471	1000	5403

CHARLES B. REYNOLDS & ASSOC.

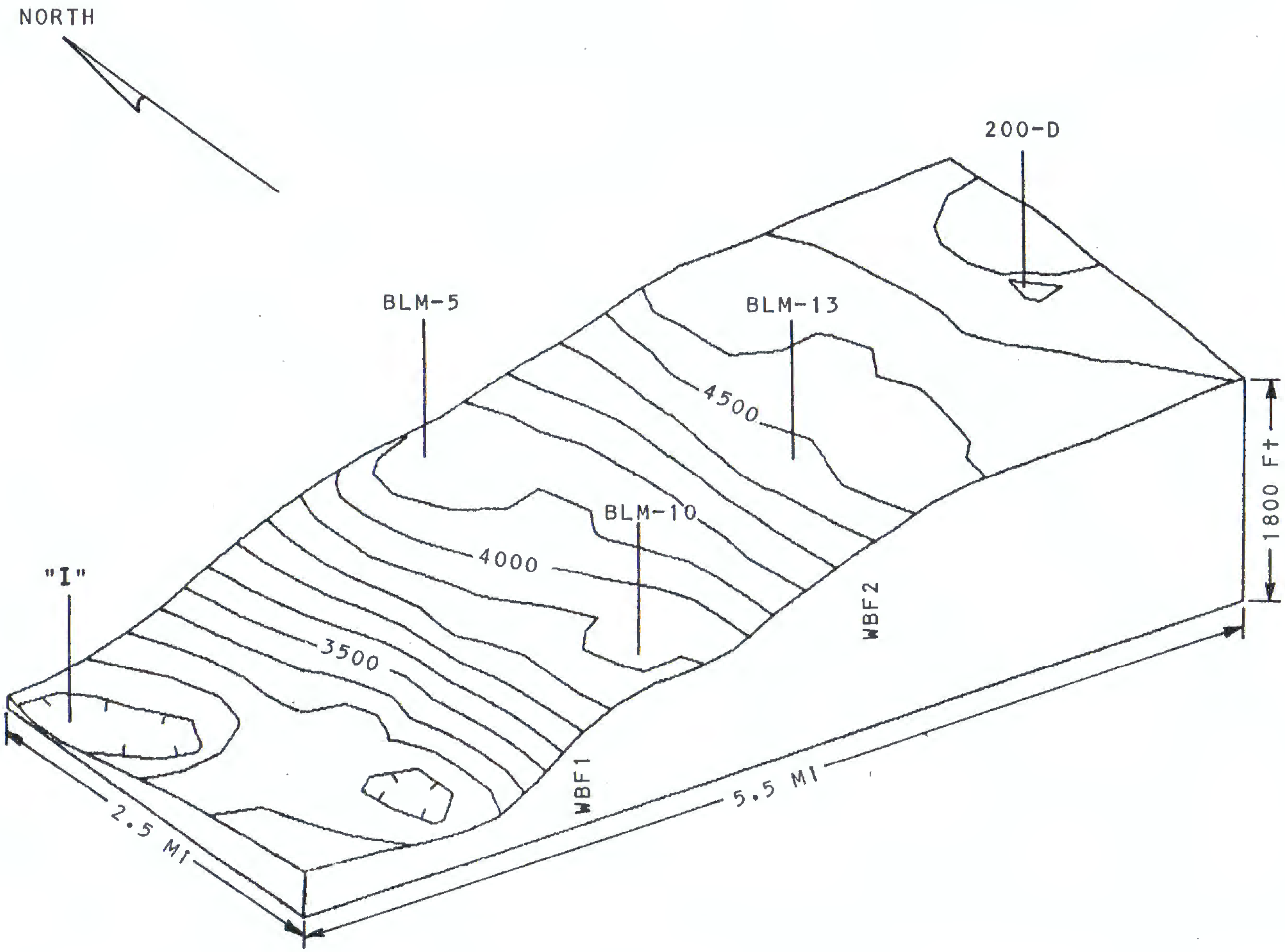


Figure 2. Conceptual block diagram of study area. Contours on top of bedrock, based on 32 selected wells (five shown to aid in location recognition). Contour interval 100 feet. Elevations in feet above sea level. Vertical exaggeration approximately 4:1. Division into three principal subareas by two major fault zones (WBF1 and WBF2) is clearly shown.

December 30, 1988 Charles B. Reynolds & Assoc.

direction varies among the major fault blocks; the dip rates are lower east of WBF2 and higher in the two more westerly major fault blocks. The principal strike direction for faults shown is northwestward, except east of WBF2, where the close detail from both seismic and drilling indicates faults of various strike directions. Possibly similarly dense detail in the rest of the area might also reveal similar diversity of fault strikes.

In the central and western major fault blocks (i.e., between WBF2 and WBF1, and also west of WBF1) a genetic relationship between many of the local anticlines and synclines on the one hand and faults on the other seems likely. In some cases faults appear to cut along the axes of local anticlines; in other cases the anticlines are on the upthrown sides of the faults. A few of the small local anticlines and synclines do not appear to be faulted at all.

Enclosure No. 76 is a tectonic elements diagram of the study area showing anticlines, synclines and faults as interpreted from seismic and well information. This illustration shows a striking difference between the structural features east of the WBF2 and those to the west of it. Most of the anticlines and synclines east of WBF2 strike southwesterly, whereas most of these features lying west of WBF2 strike northwesterly. The reason for this seems to be that east of WBF2 the unconsolidated Quaternary and Tertiary are very thin, and the structural grain present is likely to be inherited from the underlying bedrock; in fact most of the anticlines and synclines east of WBF2 appear to be formed by a combination of faulting and pre-Santa Fe erosion of bedrock. The large anticline crossed by Line GC-16 has the appearance of a buried erosional mesa, with the overlying Santa Fe grp draped over it (see Enclosure No.64). The synclines shown east of WBF2 appear, for the most part, to be buried stream valleys located in grabens or other fault-related structural lows. This is well illustrated by Line GC-7 (Enclosure No. 56). Because of their potential importance with regard to groundwater movement east of WBF2, these synclines/valleys are highlighted with blue on the Tectonic Elements Diagram (Enclosure No. 76). Between WBF2 and WBF1, most of the structural features appear to trend to the northwest, more or less parallel to a large fault which evidently cuts across this area between the BLM-1 and BLM-2 wells. West of WBF1, the structural grain trends more north-northwesterly. It seems likely that the difference in structural grain and style on either side of WBF2 is a result of the difference in thickness of the unconsolidated Quaternary and Tertiary strata; where thicker, it has reacted in a more plastic manner, developing minor folds subparallel to the major faults.

Groundwater in the unconsolidated Santa Fe grp appears likely to flow southwesterly along the buried stream channels indicated in the area east of WBF2. Between WBF2 and WBF1, the southward deepening of bedrock may make groundwater continue to flow more southwesterly than northwesterly. West of WBF1, even though there may be some northwesterly component of dip at the top of bedrock, shallow groundwater may continue to flow southwest.

Conclusions - The following conclusions seem to be merited on the basis of the geological and geophysical evidence now available:

A. The base of Santa Fe grp (or top of bedrock) appears to deepen to the west-southwest, partly through dip but mostly through two major fault zones, WBF1 and WBF2, plus a major diagonal cross-fault between WBF1 and WBF2.

B. Most of the faults in the area appear to be high-angle or vertical normal faults, with WBF2, which may be a listric fault, being the most important possible exception.

C. Several southwest-plunging partly fault-controlled buried stream valleys may be of importance in influencing groundwater motion in the shallow fault block east of WBF2.

D. There seems to be, in numerous cases, an association of faults and minor local anticlines and synclines, possibly suggesting that the folds are secondary to the faults.

Respectfully submitted,

Charles B. Reynolds

Charles B. Reynolds
Registered Geophysicist (Calif.)
Certified Professional Geologist

Enclosures in accompanying folder.

Reference:

Seager, W.R., 1981, Geology of Organ Mountains and Southern San Andres Mountains, New Mexico: Memoir 36, New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico.

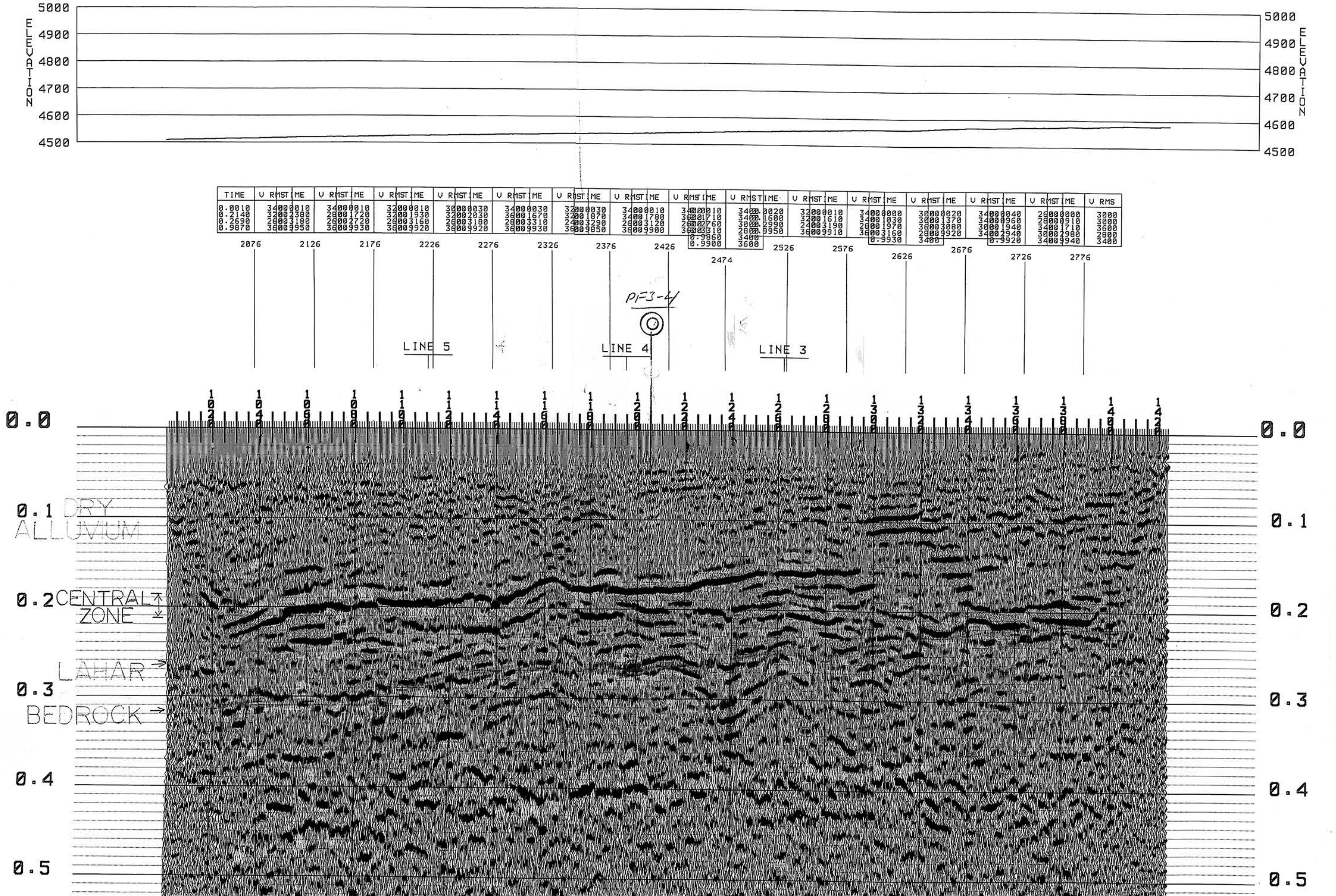
LIST OF ENCLOSURES

45. Line GC-21, 0-20 Hz
46. Line GC-22, 0-20 Hz
47. Line GC-23, 0-20 Hz
48. Line GC-24, 0-20 Hz
49. Line GC-25, 0-20 Hz

50. Line GC-1, 0-120 Hz, interpreted
51. Line GC-2, 0-120 Hz, interpreted
52. Line GC-3, 0-120 Hz, interpreted
53. Line GC-4, 0-120 Hz, interpreted
54. Line GC-5, 0-120 Hz, interpreted (combined with Line GC-12)
55. Line GC-6, 0-120 Hz, interpreted
56. Line GC-7, 0-120 Hz, interpreted
57. Line GC-8, 0-120 Hz, interpreted
58. Line GC-9, 0-120 Hz, interpreted
59. Line GC-10, 0-120 Hz, interpreted
60. Line GC-11, 0-120 Hz, interpreted
61. Line GC-13, 0-120 Hz, interpreted
62. Line GC-14N, 0-120 Hz, interpreted
63. Line GC-15, 0-120 Hz, interpreted
64. Line GC-16, 0-120 Hz, interpreted
65. Line GC-17, 0-120 Hz, interpreted
66. Line GC-18, 0-120 Hz, interpreted
67. Line GC-19, 0-120 Hz, interpreted
68. Line GC-20, 0-120 Hz, interpreted
69. Line GC-21, 0-120 Hz, interpreted
70. Line GC-22, 0-120 Hz, interpreted
71. Line GC-23, 0-120 Hz, interpreted
72. Line GC-24, 0-120 Hz, interpreted
73. Line GC-25, 0-120 Hz, interpreted

MAPS

Enclosure No. 74 - Depth contour map, base of Santa Fe grp, scale one inch equals 1,000 feet.
Enclosure No. 75 - Structure (elevation) contour map, base of Santa Fe grp, scale one inch equals 1,000 feet.
Enclosure No. 76 - Tectonic elements diagram, base of Santa Fe grp, scale one inch equals 1,000 feet.



-----NORTHEAST----->

HONEYWELL TECHNOLOGY SOLUTIONS, INC.

WEST PLUME
LINE 1
DONA ANNA, NM
FINAL STACK

FIELD PARAMETERS

RECORDING PARAMETERS

RECORDED BY	SUBSURFACE EXPL	DATE RECORDED	MAR 2000
INSTRUMENTS	GEOCOR IV	NOTCH FILTER	
RECORD LENGTH	8.0 SEC	SAMPLE RATE	1 MSEC

SOURCE PARAMETERS

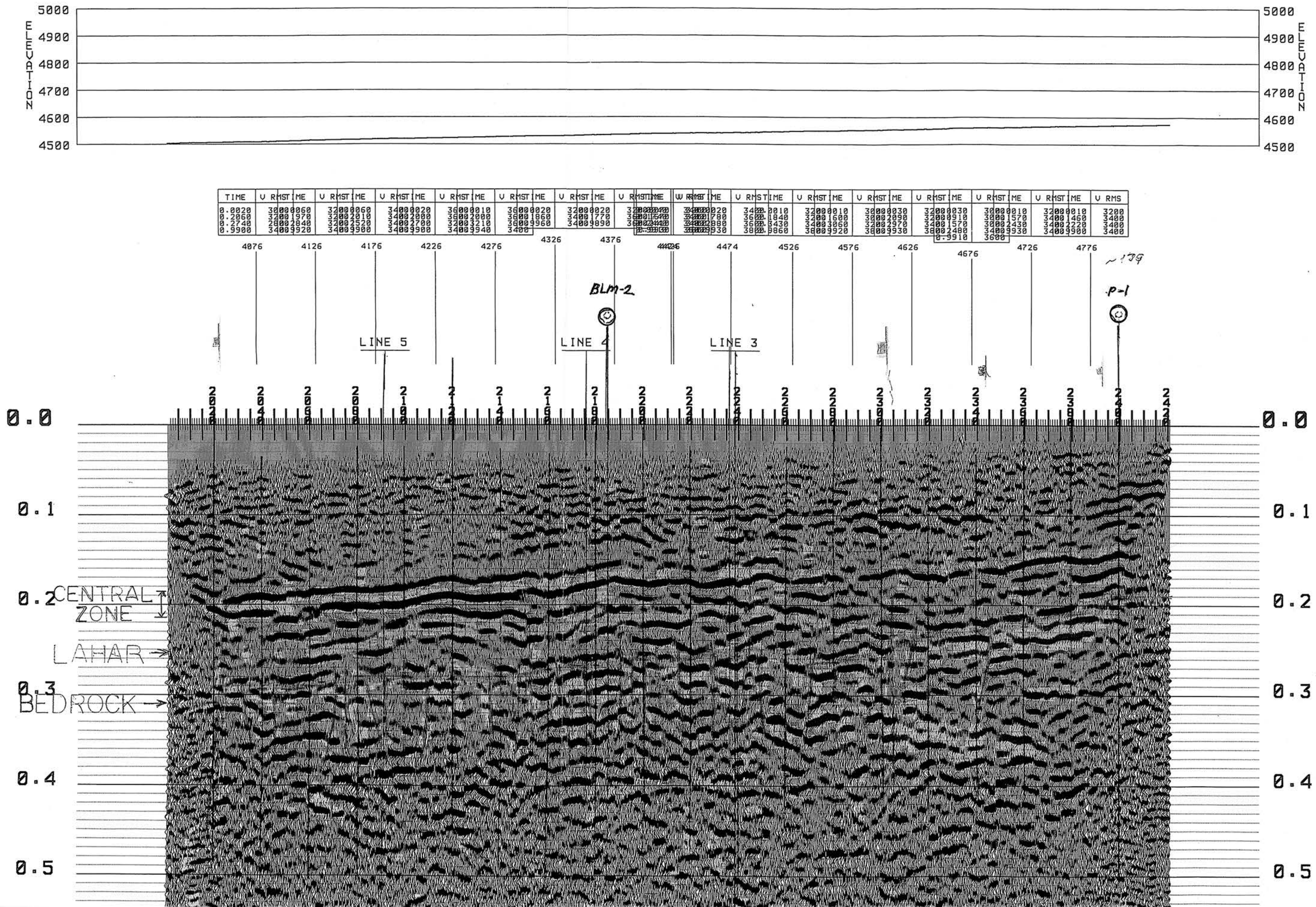
SOURCE	VIBROSEIS	SWEEP FREQ	20/120
SWEEP LENGTH	6.0 SEC		

GEOMETRY

GP INTERVAL 10 FT. SP INTERVAL 10 FT.

SPREAD

TR 1 590 — 60 0 — 120 TR 600 FT



-----NORTHEAST---->

HONEYWELL TECHNOLOGY SOLUTIONS, INC.

WEST PLUME
LINE 2
DONA ANNA, NM
FINAL STACK

FIELD PARAMETERS

RECORDING PARAMETERS

RECORDED BY	SUBSURFACE EXPL	DATE RECORDED	MAR 2000
INSTRUMENTS	GEOCOR IV	NOTCH FILTER	
RECORD LENGTH	8.0 SEC	SAMPLE RATE	1 MSEC

SOURCE PARAMETERS

SOURCE	VIBROSEIS	SWEEP FREQ	20/120
SWEEP LENGTH	6.0 SEC		

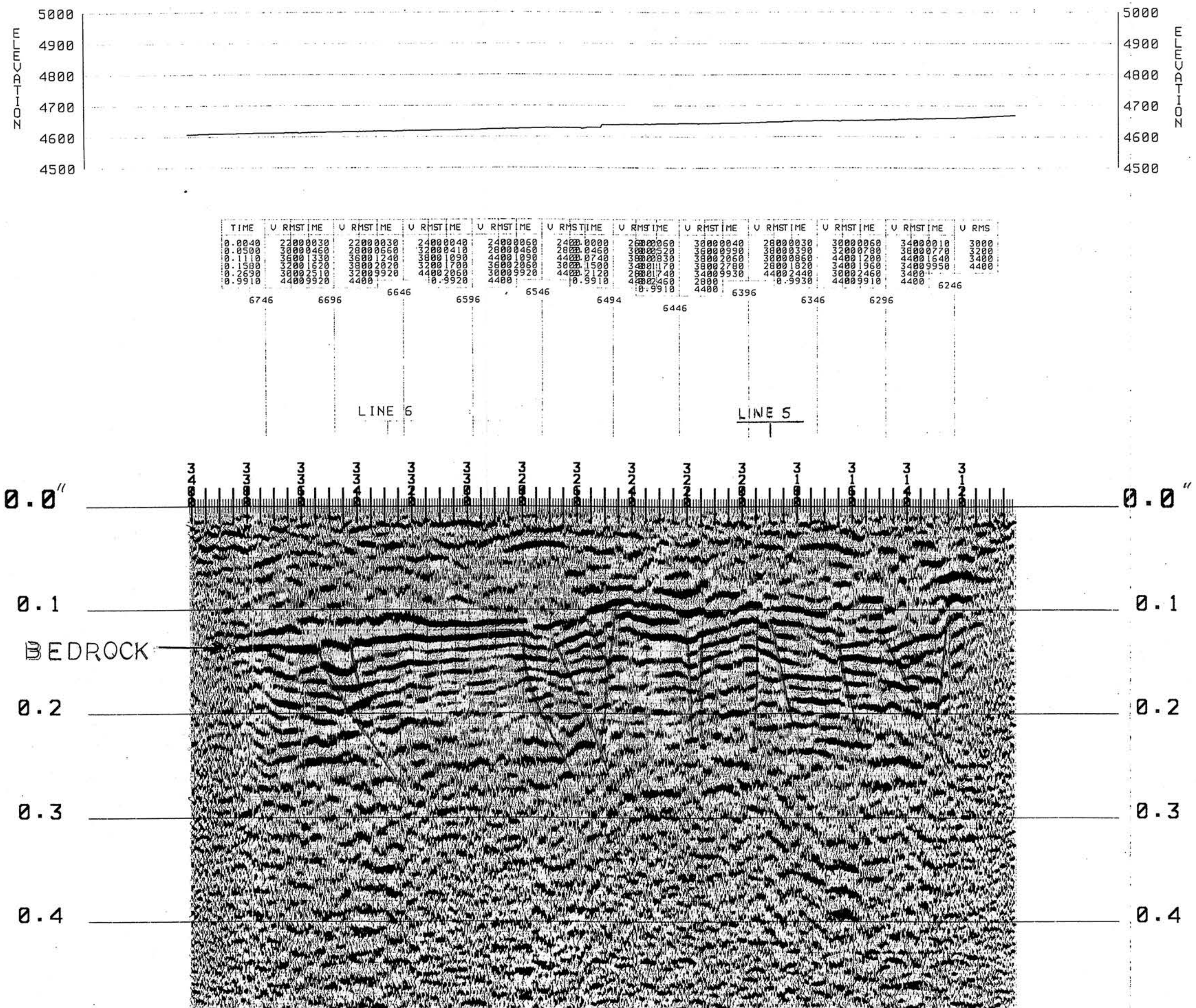
GEOMETRY

GP INTERVAL	10 FT.	SP INTERVAL	10 FT.

SPREAD

O------------------------------X------------------------------O
X------------------------------S------------------------------X
TR 1 590 — 60 0 — 120 TR 600 FT

PROCESSING SEQUENCE



-----NORTHEAST----->

HONEYWELL TECHNOLOGY SOLUTIONS, INC.

WHITE SANDS TEST FACILTY

LINE 3

DONA ANNA, NM

FINAL STACK

FIELD PARAMETERS

RECORDING PARAMETERS

RECORDED BY	SUBSURFACE EXPL	DATE RECORDED	NOV 2000
INSTRUMENTS	GEOCOR IV	NOTCH FILTER	
RECORD LENGTH	8.0 SEC	SAMPLE RATE	1 MSEC

SOURCE PARAMETERS

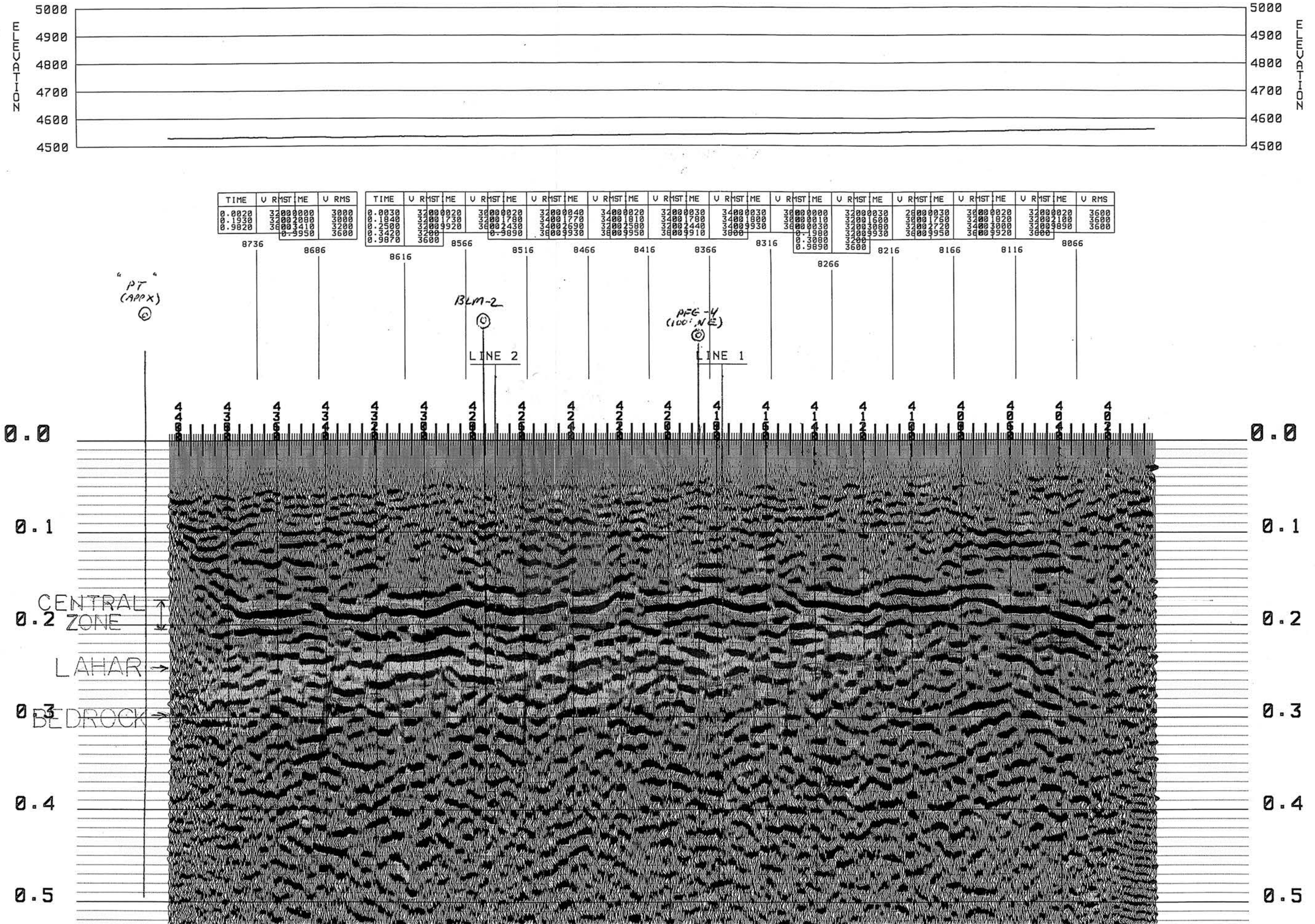
SOURCE	VIBROSEIS	SWEEP FREQ	40-160/80-180
SWEEP LENGTH	6.0 SEC		

GEOMETRY

GP INTERVAL	10 FT.	SP INTERVAL	20 FT.

SPREAD

O------X------O
X------S------X
TR 1 590 — 60 0 — 120 TR 600 FT



I

-----SOUTHEAST----->

HONEYWELL TECHNOLOGY SOLUTIONS, INC.

WEST PLUME
LINE 4
DONA ANNA, NM
FINAL STACK

FIELD PARAMETERS

RECORDING PARAMETERS

RECORDED BY	SUBSURFACE EXPL	DATE RECORDED	MAR 2000
INSTRUMENTS	GEOCOR IV	NOTCH FILTER	
RECORD LENGTH	8.0 SEC	SAMPLE RATE	1 MSEC

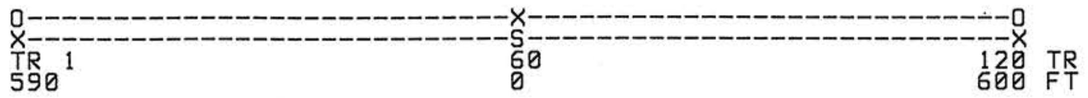
SOURCE PARAMETERS

SOURCE	VIBROSEIS	SWEEP FREQ	20/120
SWEEP LENGTH	6.0 SEC		

GEOMETRY

GP INTERVAL	10 FT.	SP INTERVAL	10 FT.

SPREAD



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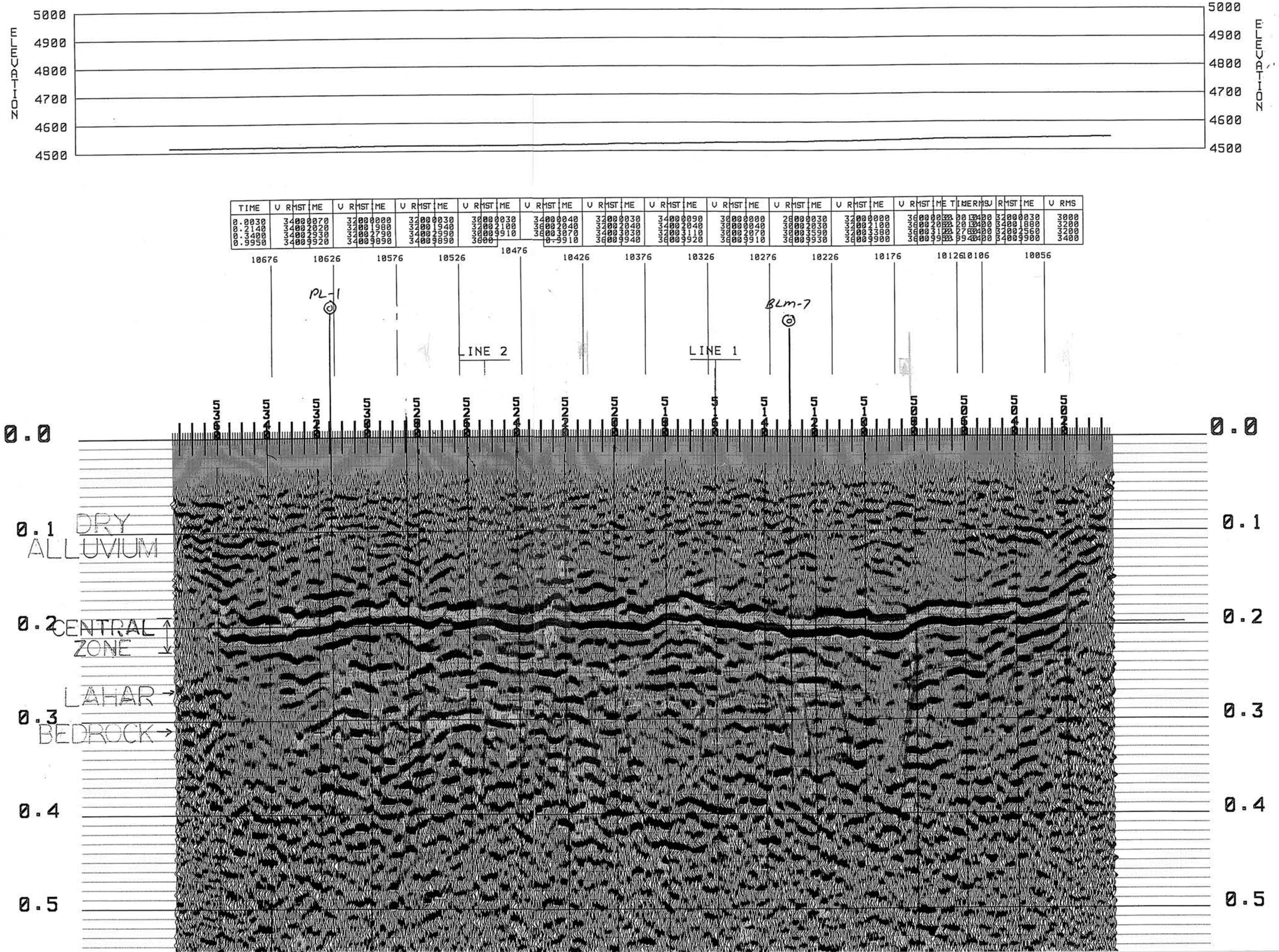


I

-----SOUTHEAST---->

HONEYWELL TECHNOLOGY SOLUTIONS, INC.

WEST PLUME

LINE 5

DONA ANNA, NM

FINAL STACK

FIELD PARAMETERS

RECORDING PARAMETERS

RECORDED BY	SUBSURFACE EXPL	DATE RECORDED	MAR 2000
INSTRUMENTS	GEOCOR IV	NOTCH FILTER	
RECORD LENGTH	8.0 SEC	SAMPLE RATE	1 MSEC

SOURCE PARAMETERS

SOURCE	VIBROSEIS	SWEEP FREQ	20/120
SWEEP LENGTH	6.0 SEC		

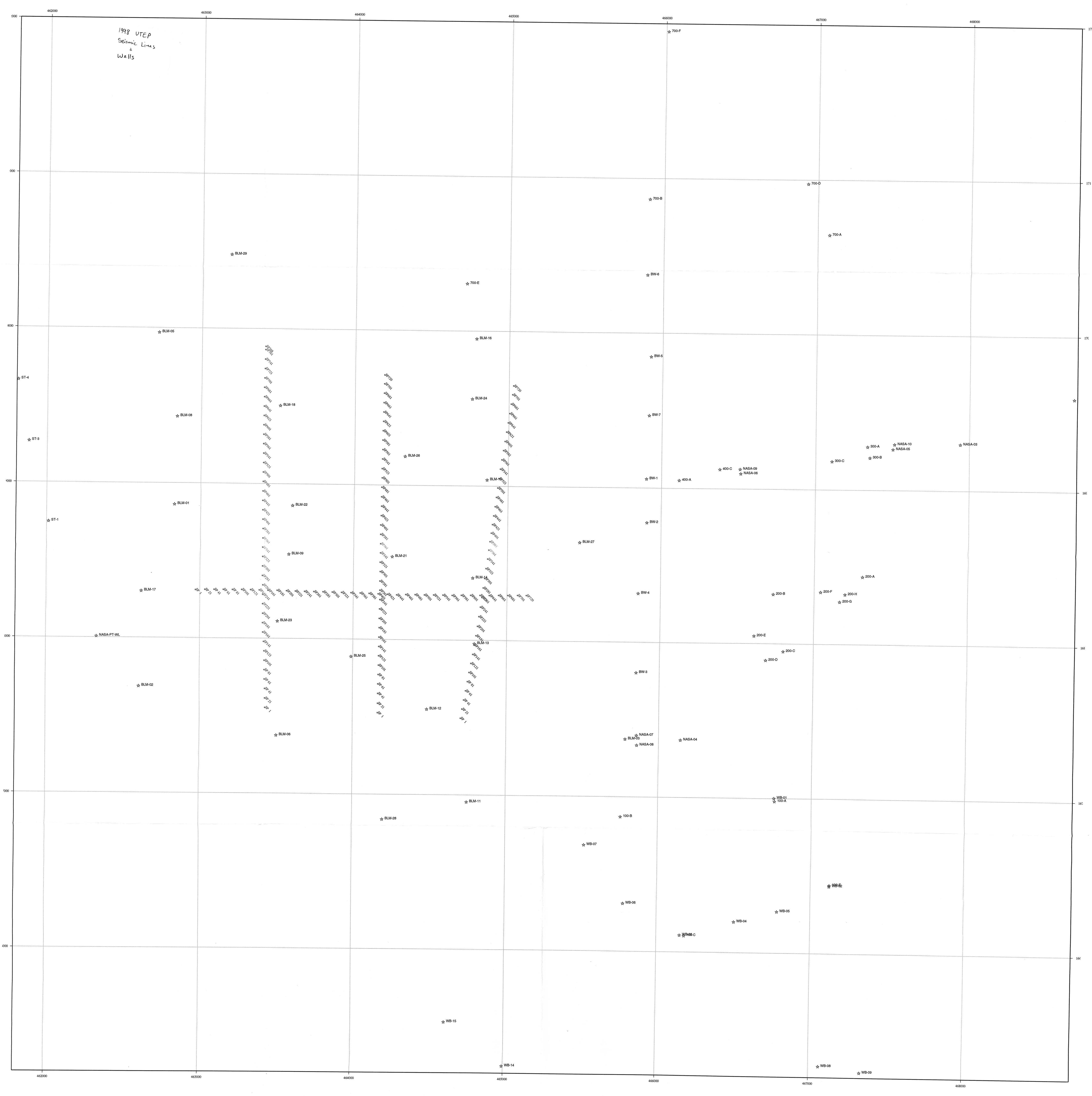
GEOMETRY

GP INTERVAL	10 FT.	SP INTERVAL	10 FT.

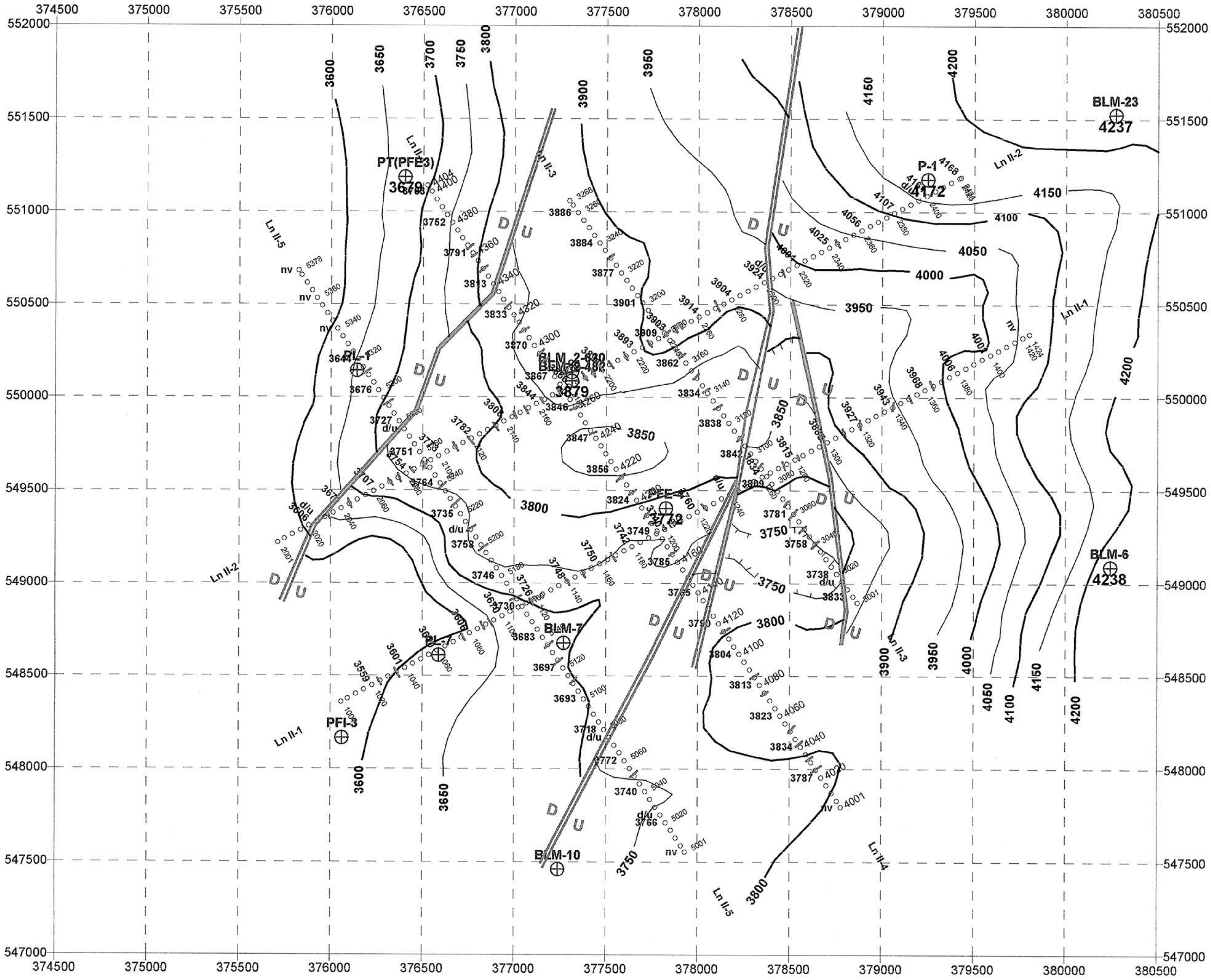
SPREAD

```
O----------------------------X----------------------------O
X----------------------------S----------------------------X
TR 1                         60                         120 TR
590                          0                          600 FT
```

PROCESSING SEQUENCE



1998 UTEP
Seismic Lines
&
Wells
462000
463000
464000
465000
466000
467000
468000
700-F
700-D
700-B
700-A
BLM-29
700-E
BW-8
BLM-05
BLM-16
BW-6
ST-4
BLM-19
BLM-24
BLM-08
BW-7
ST-3
BLM-26
300-A
NASA-10
NASA-05
NASA-03
300-B
300-C
400-C
NASA-09
NASA-08
BW-1
400-A
BLM-01
BLM-22
ST-1
BW-2
BLM-27
BLM-09
BLM-21
200-A
BLM-17
BW-4
200-B
200-F
200-H
200-G
BLM-23
NASA-PT-WL
200-E
BLM-13
200-C
BLM-25
200-D
BW-3
BLM-02
BLM-12
BLM-06
NASA-07
BLM-03
NASA-06
NASA-04
WB-01
100-A
BLM-11
BLM-28
100-B
WB-07
WB-06
WB-04
WB-05
WB-15
WB-14
WB-08
WB-09

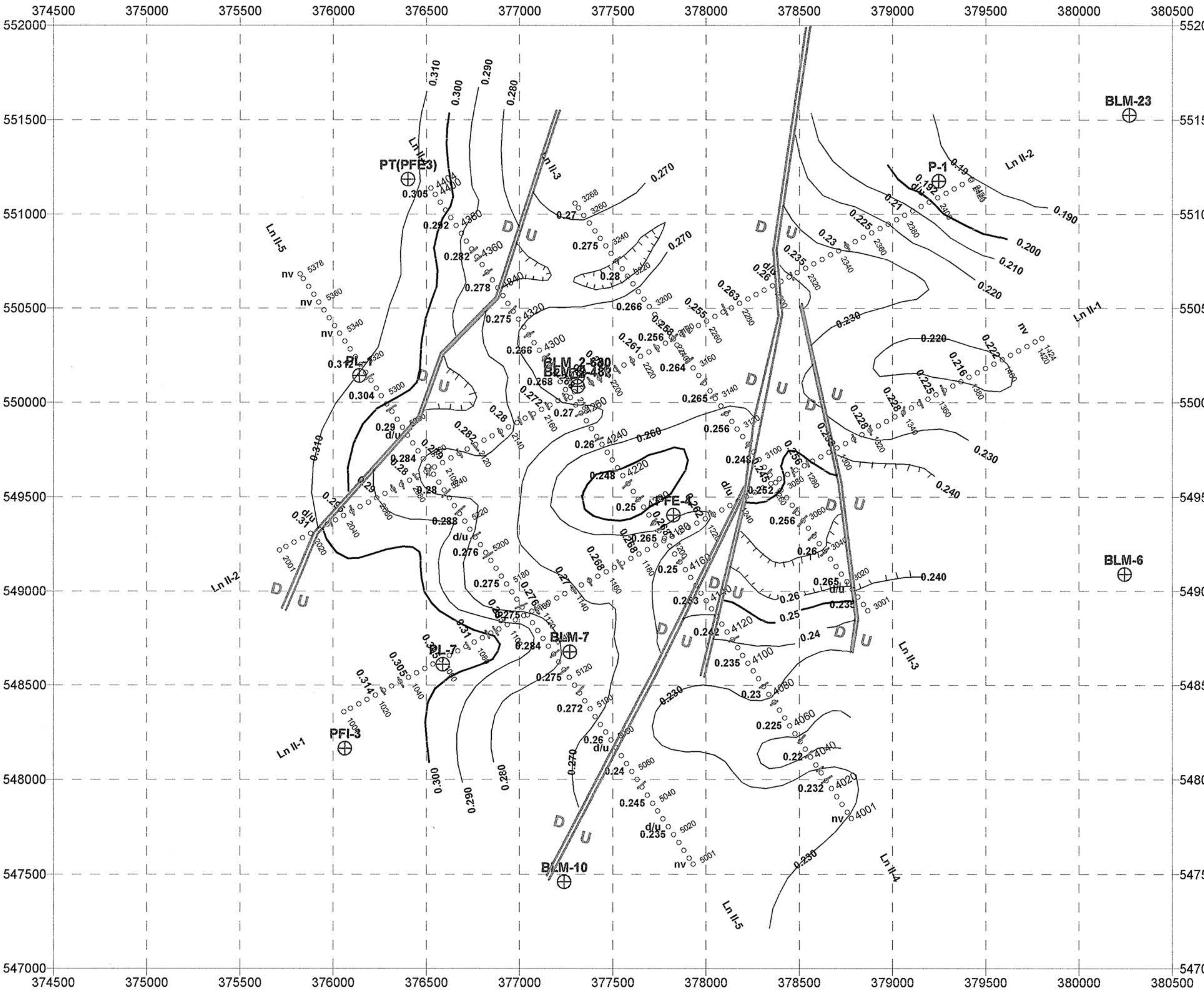


0 500 1000 1500 2000

Fractures interpreted to cut the bedrock surface are annotated by red dashes

WHITE SANDS SEISMIC PROJECT
(WEST PLUME AREA)
Dona Ana County, New Mexico
STRUCTURE
TOP OF BEDROCK

Scale: 1:500 CI: 50 feet Renick & Associates (dge) 6/01



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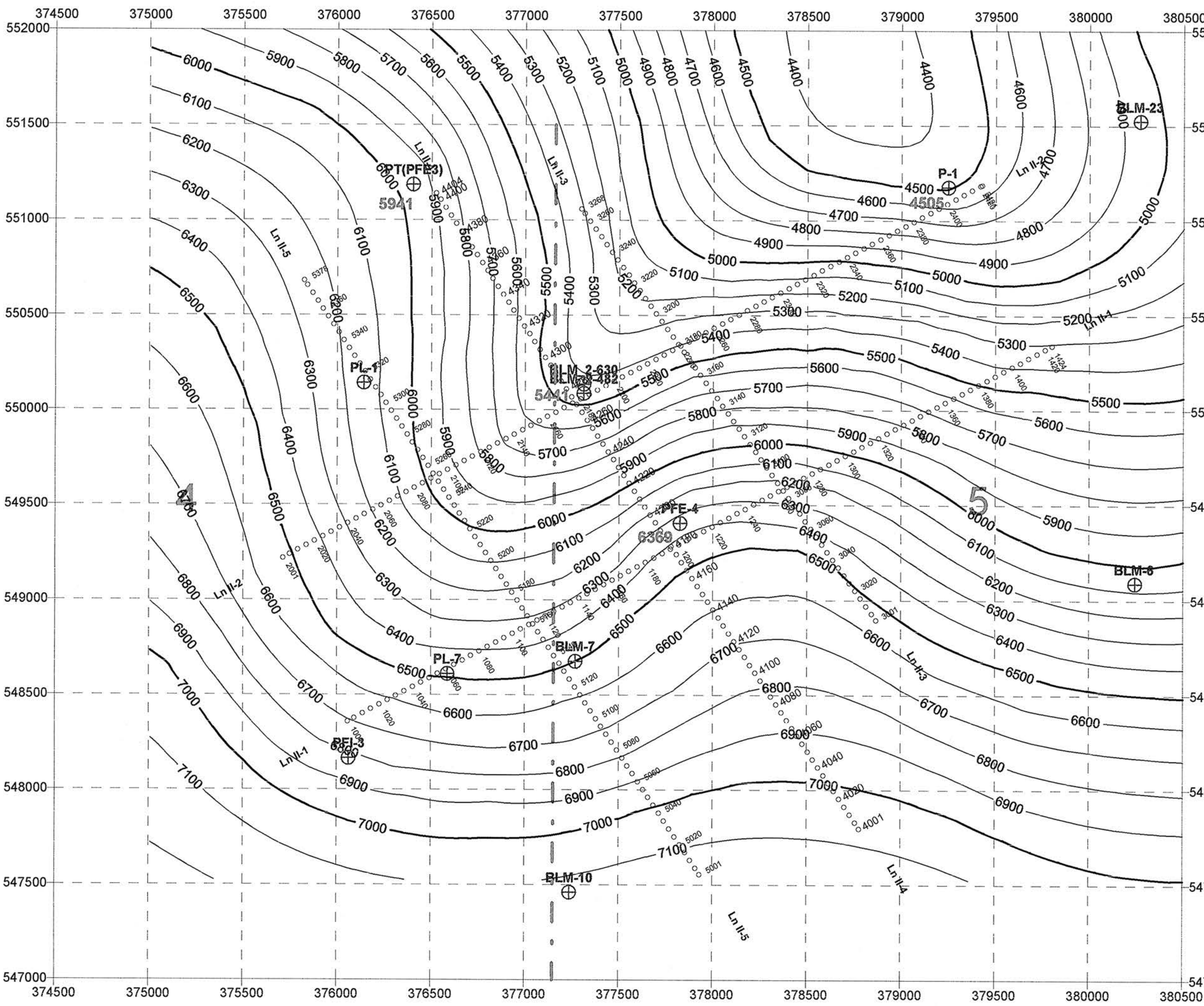
WHITE SANDS SEISMIC PROJECT
(WEST PLUME AREA)
Dona Ana County, New Mexico

TIME STRUCTURE
TOP OF BEDROCK

Scale: 1:500 CI: 10millisec. Renick & Associates (dge) 6/01

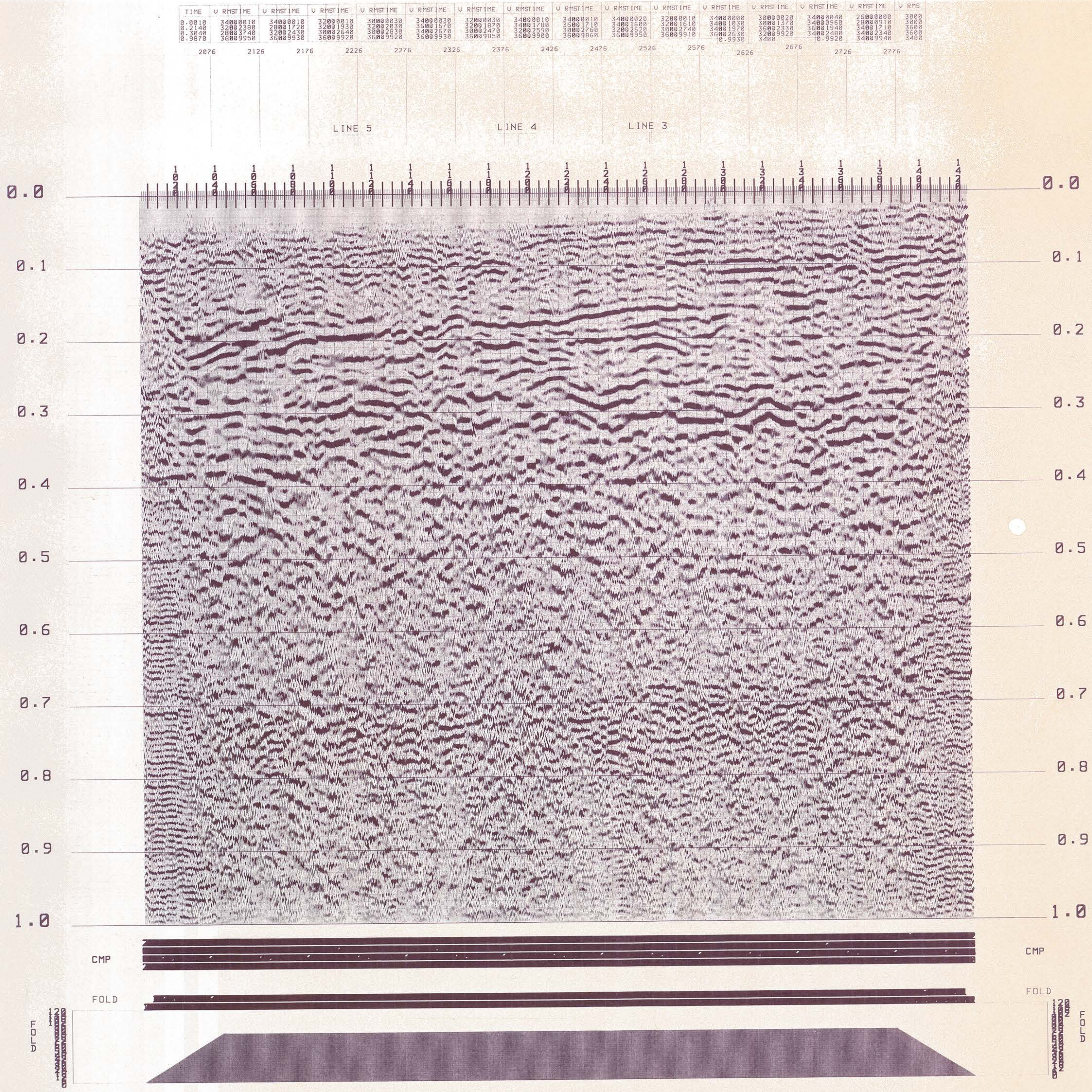
Fractures interpreted to cut the bedrock surface are annotated by red dashes



Red Numbers: Velocity values at wells:
Velocity Relationship: V = (IP * 2) / T
V=velocity
IP=isopach from seismic datum (4600') to top/bedrock
T= time from seismic section

0 500 1000 1500 2000

WHITE SANDS SEISMIC PROJECT
(WEST PLUME AREA)
Dona Ana County, New Mexico
VELOCITY
SEISMIC DATUM (4600') TO TOP OF BEDROCK
Scale: 1:500 CI: 100 ft/sec Renick & Associates (dge) 6/01



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HONEYWELL TECHNOLOGY SOLUTIONS, INC.

DATA ACQUIRED BY
SUBSURFACE EXPLORAITON COMPANY

WEST PLUME
LINE 1
DONA ANNA, NM
FINAL STACK

FIELD PARAMETERS

RECORDING PARAMETERS

RECORDED BY	SECO PTY 42	DATE RECORDED	MAR 2000
INSTRUMENTS	SECO-IMAGE	SAMPLE RATE	1 MSEC
RECORD LENGTH	7.0 SEC	CORRELATED O/P	1 SEC
GEOPHONE	MARK PRODUCT 21A 10 HZ PHONES 6 PHONES/CHANNEL		

SOURCE PARAMETERS

SOURCE	VIBROSEIS	NO OF VIBS	1
SWEEP LENGTH	6.0 SEC	SWEEP FREQ	VARISWEEP 20-120 30-120 40-140 50-150

GEOMETRY

GP INTERVAL 10 FT. SP INTERVAL 10 FT.

SPREAD

```
O---------------------------X---------------------------O
X---------------------------S---------------------------X
TR 1                        60                     120 TR
590                         0                      600 FT
```

PROCESSING SEQUENCE

GEOMETRY DEFINITION

TRUE AMPLITUDE RECOVERY

SURFACE CONSISTENT DECON
GAP: 16 MS
OPERATOR: 160 MS

DATUM STATICS
DATUM: 4600 VELOCITY: 3000

VELOCITY ANALYSIS
ANALYSIS EVERY 500 FT

NORMAL MOVEOUT

AUTOMATIC SURFACE CONSISTENT STATICS

VELOCITY ANALYSIS
ANALYSIS EVERY 500 FT

AUTOMATIC RESIDUAL STATICS

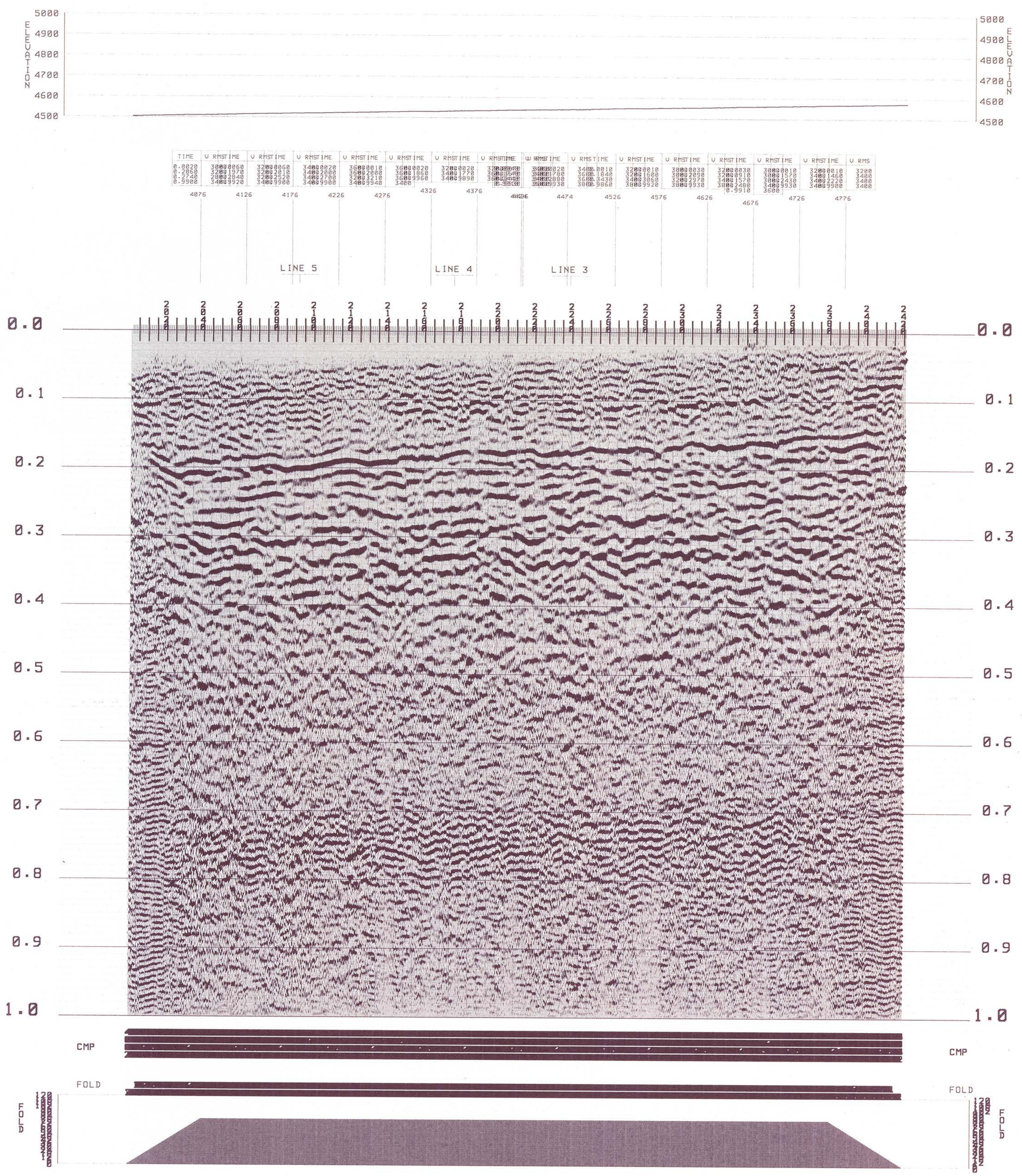
CDP STACK
80 FOLD

FX DECON

DISPLAY PARAMETERS

PROCESSED BY:	D. LAWRENCE		
DATE PROCESSED	MAY 2001	POLARITY	NORMAL
VERTICAL SCALE	10.0 IN/SEC	HORIZ SCALE	72 TR/IN

PINNACLE SEISMIC LTD.
THE ROHILL BUILDING
3100 NORTH A, SUITE 135
MIDLAND, TEXAS 79705
(915) 682-3605



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HONEYWELL TECHNOLOGY SOLUTIONS, INC.

DATA ACQUIRED BY
SUBSURFACE EXPLORAITON COMPANY

WEST PLUME
LINE 2
DONA ANNA, NM
FINAL STACK

FIELD PARAMETERS

RECORDING PARAMETERS

RECORDED BY	SECO PTY 42	DATE RECORDED	MAR 2000
INSTRUMENTS	SECO-IMAGE	SAMPLE RATE	1 MSEC
RECORD LENGTH	7.0 SEC	CORRELATED O/P	1 SEC
GEOPHONE	MARK PRODUCT 21A 10 HZ PHONES 6 PHONES/CHANNEL		

SOURCE PARAMETERS

SOURCE	VIBROSEIS	NO OF VIBS	1
SWEEP LENGTH	6.0 SEC	SWEEP FREQ	VARISWEEP 20-120 30-120 40-140 50-150

GEOMETRY

GP INTERVAL 10 FT. SP INTERVAL 10 FT.

SPREAD

O---------X---------O
X---------S---------X
TR 1 590 · 60 0 · 120 TR 600 FT

PROCESSING SEQUENCE

GEOMETRY DEFINITION

TRUE AMPLITUDE RECOVERY

SURFACE CONSISTENT DECON
GAP: 16 MS
OPERATOR: 160 MS

DATUM STATICS
DATUM: 4600 VELOCITY: 3000

VELOCITY ANALYSIS
ANALYSIS EVERY 500 FT

NORMAL MOVEOUT

AUTOMATIC SURFACE CONSISTENT STATICS

VELOCITY ANALYSIS
ANALYSIS EVERY 500 FT

AUTOMATIC RESIDUAL STATICS

CDP STACK
80 FOLD

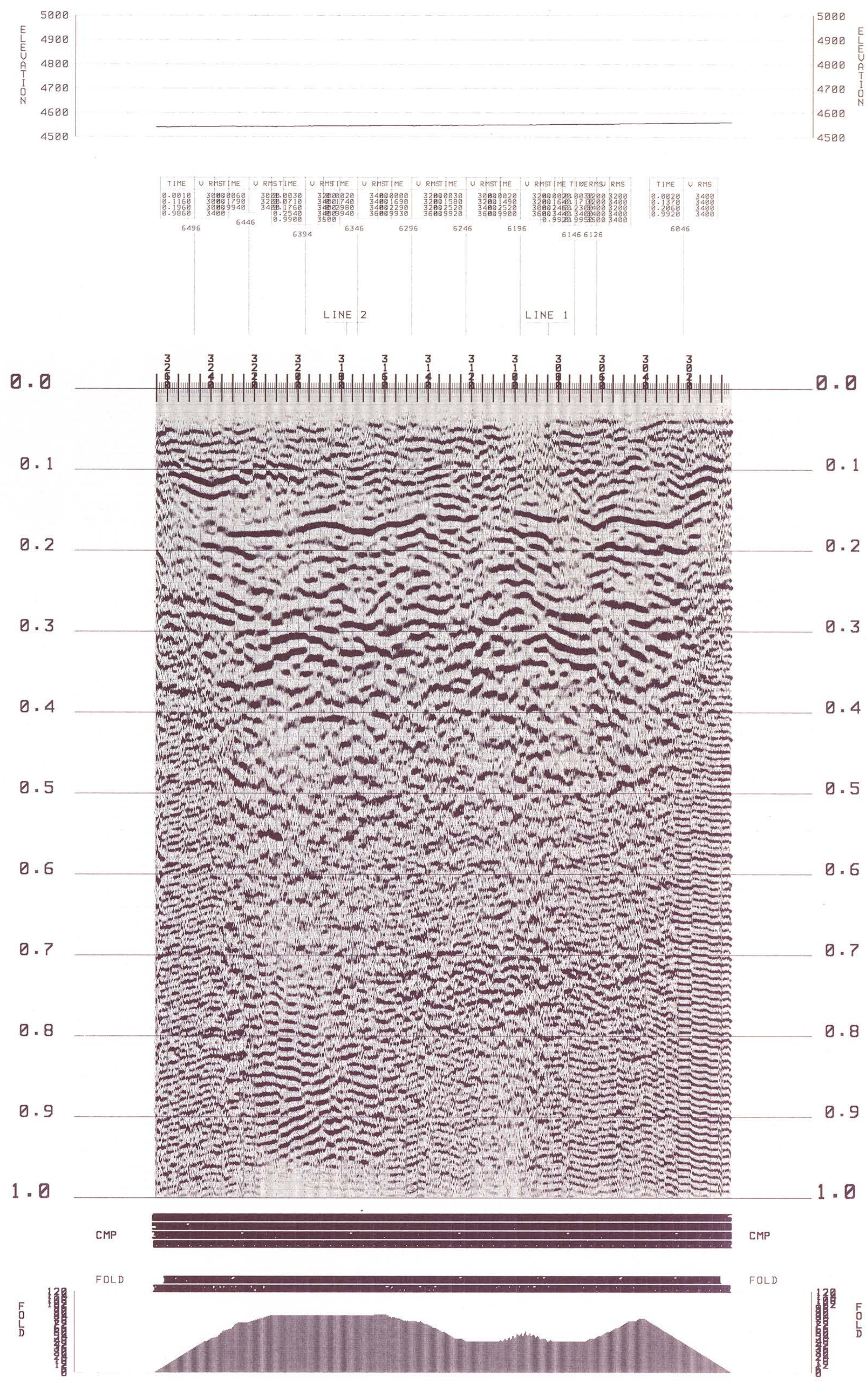
FX DECON

DISPLAY PARAMETERS

PROCESSED BY:	D. LAWRENCE		
DATE PROCESSED	MAY 2001	POLARITY	NORMAL
VERTICAL SCALE	10.0 IN/SEC	HORIZ SCALE	72 TR/IN

PINNACLE SEISMIC LTD.

THE ROHILL BUILDING
3100 NORTH A, SUITE 135
MIDLAND, TEXAS 79705
(915) 682-3685



-----SOUTHEAST---->

HONEYWELL TECHNOLOGY SOLUTIONS, INC.

DATA ACQUIRED BY
SUBSURFACE EXPLORAITON COMPANY

WEST PLUME
LINE 3
DONA ANNA, NM
FINAL STACK

FIELD PARAMETERS

RECORDING PARAMETERS

RECORDED BY	SECO PTY 42	DATE RECORDED	MAR 2000
INSTRUMENTS	SECO-IMAGE	SAMPLE RATE	1 MSEC
RECORD LENGTH	7.0 SEC	CORRELATED O/P	1 SEC
GEOPHONE	MARK PRODUCT 21A		
	10 HZ PHONES		
	6 PHONES/CHANNEL		

SOURCE PARAMETERS

SOURCE	VIBROSEIS	NO OF VIBS	1
SWEEP LENGTH	6.0 SEC	SWEEP FREQ	VARISWEEP
			20-120
			30-120
			40-140
			50-150

GEOMETRY

GP INTERVAL 10 FT. SP INTERVAL 10 FT.

SPREAD

O-----------------------X-----------------------O
X-----------------------S-----------------------X
TR 1 60 120 TR
590 0 600 FT

PROCESSING SEQUENCE

GEOMETRY DEFINITION

TRUE AMPLITUDE RECOVERY

SURFACE CONSISTENT DECON
GAP: 16 MS
OPERATOR: 160 MS

DATUM STATICS
DATUM: 4600 VELOCITY: 3000

VELOCITY ANALYSIS
ANALYSIS EVERY 500 FT

NORMAL MOVEOUT

AUTOMATIC SURFACE CONSISTENT STATICS

VELOCITY ANALYSIS
ANALYSIS EVERY 500 FT

AUTOMATIC RESIDUAL STATICS

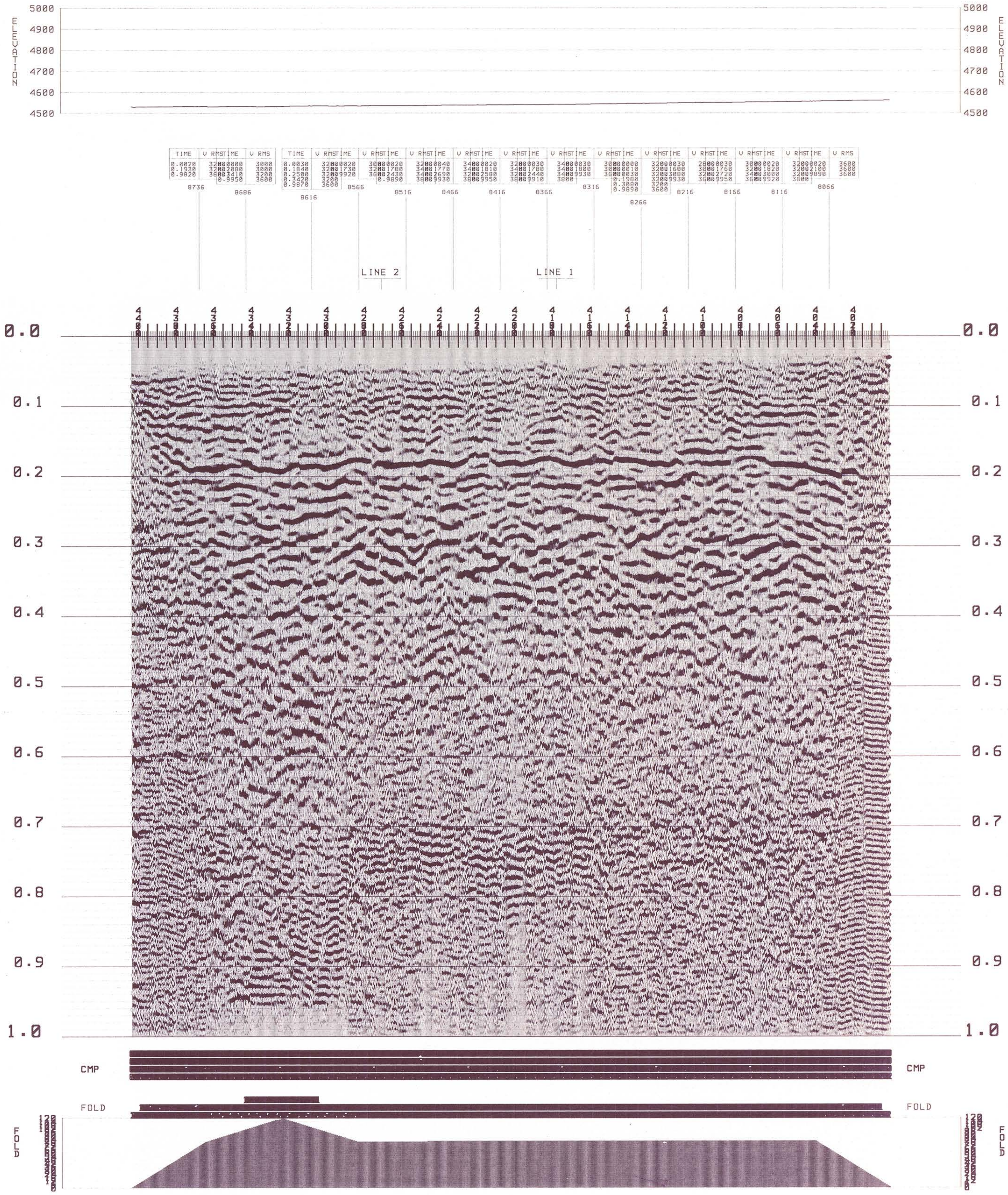
CDP STACK
80 FOLD

FX DECON

DISPLAY PARAMETERS

PROCESSED BY:	D. LAWRENCE		
DATE PROCESSED	MAY 2001	POLARITY	NORMAL
VERTICAL SCALE	10.0 IN/SEC	HORIZ SCALE	72 TR/IN

PINNACLE SEISMIC LTD.
THE ROHILL BUILDING
3100 NORTH A, SUITE 135
MIDLAND, TEXAS 79705
(915) 682-3685



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HONEYWELL TECHNOLOGY SOLUTIONS, INC.

DATA ACQUIRED BY
SUBSURFACE EXPLORAITON COMPANY

WEST PLUME
LINE 4
DONA ANNA, NM
FINAL STACK

FIELD PARAMETERS

RECORDING PARAMETERS

RECORDED BY	SECO PTY 42	DATE RECORDED	MAR 2000
INSTRUMENTS	SECO-IMAGE	SAMPLE RATE	1 MSEC
RECORD LENGTH	7.0 SEC	CORRELATED O/P	1 SEC
GEOPHONE	MARK PRODUCT 21A 10 HZ PHONES 6 PHONES/CHANNEL		

SOURCE PARAMETERS

SOURCE	VIBROSEIS	NO OF VIBS	1
SWEEP LENGTH	6.0 SEC	SWEEP FREQ	VARISWEEP 20-120 30-120 40-140 50-150

GEOMETRY

GP INTERVAL 10 FT. SP INTERVAL 10 FT.

SPREAD

O----------------------------X----------------------------O
X----------------------------S----------------------------X
TR 1 60 120 TR
590 0 600 FT

PROCESSING SEQUENCE

GEOMETRY DEFINITION

TRUE AMPLITUDE RECOVERY

SURFACE CONSISTENT DECON
GAP: 16 MS
OPERATOR: 160 MS

DATUM STATICS
DATUM: 4600 VELOCITY: 3000

VELOCITY ANALYSIS
ANALYSIS EVERY 500 FT

NORMAL MOVEOUT

AUTOMATIC SURFACE CONSISTENT STATICS

VELOCITY ANALYSIS
ANALYSIS EVERY 500 FT

AUTOMATIC RESIDUAL STATICS

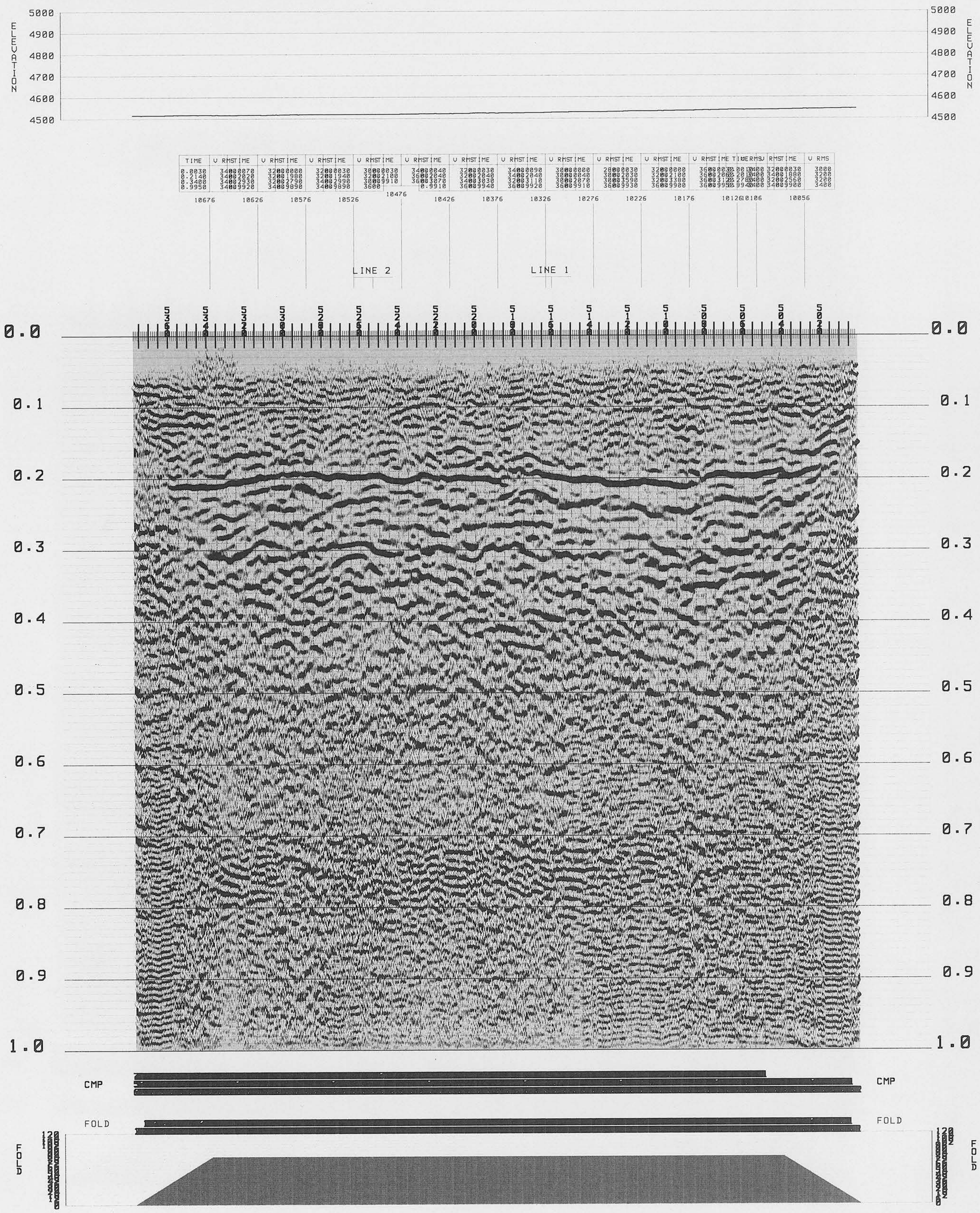
CDP STACK
80 FOLD

FX DECON

DISPLAY PARAMETERS

PROCESSED BY:	D. LAWRENCE		
DATE PROCESSED	MAY 2001	POLARITY	NORMAL
VERTICAL SCALE	10.0 IN/SEC	HORIZ SCALE	72 TR/IN

PINNACLE SEISMIC LTD.
THE ROHILL BUILDING
3100 NORTH A, SUITE 135
MIDLAND, TEXAS 79705
(915) 682-3685



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HONEYWELL TECHNOLOGY SOLUTIONS, INC.

DATA ACQUIRED BY
SUBSURFACE EXPLORAITON COMPANY

WEST PLUME
LINE 5
DONA ANNA, NM
FINAL STACK

FIELD PARAMETERS

RECORDING PARAMETERS

RECORDED BY	SECO PTY 42	DATE RECORDED	MAR 2000
INSTRUMENTS	SECO-IMAGE	SAMPLE RATE	1 MSEC
RECORD LENGTH	7.0 SEC	CORRELATED O/P	1 SEC
GEOPHONE	MARK PRODUCT 21A 10 HZ PHONES 6 PHONES/CHANNEL		

SOURCE PARAMETERS

SOURCE	VIBROSEIS	NO OF VIBS	1
SWEEP LENGTH	6.0 SEC	SWEEP FREQ	VARISWEEP 20-120 30-120 40-140 50-150

GEOMETRY

GP INTERVAL 10 FT. SP INTERVAL 10 FT.

SPREAD

```
O---------------------------X---------------------------O
X---------------------------S---------------------------X
TR 1                        60                     120 TR
590                         0                      600 FT
```

PROCESSING SEQUENCE

GEOMETRY DEFINITION

TRUE AMPLITUDE RECOVERY

SURFACE CONSISTENT DECON
GAP: 16 MS
OPERATOR: 160 MS

DATUM STATICS
DATUM: 4600 VELOCITY: 3000

VELOCITY ANALYSIS
ANALYSIS EVERY 500 FT

NORMAL MOVEOUT

AUTOMATIC SURFACE CONSISTENT STATICS

VELOCITY ANALYSIS
ANALYSIS EVERY 500 FT

AUTOMATIC RESIDUAL STATICS

CDP STACK
80 FOLD

FX DECON

DISPLAY PARAMETERS

PROCESSED BY:	D. LAWRENCE		
DATE PROCESSED	MAY 2001	POLARITY	NORMAL
VERTICAL SCALE	10.0 IN/SEC	HORIZ SCALE	72 TR/IN

PINNACLE SEISMIC LTD.
THE ROHILL BUILDING
3100 NORTH A, SUITE 135
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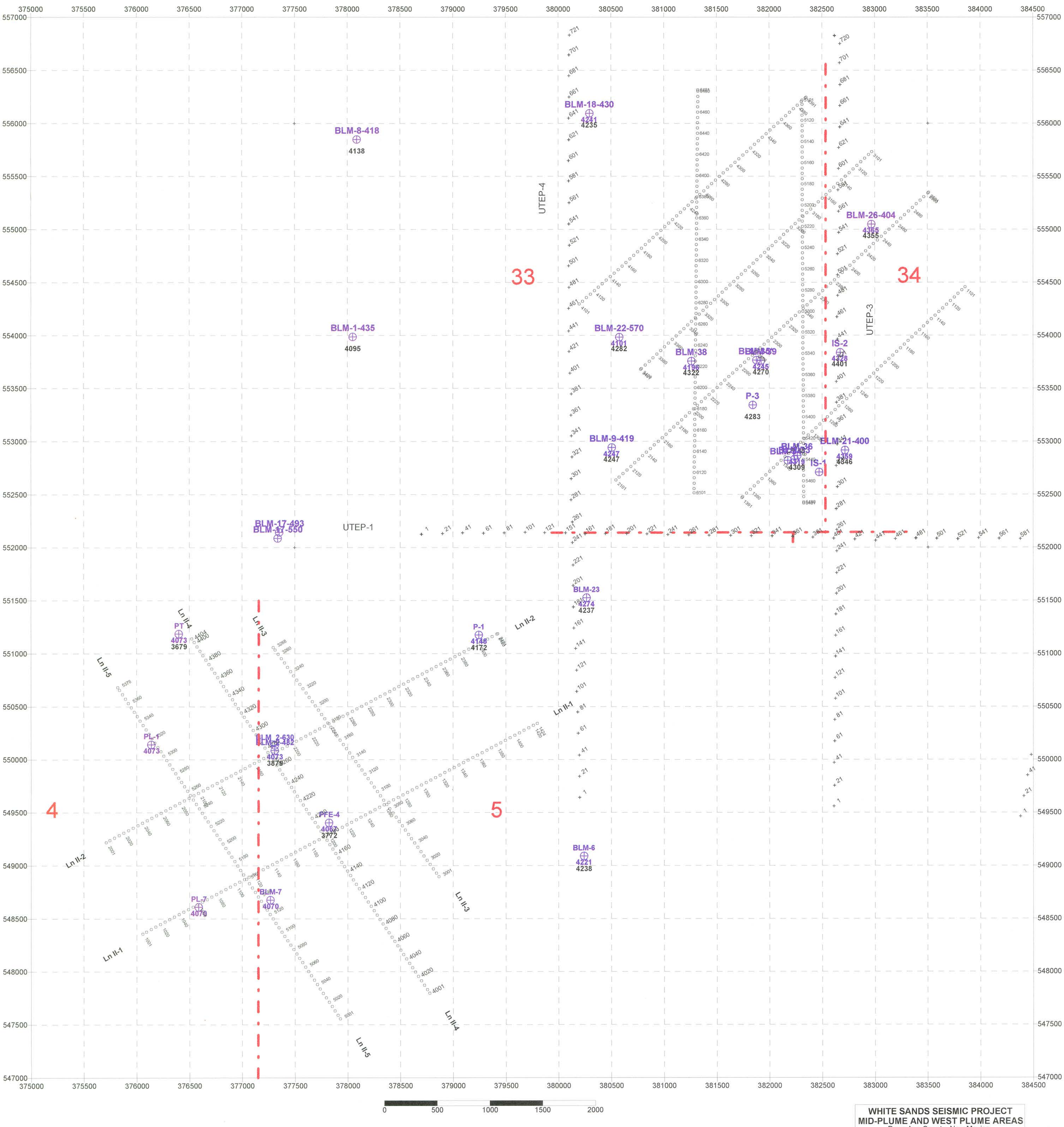
(915) 682-3685



WHITE SANDS SEISMIC PROJECT
MID-PLUME AND WEST PLUME AREAS
Dona Ana County, New Mexico

1:500

Final Report

Mid-Plume Area Seismic Reflection Study
NASA White Sands Test Facility
Dona Ana County, New Mexico

For
Honeywell Technology Solutions, Inc.
PO# 821180

COPY A

by

Subsurface Exploration Company
3100 East Foothill Boulevard
Pasadena, CA 91107-3107
626.584.9258

March 5, 2001

Contents

Enclosures

Introduction

This is the final report for the high resolution 2D seismic survey conducted over the "Mid-Plume" area of the White Sands Test Facility. Subsurface Exploration Company (SECO) of Pasadena, California acquired the seismic data. Data processing and data interpretation was subcontracted by SECO to Pinnacle Seismic, Ltd. (Midland, Texas) and Renick & Associates (Buffalo Gap, Texas, and Midland, Texas), respectively.

Data acquisition was completed in November, 2000. The whole project was completed with the delivery of final maps in February, 2001. In all, approximately four (4) linear miles of high-resolution 2D seismic data were acquired (see Figure 1). Copies of the seismic sections are attached to this report.

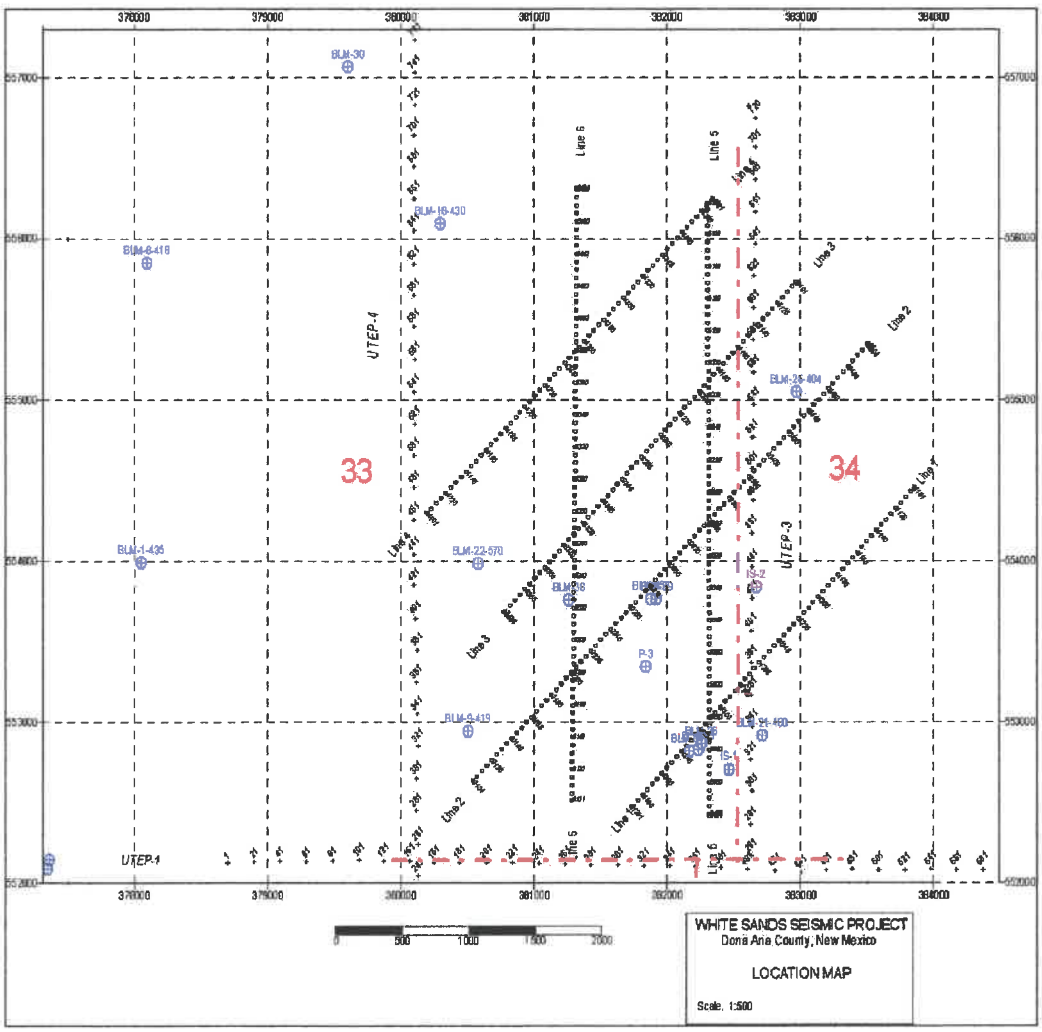


Figure 1 - Map of Seismic Program

Survey Design

See Figure 2 for a summary of survey parameters.

Figure 2 – Survey Parameters

Recording System	SECO-IMAGE
Active Channels	120
Roll Type	Roll-In/Out
Spread (feet)	600-0-600
Group Interval (feet)	10
Source Interval (feet)	20
Nominal Fold	30
Number of Geophone per Channel	6
Geophone Array	Flag-to-Flag over 10-feet.
Geophone Type	Mark Product Model L-21A (10 Hz)
Source Type	Vibroseis
Number of Sweeps/VP	2
Sweep Length (seconds)	6
Sweep Type	VARISWEEP™
Sweep Frequencies	40-160, 80-180 Hz
Vibrator Model	Litton 311
Number of Vibrators	1
Total Listen Time (seconds)	8
Correlated Output (seconds)	2
Sample Interval (milliseconds)	1

The 2000 survey design was based on the seismic survey acquired in this area in 1998. The survey geometry (10-ft group interval, 20-ft source interval and 120 active recording channels) was the same between the two surveys. Recording parameters (2 seconds record length and 1-millisecond sample interval) were also the same between the two surveys.

Source type and parameters were different between the two surveys. The 1998 survey used an impulsive source (0.5 lbs. pentolite cast booster) in a 1.5m deep hole. Vibroseis was chosen for 2000 survey because of operational considerations (mainly because shot holes could not be left unattended overnight).

There was no previous vibroseis data in the area from which to determine vibration effort. Based on what was known about the area and comparing that to similar areas, a vibration effort of two six-second sweeps per vibration point (VP) was proposed with the caveat that should initial sweep testing show that level of effort to be insufficient, more sweeps would be added to each VP until sufficient effort was achieved. Initial sweep testing did show that two sweeps per VP were adequate.

Permitting

Permits to conduct this seismic survey were acquired by Lynx Environmental.

Surveying

Seismic line locations were marked by Lynx Environmental. Line end-points were marked with survey lathe. Every 10th receiver flag location was located using electronic distance measuring (EDM) equipment and marked with pin flags. Receiver locations in between every 10th location were located using a survey chain.

Irish Setter Surveying, Inc. was subcontracted to acquire land survey data. Measurement of X, Y and elevation for each receiver location were done using GPS surveying equipment. The surveyor produced a receiver location map and an electronic data file containing the survey information in ASCII format. The coordinate systems used were State Plane Coordinates, New Mexico Central Zone, NAD27 datum for the horizontal datum, and NAVD88 using the Clarke Ellipsoid for the vertical datum. A map showing the receiver locations superimposed on the topography is enclosed. A summary of receiver locations is listed in Appendix B.

Sweep Testing

An advantage of using a vibroseis source over an impulsive source is that the frequency bandwidth of the source signal can be controlled. A seismic signal imparted into the earth excites several energy modes: compressive, shear and ground-roll. Signal amplitude for each mode varies with frequency. An impulsive source signal is broadband and excites low frequency, high-amplitude ground-roll noise. A vibroseis signal can be controlled to minimize low frequency, high-amplitude ground-roll noise by adjusting the low frequency of the vibroseis sweep.

Sweep testing involved two parts: first, determining the low and high end-points of the seismic signal bandwidth, and, second, determining the shape of the input sweep spectrum to achieve good signal-to-noise ratio across the recorded data's frequency spectrum.

The first part involved testing a series of sweeps with varying low and high frequency cut-off. On the low end, different low frequency sweeps were compared and the low frequency that minimized ground-roll noise contamination while achieving signal penetration to the exploration objective was selected. On the high end, the received signal was analyzed to determine the highest frequency returned from the exploration objective. These two end points determined the seismic bandwidth.

The second part involved applying different weighting to different frequency bands. Greater weighting was applied to the higher frequencies which are attenuated at a greater rate than the low frequencies. Different weighting rates were applied to several sweep sets of the bandwidth as determined in the first part of testing.

Sweep testing took place before the start of production data acquisition. When the first 120-channels were activated, the vibrator truck was placed in the middle of the active spread for testing. Testing determined that 40 Hz was the optimum low frequency mainly based on reduced ground-roll amplitude. For a shallow exploration objective such as the objective for this survey, signal attenuation by earth filtering is usually not a problem. Tests showed little attenuation up to about 180 Hz. A signal bandwidth of 40-180 Hz was chosen. Frequency analysis showed the return signal would be helped by weighting the signal in the 80 to 180 Hz range. Based on this analysis, a Varisweep consisting of two sweeps (40-160 and 80-180 Hz) was chosen as the production sweep set.

Data Acquisition

After sweep testing, the field crew immediately began production data acquisition.

As proposed, every other receiver location was vibrated. Any receiver location that could not be vibrated was "made up for" by vibrating the next available unused receiver location.

A copy of the data acquisition log or "observer's log" in included in Appendix A.

At the end of data acquisition, two copies of the field data were produced. The copies were made on 8mm tape in SEG-Y format. One tape was sent to the processing contractor and the other to SECO's office in Pasadena, California for back up.

Data Processing

Data processing was conducted by Pinnacle Seismic in Midland, Texas. Progress of data processing was monitored and guided by Mr. Don Eckerty of Renick & Associates of Midland, Texas, and by Mr. Dan Hollis of SECO.

Mrs. Debbie Lawrence of Pinnacle Seismic processed the seismic data on a UNIX workstation using MIT Seismic Data Processing software.

The field seismic data was first loaded from tape to the system's hard disk and merged with the survey data. A quality control process ensured correct geometry data and edited traces of unusable signal quality.

The next proposed process in the data processing flow was to determine a weathering static solution based on refraction data. This process involved picking the refraction arrivals for each source location, building a near-surface velocity model and inverting the model to derive time-shifts for each source and receiver location to compensate for near surface velocity variations. The refraction picking process relies on good refraction signal from a continuous weathering layer-bedrock contact. In this area, the refraction signal could not be picked with consistent results. This may have been due to stringers or other inconsistencies in the upper alluvium. Therefore, a weathering static solution based on refraction static analysis was not applied in data processing.

The next step in data processing was to apply a true amplitude recovery to compensate for spherical spreading of the seismic signal.

After amplitude recovery, the data was shifted to a common elevation datum (4,600-ft above sea level). This was accomplished by calculating and applying a time shift based on source and receiver point elevation and a correction or replacement velocity of 3,000 feet-per-second. The 1998 survey used a datum of 4662-feet (1421m) and a replacement velocity of 2,789 feet-per-second (850 m/s).

The data was then run through an iterative process of NMO velocity analysis and automatic static calculation/application. NMO velocity analysis used a series of stack panels where the data has been corrected using a constant velocity. Velocity functions (time and velocity pairs) are selected by choosing time and velocity where the reflections are best imaged by constructive interference. Velocity panel analysis was performed about every 500-ft along each seismic line. Automatic static calculations compare raw data to stacked common-midpoint (CMP) traces to determine residual time shifts at each source and receiver location to remove time shifts caused by localized near-surface velocity variations.

After two iterations of velocity and residual static calculations, the data is stacked to create the seismic image. At this point several processes were tried on the data to test their effectiveness in improving data quality: migration, f/x-decon, band-pass filter, f-k filter. Based on the results of these tests, only f/x decon and a band-pass filter were applied to the stack data.

The final seismic data image was then plotted on both paper and film. The digital seismic image was written to CD-ROM. Copies of the paper and film sections and the CD-ROM accompany this final report.

Data Interpretation

Renick & Associates was subcontracted to guide data processing and interpret the seismic data. Renick & Associates' final report is contained in Appendix A

.

Appendix A

Renick & Associates
201 West Wall, Suite 307
Midland, Texas 79701

March, 2001

Mid Plume Area 2-D Seismic Survey
Discussion of Interpretation

Summary

Attached is a seismic time map and a Top of Bedrock map that Renick & Associates believes offer a realistic picture of the bedrock surface in the Mid Plume Area. In addition, we have noted the location of major fractures/fracture systems at their intersections with the seismic lines.

Maps and earlier work

Earlier seismic work in the Mid Plume Area had been laid out on a base unique to the White Sands area. We instead used the standard New Mexico grid system in our work. The maps are presented on a scale of 1:500. We have digitized the locations of seismic shot points from the 1998 survey, and show them for reference.

Comments about seismic interpretation

The general character of the data was used to guide our interpretation. We have identified three zones (vertically) in the data set.

1. The upper zone comprises the low velocity alluvium, and is characterized by lack of coherent reflection data, and mostly low amplitude returns. The lack of continuous reflections in this zone is expected for a number of reasons. They include the chaotic nature and unconsolidated state of the alluvium, and the limited sampling inherent in any seismic survey at very shallow depths.

2. The central zone (the event is highlighted in yellow on the enclosed copies of the data) consists of one or two coherent reflections of rather low apparent frequency. This zone is considered to be a combination of a reflection from the slow alluvium to fast alluvium interface, and the reflection that occurs at the base of fast alluvium and top of underlying bedrock. We mapped the lower leg of this "peak-trough-peak" event. This

event varies in time (below the seismic processing datum) from approximately 60 milliseconds to 140 milliseconds.

3. The lower zone is considered to be within the bedrock. It consists of largely coherent, higher frequency reflections. We noted many discontinuities within this zone. Complex stratigraphic features are suggested by the discontinuities. This is consistent with a volcanic sequence made up of overlapping flows and sediments complicated by erosion during and following volcanism in the area.

Appearance and Interpretation of fractures

The reflections within the third ("lower") zone are broken by generally high-angle discontinuities, which are interpreted to be fractures and local faulting. These features commonly terminate at the top/bedrock event (Zone #2), although the vertical seismic profiles indicate that the fractures commonly die out and/or merge with other fractures prior to reaching the bedrock surface.

An initial attempt was made to tie the fractures together across the area. We consider this to be unreliable given the complexity of the system. We have instead chosen to indicate the major intersections of fractures with the bedrock surface on the enclosed "Time to Bedrock" and "Depth to Bedrock" maps. We have noted the fracture intersections by red line segments on these maps.

Synthetic Seismograms

As an aid to our interpretation, we prepared synthetic seismograms from sonic logs in four wells. These wells are the BLM-36, BLM-38, BLM-39, and the IS-2. Mr. John Pearson of Lynx Environmental supplied us with copies of sonic logs in these four wells. In addition, Mr. Pearson supplied sample/drill log data in the form of a spreadsheet that indicated depth to bedrock, depth to water, and thickness of the high velocity component of the overburden above the bedrock. This data was used to aid in our understanding of what we were observing on the seismic data.

The synthetic seismograms do not tie extremely well, but support in general our Top/bedrock interpretation.

General Interpretation Procedure

We first prepared work maps from the well information supplied by Mr. Pearson. We were especially interested in the general configuration of the top of bedrock, the thickness of low velocity alluvium, and the presence and thickness of any high-velocity alluvium in the project area.

While working with the data processor, we noted that the quality of the apparent bedrock reflection is sensitive to the processing procedures, and that the reflection could be destroyed by certain processing techniques. We were uncertain at first if we were looking at a true reflection from the alluvium-bedrock surface, or if we were seeing an artifact of processing procedures at the extremely shallow depths being studied. We looked at the continuity of the reflection from line to line, and the reasonableness of interval velocities needed to tie the observed well tops, when deciding that we were seeing a valid reflection. (By a reasonable well tie, we refer to whether a specific time pick at a well results in a reasonable interval velocity with which to tie the well in depth). The early studies indicated that we are looking at a reasonably accurate "Top of Bedrock" reflection.

We then "time-tied" the strong reflection associated with fast alluvium/top of bedrock on paper copies of the data. The good overall tie of this zone among all lines supported the hypothesis that we are imaging the top of bedrock. We then read times at twenty-station intervals, and at well locations on or near the seismic lines.

The times read from the seismic profiles were posted and contoured. The final map ("Time Structure-Top of Bedrock") is included with this report.

Depth Conversion

We calculated an interval velocity at each well located on or near a seismic shot point. Since the data had been processed to a flat seismic datum of 4600 feet, we worked with the isopach from 4600 feet to Top/bedrock and the two-way time from seismic datum to Top/bedrock at each well. The velocity relationship is

V (datum to bedrock) = (Isopach * 2) / Two-way time from seismic section.

The velocity necessary to tie an observed seismic time to the known isopach value at each well was calculated using this relationship.

We then checked the reasonableness of the velocity values. We accomplished this by making a rough contour map of the velocity field in the area. In general, we expect faster velocities, as a horizon becomes shallower, and in areas complicated by thinner local isotime/isopach values. We also attempted to adjust our velocity map to accommodate known sources of anomalous velocities (zones of unusually fast or slow velocity material).

The velocity map was reasonable in shape and gradient. We note that velocity increases to the east and southeast into an area where the isopach from datum to bedrock and the thickness of alluvium decrease. In addition, the anomalous high velocity nose in the area of the BLM No. 39, 36, and 21 wells corresponds nicely with the location of thickest observed high velocity alluvium overlying the bedrock.

In addition, we took into account the general time structure to look for clues to help guide the conversion to depth. Significantly, the "Time to Bedrock" map exhibits an increase in westerly dips in the high velocity nose area. We suggest that this discontinuity in the bedrock surface (probably due to erosion) helped localize the accumulation of the high velocity alluvium in this area, and thus helped cause the observed high velocity anomaly.

We then produced a final, smoothed velocity map of the area (included with this report). We read a velocity from this map at each shot point being depth converted. The velocity values were entered into a spreadsheet and used to convert observed times to isopach values. The final "Depth to Bedrock" values were computed by adding the calculated isopach to the datum from which the isopach was computed. The final depth map ("Structure-Top of Bedrock") is included with this report.

Although computer contouring is available, we believe that we can produce a better map by using geologic insight and working by hand. This works well as long as the amount of data is limited, and is not evenly sampled in space. On the other hand, if a close spaced grid of data (a 3D survey) is available, we use the computer to produce a very close representation of the mapped surface, because there is little room for interpretation.

FURTHER COMMENTS

1. Accuracy and precision.

   By applying corrections at observed wells, we produced a map that closely (precisely) ties the wells, and is reasonable in areas between wells, based on the times that we observe on the seismic lines. Obviously, the areas farther from control points are interpretations subject to error.

2. Uncertainty in picking individual lines

   The bedrock reflection (Zone #2) is not always straightforward in interpretation. For instance, on line #6, between VP's #6220 and #6270, it at first appears that the yellow event (top of bedrock) should be picked one leg lower. However, this alternate interpretation results in an unexpectedly slow velocity function at the BLM-38 well. Therefore, we have used the upper pick as indicated. If further work necessitates a deeper time pick at this well, the resulting velocity change will alter the velocity field in this part of the area, and will thus change the Top/bedrock map. However, the overall shape and regional pattern as mapped at this time will remain similar.

3. Suggested relation of produced maps to observed water movement

Mr. Pearson indicated that a major plume of water is moving down regional dip from east to west, and that a lesser plume has been noted moving northwest toward the BLM-18 area. We note that our time and depth maps suggest a well-developed valley in the top of bedrock in the BLM 38-39 area. In addition, a less well developed low appears to be developing near the north end of Line #6 and the central portion of Line #4. Some of the water movement could be associated with these lows. However, the best well, according to Mr. Pearson, is the "IS" #2 which lies on a bedrock high. This supports Mr. Pearson's thought that the associated fracture systems are very important. At this time we are unable to precisely link individual fractures. However, we note that a greater density of fracture signatures occurs near the intersections of Lines #3 and #5, and on Lines #4 and #6 in the north and northwest part of the area. This could help explain the northwest trending plume of groundwater movement.

In addition, a greater than normal fracture density is noted near the Line #2 and Line #6 intersection, and along the south-central part of Line #5. It is probable that the IS #2 well encountered an open fracture in the observed westerly trending fracture field just mentioned. However, it is our understanding that the BLM-38 and BLM-39 wells (which lie west of the IS #2) were not especially good wells, and these wells at first glance appear to be close to the central (east-west) fracture system. A possibility is that these wells lie on the south edge of a fracture field which trends from the IS #2 along a tangent that goes just north of the BLM-22 well.

A general recommendation at this time is to consider drilling test wells on the seismic lines in areas of increased fracture density. For instance, at the Line #4-Line #6 intersection for the northwest plume, and along Line #6 between 150 feet and 350 feet north of BLM-38

Bedrock Geology

A feature of particular geologic interest can be seen within the bedrock below the BLM-26 well on Line #2. The feature appears to be a "valley" that is sided with high frequency (dense?) bedrock, and filled with less coherent material. We believe we can see hints of this feature on the northeast ends of the other lines, which will give it a southeast to northwest trend. We are not sure if it has significance to our study.

Comments concerning individual seismic profiles

Line #1: The bedrock reflection is very shallow (60ms) and uncertain on the northeast end of the line. The central portion, although broken by numerous fractures, is rather flat. A significant break occurs at VP#1315, near the intersection with Line#5. The reflection is definitely "up" at the intersection, and "down" at VP#1320. Fractures noted in the bedrock suggest faulting, although the edge of an erosional scarp could produce a similar pattern. At the present time, we favor a largely erosional origin for this feature.

Line #2: The bedrock surface exhibits steep southwest dip on the southwest end of the line (VP# 2100 to 2180).

The central portion of the line (VP# 2180 to 2340) is characterized by a gentle sag that is broken by localized "pop ups" which extend down into the bedrock and are associated with increased fracturing. These features may be preserved pressure ridges in the volcanic sequence.

The northeast portion of Line #2 exhibits a highly disturbed bedrock reflection that is uncertain in interpretation. Beneath this portion of the line lies the "valley" mentioned earlier in this report. This feature has high frequency reflections on its sides that appear to sag into a cone-shaped structure that carries to a depth of at least 0.3 second. This feature also has strong fractures that appear to emanate from the base of the cone, and become more complex upward. The BLM 26 well is just northwest of the center of this feature. Further study about this well may reveal more about the nature of this feature.

Line #3: The northeast part of the line (from VP #3100 to 3245) exhibits a rolling and broken up bedrock surface that resembles the apparent structure in the underlying rock. The underlying rock shows at least three structures that are separated by fractures (faults). A narrow cone-shaped feature at VP # 3140 could be a remnant of the major cone feature noted on Line #2.

The central part of the line (VP #3245 to 3280) is a transition zone to more undisturbed strata to the southwest. The transition zone appears to be a collapse graben that has numerous fractures.

The southwest part of the line (VP #3245 to 3400) is made up of two volcanic blocks that are separated by apparently reverse fault (fractures) at VP #3360.

Line #4: This line exhibits the general southwest dip seen across the area. The west part of the line (VP #4100 to 4195) shows a bedrock structure that rises to the northeast and is broken (faulted down) on the East Side.

The central and east part of the line is a complexly fractured and hummocky terrain, within which the deeper volcanic strata exhibit strongly unconformable relationships.

The complexly fractured anticlinal feature near the intersection with Line #6 highlights the bedrock surface.

Line #5: This line is in a semi-strike orientation with respect to the bedrock surface in the area. The northern three-fourths of the line is characterized by rather flat overall reflections at the bedrock surface and within the bedrock. Fractures are evenly distributed, in general. A time high cut by several fractures can be seen at VP #5340 (this point is 350 feet west of the IS-2 well, and may be related to the geology in this well).

The south part of the line (VP #5385 to 5480) is dominated by the highest structure on the line. The crest of the feature is at the Line #1 intersection. Both the arched nature of the strata and the breadth of the structure appear to decrease with depth. The south flank of the feature is bound by a major fracture (fault) which dips back to the north beneath the structure.

Line #6: This line is generally high in the middle part and dips toward both ends. As on Line #5 the fractures are rather evenly distributed.

A feature of interest (noted earlier) is the sag (graben) between VP's #6220 and 6270. This feature has a rather high density of fractures. Also, the bedrock reflection could be picked one leg lower, thus deepening the apparent graben (valley). This feature ties the BLM-38 well (VP #6225), and the final picks were made to more-reasonably tie this well.

Appendix B

Observer Log

IDENTIFICATION PARAMETERS:

Client:	Honeywell Technology Solutions
Prospect:	White Sands Test Facility
Line:	1-6
County:	Dona Ana
State:	New Mexico
Country:	USA
Company:	Subsurface Exploration Company, Midland, TX
Observer:	Jesus "Gordo" Galindo
Crew Number:	42

RECORDING PARAMETERS:

Acquisition Sample Interval:	1000 microseconds
Recording Sample Interval:	1000 microseconds
Time to Record:	8000 milliseconds
Survey Type:	2 Dimensional
Source Type:	Vibroseis

ROLL-ALONG AND SURVEY PARAMETERS:

Roll Type:	Roll Through
Azimuth of Source Movement:	225.00 degrees
Receiver Interval:	10.00 feet
Receiver Array Length:	10.00 feet
Distance to Center of Receiver Array:	5.00 feet
Source Array Length:	0.00 feet
Distance to Center of Source Array:	0.00 feet

PROCESSING PARAMETERS:

Output Uncorrelated Data?:	NO
Number of Uncorrelated Bits to Output:	1
Correlate Data?:	YES
Output Uncomposited Correlated Data?:	NO
Correlation Type:	Single Bit
Correlation Sweep Source:	Acquired Previously
Number of Bits from Correlator:	16
Number of Correlated Bits to Output:	16
Correlated Output Length:	2000 milliseconds
Correlation Sample Interval:	1000 microseconds

Composite Data?:	YES
Number of Composites:	2
Output Composited Data?:	YES
Number of Composited Bits to Output:	16

VIBRATOR PARAMETERS:

Number of Vibrators:	1
Vibrator Drive Level:	80%
Key to Start Delay:	0 milliseconds
Tone Delay:	2000 milliseconds
Tone Frequency:	0 Hz
End of Tone to Sweep Delay:	0 milliseconds
Vibrator Delay:	0 milliseconds
Sweep to Key Off Delay:	0 milliseconds

SWEEP PARAMETERS:

Sweep Source:	External
Automatic VP Delay:	0.00 seconds
Automatic Sweep Delay:	0.00 seconds
Number of Sweeps:	2

Sweep Number	Start Freq. (Hz)	Stop Freq. (Hz)	Sweep Length (msec)	Start Taper (msec)	Stop Taper (msec)	Atten. (db/oct)	Sweep Type
1	40	160	6000	250	250	0	Linear
2	80	180	6000	250	250	0	Linear

Shot Data

D* Date	Time	VP#	Type	File	1st Flag	Last Flag
D* 11/07/00	12:09:44	1101	CCX	1	1101	1220
D* 11/07/00	12:13:05	1103	CCX	2	1101	1220
D* 11/07/00	12:14:26	1105	CCX	3	1101	1220
D* 11/07/00	12:14:58	1107	CCX	4	1101	1220
D* 11/07/00	12:15:30	1109	CCX	5	1101	1220
D* 11/07/00	12:15:59	1111	CCX	6	1101	1220
D* 11/07/00	12:16:28	1113	CCX	7	1101	1220
D* 11/07/00	12:16:57	1115	CCX	8	1101	1220
D* 11/07/00	12:17:27	1117	CCX	9	1101	1220
D* 11/07/00	12:18:02	1119	CCX	10	1101	1220
D* 11/07/00	12:18:32	1121	CCX	11	1101	1220
D* 11/07/00	12:19:00	1123	CCX	12	1101	1220
D* 11/07/00	12:19:32	1125	CCX	13	1101	1220
D* 11/07/00	12:20:01	1127	CCX	14	1101	1220
D* 11/07/00	12:20:30	1129	CCX	15	1101	1220
D* 11/07/00	12:20:59	1131	CCX	16	1101	1220
D* 11/07/00	12:21:28	1133	CCX	17	1101	1220
D* 11/07/00	12:22:05	1135	CCX	18	1101	1220
D* 11/07/00	12:22:34	1137	CCX	19	1101	1220
D* 11/07/00	12:23:07	1139	CCX	20	1101	1220

D*	11/07/00 12:23:37	1141	CCX	21	1101	1220
D*	11/07/00 12:24:07	1143	CCX	22	1101	1220
D*	11/07/00 12:24:36	1145	CCX	23	1101	1220
D*	11/07/00 12:25:06	1147	CCX	24	1101	1220
D*	11/07/00 12:26:12	1149	CCX	25	1101	1220
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D*	11/07/00 12:29:04	1157	CCX	29	1101	1220
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D*	11/07/00 12:33:58	1169	CCX	35	1109	1228
D*	11/07/00 12:34:30	1171	CCX	36	1111	1230
D*	11/07/00 12:34:59	1173	CCX	37	1113	1232
D*	11/07/00 12:35:42	1175	CCX	38	1115	1234
D*	11/07/00 12:36:13	1177	CCX	39	1117	1236
D*	11/07/00 12:36:48	1179	CCX	40	1119	1238
D*	11/07/00 12:37:29	1181	CCX	41	1121	1240
D*	11/07/00 12:39:46	1183	CCX	42	1123	1242
D*	11/07/00 12:41:12	1185	CCX	43	1125	1244
D*	11/07/00 12:41:43	1187	CCX	44	1127	1246
D*	11/07/00 12:42:17	1189	CCX	45	1129	1248
D*	11/07/00 12:42:53	1191	CCX	46	1131	1250
D*	11/07/00 12:43:22	1193	CCX	47	1133	1252
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D*	11/07/00 12:44:24	1197	CCX	49	1137	1256
D*	11/07/00 12:45:45	1199	CCX	50	1139	1258
D*	11/07/00 12:46:14	1201	CCX	51	1141	1260
D*	11/07/00 12:52:54	1203	CCX	52	1143	1262
D*	11/07/00 12:53:28	1205	CCX	53	1145	1264
D*	11/07/00 12:54:35	1207	CCX	54	1147	1266
D*	11/07/00 12:55:09	1209	CCX	55	1149	1268
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D*	11/08/00 09:39:55	2179	CCX	181	2119	2238
D*	11/08/00 09:40:24	2181	CCX	182	2121	2240
D*	11/08/00 09:40:53	2183	CCX	183	2123	2242
D*	11/08/00 09:41:21	2185	CCX	184	2125	2244
D*	11/08/00 09:41:51	2187	CCX	185	2127	2246
D*	11/08/00 09:42:22	2189	CCX	186	2129	2248
D*	11/08/00 09:44:19	2191	CCX	187	2131	2250
D*	11/08/00 09:44:48	2193	CCX	188	2133	2252
D*	11/08/00 09:45:16	2195	CCX	189	2135	2254
D*	11/08/00 09:45:49	2197	CCX	190	2137	2256
D*	11/08/00 09:46:51	2199	CCX	191	2139	2258
D*	11/08/00 09:47:29	2201	CCX	192	2141	2260
D*	11/08/00 09:47:58	2203	CCX	193	2143	2262
D*	11/08/00 09:48:27	2205	CCX	194	2145	2264
D*	11/08/00 09:48:56	2207	CCX	195	2147	2266
D*	11/08/00 09:49:25	2209	CCX	196	2149	2268
D*	11/08/00 10:04:42	2211	CCX	197	2151	2270
D*	11/08/00 10:05:20	2213	CCX	198	2153	2272
D*	11/08/00 10:06:02	2215	CCX	199	2155	2274
D*	11/08/00 10:06:45	2217	CCX	200	2157	2276
D*	11/08/00 10:07:13	2219	CCX	201	2159	2278
D*	11/08/00 10:08:18	2221	CCX	202	2161	2280
D*	11/08/00 10:08:48	2223	CCX	203	2163	2282
D*	11/08/00 10:09:17	2225	CCX	204	2165	2284
D*	11/08/00 10:10:33	2227	CCX	205	2167	2286
D*	11/08/00 10:11:03	2229	CCX	206	2169	2288
D*	11/08/00 10:11:33	2231	CCX	207	2171	2290
D*	11/08/00 10:12:02	2233	CCX	208	2173	2292

D*	11/08/00 10:12:31	2235	CCX	209	2175	2294
D*	11/08/00 10:12:59	2237	CCX	210	2177	2296
D*	11/08/00 10:13:32	2239	CCX	211	2179	2298
D*	11/08/00 10:14:06	2241	CCX	212	2181	2300
D*	11/08/00 10:14:35	2243	CCX	213	2183	2302
D*	11/08/00 10:15:03	2245	CCX	214	2185	2304
D*	11/08/00 10:15:32	2247	CCX	215	2187	2306
D*	11/08/00 10:16:03	2249	CCX	216	2189	2308
D*	11/08/00 10:16:31	2251	CCX	217	2191	2310
D*	11/08/00 10:17:00	2253	CCX	218	2193	2312
D*	11/08/00 10:22:30	2255	CCX	219	2195	2314
D*	11/08/00 10:23:19	2257	CCX	220	2197	2316
D*	11/08/00 10:23:56	2259	CCX	221	2199	2318
D*	11/08/00 10:24:24	2261	CCX	222	2201	2320
D*	11/08/00 10:24:57	2263	CCX	223	2203	2322
D*	11/08/00 10:26:21	2265	CCX	224	2205	2324
D*	11/08/00 10:27:19	2267	CCX	225	2207	2326
D*	11/08/00 10:27:47	2269	CCX	226	2209	2328
D*	11/08/00 10:28:16	2271	CCX	227	2211	2330
D*	11/08/00 10:28:46	2273	CCX	228	2213	2332
D*	11/08/00 10:29:25	2275	CCX	229	2215	2334
D*	11/08/00 10:30:09	2277	CCX	230	2217	2336
D*	11/08/00 10:30:44	2279	CCX	231	2219	2338
D*	11/08/00 10:31:16	2281	CCX	232	2221	2340
D*	11/08/00 10:31:47	2283	CCX	233	2223	2342
D*	11/08/00 10:32:17	2285	CCX	234	2225	2344
D*	11/08/00 10:33:08	2287	CCX	235	2227	2346
D*	11/08/00 10:33:37	2289	CCX	236	2229	2348
D*	11/08/00 10:34:06	2291	CCX	237	2231	2350
D*	11/08/00 10:34:57	2293	CCX	238	2233	2352
D*	11/08/00 10:35:33	2295	CCX	239	2235	2354
D*	11/08/00 10:36:05	2297	CCX	240	2237	2356
D*	11/08/00 10:36:35	2299	CCX	241	2239	2358
D*	11/08/00 10:37:54	2301	CCX	242	2241	2360
D*	11/08/00 10:38:24	2303	CCX	243	2243	2362
D*	11/08/00 10:38:53	2305	CCX	244	2245	2364
D*	11/08/00 10:39:22	2307	CCX	245	2247	2366
D*	11/08/00 10:39:51	2309	CCX	246	2249	2368
D*	11/08/00 10:40:20	2311	CCX	247	2251	2370
D*	11/08/00 10:40:55	2313	CCX	248	2253	2372
D*	11/08/00 10:41:40	2315	CCX	249	2255	2374
D*	11/08/00 10:42:09	2317	CCX	250	2257	2376
D*	11/08/00 10:42:38	2319	CCX	251	2259	2378
D*	11/08/00 10:43:15	2321	CCX	252	2261	2380
D*	11/08/00 10:44:22	2323	CCX	253	2263	2382
D*	11/08/00 10:45:03	2325	CCX	254	2265	2384
D*	11/08/00 10:45:37	2327	CCX	255	2267	2386
D*	11/08/00 10:47:00	2329	CCX	256	2269	2388
D*	11/08/00 10:47:40	2331	CCX	257	2271	2390
D*	11/08/00 10:48:09	2333	CCX	258	2273	2392
D*	11/08/00 10:48:38	2335	CCX	259	2275	2394
D*	11/08/00 10:49:07	2337	CCX	260	2277	2396
D*	11/08/00 10:49:54	2339	CCX	261	2279	2398
D*	11/08/00 10:50:23	2341	CCX	262	2281	2400
D*	11/08/00 10:50:53	2343	CCX	263	2283	2402
D*	11/08/00 13:16:36	2345	CCX	264	2285	2404
D*	11/08/00 13:17:07	2347	CCX	265	2287	2406
D*	11/08/00 13:17:39	2349	CCX	266	2289	2408
D*	11/08/00 13:18:10	2351	CCX	267	2291	2410
D*	11/08/00 13:18:42	2353	CCX	268	2293	2412
D*	11/08/00 13:19:11	2355	CCX	269	2295	2414
D*	11/08/00 13:19:41	2357	CCX	270	2297	2416
D*	11/08/00 13:20:10	2359	CCX	271	2299	2418

D*	11/08/00 13:20:39	2361	CCX	272	2301	2420
D*	11/08/00 13:21:07	2363	CCX	273	2303	2422
D*	11/08/00 13:21:36	2365	CCX	274	2305	2424
D*	11/08/00 13:23:02	2367	CCX	275	2307	2426
D*	11/08/00 13:23:32	2369	CCX	276	2309	2428
D*	11/08/00 13:24:00	2371	CCX	277	2311	2430
D*	11/08/00 13:25:00	2371	CCX	277	2311	2430
D*	11/08/00 13:25:36	2373	CCX	278	2313	2432
D*	11/08/00 13:26:05	2375	CCX	279	2315	2434
D*	11/08/00 13:26:34	2377	CCX	280	2317	2436
D*	11/08/00 13:27:04	2379	CCX	281	2319	2438
D*	11/08/00 13:27:57	2381	CCX	282	2321	2440
D*	11/08/00 13:28:26	2383	CCX	283	2323	2442
D*	11/08/00 13:28:54	2385	CCX	284	2325	2444
D*	11/08/00 13:29:23	2387	CCX	285	2327	2446
D*	11/08/00 13:29:53	2389	CCX	286	2329	2448
D*	11/08/00 13:30:21	2391	CCX	287	2331	2450
D*	11/08/00 13:31:30	2393	CCX	288	2333	2452
D*	11/08/00 13:31:58	2395	CCX	289	2335	2454
D*	11/08/00 13:32:27	2397	CCX	290	2337	2456
D*	11/08/00 13:32:56	2399	CCX	291	2339	2458
D*	11/08/00 13:33:30	2401	CCX	292	2341	2460
D*	11/08/00 13:33:59	2403	CCX	293	2343	2462
D*	11/08/00 13:34:33	2405	CCX	294	2345	2464
D*	11/08/00 13:35:02	2407	CCX	295	2347	2466
D*	11/08/00 13:35:31	2409	CCX	296	2349	2468
D*	11/08/00 13:36:03	2411	CCX	297	2351	2470
D*	11/08/00 13:36:36	2413	CCX	298	2353	2472
D*	11/08/00 13:37:07	2415	CCX	299	2355	2474
D*	11/08/00 13:37:40	2417	CCX	300	2357	2476
D*	11/08/00 13:38:16	2419	CCX	301	2359	2478
D*	11/08/00 13:38:44	2421	CCX	302	2361	2480
D*	11/08/00 13:39:13	2423	CCX	303	2363	2482
D*	11/08/00 13:39:42	2425	CCX	304	2365	2484
D*	11/08/00 13:40:11	2427	CCX	305	2367	2486
D*	11/08/00 13:40:39	2429	CCX	306	2369	2488
D*	11/08/00 13:41:16	2431	CCX	307	2371	2490
D*	11/08/00 13:41:45	2433	CCX	308	2373	2492
D*	11/08/00 13:42:23	2435	CCX	309	2375	2494
D*	11/08/00 13:43:02	2437	CCX	310	2377	2496
D*	11/08/00 13:43:30	2439	CCX	311	2379	2498
D*	11/08/00 13:43:59	2441	CCX	312	2381	2500
D*	11/08/00 14:06:00	2443	CCX	313	2383	2501
D*	11/08/00 14:06:21	2445	CCX	314	2383	2501
D*	11/08/00 14:07:15	2446	CCX	315	2383	2501
D*	11/08/00 14:07:44	2447	CCX	316	2383	2501
D*	11/08/00 14:09:42	2455	CCX	317	2383	2501
D*	11/08/00 14:10:11	2456	CCX	318	2383	2501
D*	11/08/00 14:10:43	2457	CCX	319	2383	2501
D*	11/08/00 14:11:18	2458	CCX	320	2383	2501
D*	11/08/00 14:11:56	2459	CCX	321	2383	2501
D*	11/08/00 14:12:31	2461	CCX	322	2383	2501
D*	11/08/00 14:13:00	2463	CCX	323	2383	2501
D*	11/08/00 14:13:36	2465	CCX	324	2383	2501
D*	11/08/00 14:14:08	2467	CCX	325	2383	2501
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D*	11/08/00 14:17:44	2479	CCX	331	2383	2501
D*	11/08/00 14:18:17	2481	CCX	332	2383	2501
D*	11/08/00 14:18:48	2483	CCX	333	2383	2501

D*	11/08/00 14:24:08	2485	CCX	334	2383	2501
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D*	11/08/00 14:25:09	2489	CCX	336	2383	2501
D*	11/08/00 14:25:45	2490	CCX	337	2383	2501
D*	11/08/00 14:27:12	2491	CCX	338	2383	2501
D*	11/08/00 14:27:47	2492	CCX	339	2383	2501
D*	11/08/00 14:28:17	2493	CCX	340	2383	2501
D*	11/08/00 14:28:46	2494	CCX	341	2383	2501
D*	11/08/00 14:29:15	2495	CCX	342	2383	2501
D*	11/08/00 14:30:27	2497	(SKIPPED)			
D*	11/08/00 14:30:29	2499	(SKIPPED)			
D*	11/08/00 14:30:33	2501	(SKIPPED)			
D*	11/08/00 15:38:32	3101	CCX	343	3101	3401
D*	11/08/00 15:42:20	3103	CCX	344	3101	3220
D*	11/08/00 15:42:53	3105	CCX	345	3101	3220
D*	11/08/00 15:43:42	3107	CCX	346	3101	3220
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D*	11/08/00 15:46:29	3111	CCX	348	3101	3220
D*	11/08/00 15:47:02	3113	CCX	349	3101	3220
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D*	11/08/00 15:50:05	3125	CCX	355	3101	3220
D*	11/08/00 15:50:37	3127	CCX	356	3101	3220
D*	11/08/00 15:51:07	3129	CCX	357	3101	3220
D*	11/08/00 15:51:39	3131	CCX	358	3101	3220
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D*	11/08/00 15:53:13	3137	CCX	361	3101	3220
D*	11/08/00 15:53:42	3139	CCX	362	3101	3220
D*	11/08/00 15:54:13	3141	CCX	363	3101	3220
D*	11/08/00 15:54:44	3143	CCX	364	3101	3220
D*	11/08/00 15:55:13	3145	CCX	365	3101	3220
D*	11/08/00 15:55:43	3147	CCX	366	3101	3220
D*	11/08/00 15:56:12	3149	CCX	367	3101	3220
D*	11/08/00 15:56:41	3151	CCX	368	3101	3220
D*	11/08/00 15:57:10	3153	CCX	369	3101	3220
D*	11/08/00 15:57:39	3155	CCX	370	3101	3220
D*	11/08/00 15:58:29	3157	CCX	371	3101	3220
D*	11/08/00 15:58:57	3159	CCX	372	3101	3220
D*	11/08/00 16:00:08	3161	CCX	373	3101	3220
D*	11/08/00 16:01:19	3163	CCX	374	3103	3222
D*	11/08/00 16:02:04	3165	CCX	375	3105	3224
D*	11/08/00 16:03:25	3167	CCX	376	3107	3226
D*	11/08/00 16:04:31	3169	CCX	377	3109	3228
D*	11/08/00 16:07:53	3171	CCX	378	3111	3230
D*	11/08/00 16:17:13	3173	CCX	379	3113	3232
D*	11/08/00 16:17:42	3175	CCX	380	3115	3234
D*	11/08/00 16:18:11	3177	CCX	381	3117	3236
D*	11/08/00 16:18:39	3179	CCX	382	3119	3238
D*	11/08/00 16:19:10	3181	CCX	383	3121	3240
D*	11/08/00 16:19:43	3183	CCX	384	3123	3242
D*	11/08/00 16:20:12	3185	CCX	385	3125	3244
D*	11/08/00 16:20:47	3187	CCX	386	3127	3246
D*	11/08/00 16:21:32	3189	CCX	387	3129	3248
D*	11/08/00 16:22:19	3191	CCX	388	3131	3250
D*	11/08/00 16:24:23	3193	CCX	389	3133	3252
D*	11/08/00 16:24:52	3195	CCX	390	3135	3254
D*	11/08/00 16:25:21	3197	CCX	391	3137	3256
D*	11/08/00 16:25:50	3199	CCX	392	3139	3258
D*	11/08/00 16:26:20	3201	CCX	393	3141	3260

D*	11/08/00 16:26:49	3203	CCX	394	3143	3262
D*	11/08/00 16:27:18	3205	CCX	395	3145	3264
D*	11/08/00 16:27:47	3207	CCX	396	3147	3266
D*	11/08/00 16:28:16	3209	CCX	397	3149	3268
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D*	11/08/00 16:30:09	3213	CCX	399	3153	3272
D*	11/08/00 16:30:38	3215	CCX	400	3155	3274
D*	11/08/00 16:31:13	3217	CCX	401	3157	3276
D*	11/08/00 16:31:48	3219	CCX	402	3159	3278
D*	11/08/00 16:32:24	3221	CCX	403	3161	3280
D*	11/08/00 16:33:09	3223	CCX	404	3163	3282
D*	11/08/00 16:33:46	3225	CCX	405	3165	3284
D*	11/08/00 16:34:16	3227	CCX	406	3167	3286
D*	11/08/00 16:34:48	3229	CCX	407	3169	3288
D*	11/08/00 16:35:19	3231	CCX	408	3171	3290
D*	11/08/00 16:36:35	3233	CCX	409	3173	3292
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D*	11/08/00 16:37:33	3237	CCX	411	3177	3296
D*	11/08/00 16:38:01	3239	CCX	412	3179	3298
D*	11/08/00 16:38:33	3241	CCX	413	3181	3300
D*	11/08/00 16:39:03	3243	CCX	414	3183	3302
D*	11/08/00 16:39:32	3245	CCX	415	3185	3304
D*	11/08/00 16:40:02	3247	CCX	416	3187	3306
D*	11/08/00 16:40:30	3249	CCX	417	3189	3308
D*	11/08/00 16:40:59	3251	CCX	418	3191	3310
D*	11/08/00 16:41:28	3253	CCX	419	3193	3312
D*	11/08/00 16:42:25	3255	CCX	420	3195	3314
D*	11/08/00 16:42:54	3257	CCX	421	3197	3316
D*	11/08/00 16:43:23	3259	CCX	422	3199	3318
D*	11/08/00 16:43:52	3261	CCX	423	3201	3320
D*	11/08/00 16:44:46	3263	CCX	424	3203	3322
D*	11/08/00 16:45:15	3265	CCX	425	3205	3324
D*	11/08/00 16:45:45	3267	CCX	426	3207	3326
D*	11/08/00 16:46:22	3269	CCX	427	3209	3328
D*	11/08/00 16:47:58	3271	CCX	428	3211	3330
D*	11/08/00 16:48:26	3273	CCX	429	3213	3332
D*	11/08/00 16:48:55	3275	CCX	430	3215	3334
D*	11/08/00 16:49:25	3277	CCX	431	3217	3336
D*	11/08/00 16:49:54	3279	CCX	432	3219	3338
D*	11/08/00 16:50:24	3281	CCX	433	3221	3340
D*	11/08/00 16:50:59	3283	CCX	434	3223	3342
D*	11/08/00 16:51:29	3285	CCX	435	3225	3344
D*	11/08/00 16:52:02	3287	CCX	436	3227	3346
D*	11/08/00 16:52:30	3289	CCX	437	3229	3348
D*	11/08/00 16:53:12	3291	CCX	438	3231	3350
D*	11/08/00 16:53:42	3293	CCX	439	3233	3352
D*	11/08/00 16:54:13	3295	CCX	440	3235	3354
D*	11/08/00 16:54:42	3297	CCX	441	3237	3356
D*	11/08/00 16:55:14	3299	CCX	442	3239	3358
D*	11/08/00 16:56:19	3301	CCX	443	3241	3360
D*	11/08/00 16:57:24	3303	CCX	444	3243	3362
D*	11/08/00 16:57:53	3305	CCX	445	3245	3364
D*	11/08/00 16:58:42	3307	CCX	446	3247	3366
D*	11/08/00 17:00:21	3309	CCX	447	3249	3368
D*	11/08/00 17:00:50	3311	CCX	448	3251	3370
D*	11/08/00 17:02:26	3313	CCX	449	3253	3372
D*	11/08/00 17:03:21	3315	CCX	450	3255	3374
D*	11/08/00 17:03:50	3317	CCX	451	3257	3376
D*	11/08/00 17:04:25	3319	CCX	452	3259	3378
D*	11/08/00 17:04:54	3321	CCX	453	3261	3380
D*	11/08/00 17:05:22	3323	CCX	454	3263	3382
D*	11/08/00 17:05:55	3325	CCX	455	3265	3384
D*	11/08/00 17:06:43	3327	CCX	456	3267	3386

D* 11/08/00 17:07:12	3329	CCX	457	3269	3388
D* 11/08/00 17:08:16	3331	CCX	458	3271	3390
D* 11/08/00 17:08:45	3333	CCX	459	3273	3392
D* 11/08/00 17:09:14	3335	CCX	460	3275	3394
D* 11/08/00 17:09:43	3337	CCX	461	3277	3396
D* 11/08/00 17:10:14	3339	CCX	462	3279	3398
D* 11/08/00 17:11:17	3341	CCX	463	3281	3400
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D* 11/08/00 17:27:57	3401	CCX	477	3285	3401
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D* 11/08/00 17:29:06	3397	CCX	479	3285	3401
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D*	11/10/00 14:41:02	5177	CCX	678	5117	5236
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D*	11/10/00 15:01:15	5235	CCX	707	5175	5294
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D*	11/10/00	15:04:20	5243	CCX	711	5183	5302
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D*	11/10/00	15:06:39	5251	CCX	715	5191	5310
D*	11/10/00	15:07:09	5253	CCX	716	5193	5312
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D*	11/10/00	15:09:08	5261	CCX	720	5201	5320
D*	11/10/00	15:09:37	5263	CCX	721	5203	5322
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D*	11/10/00	15:12:04	5269	CCX	724	5209	5328
D*	11/10/00	15:13:09	5271	CCX	725	5211	5330
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D*	11/10/00	15:16:26	5275	CCX	727	5215	5334
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D*	11/10/00	15:19:05	5285	CCX	732	5225	5344
D*	11/10/00	15:20:59	5287	CCX	733	5227	5346
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D*	11/10/00	15:29:07	5297	CCX	738	5237	5356
D*	11/10/00	15:29:37	5299	CCX	739	5239	5358
D*	11/10/00	15:30:27	5301	CCX	740	5241	5360
D*	11/10/00	15:31:17	5303	CCX	741	5243	5362
D*	11/10/00	15:36:20	5305	CCX	742	5245	5364
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D*	11/10/00	15:37:37	5309	CCX	744	5249	5368
D*	11/10/00	15:38:06	5311	CCX	745	5251	5370
D*	11/10/00	15:39:03	5313	CCX	746	5253	5372
D*	11/10/00	15:41:57	5315	CCX	747	5255	5374
D*	11/10/00	15:42:55	5317	CCX	748	5257	5376
D*	11/10/00	15:43:24	5319	CCX	749	5259	5378
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D*	11/10/00	15:44:28	5323	CCX	751	5263	5382
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D*	11/10/00	15:47:26	5335	CCX	757	5275	5394
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D*	11/10/00	15:55:38	5361	CCX	770	5301	5420
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D*	11/10/00 15:58:12	5369	CCX	774	5309	5428
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D*	11/10/00 16:08:54	5389	CCX	784	5329	5448
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D*	11/10/00 16:25:12	5433	CCX	807	5365	5481
D*	11/10/00 16:25:41	5434	CCX	808	5365	5481
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D* 11/11/00	13:18:11	6169	CCX	865	6109	6228
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D* 11/11/00	13:22:53	6185	CCX	873	6125	6244
D* 11/11/00	13:23:22	6187	CCX	874	6127	6246
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D* 11/11/00	13:24:20	6191	CCX	876	6131	6250
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D* 11/11/00	13:26:31	6199	CCX	880	6139	6258
D* 11/11/00	13:27:06	6201	CCX	881	6141	6260
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D* 11/11/00	13:41:30	6231	CCX	896	6171	6290
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D*	11/11/00	13:53:08	6261	CCX	911	6201	6320
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D*	11/11/00	13:55:23	6269	CCX	915	6209	6328
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D*	11/11/00	13:58:58	6279	CCX	920	6219	6338
D*	11/11/00	13:59:27	6281	CCX	921	6221	6340
D*	11/11/00	13:59:56	6283	CCX	922	6223	6342
D*	11/11/00	14:00:26	6285	CCX	923	6225	6344
D*	11/11/00	14:00:55	6287	CCX	924	6227	6346
D*	11/11/00	14:01:23	6289	CCX	925	6229	6348
D*	11/11/00	14:01:52	6291	CCX	926	6231	6350
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D*	11/11/00	14:02:49	6295	CCX	928	6235	6354
D*	11/11/00	14:03:36	6297	CCX	929	6237	6356
D*	11/11/00	14:04:06	6299	CCX	930	6239	6358
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D*	11/11/00 14:44:54	6403	CCX	982	6343	6462
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D*	11/11/00 14:54:07	6421	CCX	991	6361	6480
D*	11/11/00 14:54:36	6423	CCX	992	6363	6481
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D*	11/11/00 14:55:36	6427	CCX	994	6367	6481
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D*	11/11/00 15:10:07	6467	CCX	1014	6363	6481
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D*	11/11/00 15:17:47	6475	CCX	1018	6363	6481
D*	11/11/00 15:18:16	6477	CCX	1019	6363	6481
D*	11/11/00 15:19:26	6479	CCX	1020	6363	6481
D*	11/11/00 15:21:00	6481	CCX	1021	6363	6481

Appendix C

Flag	Easting	Northing	Elev
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1102	3838432	5544498	46763
1103	3838360	5544429	46761
1104	3838287	5544360	46758
1105	3838214	5544291	46756
1106	3838141	5544222	46754
1107	3838068	5544153	46751
1108	3837995	5544084	46749
1109	3837922	5544015	46747
1110	3837850	5543946	46745
1111	3837777	5543877	46742
1112	3837704	5543809	46741
1113	3837631	5543741	46739
1114	3837558	5543673	46738
1115	3837485	5543606	46736
1116	3837412	5543538	46734
1117	3837339	5543470	46733
1118	3837266	5543402	46731
1119	3837193	5543334	46729
1120	3837120	5543267	46728
1121	3837047	5543199	46726
1122	3836974	5543130	46724
1123	3836901	5543060	46721
1124	3836827	5542991	46718
1125	3836754	5542922	46716
1126	3836681	5542852	46713
1127	3836608	5542783	46711
1128	3836534	5542713	46708
1129	3836461	5542644	46705
1130	3836388	5542575	46703
1131	3836314	5542506	46700
1132	3836243	5542437	46698
1133	3836171	5542368	46696
1134	3836099	5542300	46693
1135	3836027	5542231	46691
1136	3835955	5542163	46689
1137	3835883	5542094	46686
1138	3835812	5542026	46684
1139	3835740	5541957	46681
1140	3835668	5541889	46679
1141	3835596	5541820	46677
1142	3835523	5541752	46675
1143	3835450	5541683	46673
1144	3835377	5541614	46671
1145	3835303	5541546	46668
1146	3835230	5541477	46666
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1163	3833988	5540319	46625
1164	3833916	5540250	46624
1165	3833843	5540182	46623
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1167	3833698	5540044	46621
1168	3833626	5539976	46620
1169	3833554	5539907	46619
1170	3833482	5539839	46619
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1185	3832389	5538805	46608
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1187	3832244	5538668	46603
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1190	3832026	5538464	46596
1191	3831953	5538396	46593
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1193	3831807	5538259	46592
1194	3831733	5538191	46591
1195	3831660	5538122	46590
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6460	3813195	5561071	46268	6480	3813216	5563050	46322
6461	3813195	5561176	46269	6481	3813215	5563167	46329

Final Report

West-Plume Area Seismic Reflection Study
NASA White Sands Test Facility
Dona Ana County, New Mexico

For
Honeywell Technology Solutions, Inc.
PO# 822725

COPY A

by

Subsurface Exploration Company
3100 East Foothill Boulevard
Pasadena, CA 91107-3107
626.584.9258

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Contents

Enclosures

Introduction

This is the final report for the high resolution 2D seismic survey conducted over the "West-Plume" area of the White Sands Test Facility. Subsurface Exploration Company (SECO) of Pasadena, California acquired the seismic data. Data processing and data interpretation was subcontracted by SECO to Pinnacle Seismic, Ltd. (Midland, Texas) and Renick & Associates (Buffalo Gap, Texas, and Midland, Texas), respectively.

Data acquisition began February 20, 2001 and was completed on February 26, 2001. The whole project was completed with the delivery of final maps in July, 2001. In all, approximately three and six-tenths (3.6) linear miles of high-resolution 2D seismic data were acquired (see Figure 1). Copies of the seismic sections are attached to this report.

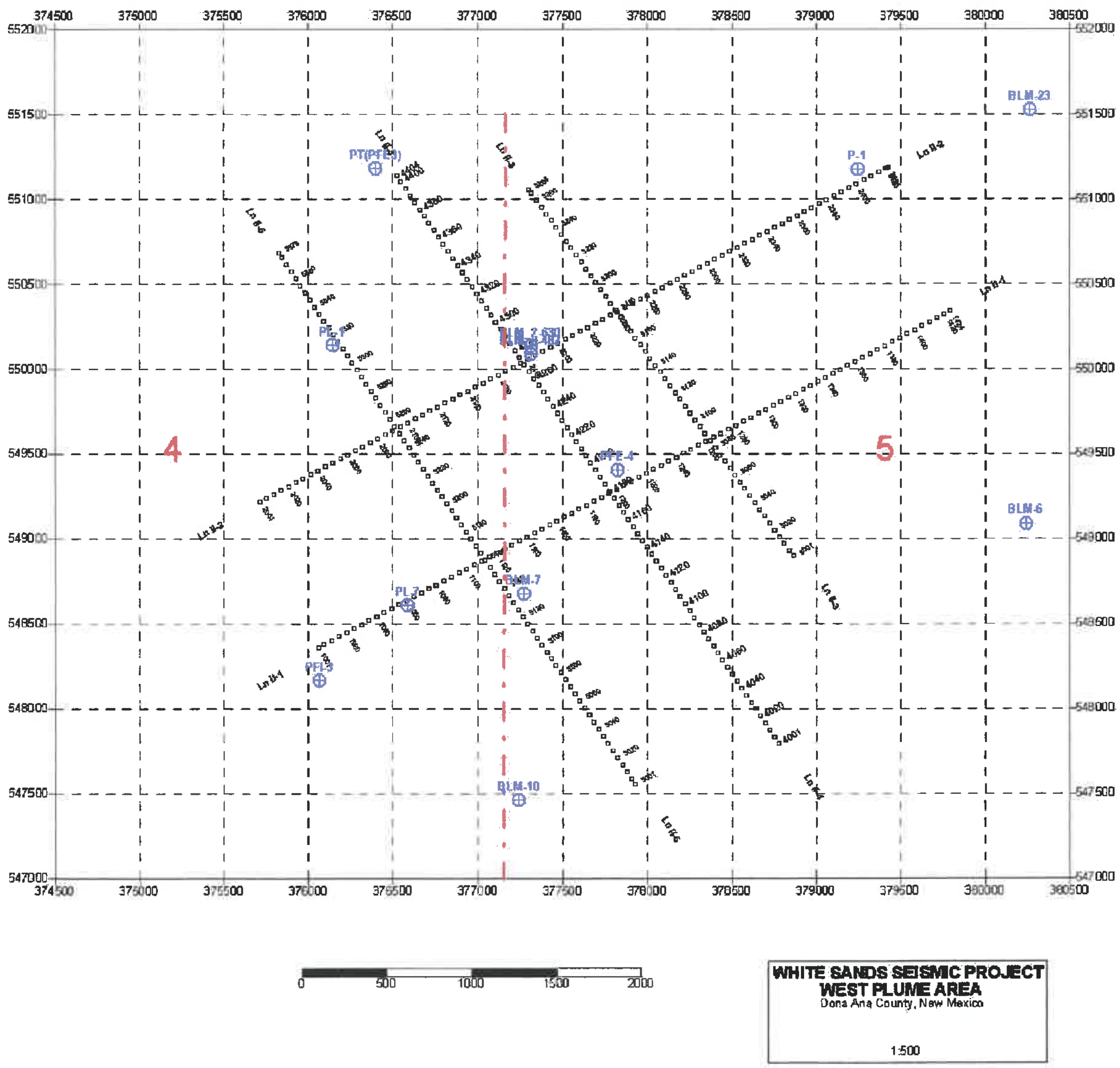

Figure 1 - Map of Seismic Program

Survey Design

See Figure 2 for a summary of survey parameters.

Figure 2 – Survey Parameters

Recording System	SECO-IMAGE
Active Channels	180
Roll Type	Roll-In/Out
Spread (feet)	900-0-900
Group Interval (feet)	10
Source Interval (feet)	10
Nominal Fold	90
Number of Geophone per Channel	6
Geophone Array	Flag-to-Flag over 10-feet.
Geophone Type	Mark Product Model L-21A (10 Hz)
Source Type	Vibroseis
Number of Sweeps/VP	4
Sweep Length (seconds)	6
Sweep Type	VARISWEEP™
Sweep Frequencies	20-120, 30-120,40-120, 50-120 Hz
Vibrator Model	Litton 311
Number of Vibrators	1
Total Listen Time (seconds)	7
Correlated Output (seconds)	1
Sample Interval (milliseconds)	1

The West Plume survey design was based on the Mid-Plume seismic survey acquired in Fall 2000. The survey parameters were modified for the slightly deeper objective (900 vs. 600 feet). Modifications include more channels (180 vs. 120), longer offsets (900 vs. 600 feet), shorter source interval (10 vs. 20 feet), higher fold (90 vs. 30) and higher source or sweep effort (4 vs. 2 sweeps). Receiver spacing, sample interval and geophone array were the same between the two surveys.

Common mid-point (CMP) fold was increased between the two surveys in order to increase shallow signal strength. Shallow data that is affected by first break energy and front or stretch muting during processing has a lower fold than deeper data. Reducing the source interval from 20 to 10 feet doubles the fold in all zones, shallow and deep.

Source effort (number of sweeps) was increased between the two surveys. The previous Mid-Plume survey used two sweeps per vibration point for a shallower target. The Mid-Plume survey imaged the shallow target, but did not seem to have good signal below the target. Therefore, additional sweeps were used on the West Plume survey in increase the likelihood of better signal-to-noise data for the deeper target.

Permitting

Permits to conduct this seismic survey were acquired by Lynx Environmental.

Surveying

Seismic line locations were marked by Lynx Environmental. Line end-points were marked with survey lathe.

Southwest Engineering, Inc. was subcontracted to acquire land survey data. Measurement of X, Y and elevation for each receiver location were done using GPS surveying equipment. The surveyor produced a receiver location map and an electronic data file containing the survey information in ASCII format. The coordinate systems used were State Plane Coordinates, New Mexico Central Zone, NAD27 datum for the horizontal datum, and NAVD88 using the Clarke Ellipsoid for the vertical datum. A map showing the receiver locations superimposed on the topography is enclosed. A summary of receiver locations is listed in Appendix B.

Sweep Testing

Sweep testing involved two parts: first, determining the low and high end-points of the seismic signal bandwidth, and, second, determining the shape of the input sweep spectrum to achieve good signal-to-noise ratio across the recorded data's frequency spectrum.

The first part involved testing a series of sweeps with varying low and high frequency cut-off. On the low end, different low frequency sweeps were compared and the low frequency that minimized ground-roll noise contamination while achieving signal penetration to the exploration objective was selected. On the high end, the received signal was analyzed to determine the highest frequency returned from the exploration objective. These two end points determined the seismic bandwidth.

The second part involved applying different weighting to different frequency bands. Greater weighting was applied to the higher frequencies which are attenuated at a greater rate than the low frequencies. Different weighting rates were applied to several sweep sets of the bandwidth as determined in the first part of testing.

Sweep testing took place before the start of production data acquisition. When the first 180-channels were activated, the vibrator truck was placed in the middle of the active spread for testing. Testing determined that 20 Hz was the optimum low frequency mainly based on reduced ground-roll amplitude. For a shallow exploration objective such as the objective for this survey, signal attenuation by earth filtering is usually not a problem. Tests showed little attenuation up to about 120 Hz. The previous Mid-Plume survey showed little attenuation up to 180 Hz. A signal bandwidth of 20-120 Hz was chosen. Frequency analysis showed the return signal would be helped by weighting the signal in the 30 to 120 Hz range. Based on this analysis, a Varisweep consisting of four sweeps (20-120. 30-120, 40-120 and 50-120 Hz) was chosen as the production sweep set.

Data Acquisition

After sweep testing, the field crew immediately began production data acquisition.

Originally, every other receiver location was to be vibrated. Sweep testing indicated that higher fold should help the signal-to-noise ratio of the data. Therefore, every receiver location was vibrated. Any receiver location that could not be vibrated was skipped for there were no unused receiver locations to "make up" for skipped locations.

A copy of the data acquisition log or "observer's log" in included in Appendix B.

At the end of data acquisition, two copies of the field data were produced. The copies were made on 8mm tape in SEG-Y format. One tape was sent to the processing contractor and the other to SECO's office in Pasadena, California for back up.

Data Processing

Data processing was conducted by Pinnacle Seismic in Midland, Texas. Progress of data processing was monitored and guided by Mr. Don Eckerty of Renick & Associates of Midland, Texas, and by Mr. Dan Hollis of SECO.

Mrs. Debbie Lawrence of Pinnacle Seismic processed the seismic data on a UNIX workstation using MIT Seismic Data Processing software.

The field seismic data was first loaded from tape to the system's hard disk and merged with the survey data. A quality control process ensured correct geometry data and edited traces of unusable signal quality.

The next proposed process in the data processing flow was to determine a weathering static solution based on refraction data. This process involved picking the refraction arrivals for each source location, building a near-surface velocity model and inverting the model to derive time-shifts for each source and receiver location to compensate for near surface velocity variations. The refraction picking process relies on good refraction signal from a continuous weathering layer-bedrock contact. In this area, the refraction signal could not be picked with consistent results. This may have been due to stringers or other inconsistencies in the upper alluvium. Therefore, a weathering static solution based on refraction static analysis was not applied in data processing.

The next step in data processing was to apply a true amplitude recovery to compensate for spherical spreading of the seismic signal.

After amplitude recovery, the data was shifted to a common elevation datum (4,600-ft above sea level). This was accomplished by calculating and applying a time shift based on source and receiver point elevation and a correction or replacement velocity of 3,000 feet-per-second. The elevation datum and correction velocity are the same as the Mid-Plume survey.

The data was then run through an iterative process of NMO velocity analysis and automatic static calculation/application. NMO velocity analysis used a series of stack panels where the data has been corrected using a constant velocity. Velocity functions (time and velocity pairs) are selected by choosing time and velocity where the reflections are best imaged by constructive interference. Velocity panel analysis was performed about every 500-ft along each seismic line. Automatic static calculations compare raw data to stacked common-midpoint (CMP) traces to determine residual time shifts at each source and receiver location to remove time shifts caused by localized near-surface velocity variations.

A great deal of time was spent on analyzing NMO velocities and muting. NMO analyses conducted on data without muting applied were difficult to pick the an unambiguous NMO correction velocity. NMO analyses conducted on data with first break (refraction) energy muted had better defined velocity picks, but questionable imaging results. Several iterations were produced and analyzed by Pinnacle, Renick & Associates and SECO. It was determined that the best results were to use a NMO stretch mute that allowed data in the just beyond the critical reflection angle into the stack.

After two iterations of velocity and residual static calculations, the data is stacked to create the seismic image. At this point several processes were tried on the data to test their effectiveness in improving data quality: migration, f/x-decon, band-pass filter, f-k filter. Based on the results of these tests, only f/x decon and a band-pass filter were applied to the stack data.

The final seismic data image was then plotted on both paper and film. The digital seismic image was written to CD-ROM.

Data Interpretation

Renick & Associates was subcontracted to guide data processing and interpret the seismic data. Renick & Associates' final report is contained in Appendix A

Appendix A

Renick & Associates
201 West Wall, Suite 307
Midland, Texas 79701

July, 2001

West Plume Area 2-D Seismic Survey
Discussion of Interpretation

Summary

We have produced a seismic time map and a Top of Bedrock map that we believe offer a reasonable, although generalized picture of the bedrock surface in the West Plume Area.

Maps and earlier work

We have used the New Mexico Central State Plane Grid System. The maps are presented on a scale of 1:500. We have included one map that indicates the spatial relationship between the Mid-Plume and West Plume Surveys. However, we have not attempted to project bedrock geology between the two areas.

General Interpretation and Processing Comments

We basically proceeded as we had in Mid-Plume area. We prepared work maps from the information supplied by Mr. John Pearson. We were especially interested in the depth to the top of bedrock, the thickness of low velocity alluvium, and the presence and thickness of any high-velocity alluvium in the project area.

As processing by Pinnacle Seismic progressed, We first noted the presence of a coherent "central" reflection, and assumed that this was again related to the bedrock. However, the geologic and well data rendered this interpretation invalid. Also, we were not seeing the quality and quantity of the high-frequency reflections we had used to guide our bedrock/fracture interpretation in Mid-Plume Area. These uncertainties caused us to return to the data processing stage several times in order to try various procedures to get better data. Unfortunately, after a considerable input of time and processing effort, we were not able to reproduce the data quality observed at Mid-Plume.

Reasons for poorer data in West Plume than in Mid-Plume Area

Perhaps the major reason for poorer data within the bedrock at West Plume Area is that the bedrock is made up of predominantly andesite flows instead of the better-bedded tuffaceous sediments and rhyolites noted as the bedrock material in Mid-Plume area. In addition, John Pearson has noted the presence of a greater amount of lahar (mudflow) material above the bedrock at West Plume. This chaotic material may be absorbing and masking much of the reflection data from deeper in the geologic section. Also, the bedrock is no longer closely associated with the top-of-water. In addition, although the greater depth to bedrock in West Plume Area produces more usable data samples (which is generally good for processing the data), the greatly increased thickness of low velocity chaotic alluvium will tend to absorb more reflected energy and deteoriate the quality of the stacked data.

1) Synthetic Seismogram:

As an aid to our interpretation, we prepared a synthetic seismogram from the sonic log in the PFE-4 well. Mr. John Pearson supplied us with the log and with the other geologic and hydrologic information derived from wells drilled in the area. We used this data to guide our interpretation of the seismic profiles.

The synthetic seismogram was critical in our interpretation. The log data indicated that the velocity increases from approximately 5000'/" (or less) to 10,000'/" at the top of water (475' below surface) in the well. At the true top of bedrock (770 feet below surface), the velocity increases to approximately 15,000'/". The synthetic seismogram suggests that the Zone 2 reflection in the seismic data coincides with the increase from 5,000'/" to 10,000'/" in the well, and that the Top-of-Bedrock reflection occurs approximately 70 milliseconds below the Zone 2 reflection.

We note that the velocities above 10,000'/" are normally associated with lithified material, and thus a case can be made that the zone 2 reflection may be indicating an "effective" top of bedrock. However we have picked as true Top-of-Bedrock, the reflection associated with the increase to 15,000'/" in the PFE-4 well. This event is caused by an andesite flow penetrated at a depth of 770 feet in the well. This is the datum considered by Mr. Pearson to be the true bedrock surface in the area.

2) Definition of zones noted in the seismic sections:

As in the Mid-Plume Area, we used the general character of the data to guide the interpretation, and we again recognize three major zones (vertically) in the data set.

A) We again consider the upper zone to comprise the low velocity alluvium. This zone is characterized by lack of coherent reflection data, and mostly low amplitude returns. The lack of continuous reflections in this zone is expected for a number of reasons. They include the chaotic nature and unconsolidated state of the alluvium, and the limited sampling inherent in any seismic survey at very shallow depth.

B) The central zone in West-Plume area has a similar appearance to the zone in Mid-Plume Area. This zone appears as the shallowest coherent reflection series in the data set. Our first inclination was to continue relating the bedrock surface to this event. However, as previously noted, the geologic data provided to us strongly suggested that the actual bedrock event is 40 to 70 milliseconds deeper than the "central zone" reflection. We now believe the Central event (Zone 2 in West Plume Area) is a combination of top-of-water effects combined with the stacking of refracted energy into the seismic profiles.

C) The lower zone is characterized by the presence of coherent reflection data. The data is much less continuous than in the Mid-Plume area, and has a lower frequency appearance. We believe the upper 40 to 70 milliseconds of this zone is a response to interbedded alluvium and volcanic mudflow (lahar) material that overlies the bedrock. This mudflow and alluvial material above the bedrock is itself partially lithified, and thus produces a seismic response similar to that of the underlying bedrock surfaces. Faults and fractures within the bedrock can be locally seen to project upward into the hard alluvium/mudflow portion of the lower seismic zone.

We used the synthetic seismogram to locate the reflection we believe to be related to the top of bedrock, and confirmed that we could time-tie this reflection around the area. We then read a time value on this reflection at twenty-station intervals, and constructed a rough map of fault trends observed in the data. The edited Time Structure Map is included with this report.

3) Fracture Analysis:

We have indicated the location of visible fractures that intersect the Top-of-Bedrock surface. Fractures are shown on the Time and Depth Structure maps as short red dashes. As at Mid-Plume Area, the fractures are so numerous that we have not attempted to connect them.

4) Depth Conversion:

We calculated an interval velocity at each well located on or near a seismic shot point. Since the data had been processed to a flat seismic datum of 4600 feet, we worked with the isopach from 4600 feet to Top/bedrock and the two-way time from seismic datum to Top/bedrock at each well. The velocity relationship is

V (datum to bedrock) = (Isopach * 2) / Two-way time from seismic section.

The velocity necessary to tie an observed seismic time to the known isopach value at each well was calculated using this relationship. We determined that the velocity values were reasonable, and then contoured a velocity map of the area. We did not have as much detail concerning anomalous alluvium zones as was available at Mid-Plume, and the increase in velocity with decrease in bedrock depth was not as pronounced as in Mid-Plume. However, the velocity map was generally reasonable in shape and gradient.
We then produced the final, smoothed velocity map of the area (included with this report). We read a velocity from this map at each shot point being depth converted. The velocity values were entered into a spreadsheet and used to convert observed times to isopach values.
Final "Depth to Bedrock" values were computed by adding the calculated isopach to the datum from which the isopach was computed. The final depth map ("Structure-Top of Bedrock") is included with this report.

As in Mid-Plume, we note that although computer contouring is available, we believe that we can produce a better map by using geologic insight and working by hand. This works well as long as the amount of data is limited.

FURTHER COMMENTS

1) Accuracy and precision:

By applying corrections at observed wells, we can produce a map that closely (precisely) ties the wells, and is reasonable in areas between wells, based on the times that we observe on the seismic lines. Obviously, the areas farther from control points are interpretations subject to error.

Comments concerning individual seismic profiles

Line #1: The line exhibits a general dip to southwest. Down-to-the west faults occur near VP's #1240 and #1300. The reflection from the andesitic bedrock dips from approximately 0.2 sec to 0.3 sec from northeast to southwest. A lahar (volcanic mudflow) is interpreted to lie about 30 to 50 milliseconds above the bedrock. The lahar (annotated in green on the sections) is present SW of VP #1385. It pinches out at VP

#1385. Bedrock highs occur near VP #1160, #1215, and #1260. Numerous fractures are visible northeast of VP #1300. This line ties the PFE-4 well at VP #1205.

Line #2: The line exhibits dip to the southwest. The andsitic bedrock reflection is at approximately 0.2 sec on the northeast end of the line and 0.3 sec on southwest end. Down-to-the-west faults are present near VP's #2025, #2300, and #2395. The lahar is again present in the southwest part of the line, but pinches out abruptly along the fault near VP #2300.

The P-1 well penetrated bedrock near VP #2405. At this well, the bedrock is still 24 feet above the water table. Note that the Central Zone reflection is well above the water table at this well. This casts more doubt on use of the Central Zone reflection in this area. Poorly imaged faults between VP #2390 and #2400 drop the Top-of-Bedrock surface below the water level in this part of the area.

No definitive bedrock structures occur on this line. There are numerous poorly imaged fractures, many of which can be seen to affect the partially lithified alluvium and lahar above the andesitic bedrock.

Line #3: This line is basically a strike line in which the andesitic bedrock occurs in the neighborhood of 0.27 sec. A major down-to-the-west fault occurs near the southwest end of the line at VP #3015. Northwest of this fault (on the downthrown side) is a complexly fractured low area.

A locally higher area is present around VP #3100. This high is visible on Line #1 but is not prominent on the map. Another poorly imaged down-to-the-west fault is present at VP #3110.

The northwest end of the line exhibits numerous fractures that occasionally extend above the bedrock. A few of these fractures exhibit movement and thus can be classified as minor faults.

Line #4: This line exhibits two distinct bedrock morphologies. The southeast portion of the line has a relatively flat bedrock surface at depth of approximately 0.24 sec. The bedrock surface is downdropped to the west along faults near VP #3135 and #3150.

Northwest of VP #3150, the bedrock surface gradually dips to the northwest and is broken by numerous small faults and fractures. A significant bedrock high occurs between VP's #4200 and #4240. This feature separates the PFE-4 well (on the southeast flank) from the BLM 2 well(s) on the northwest flank.

A significant fault occurs near the northwest end of the line at VP #4340.

Line #5: This line is similar in appearance and interpretation to Line 4. The bedrock surface dips to the northwest and is highly fractured and faulted. No definitive structures are mapped on this line.

Appendix B

Observer Log

IDENTIFICATION PARAMETERS:

Client:	Honeywell Technology Solutions
Prospect:	West Plume, White Sands Test Facility
Line:	1-5
County:	Dona Ana
State:	New Mexico
Country:	USA
Company:	Subsurface Exploration Company, Midland, TX
Observer:	Jesus "Gordo" Galindo
Crew Number:	42

RECORDING PARAMETERS:

Acquisition Sample Interval:	1000 microseconds
Recording Sample Interval:	1000 microseconds
Time to Record:	7000 milliseconds
Survey Type:	2 Dimensional
Source Type:	Vibroseis

ROLL-ALONG AND SURVEY PARAMETERS:

Roll Type:	Roll Through
Azimuth of Source Movement:	225.00 degrees
Receiver Interval:	10.00 feet
Receiver Array Length:	10.00 feet
Distance to Center of Receiver Array:	5.00 feet
Source Array Length:	0.00 feet
Distance to Center of Source Array:	0.00 feet

PROCESSING PARAMETERS:

Output Uncorrelated Data?:	NO
Number of Uncorrelated Bits to Output:	1
Correlate Data?:	YES
Output Uncomposited Correlated Data?:	NO
Correlation Type:	Single Bit
Correlation Sweep Source:	Acquired Previously
Number of Bits from Correlator:	16
Number of Correlated Bits to Output:	16
Correlated Output Length:	1000 milliseconds
Correlation Sample Interval:	1000 microseconds

Composite Data?:	YES
Number of Composites:	4
Output Composited Data?:	YES
Number of Composited Bits to Output:	16

VIBRATOR PARAMETERS:

Number of Vibrators:	1
Vibrator Drive Level:	20%
Key to Start Delay:	0 milliseconds
Tone Delay:	2000 milliseconds
Tone Frequency:	0 Hz
End of Tone to Sweep Delay:	0 milliseconds
Vibrator Delay:	0 milliseconds
Sweep to Key Off Delay:	0 milliseconds

SWEEP PARAMETERS:

Sweep Source:	External
Automatic VP Delay:	0.00 seconds
Automatic Sweep Delay:	0.00 seconds
Number of Sweeps:	2

Sweep Number	Start Freq. (Hz)	Stop Freq. (Hz)	Sweep Length (msec)	Start Taper (msec)	Stop Taper (msec)	Atten. (db/oct)	Sweep Type
1	20	120	6000	500	500	0	Linear
2	30	120	6000	500	500	0	Linear
3	40	120	6000	500	500	0	Linear
4	50	120	6000	500	500	0	Linear

Shot Data

D*	Date	Time	VP#	Type	File	1st Rcv	Last Rcv	Comments
D*	02/02/01	14:11:33	3001	CCX	101	3001	3080	bol
D*	02/02/01	14:29:34	3002	CCX	102	3001	3081	
D*	02/02/01	14:31:19	3003	CCX	103	3001	3082	
D*	02/02/01	14:33:17	3004	CCX	104	3001	3083	
D*	02/02/01	14:34:30	3005	CCX	105	3001	3084	
D*	02/02/01	14:35:14	3006	CCX	106	3001	3085	
D*	02/02/01	14:35:59	3007	CCX	107	3001	3086	
D*	02/02/01	14:36:57	3008	CCX	108	3001	3087	
D*	02/02/01	14:37:44	3009	CCX	109	3001	3088	
D*	02/02/01	14:38:31	3010	CCX	110	3001	3089	
D*	02/02/01	14:40:51	3011	CCX	111	3001	3090	
D*	02/02/01	14:41:38	3012	CCX	112	3001	3091	
D*	02/02/01	14:44:36	3013	CCX	113	3001	3092	
D*	02/02/01	14:45:32	3014	CCX	114	3001	3093	

D* 02/02/01 14:46:26	3015	CCX	115	3001	3094
D* 02/02/01 14:47:11	3016	CCX	116	3001	3095
D* 02/02/01 14:47:57	3017	CCX	117	3001	3096
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D* 02/02/01 17:45:59	3152	CCX	252	3072	3231
D* 02/02/01 17:46:43	3153	CCX	253	3073	3232
D* 02/02/01 17:47:45	3154	CCX	254	3074	3233
D* 02/02/01 17:48:42	3155	CCX	255	3075	3234
D* 02/02/01 17:49:26	3156	CCX	256	3076	3235
D* 02/02/01 17:50:10	3157	CCX	257	3077	3236
D* 02/02/01 17:50:54	3158	CCX	258	3078	3237
D* 02/02/01 17:51:37	3159	CCX	259	3079	3238
D* 02/02/01 17:52:24	3160	CCX	260	3080	3239
D* 02/02/01 17:53:08	3161	CCX	261	3081	3240
D* 02/02/01 17:54:05	3162	CCX	262	3082	3241
D* 02/02/01 17:54:53	3163	CCX	263	3083	3242
D* 02/02/01 17:55:38	3164	CCX	264	3084	3243
D* 02/02/01 17:56:30	3165	CCX	265	3085	3244
D* 02/02/01 17:57:23	3166	CCX	266	3086	3245
D* 02/02/01 17:58:06	3167	CCX	267	3087	3246
D* 02/02/01 17:58:52	3168	CCX	268	3088	3247
D* 02/02/01 17:59:36	3169	CCX	269	3089	3248
D* 02/02/01 18:00:25	3170	CCX	270	3090	3249
D* 02/02/01 18:01:08	3171	CCX	271	3091	3250
D* 02/02/01 18:01:55	3172	CCX	272	3092	3251
D* 02/02/01 18:03:08	3173	CCX	273	3093	3252
D* 02/02/01 18:04:00	3174	CCX	274	3094	3253
D* 02/02/01 18:04:45	3175	CCX	275	3095	3254
D* 02/02/01 18:05:29	3176	CCX	276	3096	3255
D* 02/02/01 18:06:13	3177	CCX	277	3097	3256
D* 02/02/01 18:06:56	3178	CCX	278	3098	3257
D* 02/02/01 18:07:40	3179	CCX	279	3099	3258
D* 02/02/01 18:08:26	3180	CCX	280	3100	3259
D* 02/02/01 18:09:14	3181	CCX	281	3101	3260
D* 02/02/01 18:10:37	3182	CCX	282	3102	3261

D* 02/02/01 18:11:30	3183	CCX	283	3103	3262	
D* 02/02/01 18:13:02	3184 (SKIPPED)					
D* 02/02/01 18:13:09	3185 (SKIPPED)					
D* 02/02/01 18:16:45	3186 (SKIPPED)					
D* 02/02/01 18:16:50	3187 (SKIPPED)					
D* 02/02/01 18:17:35	3188	CCX	284	3108	3267	skip for creek
D* 02/02/01 18:18:19	3189	CCX	285	3109	3268	
D* 02/02/01 18:20:18	3190	CCX	286	3110	3269	
D* 02/02/01 18:21:06	3191	CCX	287	3111	3270	
D* 02/02/01 18:22:05	3192	CCX	288	3112	3271	
D* 02/02/01 18:25:10	3193	CCX	289	3113	3263	
D* 02/02/01 18:27:01	3194	CCX	290	3105	3264	
D* 02/02/01 18:30:04	3195	CCX	291	3115	3263	
D* 02/02/01 18:31:04	3196	CCX	292	3105	3264	
D* 02/02/01 18:32:02	3197	CCX	293	3106	3265	
D* 02/02/01 18:32:49	3198	CCX	294	3107	3266	
D* 02/02/01 18:33:36	3199	CCX	295	3108	3267	
D* 02/02/01 18:34:31	3200	CCX	296	3109	3268	
D* 02/02/01 18:35:17	3201	CCX	297	3110	3269	
D* 02/02/01 18:36:09	3202	CCX	298	3111	3270	
D* 02/02/01 18:36:56	3203	CCX	299	3112	3271	
D* 02/02/01 18:37:47	3204	CCX	300	3113	3272	
D* 02/02/01 18:38:35	3205	CCX	301	3114	3273	
D* 02/02/01 18:43:34	3206	CCX	302	3126	3263	
D* 02/02/01 18:52:11	3207	CCX	303	3105	3264	
D* 02/02/01 18:52:57	3208	CCX	304	3106	3265	
D* 02/02/01 18:53:42	3209	CCX	305	3107	3266	
D* 02/02/01 18:55:20	3210	CCX	306	3108	3267	
D* 02/02/01 18:56:12	3211	CCX	307	3109	3268	
D* 02/02/01 18:57:04	3212	CCX	308	3110	3269	
D* 02/02/01 18:58:06	3213	CCX	309	3111	3270	
D* 02/02/01 18:59:03	3214	CCX	310	3112	3271	
D* 02/02/01 18:59:59	3215	CCX	311	3113	3272	
D* 02/02/01 19:03:43	3216 (SKIPPED)					
D* 02/02/01 19:03:45	3217 (SKIPPED)					
D* 02/02/01 19:05:37	3218	CCX	312	3116	3272	skip for creek
D* 02/02/01 19:06:33	3219	CCX	313	3117	3272	skip for creek
D* 02/02/01 19:07:40	3220	CCX	314	3118	3272	
D* 02/02/01 19:09:20	3221	CCX	315	3119	3272	
D* 02/02/01 19:10:03	3222	CCX	316	3120	3272	
D* 02/02/01 19:12:17	3223	CCX	317	3121	3272	
D* 02/02/01 19:13:02	3224	CCX	318	3122	3272	
D* 02/02/01 19:13:51	3225	CCX	319	3123	3272	
D* 02/02/01 19:15:01	3226	CCX	320	3124	3272	
D* 02/02/01 19:15:48	3227	CCX	321	3125	3272	
D* 02/02/01 19:16:34	3228	CCX	322	3126	3272	
D* 02/02/01 19:17:18	3229	CCX	323	3127	3272	
D* 02/02/01 19:18:26	3230	CCX	324	3128	3272	
D* 02/02/01 19:19:10	3231	CCX	325	3129	3272	
D* 02/02/01 19:19:55	3232	CCX	326	3130	3272	
D* 02/02/01 19:20:43	3233	CCX	327	3131	3272	
D* 02/02/01 19:22:00	3234	CCX	328	3132	3272	
D* 02/02/01 19:22:43	3235	CCX	329	3133	3272	
D* 02/02/01 19:23:26	3236	CCX	330	3134	3272	
D* 02/02/01 19:24:09	3237	CCX	331	3135	3272	
D* 02/02/01 19:24:53	3238	CCX	332	3136	3272	

D* 02/02/01 19:25:58	3239	CCX	333	3137	3272
D* 02/02/01 19:26:51	3240	CCX	334	3138	3272
D* 02/02/01 19:27:34	3241	CCX	335	3139	3272
D* 02/02/01 19:28:17	3242	CCX	336	3140	3272
D* 02/02/01 19:29:00	3243	CCX	337	3141	3272
D* 02/02/01 19:29:49	3244	CCX	338	3142	3272
D* 02/02/01 19:30:32	3245	CCX	339	3143	3272
D* 02/02/01 19:31:14	3246	CCX	340	3144	3272
D* 02/02/01 19:32:05	3247	CCX	341	3145	3272
D* 02/02/01 19:32:49	3248	CCX	342	3146	3272
D* 02/02/01 19:33:31	3249	CCX	343	3147	3272
D* 02/02/01 19:34:16	3250	CCX	344	3148	3272
D* 02/02/01 19:35:01	3251	CCX	345	3149	3272
D* 02/02/01 19:35:50	3252	CCX	346	3150	3272
D* 02/02/01 19:36:35	3253	CCX	347	3151	3272
D* 02/02/01 19:37:26	3254	CCX	348	3152	3272
D* 02/02/01 19:38:32	3255	CCX	349	3153	3272
D* 02/02/01 19:39:15	3256	CCX	350	3154	3272
D* 02/02/01 19:39:57	3257	CCX	351	3155	3272
D* 02/02/01 19:40:41	3258	CCX	352	3156	3272
D* 02/02/01 19:41:26	3259	CCX	353	3157	3272
D* 02/02/01 19:42:12	3260	CCX	354	3158	3272
D* 02/02/01 19:43:02	3261	CCX	355	3159	3272
D* 02/02/01 19:43:58	3262	CCX	356	3160	3272
D* 02/02/01 19:44:43	3263	CCX	357	3161	3272
D* 02/03/01 13:10:06	4404	CCX	358	4326	4404
D* 02/03/01 13:23:00	4403	CCX	359	4245	4404
D* 02/03/01 13:24:02	4402	CCX	360	4245	4404
D* 02/03/01 13:25:06	4401	CCX	361	4245	4404
D* 02/03/01 13:25:56	4400	CCX	362	4245	4404
D* 02/03/01 13:26:47	4399	CCX	363	4245	4404
D* 02/03/01 13:27:33	4398	CCX	364	4245	4404
D* 02/03/01 13:28:44	4397	CCX	365	4245	4404
D* 02/03/01 13:29:40	4396	CCX	366	4245	4404
D* 02/03/01 13:30:48	4395	CCX	367	4245	4404
D* 02/03/01 13:31:43	4394	CCX	368	4245	4404
D* 02/03/01 13:32:36	4393	CCX	369	4245	4404
D* 02/03/01 13:35:15	4392	CCX	370	4245	4404
D* 02/03/01 13:36:00	4391	CCX	371	4245	4404
D* 02/03/01 13:36:48	4390	CCX	372	4245	4404
D* 02/03/01 13:37:32	4389	CCX	373	4245	4404
D* 02/03/01 13:38:19	4388	CCX	374	4245	4404
D* 02/03/01 13:39:03	4387	CCX	375	4245	4404
D* 02/03/01 13:39:47	4386	CCX	376	4245	4404
D* 02/03/01 13:40:56	4385	CCX	377	4245	4404
D* 02/03/01 13:41:41	4384	CCX	378	4245	4404
D* 02/03/01 13:42:32	4383	CCX	379	4245	4404
D* 02/03/01 13:43:18	4382	CCX	380	4245	4404
D* 02/03/01 13:44:12	4381	CCX	381	4245	4404
D* 02/03/01 13:45:10	4380	CCX	382	4245	4404
D* 02/03/01 13:45:55	4379	CCX	383	4245	4404
D* 02/03/01 13:46:42	4378	CCX	384	4245	4404
D* 02/03/01 13:47:27	4377	CCX	385	4245	4404
D* 02/03/01 13:48:15	4376	CCX	386	4245	4404
D* 02/03/01 13:49:01	4375	CCX	387	4245	4404
D* 02/03/01 13:49:47	4374	CCX	388	4245	4404

D* 02/03/01 13:50:35	4373	CCX	389	4245	4404
D* 02/03/01 13:51:29	4372	CCX	390	4245	4404
D* 02/03/01 13:52:35	4371	CCX	391	4245	4404
D* 02/03/01 13:53:22	4370	CCX	392	4245	4404
D* 02/03/01 13:54:06	4369	CCX	393	4245	4404
D* 02/03/01 13:54:52	4368	CCX	394	4245	4404
D* 02/03/01 13:55:35	4367	CCX	395	4245	4404
D* 02/03/01 13:56:27	4366	CCX	396	4245	4404
D* 02/03/01 13:57:11	4365	CCX	397	4245	4404
D* 02/03/01 13:57:55	4364	CCX	398	4245	4404
D* 02/03/01 13:59:32	4363	CCX	399	4245	4404
D* 02/03/01 14:00:17	4362	CCX	400	4245	4404
D* 02/03/01 14:01:06	4361	CCX	401	4245	4404
D* 02/03/01 14:01:52	4360	CCX	402	4245	4404
D* 02/03/01 14:02:36	4359	CCX	403	4245	4404
D* 02/03/01 14:03:21	4358	CCX	404	4245	4404
D* 02/03/01 14:04:04	4357	CCX	405	4245	4404
D* 02/03/01 14:04:58	4356	CCX	406	4245	4404
D* 02/03/01 14:06:37	4355	CCX	407	4245	4404
D* 02/03/01 14:07:21	4354	CCX	408	4245	4404
D* 02/03/01 14:08:09	4353	CCX	409	4245	4404
D* 02/03/01 14:08:56	4352	CCX	410	4245	4404
D* 02/03/01 14:09:41	4351	CCX	411	4245	4404
D* 02/03/01 14:10:26	4350	CCX	412	4245	4404
D* 02/03/01 14:11:18	4349	CCX	413	4245	4404
D* 02/03/01 14:12:12	4348	CCX	414	4245	4404
D* 02/03/01 14:13:19	4347	CCX	415	4245	4404
D* 02/03/01 14:14:03	4346	CCX	416	4245	4404
D* 02/03/01 14:14:49	4345	CCX	417	4245	4404
D* 02/03/01 14:15:33	4344	CCX	418	4245	4404
D* 02/03/01 14:16:21	4343	CCX	419	4245	4404
D* 02/03/01 14:17:07	4342	CCX	420	4245	4404
D* 02/03/01 14:17:51	4341	CCX	421	4245	4404
D* 02/03/01 14:19:12	4340	CCX	422	4245	4404
D* 02/03/01 14:19:55	4339	CCX	423	4245	4404
D* 02/03/01 14:20:46	4338	CCX	424	4245	4404
D* 02/03/01 14:21:30	4337	CCX	425	4245	4404
D* 02/03/01 14:22:17	4336	CCX	426	4245	4404
D* 02/03/01 14:23:23	4335	CCX	427	4245	4404
D* 02/03/01 14:24:15	4334	CCX	428	4245	4404
D* 02/03/01 14:24:59	4333	CCX	429	4245	4404
D* 02/03/01 14:25:43	4332	CCX	430	4245	4404
D* 02/03/01 14:26:28	4331	CCX	431	4245	4404
D* 02/03/01 14:27:15	4330	CCX	432	4245	4404
D* 02/03/01 14:27:59	4329	CCX	433	4245	4404
D* 02/03/01 14:28:43	4328	CCX	434	4245	4404
D* 02/03/01 14:29:26	4327	CCX	435	4245	4404
D* 02/03/01 14:30:11	4326	CCX	436	4245	4404
D* 02/03/01 14:31:00	4325	CCX	437	4245	4404
D* 02/03/01 14:31:51	4324	CCX	438	4245	4404
D* 02/03/01 14:34:10	4323	CCX	439	4244	4403
D* 02/03/01 14:34:58	4322	CCX	440	4243	4402
D* 02/03/01 14:35:49	4321	CCX	441	4242	4401
D* 02/03/01 14:36:36	4320	CCX	442	4241	4400
D* 02/03/01 14:37:36	4319	CCX	443	4240	4399
D* 02/03/01 14:38:21	4318	CCX	444	4239	4398

D* 02/03/01 14:39:22	4317	CCX	445	4238	4397	
D* 02/03/01 14:40:14	4316	CCX	446	4237	4396	
D* 02/03/01 14:42:06	4315	CCX	447	4236	4395	
D* 02/03/01 14:42:58	4314	CCX	448	4235	4394	
D* 02/03/01 14:43:42	4313	CCX	449	4234	4393	
D* 02/03/01 14:44:31	4312	CCX	450	4233	4392	
D* 02/03/01 14:45:18	4311	CCX	451	4232	4391	
D* 02/03/01 14:46:02	4310	CCX	452	4231	4390	
D* 02/03/01 14:46:56	4309	CCX	453	4230	4389	
D* 02/03/01 14:47:39	4308	CCX	454	4229	4388	
D* 02/03/01 14:48:30	4307	CCX	455	4228	4387	
D* 02/03/01 14:49:18	4306	CCX	456	4227	4386	
D* 02/03/01 14:50:14	4305	CCX	457	4226	4385	
D* 02/03/01 14:51:16	4304	CCX	458	4225	4384	
D* 02/03/01 20:21:43	4303	CCX	2001	4224	4383	
D* 02/03/01 20:24:02	4302	CCX	2002	4223	4382	
D* 02/03/01 20:24:51	4301	CCX	2003	4222	4381	
D* 02/03/01 20:25:38	4300	CCX	2004	4221	4380	
D* 02/03/01 20:26:27	4299	CCX	2005	4220	4379	
D* 02/03/01 20:27:16	4298	CCX	2006	4219	4378	
D* 02/03/01 20:28:02	4297	CCX	2007	4218	4377	
D* 02/03/01 20:28:59	4296	CCX	2008	4217	4376	
D* 02/03/01 20:29:50	4295	CCX	2009	4216	4375	
D* 02/03/01 20:30:34	4294	CCX	2010	4215	4374	
D* 02/03/01 20:31:33	4293	CCX	2011	4214	4373	
D* 02/03/01 20:32:21	4292	CCX	2012	4213	4372	
D* 02/03/01 20:33:06	4291	CCX	2013	4212	4371	
D* 02/03/01 20:33:52	4290	CCX	2014	4211	4370	
D* 02/03/01 20:34:42	4289	CCX	2015	4210	4369	
D* 02/03/01 20:35:33	4288	CCX	2016	4209	4368	
D* 02/03/01 20:38:40	4287 (SKIPPED)					
D* 02/03/01 20:39:19	4286	CCX	2017	4207	4366	skip for creek
D* 02/03/01 20:40:04	4285	CCX	2018	4206	4365	
D* 02/03/01 20:40:49	4284	CCX	2019	4205	4364	
D* 02/03/01 20:41:34	4283	CCX	2020	4204	4363	
D* 02/03/01 20:42:22	4282	CCX	2021	4203	4362	
D* 02/03/01 20:43:07	4281	CCX	2022	4202	4361	
D* 02/03/01 20:43:52	4280	CCX	2023	4201	4360	
D* 02/03/01 20:44:41	4279	CCX	2024	4200	4359	
D* 02/03/01 20:46:03	4278	CCX	2025	4199	4358	
D* 02/03/01 20:46:49	4277	CCX	2026	4198	4357	
D* 02/03/01 20:48:05	4276	CCX	2027	4197	4356	
D* 02/03/01 20:48:57	4275	CCX	2028	4196	4355	
D* 02/03/01 20:49:42	4274	CCX	2029	4195	4354	
D* 02/03/01 20:50:28	4273	CCX	2030	4194	4353	
D* 02/03/01 20:51:42	4272	CCX	2031	4193	4352	
D* 02/03/01 20:52:26	4271	CCX	2032	4192	4351	
D* 02/03/01 20:53:16	4270	CCX	2033	4191	4350	
D* 02/03/01 20:54:03	4269	CCX	2034	4190	4349	
D* 02/03/01 20:54:48	4268	CCX	2035	4189	4348	
D* 02/03/01 20:55:32	4267	CCX	2036	4188	4347	
D* 02/03/01 20:56:26	4266	CCX	2037	4187	4346	
D* 02/23/01 07:26:37	4265	CCX	2038	4186	4345	
D* 02/23/01 07:29:08	4264	CCX	2039	4185	4344	
D* 02/23/01 07:29:52	4263	CCX	2040	4184	4343	
D* 02/23/01 07:30:37	4262	CCX	2041	4183	4342	

D* 02/23/01 07:31:21	4261	CCX	2042	4182	4341
D* 02/23/01 07:32:05	4260	CCX	2043	4181	4340
D* 02/23/01 07:32:55	4259	CCX	2044	4180	4339
D* 02/23/01 07:33:45	4258	CCX	2045	4179	4338
D* 02/23/01 07:34:29	4257	CCX	2046	4178	4337
D* 02/23/01 07:35:12	4256	CCX	2047	4177	4336
D* 02/23/01 07:36:02	4255	CCX	2048	4176	4335
D* 02/23/01 07:36:46	4254	CCX	2049	4175	4334
D* 02/23/01 07:37:31	4253	CCX	2050	4174	4333
D* 02/23/01 07:38:30	4252	CCX	2051	4173	4332
D* 02/23/01 07:39:13	4251	CCX	2052	4172	4331
D* 02/23/01 07:39:59	4250	CCX	2053	4171	4330
D* 02/23/01 07:40:43	4249	CCX	2054	4170	4329
D* 02/23/01 07:41:26	4248	CCX	2055	4169	4328
D* 02/23/01 07:42:11	4247	CCX	2056	4168	4327
D* 02/23/01 07:43:01	4246	CCX	2057	4167	4326
D* 02/23/01 07:43:54	4245	CCX	2058	4166	4325
D* 02/23/01 07:44:59	4244	CCX	2059	4165	4324
D* 02/23/01 07:45:43	4243	CCX	2060	4164	4323
D* 02/23/01 07:46:28	4242	CCX	2061	4163	4322
D* 02/23/01 07:47:12	4241	CCX	2062	4162	4321
D* 02/23/01 07:47:55	4240	CCX	2063	4161	4320
D* 02/23/01 07:50:36	4239	CCX	2064	4160	4319
D* 02/23/01 07:51:20	4238	CCX	2065	4159	4318
D* 02/23/01 07:52:04	4237	CCX	2066	4158	4317
D* 02/23/01 07:52:47	4236	CCX	2067	4157	4316
D* 02/23/01 07:53:32	4235	CCX	2068	4156	4315
D* 02/23/01 07:54:22	4234	CCX	2069	4155	4314
D* 02/23/01 07:55:09	4233	CCX	2070	4154	4313
D* 02/23/01 07:57:08	4232	CCX	2071	4153	4312
D* 02/23/01 07:58:51	4231	CCX	2072	4152	4311
D* 02/23/01 07:59:44	4230	CCX	2073	4151	4310
D* 02/23/01 08:00:37	4229	CCX	2074	4150	4309
D* 02/23/01 08:01:31	4228	CCX	2075	4149	4308
D* 02/23/01 08:02:28	4227	CCX	2076	4148	4307
D* 02/23/01 08:03:12	4226	CCX	2077	4147	4306
D* 02/23/01 08:04:04	4225	CCX	2078	4146	4305
D* 02/23/01 08:04:50	4224	CCX	2079	4145	4304
D* 02/23/01 08:05:39	4223	CCX	2080	4144	4303
D* 02/23/01 08:06:46	4222	CCX	2081	4143	4302
D* 02/23/01 08:07:54	4221	CCX	2082	4142	4301
D* 02/23/01 08:08:49	4220	CCX	2083	4141	4300
D* 02/23/01 08:09:45	4219	CCX	2084	4140	4299
D* 02/23/01 08:10:29	4218	CCX	2085	4139	4298
D* 02/23/01 08:11:12	4217	CCX	2086	4138	4297
D* 02/23/01 08:12:00	4216	CCX	2087	4137	4296
D* 02/23/01 08:12:46	4215	CCX	2088	4136	4295
D* 02/23/01 08:13:32	4214	CCX	2089	4135	4294
D* 02/23/01 08:14:20	4213	CCX	2090	4134	4293
D* 02/23/01 08:15:05	4212	CCX	2091	4133	4292
D* 02/23/01 08:15:54	4211	CCX	2092	4132	4291
D* 02/23/01 08:16:45	4210	CCX	2093	4131	4290
D* 02/23/01 08:17:31	4209	CCX	2094	4130	4289
D* 02/23/01 08:18:18	4208	CCX	2095	4129	4288
D* 02/23/01 08:19:02	4207	CCX	2096	4128	4287
D* 02/23/01 08:19:47	4206	CCX	2097	4127	4286

D* 02/23/01 08:20:35	4205	CCX	2098	4126	4285
D* 02/23/01 08:21:25	4204	CCX	2099	4125	4284
D* 02/23/01 08:22:09	4203	CCX	2100	4124	4283
D* 02/23/01 08:22:52	4202	CCX	2101	4123	4282
D* 02/23/01 08:23:37	4201	CCX	2102	4122	4281
D* 02/23/01 08:25:12	4200	CCX	2103	4121	4280
D* 02/23/01 08:26:08	4199	CCX	2104	4120	4279
D* 02/23/01 08:26:52	4198	CCX	2105	4119	4278
D* 02/23/01 08:27:36	4197	CCX	2106	4118	4277
D* 02/23/01 08:28:21	4196	CCX	2107	4117	4276
D* 02/23/01 08:29:08	4195	CCX	2108	4116	4275
D* 02/23/01 08:29:56	4194	CCX	2109	4115	4274
D* 02/23/01 08:30:42	4193	CCX	2110	4114	4273
D* 02/23/01 08:31:42	4192	CCX	2111	4113	4272
D* 02/23/01 08:32:29	4191	CCX	2112	4112	4271
D* 02/23/01 08:33:14	4190	CCX	2113	4111	4270
D* 02/23/01 08:34:02	4189	CCX	2114	4110	4269
D* 02/23/01 08:34:56	4188	CCX	2115	4109	4268
D* 02/23/01 08:35:58	4187	CCX	2116	4108	4267
D* 02/23/01 08:37:03	4186	CCX	2117	4107	4266
D* 02/23/01 08:38:08	4185	CCX	2118	4106	4265
D* 02/23/01 08:38:57	4184	CCX	2119	4105	4264
D* 02/23/01 08:39:44	4183	CCX	2120	4104	4263
D* 02/23/01 08:40:27	4182	CCX	2121	4103	4262
D* 02/23/01 08:41:19	4181	CCX	2122	4102	4261
D* 02/23/01 08:42:04	4180	CCX	2123	4101	4260
D* 02/23/01 08:43:03	4179	CCX	2124	4100	4259
D* 02/23/01 08:43:54	4178	CCX	2125	4099	4258
D* 02/23/01 08:44:43	4177	CCX	2126	4098	4257
D* 02/23/01 08:45:29	4176	CCX	2127	4097	4256
D* 02/23/01 08:46:14	4175	CCX	2128	4096	4255
D* 02/23/01 08:46:58	4174	CCX	2129	4095	4254
D* 02/23/01 08:47:51	4173	CCX	2130	4094	4253
D* 02/23/01 08:48:35	4172	CCX	2131	4093	4252
D* 02/23/01 08:49:18	4171	CCX	2132	4092	4251
D* 02/23/01 08:50:06	4170	CCX	2133	4091	4250
D* 02/23/01 08:51:04	4169	CCX	2134	4090	4249
D* 02/23/01 08:51:47	4168	CCX	2135	4089	4248
D* 02/23/01 08:52:41	4167	CCX	2136	4088	4247
D* 02/23/01 08:53:25	4166	CCX	2137	4087	4246
D* 02/23/01 08:54:29	4165	CCX	2138	4086	4245
D* 02/23/01 08:55:16	4164	CCX	2139	4085	4244
D* 02/23/01 08:56:01	4163	CCX	2140	4084	4243
D* 02/23/01 08:56:45	4162	CCX	2141	4083	4242
D* 02/23/01 08:57:34	4161	CCX	2142	4082	4241
D* 02/23/01 08:58:21	4160	CCX	2143	4081	4240
D* 02/23/01 08:59:10	4159	CCX	2144	4080	4239
D* 02/23/01 08:59:54	4158	CCX	2145	4079	4238
D* 02/23/01 09:00:48	4157	CCX	2146	4078	4237
D* 02/23/01 09:01:35	4156	CCX	2147	4077	4236
D* 02/23/01 09:02:31	4155	CCX	2148	4076	4235
D* 02/23/01 09:03:18	4154	CCX	2149	4075	4234
D* 02/23/01 09:04:06	4153	CCX	2150	4074	4233
D* 02/23/01 09:04:53	4152	CCX	2151	4073	4232
D* 02/23/01 09:05:37	4151	CCX	2152	4072	4231
D* 02/23/01 09:07:09	4150	CCX	2153	4071	4230

D* 02/23/01 09:07:56	4149	CCX	2154	4070	4229
D* 02/23/01 09:08:49	4148	CCX	2155	4069	4228
D* 02/23/01 09:09:34	4147	CCX	2156	4068	4227
D* 02/23/01 09:10:18	4146	CCX	2157	4067	4226
D* 02/23/01 09:11:02	4145	CCX	2158	4066	4225
D* 02/23/01 09:11:46	4144	CCX	2159	4065	4224
D* 02/23/01 09:12:44	4143	CCX	2160	4064	4223
D* 02/23/01 09:13:30	4142	CCX	2161	4063	4222
D* 02/23/01 09:14:50	4141	CCX	2162	4062	4221
D* 02/23/01 09:15:40	4140	CCX	2163	4061	4220
D* 02/23/01 09:16:29	4139	CCX	2164	4060	4219
D* 02/23/01 09:17:13	4138	CCX	2165	4059	4218
D* 02/23/01 09:17:56	4137	CCX	2166	4058	4217
D* 02/23/01 09:18:41	4136	CCX	2167	4057	4216
D* 02/23/01 09:19:29	4135	CCX	2168	4056	4215
D* 02/23/01 09:20:18	4134	CCX	2169	4055	4214
D* 02/23/01 09:21:02	4133	CCX	2170	4054	4213
D* 02/23/01 09:21:46	4132	CCX	2171	4053	4212
D* 02/23/01 09:22:31	4131	CCX	2172	4052	4211
D* 02/23/01 09:23:15	4130	CCX	2173	4051	4210
D* 02/23/01 09:23:59	4129	CCX	2174	4050	4209
D* 02/23/01 09:24:43	4128	CCX	2175	4049	4208
D* 02/23/01 09:25:26	4127	CCX	2176	4048	4207
D* 02/23/01 09:26:11	4126	CCX	2177	4047	4206
D* 02/23/01 09:26:55	4125	CCX	2178	4046	4205
D* 02/23/01 09:28:00	4124	CCX	2179	4045	4204
D* 02/23/01 09:28:43	4123	CCX	2180	4044	4203
D* 02/23/01 09:29:28	4122	CCX	2181	4043	4202
D* 02/23/01 09:30:12	4121	CCX	2182	4042	4201
D* 02/23/01 09:30:58	4120	CCX	2183	4041	4200
D* 02/23/01 09:31:48	4119	CCX	2184	4040	4199
D* 02/23/01 09:32:32	4118	CCX	2185	4039	4198
D* 02/23/01 09:33:19	4117	CCX	2186	4038	4197
D* 02/23/01 09:34:02	4116	CCX	2187	4037	4196
D* 02/23/01 09:34:52	4115	CCX	2188	4036	4195
D* 02/23/01 09:35:40	4114	CCX	2189	4035	4194
D* 02/23/01 09:36:30	4113	CCX	2190	4034	4193
D* 02/23/01 09:37:15	4112	CCX	2191	4033	4192
D* 02/23/01 09:38:00	4111	CCX	2192	4032	4191
D* 02/23/01 09:38:47	4110	CCX	2193	4031	4190
D* 02/23/01 09:39:37	4109	CCX	2194	4030	4189
D* 02/23/01 09:40:21	4108	CCX	2195	4029	4188
D* 02/23/01 09:41:51	4107	CCX	2196	4028	4187
D* 02/23/01 09:42:36	4106	CCX	2197	4027	4186
D* 02/23/01 09:43:30	4105	CCX	2198	4026	4185
D* 02/23/01 09:44:14	4104	CCX	2199	4025	4184
D* 02/23/01 09:44:58	4103	CCX	2200	4024	4183
D* 02/23/01 09:45:42	4102	CCX	2201	4023	4182
D* 02/23/01 09:46:26	4101	CCX	2202	4022	4181
D* 02/23/01 09:47:12	4100	CCX	2203	4021	4180
D* 02/23/01 09:47:56	4099	CCX	2204	4020	4179
D* 02/23/01 09:48:40	4098	CCX	2205	4019	4178
D* 02/23/01 09:49:24	4097	CCX	2206	4018	4177
D* 02/23/01 09:50:10	4096	CCX	2207	4017	4176
D* 02/23/01 09:51:03	4095	CCX	2208	4016	4175
D* 02/23/01 09:51:51	4094	CCX	2209	4015	4174

D* 02/23/01 09:52:50	4093	CCX	2210	4014	4173
D* 02/23/01 09:53:35	4092	CCX	2211	4013	4172
D* 02/23/01 09:54:31	4091	CCX	2212	4012	4171
D* 02/23/01 09:55:20	4090	CCX	2213	4011	4170
D* 02/23/01 09:56:04	4089	CCX	2214	4010	4169
D* 02/23/01 09:58:10	4088	CCX	2215	4009	4168
D* 02/23/01 09:58:55	4087	CCX	2216	4008	4167
D* 02/23/01 09:59:48	4086	CCX	2217	4007	4166
D* 02/23/01 10:00:50	4085	CCX	2218	4006	4165
D* 02/23/01 10:01:38	4084	CCX	2219	4005	4164
D* 02/23/01 10:02:28	4083	CCX	2220	4004	4163
D* 02/23/01 10:03:13	4082	CCX	2221	4003	4162
D* 02/23/01 10:04:00	4081	CCX	2222	4002	4161
D* 02/23/01 10:04:50	4080	CCX	2223	4001	4160
D* 02/23/01 10:05:37	4079	CCX	2224	4001	4159
D* 02/23/01 10:06:21	4078	CCX	2225	4001	4158
D* 02/23/01 10:07:05	4077	CCX	2226	4001	4157
D* 02/23/01 10:08:00	4076	CCX	2227	4001	4156
D* 02/23/01 10:08:44	4075	CCX	2228	4001	4155
D* 02/23/01 10:09:32	4074	CCX	2229	4001	4154
D* 02/23/01 10:10:39	4073	CCX	2230	4001	4153
D* 02/23/01 10:11:23	4072	CCX	2231	4001	4152
D* 02/23/01 10:12:08	4071	CCX	2232	4001	4151
D* 02/23/01 10:13:03	4070	CCX	2233	4001	4150
D* 02/23/01 10:13:47	4069	CCX	2234	4001	4149
D* 02/23/01 10:14:40	4068	CCX	2235	4001	4148
D* 02/23/01 10:15:24	4067	CCX	2236	4001	4147
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D* 02/23/01 10:16:57	4065	CCX	2238	4001	4145
D* 02/23/01 10:17:41	4064	CCX	2239	4001	4144
D* 02/23/01 10:18:26	4063	CCX	2240	4001	4143
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D* 02/23/01 10:22:19	4059	CCX	2244	4001	4139
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D* 02/23/01 10:24:55	4057	CCX	2246	4001	4137
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D* 02/23/01 10:26:24	4055	CCX	2248	4001	4135
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D* 02/23/01 10:28:38	4052	CCX	2251	4001	4132
D* 02/23/01 10:29:23	4051	CCX	2252	4001	4131
D* 02/23/01 10:30:09	4050	CCX	2253	4001	4130
D* 02/23/01 10:30:55	4049	CCX	2254	4001	4129
D* 02/23/01 10:31:37	4048	CCX	2255	4001	4128
D* 02/23/01 10:32:22	4047	CCX	2256	4001	4127
D* 02/23/01 10:33:04	4046	CCX	2257	4001	4126
D* 02/23/01 10:33:47	4045	CCX	2258	4001	4125
D* 02/23/01 10:42:56	4049	CCX	2254	4001	4129
D* 02/23/01 10:46:56	4049	CCX	2254	4001	4129
D* 02/23/01 10:48:12	4048	CCX	2255	4001	4128
D* 02/23/01 10:48:58	4047	CCX	2256	4001	4127
D* 02/23/01 10:49:39	4046	CCX	2257	4001	4126
D* 02/23/01 10:50:23	4045	CCX	2258	4001	4125
D* 02/23/01 10:51:05	4044	CCX	2259	4001	4124

D* 02/23/01 10:51:54	4043	CCX	2260	4001	4123
D* 02/23/01 10:52:41	4042	CCX	2261	4001	4122
D* 02/23/01 10:53:29	4041	CCX	2262	4001	4121
D* 02/23/01 10:54:13	4040	CCX	2263	4001	4120
D* 02/23/01 10:54:57	4039	CCX	2264	4001	4119
D* 02/23/01 10:55:39	4038	CCX	2265	4001	4118
D* 02/23/01 10:56:23	4037	CCX	2266	4001	4117
D* 02/23/01 10:57:30	4036	CCX	2267	4001	4116
D* 02/23/01 10:58:20	4035	CCX	2268	4001	4115
D* 02/23/01 10:59:37	4034	CCX	2269	4001	4114
D* 02/23/01 11:00:26	4033	CCX	2270	4001	4113
D* 02/23/01 11:01:13	4032	CCX	2271	4001	4112
D* 02/23/01 11:01:59	4031	CCX	2272	4001	4111
D* 02/23/01 11:02:48	4030	CCX	2273	4001	4110
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D* 02/23/01 11:04:29	4028	CCX	2275	4001	4108
D* 02/23/01 11:05:10	4027	CCX	2276	4001	4107
D* 02/23/01 11:05:59	4026	CCX	2277	4001	4106
D* 02/23/01 11:06:42	4025	CCX	2278	4001	4105
D* 02/23/01 11:07:25	4024	CCX	2279	4001	4104
D* 02/23/01 11:08:08	4023	CCX	2280	4001	4103
D* 02/23/01 11:08:52	4022	CCX	2281	4001	4102
D* 02/23/01 11:09:36	4021	CCX	2282	4001	4101
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D* 02/23/01 11:11:03	4019	CCX	2284	4001	4099
D* 02/23/01 11:11:54	4018	CCX	2285	4001	4098
D* 02/23/01 11:12:36	4017	CCX	2286	4001	4097
D* 02/23/01 11:14:56	4016	CCX	2287	4001	4096
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D* 02/23/01 11:17:36	4013	CCX	2290	4001	4093
D* 02/23/01 11:18:18	4012	CCX	2291	4001	4092
D* 02/23/01 11:18:58	4011	CCX	2292	4001	4091
D* 02/23/01 11:19:42	4010	CCX	2293	4001	4090
D* 02/23/01 11:20:23	4009	CCX	2294	4001	4089
D* 02/23/01 11:21:06	4008	CCX	2295	4001	4088
D* 02/23/01 11:21:48	4007	CCX	2296	4001	4087
D* 02/23/01 11:22:31	4006	CCX	2297	4001	4086
D* 02/23/01 11:23:17	4005	CCX	2298	4001	4085
D* 02/23/01 11:23:58	4004	CCX	2299	4001	4084
D* 02/23/01 11:24:41	4003	CCX	2300	4001	4083
D* 02/23/01 11:25:23	4002	CCX	2301	4001	4082
D* 02/23/01 11:26:06	4001	CCX	2302	4001	4081
D* 02/23/01 12:27:30	5001	CCX	2303	5001	5080
D* 02/23/01 12:30:17	5002	CCX	2304	5001	5081
D* 02/23/01 12:31:23	5003	CCX	2305	5001	5082
D* 02/23/01 12:32:08	5004	CCX	2306	5001	5083
D* 02/23/01 12:32:54	5005	CCX	2307	5001	5084
D* 02/23/01 12:33:40	5006	CCX	2308	5001	5085
D* 02/23/01 12:34:31	5007	CCX	2309	5001	5086
D* 02/23/01 12:35:16	5008	CCX	2310	5001	5087
D* 02/23/01 12:36:04	5009	CCX	2311	5001	5088
D* 02/23/01 12:36:54	5010	CCX	2312	5001	5089
D* 02/23/01 12:37:39	5011	CCX	2313	5001	5090
D* 02/23/01 12:38:25	5012	CCX	2314	5001	5091
D* 02/23/01 12:39:16	5013	CCX	2315	5001	5092

D* 02/23/01 12:40:00	5014	CCX	2316	5001	5093
D* 02/23/01 12:40:47	5015	CCX	2317	5001	5094
D* 02/23/01 12:41:30	5016	CCX	2318	5001	5095
D* 02/23/01 12:42:14	5017	CCX	2319	5001	5096
D* 02/23/01 12:42:58	5018	CCX	2320	5001	5097
D* 02/23/01 12:43:45	5019	CCX	2321	5001	5098
D* 02/23/01 12:44:32	5020	CCX	2322	5001	5099
D* 02/23/01 12:46:09	5021	CCX	2323	5001	5100
D* 02/23/01 12:47:06	5022	CCX	2324	5001	5101
D* 02/23/01 12:47:53	5023	CCX	2325	5001	5102
D* 02/23/01 12:48:59	5024	CCX	2326	5001	5103
D* 02/23/01 12:49:48	5025	CCX	2327	5001	5104
D* 02/23/01 12:50:34	5026	CCX	2328	5001	5105
D* 02/23/01 12:51:19	5027	CCX	2329	5001	5106
D* 02/23/01 12:52:08	5028	CCX	2330	5001	5107
D* 02/23/01 12:52:56	5029	CCX	2331	5001	5108
D* 02/23/01 12:54:02	5030	CCX	2332	5001	5109
D* 02/23/01 12:54:55	5031	CCX	2333	5001	5110
D* 02/23/01 12:55:40	5032	CCX	2334	5001	5111
D* 02/23/01 12:56:23	5033	CCX	2335	5001	5112
D* 02/23/01 12:57:07	5034	CCX	2336	5001	5113
D* 02/23/01 12:57:50	5035	CCX	2337	5001	5114
D* 02/23/01 12:58:53	5036	CCX	2338	5001	5115
D* 02/23/01 13:01:58	5037	CCX	2339	5001	5116
D* 02/23/01 13:02:41	5038	CCX	2340	5001	5117
D* 02/23/01 13:03:29	5039	CCX	2341	5001	5118
D* 02/23/01 13:04:20	5040	CCX	2342	5001	5119
D* 02/23/01 13:05:10	5041	CCX	2343	5001	5120
D* 02/23/01 13:05:54	5042	CCX	2344	5001	5121
D* 02/23/01 13:06:37	5043	CCX	2345	5001	5122
D* 02/23/01 13:07:20	5044	CCX	2346	5001	5123
D* 02/23/01 13:08:03	5045	CCX	2347	5001	5124
D* 02/23/01 13:08:47	5046	CCX	2348	5001	5125
D* 02/23/01 13:09:31	5047	CCX	2349	5001	5126
D* 02/23/01 13:10:15	5048	CCX	2350	5001	5127
D* 02/23/01 13:10:58	5049	CCX	2351	5001	5128
D* 02/23/01 13:11:46	5050	CCX	2352	5001	5129
D* 02/23/01 13:12:33	5051	CCX	2353	5001	5130
D* 02/23/01 13:13:55	5052	CCX	2354	5001	5131
D* 02/23/01 13:14:37	5053	CCX	2355	5001	5132
D* 02/23/01 13:15:44	5054	CCX	2356	5001	5133
D* 02/23/01 13:16:56	5055	CCX	2357	5001	5134
D* 02/23/01 13:17:50	5056	CCX	2358	5001	5135
D* 02/23/01 13:18:33	5057	CCX	2359	5001	5136
D* 02/23/01 13:19:16	5058	CCX	2360	5001	5137
D* 02/23/01 13:20:01	5059	CCX	2361	5001	5138
D* 02/23/01 13:20:46	5060	CCX	2362	5001	5139
D* 02/23/01 13:21:35	5061	CCX	2363	5001	5140
D* 02/23/01 13:22:30	5062	CCX	2364	5001	5141
D* 02/23/01 13:23:18	5063	CCX	2365	5001	5142
D* 02/23/01 13:24:12	5064	CCX	2366	5001	5143
D* 02/23/01 13:25:03	5065	CCX	2367	5001	5144
D* 02/23/01 13:25:48	5066	CCX	2368	5001	5145
D* 02/23/01 13:26:35	5067	CCX	2369	5001	5146
D* 02/23/01 13:27:19	5068	CCX	2370	5001	5147
D* 02/23/01 13:28:02	5069	CCX	2371	5001	5148

D* 02/23/01 13:28:54	5070	CCX	2372	5001	5149
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D* 02/23/01 13:30:24	5072	CCX	2374	5001	5151
D* 02/23/01 13:33:38	5073	CCX	2375	5001	5152
D* 02/23/01 13:34:21	5074	CCX	2376	5001	5153
D* 02/23/01 13:35:09	5075	CCX	2377	5001	5154
D* 02/23/01 13:35:55	5076	CCX	2378	5001	5155
D* 02/23/01 13:36:45	5077	CCX	2379	5001	5156
D* 02/23/01 13:37:30	5078	CCX	2380	5001	5157
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D* 02/23/01 13:42:13	5084	CCX	2386	5004	5163
D* 02/23/01 13:42:57	5085	CCX	2387	5005	5164
D* 02/23/01 13:43:44	5086	CCX	2388	5006	5165
D* 02/23/01 13:44:28	5087	CCX	2389	5007	5166
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D* 02/23/01 13:46:45	5090	CCX	2392	5010	5169
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D* 02/23/01 13:49:53	5094	CCX	2396	5014	5173
D* 02/23/01 13:50:37	5095	CCX	2397	5015	5174
D* 02/23/01 13:51:20	5096	CCX	2398	5016	5175
D* 02/23/01 13:52:06	5097	CCX	2399	5017	5176
D* 02/23/01 13:52:52	5098	CCX	2400	5018	5177
D* 02/23/01 13:53:38	5099	CCX	2401	5019	5178
D* 02/23/01 13:54:30	5100	CCX	2402	5020	5179
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D* 02/23/01 13:56:00	5102	CCX	2404	5022	5181
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D* 02/23/01 13:57:30	5104	CCX	2406	5024	5183
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D* 02/23/01 14:04:42	5112	CCX	2414	5032	5191
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D* 02/23/01 14:12:52	5122	CCX	2424	5042	5201
D* 02/23/01 14:13:36	5123	CCX	2425	5043	5202
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D* 02/23/01 14:18:24	5128	CCX	2430	5048	5207
D* 02/23/01 14:19:09	5129	CCX	2431	5049	5208
D* 02/23/01 14:19:55	5130	CCX	2432	5050	5209
D* 02/23/01 14:20:39	5131	CCX	2433	5051	5210
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D* 02/23/01 14:24:03	5134	CCX	2436	5054	5213
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D* 02/23/01 14:29:57	5140	CCX	2442	5060	5219
D* 02/23/01 14:30:48	5141	CCX	2443	5061	5220
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D* 02/23/01 14:39:43	5144	CCX	2446	5064	5223
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D* 02/23/01 14:42:21	5146	CCX	2448	5066	5225
D* 02/23/01 14:43:09	5147	CCX	2449	5067	5226
D* 02/23/01 14:44:02	5148	CCX	2450	5068	5227
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D* 02/23/01 14:45:40	5150	CCX	2452	5070	5229
D* 02/23/01 14:46:24	5151	CCX	2453	5071	5230
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D* 02/23/01 14:48:45	5154	CCX	2456	5074	5233
D* 02/24/01 07:15:25	5155	CCX	2457	5075	5234
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D* 02/24/01 07:18:22	5157	CCX	2459	5077	5236
D* 02/24/01 07:19:09	5158	CCX	2460	5078	5237
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D* 02/24/01 07:20:38	5160	CCX	2462	5080	5239
D* 02/24/01 07:21:26	5161	CCX	2463	5081	5240
D* 02/24/01 07:22:13	5162	CCX	2464	5082	5241
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D* 02/24/01 07:23:47	5164	CCX	2466	5084	5243
D* 02/24/01 07:24:31	5165	CCX	2467	5085	5244
D* 02/24/01 07:25:16	5166	CCX	2468	5086	5245
D* 02/24/01 07:26:02	5167	CCX	2469	5087	5246
D* 02/24/01 07:26:46	5168	CCX	2470	5088	5247
D* 02/24/01 07:27:30	5169	CCX	2471	5089	5248
D* 02/24/01 07:28:19	5170	CCX	2472	5090	5249
D* 02/24/01 07:29:07	5171	CCX	2473	5091	5250
D* 02/24/01 07:29:52	5172	CCX	2474	5092	5251
D* 02/24/01 07:30:36	5173	CCX	2475	5093	5252
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D* 02/24/01 07:32:14	5175	CCX	2477	5095	5254
D* 02/24/01 07:32:59	5176	CCX	2478	5096	5255
D* 02/24/01 07:33:43	5177	CCX	2479	5097	5256
D* 02/24/01 07:34:28	5178	CCX	2480	5098	5257
D* 02/24/01 07:35:14	5179	CCX	2481	5099	5258
D* 02/24/01 07:35:58	5180	CCX	2482	5100	5259
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D* 02/24/01 07:37:27	5182	CCX	2484	5102	5261
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D* 02/24/01 07:38:59	5184	CCX	2486	5104	5263
D* 02/24/01 07:39:48	5185	CCX	2487	5105	5264
D* 02/24/01 07:40:33	5186	CCX	2488	5106	5265
D* 02/24/01 07:41:23	5187	CCX	2489	5107	5266
D* 02/24/01 07:42:07	5188	CCX	2490	5108	5267
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D* 02/24/01 07:43:42	5190	CCX	2492	5110	5269
D* 02/24/01 07:44:27	5191	CCX	2493	5111	5270
D* 02/24/01 07:45:16	5192	CCX	2494	5112	5271
D* 02/24/01 07:46:02	5193	CCX	2495	5113	5272
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D* 02/24/01 07:48:28	5196	CCX	2498	5116	5275
D* 02/24/01 07:50:12	5197	CCX	2499	5117	5276
D* 02/24/01 07:50:58	5198	CCX	2500	5118	5277
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D* 02/24/01 07:52:38	5200	CCX	2502	5120	5279
D* 02/24/01 07:53:24	5201	CCX	2503	5121	5280
D* 02/24/01 07:54:09	5202	CCX	2504	5122	5281
D* 02/24/01 07:54:59	5203	CCX	2505	5123	5282
D* 02/24/01 07:55:46	5204	CCX	2506	5124	5283
D* 02/24/01 07:56:32	5205	CCX	2507	5125	5284
D* 02/24/01 07:57:19	5206	CCX	2508	5126	5285
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D* 02/24/01 08:03:43	5212	CCX	2514	5132	5291
D* 02/24/01 08:04:28	5213	CCX	2515	5133	5292
D* 02/24/01 08:05:18	5214	CCX	2516	5134	5293
D* 02/24/01 08:06:03	5215	CCX	2517	5135	5294
D* 02/24/01 08:06:48	5216	CCX	2518	5136	5295
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D* 02/24/01 08:08:17	5218	CCX	2520	5138	5297
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D* 02/24/01 08:12:47	5223	CCX	2525	5143	5302
D* 02/24/01 08:13:31	5224	CCX	2526	5144	5303
D* 02/24/01 08:14:35	5225	CCX	2527	5145	5304
D* 02/24/01 08:15:19	5226	CCX	2528	5146	5305
D* 02/24/01 08:16:02	5227	CCX	2529	5147	5306
D* 02/24/01 08:16:47	5228	CCX	2530	5148	5307
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D* 02/24/01 08:18:24	5230	CCX	2532	5150	5309
D* 02/24/01 08:19:27	5231	CCX	2533	5151	5310
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D* 02/24/01 08:21:04	5233	CCX	2535	5153	5312
D* 02/24/01 08:21:48	5234	CCX	2536	5154	5313
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D* 02/24/01 08:23:31	5236	CCX	2538	5156	5315
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D* 02/24/01 08:26:38	5240	CCX	2542	5160	5319
D* 02/24/01 08:27:25	5241	CCX	2543	5161	5320
D* 02/24/01 08:28:09	5242	CCX	2544	5162	5321
D* 02/24/01 08:29:02	5243	CCX	2545	5163	5322
D* 02/24/01 08:30:12	5244	CCX	2546	5164	5323
D* 02/24/01 08:31:02	5245	CCX	2547	5165	5324
D* 02/24/01 08:31:47	5246	CCX	2548	5166	5325
D* 02/24/01 08:32:31	5247	CCX	2549	5167	5326
D* 02/24/01 08:33:16	5248	CCX	2550	5168	5327
D* 02/24/01 08:34:00	5249	CCX	2551	5169	5328
D* 02/24/01 08:34:53	5250	CCX	2552	5170	5329
D* 02/24/01 08:35:37	5251	CCX	2553	5171	5330
D* 02/24/01 08:37:01	5252	CCX	2554	5172	5331
D* 02/24/01 08:37:47	5253	CCX	2555	5173	5332
D* 02/24/01 08:38:32	5254	CCX	2556	5174	5333
D* 02/24/01 08:39:16	5255	CCX	2557	5175	5334
D* 02/24/01 08:40:00	5256	CCX	2558	5176	5335
D* 02/24/01 08:40:45	5257	CCX	2559	5177	5336
D* 02/24/01 08:41:29	5258	CCX	2560	5178	5337
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D* 02/24/01 08:42:59	5260	CCX	2562	5180	5339
D* 02/24/01 08:43:52	5261	CCX	2563	5181	5340
D* 02/24/01 08:44:38	5262	CCX	2564	5182	5341
D* 02/24/01 08:45:22	5263	CCX	2565	5183	5342
D* 02/24/01 08:46:06	5264	CCX	2566	5184	5343
D* 02/24/01 08:46:50	5265	CCX	2567	5185	5344
D* 02/24/01 08:47:41	5266	CCX	2568	5186	5345
D* 02/24/01 08:48:34	5267	CCX	2569	5187	5346
D* 02/24/01 08:49:29	5268	CCX	2570	5188	5347
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D* 02/24/01 08:51:02	5270	CCX	2572	5190	5349
D* 02/24/01 08:51:47	5271	CCX	2573	5191	5350
D* 02/24/01 08:52:32	5272	CCX	2574	5192	5351
D* 02/24/01 08:53:16	5273	CCX	2575	5193	5352
D* 02/24/01 08:55:08	5274	CCX	2576	5194	5353
D* 02/24/01 08:56:10	5275	CCX	2577	5195	5354
D* 02/24/01 08:57:30	5276	CCX	2578	5196	5355
D* 02/24/01 08:58:19	5277	CCX	2579	5197	5356
D* 02/24/01 08:59:05	5278	CCX	2580	5198	5357
D* 02/24/01 08:59:49	5279	CCX	2581	5199	5358
D* 02/24/01 09:00:34	5280	CCX	2582	5200	5359
D* 02/24/01 09:01:19	5281	CCX	2583	5201	5360
D* 02/24/01 09:02:03	5282	CCX	2584	5202	5361
D* 02/24/01 09:02:52	5283	CCX	2585	5203	5362
D* 02/24/01 09:03:40	5284	CCX	2586	5204	5363
D* 02/24/01 09:04:29	5285	CCX	2587	5205	5364
D* 02/24/01 09:05:18	5286	CCX	2588	5206	5365
D* 02/24/01 09:06:03	5287	CCX	2589	5207	5366
D* 02/24/01 09:06:49	5288	CCX	2590	5208	5367
D* 02/24/01 09:07:36	5289	CCX	2591	5209	5368
D* 02/24/01 09:08:30	5290	CCX	2592	5210	5369
D* 02/24/01 09:09:14	5291	CCX	2593	5211	5370
D* 02/24/01 09:09:59	5292	CCX	2594	5212	5371
D* 02/24/01 09:10:48	5293	CCX	2595	5213	5372

D* 02/24/01 09:11:34	5294	CCX	2596	5214	5373
D* 02/24/01 09:12:21	5295	CCX	2597	5215	5374
D* 02/24/01 09:13:05	5296	CCX	2598	5216	5375
D* 02/24/01 09:13:49	5297	CCX	2599	5217	5376
D* 02/24/01 09:14:34	5298	CCX	2600	5218	5377
D* 02/24/01 09:15:18	5299	CCX	2601	5219	5378
D* 02/24/01 09:16:06	5300	CCX	2602	5220	5378
D* 02/24/01 09:16:51	5301	CCX	2603	5221	5378
D* 02/24/01 09:17:36	5302	CCX	2604	5222	5378
D* 02/24/01 09:18:19	5303	CCX	2605	5223	5378
D* 02/24/01 09:19:03	5304	CCX	2606	5224	5378
D* 02/24/01 09:19:48	5305	CCX	2607	5225	5378
D* 02/24/01 09:20:32	5306	CCX	2608	5226	5378
D* 02/24/01 09:21:19	5307	CCX	2609	5227	5378
D* 02/24/01 09:22:03	5308	CCX	2610	5228	5378
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D* 02/24/01 09:23:33	5310	CCX	2612	5230	5378
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D* 02/24/01 09:26:28	5313	CCX	2615	5233	5378
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D* 02/24/01 09:28:41	5316	CCX	2618	5236	5378
D* 02/24/01 09:29:35	5317	CCX	2619	5237	5378
D* 02/24/01 09:30:20	5318	CCX	2620	5238	5378
D* 02/24/01 09:31:07	5319	CCX	2621	5239	5378
D* 02/24/01 09:31:52	5320	CCX	2622	5240	5378
D* 02/24/01 09:32:49	5321	CCX	2623	5241	5378
D* 02/24/01 09:33:42	5322	CCX	2624	5242	5378
D* 02/24/01 09:34:28	5323	CCX	2625	5243	5378
D* 02/24/01 09:35:10	5324	CCX	2626	5244	5378
D* 02/24/01 09:35:53	5325	CCX	2627	5245	5378
D* 02/24/01 09:36:37	5326	CCX	2628	5246	5378
D* 02/24/01 09:37:23	5327	CCX	2629	5247	5378
D* 02/24/01 09:38:06	5328	CCX	2630	5248	5378
D* 02/24/01 09:39:05	5329	CCX	2631	5249	5378
D* 02/24/01 09:39:50	5330	CCX	2632	5250	5378
D* 02/24/01 09:40:41	5331	CCX	2633	5251	5378
D* 02/24/01 09:41:26	5332	CCX	2634	5252	5378
D* 02/24/01 09:42:10	5333	CCX	2635	5253	5378
D* 02/24/01 09:42:53	5334	CCX	2636	5254	5378
D* 02/24/01 09:43:36	5335	CCX	2637	5255	5378
D* 02/24/01 09:44:21	5336	CCX	2638	5256	5378
D* 02/24/01 09:45:08	5337	CCX	2639	5257	5378
D* 02/24/01 09:45:52	5338	CCX	2640	5258	5378
D* 02/24/01 09:46:36	5339	CCX	2641	5259	5378
D* 02/24/01 09:47:30	5340	CCX	2642	5260	5378
D* 02/24/01 09:48:14	5341	CCX	2643	5261	5378
D* 02/24/01 09:48:58	5342	CCX	2644	5262	5378
D* 02/24/01 09:49:55	5343	CCX	2645	5263	5378
D* 02/24/01 09:50:38	5344	CCX	2646	5264	5378
D* 02/24/01 09:51:21	5345	CCX	2647	5265	5378
D* 02/24/01 09:52:04	5346	CCX	2648	5266	5378
D* 02/24/01 09:52:47	5347	CCX	2649	5267	5378
D* 02/24/01 09:54:00	5348	CCX	2650	5268	5378
D* 02/24/01 09:54:43	5349	CCX	2651	5269	5378

D* 02/24/01 09:55:35	5350	CCX	2652	5270	5378
D* 02/24/01 09:56:19	5351	CCX	2653	5271	5378
D* 02/24/01 09:57:03	5352	CCX	2654	5272	5378
D* 02/24/01 09:57:53	5353	CCX	2655	5273	5378
D* 02/24/01 09:58:35	5354	CCX	2656	5274	5378
D* 02/24/01 09:59:17	5355	CCX	2657	5275	5378
D* 02/24/01 10:00:51	5356	CCX	2658	5276	5378
D* 02/24/01 10:01:34	5357	CCX	2659	5277	5378
D* 02/24/01 10:02:18	5358	CCX	2660	5278	5378
D* 02/24/01 10:03:01	5359	CCX	2661	5279	5378
D* 02/24/01 10:03:49	5360	CCX	2662	5280	5378
D* 02/24/01 10:05:32	5361	CCX	2663	5281	5378
D* 02/24/01 10:06:14	5362	CCX	2664	5282	5378
D* 02/24/01 10:07:02	5363	CCX	2665	5283	5378
D* 02/24/01 10:07:44	5364	CCX	2666	5284	5378
D* 02/24/01 10:08:27	5365	CCX	2667	5285	5378
D* 02/24/01 10:09:10	5366	CCX	2668	5286	5378
D* 02/24/01 10:09:53	5367	CCX	2669	5287	5378
D* 02/24/01 10:10:42	5368	CCX	2670	5288	5378
D* 02/24/01 10:11:28	5369	CCX	2671	5289	5378
D* 02/24/01 10:12:16	5370	CCX	2672	5290	5378
D* 02/24/01 10:13:14	5371	CCX	2673	5291	5378
D* 02/24/01 10:13:55	5372	CCX	2674	5292	5378
D* 02/24/01 10:14:37	5373	CCX	2675	5293	5378
D* 02/24/01 10:15:18	5374	CCX	2676	5294	5378
D* 02/24/01 10:16:07	5375	CCX	2677	5295	5378
D* 02/24/01 10:16:51	5376	CCX	2678	5296	5378
D* 02/24/01 10:17:35	5377	CCX	2679	5297	5378
D* 02/24/01 10:18:17	5378	CCX	2680	5298	5378
D* 02/24/01 11:09:42	1001	CCX	2681	1001	1080
D* 02/24/01 11:11:22	1002	CCX	2682	1001	1081
D* 02/24/01 11:12:07	1003	CCX	2683	1001	1082
D* 02/24/01 11:12:48	1004	CCX	2684	1001	1083
D* 02/24/01 11:13:52	1005	CCX	2685	1001	1084
D* 02/24/01 11:14:43	1006	CCX	2686	1001	1085
D* 02/24/01 11:15:28	1007	CCX	2687	1001	1086
D* 02/24/01 11:16:58	1008	CCX	2688	1001	1087
D* 02/24/01 11:17:43	1009	CCX	2689	1001	1088
D* 02/24/01 11:18:32	1010	CCX	2690	1001	1089
D* 02/24/01 11:19:14	1011	CCX	2691	1001	1090
D* 02/24/01 11:19:58	1012	CCX	2692	1001	1091
D* 02/24/01 11:20:40	1013	CCX	2693	1001	1092
D* 02/24/01 11:21:40	1014	CCX	2694	1001	1093
D* 02/24/01 11:22:21	1015	CCX	2695	1001	1094
D* 02/24/01 11:23:03	1016	CCX	2696	1001	1095
D* 02/24/01 11:23:46	1017	CCX	2697	1001	1096
D* 02/24/01 11:24:30	1018	CCX	2698	1001	1097
D* 02/24/01 11:25:13	1019	CCX	2699	1001	1098
D* 02/24/01 11:26:00	1020	CCX	2700	1001	1099
D* 02/24/01 11:27:10	1021	CCX	2701	1001	1100
D* 02/24/01 11:27:53	1022	CCX	2702	1001	1101
D* 02/24/01 11:28:44	1023	CCX	2703	1001	1102
D* 02/24/01 11:29:25	1024	CCX	2704	1001	1103
D* 02/24/01 11:30:08	1025	CCX	2705	1001	1104
D* 02/24/01 11:30:49	1026	CCX	2706	1001	1105
D* 02/24/01 11:33:18	1027	CCX	2707	1001	1106

D*	02/24/01	11:34:08	1028	CCX	2708	1001	1107
D*	02/24/01	11:34:50	1029	CCX	2709	1001	1108
D*	02/24/01	11:35:33	1030	CCX	2710	1001	1109
D*	02/24/01	11:36:29	1031	CCX	2711	1001	1110
D*	02/24/01	11:37:12	1032	CCX	2712	1001	1111
D*	02/24/01	11:38:01	1033	CCX	2713	1001	1112
D*	02/24/01	11:38:45	1034	CCX	2714	1001	1113
D*	02/24/01	11:39:28	1035	CCX	2715	1001	1114
D*	02/24/01	11:40:11	1036	CCX	2716	1001	1115
D*	02/24/01	11:40:56	1037	CCX	2717	1001	1116
D*	02/24/01	11:41:42	1038	CCX	2718	1001	1117
D*	02/24/01	11:42:25	1039	CCX	2719	1001	1118
D*	02/24/01	11:43:38	1040	CCX	2720	1001	1119
D*	02/24/01	11:44:25	1041	CCX	2721	1001	1120
D*	02/24/01	11:45:28	1042	CCX	2722	1001	1121
D*	02/24/01	11:46:12	1043	CCX	2723	1001	1122
D*	02/24/01	11:46:57	1044	CCX	2724	1001	1123
D*	02/24/01	11:47:40	1045	CCX	2725	1001	1124
D*	02/24/01	11:48:25	1046	CCX	2726	1001	1125
D*	02/24/01	11:49:07	1047	CCX	2727	1001	1126
D*	02/24/01	11:50:03	1048	CCX	2728	1001	1127
D*	02/24/01	11:50:53	1049	CCX	2729	1001	1128
D*	02/24/01	11:51:42	1050	CCX	2730	1001	1129
D*	02/24/01	11:52:27	1051	CCX	2731	1001	1130
D*	02/24/01	11:53:11	1052	CCX	2732	1001	1131

DATE TIME SP FLAG DATA TYPE RCRD # START RCVR FINISH RCVR
COMMENT

D*	02/24/01	11:53:54	1053	CCX	2733	1001	1132
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D*	02/24/01	11:57:21	1056	CCX	2736	1001	1135
D*	02/24/01	11:58:06	1057	CCX	2737	1001	1136
D*	02/24/01	11:58:51	1058	CCX	2738	1001	1137
D*	02/24/01	11:59:42	1059	CCX	2739	1001	1138
D*	02/24/01	12:00:33	1060	CCX	2740	1001	1139
D*	02/24/01	12:01:19	1061	CCX	2741	1001	1140
D*	02/24/01	12:02:10	1062	CCX	2742	1001	1141
D*	02/24/01	12:03:07	1063	CCX	2743	1001	1142
D*	02/24/01	12:03:51	1064	CCX	2744	1001	1143
D*	02/24/01	12:04:37	1065	CCX	2745	1001	1144
D*	02/24/01	12:05:26	1066	CCX	2746	1001	1145
D*	02/24/01	12:06:37	1067	CCX	2747	1001	1146
D*	02/24/01	12:07:25	1068	CCX	2748	1001	1147
D*	02/24/01	12:08:49	1069	CCX	2749	1001	1148
D*	02/24/01	12:09:55	1070	CCX	2750	1001	1149
D*	02/24/01	12:10:53	1071	CCX	2751	1001	1150
D*	02/24/01	12:12:10	1072	CCX	2752	1001	1151
D*	02/24/01	12:13:01	1073	CCX	2753	1001	1152
D*	02/24/01	12:13:53	1074	CCX	2754	1001	1153
D*	02/24/01	12:14:41	1075	CCX	2755	1001	1154
D*	02/24/01	12:15:31	1076	CCX	2756	1001	1155
D*	02/24/01	12:16:27	1077	CCX	2757	1001	1156

D* 02/24/01 12:17:20	1078	CCX	2758	1001	1157
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D* 02/24/01 12:18:52	1080	CCX	2760	1001	1159
D* 02/24/01 12:19:39	1081	CCX	2761	1001	1160
D* 02/24/01 12:20:25	1082	CCX	2762	1002	1161
D* 02/24/01 12:21:15	1083	CCX	2763	1003	1162
D* 02/24/01 12:22:00	1084	CCX	2764	1004	1163
D* 02/24/01 12:22:46	1085	CCX	2765	1005	1164
D* 02/24/01 12:23:35	1086	CCX	2766	1006	1165
D* 02/24/01 12:24:36	1087	CCX	2767	1007	1166
D* 02/24/01 12:25:24	1088	CCX	2768	1008	1167
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D* 02/24/01 12:27:32	1090	CCX	2770	1010	1169
D* 02/24/01 12:28:26	1091	CCX	2771	1011	1170
D* 02/24/01 12:29:28	1092	CCX	2772	1012	1171
D* 02/24/01 12:30:15	1093	CCX	2773	1013	1172
D* 02/24/01 12:31:01	1094	CCX	2774	1014	1173
D* 02/24/01 12:31:46	1095	CCX	2775	1015	1174
D* 02/24/01 12:32:37	1096	CCX	2776	1016	1175
D* 02/24/01 12:33:34	1097	CCX	2777	1017	1176
D* 02/24/01 12:34:22	1098	CCX	2778	1018	1177
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D* 02/24/01 12:36:06	1100	CCX	2780	1020	1179
D* 02/24/01 12:37:04	1101	CCX	2781	1021	1180
D* 02/24/01 12:38:05	1102	CCX	2782	1022	1181
D* 02/24/01 12:38:58	1103	CCX	2783	1023	1182
D* 02/24/01 12:39:43	1104	CCX	2784	1024	1183
D* 02/24/01 12:40:33	1105	CCX	2785	1025	1184
D* 02/24/01 12:41:25	1106	CCX	2786	1026	1185
D* 02/24/01 12:42:09	1107	CCX	2787	1027	1186
D* 02/24/01 12:42:53	1108	CCX	2788	1028	1187
D* 02/24/01 12:43:42	1109	CCX	2789	1029	1188
D* 02/24/01 12:44:32	1110	CCX	2790	1030	1189
D* 02/24/01 12:45:21	1111	CCX	2791	1031	1190
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D* 02/24/01 12:46:57	1113	CCX	2793	1033	1192
D* 02/24/01 12:47:45	1114	CCX	2794	1034	1193
D* 02/24/01 12:48:35	1115	CCX	2795	1035	1194
D* 02/24/01 12:49:20	1116	CCX	2796	1036	1195
D* 02/24/01 12:50:04	1117	CCX	2797	1037	1196
D* 02/24/01 12:50:48	1118	CCX	2798	1038	1197
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D* 02/24/01 12:53:53	1122	CCX	2802	1042	1201
D* 02/24/01 12:54:42	1123	CCX	2803	1043	1202
D* 02/24/01 12:55:26	1124	CCX	2804	1044	1203
D* 02/24/01 12:56:22	1125	CCX	2805	1045	1204
D* 02/24/01 12:57:07	1126	CCX	2806	1046	1205
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D* 02/24/01 13:00:39	1130	CCX	2810	1050	1209
D* 02/24/01 13:01:32	1131	CCX	2811	1051	1210
D* 02/24/01 13:02:19	1132	CCX	2812	1052	1211
D* 02/24/01 13:03:03	1133	CCX	2813	1053	1212

D* 02/24/01 13:03:51	1134	CCX	2814	1054	1213
D* 02/24/01 13:04:35	1135	CCX	2815	1055	1214
D* 02/24/01 13:05:26	1136	CCX	2816	1056	1215
D* 02/24/01 13:06:17	1137	CCX	2817	1057	1216
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D* 02/24/01 13:08:41	1140	CCX	2820	1060	1219
D* 02/24/01 13:09:27	1141	CCX	2821	1061	1220
D* 02/24/01 13:10:23	1142	CCX	2822	1062	1221
D* 02/24/01 13:11:11	1143	CCX	2823	1063	1222
D* 02/24/01 13:11:55	1144	CCX	2824	1064	1223
D* 02/24/01 13:12:48	1145	CCX	2825	1065	1224
D* 02/24/01 13:13:37	1146	CCX	2826	1066	1225
D* 02/24/01 13:14:26	1147	CCX	2827	1067	1226
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D* 02/24/01 13:16:31	1149	CCX	2829	1069	1228
D* 02/24/01 13:17:23	1150	CCX	2830	1070	1229
D* 02/24/01 13:18:12	1151	CCX	2831	1071	1230
D* 02/24/01 13:18:56	1152	CCX	2832	1072	1231
D* 02/24/01 13:19:42	1153	CCX	2833	1073	1232
D* 02/24/01 13:20:28	1154	CCX	2834	1074	1233
D* 02/24/01 13:21:12	1155	CCX	2835	1075	1234
D* 02/24/01 13:22:00	1156	CCX	2836	1076	1235
D* 02/24/01 13:22:46	1157	CCX	2837	1077	1236
D* 02/24/01 13:25:51	1158	CCX	2838	1078	1237
D* 02/24/01 13:26:36	1159	CCX	2839	1079	1238
D* 02/24/01 13:27:24	1160	CCX	2840	1080	1239
D* 02/24/01 13:28:08	1161	CCX	2841	1081	1240
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D* 02/24/01 13:29:37	1163	CCX	2843	1083	1242
D* 02/24/01 13:30:23	1164	CCX	2844	1084	1243
D* 02/24/01 13:31:07	1165	CCX	2845	1085	1244
D* 02/24/01 13:31:51	1166	CCX	2846	1086	1245
D* 02/24/01 13:32:35	1167	CCX	2847	1087	1246
D* 02/24/01 13:33:34	1168	CCX	2848	1088	1247
D* 02/24/01 13:34:18	1169	CCX	2849	1089	1248
D* 02/24/01 13:35:05	1170	CCX	2850	1090	1249
D* 02/24/01 13:35:50	1171	CCX	2851	1091	1250
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D* 02/24/01 13:38:07	1173	CCX	2853	1093	1252
D* 02/24/01 13:39:37	1174	CCX	2854	1094	1253
D* 02/24/01 13:40:21	1175	CCX	2855	1095	1254
D* 02/24/01 13:41:59	1176	CCX	2856	1096	1255
D* 02/24/01 13:42:44	1177	CCX	2857	1097	1256
D* 02/24/01 13:43:30	1178	CCX	2858	1098	1257
D* 02/24/01 13:44:17	1179	CCX	2859	1099	1258
D* 02/24/01 13:45:31	1180	CCX	2860	1100	1259
D* 02/24/01 13:51:34	1181	CCX	2861	1101	1260
D* 02/24/01 13:52:19	1182	CCX	2862	1102	1261
D* 02/24/01 13:53:15	1183	CCX	2863	1103	1262
D* 02/24/01 13:53:59	1184	CCX	2864	1104	1263
D* 02/24/01 13:54:44	1185	CCX	2865	1105	1264
D* 02/24/01 13:56:35	1186	CCX	2866	1106	1265
D* 02/24/01 13:57:25	1187	CCX	2867	1107	1266
D* 02/24/01 13:58:11	1188	CCX	2868	1108	1267
D* 02/24/01 13:58:57	1189	CCX	2869	1109	1268

D* 02/24/01 13:59:42	1190	CCX	2870	1110	1269
D* 02/24/01 14:00:26	1191	CCX	2871	1111	1270
D* 02/24/01 14:01:11	1192	CCX	2872	1112	1271
D* 02/24/01 14:02:01	1193	CCX	2873	1113	1272
D* 02/24/01 14:03:07	1194	CCX	2874	1114	1273
D* 02/24/01 14:07:13	1195	CCX	2875	1115	1274
D* 02/24/01 14:08:24	1196	CCX	2876	1116	1275
D* 02/24/01 14:09:08	1197	CCX	2877	1117	1276
D* 02/24/01 14:09:53	1198	CCX	2878	1118	1277
D* 02/24/01 14:10:39	1199	CCX	2879	1119	1278
D* 02/24/01 14:11:30	1200	CCX	2880	1120	1279
D* 02/24/01 14:12:28	1201	CCX	2881	1121	1280
D* 02/24/01 14:13:14	1202	CCX	2882	1122	1281
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D* 02/24/01 14:14:49	1204	CCX	2884	1124	1283
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D* 02/24/01 14:16:21	1206	CCX	2886	1126	1285
D* 02/24/01 14:17:09	1207	CCX	2887	1127	1286
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D* 02/24/01 14:20:25	1209	CCX	2889	1129	1288
D* 02/24/01 14:21:10	1210	CCX	2890	1130	1289
D* 02/24/01 14:22:59	1210	CCX	2890	1130	1289
D* 02/24/01 14:24:19	1211	CCX	2891	1131	1290
D* 02/24/01 14:25:03	1212	CCX	2892	1132	1291
D* 02/24/01 14:25:48	1213	CCX	2893	1133	1292
D* 02/24/01 14:26:35	1214	CCX	2894	1134	1293
D* 02/24/01 14:27:20	1215	CCX	2895	1135	1294
D* 02/24/01 14:28:12	1216	CCX	2896	1136	1295
D* 02/24/01 14:28:59	1217	CCX	2897	1137	1296
D* 02/24/01 14:29:45	1218	CCX	2898	1138	1297
D* 02/24/01 14:30:29	1219	CCX	2899	1139	1298
D* 02/24/01 14:31:19	1220	CCX	2900	1140	1299
D* 02/24/01 14:33:17	1221	CCX	2901	1141	1300
D* 02/24/01 14:34:03	1222	CCX	2902	1142	1301
D* 02/24/01 14:34:53	1223	CCX	2903	1143	1302
D* 02/24/01 14:35:40	1224	CCX	2904	1144	1303
D* 02/24/01 14:36:26	1225	CCX	2905	1145	1304
D* 02/24/01 14:37:10	1226	CCX	2906	1146	1305
D* 02/24/01 14:37:56	1227	CCX	2907	1147	1306
D* 02/24/01 14:39:03	1228	CCX	2908	1148	1307
D* 02/24/01 14:40:06	1229	CCX	2909	1149	1308
D* 02/24/01 14:40:59	1230	CCX	2910	1150	1309
D* 02/24/01 14:41:44	1231	CCX	2911	1151	1310
D* 02/24/01 14:42:27	1232	CCX	2912	1152	1311
D* 02/24/01 14:43:12	1233	CCX	2913	1153	1312
D* 02/24/01 14:43:57	1234	CCX	2914	1154	1313
D* 02/24/01 14:44:44	1235	CCX	2915	1155	1314
D* 02/24/01 14:45:34	1236	CCX	2916	1156	1315
D* 02/24/01 14:46:18	1237	CCX	2917	1157	1316
D* 02/24/01 14:47:54	1238	CCX	2918	1158	1317
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D* 02/24/01 14:49:40	1240	CCX	2920	1160	1319
D* 02/24/01 14:50:33	1241	CCX	2921	1161	1320
D* 02/24/01 14:51:23	1242	CCX	2922	1162	1321
D* 02/24/01 14:52:11	1243	CCX	2923	1163	1322
D* 02/24/01 14:52:58	1244	CCX	2924	1164	1323

D* 02/24/01 14:53:50	1245	CCX	2925	1165	1324
D* 02/24/01 14:54:34	1246	CCX	2926	1166	1325
D* 02/24/01 14:55:26	1247	CCX	2927	1167	1326
D* 02/24/01 14:56:12	1248	CCX	2928	1168	1327
D* 02/24/01 14:56:59	1249	CCX	2929	1169	1328
D* 02/24/01 14:57:58	1250	CCX	2930	1170	1329
D* 02/24/01 14:58:48	1251	CCX	2931	1171	1330
D* 02/24/01 14:59:33	1252	CCX	2932	1172	1331
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D* 02/24/01 15:01:03	1254	CCX	2934	1174	1333
D* 02/24/01 15:02:41	1255	CCX	2935	1175	1334
D* 02/24/01 15:03:39	1256	CCX	2936	1176	1335
D* 02/24/01 15:04:23	1257	CCX	2937	1177	1336
D* 02/24/01 15:05:08	1258	CCX	2938	1178	1337
D* 02/24/01 15:05:56	1259	CCX	2939	1179	1338
D* 02/24/01 15:06:43	1260	CCX	2940	1180	1339
D* 02/24/01 15:07:31	1261	CCX	2941	1181	1340
D* 02/24/01 15:08:14	1262	CCX	2942	1182	1341
D* 02/24/01 15:09:00	1263	CCX	2943	1183	1342
D* 02/24/01 15:09:44	1264	CCX	2944	1184	1343
D* 02/24/01 15:10:41	1265	CCX	2945	1185	1344
D* 02/24/01 15:11:40	1266	CCX	2946	1186	1345
D* 02/24/01 15:12:28	1267	CCX	2947	1187	1346
D* 02/24/01 15:13:18	1268	CCX	2948	1188	1347
D* 02/24/01 15:14:05	1269	CCX	2949	1189	1348
D* 02/24/01 15:14:52	1270	CCX	2950	1190	1349
D* 02/24/01 15:15:37	1271	CCX	2951	1191	1350
D* 02/24/01 15:16:26	1272	CCX	2952	1192	1351
D* 02/24/01 15:18:42	1273	CCX	2953	1193	1352
D* 02/24/01 15:19:28	1274	CCX	2954	1194	1353
D* 02/24/01 15:20:23	1275	CCX	2955	1195	1354
D* 02/24/01 15:21:13	1276	CCX	2956	1196	1355
D* 02/24/01 15:22:05	1277	CCX	2957	1197	1356
D* 02/24/01 15:23:20	1278	CCX	2958	1198	1357
D* 02/24/01 15:24:11	1279	CCX	2959	1199	1358
D* 02/24/01 15:25:03	1280	CCX	2960	1200	1359
D* 02/24/01 15:25:49	1281	CCX	2961	1201	1360
D* 02/24/01 15:26:41	1282	CCX	2962	1202	1361
D* 02/24/01 15:27:27	1283	CCX	2963	1203	1362
D* 02/24/01 15:28:20	1284	CCX	2964	1204	1363
D* 02/24/01 15:29:04	1285	CCX	2965	1205	1364
D* 02/24/01 15:29:49	1286	CCX	2966	1206	1365
D* 02/24/01 15:30:33	1287	CCX	2967	1207	1366
D* 02/24/01 15:31:18	1288	CCX	2968	1208	1367
D* 02/24/01 15:32:02	1289	CCX	2969	1209	1368
D* 02/24/01 15:32:47	1290	CCX	2970	1210	1369
D* 02/24/01 15:33:57	1291	CCX	2971	1211	1370
D* 02/24/01 15:34:45	1292	CCX	2972	1212	1371
D* 02/24/01 15:35:32	1293	CCX	2973	1213	1372
D* 02/24/01 15:36:21	1294	CCX	2974	1214	1373
D* 02/24/01 15:37:11	1295	CCX	2975	1215	1374
D* 02/24/01 15:37:56	1296	CCX	2976	1216	1375
D* 02/24/01 15:38:40	1297	CCX	2977	1217	1376
D* 02/24/01 15:39:29	1298	CCX	2978	1218	1377
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D* 02/24/01 15:41:15	1300	CCX	2980	1220	1379

D* 02/24/01 15:42:01	1301	CCX	2981	1221	1380
D* 02/24/01 15:42:50	1302	CCX	2982	1222	1381
D* 02/24/01 15:43:34	1303	CCX	2983	1223	1382
D* 02/24/01 15:44:29	1304	CCX	2984	1224	1383
D* 02/24/01 15:45:17	1305	CCX	2985	1225	1384
D* 02/24/01 15:46:07	1306	CCX	2986	1226	1385
D* 02/24/01 15:46:56	1307	CCX	2987	1227	1386
D* 02/24/01 15:47:54	1308	CCX	2988	1228	1387
D* 02/24/01 15:48:39	1309	CCX	2989	1229	1388
D* 02/24/01 15:49:24	1310	CCX	2990	1230	1389
D* 02/24/01 15:50:27	1311	CCX	2991	1231	1390
D* 02/24/01 15:51:21	1312	CCX	2992	1232	1391
D* 02/24/01 15:52:05	1313	CCX	2993	1233	1392
D* 02/24/01 15:53:05	1314	CCX	2994	1234	1393
D* 02/24/01 15:53:48	1315	CCX	2995	1235	1394
D* 02/24/01 15:54:33	1316	CCX	2996	1236	1395
D* 02/24/01 15:55:24	1317	CCX	2997	1237	1396
D* 02/24/01 15:56:09	1318	CCX	2998	1238	1397
D* 02/24/01 15:56:54	1319	CCX	2999	1239	1398
D* 02/24/01 15:57:39	1320	CCX	3000	1240	1399
D* 02/24/01 15:58:23	1321	CCX	3001	1241	1400
D* 02/24/01 15:59:08	1322	CCX	3002	1242	1401
D* 02/24/01 15:59:52	1323	CCX	3003	1243	1402
D* 02/24/01 16:01:36	1324	CCX	3004	1244	1403
D* 02/24/01 16:02:49	1325	CCX	3005	1245	1404
D* 02/24/01 16:03:37	1326	CCX	3006	1246	1405
D* 02/24/01 16:04:46	1327	CCX	3007	1247	1406
D* 02/24/01 16:05:50	1328	CCX	3008	1248	1407
D* 02/24/01 16:06:36	1329	CCX	3009	1249	1408
D* 02/24/01 16:07:28	1330	CCX	3010	1250	1409
D* 02/24/01 16:08:14	1331	CCX	3011	1251	1410
D* 02/24/01 16:09:08	1332	CCX	3012	1252	1411
D* 02/24/01 16:09:53	1333	CCX	3013	1253	1412
D* 02/24/01 16:10:40	1334	CCX	3014	1254	1413
D* 02/24/01 16:11:29	1335	CCX	3015	1255	1414
D* 02/24/01 16:12:14	1336	CCX	3016	1256	1415
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D* 02/24/01 16:15:48	1339	CCX	3019	1259	1418
D* 02/24/01 16:17:45	1340	CCX	3020	1260	1419
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D* 02/24/01 16:19:16	1342	CCX	3022	1262	1421
D* 02/24/01 16:20:03	1343	CCX	3023	1263	1422
D* 02/24/01 16:20:49	1344	CCX	3024	1264	1423
D* 02/24/01 16:21:33	1345	CCX	3025	1265	1424
D* 02/24/01 16:22:18	1346	CCX	3026	1266	1424
D* 02/24/01 16:23:04	1347	CCX	3027	1267	1424
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D* 02/24/01 16:24:33	1349	CCX	3029	1269	1424
D* 02/24/01 16:25:17	1350	CCX	3030	1270	1424
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D* 02/24/01 16:27:40	1353	CCX	3033	1273	1424
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D* 02/24/01 16:32:26	1359	CCX	3039	1279	1424
D* 02/24/01 16:33:18	1360	CCX	3040	1280	1424
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D* 02/24/01 16:40:52	1369	CCX	3049	1289	1424
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D* 02/24/01 16:52:09	1383	CCX	3063	1303	1424
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D* 02/24/01 17:00:44	1394	CCX	3074	1314	1424
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D* 02/24/01 17:04:21	1399	CCX	3079	1319	1424
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D* 02/24/01 17:07:58	1404	CCX	3084	1324	1424
D* 02/24/01 17:08:44	1405	CCX	3085	1325	1424
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D* 02/24/01 17:11:40	1409	CCX	3089	1329	1424
D* 02/24/01 17:12:24	1410	CCX	3090	1330	1424
D* 02/24/01 17:13:12	1411	CCX	3091	1331	1424
D* 02/24/01 17:13:59	1412	CCX	3092	1332	1424

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D*	02/24/01 17:16:10	1415	CCX	3095	1335	1424
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D*	02/24/01 17:17:33	1417	CCX	3097	1337	1424
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D*	02/24/01 17:19:37	1420	CCX	3100	1340	1424
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D*	02/24/01 17:21:02	1422	CCX	3102	1342	1424
D*	02/24/01 17:21:43	1423	CCX	3103	1343	1424
D*	02/24/01 17:22:24	1424	CCX	3104	1344	1424
D*	02/25/01 08:13:15	2001	CCX	3105	2001	2080
D*	02/25/01 08:15:59	2002	CCX	3106	2001	2081
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D*	02/25/01 08:21:47	2004	CCX	3108	2001	2083
D*	02/25/01 08:22:31	2005	CCX	3109	2001	2084
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D*	02/25/01 08:26:47	2010	CCX	3114	2001	2089
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D*	02/25/01 08:29:47	2014	CCX	3118	2001	2093
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D*	02/25/01 08:31:24	2016	CCX	3120	2001	2095
D*	02/25/01 08:32:07	2017	CCX	3121	2001	2096
D*	02/25/01 08:32:55	2018	CCX	3122	2001	2097
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D*	02/25/01 08:36:30	2022	CCX	3126	2001	2101
D*	02/25/01 08:37:21	2023	CCX	3127	2001	2102
D*	02/25/01 08:38:03	2024	CCX	3128	2001	2103
D*	02/25/01 08:38:49	2025	CCX	3129	2001	2104
D*	02/25/01 08:39:33	2026	CCX	3130	2001	2105
D*	02/25/01 08:40:22	2027	CCX	3131	2001	2106
D*	02/25/01 08:41:22	2028	CCX	3132	2001	2107
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D*	02/25/01 08:42:50	2030	CCX	3134	2001	2109
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D*	02/25/01 08:45:30	2033	CCX	3137	2001	2112
D*	02/25/01 08:46:14	2034	CCX	3138	2001	2113
D*	02/25/01 08:46:57	2035	CCX	3139	2001	2114
D*	02/25/01 08:47:42	2036	CCX	3140	2001	2115
D*	02/25/01 08:48:25	2037	CCX	3141	2001	2116
D*	02/25/01 08:49:07	2038	CCX	3142	2001	2117
D*	02/25/01 08:49:49	2039	CCX	3143	2001	2118
D*	02/25/01 08:50:36	2040	CCX	3144	2001	2119
D*	02/25/01 08:51:40	2041	CCX	3145	2001	2120
D*	02/25/01 08:52:22	2042	CCX	3146	2001	2121
D*	02/25/01 08:53:09	2043	CCX	3147	2001	2122

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D* 02/25/01 08:54:34	2045	CCX	3149	2001	2124
D* 02/25/01 08:55:18	2046	CCX	3150	2001	2125
D* 02/25/01 08:56:00	2047	CCX	3151	2001	2126
D* 02/25/01 08:56:45	2048	CCX	3152	2001	2127
D* 02/25/01 08:57:32	2049	CCX	3153	2001	2128
D* 02/25/01 08:58:18	2050	CCX	3154	2001	2129
D* 02/25/01 08:59:08	2051	CCX	3155	2001	2130
D* 02/25/01 08:59:57	2052	CCX	3156	2001	2131
D* 02/25/01 09:00:40	2053	CCX	3157	2001	2132
D* 02/25/01 09:01:24	2054	CCX	3158	2001	2133
D* 02/25/01 09:02:09	2055	CCX	3159	2001	2134
D* 02/25/01 09:02:58	2056	CCX	3160	2001	2135
D* 02/25/01 09:03:41	2057	CCX	3161	2001	2136
D* 02/25/01 09:04:24	2058	CCX	3162	2001	2137
D* 02/25/01 09:05:07	2059	CCX	3163	2001	2138
D* 02/25/01 09:05:54	2060	CCX	3164	2001	2139
D* 02/25/01 09:06:43	2061	CCX	3165	2001	2140
D* 02/25/01 09:07:30	2062	CCX	3166	2001	2141
D* 02/25/01 09:08:27	2063	CCX	3167	2001	2142
D* 02/25/01 09:09:10	2064	CCX	3168	2001	2143
D* 02/25/01 09:09:57	2065	CCX	3169	2001	2144
D* 02/25/01 09:10:40	2066	CCX	3170	2001	2145
D* 02/25/01 09:11:24	2067	CCX	3171	2001	2146
D* 02/25/01 09:12:29	2068	CCX	3172	2001	2147
D* 02/25/01 09:13:14	2069	CCX	3173	2001	2148
D* 02/25/01 09:13:57	2070	CCX	3174	2001	2149
D* 02/25/01 09:14:40	2071	CCX	3175	2001	2150
D* 02/25/01 09:15:23	2072	CCX	3176	2001	2151
D* 02/25/01 09:16:10	2073	CCX	3177	2001	2152
D* 02/25/01 09:16:53	2074	CCX	3178	2001	2153
D* 02/25/01 09:17:36	2075	CCX	3179	2001	2154
D* 02/25/01 09:18:27	2076	CCX	3180	2001	2155
D* 02/25/01 09:19:12	2077	CCX	3181	2001	2156
D* 02/25/01 09:19:58	2078	CCX	3182	2001	2157
D* 02/25/01 09:20:42	2079	CCX	3183	2001	2158
D* 02/25/01 09:21:31	2080	CCX	3184	2001	2159
D* 02/25/01 09:22:14	2081	CCX	3185	2001	2160
D* 02/25/01 09:22:58	2082	CCX	3186	2002	2161
D* 02/25/01 09:23:43	2083	CCX	3187	2003	2162
D* 02/25/01 09:24:27	2084	CCX	3188	2004	2163
D* 02/25/01 09:25:11	2085	CCX	3189	2005	2164
D* 02/25/01 09:26:20	2086	CCX	3190	2006	2165
D* 02/25/01 09:27:06	2087	CCX	3191	2007	2166
D* 02/25/01 09:27:50	2088	CCX	3192	2008	2167
D* 02/25/01 09:28:34	2089	CCX	3193	2009	2168
D* 02/25/01 09:29:22	2090	CCX	3194	2010	2169
D* 02/25/01 09:30:09	2091	CCX	3195	2011	2170
D* 02/25/01 09:31:28	2092	CCX	3196	2012	2171
D* 02/25/01 09:32:13	2093	CCX	3197	2013	2172
D* 02/25/01 09:32:56	2094	CCX	3198	2014	2173
D* 02/25/01 09:33:41	2095	CCX	3199	2015	2174
D* 02/25/01 09:34:26	2096	CCX	3200	2016	2175
D* 02/25/01 09:35:11	2097	CCX	3201	2017	2176
D* 02/25/01 09:35:55	2098	CCX	3202	2018	2177
D* 02/25/01 09:36:39	2099	CCX	3203	2019	2178

D* 02/25/01 09:37:31	2100	CCX	3204	2020	2179
D* 02/25/01 09:38:29	2101	CCX	3205	2021	2180
D* 02/25/01 09:39:18	2102	CCX	3206	2022	2181
D* 02/25/01 09:40:03	2103	CCX	3207	2023	2182
D* 02/25/01 09:40:49	2104	CCX	3208	2024	2183
D* 02/25/01 09:41:40	2105	CCX	3209	2025	2184
D* 02/25/01 09:42:25	2106	CCX	3210	2026	2185
D* 02/25/01 09:43:09	2107	CCX	3211	2027	2186
D* 02/25/01 09:43:56	2108	CCX	3212	2028	2187
D* 02/25/01 09:45:07	2109	CCX	3213	2029	2188
D* 02/25/01 09:46:11	2110	CCX	3214	2030	2189
D* 02/25/01 09:46:54	2111	CCX	3215	2031	2190
D* 02/25/01 09:47:38	2112	CCX	3216	2032	2191
D* 02/25/01 09:48:22	2113	CCX	3217	2033	2192
D* 02/25/01 09:49:06	2114	CCX	3218	2034	2193
D* 02/25/01 09:49:50	2115	CCX	3219	2035	2194
D* 02/25/01 09:50:34	2116	CCX	3220	2036	2195
D* 02/25/01 09:51:18	2117	CCX	3221	2037	2196
D* 02/25/01 09:52:02	2118	CCX	3222	2038	2197
D* 02/25/01 09:52:47	2119	CCX	3223	2039	2198
D* 02/25/01 09:53:32	2120	CCX	3224	2040	2199
D* 02/25/01 09:54:16	2121	CCX	3225	2041	2200
D* 02/25/01 09:55:08	2122	CCX	3226	2042	2201
D* 02/25/01 09:55:52	2123	CCX	3227	2043	2202
D* 02/25/01 09:56:46	2124	CCX	3228	2044	2203
D* 02/25/01 09:57:31	2125	CCX	3229	2045	2204
D* 02/25/01 09:58:16	2126	CCX	3230	2046	2205
D* 02/25/01 09:59:01	2127	CCX	3231	2047	2206
D* 02/25/01 09:59:54	2128	CCX	3232	2048	2207
D* 02/25/01 10:00:39	2129	CCX	3233	2049	2208
D* 02/25/01 10:01:28	2130	CCX	3234	2050	2209
D* 02/25/01 10:02:14	2131	CCX	3235	2051	2210
D* 02/25/01 10:02:58	2132	CCX	3236	2052	2211
D* 02/25/01 10:04:33	2133	CCX	3237	2053	2212
D* 02/25/01 10:05:17	2134	CCX	3238	2054	2213
D* 02/25/01 10:06:01	2135	CCX	3239	2055	2214
D* 02/25/01 10:06:47	2136	CCX	3240	2056	2215
D* 02/25/01 10:07:31	2137	CCX	3241	2057	2216
D* 02/25/01 10:08:15	2138	CCX	3242	2058	2217
D* 02/25/01 10:09:06	2139	CCX	3243	2059	2218
D* 02/25/01 10:09:58	2140	CCX	3244	2060	2219
D* 02/25/01 10:10:46	2141	CCX	3245	2061	2220
D* 02/25/01 10:11:32	2142	CCX	3246	2062	2221
D* 02/25/01 10:12:17	2143	CCX	3247	2063	2222
D* 02/25/01 10:13:37	2144	CCX	3248	2064	2223
D* 02/25/01 10:14:22	2145	CCX	3249	2065	2224
D* 02/25/01 10:15:49	2146	CCX	3250	2066	2225
D* 02/25/01 10:16:35	2147	CCX	3251	2067	2226
D* 02/25/01 10:17:21	2148	CCX	3252	2068	2227
D* 02/25/01 10:18:05	2149	CCX	3253	2069	2228
D* 02/25/01 10:18:58	2150	CCX	3254	2070	2229
D* 02/25/01 10:19:42	2151	CCX	3255	2071	2230
D* 02/25/01 10:20:28	2152	CCX	3256	2072	2231
D* 02/25/01 10:21:15	2153	CCX	3257	2073	2232
D* 02/25/01 10:21:59	2154	CCX	3258	2074	2233
D* 02/25/01 10:22:45	2155	CCX	3259	2075	2234

D* 02/25/01 10:23:29	2156	CCX	3260	2076	2235
D* 02/25/01 10:24:14	2157	CCX	3261	2077	2236
D* 02/25/01 10:24:57	2158	CCX	3262	2078	2237
D* 02/25/01 10:25:44	2159	CCX	3263	2079	2238
D* 02/25/01 10:27:03	2160	CCX	3264	2080	2239
D* 02/25/01 10:27:47	2161	CCX	3265	2081	2240
D* 02/25/01 10:28:35	2162	CCX	3266	2082	2241
D* 02/25/01 10:29:22	2163	CCX	3267	2083	2242
D* 02/25/01 10:30:12	2164	CCX	3268	2084	2243
D* 02/25/01 10:30:59	2165	CCX	3269	2085	2244
D* 02/25/01 10:31:52	2166	CCX	3270	2086	2245
D* 02/25/01 10:32:36	2167	CCX	3271	2087	2246
D* 02/25/01 10:33:46	2168	CCX	3272	2088	2247
D* 02/25/01 10:34:31	2169	CCX	3273	2089	2248
D* 02/25/01 10:35:48	2170	CCX	3274	2090	2249
D* 02/25/01 10:36:44	2171	CCX	3275	2091	2250
D* 02/25/01 10:37:31	2172	CCX	3276	2092	2251
D* 02/25/01 10:38:19	2173	CCX	3277	2093	2252
D* 02/25/01 10:39:27	2174	CCX	3278	2094	2253
D* 02/25/01 10:40:32	2175	CCX	3279	2095	2254
D* 02/25/01 10:41:25	2176	CCX	3280	2096	2255
D* 02/25/01 10:42:23	2177	CCX	3281	2097	2256
D* 02/25/01 10:43:10	2178	CCX	3282	2098	2257
D* 02/25/01 10:43:56	2179	CCX	3283	2099	2258
D* 02/25/01 10:44:44	2180	CCX	3284	2100	2259
D* 02/25/01 10:45:36	2181	CCX	3285	2101	2260
D* 02/25/01 10:46:21	2182	CCX	3286	2102	2261
D* 02/25/01 10:47:11	2183	CCX	3287	2103	2262
D* 02/25/01 10:47:57	2184	CCX	3288	2104	2263
D* 02/25/01 10:48:49	2185	CCX	3289	2105	2264
D* 02/25/01 10:49:45	2186	CCX	3290	2106	2265
D* 02/25/01 10:50:29	2187	CCX	3291	2107	2266
D* 02/25/01 10:51:13	2188	CCX	3292	2108	2267
D* 02/25/01 10:52:03	2189	CCX	3293	2109	2268
D* 02/25/01 10:53:30	2190	CCX	3294	2110	2269
D* 02/25/01 10:54:45	2191	CCX	3295	2111	2270
D* 02/25/01 10:55:50	2192	CCX	3296	2112	2271
D* 02/25/01 10:56:45	2193	CCX	3297	2113	2272
D* 02/25/01 10:57:29	2194	CCX	3298	2114	2273
D* 02/25/01 10:58:22	2195	CCX	3299	2115	2274
D* 02/25/01 10:59:07	2196	CCX	3300	2116	2275
D* 02/25/01 10:59:54	2197	CCX	3301	2117	2276
D* 02/25/01 11:00:38	2198	CCX	3302	2118	2277
D* 02/25/01 11:01:24	2199	CCX	3303	2119	2278
D* 02/25/01 11:02:08	2200	CCX	3304	2120	2279
D* 02/25/01 11:02:52	2201	CCX	3305	2121	2280
D* 02/25/01 11:03:37	2202	CCX	3306	2122	2281
D* 02/25/01 11:04:24	2203	CCX	3307	2123	2282
D* 02/25/01 11:05:08	2204	CCX	3308	2124	2283
D* 02/25/01 11:05:55	2205	CCX	3309	2125	2284
D* 02/25/01 11:06:46	2206	CCX	3310	2126	2285
D* 02/25/01 11:07:32	2207	CCX	3311	2127	2286
D* 02/25/01 11:08:17	2208	CCX	3312	2128	2287
D* 02/25/01 11:09:06	2209	CCX	3313	2129	2288
D* 02/25/01 11:09:54	2210	CCX	3314	2130	2289
D* 02/25/01 11:10:40	2211	CCX	3315	2131	2290

D* 02/25/01 11:12:16	2212	CCX	3316	2132	2291
D* 02/25/01 11:13:01	2213	CCX	3317	2133	2292
D* 02/25/01 11:13:46	2214	CCX	3318	2134	2293
D* 02/25/01 11:14:31	2215	CCX	3319	2135	2294
D* 02/25/01 11:15:20	2216	CCX	3320	2136	2295
D* 02/25/01 11:16:04	2217	CCX	3321	2137	2296
D* 02/25/01 11:17:02	2218	CCX	3322	2138	2297
D* 02/25/01 11:17:46	2219	CCX	3323	2139	2298
D* 02/25/01 11:18:52	2220	CCX	3324	2140	2299
D* 02/25/01 11:19:39	2221	CCX	3325	2141	2300
D* 02/25/01 11:20:24	2222	CCX	3326	2142	2301
D* 02/25/01 11:21:15	2223	CCX	3327	2143	2302
D* 02/25/01 11:21:59	2224	CCX	3328	2144	2303
D* 02/25/01 11:22:44	2225	CCX	3329	2145	2304
D* 02/25/01 11:23:29	2226	CCX	3330	2146	2305
D* 02/25/01 11:24:13	2227	CCX	3331	2147	2306
D* 02/25/01 11:25:00	2228	CCX	3332	2148	2307
D* 02/25/01 11:25:45	2229	CCX	3333	2149	2308
D* 02/25/01 11:26:33	2230	CCX	3334	2150	2309
D* 02/25/01 11:27:36	2231	CCX	3335	2151	2310
D* 02/25/01 11:28:21	2232	CCX	3336	2152	2311
D* 02/25/01 11:29:08	2233	CCX	3337	2153	2312
D* 02/25/01 11:29:52	2234	CCX	3338	2154	2313
D* 02/25/01 11:30:36	2235	CCX	3339	2155	2314
D* 02/25/01 11:32:19	2236	CCX	3340	2156	2315
D* 02/25/01 11:33:05	2237	CCX	3341	2157	2316
D* 02/25/01 11:33:58	2238	CCX	3342	2158	2317
D* 02/25/01 11:34:44	2239	CCX	3343	2159	2318
D* 02/25/01 11:35:27	2240	CCX	3344	2160	2319
D* 02/25/01 11:36:15	2241	CCX	3345	2161	2320
D* 02/25/01 11:36:59	2242	CCX	3346	2162	2321
D* 02/25/01 11:39:06	2243	CCX	3347	2163	2322
D* 02/25/01 11:39:52	2244	CCX	3348	2164	2323
D* 02/25/01 11:40:41	2245	CCX	3349	2165	2324
D* 02/25/01 11:43:40	2246	CCX	3350	2166	2325
D* 02/25/01 11:44:25	2247	CCX	3351	2167	2326
D* 02/25/01 11:45:11	2248	CCX	3352	2168	2327
D* 02/25/01 11:45:55	2249	CCX	3353	2169	2328
D* 02/25/01 11:46:39	2250	CCX	3354	2170	2329
D* 02/25/01 11:47:29	2251	CCX	3355	2171	2330
D* 02/25/01 11:48:13	2252	CCX	3356	2172	2331
D* 02/25/01 11:48:58	2253	CCX	3357	2173	2332
D* 02/25/01 11:49:44	2254	CCX	3358	2174	2333
D* 02/25/01 11:50:34	2255	CCX	3359	2175	2334
D* 02/25/01 11:51:38	2256	CCX	3360	2176	2335
D* 02/25/01 11:52:26	2257	CCX	3361	2177	2336
D* 02/25/01 11:53:29	2258	CCX	3362	2178	2337
D* 02/25/01 11:54:19	2259	CCX	3363	2179	2338
D* 02/25/01 11:55:03	2260	CCX	3364	2180	2339
D* 02/25/01 11:55:47	2261	CCX	3365	2181	2340
D* 02/25/01 11:56:33	2262	CCX	3366	2182	2341
D* 02/25/01 11:57:19	2263	CCX	3367	2183	2342
D* 02/25/01 11:58:03	2264	CCX	3368	2184	2343
D* 02/25/01 11:58:47	2265	CCX	3369	2185	2344
D* 02/25/01 11:59:49	2266	CCX	3370	2186	2345
D* 02/25/01 12:00:43	2267	CCX	3371	2187	2346

D* 02/25/01 12:01:35	2268	CCX	3372	2188	2347
D* 02/25/01 12:02:23	2269	CCX	3373	2189	2348
D* 02/25/01 12:03:12	2270	CCX	3374	2190	2349
D* 02/25/01 12:04:00	2271	CCX	3375	2191	2350
D* 02/25/01 12:04:47	2272	CCX	3376	2192	2351
D* 02/25/01 12:07:41	2273	CCX	3377	2193	2352
D* 02/25/01 12:08:26	2274	CCX	3378	2194	2353
D* 02/25/01 12:09:12	2275	CCX	3379	2195	2354
D* 02/25/01 12:09:57	2276	CCX	3380	2196	2355
D* 02/25/01 12:10:44	2277	CCX	3381	2197	2356
D* 02/25/01 12:11:29	2278	CCX	3382	2198	2357
D* 02/25/01 12:12:14	2279	CCX	3383	2199	2358
D* 02/25/01 12:12:59	2280	CCX	3384	2200	2359
D* 02/25/01 12:13:44	2281	CCX	3385	2201	2360
D* 02/25/01 12:14:41	2282	CCX	3386	2202	2361
D* 02/25/01 12:15:28	2283	CCX	3387	2203	2362
D* 02/25/01 12:16:13	2284	CCX	3388	2204	2363
D* 02/25/01 12:16:59	2285	CCX	3389	2205	2364
D* 02/25/01 12:17:45	2286	CCX	3390	2206	2365
D* 02/25/01 12:18:38	2287	CCX	3391	2207	2366
D* 02/25/01 12:19:22	2288	CCX	3392	2208	2367
D* 02/25/01 12:20:06	2289	CCX	3393	2209	2368
D* 02/25/01 12:20:50	2290	CCX	3394	2210	2369
D* 02/25/01 12:21:34	2291	CCX	3395	2211	2370
D* 02/25/01 12:23:12	2292	CCX	3396	2212	2371
D* 02/25/01 12:23:56	2293	CCX	3397	2213	2372
D* 02/25/01 12:24:42	2294	CCX	3398	2214	2373
D* 02/25/01 12:25:27	2295	CCX	3399	2215	2374
D* 02/25/01 12:26:18	2296	CCX	3400	2216	2375
D* 02/25/01 12:27:02	2297	CCX	3401	2217	2376
D* 02/25/01 12:27:58	2298	CCX	3402	2218	2377
D* 02/25/01 12:28:45	2299	CCX	3403	2219	2378
D* 02/25/01 12:29:29	2300	CCX	3404	2220	2379
D* 02/25/01 12:30:13	2301	CCX	3405	2221	2380
D* 02/25/01 12:31:00	2302	CCX	3406	2222	2381
D* 02/25/01 12:31:47	2303	CCX	3407	2223	2382
D* 02/25/01 12:32:36	2304	CCX	3408	2224	2383
D* 02/25/01 12:33:26	2305	CCX	3409	2225	2384
D* 02/25/01 12:34:12	2306	CCX	3410	2226	2385
D* 02/25/01 12:34:56	2307	CCX	3411	2227	2386
D* 02/25/01 12:35:44	2308	CCX	3412	2228	2387
D* 02/25/01 12:36:30	2309	CCX	3413	2229	2388
D* 02/25/01 12:37:52	2310	CCX	3414	2230	2389
D* 02/25/01 12:38:40	2311	CCX	3415	2231	2390
D* 02/25/01 12:39:31	2312	CCX	3416	2232	2391
D* 02/25/01 12:40:49	2313	CCX	3417	2233	2392
D* 02/25/01 12:41:33	2314	CCX	3418	2234	2393
D* 02/25/01 12:42:18	2315	CCX	3419	2235	2394
D* 02/25/01 12:43:03	2316	CCX	3420	2236	2395
D* 02/25/01 12:43:48	2317	CCX	3421	2237	2396
D* 02/25/01 12:44:34	2318	CCX	3422	2238	2397
D* 02/25/01 12:45:19	2319	CCX	3423	2239	2398
D* 02/25/01 12:46:03	2320	CCX	3424	2240	2399
D* 02/25/01 12:46:49	2321	CCX	3425	2241	2400
D* 02/25/01 12:47:33	2322	CCX	3426	2242	2401
D* 02/25/01 12:48:17	2323	CCX	3427	2243	2402

D*	02/25/01 12:49:02	2324	CCX	3428	2244	2403
D*	02/25/01 12:49:47	2325	CCX	3429	2245	2404
D*	02/25/01 12:50:32	2326	CCX	3430	2246	2405
D*	02/25/01 12:51:16	2327	CCX	3431	2247	2406
D*	02/25/01 12:52:00	2328	CCX	3432	2248	2407
D*	02/25/01 12:52:45	2329	CCX	3433	2249	2408
D*	02/25/01 12:53:38	2330	CCX	3434	2250	2409
D*	02/25/01 12:54:29	2331	CCX	3435	2251	2410
D*	02/25/01 12:55:19	2332	CCX	3436	2252	2411
D*	02/25/01 12:56:05	2333	CCX	3437	2253	2412
D*	02/25/01 12:56:49	2334	CCX	3438	2254	2413
D*	02/25/01 12:57:34	2335	CCX	3439	2255	2414
D*	02/25/01 12:58:20	2336	CCX	3440	2256	2415
D*	02/25/01 12:59:06	2337	CCX	3441	2257	2416
D*	02/25/01 12:59:54	2338	CCX	3442	2258	2417
D*	02/25/01 13:00:40	2339	CCX	3443	2259	2418
D*	02/25/01 13:01:38	2340	CCX	3444	2260	2419
D*	02/25/01 13:02:24	2341	CCX	3445	2261	2420
D*	02/25/01 13:03:26	2342	CCX	3446	2262	2421
D*	02/25/01 13:04:12	2343	CCX	3447	2263	2421
D*	02/25/01 13:04:57	2344	CCX	3448	2264	2421
D*	02/25/01 13:05:43	2345	CCX	3449	2265	2421
D*	02/25/01 13:06:43	2346	CCX	3450	2266	2421
D*	02/25/01 13:07:26	2347	CCX	3451	2267	2421
D*	02/25/01 13:09:18	2348	CCX	3452	2268	2421
D*	02/25/01 13:10:02	2349	CCX	3453	2269	2421
D*	02/25/01 13:10:46	2350	CCX	3454	2270	2421
D*	02/25/01 13:11:30	2351	CCX	3455	2271	2421
D*	02/25/01 13:16:12	2352	CCX	3456	2272	2421
D*	02/25/01 13:16:55	2353	CCX	3457	2273	2421
D*	02/25/01 13:17:39	2354	CCX	3458	2274	2421
D*	02/25/01 13:18:24	2355	CCX	3459	2275	2421
D*	02/25/01 13:19:16	2356	CCX	3460	2276	2421
D*	02/25/01 13:20:02	2357	CCX	3461	2277	2421
D*	02/25/01 13:20:46	2358	CCX	3462	2278	2421
D*	02/25/01 13:21:30	2359	CCX	3463	2279	2421
D*	02/25/01 13:22:17	2360	CCX	3464	2280	2421
D*	02/25/01 13:23:04	2361	CCX	3465	2281	2421
D*	02/25/01 13:23:51	2362	CCX	3466	2282	2421
D*	02/25/01 13:24:36	2363	CCX	3467	2283	2421
D*	02/25/01 13:25:19	2364	CCX	3468	2284	2421
D*	02/25/01 13:26:34	2365	CCX	3469	2285	2421
D*	02/25/01 13:27:19	2366	CCX	3470	2286	2421
D*	02/25/01 13:28:07	2367	CCX	3471	2287	2421
D*	02/25/01 13:28:50	2368	CCX	3472	2288	2421
D*	02/25/01 13:29:34	2369	CCX	3473	2289	2421
D*	02/25/01 13:30:23	2370	CCX	3474	2290	2421
D*	02/25/01 13:31:14	2371	CCX	3475	2291	2421
D*	02/25/01 13:31:57	2372	CCX	3476	2292	2421
D*	02/25/01 13:32:41	2373	CCX	3477	2293	2421
D*	02/25/01 13:33:34	2374	CCX	3478	2294	2421
D*	02/25/01 13:34:28	2375	CCX	3479	2295	2421
D*	02/25/01 13:35:11	2376	CCX	3480	2296	2421
D*	02/25/01 13:35:53	2377	CCX	3481	2297	2421
D*	02/25/01 13:36:37	2378	CCX	3482	2298	2421
D*	02/25/01 13:37:21	2379	CCX	3483	2299	2421

D* 02/25/01 13:38:07	2380	CCX	3484	2300	2421
D* 02/25/01 13:38:50	2381	CCX	3485	2301	2421
D* 02/25/01 13:39:32	2382	CCX	3486	2302	2421
D* 02/25/01 13:40:17	2383	CCX	3487	2303	2421
D* 02/25/01 13:40:59	2384	CCX	3488	2304	2421
D* 02/25/01 13:41:49	2385	CCX	3489	2305	2421
D* 02/25/01 13:42:35	2386	CCX	3490	2306	2421
D* 02/25/01 13:43:20	2387	CCX	3491	2307	2421
D* 02/25/01 13:44:02	2388	CCX	3492	2308	2421
D* 02/25/01 13:44:44	2389	CCX	3493	2309	2421
D* 02/25/01 13:45:50	2390	CCX	3494	2310	2421
D* 02/25/01 13:46:32	2391	CCX	3495	2311	2421
D* 02/25/01 13:47:13	2392	CCX	3496	2312	2421
D* 02/25/01 13:48:07	2393	CCX	3497	2313	2421
D* 02/25/01 13:48:55	2394	CCX	3498	2314	2421
D* 02/25/01 13:49:37	2395	CCX	3499	2315	2421
D* 02/25/01 13:50:19	2396	CCX	3500	2316	2421
D* 02/25/01 13:51:02	2397	CCX	3501	2317	2421
D* 02/25/01 13:51:44	2398	CCX	3502	2318	2421
D* 02/25/01 13:52:27	2399	CCX	3503	2319	2421
D* 02/25/01 13:53:12	2400	CCX	3504	2320	2421
D* 02/25/01 13:53:54	2401	CCX	3505	2321	2421
D* 02/25/01 13:54:41	2402	CCX	3506	2322	2421
D* 02/25/01 13:55:22	2403	CCX	3507	2323	2421
D* 02/25/01 13:56:14	2404	CCX	3508	2324	2421
D* 02/25/01 13:56:58	2405	CCX	3509	2325	2421
D* 02/25/01 13:57:46	2406	CCX	3510	2326	2421
D* 02/25/01 13:58:31	2407	CCX	3511	2327	2421
D* 02/25/01 13:59:12	2408	CCX	3512	2328	2421
D* 02/25/01 13:59:54	2409	CCX	3513	2329	2421
D* 02/25/01 14:00:38	2410	CCX	3514	2330	2421
D* 02/25/01 14:01:21	2411	CCX	3515	2331	2421
D* 02/25/01 14:02:02	2412	CCX	3516	2332	2421
D* 02/25/01 14:02:44	2413	CCX	3517	2333	2421
D* 02/25/01 14:03:27	2414	CCX	3518	2334	2421
D* 02/25/01 14:04:09	2415	CCX	3519	2335	2421
D* 02/25/01 14:04:56	2416	CCX	3520	2336	2421
D* 02/25/01 14:05:38	2417	CCX	3521	2337	2421
D* 02/25/01 14:06:19	2418	CCX	3522	2338	2421
D* 02/25/01 14:07:02	2419	CCX	3523	2339	2421
D* 02/25/01 14:07:53	2420	CCX	3524	2340	2421
D* 02/25/01 14:08:48	2421	CCX	3525	2341	2421

Appendix C

Flag	Easting	Northing	Elevation
1001	376059	548359	4510
1002	376068	548364	4510
1003	376077	548368	4511
1004	376085	548373	4511
1005	376095	548378	4512
1006	376103	548382	4512
1007	376112	548387	4512
1008	376121	548392	4512
1009	376130	548396	4512
1010	376139	548401	4512
1011	376147	548406	4512
1012	376156	548411	4512
1013	376165	548415	4512
1014	376174	548420	4512
1015	376183	548424	4512
1016	376191	548429	4513
1017	376201	548434	4513
1018	376209	548439	4513
1019	376218	548444	4514
1020	376227	548448	4514
1021	376236	548453	4513
1022	376245	548457	4513
1023	376254	548462	4514
1024	376262	548467	4514
1025	376271	548472	4514
1026	376280	548476	4514
1027	376289	548481	4514
1028	376298	548486	4515
1029	376306	548490	4515
1030	376315	548495	4515
1031	376324	548500	4515
1032	376333	548504	4515
1033	376342	548509	4515
1034	376350	548514	4515
1035	376360	548518	4516
1036	376368	548523	4516
1037	376377	548528	4516
1038	376386	548532	4516
1039	376395	548537	4517
1040	376404	548542	4517
1041	376412	548546	4517
1042	376421	548551	4517
1043	376430	548556	4517
1044	376439	548561	4518
1045	376448	548565	4518
1046	376457	548570	4518
1047	376466	548575	4518
1048	376474	548580	4518
1049	376483	548584	4519
1050	376492	548589	4519
1051	376501	548593	4519
1052	376510	548598	4519
1053	376518	548603	4520
1054	376527	548608	4520
1055	376536	548612	4520
1056	376545	548617	4520
1057	376554	548621	4520
1058	376563	548626	4520
1059	376571	548631	4520
1060	376580	548636	4520
1061	376589	548640	4520
1062	376598	548645	4521
1063	376607	548649	4521
1064	376615	548654	4521
1065	376624	548659	4521
1066	376633	548664	4522
1067	376642	548669	4522
1068	376651	548673	4521
1069	376660	548678	4522
1070	376669	548682	4522
1071	376677	548687	4521
1072	376686	548692	4522
1073	376695	548697	4522
1074	376704	548701	4522
1075	376713	548706	4523
1076	376722	548711	4523
1077	376730	548715	4523
1078	376739	548720	4523
1079	376748	548725	4523
1080	376757	548729	4523
1081	376766	548734	4523
1082	376775	548739	4524
1083	376784	548743	4524
1084	376792	548748	4524
1085	376801	548753	4524
1086	376810	548757	4524
1087	376819	548762	4525
1088	376828	548767	4525
1089	376837	548772	4525
1090	376845	548776	4525
1091	376854	548781	4525
1092	376863	548786	4525
1093	376872	548790	4525
1094	376881	548795	4526
1095	376890	548800	4527
1096	376898	548804	4527
1097	376907	548809	4528
1098	376916	548814	4528
1099	376925	548818	4528
1100	376934	548823	4528
1101	376942	548828	4528
1102	376951	548832	4528

1103	376960	548837	4528
1104	376969	548842	4528
1105	376978	548846	4529
1106	376987	548851	4529
1107	376995	548856	4529
1108	377004	548861	4529
1109	377013	548865	4529
1110	377022	548870	4529
1111	377031	548875	4529
1112	377040	548880	4529
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1117	377084	548903	4528
1118	377092	548907	4528
1119	377101	548912	4528
1120	377110	548917	4528
1121	377119	548922	4528
1122	377128	548926	4529
1123	377137	548931	4528
1124	377146	548936	4529
1125	377155	548940	4529
1126	377163	548945	4529
1127	377172	548950	4529
1128	377181	548954	4529
1129	377190	548959	4529
1130	377198	548964	4530
1131	377207	548968	4530
1132	377216	548973	4531
1133	377225	548978	4531
1134	377234	548982	4531
1135	377243	548987	4531
1136	377252	548992	4531
1137	377261	548997	4531
1138	377269	549001	4532
1139	377278	549006	4532
1140	377287	549011	4532
1141	377296	549015	4532
1142	377305	549020	4532
1143	377313	549025	4532
1144	377322	549029	4533
1145	377331	549034	4533
1146	377340	549039	4533
1147	377349	549043	4533
1148	377357	549048	4533
1149	377366	549053	4533
1150	377375	549058	4533
1151	377384	549062	4533
1152	377393	549067	4533
1153	377402	549072	4533
1154	377411	549076	4534
1155	377419	549081	4534
1156	377428	549086	4534
1157	377437	549090	4534
1158	377446	549095	4534
1159	377455	549100	4534
1160	377464	549104	4534
1161	377473	549109	4534
1162	377481	549114	4535
1163	377490	549119	4535
1164	377499	549123	4535
1165	377508	549128	4535
1166	377517	549132	4536
1167	377525	549137	4536
1168	377534	549142	4536
1169	377543	549146	4536
1170	377552	549151	4537
1171	377561	549156	4537
1172	377570	549161	4537
1173	377578	549165	4537
1174	377587	549170	4538
1175	377596	549175	4538
1176	377605	549179	4538
1177	377614	549184	4538
1178	377623	549189	4538
1179	377632	549193	4538
1180	377640	549198	4538
1181	377649	549203	4538
1182	377658	549207	4538
1183	377667	549212	4539
1184	377676	549217	4539
1185	377684	549222	4539
1186	377693	549226	4539
1187	377702	549231	4539
1188	377711	549236	4539
1189	377720	549240	4539
1190	377728	549245	4540
1191	377738	549250	4540
1192	377746	549255	4540
1193	377755	549259	4540
1194	377764	549264	4540
1195	377773	549268	4541
1196	377781	549273	4541
1197	377791	549278	4541
1198	377799	549282	4541
1199	377808	549287	4541
1200	377817	549292	4541
1201	377826	549297	4541
1202	377834	549301	4542
1203	377843	549306	4542
1204	377852	549311	4542
1205	377861	549315	4542
1206	377870	549320	4542
1207	377879	549325	4543
1208	377888	549330	4543
1209	377896	549334	4543
1210	377905	549339	4543
1211	377914	549343	4543
1212	377923	549348	4543
1213	377932	549353	4543
1214	377940	549357	4543
1215	377949	549362	4543
1216	377958	549367	4543

1217	377967	549372	4544
1218	377976	549376	4544
1219	377984	549381	4544
1220	377993	549386	4544
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1222	378011	549395	4544
1223	378020	549400	4545
1224	378029	549405	4545
1225	378038	549409	4545
1226	378046	549414	4545
1227	378055	549419	4545
1228	378064	549423	4546
1229	378073	549428	4546
1230	378082	549433	4546
1231	378090	549437	4546
1232	378099	549442	4547
1233	378108	549447	4547
1234	378117	549451	4547
1235	378126	549456	4547
1236	378135	549461	4548
1237	378144	549465	4548
1238	378152	549470	4548
1239	378161	549475	4547
1240	378170	549479	4548
1241	378179	549484	4548
1242	378188	549489	4548
1243	378196	549493	4548
1244	378205	549498	4548
1245	378214	549503	4548
1246	378223	549507	4549
1247	378232	549512	4549
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1256	378312	549554	4551
1257	378320	549559	4551
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1265	378391	549597	4552
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1267	378409	549606	4553
1268	378417	549611	4553
1269	378426	549616	4553
1270	378435	549620	4553
1271	378444	549625	4554
1272	378453	549629	4553
1273	378462	549634	4554
1274	378471	549639	4554
1275	378479	549644	4553
1276	378488	549648	4554
1277	378497	549653	4554
1278	378506	549658	4555
1279	378515	549662	4554
1280	378523	549667	4555
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1284	378559	549685	4556
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1288	378594	549704	4558
1289	378603	549709	4558
1290	378612	549714	4558
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1292	378629	549723	4559
1293	378638	549728	4559
1294	378647	549732	4560
1295	378656	549737	4560
1296	378665	549742	4560
1297	378674	549747	4561
1298	378682	549751	4561
1299	378691	549756	4561
1300	378700	549761	4562
1301	378709	549766	4562
1302	378718	549770	4562
1303	378727	549774	4562
1304	378735	549779	4562
1305	378744	549784	4563
1306	378753	549789	4563
1307	378762	549793	4563
1308	378771	549798	4563
1309	378780	549803	4563
1310	378788	549807	4564
1311	378797	549812	4564
1312	378806	549817	4564
1313	378815	549821	4564
1314	378823	549826	4564
1315	378832	549831	4565
1316	378841	549836	4565
1317	378850	549840	4565
1318	378859	549845	4566
1319	378868	549850	4566
1320	378877	549854	4566
1321	378886	549859	4566
1322	378895	549864	4567
1323	378903	549868	4567
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1325	378921	549878	4567
1326	378930	549883	4567
1327	378938	549887	4567
1328	378947	549892	4567
1329	378956	549897	4568
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1332	378983	549911	4568
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1334	379000	549920	4568
1335	379009	549925	4568
1336	379018	549930	4568
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1349	379133	549990	4569
1350	379142	549995	4569
1351	379150	550000	4568
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1367	379292	550075	4573
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1371	379327	550093	4574
1372	379336	550098	4575
1373	379345	550103	4575
1374	379354	550108	4575
1375	379363	550113	4576
1376	379371	550117	4576
1377	379380	550122	4576
1378	379389	550126	4576
1379	379398	550131	4577
1380	379407	550135	4577
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1382	379425	550145	4577
1383	379433	550150	4577
1384	379442	550154	4577
1385	379451	550159	4577
1386	379460	550164	4577
1387	379468	550168	4577
1388	379478	550173	4577
1389	379486	550178	4577
1390	379495	550182	4577
1391	379504	550187	4577
1392	379513	550192	4577
1393	379521	550197	4577
1394	379530	550201	4577
1395	379539	550206	4577
1396	379548	550211	4578
1397	379557	550215	4578
1398	379566	550220	4578
1399	379575	550225	4579
1400	379583	550229	4579
1401	379592	550234	4579
1402	379601	550239	4580
1403	379610	550244	4580
1404	379619	550248	4580
1405	379628	550253	4580
1406	379636	550257	4580
1407	379645	550262	4580
1408	379654	550267	4580
1409	379663	550272	4580
1410	379672	550276	4580
1411	379680	550281	4580
1412	379689	550286	4579
1413	379698	550291	4580
1414	379707	550295	4580
1415	379716	550300	4580
1416	379724	550304	4581
1417	379733	550309	4581
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1419	379751	550318	4582
1420	379760	550323	4582
1421	379769	550328	4582
1422	379778	550333	4583
1423	379786	550337	4583
1424	379795	550342	4583
2001	375713	549219	4504
2002	375722	549224	4504
2003	375731	549228	4504
2004	375740	549233	4504
2005	375749	549238	4504
2006	375757	549242	4505
2007	375766	549247	4505
2008	375775	549252	4505
2009	375784	549256	4505
2010	375793	549261	4506
2011	375802	549266	4506
2012	375811	549271	4506
2013	375820	549275	4506
2014	375828	549280	4507
2015	375837	549285	4507
2016	375846	549289	4507
2017	375854	549294	4507
2018	375863	549299	4508
2019	375872	549303	4508
2020	375881	549308	4508

2021	375890	549313	4508	2078	376394	549580	4517
2022	375899	549317	4508	2079	376403	549585	4518
2023	375908	549322	4508	2080	376411	549589	4517
2024	375917	549327	4508	2081	376420	549594	4518
2025	375926	549331	4508	2082	376429	549598	4518
2026	375934	549336	4509	2083	376438	549603	4518
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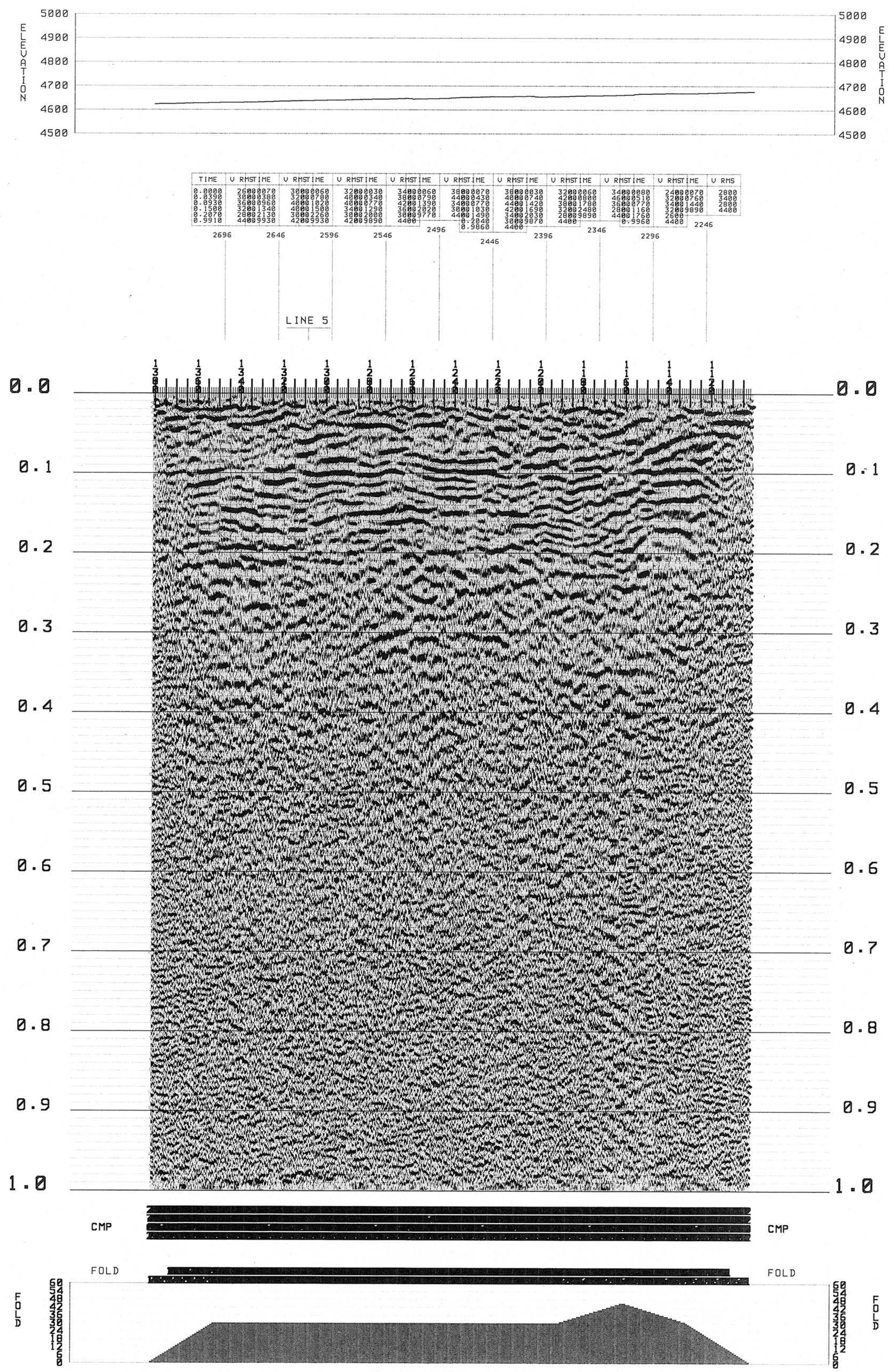

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HONEYWELL TECHNOLOGY SOLUTIONS, INC.

WHITE SANDS TEST FACILTY
LINE 1
DONA ANNA, NM
FINAL STACK

FIELD PARAMETERS

RECORDING PARAMETERS

RECORDED BY	SUBSURFACE EXPL	DATE RECORDED	NOV 2000
INSTRUMENTS	GEOCOR IV	NOTCH FILTER	
RECORD LENGTH	8.0 SEC	SAMPLE RATE	1 MSEC

SOURCE PARAMETERS

SOURCE	VIBROSEIS	SWEEP FREQ	40-160/80-180
SWEEP LENGTH	6.0 SEC		

GEOMETRY

GP INTERVAL	10 FT.	SP INTERVAL	20 FT.

SPREAD

O---------------X---------------O
X---------------S---------------X
TR 1 590 — 60 0 — 120 TR 600 FT

PROCESSING SEQUENCE

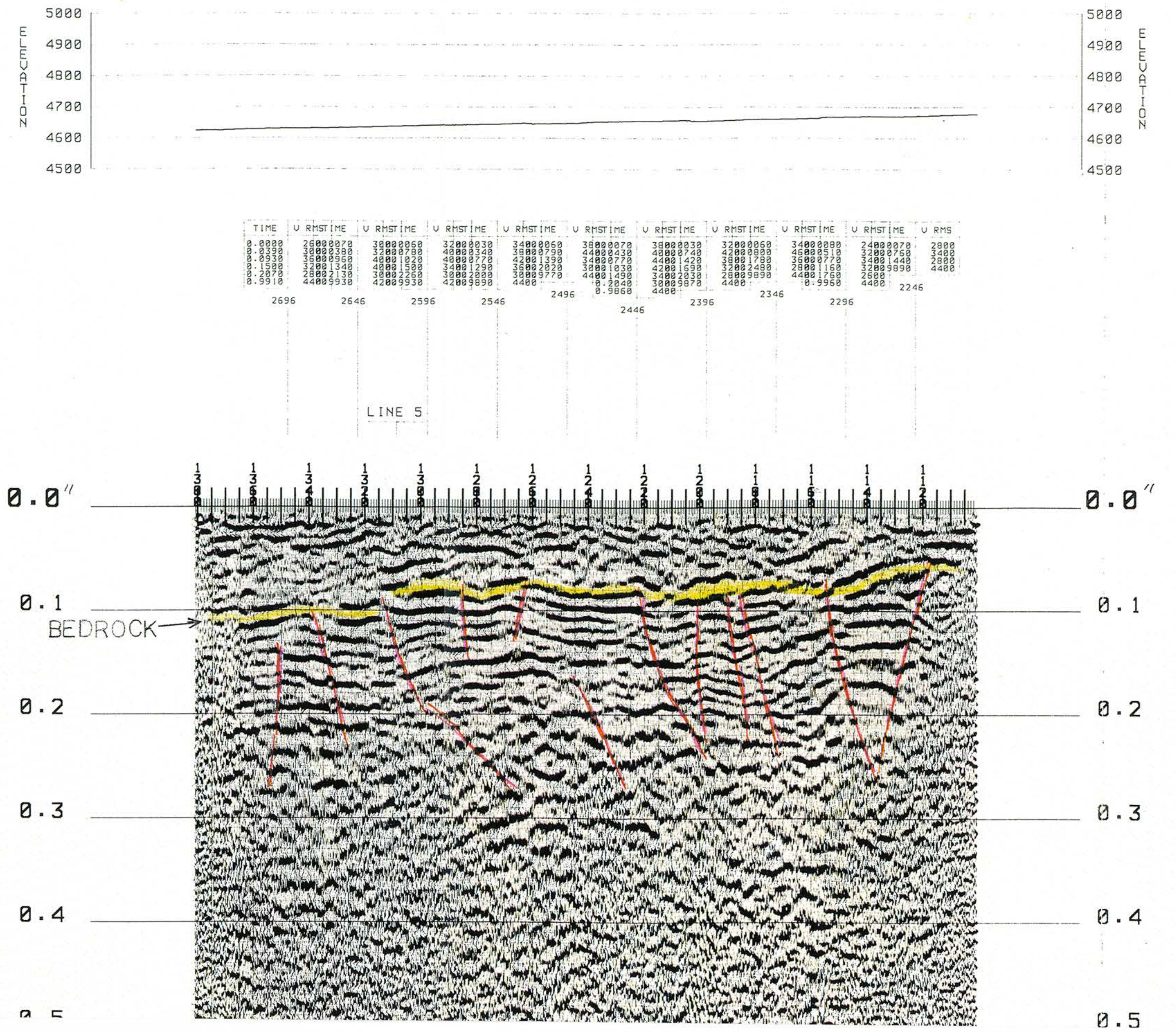
GEOMETRY DEFINITION
TRUE AMPLITUDE RECOVERY
DATUM STATICS
DATUM: 4600 VELOCITY: 3000
VELOCITY ANALYSIS
NORMAL MOVEOUT
AUTOMATIC SURFACE CONSISTENT STATICS
VELOCITY ANALYSIS
AUTOMATIC RESIDUAL STATICS
CDP STACK
FX DECON

DISPLAY PARAMETERS

PROCESSED BY:	D. LAWRENCE		
DATE PROCESSED	JAN 2001	POLARITY	NORMAL
VERTICAL SCALE	10.0 IN/SEC	HORIZ SCALE	72 TR/IN

PINNACLE SEISMIC LTD.

THE ROHILL BUILDING
3100 NORTH A, SUITE 135
MIDLAND, TEXAS 79705
(915) 682-3685



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HONEYWELL TECHNOLOGY SOLUTIONS, INC.

WHITE SANDS TEST FACILTY
LINE 1
DONA ANNA, NM
FINAL STACK

FIELD PARAMETERS

RECORDING PARAMETERS

RECORDED BY	SUBSURFACE EXPL	DATE RECORDED	NOV 2000
INSTRUMENTS	GEOCOR IV	NOTCH FILTER	
RECORD LENGTH	8.0 SEC	SAMPLE RATE	1 MSEC

SOURCE PARAMETERS

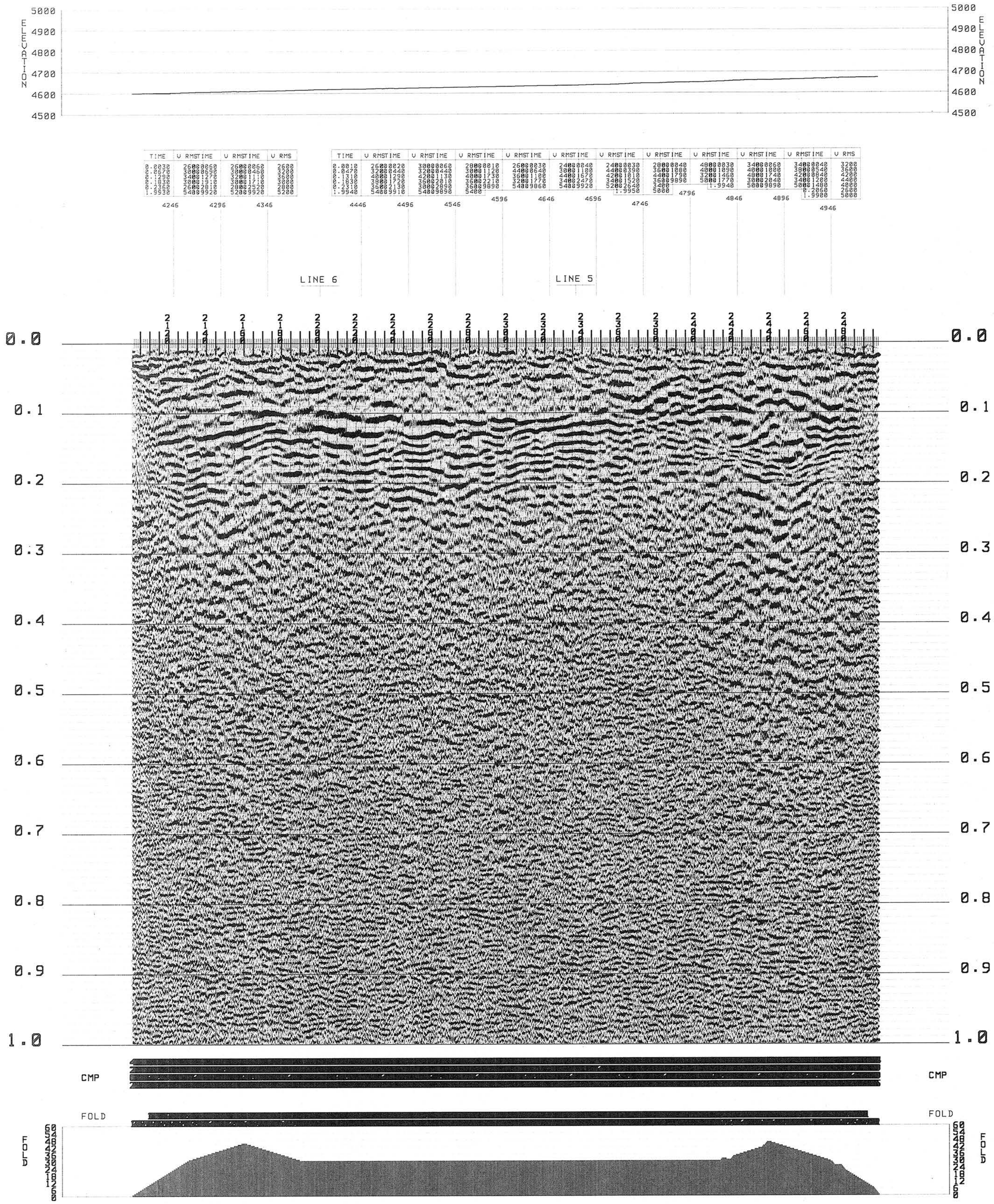
SOURCE	VIBROSEIS	SWEEP FREQ	40-160/80-180
SWEEP LENGTH	6.0 SEC		

GEOMETRY

GP INTERVAL	10 FT.	SP INTERVAL	20 FT.

SPREAD

O-----------X-----------O
X-----------S-----------X
TR 1 590 — 60 0 — 120 TR 600 FT



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HONEYWELL TECHNOLOGY SOLUTIONS, INC.

WHITE SANDS TEST FACILTY
LINE 2
DONA ANNA, NM
FINAL STACK

FIELD PARAMETERS

RECORDING PARAMETERS

RECORDED BY	SUBSURFACE EXPL	DATE RECORDED	NOV 2000
INSTRUMENTS	GEOCOR IV	NOTCH FILTER	
RECORD LENGTH	8.0 SEC	SAMPLE RATE	1 MSEC

SOURCE PARAMETERS

SOURCE	VIBROSEIS	SWEEP FREQ	40-160/80-180
SWEEP LENGTH	6.0 SEC		

GEOMETRY

GP INTERVAL 10 FT. SP INTERVAL 20 FT.

SPREAD

TR 1 590 — 60 0 — 120 TR 600 FT

PROCESSING SEQUENCE

GEOMETRY DEFINITION
TRUE AMPLITUDE RECOVERY
DATUM STATICS
DATUM: 4600 VELOCITY: 3000
VELOCITY ANALYSIS
NORMAL MOVEOUT
AUTOMATIC SURFACE CONSISTENT STATICS
VELOCITY ANALYSIS
AUTOMATIC RESIDUAL STATICS
CDP STACK
FX DECON

DISPLAY PARAMETERS

PROCESSED BY:	D. LAWRENCE		
DATE PROCESSED	JAN 2001	POLARITY	NORMAL
VERTICAL SCALE	10.0 IN/SEC	HORIZ SCALE	72 TR/IN

PINNACLE SEISMIC LTD.
THE ROHILL BUILDING
3100 NORTH A, SUITE 135
MIDLAND, TEXAS 79705
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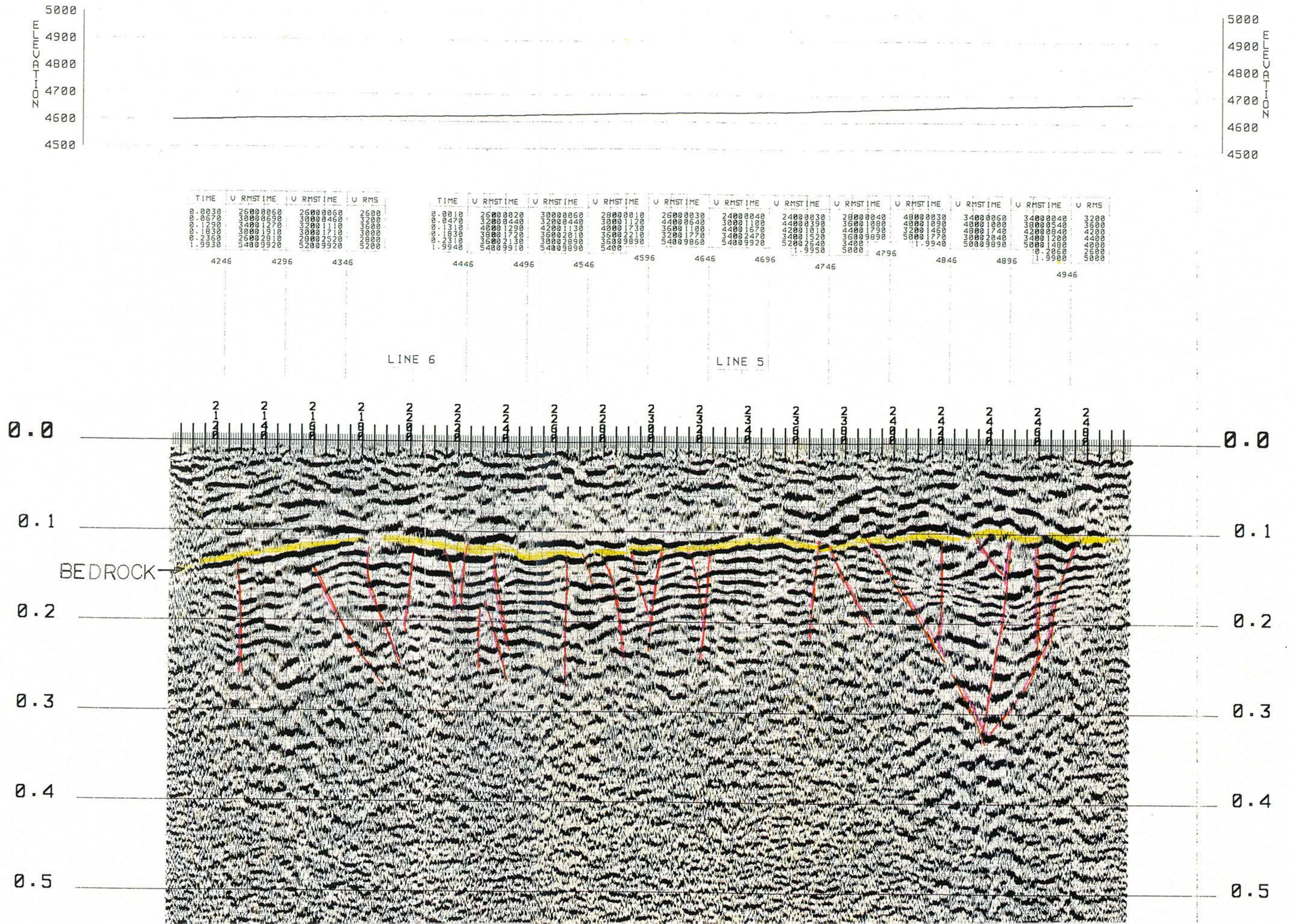

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HONEYWELL TECHNOLOGY SOLUTIONS, INC.

WHITE SANDS TEST FACILTY

LINE 2

DONA ANNA, NM

FINAL STACK

FIELD PARAMETERS

RECORDING PARAMETERS

RECORDED BY	SUBSURFACE EXPL	DATE RECORDED	NOV 2000
INSTRUMENTS	GEOCOR IV	NOTCH FILTER	
RECORD LENGTH	8.0 SEC	SAMPLE RATE	1 MSEC

SOURCE PARAMETERS

SOURCE	VIBROSEIS	SWEEP FREQ	40-160/80-180
SWEEP LENGTH	6.0 SEC		

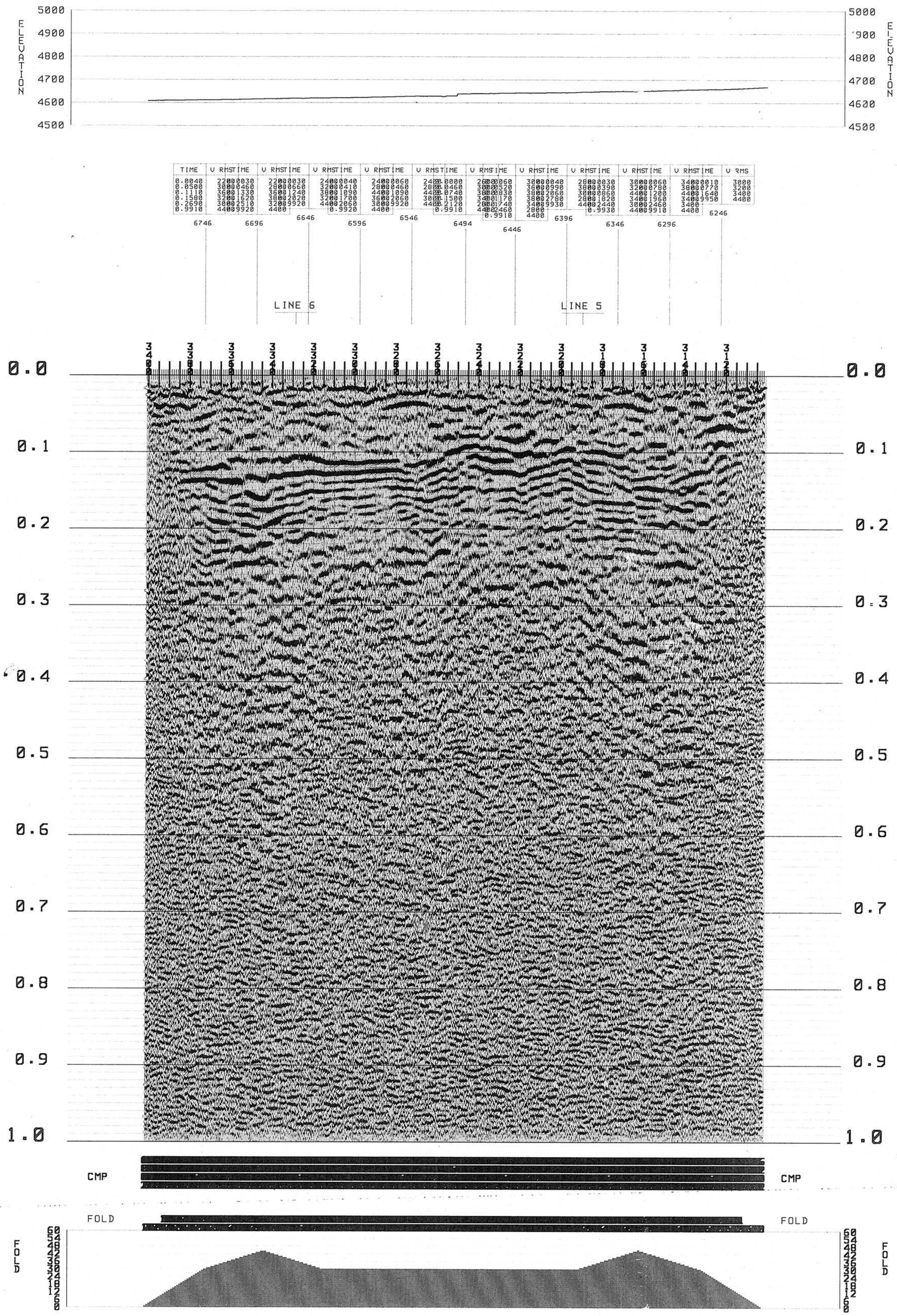
GEOMETRY

GP INTERVAL	10 FT.	SP INTERVAL	20 FT.

SPREAD

O---------------------X---------------------O
X---------------------S---------------------X
TR 1 60 120 TR
590 0 600 FT

PROCESSING SEQUENCE



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HONEYWELL TECHNOLOGY SOLUTIONS, INC.

WHITE SANDS TEST FACILTY

LINE 3

DONA ANNA, NM

FINAL STACK

FIELD PARAMETERS

RECORDING PARAMETERS

RECORDED BY	SUBSURFACE EXPL	DATE RECORDED	NOV 2000
INSTRUMENTS	GEOCOR IV	NOTCH FILTER	
RECORD LENGTH	8.0 SEC	SAMPLE RATE	1 MSEC

SOURCE PARAMETERS

SOURCE	VIBROSEIS	SWEEP FREQ	40-160/80-180
SWEEP LENGTH	6.0 SEC		

GEOMETRY

GP INTERVAL	10 FT.	SP INTERVAL	20 FT.

SPREAD

O-----------------X-----------------O
TR 1 590 — S 60 0 — 120 TR 600 FT

PROCESSING SEQUENCE

GEOMETRY DEFINITION
TRUE AMPLITUDE RECOVERY
DATUM STATICS
DATUM: 4600 VELOCITY: 3000
VELOCITY ANALYSIS
NORMAL MOVEOUT
AUTOMATIC SURFACE CONSISTENT STATICS
VELOCITY ANALYSIS
AUTOMATIC RESIDUAL STATICS
CDP STACK
FX DECON

DISPLAY PARAMETERS

PROCESSED BY:	D. LAWRENCE		
DATE PROCESSED	JAN 2001	POLARITY	NORMAL
VERTICAL SCALE	10.0 IN/SEC	HORIZ SCALE	72 TR/IN

PINNACLE SEISMIC LTD.
THE ROHILL BUILDING
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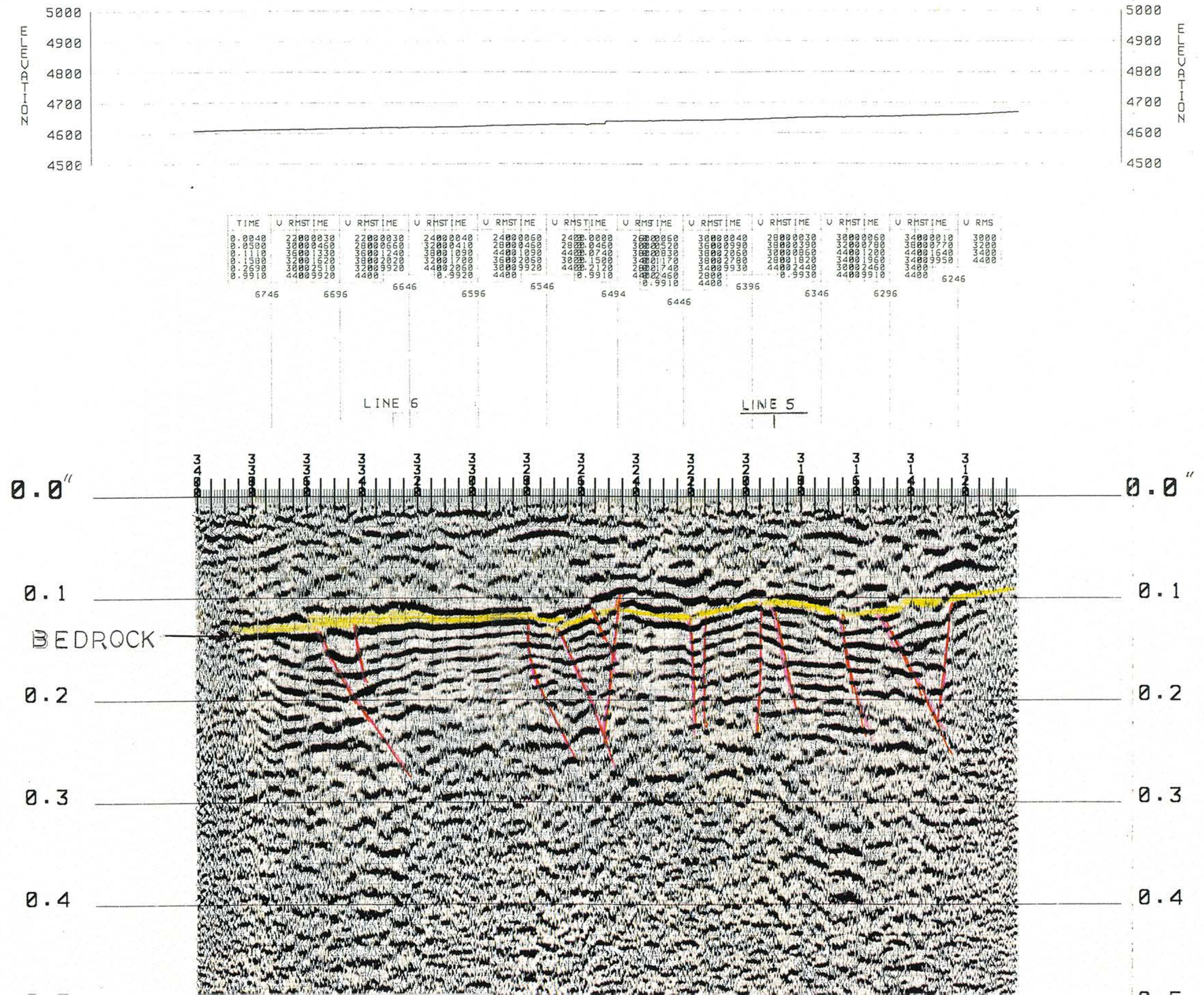

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HONEYWELL TECHNOLOGY SOLUTIONS, INC.

WHITE SANDS TEST FACILTY
LINE 3
DONA ANNA, NM
FINAL STACK

FIELD PARAMETERS

RECORDING PARAMETERS

RECORDED BY	SUBSURFACE EXPL	DATE RECORDED	NOV 2000
INSTRUMENTS	GEOCOR IV	NOTCH FILTER	
RECORD LENGTH	8.0 SEC	SAMPLE RATE	1 MSEC

SOURCE PARAMETERS

SOURCE	VIBROSEIS	SWEEP FREQ	40-160/80-180
SWEEP LENGTH	6.0 SEC		

GEOMETRY

GP INTERVAL	10 FT.	SP INTERVAL	20 FT.

SPREAD

```
O---------------------------X---------------------------O
X---------------------------S---------------------------X
TR 1                        60                     120 TR
590                         0                      600 FT
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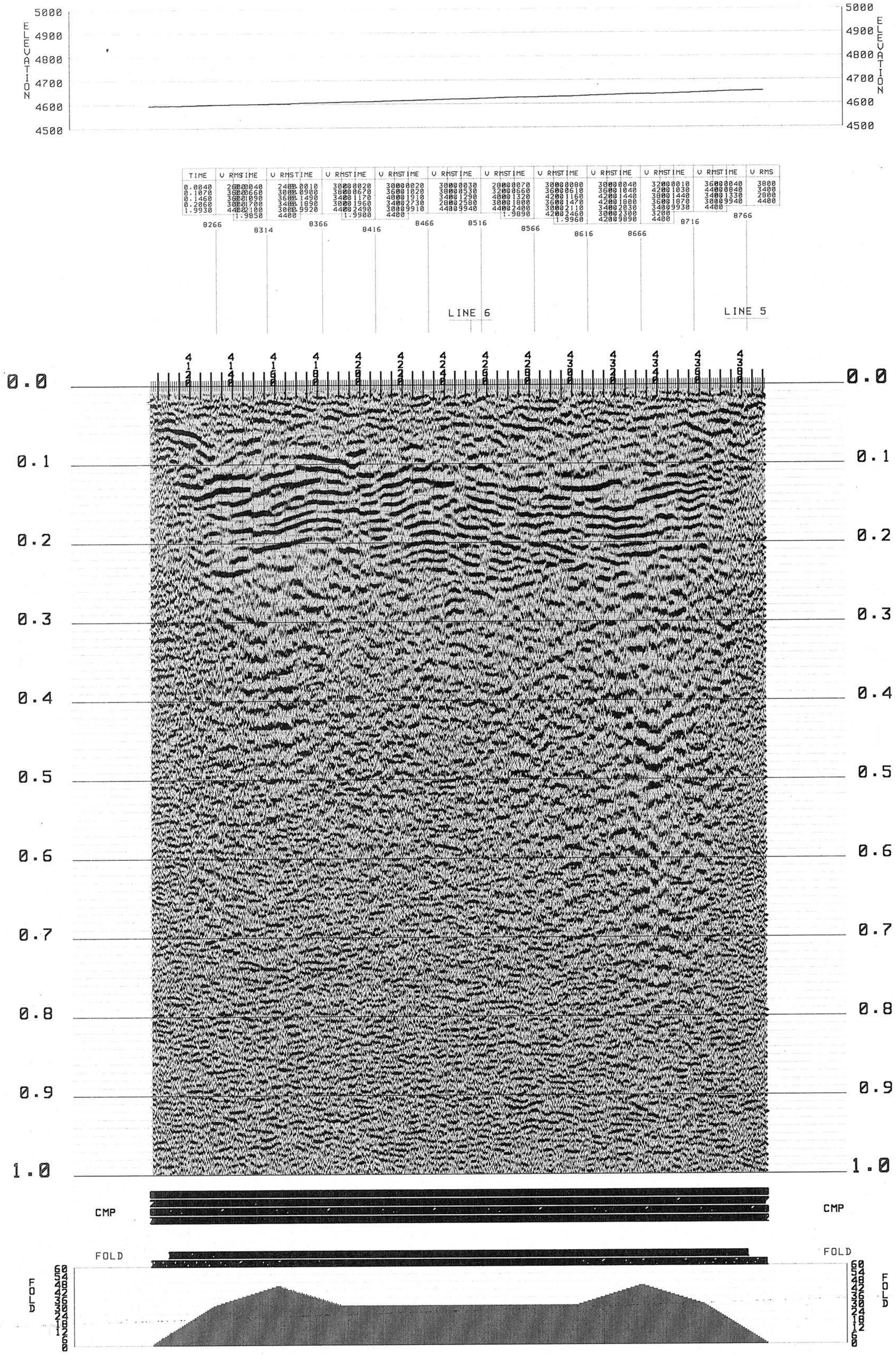

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HONEYWELL TECHNOLOGY SOLUTIONS, INC.

WHITE SANDS TEST FACILTY

LINE 4

DONA ANNA, NM

FINAL STACK

FIELD PARAMETERS

RECORDING PARAMETERS

RECORDED BY	SUBSURFACE EXPL	DATE RECORDED	NOV 2000
INSTRUMENTS	GEOCOR IV	NOTCH FILTER	
RECORD LENGTH	8.0 SEC	SAMPLE RATE	1 MSEC

SOURCE PARAMETERS

SOURCE	VIBROSEIS	SWEEP FREQ	40-160/80-180
SWEEP LENGTH	6.0 SEC		

GEOMETRY

GP INTERVAL 10 FT. SP INTERVAL 20 FT.

SPREAD

O-----X-----O
X-----S-----X
TR 1 60 120 TR
590 0 600 FT

PROCESSING SEQUENCE

GEOMETRY DEFINITION

TRUE AMPLITUDE RECOVERY

DATUM STATICS
DATUM: 4600 VELOCITY: 3000

VELOCITY ANALYSIS

NORMAL MOVEOUT

AUTOMATIC SURFACE CONSISTENT STATICS

VELOCITY ANALYSIS

AUTOMATIC RESIDUAL STATICS

CDP STACK

FX DECON

DISPLAY PARAMETERS

PROCESSED BY:	D. LAWRENCE		
DATE PROCESSED	JAN 2001	POLARITY	NORMAL
VERTICAL SCALE	10.0 IN/SEC	HORIZ SCALE	72 TR/IN

PINNACLE SEISMIC LTD.
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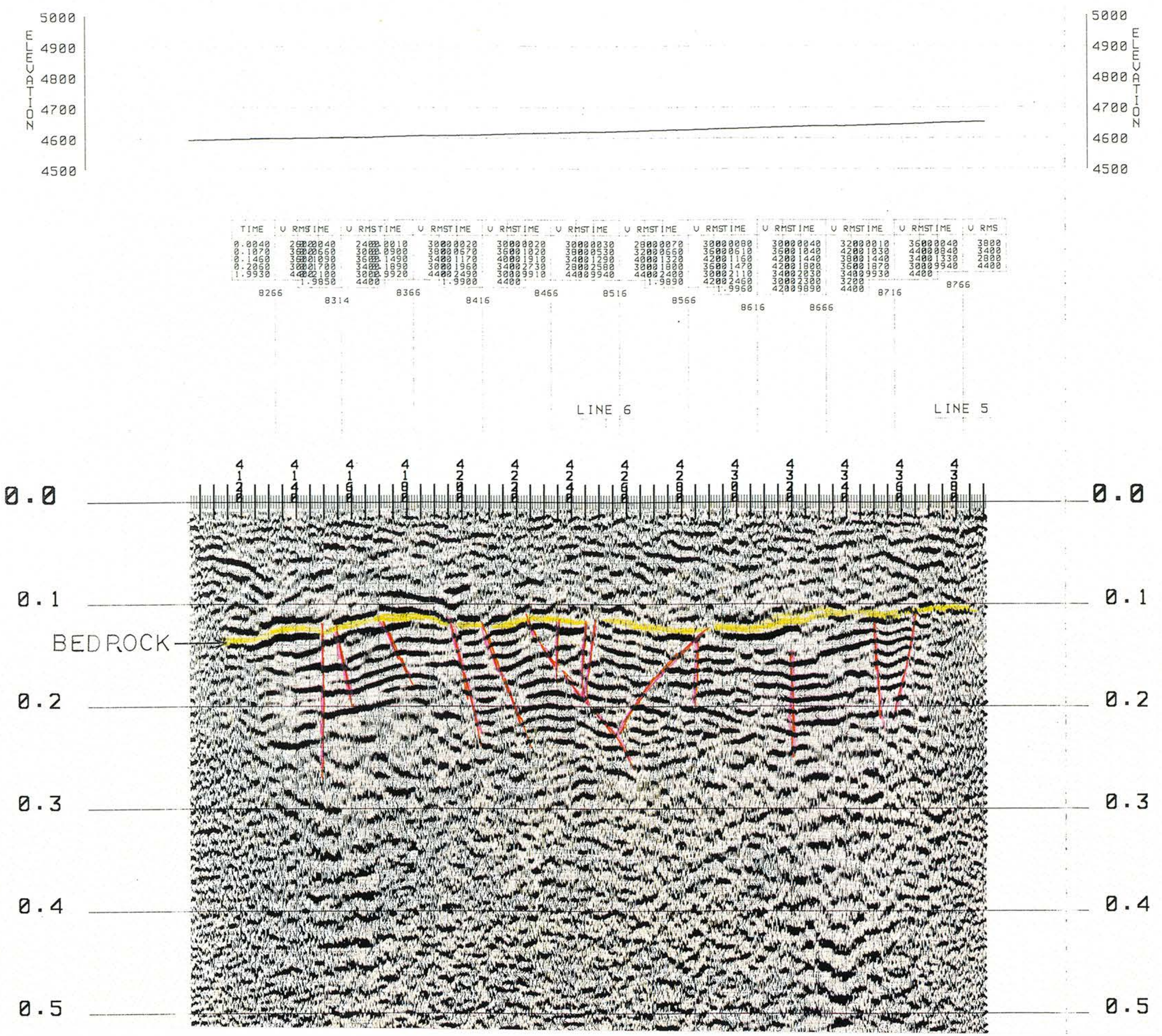
(915) 682-3685



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HONEYWELL TECHNOLOGY SOLUTIONS, INC.

WHITE SANDS TEST FACILTY

LINE 4

DONA ANNA, NM

FINAL STACK

FIELD PARAMETERS

RECORDING PARAMETERS

RECORDED BY	SUBSURFACE EXPL	DATE RECORDED	NOV 2000
INSTRUMENTS	GEOCOR IV	NOTCH FILTER	
RECORD LENGTH	8.0 SEC	SAMPLE RATE	1 MSEC

SOURCE PARAMETERS

SOURCE	VIBROSEIS	SWEEP FREQ	40-160/80-180
SWEEP LENGTH	6.0 SEC		

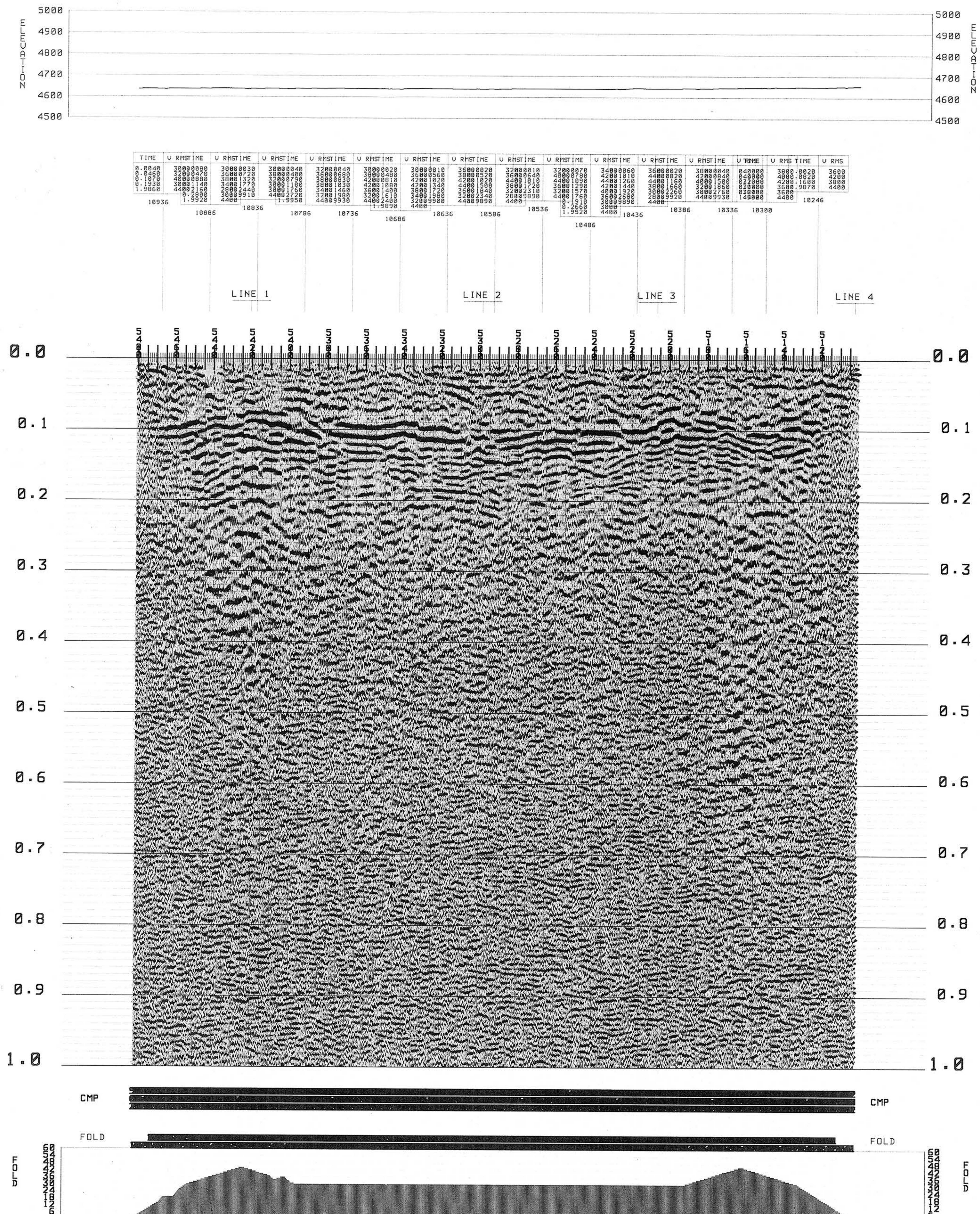
GEOMETRY

GP INTERVAL	10 FT.	SP INTERVAL	20 FT.

SPREAD

```
O-------------------------X-------------------------O
X-------------------------S-------------------------X
TR 1                      60                   120 TR
590                       0                    600 FT
```

PROCESSING SEQUENCE



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HONEYWELL TECHNOLOGY SOLUTIONS, INC.

WHITE SANDS TEST FACILTY
LINE 5
DONA ANNA, NM
FINAL STACK

FIELD PARAMETERS

RECORDING PARAMETERS

RECORDED BY	SUBSURFACE EXPL	DATE RECORDED	NOV 2000
INSTRUMENTS	GEOCOR IV	NOTCH FILTER	
RECORD LENGTH	8.0 SEC	SAMPLE RATE	1 MSEC

SOURCE PARAMETERS

SOURCE	VIBROSEIS	SWEEP FREQ	40-160/80-180
SWEEP LENGTH	6.0 SEC		

GEOMETRY

GP INTERVAL	10 FT.	SP INTERVAL	20 FT.

SPREAD

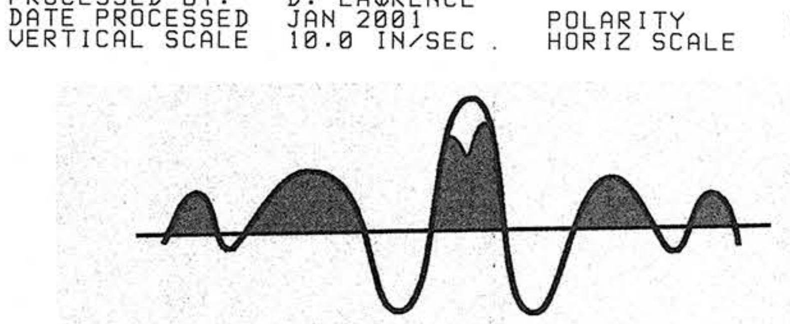
O-----X-----O
TR 1 590 — 60 0 — 120 TR 600 FT

PROCESSING SEQUENCE

GEOMETRY DEFINITION
TRUE AMPLITUDE RECOVERY
DATUM STATICS
DATUM: 4600 VELOCITY: 3000
VELOCITY ANALYSIS
NORMAL MOVEOUT
AUTOMATIC SURFACE CONSISTENT STATICS
VELOCITY ANALYSIS
AUTOMATIC RESIDUAL STATICS
CDP STACK
FX DECON

DISPLAY PARAMETERS

PROCESSED BY:	D. LAWRENCE		
DATE PROCESSED	JAN 2001	POLARITY	NORMAL
VERTICAL SCALE	10.0 IN/SEC	HORIZ SCALE	72 TR/IN



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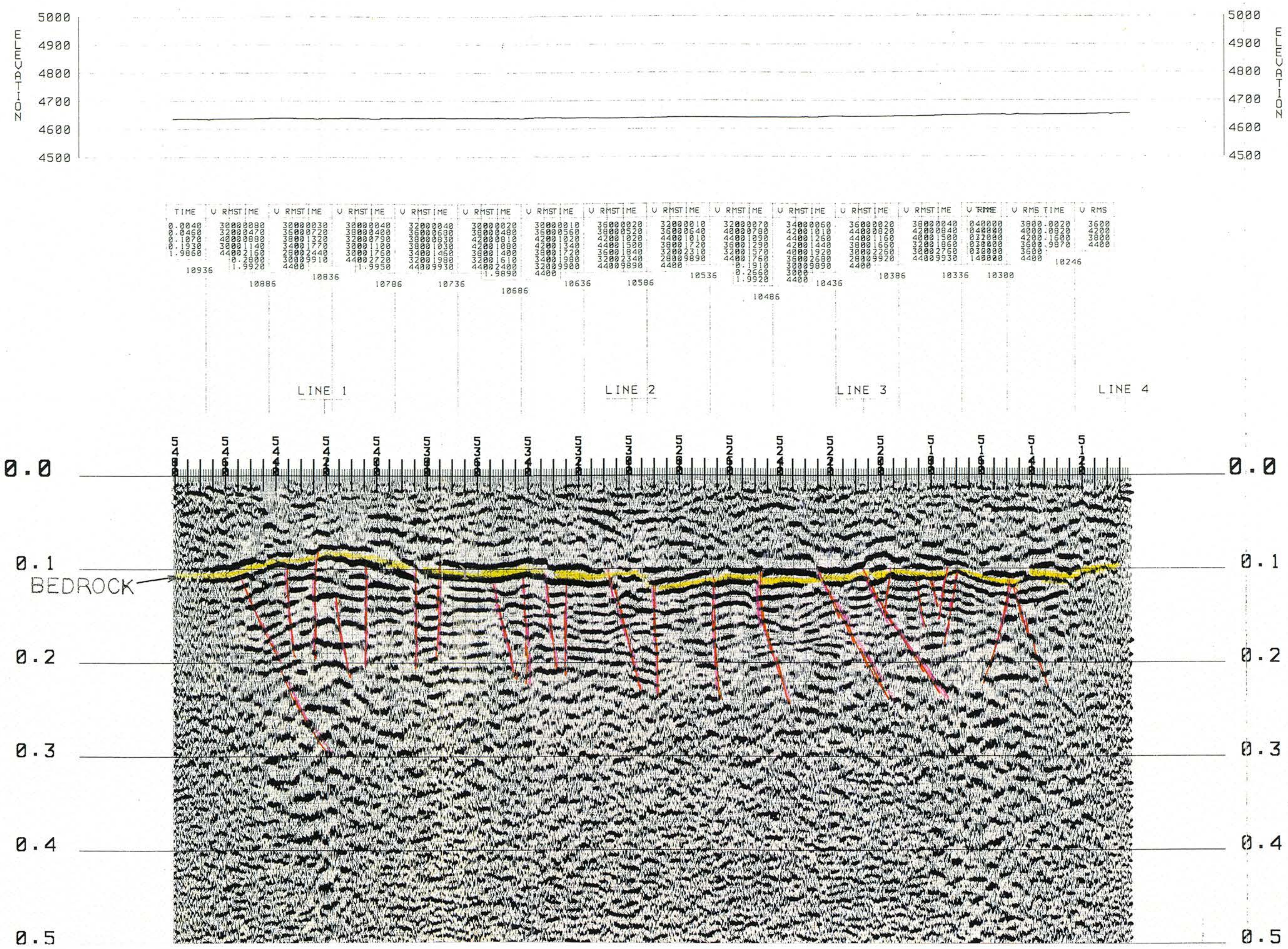

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HONEYWELL TECHNOLOGY SOLUTIONS, INC.

WHITE SANDS TEST FACILTY

LINE 5

DONA ANNA, NM

FINAL STACK

FIELD PARAMETERS

RECORDING PARAMETERS

RECORDED BY	SUBSURFACE EXPL	DATE RECORDED	NOV 2000
INSTRUMENTS	GEOCOR IV	NOTCH FILTER	
RECORD LENGTH	8.0 SEC	SAMPLE RATE	1 MSEC

SOURCE PARAMETERS

SOURCE	VIBROSEIS	SWEEP FREQ	40-160/80-180
SWEEP LENGTH	6.0 SEC		

GEOMETRY

GP INTERVAL 10 FT. SP INTERVAL 20 FT.

SPREAD

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0----------------------------X---------------------------0
X----------------------------S---------------------------X
TR 1                         60                       120 TR
590                          0                        600 FT
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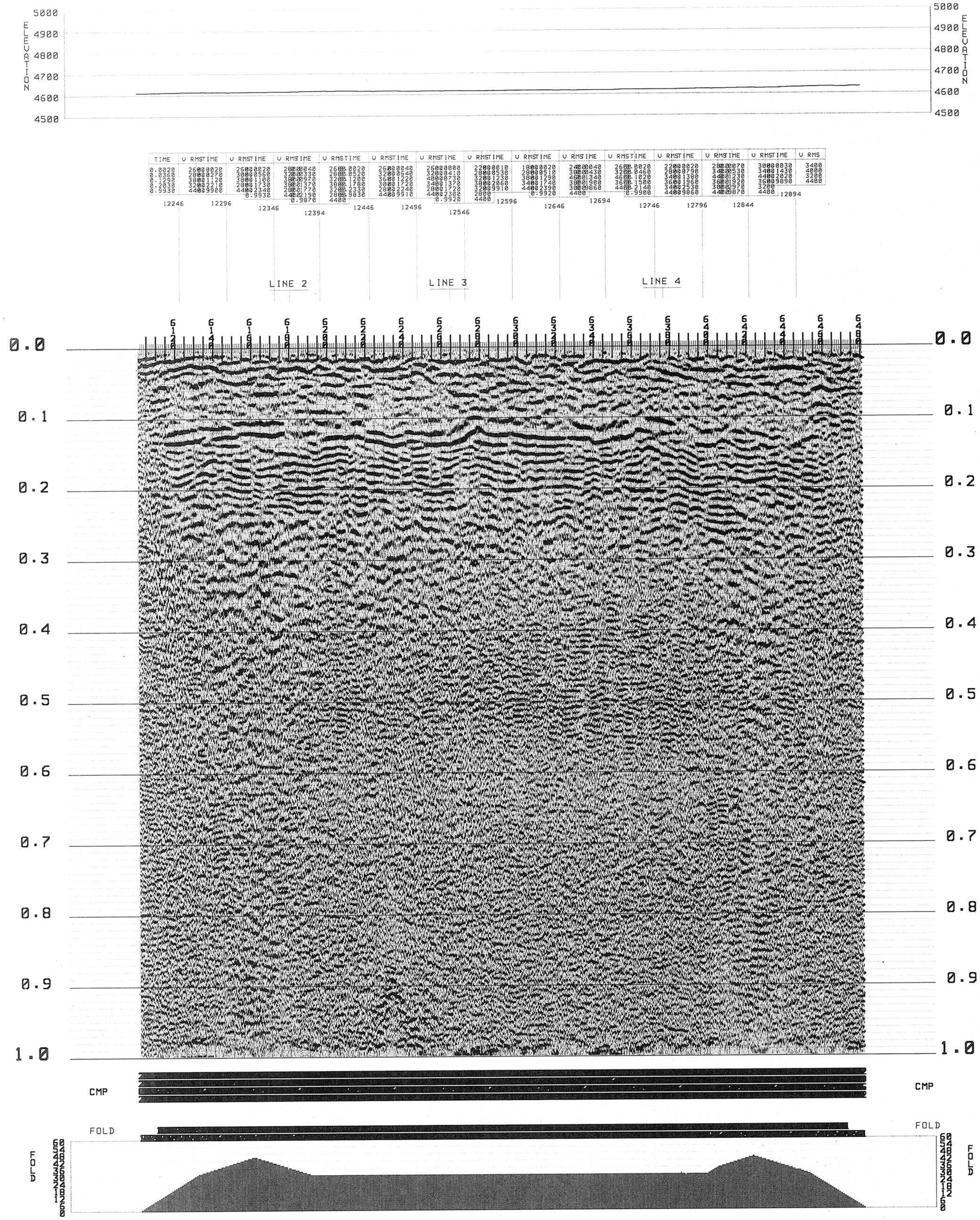
PROCESSING SEQUENCE



-----NORTH---->

HONEYWELL TECHNOLOGY SOLUTIONS, INC.

WHITE SANDS TEST FACILTY
LINE 6
DONA ANNA, NM
FINAL STACK

FIELD PARAMETERS

RECORDING PARAMETERS

RECORDED BY	SUBSURFACE EXPL	DATE RECORDED	NOV 2000
INSTRUMENTS	GEOCOR IV	NOTCH FILTER	
RECORD LENGTH	8.0 SEC	SAMPLE RATE	1 MSEC

SOURCE PARAMETERS

SOURCE	VIBROSEIS	SWEEP FREQ	40-160/80-180
SWEEP LENGTH	6.0 SEC		

GEOMETRY

GP INTERVAL	10 FT.	SP INTERVAL	20 FT.

SPREAD

O----------------------------X----------------------------O
X----------------------------S----------------------------X
TR 1 590 — 60 0 — 120 TR 600 FT

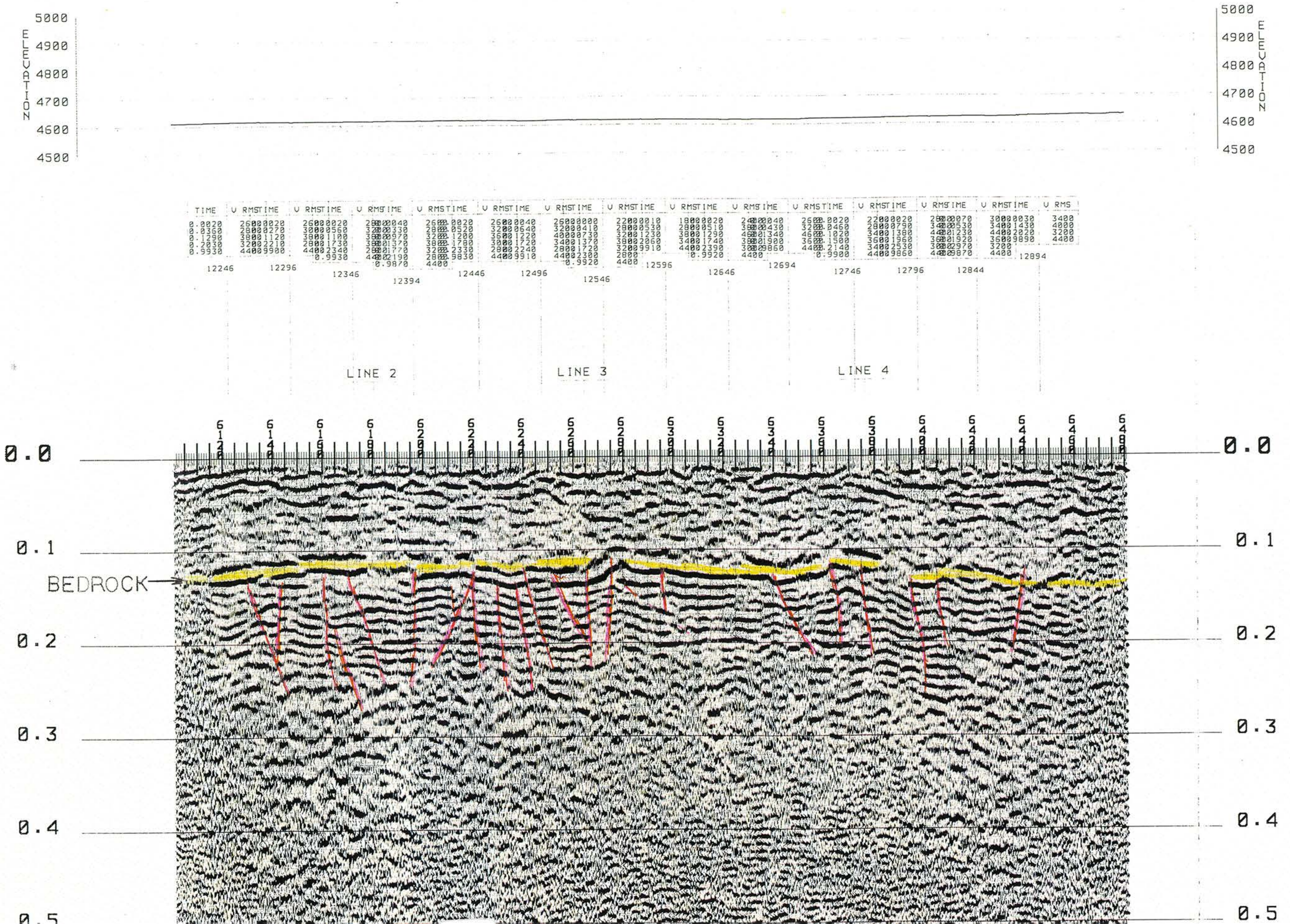
PROCESSING SEQUENCE

GEOMETRY DEFINITION
TRUE AMPLITUDE RECOVERY
DATUM STATICS DATUM: 4600 VELOCITY: 3000
VELOCITY ANALYSIS
NORMAL MOVEOUT
AUTOMATIC SURFACE CONSISTENT STATICS
VELOCITY ANALYSIS
AUTOMATIC RESIDUAL STATICS
CDP STACK
FX DECON

DISPLAY PARAMETERS

PROCESSED BY:	D. LAWRENCE		
DATE PROCESSED	JAN 2001	POLARITY	NORMAL
VERTICAL SCALE	10.0 IN/SEC	HORIZ SCALE	72 TR/IN

PINNACLE SEISMIC LTD.
THE ROHILL BUILDING
3100 NORTH A, SUITE 135
MIDLAND, TEXAS 79705
(915) 682-3685



-----NORTH---->

HONEYWELL TECHNOLOGY SOLUTIONS, INC.

WHITE SANDS TEST FACILTY

LINE 6

DONA ANNA, NM

FINAL STACK

FIELD PARAMETERS

RECORDING PARAMETERS

RECORDED BY	SUBSURFACE EXPL	DATE RECORDED	NOV 2000
INSTRUMENTS	GEOCOR IV	NOTCH FILTER	
RECORD LENGTH	8.0 SEC	SAMPLE RATE	1 MSEC

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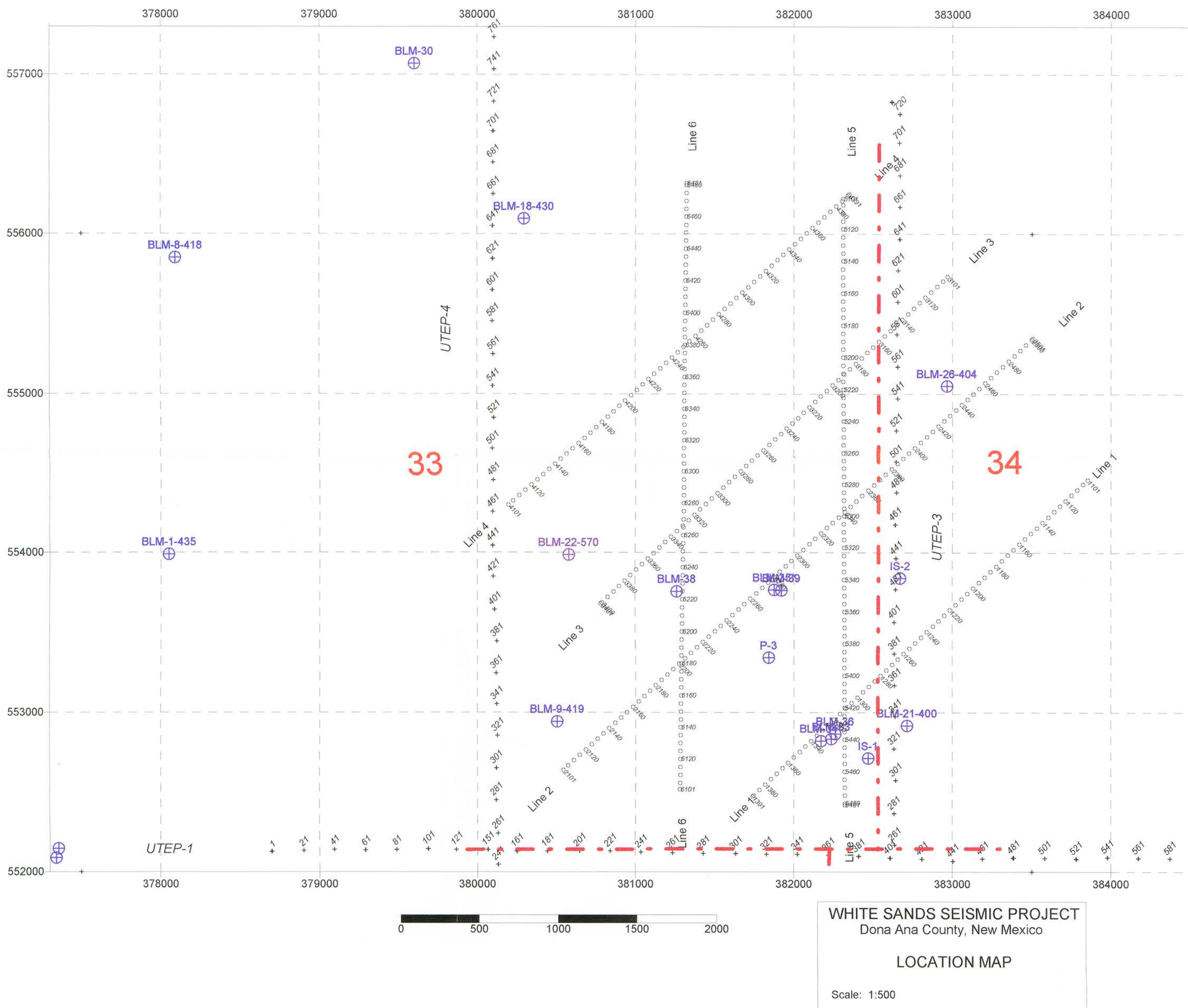
GEOMETRY

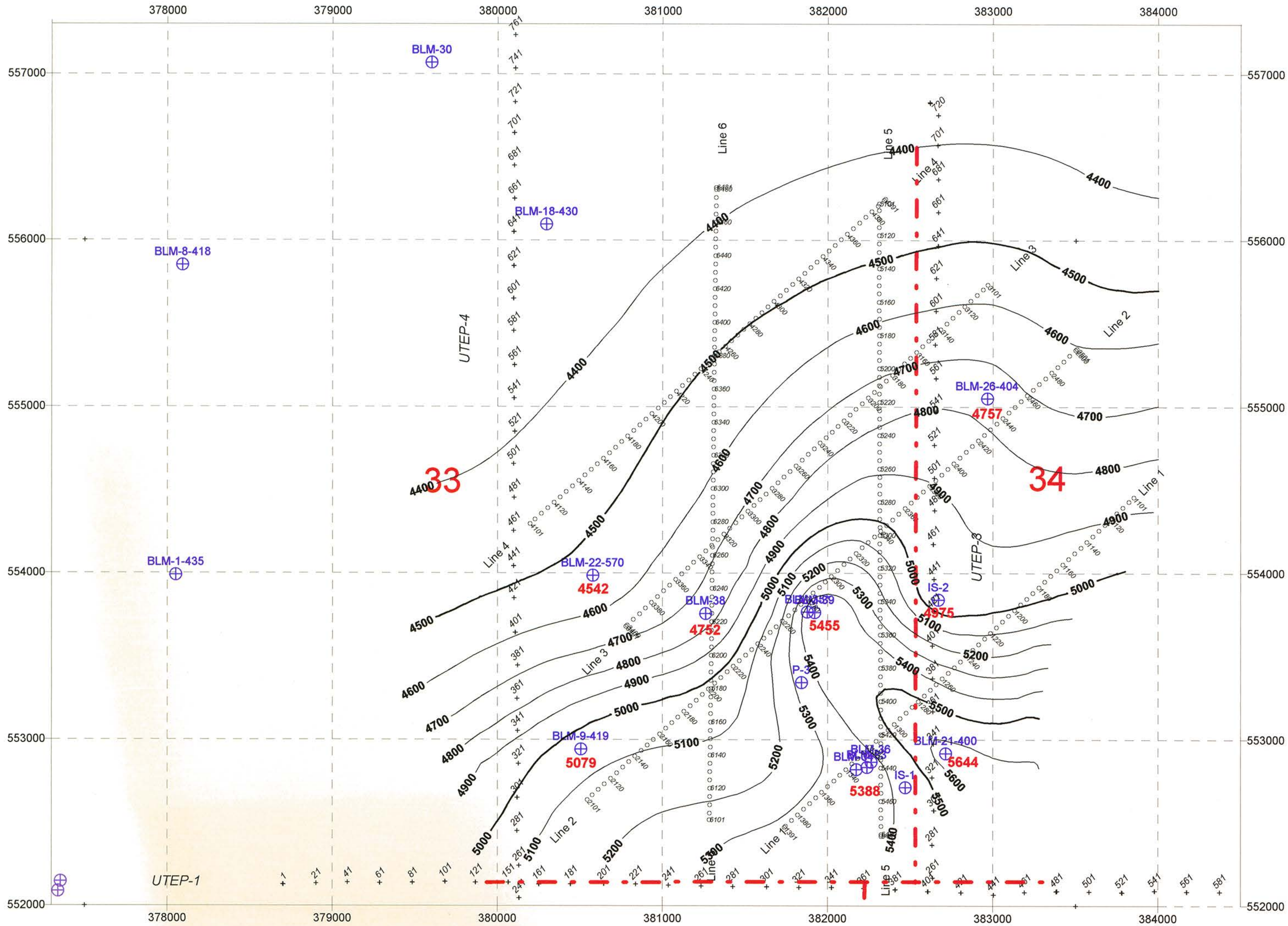
GP INTERVAL 10 FT. SP INTERVAL 20 FT.

SPREAD

O----------------X----------------O
X----------------S----------------X
TR 1 60 120 TR
590 0 600 FT



WHITE SANDS SEISMIC PROJECT
Dona Ana County, New Mexico
LOCATION MAP
Scale: 1:500
378000
379000
380000
381000
382000
383000
384000
557000
556000
555000
554000
553000
552000
33
34
UTEP-1
UTEP-3
UTEP-4
Line 1
Line 2
Line 3
Line 4
Line 5
Line 6
BLM-30
BLM-18-430
BLM-8-418
BLM-1-435
BLM-22-570
BLM-9-419
BLM-38
BLM-26-404
BLM-21-400
IS-1
IS-2
P-3
0
500
1000
1500
2000



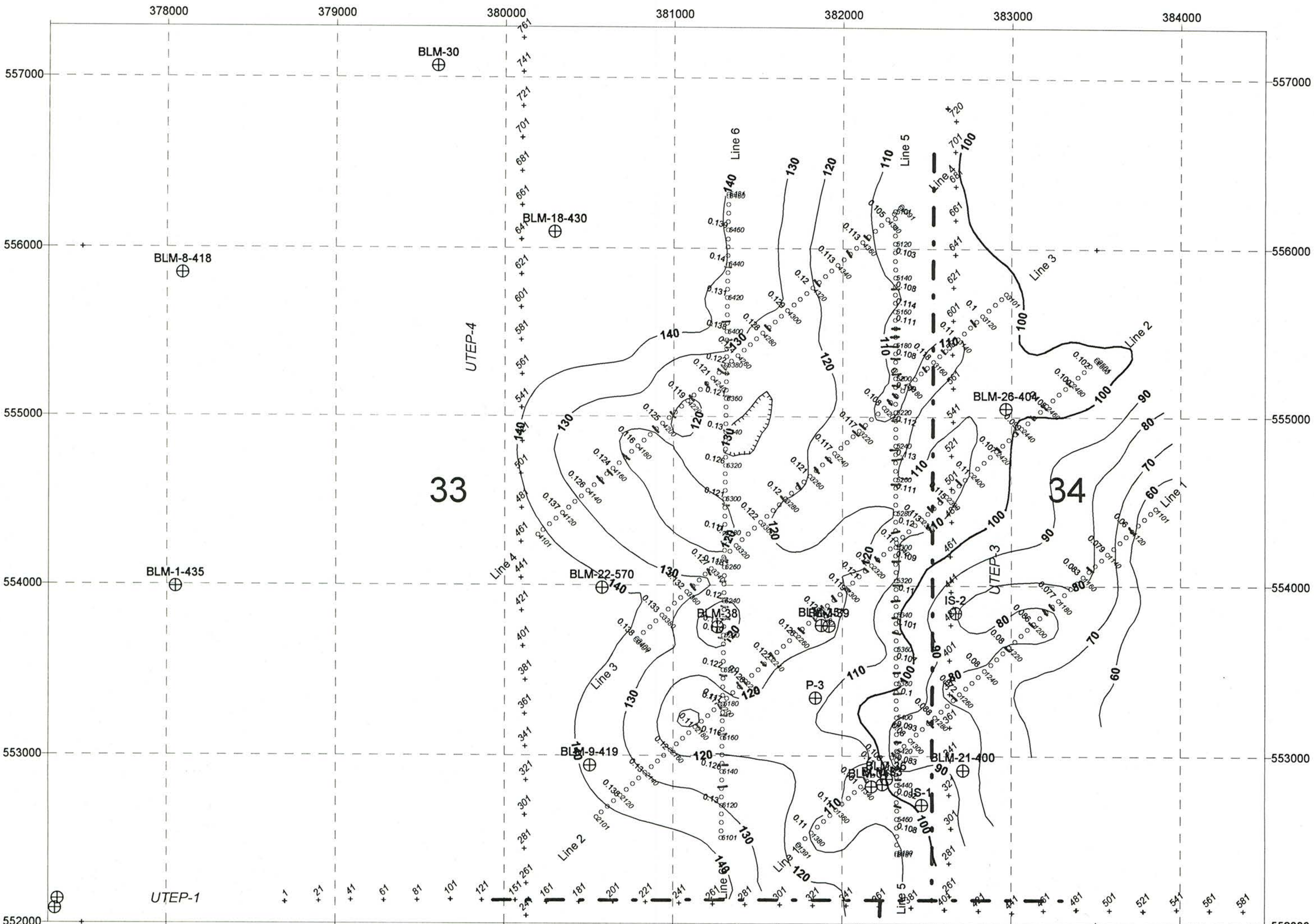
0 500 1000 1500 2000

Red Numbers: Velocity values at wells:
Velocity Relationship: V = (IP * 2) / T
V=velocity
IP=isopach from seismic datum (4600') to top/bedrock
T= time from seismic section

WHITE SANDS SEISMIC PROJECT
(Mid Plume Area)
Dona Ana County, New Mexico

VELOCITY
SEISMIC DATUM (4600') TO TOP OF BEDROCK

Scale: 1:500 CI: 100 ft/sec RAA (dge) 2/01



Blue Numbers: Time to Bedrock in milliseconds
Orange Ticks: Fracture Locations at Top of Bedrock

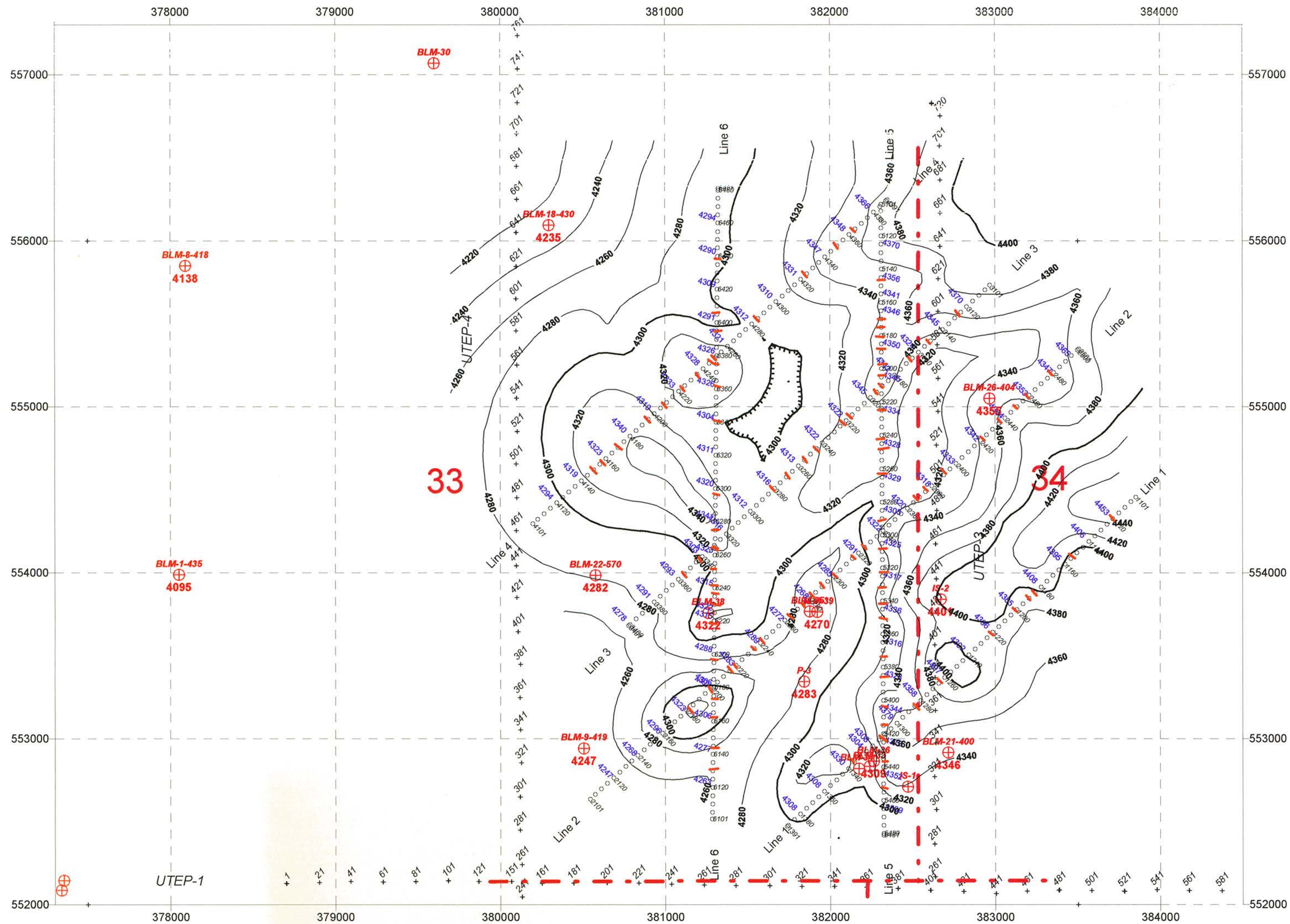
0 500 1000 1500 2000

GRID: WS_T301_BLN.GRD

WHITE SANDS SEISMIC PROJECT
(Mid Plume Area)
Dona Ana County, New Mexico

TIME STRUCTURE
TOP OF BEDROCK

Scale: 1:500 CI: 10 msec Renick & Associates 2/13/01



0 500 1000 1500 2000

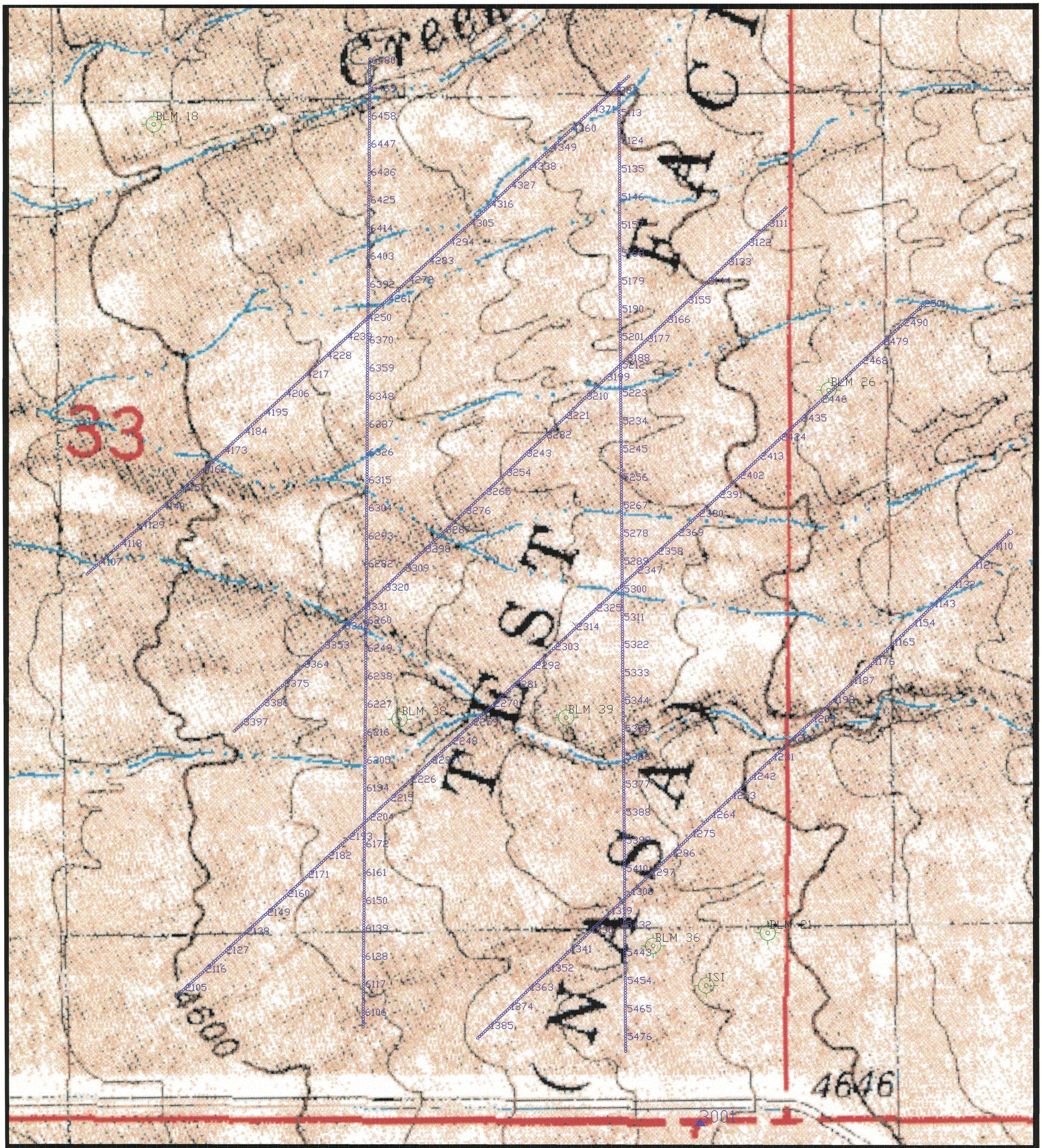
Blue Numbers: Top of Bedrock values
Orange Ticks: Fracture Locations at Top of Bedrock

GRID: Z_BR_301_BLN.GRD

WHITE SANDS SEISMIC PROJECT
(Mid Plume Area)
Dona Ana County, New Mexico

STRUCTURE
TOP OF BEDROCK

Scale: 1:500 CI: 20 ft Renick & Associates 2/13/01



WHITE SANDS TEST FACILITY

Dona Vera County New Mexico

Subsurface Explorations Company

Irish Setter Surveys

Red Lodge, Montana

HORIZONTAL DATUM: NAD27 SPC NEW MEXICO CENTRAL ZONE
VERTICAL DATUM:NAVD88
ELLIPSOID:CLARKE 1866
PROJECTION:TRANSVERSE MERCATOR
HORIZONTAL AND VERTICAL CONTROL BASED ON CLIENT PROVIDED DATA
CONTROL 3001(WGS84)
LATITUDE 32 31 02.87816 N
LONGITUDE 106 37 52.98013 W
HEIGHT 4638.26 M.S.L.

2046 RECEIVER POINTS
NOVEMBER 10, 2000
SCALE TO FIT

WELL
CONTROL POINT
RECEIVER POINT

National Aeronautics and Space Administration

Site-wide Geophysical Survey Investigation Work Plan

April 2019

Updated December 2019

NM8800019434

NASA Johnson Space Center White Sands Test Facility

Site-wide Geophysical Survey Investigation Work Plan

April 2019

Updated December 2019

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Timothy J. Davis Chief, NASA Environmental Office	Date

National Aeronautics and Space Administration

Johnson Space Center
White Sands Test Facility
12600 NASA Road
Las Cruces, NM 88012
www.nasa.gov/centers/wstf

www.nasa.gov

Executive Summary

This IWP (investigation work plan) describes the approach for an iterative site-wide geophysical survey that will be performed to improve the conceptual bedrock model for WSTF (White Sands Test Facility), specifically with regard to site-wide lithologies, bedrock elevations, and the location and attitude of primary bedrock structures. The first step, and foundation of the project, is an airborne magnetic-gravity bedrock survey to be performed across the western half of WSTF. The study area is bounded on the east by the foothills of the SAM (San Andres Mountains) and on the west, north, and south by the WSTF site boundary. The investigation will also include the reprocessing and reinterpretation of select historical geophysical data, and a limited passive seismic survey in the vicinity of the WSTF plume area over a portion of the WBFZ (Western Boundary Fault Zone). Based on the results of the initial investigation, other geophysical techniques may be subsequently applied to provide additional resolution of WSTF bedrock lithology and structure. These may include more extensive passive seismic surveys, ~~conventional~~ ground-based refraction and/or reflection surveys, and borehole geophysics.

In July and August of 2018, NASA (National Aeronautics and Space Administration) invited seven independent geophysical contractors to review historical WSTF geophysical surveys. Following the data review and site visits, the contractors provided recommendations on technologies that could potentially improve the definition of the site bedrock map to support future source area investigations, well placements, groundwater modeling, and other related studies at WSTF. Proposed geophysical methods for this IWP focus on the site-wide airborne magnetic-gravity survey. The design strategy for the survey is based on recommendations from the seven geophysical contractors. The objective of the airborne magnetic-gravity survey is to effectively improve site-wide resolution of the bedrock formation contacts, alluvial thicknesses, and bedrock structural features. The WSTF Environmental Contractor will manage the geophysical survey, while data collection, processing, and interpretation will be completed by an off-site geophysical subcontractor. The technical details relative to design of the airborne magnetic-gravity bedrock survey will be finalized based on recommendations of the geophysical subcontractor that is selected during the competitive procurement process.

Additional geophysical elements that will be used to refine the lithological and structural interpretation of the site comprise reprocessing of historical geophysical data (utilizing working raw project files where available), and performing a limited passive seismic survey over a portion of the WBFZ. Historical reprocessing and borehole geophysics will be applied where feasible following the airborne magnetic-gravity survey to refine the bedrock profile in specific areas. Passive seismic evaluations may be considered for other specific investigation sites or on a site-wide basis.

This IWP is being proposed voluntarily by NASA, and is not directly associated with a specific SWMU (Solid Waste Management Unit) or source area. The performance of the work will not affect any of NASA’s current investigation, monitoring, or remediation activities required by the Permit or associated documents. The survey will be non-intrusive; no drilling will be performed, and no soil or groundwater samples will be collected for analysis. Following award of a contract for the airborne magnetic-gravity component of the geophysical survey to a qualified subcontractor, a study performance window will be established based on the logistical schedule of WSTF and adjacent installations, subcontractor schedule, and desired timing of the field survey. NASA expects that completing the full site-wide geophysical survey will require one to two years, including the preparatory period for the airborne survey through performance of the supplemental geophysical methods. The project start date will be determined during procurement negotiations with the successful subcontractor. NASA will provide project updates to the

NMED (New Mexico Environment Department) in the monthly Environmental Activity Reports and quarterly Periodic Monitoring Reports.

Table of Contents

List of Figures

List of Acronyms

ags	Above ground surface
ft	Feet/foot
gpm	Gallon per minute
IR	Investigation Report
IWP	Investigation Work Plan
JDMB	Jornada del Muerto Basin
mi	Mile(s)
MPITS	Mid-plume Interception Treatment System
NASA	National Aeronautics and Space Administration
NDMA	N-nitrosodimethylamine
NMED	New Mexico Environment Department
SAM	San Andres Mountains
SECO	Subsurface Exploration Company
STGT	Second TDRSS Ground Terminal
SWMU	Solid Waste Management Unit
TDRSS	Tracking and Data Relay Satellite Station
WBFZ	Western Boundary Fault Zone
WSMR	White Sands Missile Range
WSTF	White Sands Test Facility

1.0 Introduction

NASA (National Aeronautics and Space Administration) WSTF (White Sands Test Facility) is located at 12600 NASA Road in central Doña Ana County, New Mexico. The site is approximately 18 mi (miles) northeast of Las Cruces, New Mexico and 65 mi north of El Paso, Texas (Figure 1.1). WSTF has supported testing of space flight equipment and materials since 1964 and continues to operate as a field installation of the NASA Johnson Space Center. The WSTF U.S. EPA (Environmental Protection Agency) Facility Identification Number is NM8800019434. Historical operations at WSTF have resulted in a groundwater plume requiring extensive investigation activities and associated corrective actions.

NASA operates two groundwater remediation systems to extract contaminated groundwater, remediate it using air stripping and ultraviolet photolysis, and inject treated groundwater into the aquifer. Delineation of the boundaries of the groundwater contaminant plume and interception of contaminated water depend on the proper placement of groundwater monitoring, extraction, and injection wells. In addition, accurate conceptualization of the groundwater contaminant plume and the effects of groundwater remediation efforts depend on valid hydrogeologic inputs to the site-wide conceptual and numerical groundwater models.

Establishing the best conceptual model of the subsurface geology at WSTF is critical for effectively planning investigations, locating monitoring and extraction wells, and supporting input information for the numerical groundwater model. This IWP (investigation work plan) describes the approach for an iterative site-wide geophysical survey that will be performed to improve the conceptual bedrock model for WSTF, specifically with regard to site-wide lithologies, bedrock elevations, and the location and attitude of primary bedrock structures. The current bedrock map for WSTF is based on interpretations of historical geophysical surveys from the late 1980s through 1990s, calibrated with geologic logs from the multiple site wells installed as a part of environmental investigation and remediation projects. In addition, there are several areas where drilling data are limited and interpretation of subsurface geology based on historical geophysical survey is speculative. In order to better define and delineate the subsurface geological units and produce an updated top-of-bedrock and structural map as part of the groundwater investigation and remediation effort, NASA plans to conduct a site-wide geophysical survey. The site-wide survey will include an airborne magnetic-gravity survey that utilizes the latest geophysical investigative tools, data collection methods, and data processing software. NASA also plans to reprocess and reinterpret select historical geophysical data and perform a limited passive seismic survey. Depending on the results of this effort, NASA may initiate a more extensive passive seismic survey or perform borehole geophysical surveys at existing wells to better define structures in bedrock in specific areas.

1.1 Approach

This IWP describes the approach for the planned site-wide airborne magnetic-gravity bedrock survey and the supplemental geophysical methods that may be performed to help refine the interpretation. The airborne magnetic-gravity bedrock survey area, shown in Figure 1.2, is bounded on the east by the foothills of the SAM (San Andres Mountains) and on the west, north, and south by the WSTF site boundary. Two "No Fly" zones have been designated at WSTF by two tenants (the Goddard Space Flight Center and the United States Air Force). These zones are identified on the figure, and comprise the areas surrounding the Tracking and Data Relay Satellite Station (TDRSS) to the south and Second TDRSS Ground Terminal (STGT) to the north.

In July and August of 2018, NASA invited seven independent geophysical contractors from across the United States (selected on the basis of expertise) to perform a review of historical WSTF geophysical surveys and provide recommendations for future geophysical evaluations. In general, the geophysical contractors did not express confidence in the original 1988 seismic reflection survey data interpreted by

Reynolds (1988), primarily due to the fact that interpretations were primarily focused on drilling data in lieu of the low resolution seismic data.

During site visits, NASA geologists and geophysical subcontractor representatives also reviewed the gravity data presented by Maciejewski (1996). Although the geophysical contractors believed the data were valid, they remained uncertain as to the accuracy of the interpretation, since it was largely based on the 1988 Reynolds survey. Experts agreed it would be a prudent step to perform a new survey utilizing modern techniques, compare gathered data to well data that has been compiled since 1988, and produce a revised site-wide bedrock lithology and structural map for the site. The work proposed in this IWP is based on the recommendations provided by the seven geophysical contractors.

1.2 Objectives and General Scope of Site-Wide Geophysical Survey

The primary objective of the site-wide geophysical survey is to use the airborne magnetic-gravity method to enhance NASA's conceptual model of the WSTF bedrock surface, specifically with regard to the definition of bedrock lithological contacts, alluvial thicknesses on top of bedrock, and the attitude of significant structural features. The WSTF Environmental Contractor will manage and supervise the geophysical survey. Data collection, processing, and interpretation will be performed by an off-site geophysical subcontractor. The final design of the geophysical survey is subject to revisions, per the recommendations of the geophysical subcontractor ultimately awarded the contract; however, in order to provide a uniform basis for each contractor to construct a cost proposal, the technical requirements outlined in Section 4.0 (Scope) are presented. The investigation will also include the reprocessing and reinterpretation of select historical geophysical data, and a limited passive seismic survey in the vicinity of the WSTF plume area over a portion of the WBFZ (Western Boundary Fault Zone). Additional geophysical techniques may be subsequently performed to provide more resolution of WSTF bedrock lithology and structure. These may include more extensive passive seismic surveys, ~~conventional~~ ground-based refraction and/or reflection surveys, and borehole geophysics. Evaluation of the results of the investigation and interaction with NMED will be used to establish the utility of future geophysical surveys at WSTF.

1.3 Magnetic Survey Description

Local variations in the earth's magnetic field can occur due to either differences in the permanent magnetization of materials, or differences in magnetic susceptibility. The subsurface bedrock lithologies at WSTF are anticipated to differ to a sufficient degree that lithologic contacts along near-vertical geologic features (contacts/faults) may be interpretable from magnetic anomalies or gradients. The following materials and their magnetic properties are expected:

- **Alluvial/colluvial overburden:** no permanent magnetization, low magnetic susceptibility; essentially, the overburden should be transparent.
- **Limestone:** no permanent magnetization, very low magnetic susceptibility; limestone should also be transparent.
- **Andesite:** high permanent magnetization due to thermoremnant magnetization of iron minerals, high susceptibility due to iron minerals.
- **Rhyolite:** moderate permanent magnetization due to thermoremnant magnetization of iron sparse minerals, low susceptibility due to general lack of iron minerals.
- **Flow-banded Rhyolite:** possibly different (to some unknown degree) from other rhyolite.

These differences in magnetic properties have the potential to allow for site-wide mapping of geologic contacts beneath the overburden using an airborne magnetic survey.

1.4 Gravity Survey Description

Local variations in the earth's gravitational field can result from lateral changes in the density or thickness of surficial alluvial overburden on top of bedrock. The alluvial overburden at WSTF generally has porosities between 25 to 40%, while the bedrock has less than 5% primary porosity with secondary porosity along permeable faults and fractures. For similar mineral grain densities, there should be a large difference in bulk density between overburden and bedrock. Gravity variations should be dominated by overburden thickness, which should make the WBFZ, consisting of a series of subparallel half-graben faults with significant displacement of the bedrock to depth,~~)~~ readily detectable. If there is a difference in density between the andesite, rhyolite, and flow-banded rhyolite on the fractured bedrock pediment, the contacts may also be subtly apparent in the gravity survey results. Highly permeable fault zones should create linear gravity anomalies, which would also assist in WSTF conceptual model enhancement.

1.5 Regulatory Requirements

The WSTF site-wide geophysical survey is not part of a specific solid waste management unit investigation or remediation effort required by the NMED (New Mexico Environment Department). The proposed survey will be performed at the discretion and risk of NASA to enhance the understanding the subsurface bedrock lithology and structure of the site. However, since information and data reported for the site-wide geophysical survey investigation will be used to enhance the understanding of the geologic conceptual model at WSTF, it will be applicable to periodic groundwater monitoring and contamination remediation and investigations regulated under the WSTF Hazardous Waste Permit.

1.6 Other Considerations

Revisions to the site-wide geophysical survey design for the IWP may be implemented based on developing logistical factors at WSTF, suggestions from potential vendors, and potential costs of the project. Problems with logistical issues at WSTF such as flight path approvals, data acquisition frequencies, safety, or security may affect the scope or schedule of the survey.

NASA recognizes that there are no guarantees that the initial investigation will enhance the existing interpretation of WSTF subsurface bedrock lithology and structure. Based on the data processing and interpretation from the site-wide airborne magnetic-gravity survey, ~~the~~ additional geophysical methods may be applied to collect higher resolution geophysical data.

2.0 Background

2.1 Current Subsurface Bedrock and Structural Interpretation

WSTF bedrock lithology and structural maps have been developed based largely on the interpretation provided on the site-wide, seismic reflection survey performed by Reynolds in 1988 (Figure 2.1). As monitoring and remediation well boreholes at WSTF were subsequently drilled and lithological and geophysical logging performed, updates were made to the interpretation based on the new data points available. An integrated geophysical interpretation performed by Maciejewski in 1996 as part of a master's thesis at the University of Texas El Paso refined bedrock elevations and some of the major site faulting using 90 widely-spaced gravity data points (Figure 2.2). The results of the thesis were summarized in Volume 2, Chapter 4 of NASA's draft site-wide RCRA Facility Investigation report (NASA, 1996).

2.2 Impact of Bedrock Lithology and Structure on the Placement of Groundwater Wells

Monitoring and remediation wells at WSTF are designed and placed with specific objectives in mind, which include proximity to perceived bedrock drainage areas, bedrock structures, and areas with potentially elevated groundwater contaminant concentrations. Factors influencing the ability to install monitoring and remediation wells successfully to meet various project objectives include the bedrock lithology, depth to bedrock, and characteristics of individual structures or structural zones.

In the WSTF Mid-plume Area (Figure 1.2), typical groundwater yields in wells screened in a fractured bedrock aquifer are less than 5 gallons per minute. Structural flow zones with enhanced groundwater flow have been an important exploration target. The MPITS (Mid-plume Infiltration Treatment System) was located in an area indicated by focused seismic reflection surveys (e.g., SECO [Subsurface Exploration Co.], 2001a) to be structurally complex. The MPITS incorporates extraction wells with relatively higher production rates than are typical for the area. Targets for additional extraction well locations may be generated from an enhanced bedrock lithology and structure map.

At the Plume Front (Figure 1.2), extraction wells have been completed in the alluvial aquifer; however, there are indications that flow of groundwater contaminants may be enhanced along a specific section of the WBFZ near the southwest margin of WSTF. Previous focused seismic reflection surveys have been performed (e.g., SECO, 2001b). Despite this, d~~D~~elineation of the WBFZ in this area remains uncertain, and a refinement with enhanced resolution of lithology and structure would be highly beneficial to support NASA’s ongoing efforts to continually improve operational efficiency of the Plume Front Treatment System. An enhanced site bedrock and structural map would provide a critical resource relative to the definition of individual fault blocks within the WBFZ and optimization of groundwater extraction and contaminant mass removal. This could directly impact the contaminant plume remediation efforts by reducing the remediation timeframe and associated cost.

2.3 Impact of Bedrock Lithology and Structural Interpretation on the Site Groundwater Flow Model

Bedrock lithology and structural interpretations will support future efforts to characterize fractured bedrock and remediate contaminated groundwater through inclusion in the WSTF site groundwater flow model. The model assigns aquifer properties based on the hydrogeological characteristics (affected by lithology and structure) within each individual model cell in order to predict future contaminant plume migration and the effectiveness of the remediation systems. It is critical that inputs to the model be as accurate as possible in order to minimize assumptions and the compounding effect of interpretive error. An enhanced bedrock lithology and structural interpretation would directly impact the quality and defensibility of the groundwater flow model predictions.

3.0 Site Conditions

WSTF encompasses an area of approximately 60,500 acres along the western flank of the southern SAM (Figure 1.2). The area proposed for the airborne magnetic-gravity survey covers approximately 20 square mi that corresponds to the majority of the western half of the WSTF property. This area is inclusive of all the property between the northern and southern site boundaries and includes the western SAM foothills, pediment slope, and JDMB (Jornada del Muerto Basin) west to the western site boundary. Two “No Fly” zones at WSTF comprise the areas surrounding the TDRSS and STGT facilities to the south and north, respectively.

3.1 Surface Topography

The flight lines for the airborne survey are proposed at an approximate altitude of 300 ft (feet) ags (above ground surface) for the majority of the survey where topography is gently inclined at between 2 to 10 degrees along the WSTF alluvial-covered pediment slope and JDMB. The ground surface is vegetated by relatively sparse scrub and brush, is relatively flat, and should not pose any difficulty for the aircraft to maintain a relatively uniform elevation ags across the flight paths. The low undulating foothills and shallow arroyos east of the WSTF industrialized areas and adjacent to the SAM provide the most varied of the survey topography encountered.

3.2 Subsurface Geology

A significant amount of geological and geophysical investigation has been performed at WSTF over the last 30 years. All pertinent information currently on file (investigation reports, topographic and geologic maps, historical geophysical surveys, and well lithologic and geophysical logs) will be made available to the geophysical subcontractor in order to assist with planning, processing, and interpreting site-wide geophysical survey data generated during this study.

3.3 Weather

The weather at WSTF is characterized by abundant sunshine, low humidity, slight rainfall, and large day-to-night temperature variance. Spring (March and April) is the driest time of the year with mild temperatures and dust storms caused by sustained winds. Summers (May through September) are characterized by clear hot days, progressing to warm cloudy weather with seasonal monsoon rains in July through September. Fall (October through November) is characterized by warm sunny days and cool nights with mild winds. Winters (November through February) are mild with clear sunny days and cold clear nights. The WSTF Environmental Contractor will coordinate with the subcontractor and surrounding entities: White Sands Missile Range; WSTF, the United States Air Force; Federal Aviation Administration; Las Cruces International Airport and any other local regulatory agencies to schedule the flights in conjunction with the weather and preference of the geophysical subcontractor accordingly.

4.0 Scope of Site-wide Geophysical Survey Activities

4.1 Airborne Magnetic-Gravity Survey Design

The gravity survey component accounts for the more bulky equipment requirements for the airborne survey, and is the primary factor requiring the use of a manned aircraft. The proposed airborne geophysical survey will be revised based on the expertise of the geophysical contractor selected during the competitive procurement process, with the intent of meeting project objectives at a lower cost or with enhanced results. The finalized design parameters for the survey will follow the detailed approach recommended by the geophysical subcontractor awarded the contract. In general, the planned airborne magnetic-gravity bedrock survey design parameters include the following elements.

- The survey will cover a rectangular area with dimensions of approximately 4 x 5 mi (Figure 1.2). This 20 square mi area covers the majority of the western half of WSTF, primarily across a gentle alluvial-covered pediment slope on the west side of the SAM into flat alluvial-covered terrain of the JDMB.
- Survey lines are anticipated to be positioned along east-west transects parallel to the long axis of the survey area, and oblique to the primary northwest-trending structures in the area characteristic of basin-range faulting (for example the WBFZ). The final orientation of the survey lines will be selected and justified by the geophysical contractor.

- The anticipated survey line spacing along east-west transects is approximately 200 ft across the entire area, representing up to 400 line mi of airborne data collection.
- Control survey lines are anticipated to be positioned perpendicular to survey lines in a north-south direction; because many geological features are in the east-west direction (for example Laramide structures that may extend into the northeastern corner of the survey area from Bear Canyon within the SAM). The final orientation of the control survey lines will be selected and justified by the geophysical subcontractor.
- The north-south transects may be arranged with a line spacing of approximately 200 ft. This data collection effort, representing up to an additional 400 line mi will provide grid data to establish more defensible 3-D bedrock and structural maps.
- The optimum altitude for successful data acquisition ranges between 265 and 400 ft ags. The elevation of the airborne flight lines are anticipated to be approximately 300 ft ags where feasible based on all available safety and security protocols.
- The sample acquisition frequency along each airborne survey line will be approximately 20 to 30 ft, or otherwise as suggested and justified by the geophysical subcontractor.

4.2 Airborne Magnetic-Gravity Survey Responsibilities

The geophysical subcontractor will be responsible for the following.

- Coordination of clearances required within restricted airspace, including White Sands Missile Range, NASA-WSTF, the United States Air Force, Federal Aviation Administration, Las Cruces International Airport and any other local regulatory agencies, and filing of the required flight plans.
- Provision of the field airborne magnetic-gravity survey equipment and instrumentation required to record the required geophysical data.
- Provision of qualified personnel necessary to prepare the instrumentation, perform the airborne survey, and collect the required geophysical survey data.
- Provision of the equipment and personnel required to download, process and interpret the data collected during the airborne survey.
- Submittal of a final airborne magnetic-gravity survey report with a summary of survey design, a description of the geophysical methods employed, data collection details, survey results, interpretation of the geophysical data generated, and further recommendations. A comprehensive bedrock map, with cross-sections along selected flight lines (where feasible), will also be included.

NASA and the WSTF Environmental Contractor will be responsible for the following.

- Obtain approval for the contractor aircraft to fly over WSTF and the adjacent tenant facilities.
- Provision of preparatory geological investigation reports, site historical geophysical data, geologic maps, and existing well logs to the geophysical contractor for the purposes of calibrating the geophysical survey.
- Provision of qualified field survey supervision for the duration of the field project.
- Provision of WSTF Environmental Contractor geological staff familiar with site geophysics to support the preparation and evaluation of field airborne magnetic-gravity survey data.

4.3 Airborne Magnetic-Gravity Survey Methods

The following procedures are anticipated when collecting the airborne magnetic-gravity measurements.

- Record first real time measurements from geophysical instrumentation mounted in the aircraft to produce magnetic-gravity data related to the ground surface below.
- Collect second real time measurements from navigation and mapping instruments associated with or carried by the aircraft.
- Compute a background response of each geophysical instrument using the second real time measurements to take account of its time varying altitude, and the time varying topography of the ground surface below.
- Adjust an operating or data processing condition of each geophysical instrument using the respective background response and the instrument's altitude to enhance the performance of that instrument.
- Adjust the geophysical data output for that instrument having reduced effects resulting from variations in altitude, attitude and topography.
- Subsequently process and interpret the geophysical data with the support of WSTF Environmental Contractor geological staff as necessary. Structural discontinuities such as faults, fractures and geological contacts may create lateral contrasts in density and magnetization of rocks, which generate gravity and magnetic signatures. Due to density and magnetic variations of the rocks, these structural discontinuities may be partly detected on the gravity image and partly on the magnetic image.
- In addition to creating the site-wide separate gravity and magnetic images, a combined image that integrates the two images using an image fusion technique will be generated if feasible for better interpretation of the acquired data.

5.0 Scope of Geophysical Reprocessing and Limited Passive Seismic Survey

The other elements of the geophysical investigation that will be applied to provide additional resolution to WSTF bedrock lithology and structure include the reprocessing and reinterpretation of select historical geophysical data and aerial photography, and a limited passive seismic survey in the vicinity of the WSTF plume area over a portion of the WBFZ. These geophysical elements will be applied to provide supplemental data to the airborne magnetic-gravity survey either to address deficiencies specific to individual investigation sites or to provide more optimal site-wide coverage. Other geophysical techniques may be subsequently performed to provide more resolution of WSTF bedrock lithology and structure. These may include more extensive passive seismic surveys, ground-based~~conventional~~ refraction and/or reflection surveys, and borehole geophysics.

Specific data are available from historical geophysical surveys performed and from borehole geophysics that can be used to address the "data gaps." Site-wide coverage can be provided by passive seismic surveys performed on the ground (also known as ambient noise surface wave tomography), which provides a cost-effective alternative to standard seismic reflection and refraction. A discussion of the methods to be used are provided below.

- Reprocessing and reinterpretation of historical geophysical data and aerial photography: This element will be applied where the detail for specific previously studied areas can potentially be improved, and added benefit could result from this evaluation. NASA will contract geophysical subcontractors in an attempt to reprocess and reinterpret seismic data from previous site-wide, Mid-plume, and/or Plume Front surveys, along with resistivity and refraction data from the 200 Area. The success of this action will depend on the availability of the raw historical data, the ability of subcontractors to perform reprocessing, and the associated cost. Several of the geophysical subcontractor representatives that visited WSTF expressed that it may be possible to extract additional detail from the historical survey results using modern data processing methods.

- Limited passive seismic survey: This element will be performed to investigate a specific area of the airborne survey. NASA plans to perform a limited passive survey over a portion of the WBFZ. The outcome of this survey will be used to decide whether to perform additional passive seismic survey work. Passive seismic nodes will be utilized in "rolling" grids, which will allow the data collection to extend progressively across the area of interest while efficiently managing the number of nodes. Passive seismic or ambient noise surface wave tomography uses natural low-frequency signals (0 to 10 hertz) to generate vertical profiles in the ground. The results would be used to supplement the alluvial depth isopach map and structural interpretations. Some of the geophysical contractors believed that the airborne magnetic-gravity survey may not require further refinement; however, the design of the limited passive seismic survey will be based on the site-wide results of the airborne survey.
- Other geophysical techniques – more extensive passive seismic surveys, ~~conventional~~ ground-based refraction and/or reflection surveys, and borehole geophysics: These additional techniques will be evaluated following completion of the investigation. For the borehole geophysics, acoustic televiewer logging may be employed in new boreholes to verify fracturing indicated by the airborne and passive geophysical surveys. Synthetic seismographs may also be produced from the logging of new boreholes using density and sonic logs to calibrate any future seismic surveys. Existing cased holes cannot be used for these logging techniques.

6.0 Schedule

The schedule for conducting the site-wide geophysical survey, geophysical processing, and the limited passive seismic survey is tentative at this time. Following award of the contract for the airborne magnetic-gravity component of the geophysical survey to the subcontractor, all necessary permissions will be obtained to perform the fieldwork. Depending on the WSTF logistical schedule, subcontractor schedule, and desired timing of the field survey, a performance window will be established. Geophysical processing work and the limited passive seismic survey will be performed contemporaneously with the airborne geophysical survey to the best extent possible. The anticipated schedule below is dependent on the award date for the contract.

- Award of airborne magnetic-gravity survey contract purchase order – December~~June~~ 2019 (tentative).
- Preparatory period (3 months) – acquisition of permits and permissions, determination of airborne and geophysical equipment, and scheduling of the optimum performance window.
- Potential lag time between preparatory period and airborne field survey (3~~6~~ months) – may be affected by timing of optimal conditions to perform field survey.
- Airborne field survey window (1 month) – to follow preparatory period and lag time (includes pre-flight protocol, flyovers, and post-flight protocol).
- Geophysical data reprocessing and performance of the limited passive seismic survey will be performed concurrently with the lag time between the preparatory period and the airborne field survey (6 months).
- Data evaluation and processing/report generation (3~~2~~ months) – to follow airborne field survey, includes data evaluation, processing, interpretation, and subcontractor report preparation.

- Preparation of Site-wide Geophysical Survey IR (Investigation Report) for submittal to NMED (2 months).
- The anticipated duration for the site-wide geophysical survey investigation and submittal of the IR is 18 months~~is 1 to 2 years~~. A Site-wide Geophysical Survey Investigation Report investigation report will be submitted to NMED by June 30, 2021.
- Other geophysical techniques – will be performed iteratively depending on the quality of the geophysical data generated for the site-wide geophysical survey and the magnitude of effort required (labor, materials, and cost). Other geophysical techniques may include more extensive passive seismic surveys, ~~conventional~~ ground-based refraction and/or reflection surveys, and borehole geophysics.

7.0 References

NASA. (1996, May 2). Draft RCRA Facility Investigation (RFI) and Corrective Measures Study (CMS) for NASA WSTF. NASA Johnson Space Center White Sands Test Facility, Las Cruces, NM.

Maciejewski, T.J. (1996). Integrated Geophysical Interpretation of Bedrock Geology, San Andres Mountains, New Mexico. Unpublished master's thesis, University of Texas at El Paso, TX.

Reynolds, C.B. (1988). Final Report, Shallow Seismic Reflection Survey, NASA Lyndon B. Johnson Test Facility Area, Dona Ana County, New Mexico. Charles B. Reynolds & Associates, Consulting Geophysicists and Geologists. Albuquerque, NM.

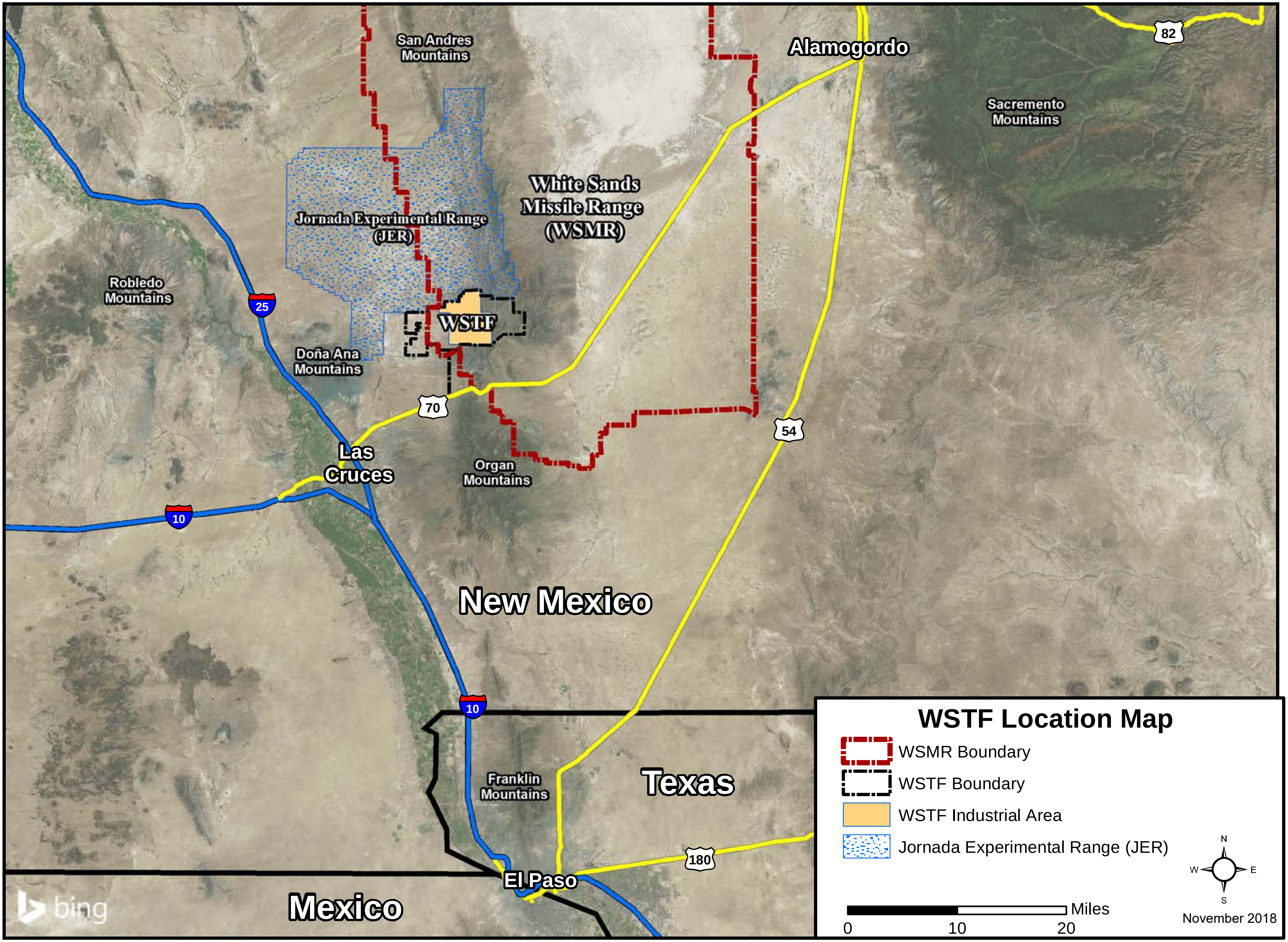
SECO. (March 5, 2001a). Final Report, Mid-Plume Area Seismic Reflection Study, NASA White Sands Test Facility, Dona Ana County, New Mexico. Subsurface Exploration Company, Pasadena, CA.

SECO. (July 23, 2001b). Final Report, West-Plume Area Seismic Reflection Study, NASA White Sands Test Facility, Dona Ana County, New Mexico. Subsurface Exploration Company, Pasadena, CA.

Figures

Figure 1.1 **WSTF Location Map**

(SEE NEXT PAGE)



San Andres Mountains
Alamogordo
82
Sacremento Mountains
White Sands Missile Range (WSMR)
Jornada Experimental Range (JER)
Robledo Mountains
25
WSTF
Doña Ana Mountains
70
54
Las Cruces
Organ Mountains
10
New Mexico
10
Franklin Mountains
Texas
180
El Paso
Mexico
bing
WSTF Location Map
WSMR Boundary
WSTF Boundary
WSTF Industrial Area
Jornada Experimental Range (JER)
N
W
E
S
Miles
0
10
20
November 2018

Figure 1.2 Proposed Site-wide Geophysical Survey Area

(SEE NEXT PAGE)

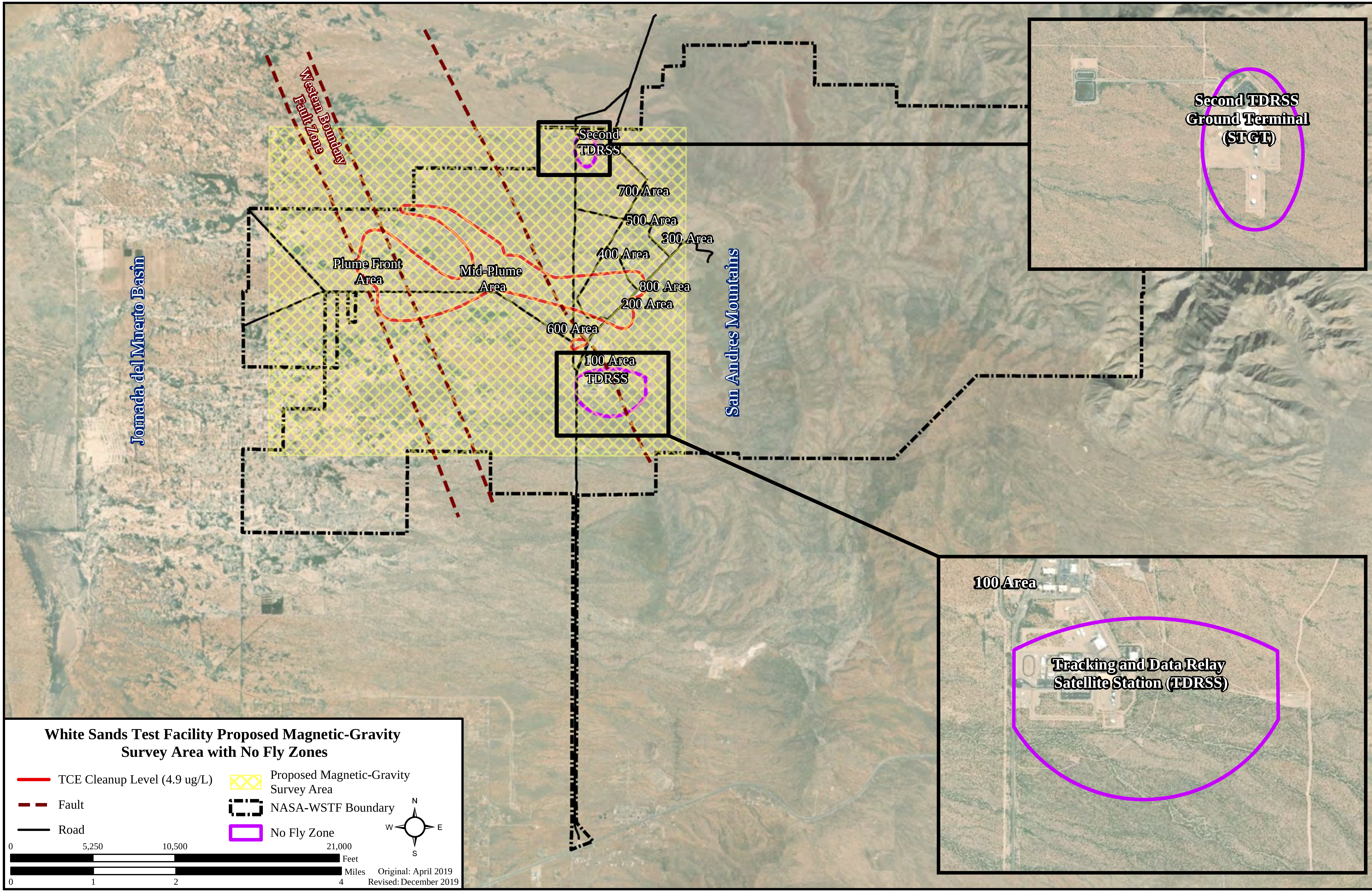

White Sands Test Facility Proposed Magnetic-Gravity Survey Area with No Fly Zones
TCE Cleanup Level (4.9 ug/L)
Fault
Road
Proposed Magnetic-Gravity Survey Area
NASA-WSTF Boundary
No Fly Zone
0
5,250
10,500
21,000
Feet
0
1
2
4
Miles
N
W
E
S
Original: April 2019
Revised: December 2019
Western Boundary Fault Zone
Second TDRSS
700 Area
500 Area
300 Area
400 Area
Plume Front Area
Mid-Plume Area
800 Area
200 Area
600 Area
100 Area
TDRSS
Jornada del Muerto Basin
San Andres Mountains
Second TDRSS Ground Terminal (STGT)
100 Area
Tracking and Data Relay Satellite Station (TDRSS)

Figure 2.1 WSTF Bedrock Structures – Reynolds Interpretation 1988

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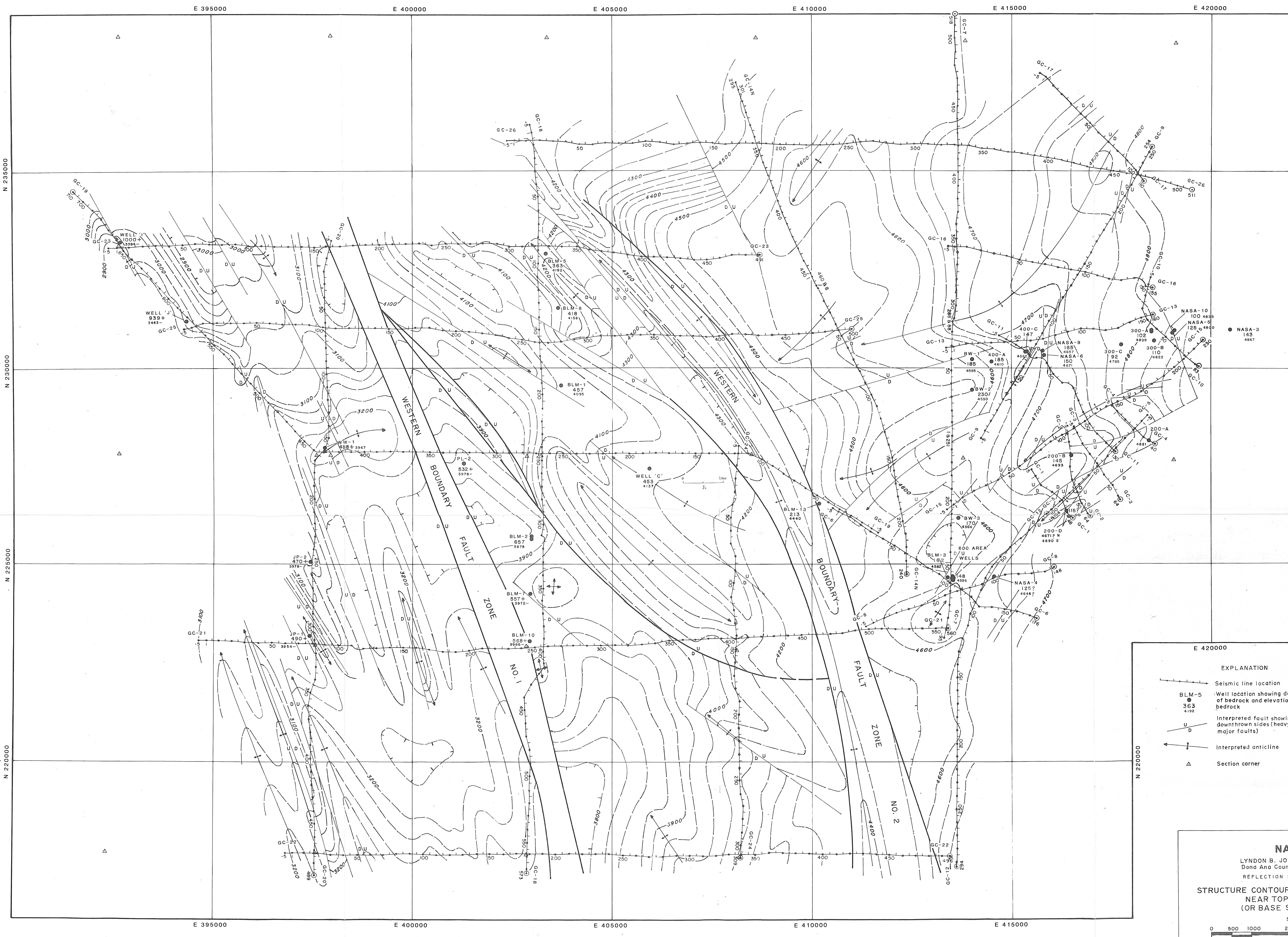


NASA

LYNDON B. JOHNSON FACILITY
Dona Ana County, New Mexico

REFLECTION SEISMIC SURVEY

STRUCTURE CONTOURS ON A SEISMIC HORIZON
NEAR TOP OF BEDROCK
(OR BASE SANTA FE GRP)

SCALE

0 500 1000 2000 3000 4000 FEET

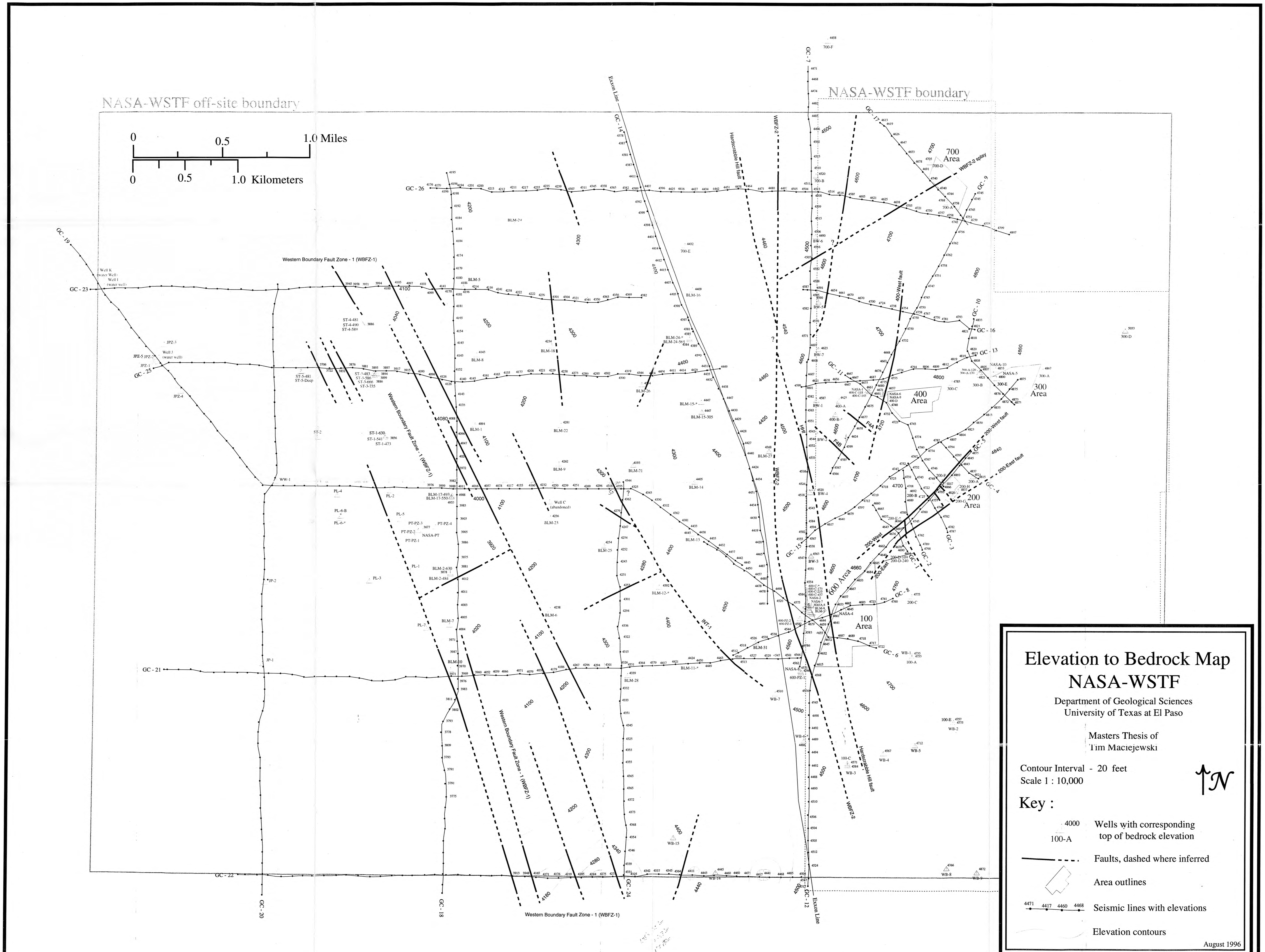
CONTOUR INTERVAL: 25 FEET
ELEVATIONS IN FEET ABOVE SEA LEVEL

JULY 26, 1989 CHARLES B. REYNOLDS & ASSOC.

ENCLOSURE NO. 8

Figure 2.2 WSTF Elevation to Bedrock Map – Maciejewski Interpretation 1996

(SEE NEXT PAGE)



Elevation to Bedrock Map NASA-WSTF

Department of Geological Sciences
University of Texas at El Paso

Masters Thesis of
Tim Maciejewski

Contour Interval - 20 feet
Scale 1 : 10,000

N

Key :

4000 / 100-A — Wells with corresponding top of bedrock elevation

Faults, dashed where inferred

Area outlines

4471 4417 4460 4468 — Seismic lines with elevations

Elevation contours

August 1996

Enclosure No. 1