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ESTIMATING FRACTURE PARAMETERS
FROM P-WAVE VELOCITY PROFILES
ABOUT A GEOTHERMAL WELL

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ABSTRACT

The feasibility of locating fracture zones and estimating their crack parameters was examined using an "areal well shoot" method centered on Utah State Geothermal Well 9-1, Beaver County, Utah. High-resolution travel time measurements were made between a borehole sensor and an array of shot stations distributed radially and azimuthally about the well. Directional velocity behavior in the vicinity of the well was investigated by comparing velocity logs derived from the travel time data.

Three fracture zones were identified from the velocity data, corroborating fracture indicators seen in other geophysical logs conducted in Well 9-1. Crack densities and average crack aspect ratios for these fracture zones were estimated using a self-consistent velocity theory (O'Connell and Budiansky 1974). Probable trends of these fracture zones were established from a combination of the data from the more distant shot stations and the results of a gravity survey.

The results of this study indicate that the areal well shoot is a potentially powerful tool for the reconnaissance of fracture-controlled fluid and gas reservoirs. Improvements in methodology and hardware could transform it into an operationally viable survey method.

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- neutron log. (in back pocket)

INTRODUCTION

Statement of the Problem

Knowledge of the trend and permeability of fracture zones in the region adjacent to a well would facilitate investigations of fractured reservoirs which contain exploitable fluid and gas resources. Recent studies of the effects of cracks on the seismic properties of rocks provide the rationale for application of an "areal well shoot" approach to locate fracture zones and to estimate crack parameters in the vicinity of a well (Garbin and Knopoff 1973, 1975a, 1975b; Anderson and others 1974; O'Connell and Budiansky 1974, 1976, 1977; Simmons and others 1975, Crampin 1978, Bamford and Nunn 1979, Crampin and others 1980).

The areal well shoot method uses an array of shot stations distributed radially and azimuthally about the well head, and recording hardware interfaced with a variable-depth borehole sensor. P-wave shot-to-sensor travel times from each station are recorded with the downhole package at a number of depths. Velocity-depth functions-- $V(z)$'s--are then reduced from the travel time data sets. This gives a set of velocity-depth profiles which reflect the velocity behavior "seen" by direct rays traveling from the shot stations to the well bore. In this manner, a three-dimensional model of seismic P-wave velocity

anisotropy--that is, directionally dependent behavior--about the well is obtained.

Background/Literature Review

Measurements of $V(z)$ by the well shooting method are not new to the realm of geophysical exploration techniques (Grant and West 1965, Dobrin 1976, Telford and others 1976, Waters 1978). Velocity anisotropy measurement by well shooting is also not a novel experiment (Vander Stoep 1966).

Application of the method to the investigation of fracture zones requires higher resolution of the velocity behavior about the well than conventional well shoots do. This requirement is met by increasing the number and areal distribution of shot stations, decreasing the depth-sampling interval, and improving the accuracy of shot-sensor travel time measurements. Thus, the degree of success achieved in our investigation reflects the degree of success we had in satisfying this "high-resolution" requirement.

The importance of velocity anisotropy--the directional variation of seismic velocities in crustal rock--as a potential diagnostic feature of geologic structure has become increasingly apparent in the last decade. Recent evidence suggests that oriented cracks in rock are a principal cause of velocity anisotropy (Garbin and Knopoff 1973, 1975a, 1975b; Anderson and others 1974, Rothman 1975, Hadley 1976, Crampin 1978, Bamford and Nunn 1979, Crampin

and others 1980), and advanced recording techniques have improved the chances of measuring velocity anisotropy in field situations, e.g., shot stacking and digital recording.

Interpretation of well shoot velocity profiles must consider that structural features other than rock fractures can influence directional velocity properties in the vicinity of the well. An appreciation of all possible causes of the measured anisotropies is essential if we are to discriminate between the key features--those associated with fractures--and other anomalies in the data set. Therefore, ancillary geophysical surveys are needed to assess the relative importance of local structures to the observed anisotropies.

The "well shoot integral"

Grant and West (1965) give an integral equation which may be solved for $V(z)$ from travel times-- $t(z)$ --of surface shots to a borehole sensor. The equation is

$$t(z) = \int_0^z \left\{ 1 - V^2(s) \left[\frac{1}{V^2(z)} - \left(\frac{dt}{dz} \right)^2 \right] \right\}^{-\frac{1}{2}} \frac{ds}{V(s)} . \quad (1)$$

The equation assumes the operation of Snell's Law in its usual form--

$$\frac{\sin \theta}{V(z)} = p(\text{constant}). \quad (2)$$

It also assumes that the horizontal shot-sensor distance

remains constant, and that no significant lateral velocity gradients exist between the shotpoint and the well. With these assumptions, the parametric ray equations are

$$t(z) = \int_0^z \frac{d\xi}{V(\xi) \sqrt{1 - p^2(z) V^2(\xi)}} \quad (3)$$

and

$$x = p(z) \int_0^z \frac{V(\xi) d\xi}{\sqrt{1 - p^2(z) V^2(\xi)}} \quad (4)$$

Setting x constant, p is determined from (3) and (4) to be

$$p(z) = \left[\frac{1}{V^2(z)} - \left(\frac{dt}{dz} \right)^2 \right]^{\frac{1}{2}} \quad (5)$$

Substituting (5) in (3) gives equation (1) which may be solved numerically for $V(z)$.

Seismic effects of fractures in rock

In any investigation of a fracture-controlled geothermal or hydrocarbon reservoir, three crack parameters--porosity, permeability, and fluid content--are of major interest. Velocity variations in fractured rock appear to be most dependent on crack density, aspect ratio, orientation, and degree of fluid saturation (Garbin and Knopoff 1973, 1975a, 1975b; Anderson and others 1974; O'Connell and Budiansky 1974, 1976, 1977). These parameters may be estimated from observations of seismic wave behavior in the fractured rock (Crampin and others 1980) and may be used to infer porosity and permeability.

Garbin and Knopoff (1973; 1975a, b) showed that the presence of a dilute distribution of randomly oriented, flat "penny-shaped" cracks in an otherwise isotropic matrix will isotropically reduce the compressional velocity of the composite material. The appropriate equation for dry cracks is

$$V_p = V_{p0} / \left(1 + \frac{262}{105} \mathcal{E}\right)^{\frac{1}{2}}, \quad (6)$$

and for fluid-saturated cracks

$$V_p = V_{p0} / \left(1 + \frac{128}{105} \mathcal{E}\right)^{\frac{1}{2}}, \quad (7)$$

where $\mathcal{E} = 2N\langle A^2/P \rangle/\pi$ is the crack density (N = no. of cracks per unit volume, A = crack area, and P = crack perimeter), V_{p0} = velocity of the uncracked material and V_p = observed velocity. Garbin and Knopoff (1973) used circular cracks of radius = a , simplifying the expression for crack density to $\mathcal{E} = Na^3$.

Crampin (1978) obtained equations from the results of Garbin and Knopoff (1973; 1975a, b) for the azimuthal dependence of compressional velocity in a solid containing parallel cracks. For dry parallel cracks, the equation is

$$V_p = V_{p0} / \left(1 + \frac{8}{3} \mathcal{E} \left\{ \frac{8}{7} (c^2 - c^4) + \left[(1 + 2c^2)^2 / 4 \right] \right\} \right)^{\frac{1}{2}}, \quad (8)$$

where $c = \cos\phi$ and ϕ is the angle of the incident ray with

respect to the crack normals. For saturated parallel cracks, the bracketed term in (8) is dropped, giving

$$V_p = V_{p0} / \left\{ 1 + \frac{64}{21} \epsilon (c^2 - c^4) \right\}^{\frac{1}{2}} . \quad (9)$$

Equations (8) and (9) show that the composite material is anisotropic to the propagation of P-waves. Since fractures generally occur with some overall alignment (Brace and others 1966, Hadley 1976), they may be detected by observations of velocity anisotropy.

Crampin and others (1980) used the Garbin and Knopoff equations to interpret refraction measurements taken in shallow fractured limestone (Bamford and Nunn 1979). Writing equations (8) and (9) for convenience as

$$V_p = V_{p0} R_p^D(\epsilon, c) , \quad (10)$$

where

$$R_p^D(\epsilon, c) = 1 / \left\{ 1 + \frac{8}{3} \epsilon \left[\frac{8}{7} (c^2 - c^4) + (1 + 2c^2)^2 / 4 \right] \right\}^{\frac{1}{2}}$$

and

$$V_p = V_{p0} R_p^S(\epsilon, c) , \quad (11)$$

where

$$R_p^S(\epsilon, c) = 1 / \left\{ 1 + \frac{64}{21} \epsilon (c^2 - c^4) \right\}^{\frac{1}{2}} ,$$

they showed that biplanar vertical fracture sets can be modelled by a modified Garbin and Knopoff equation,

$$V_p = V_{p0} / \left[(1 - q) / (R_{p1}^D R_{p2}^D) + q / (R_{p1}^S R_{p2}^S) \right] . \quad (12)$$

Here the ratio of saturated to dry cracks is $q:(1-q)$, and $R_{pi}^K = R_{pi}^K [\xi_i, \cos(\phi - \alpha_i)]$, with $K = D$ or S (dry or saturated), α_1 and α_2 are the azimuths of the two parallel crack systems with respect to north, ξ_1 and ξ_2 are the respective crack densities, and ϕ is the angle of incidence from north.

There is, however, some disagreement for the case of fluid-filled parallel cracks (Figure 1). Equation (9) shows a directional velocity variation of approximately $\cos 4\phi$ for saturated parallel cracks, i.e., velocity maximums should be observed for normally-incident and plane-parallel rays (Figure 1a). Another treatment implies that fluid-filled parallel cracks will display a $\sin 2\phi$ (nearly elliptical) velocity variation with velocity a minimum for normally-incident rays and a maximum for plane-parallel rays (Figure 1b, from Anderson and others 1974). Both predict a more pronounced $\sin 2\phi$ -variation for the case of dry parallel cracks and both assume a dilute crack distribution ($\xi < 0.1$). There are no published data which clearly establish the validity of one of these treatments over the other, since most laboratory investigations utilize dry rock samples (for example, Rothman 1975, Simmons and others 1975, Hadley 1976).

The study of Crampin and others (1980) examined velocity variations at dry, partially saturated, and saturated sites. Predominantly $\sin 4\phi$ variations were

Figure 1. A comparison of the results of two theoretical treatments predicting directional velocity variations in granitic rocks containing dry (gas-filled) and saturated (fluid-filled) parallel flat cracks. Velocity is shown for $\phi = 0^\circ$ (rays normal to the fracture plane) to $\phi = 90^\circ$ (tangentially incident rays). a) V_p varies roughly as $\sin 2\phi$ for dry cracks and as $\cos 4\phi$ for saturated cracks according to equations (8) and (9) (from Crampin 1977). $\xi = 0.05$ for this figure. b) V_p varies as $\sin 2\phi$ for both the dry and saturated cases; the azimuthal variation is more pronounced for gas-filled than for fluid-filled cracks (from Anderson and others 1974). Here $\xi = 0.048$, the short-dashed lines show the uncracked velocity, the long-dashed line is for the fluid-filled case, and the solid lines show the variations predicted for the gas-filled case.

observed at all sites, and were most pronounced at the drier sites. This outcome was predicted by equation (12). However, the fact that Crampin and others (1980) modelled two nearly orthogonal fracture sets suggests that the results of Anderson and others (1974) would have predicted the same variations.

Theoretical investigations of the effective compressional modulus of a solid permeated by a random distribution of flat cracks, under varying degrees of saturation and crack densities, show that seismic wave velocities decrease with increasing crack densities (O'Connell and Budiansky 1974). V_p/V_s decreases for dry cracks and increases for saturated cracks (Figure 2). If the values of the uncracked velocity (V_p) and the volume porosity, ($\eta = \xi(4\pi/3)(c/a)$) of a cracked solid are known, the graph in Figure 2b may be used to estimate crack densities and aspect ratios (width-to-length ratio = c/a) from measurements of $\bar{V}_p$ (observed velocity). These results are considered valid for large crack densities, but a similar treatment for oriented cracks is not available.

O'Connell and Budiansky (1974) point out that not only microcracks (long axis < 10 cm), but joints and macroscopic fractures may also be considered as flat cracks. Hence, theoretical and experimental results should hold for all fractures shorter than a seismic wavelength (~ 100 meters for seismic exploration frequencies).

Figure 2a. Effective wave velocities $\bar{V}_s/V_s$ and $\bar{V}_p/V_p$ and their ratio for a partially saturated cracked solid. The fraction of saturated cracks is ξ (from O'Connell and Budiansky 1974).

Figure 2b. Same as 2a, but for a solid with cracks of aspect ratio c/a , all filled with a fluid of bulk modulus $\bar{K}$ (from O'Connell and Budiansky 1974).

Other causes of velocity anisotropy

Rock fabric elements other than aligned cracks can cause seismic anisotropy. Waters (1978) discusses "pseudoanisotropy" in a composite material consisting of a laminated series of thin, alternately high- and low-velocity layers. The velocity dependence is approximately elliptical in such a material. The slow direction (V_v) is normal and the fast direction (V_h) parallel to the foliation or bedding plane. This case may be a macroscopic example of the effect produced by aligned mineral grains in a rock matrix.

Early measurements of velocity anisotropy in wells in sedimentary environments (Vander Stoep 1966) were probably due to laminated high and low velocity beds, as well as to mineral grains aligned parallel to the bedding plane. Assuming an elliptical velocity dependence, the anisotropic ratio-- $A = V_h/V_v$ --was found to be 1.03 in the Texas Gulf Coast Section and 1.077 for redbeds in New Mexico. As in the derivation of equation (1), Vander Stoep was able to assume horizontal rock layers, i.e., no significant lateral velocity gradients were present.

The most important source of non-fracture-related anisotropy, likely to be observed by an areal well shoot, is introduced by geologic structure--e.g., non-horizontal rock layers--in the vicinity of the well. These structurally-induced anisotropies may be much more pronounced than those related to fractures, and must be

accounted for if crack orientations are to be estimated from the velocity data. The identification and subsequent separation of large, structurally-induced anisotropies from fracture-related anisotropy may be a difficult, indeed hopeless task without supplemental geophysical data--e.g., gravity, reflection, and refraction.

Study Objectives

To investigate the application of the areal well shoot to rock fracture reconnaissance, a study was conducted in the Roosevelt Hot Springs Known Geothermal Resource Area (KGRA) in Beaver County, Utah (Figure 3). This paper:

- Reviews the methodology developed to collect, reduce, and interpret the data from an areal well shoot.
- Reports the areal well shoot conducted in the Roosevelt Hot Springs KGRA and compares the results with previous work in the area.
- Evaluates the potential of the areal well shoot method and discusses improvements to enhance its resolving power.

TEST LOCALITY/GEOLOGY AND GEOPHYSICS

The study was centered at the site of Utah State Geothermal Well 9-1 (Figure 4a), which was made available through the Los Alamos Scientific Laboratory (LASL) by Phillips Petroleum Company for calibration and testing of well logging equipment in the geothermal environment. The well is also known as Well C/T-2, as it is the second of two Calibration/Test Wells in LASL's Geothermal Log Interpretation Program.

The large amount of published ancillary geologic and geophysical data, for the KGRA in general (Nielson and others 1978, Ward and others 1978, Gertson and Smith 1979, Glenn and Hulen 1979) and Well 9-1 in particular (Glenn and others 1981), made this a desirable location to test the method. Also, the fact that Well 9-1 penetrates fractured crystalline rock made it desirable as a test site.

Roosevelt Hot Springs KGRA

The viable portion of the KGRA presently contains seven productive geothermal wells (Plate I). Centered around a small graben (Figure 4a, b), this active zone is transected by the east-west trending Hot Springs Fault, bounded on the east by normal faults corresponding to the outcrop of the Mineral Mountains Pluton, and limited on the west by the Opal Mound Fault, which is estimated to have a maximum

Figure 3. Location map for Roosevelt Hot Springs KGRA
(from Glenn and others 1981).

Figure 4a. Geologic map of a portion of the Roosevelt Hot Springs KGRA (from Nielson and others 1978). See Figure 4c for symbol explanations.

Figure 4b. A west-to-east geologic cross section (line A - A' in Figure 4a) through the Roosevelt Hot Springs KGRA and Well 9-1 (from Glenn and others 1981). Geothermal production in the KGRA is centered about the small graben shown here.

QUATERNARY	Os	Opaline and chalcedonic sinter
	Oca	Silica-cemented alluvium
	Oh	Hematite-cemented alluvium
	Oal	Alluvium
	Ore	Air-fall and non-welded ash-flow tuff
TERTIARY	Tds	Diabase dikes
	Tmd	Microdiorite dikes
	Tgr	Granite dikes; fine-grained
	Ts	Granite; medium- to coarse-grained
	Ts	Syenite; medium-grained
	Tbg	Biotite granite; medium- to coarse-grained
	Tqm	Quartz monzonite
	Td	Diorite; fine- to medium-grained
	gd	Biotite granodiorite; fine- to medium-grained
	hgn	Hornblende gneiss; medium- to coarse-grained meta-quartz monzonite
ABO	PCbg	Banded gneiss; conspicuously layered feldspar-quartz-biotite gneiss, schist and migmatite
		Contact, dashed where uncertain
		Fault, intruded by microdiorite dike; arrow shows dip
		Fault, dashed where inferred, dotted where concealed; arrow shows dip
		Brecciation
		Strike and dip of inclined and vertical joints
		Strike and dip of inclined and vertical foliation
		Prospect
		Shallow diamond drill hole
		Geothermal well

From Sibbett & Nielson, 1980

Figure 4c. Explanation of the symbols appearing in Figure 4a, b.

offset of about 50 meters (Gertson and Smith 1979). The upper bedrock portions of the productive wells are in convective heat flow environments and are believed to be fracture-controlled (Glenn and Hulen 1979). Points of fluid entry in these wells are typically shallow, less than 2000 to 3000 ft deep, and well logs demonstrate fracture-related effects, e.g., lower velocity, resistivity and density, and higher neutron porosity.

The bedrock geology of the area is dominated by Precambrian metamorphic and plutonic rocks and felsic plutonic phases of the Tertiary Mineral Mountains Pluton. A thick wedge of detrital arkosic alluvium covers all bedrock west of the Mineral Mountains. Buried Tertiary sediments may be present in the Milford Graben, west of the KGRA (Gertson and Smith 1979).

The structure is influenced by three principal fault systems. Because the reservoir rocks demonstrate little primary permeability, Nielson and others (1978) suggested that the geothermal reservoirs are controlled by intersections among the principal zones of faulting.

The oldest fault system is dominated by a west-dipping low-angle fault (Figure 4b) that has been interpreted to be a denudation fault based upon normal offsets--up to 2000 ft--of Tertiary intrusives mapped in the Mineral Mountains (Nielson and others 1978). It is also possible that this fault initiated as a thrust fault during the Cretaceous, and

was reactivated during the Tertiary. Associated with this system are numerous northwest-trending, high-angle normal faults in the hanging wall of the low-angle fault.

Faults in the second system are east-west trending, have been mapped as high-angle normal faults, and are thought to be quite old. Recent microearthquake data suggest these are deep-seated shear zones that may have significant strike-slip displacements (Schuyler C. Schaff, personal communication). The most evident of these is the Hot Springs or Negro Mag Fault (Plate I, Figure 4a).

The youngest system consists of north-trending, steeply dipping normal faults that are typical of Basin and Range geology. These faults control the present fumarolic activity and are responsible for recent hydrothermal activity which has deposited opaline and chalcedonic sinters. The deposits are exposed at several sites along the trace of the Opal Mound Fault (Figure 4a).

Well 9-1 and Vicinity

Utah State Geothermal Well 9-1 is located about 1800 feet west of the Opal Mound Fault. Although the well is 6875 ft (2099 m) deep and attains a maximum temperature of 440°F (227°C) at the bottom, it apparently has no significant fluid-entry points and is a non-producer. Numerous geophysical logs, including temperature, neutron porosity, magnetic susceptibility, bulk density, and gamma

radiation, have been run over the entire length of the well. Others, including interval transit time, spontaneous potential, and conductivity, were run only at depths below 4200 ft (casing depth).

The well logs show a major fracture zone between 2740 and 2770 ft. Believed to be the principal low-angle fault, it divides Well 9-1 into two distinct structural, lithologic, and alteration regimes (Figure 4b). Above this fault zone, lithology is complex, hydrothermal alteration is moderate to locally intense, and evidence of structural disruption is abundant. Below 2770 ft, only a few relatively unbroken and weakly altered rock types are present (Glenn and others 1981).

PROCEDURES

Field Methods

The hardware and methodology were tested in July 1980, in a deep well located near Phelan, 50 miles east of Los Angeles, California. The value of the areal well shoot for fracture investigations could not be assessed at the Phelan site, because the well was drilled in a thick section of Plio-Pleistocene and Holocene sediments and does not penetrate crystalline bedrock. Nevertheless, this "dry run" was particularly helpful to the planning of the shot size and location strategy used at the Utah site.

The Roosevelt Hot Springs site was staked, surveyed, and drilled for shot and gravity stations in early Fall 1980. In late October, 262 shots, fired at 22 shot stations located within a 0.6 mile radius of the well head (Plate I), were recorded for well depths ranging from 96 to 2180 ft. Equipment failure precluded logging the well to the planned depth of 4000 ft.

Supplementary gravity and refraction surveys were planned to constrain the structural model for the vicinity of the well. Thus, certain survey stakes in the station grid served a dual or treble purpose as gravity, refraction and/or downhole shot stations. A 310-station gravity survey was conducted to provide Bouguer gravity data (Plate I). However, time considerations precluded running the refraction survey, which was designed to provide near-surface velocity information along the seismic profile azimuths.

Site preparation

Using established roads as much as possible, six shot/gravity lines were staked out radially to a maximum distance of 2 miles from Well 9-1 (Plate I). These lines were designated NE, SE, SSW, SW, W, and NW with respect to the well. Two additional gravity lines, T and EW, were tied into this grid.

Stations were spaced an average of 0.05 mile (264 ft) apart and were numbered beginning with 1 at the first

station out from the well head. As an example, the fifth station out along the northeast line was approximately 0.25 mile from the well and was designated NE5.

The coordinates of the station markers with respect to the well head were surveyed using a Hewlett Packard HP-3810 Total Station infrared ranging system. Radial distances were accurate to ± 2 feet and elevations to ± 6 inches.

Shot holes were drilled in clusters at stations 5, 9, and 12 on each radial line. These stations were initially intended for logging of depth intervals from 800 to 2000, 1900 to 3000, and 2900 to 4000 ft, respectively. Also, 36 shotpoints, station NV, were carefully staked out from 300 to 362 ft on a line bearing $N20^{\circ}E$ from the well head. This shot group traced the horizontal projection of the well bore, and effectively kept the horizontal shot-sensor distance a constant 300 ft. Because station NV adhered most closely to the assumptions of equation (1), data from this shot group provided the most reliable log of the vertical velocity function.

Three more shot stations were added during the recording phase to increase the areal coverage of the 800 to 2000 ft depth interval. Stations E1 and E5 were set at 364 ft and roughly 1200 ft along a line running east from the well head and a series of shots was situated about station W2. The shots at these stations were somewhat randomly scattered and fired about the station markers. This was

especially true at the W2 site and is evident upon examination of the surface arrival data. For this reason, the velocity log obtained from station W2 is less reliable than logs from other stations in the shot array.

Shooting strategy

An idealized schematic diagram of the shot-sensor configuration for the areal well shoot is shown in Figure 5a. Figure 5b shows the 2-dimensional region covered by a profile from a distant shot station along with some of the parameters considered in the data reduction process.

The degree of resolution sought made at least six considerations essential to the planning of the shot station locations:

- In order to determine velocity as a function of raypath direction, the shot stations and downhole sensor positions had to be located in such a way that several azimuths and raypath angles were sampled in the region surrounding the well. Thus, the shot array included stations close to the well--NV, E1, and W2 (Plate I)--such that first arrivals were rays having near-vertical angles of incidence at the downhole package; the possibility of casing arrivals had to be considered in locating these shots. The stations at greater radial distances were necessary to obtain downhole arrivals having a significant horizontal component.

- It was necessary to consider what effects might be introduced by intervening structural features when choosing

Figure 5. Shot-sensor configurations for an areal well shoot: 5a) Shot stations are distributed radially and azimuthally about the well. Shots fired at station X_1 provide $t(z)$ data for vertical velocity determination. Those fired at the more distant stations are used to determine directional velocity variation; the corresponding down-hole sensor positions are chosen to provide optimal $t(z)$ data for the intervals shown. 5b) Variables used in data reduction. The velocity log determined from this profile should be valid for the shaded area. Refraction data may be required to adequately determine the velocity structure for the area above the dashed line, particularly if lateral variations in this region are substantial.

sites for the more distant shots. Stations were not located where there were obvious structural problems that would make static corrections difficult. For example, no shot stations were located across the Opal Mound Fault (Plate I). Since the near-surface velocity structure varied significantly between the well and the distant shot stations, independent geophysical data were required to determine the lateral velocity variations, i.e., the planned gravity and refraction surveys.

● The shots were clustered as tightly as possible about each surveyed station position in order to minimize source variability. Ideally, all shots fired at a particular shot station should produce identical effects, because solution of the well shoot integral--equation (1)--assumes the horizontal shot-sensor distance remains constant. The shot charges were NIPAK (ammonium nitrate/nitro methane), varied from 1 to 6 pounds with increasing distance from the well head, and were buried at depths of 5 to 8 ft. These shots were significantly smaller than those utilized in other types of seismic exploration work because of the extremely favorable signal-to-noise ratio attendant to a downhole sensor, and because of the relatively competent local surface layer. Accordingly, shothole spacings in the shot clusters ranged from 5 ft near the well head (smaller charges) to 10 ft for the more distant stations.

● Because solution of equation (1) requires direct arrivals, an effort was made to locate the shots sufficiently near the well that the first arrivals over a given depth interval were not refracted rays.

● Another factor limiting the distance at which shot stations could be usefully located was a loss of resolution for the travel time derivative (dt/dz). This occurs when the direct rays have a very shallow incident angle over several sampling intervals. The net effect is a steepened $t(z)$ curve where the travel time derivatives are poorly constrained, given the ± 1 millisecond error of the recording system.

● Finally, choosing the locations of shotpoints and downhole sampling intervals required consideration of the accuracy of the timing system versus shot siting-related errors. The previous example clearly illustrates this point.

Recording/data collection

A schematic of the electrical components of the system used to record travel time is shown in Figure 6.

Because the geothermal environment is very harsh (corrosive and hot) the cable head for the downhole package was specially designed to be heat, corrosion, and pressure resistant. The cable head design was borrowed from Archuleta and Todd (IASL technical report no. LA-7325-MS, 1978). The sensors were Mark Products 4.5 hertz

Figure 6. The principal components of the shot recording system used at the Well 9-1 site.

seismometers, and were specified to tolerate 500°F (they failed below 350°F). One vertical and two series-wired, orthogonal horizontal phones were housed in an airtight compartment. A hole-lock mechanism, threaded to the bottom of the seismometer housing, completed the package.

The package was lowered into the well by an insulated, 4-conductor, stainless-steel-armored cable connected to a trailer-mounted, electric winch. The ascent and descent rates were regulated by a rheostat control and sensor depths were determined to ± 1 ft from a depth guage attached to the winch assembly. When positioned at the appropriate depth, the cable was slackened to reduce transmission of surface noise to the downhole package. We found it most efficient to record all shots planned for a given depth before moving the package uphole to the next level, as it took much less time to drive the shotbox and transmitter between shot stations than to reposition the package.

A 4-channel Teac 61 FM/DR/Casette recorder taped the data. Two channels recorded the horizontal and vertical components from the downhole package, a third monitored a surface geophone located near the well head, and the fourth recorded voice annotations and the 1 KHz timing break transmitted simultaneously with the detonation of each shot. Operators at the recording site and shotpoint communicated via two General Electric 50 watt/35 MHz radios.

Well Shoot Data Reduction and Analysis

Although the results of the gravity survey made it clear that the assumption of insignificant lateral velocity gradients was violated at the more distant shot stations, equation (1) was still used to reduce all of the travel time data. This practice was justified as follows:

- The velocity log derived using equation (1) on travel time data collected along a profile where non-horizontal lithologic structure is present, can be shown to be a function which still reflects the average velocity as a function of depth in the profile (shaded portion in Figure 5b). The effects of non-horizontal structure on these logs may be examined by applying equation (1) to $t(z)$ data created by forward ray tracing through simple layered models having dipping strata.
- Comparison of logs derived from each shot station can be shown to reflect the azimuthal variation of depths to any critical (high velocity impedance) structural horizon(s). The structural information derived from the gravity survey can be used to explain most of the azimuthal variations among the Well 9-1 velocity logs.

● Solution of a parametric ray equation which considers lateral velocity gradients would be most difficult, as several poorly constrained variables (e.g., lateral velocity functions, $V(x,y)$) are introduced to the problem. Equation (1) provides an adequate solution, because the lateral velocity gradient, for any given profile in the survey, is at least an order of magnitude less than the vertical gradient. This means that lateral velocity variation could introduce an approximate uncertainty of $\pm 10\%$ to the velocity determinations. However, there is no way around this problem unless ancillary seismic data is available to constrain the lateral velocity model. This problem is especially critical in the upper portions of the downhole profiles obtained from distant shot stations.

Data playback

Hardcopy seismograms were produced from the data tapes using the system diagrammed schematically in Figure 7. One such seismogram is shown in Figure 8.

A Digital PDP 11 computer was programmed so that the onset of the 1 KHz shot tone caused digitization of the data channels at a 1 KHz sampling rate. The digitized traces were displayed on a screen and first arrivals were picked with a moveable cursor. Multiple shot checks and repeated

Figure 7. Schematic diagram of the system used to produce hardcopy seismograms from the taped shot records.

playbacks indicated that these picks were valid to within 1 millisecond. A labelling string was also added to each record. Shots were identified by voice annotations preceding each shot record, and from logbook entries made at the time of recording. In addition to the hardcopy, the digitized records were stored on floppy discs for future reference.

The record from the surface geophone proved to be most useful for making a qualitative assessment of source variations by allowing a comparison of all of the shots in a given cluster. The tightly grouped shot clusters showed surface phone travel time variations of less than ± 5 milliseconds; the more poorly grouped clusters showed much larger variations (± 15 msec in the worst case). Despite the large variations seen for the surface arrivals, the downhole arrival variations were approximately an order of magnitude less because the raypath distances were much less variable for direct arrivals than for surface-to-surface refracted arrivals.

Solving the well shoot integral

The set of FORTRAN programs used to compute velocity functions from the travel time data and to analyze the results is provided in Appendix A. The reduction and analysis of the seismic data were performed using a Digital PDP 11/34 computer system at the U. S. C. Geophysical Laboratory.

The programs TZINT and VELRED were designed to provide $V(z)$ through solution of equation (1). The method used to solve the well shoot integral is the subject of this section.

Starting with a raw data set of downhole travel times measured from a single shot station ($t_m(z_k)$, $k=1, n$) a digitized travel time data set was produced by TZINT. This program fits a Chebyshev polynomial to the measured travel time data by the method of least squares. The order and/or tolerance of the polynomial fit can be specified by the user. On output, a set of evenly spaced calculated travel times is obtained (spacing was user-specified). Although this step is not necessary, it was found to be a desirable one as the final result is a smoothed $V(z)$ curve that is less likely to be biased by a single errant data point.

The principal reason for using a Chebyshev polynomial fit to the data was to obtain reasonable values for the derivatives (dt/dz). Critics may argue that the velocity-depth curves produced from these smoothed travel time curves show velocity variations which are an artifact of the smoothing method. However, upon closer examination, the derivatives from the smoothed curves vary less radically than those taken from a straight-line fit between adjacent measured data points. Furthermore, unless an inordinately high order polynomial was fit to the data, the maximum and minimum values of the derivatives from the smoothed curve

were less than those obtained from a point-to-point fit. Experience has shown that, except at the endpoints, the resulting velocity curves demonstrate more subdued (less noisy) variations than curves obtained from any other method.

The preceding step gives a monotonic, evenly spaced data set-- $t(z_i)$ --over an interval between the uppermost and lowermost measurement points in the well. If the z -spacing is small enough (20 ft was used in reducing the Well 9-1 data) it is useful to assume that $V(z)$ is linear between adjacent data points. Given this assumption, equation (1) can be written as a sum of integrals:

$$t(z_j) = \sum_{i=1}^{j-1} \int_{z_i}^{z_{i+1}} \left\{ 1 - V^2(s) \left[\frac{1}{V_j^2} - \left(\frac{dt}{dz} \right)_j^2 \right] \right\}^{-\frac{1}{2}} \frac{ds}{V(s)}, \quad (13)$$

where

$$V(s) = g_i(s - z_i) + V_i$$

and

$$g_i = \frac{V_{i+1} - V_i}{z_{i+1} - z_i}$$

describe the velocity functions between data points. Each of these integrals has an analytic solution given by (Michaels 1979)

$$dt_i = \frac{1}{g_i} \ln \left[\frac{(1 - \sqrt{1 - p^2 V_{i+1}^2})(1 + \sqrt{1 - p^2 V_i^2})}{p^2 V_i V_{i+1}} \right]. \quad (14)$$

Hence, equation (13) may be written as

$$t(z_j) = \sum_{i=1}^{j-1} \frac{1}{g_i} \ln \left[\frac{(1 - \sqrt{1 - p^2 V_{i+1}^2})(1 + \sqrt{1 - p^2 V_i^2})}{p^2 V_i V_{i+1}} \right]. \quad (15)$$

To solve equation (1), $V(z)$ must be known (or estimated) for the section above the point at which $V(z)$ is being evaluated. Therefore, a valid velocity-depth curve is most easily produced by working from the top to the bottom of the profile. If this is done, then the values of the V_i 's will be known for all the points above z_j and equation (15) will contain only two interdependent variables-- V_j and p . The relation between these variables is given by equation (5). Since dt/dz_j is a computable quantity, V_j can be determined by an iterative method which varies its (V_j 's) value until a tolerable value of $t(z_j)$ is reached.

The validity of $V(z)$ can be checked by calculating x from equation (4); if the reduced velocity function is an appropriate one, this calculated value should be the same as the shotpoint distance. Equation (4) also has an analytic solution which can be written in summation form as

$$x = \sum_{i=1}^{j-1} dx_i = \sum_{i=1}^{j-1} \frac{1}{p g_i} \left(\sqrt{1 - p^2 V_i^2} - \sqrt{1 - p^2 V_{i+1}^2} \right) \quad (16)$$

when linear velocity functions are assumed (Michaels 1979).

When $V_i = V_{i+1}$, the equations for dt_i and dx_i --(14) and (16)--become invalid. In this case their solutions are

$$dt_i = \frac{(z_{i+1} - z_i)}{V_i \sqrt{1 - p^2 V_i^2}} \quad (17)$$

and

$$dx_i = \frac{p V_i}{\sqrt{1 - p^2 V_i^2}} (z_{i+1} - z_i) . \quad (18)$$

Refraction

The planned refraction lines were not shot. However, a small amount of information, believed to be valid for the upper 250 ft of the alluvium, was obtained from the surface arrivals of the 39 shots fired at station NV. These shots ranged in distance from 86 to 390 ft from the surface sensor.

A smoothed travel time curve was constructed using least squares fits of a spliced linear and cubic function (Figure 9a). Velocity as a function of depth was then calculated in the standard manner, using the Wiechert-Herglotz-Bateman integral--

$$z(V) = \frac{1}{\pi} \int_0^{\Delta} \cosh^{-1} \left(V \frac{dt}{dx} \right) dx , \quad (19)$$

where

$$\frac{1}{V} = \left(\frac{dt}{dx} \right)_{x=\Delta} .$$

This procedure gave a set of data points which were least squares fit to the function $V(z) = az^b + v_0$ (Figure 9b).

Figure 9a. Travel time curve for refracted P-wave arrivals from station NV shots to surface sensor. Dots are data; solid line is a tangentially-spliced least squares fit of a cubic with a linear function.

Construction of a near-surface velocity correction function

The lack of refraction data--essential to provide near-surface velocity information--made it necessary to construct a velocity function for the upper portions of the profiles so that $V(z)$ could be solved at depth. The program VELRED produced such a function by patching the near-surface function--determined from the NV surface arrivals--to a linear function extending to the depth of the second calculated downhole travel time point $t(z_2)$ (Figure 10). The depth of the patch between the two functions was varied until both $t(z_2)$ and the shotpoint distance could be reproduced by integration of the composite function in equations (3) and (4). VELRED then solved for $V(z)$ at z_2 to z_n using the method introduced earlier. Integration of equation (16) was also performed at each sampled depth and showed that the correction procedure was appropriate, and therefore justified, as the calculated shot distance varied by less than 5 ft.

This step was performed to allow tractability in reducing velocity structure from the downhole travel time data sets. Refraction data would have given important information about lateral velocity variations along the shot profiles. Because the constructed velocity model is, at best, an average function over the first 1000 ft of the distant shot profiles, there is no reason to believe that

Figure 10. Schematic diagram showing the construction of a near-surface velocity function to allow computation of $V(z)$ at depth. The point z_{patch} and the slope of the line segment between z_{patch} and z_2 are varied iteratively until the travel time (t_2) and the shot distance (x) are both matched to their measured values. The function $V(z) = az^b + V_0$ was determined from refracted P-wave arrivals recorded for station NV shots (Figure 9). The composite function is tied to the point $t(z_2)$ because calculation of the derivative dt/dz_2 is accomplished by least squares fitting a line to three adjacent points on the travel time curve (t_1, t_2, t_3).

the ray parameters determined from this model adequately represent the true ray parameters. Thus, a significant uncertainty ($\sim 10\%$) may be introduced to the determination of azimuthal velocity variation at depth due to the poorly constrained velocity structure in the upper 1000 ft of the distant shot profiles. This uncertainty, coupled with approximate errors of 10% in the measurement of dt/dz , makes any interpretation of crack orientations from the azimuthal variations less credible.

Residual velocity calculation/analysis

A useful way of examining the azimuthal variation of the velocity profiles was to compare velocity residuals of the individual profiles with respect to a reference function derived from a weighted average of the logs from stations NV, W2, and E1. This was done by using FORTRAN programs which calculate the absolute difference, ratio, or percent difference of two digitized velocity-depth functions. As with the travel time and velocity data, a plotting program was written to allow visual appraisal of the results of these calculations (Appendix A).

Forward modelling

Forward modelling programs were written to produce travel time data by ray-tracing through a user-specified velocity model. They were used to assess the validity of simple models interpreted from field data and to test the velocity reduction programs. Two such programs appear in Appendix A.

Gravity Reduction

Gravity data reduction and some simple modelling were performed with the aid of a programmable Hewlett Packard HP-34C pocket calculator (Appendix B). Density values used in the gravity reduction process were obtained from published log data from Well 9-1 (Glenn and others 1981) and other wells in the KGRA (Glenn and Hulen 1979). Bouguer gravity values were computed assuming an average density of $\rho = 2.4$ gm/cc for the alluvium encountered in the upper 750 ft of Well 9-1. Terrain corrections for 35 selected stations were calculated using a Hammer chart; the terrain corrections for the other stations in the grid were then interpolated from these 35 calculated corrections. In making the terrain corrections, $\rho = 2.67$ was assumed for the Mineral Mountains, which constituted a substantial portion of the topography.

A simple model employing the method of Talwani and others (1959) was used to estimate the depth to crystalline basement beneath stations west of the Opal Mound Fault (Appendix B). For these calculations, a density contrast of 0.25 gm/cc at the alluvium-bedrock interface was assumed.

RESULTS

Gravity Data

The results of the gravity survey are provided graphically in Plate I and are tabulated in Appendix C. Many of the normal faults shown on Plate I were qualitatively identified from anomalous signals in the Bouguer gravity profiles which exceeded the regional gradient.

Depth to basement calculations gave a dip of approximately 22° W for the alluvium-bedrock interface west of the Opal Mound Fault. This has been confirmed by data from an east-west reflection profile which was run 1/2 mile south of Well 9-1 (Howard P. Ross, personal communication).

Seismic Data

Travel time curves, velocity-depth functions for selected profiles, an average vertical velocity log, and residual plots from the areal well shoot of Well 9-1, are provided in Figures 11, 12, 13, and 14, respectively. The travel time data is also tabulated in Appendix D, and outputs from the velocity reduction program appear in Appendix E.

The most obvious azimuthal velocity variation, as expected, can be attributed to the west-dipping alluvium-bedrock interface (Figure 11, 12, 14).

Figure 11. Travel time data (crosses) and least squares fit Chebyshev polynomial curves from the areal well shoot of Utah State Geothermal Well 9-1. Data from the more westerly shot stations show greater separation between stations on the time axis, reflecting the westward increase of the depth to basement beneath the alluvium. Data from most of the more distant shot stations (9 & 12) are not sufficient (i.e., sparse and/or the fit curves were too steep to adequately resolve dt/dz) to produce useful velocity logs.

Figure 12. Velocity-depth curves for selected seismic profiles about Well 9-1. Each curve is identified by the name of the shot station from which the $t(z)$ data was measured; this is followed by the degree of the Chebyshev polynomial fit to the $t(z)$ data in the process of determining

Figure 12 (cont'd). $V(z)$. Curves corresponding to the more westerly shot stations show lower velocities overall, a direct result of the increased depth to crystalline basement beneath these stations. Most of the curves display a zone of decreased velocity centered about the 1600

Figure 12 (cont'd). ft depth. Several of the curves also show velocity decreases about 1000 ft and below 2000 ft. These three zones of decreased seismic velocity are attributed to fracture zones intersecting Well 9-1 at approximate depths of 1000, 1600, and 2050 ft.

Figure 14. Velocity residual plots: Distant station velocity profiles with respect to VZREF. These plots compare the velocity logs determined from distant shot station $t(z)$ data with the vertical velocity structure (Figure 13) of Well 9-1. Above 1000 ft, these plots show greater average velocities for easterly stations (e.g., shallower crystalline

Figure 14 (cont'd). basement) and decreasing average velocities for the more westerly stations. Below 1000 ft, oscillations in these plots reflect a less exaggerated response of the distant logs to the low velocity zones. This may be attributed to steep dips of the fracture zones and/or to poorer resolution of dt/dz at greater shot distances.

Three zones which show marked 20 to 40% velocity decreases are centered roughly at 1000, 1600, and 2050 ft. This is a very encouraging result, as these zones--particularly the one at 1600 ft, which is best constrained by the data--correlate quite well with fracture indicators in other well logs (Plate II).

DISCUSSION

The aim of any geophysical exploration method is to assess specific geologic structure from direct and indirect measurements of physical rock properties in a particular area. In the Roosevelt Hot Springs KGRA, information from the areal well shoot method generally confirms previous interpretations and adds substantially to the present structural model of the area surrounding Utah State Geothermal Well 9-1. Through a combination of the gravity and well shoot results, it was possible to interpret the crack densities, aspect ratios, and probable trends of some of the fracture zones which intersect the well. No attempt was made to determine crack orientations within these zones, as the data set was insufficient.

Geologic Structure

The addition of our information to that provided by Glenn and others (1981) has produced the revised cross-section shown in Figure 15. Examination of the gravity data (Plate I and Appendix C) indicates the presence of several small-displacement, west-dipping normal faults located west of the Opal Mound Fault and east of Well 9-1. These faults strike roughly N15°E and have estimated displacements of only 50 to 100 ft. Assuming that the closest two faults intersect Well 9-1 at 1000 and 1600 ft requires that they dip from 60° to 70°W. Dips of 60° to 70° and the northerly strike of these faults are consistent with those observed locally for other faults in the youngest Basin and Range system. There is no evidence in the gravity data for the large displacement of the steep, west-dipping fault shown intersecting Well 9-1 in Figure 4b.

Azimuthal variations among velocity logs from distant shot stations reflect the west-dipping alluvium-bedrock unconformity (Figure 14, 15, 16). Most of these logs (Figure 12a - h) show the same distinct (although less pronounced) velocity decrease at about 1600 ft as do the logs for stations nearest the well head (Figure 12i - l, 13). The velocity at 1600 ft shows azimuthal variation which should allow an interpretation of the strike and dip and/or crack orientations in this fault zone. However, the strong correlation between the azimuthal variation of

Figure 15a. A revised east-west geologic profile through Well 9-1 which has been interpreted from the results of this study. See Figure 15b for lithology explanation.

Figure 15 lithologic symbols & counterparts from Glenn & others (1981)

COMMENTS		GRAPHIC LITHOLOGY EXPLANATION	
		LITHOLOGY (J. Hulen, 1979)	Probable surface equivalent (Sibbett and Nielson, 1980, Nielson and others, 1978)
Qal		Qal (Quaternary alluvium)
	not shown		Tmd (Tertiary microdiarite)
	not shown		Partially felsic segregations in Pcbg (Precambrian banded gneiss) also various felsic phases of the Tertiary Mineral Mountains Pluton.
Ts		Ts (Tertiary syenite)
Tqm		Tqm (Tertiary quartz monzonite)
Tpd — probably Tertiary?		No obvious surface equivalent
?gd — older than Tertiary?		Probably Td (Tertiary diorite) or gd (biotite granodiorite)
Pcbg		Pcbg (Precambrian banded gneiss)

Figure 15b. Explanation of the lithology shown in Figure 15a. These figures (15a, b) should be compared to Figure 4a and Plate II.

Figure 16. Azimuthal variation of the velocities determined from $t(z)$ data from the number 5 stations (~ 0.25 mi from Well 9-1). Also shown are the estimated depths to basement beneath these stations which were calculated from the results of the gravity survey. Calculated errors in the average velocities for the surface to 1000 ft interval were less than 1% while those for the 1500 to 1700 ft zone ranged from 10 to 20% of the values shown. See text for further discussion.

average velocity near 1600 ft and that above 1000 ft indicates that most of the observed anisotropy is structurally-induced (Figure 16).

The estimated depth to basement suggests that the average velocities should vary azimuthally as $\sin \phi$. The departure from this variation seen for the near-surface interval (surface to 1000 ft) and the 1600 ft interval is probably due to structural irregularities (e.g., buried fault scarps and erosional troughs) in the dipping alluvium-bedrock unconformity and not to oriented rock fractures. Some forward modelling has shown that the structurally-induced variations produced by a shallow dipping unconformity will propagate to greater depths when the velocity data is reduced using equation (1). This would explain the strong correlation between the azimuthal velocity variations of the two intervals shown in Figure 16. The apparent velocity break between stations SE5 and SW5 (arrows in Figure 16) corroborates the strike and dip interpreted for the 1000 and/or 1600 ft zone(s) (Figure 15).

If any fracture-related anisotropy is present, it has been obscured by the preceding structural considerations. In order to extract fracture-related anisotropies from the velocity data, we should look for anticorrelations between the upper and lower intervals in Figure 16. Except for those at stations SSW5 and NW5, no obvious disparities exist, and these may be attributed to the steep,

west-dipping fault zones intersecting Well 9-1. Without more velocity information above 1000 ft to account for the structurally-induced anisotropy, it is not possible to evaluate the presence of anisotropy due to oriented cracks.

The less exaggerated signature of the decreased velocity zones seen in the logs from the more distant shot stations (Figure 12, 14) could be attributed to the steep dip of the fracture zones. However, the loss of resolution in dt/dz attendant to more distant shots may also be responsible.

Several sections of the temperature log show near-zero temperature gradients (Plate II). These were attributed to tool sticking (Glenn and others 1981), but the coincidence of these sections with well velocity lows and fault zones--at depths of 1000, 1600, 2050, and 2800 ft--indicates a different interpretation. Given the response time and descent rate of the temperature sensor in the cased hole, it seems unlikely that the step increases at the top of each isothermal segment can be attributed to tool sticking. Fluid circulation in the fractured zones intersecting the well would explain these anomalous log segments. Fractures are also indicated at these depths by the neutron and geology logs (Plate II).

Another possible structural interpretation is depicted in Figure 15. Two intrusive units--the pyroxene diorite (Tpd) at 1600 to 2000 ft and syenite (Ts) at 3500 to 4000

ft--appear to lie almost entirely between sets of parallel normal faults. Thus, it seems likely that these are Tertiary dikes intruded upward along steep fracture zones. The weaker contact surfaces might have become sites of renewed faulting.

Crack Parameter Estimation

Using the composite vertical velocity log (Figure 13) and volume porosities reported for fault zones below the casing (Glenn and others 1981), crack densities and average crack aspect ratios were estimated for the fracture zones detected by the areal well shoot (Table 1). The fractures were assumed to be completely saturated, as these zones lie well below the water table, thus permitting use of Figure 2b. The values of three variables in these calculations had to be assumed:

$\frac{\bar{V}_p}{V_p}$ = cracked velocity/uncracked velocity. The maximum velocity observed in the well log--19,000 to 24,000 ft/sec--was taken to be the uncracked velocity for the igneous and metamorphic rocks occurring in Well 9-1. Minimum velocities of 14,000 to 16,000 ft/sec were observed to be coincident with interpreted fracture zones and were used as cracked velocities.

$\frac{K}{K}$ = fluid bulk modulus/uncracked rock bulk modulus.

This value is given as 3.0×10^{-2} for water-saturated rock (O'Connell and Budiansky 1974). Anderson and Whitcomb (1973) indicated that a value of 10^{-3} is more appropriate for water at mid-crustal depths and temperatures. The latter value is favored for the calculations here as the above-normal temperatures encountered in the geothermal well suggest the water would behave as a "softer" (more compressible) fluid in such an environment.

η = volume porosity. Glenn and others (1981) determined volume porosities of roughly 5 to 7% in fault zones intersecting Well 9-1 at depths below the casing. Because the region above 2800 ft has been subjected to greater fracturing and hydrothermal alteration, porosities in the major fractures may be more on the order of 10%. η , ϵ , and c/a are related by $\eta = \epsilon(4\pi/3)(c/a)$. Thus, values of c/a and ϵ were deemed appropriate when this relation gave values of η between 5 and 10%.

With the preceeding assumptions, crack aspect ratios of approximately 10^{-2} have been estimated for the fracture zones in the upper bedrock portion of Well 9-1. This cannot be verified by physical observations. However, crack aspect ratios ranging from 10^{-4} to 10^{-2} have been reported for

Table 1. Crack density and aspect ratio calculations
for fracture zones intersecting Well 9-1.¹

$\bar{v}_p/v_p$	$\tilde{K}/K$	c/a	ω	ϵ	η	
0.58 (14/24)	3×10^{-2}	3×10^{-4}	100	----	-----	
		3×10^{-3}	10	1.43	1.80%	
		<u>3×10^{-2}</u>	1	0.63	7.92%	←
		3×10^{-1}	10^{-1}	0.38	47.75%	
		3	10^{-2}	0.34	-----	
0.71 (15/21)	3×10^{-2}	3×10^{-4}	100	1.44	.18%	
		3×10^{-3}	10	0.92	1.16%	
		<u>3×10^{-2}</u>	1	0.40	5.03%	←
		3×10^{-1}	10^{-1}	0.26	32.67%	
		3	10^{-2}	0.23	-----	
0.84 (16/19)	3×10^{-2}	3×10^{-4}	100	0.75	.09%	
		3×10^{-3}	10	0.50	.63%	
		<u>3×10^{-2}</u>	1	0.20	2.51%	←
		<u>3×10^{-1}</u>	10^{-1}	0.13	16.34%	
		3	10^{-2}	0.125	-----	

¹ $\omega = (\tilde{K}/K)(a/c)$; $\tilde{K}/K = 3 \times 10^{-2}$ for near-surface groundwater. Arrows and underlines indicate the appropriate range of values for c/a and ϵ given $0.58 < \bar{v}_p/v_p < 0.84$ and $\eta \sim 10\%$. Here $c/a \sim 3 \times 10^{-2}$ to 10^{-2} and $\epsilon \sim 0.63$ to 0.13 . See text for explanations of variables.

Table 1 (cont'd). Crack density and aspect ratios
calculated for Well 9-1 fracture zones.²

$\bar{v}_p/v_p$	$\tilde{K}/K$	c/a	ω	ε	η
0.58	10^{-3}	10^{-4}	10	1.43	.06%
		10^{-3}	1	0.63	.26%
		10^{-2}	10^{-1}	0.38	1.59%
		10^{-1}	10^{-2}	0.34	14.24%
		1	10^{-3}	0.33	-----
0.71	10^{-3}	10^{-4}	10	0.92	.04%
		10^{-3}	1	0.40	.17%
		10^{-2}	10^{-1}	0.26	1.09%
		10^{-1}	10^{-2}	0.23	9.63%
		1	10^{-3}	0.22	92.15%
0.84	10^{-3}	10^{-4}	10	0.50	.02%
		10^{-3}	1	0.20	.08%
		10^{-2}	10^{-1}	0.13	.54%
		10^{-1}	10^{-2}	0.125	2.85%
		1	10^{-3}	0.12	50.27%

² $\omega = (\tilde{K}/K)(a/c)$; $\tilde{K}/K = 10^{-3}$ for water at mid-crustal depths and temperatures. For $0.58 < \bar{v}_p/v_p < 0.84$ and $\eta \sim 10\%$, $c/a \sim 10^{-1}$ to 10^{-2} and $\varepsilon \sim 0.38$ to 0.12 .

samples of Westerly granite (Hadley 1976). The metamorphic and igneous complex encountered in Well 9-1 has apparently been subjected to several phases of deformation and alteration. Therefore, it does not seem unreasonable that cracks occurring in this formation would be rounder, on the average, than those found in a relatively undisturbed sample of granite.

Estimated crack densities for the fracture zones range from 0.2 to 0.6. These relatively high crack densities (normal values of ξ for crystalline rocks are less than 0.1) and the isothermal anomalies in the temperature log indicate that the fracture zones intersecting Well 9-1 are substantially permeable. Therefore, it is suggested that the well is not a non-producer for lack of hydrothermal conduits, but because the conduits have been structurally isolated from the primary geothermal system located east of the Opal Mound Fault.

Potential Applications

The areal well shoot method appears to be particularly well-suited for several applications. A higher signal-to-noise ratio and accurate depth control are significant advantages over other seismic methods. Because of the favorable signal-to-noise ratio, it should be possible to resolve relatively high-frequency seismic signals, a distinct plus for local attenuation studies (O'Connell and Budiansky 1977).

The most obvious disadvantage is the need for a well. However, in the search for fluid and gas resources, dry wells are often drilled in the vicinity of a known reservoir. In these cases, an areal well shoot may yield structural and physical information useful for determining the next well site(s).

The areal well shoot method also has a potential application to earthquake prediction. There is evidence that the dilatant region preceding an earthquake is constrained to a relatively narrow area about the fault zone (Mazzella and Morrison 1974). Thus, the anomalous seismic velocity behavior associated with dilatant rock fractures might be measured in a deep well located in the fault zone.

The well shoot integral for elliptically anisotropic media

Efforts to design velocity reduction programs produced an interesting by-product, the derivation of the well shoot integral for elliptically anisotropic media (Appendix F). Although not readily applicable at the Roosevelt Hot Springs site, its applicability may be seen to investigations of other geologic environments:

In some structural situations, particularly in sedimentary environments, one may assume that the velocity behavior is elliptically anisotropic (Vander Stoep 1966, Carlson and Christensen 1979, Bachman 1979). If, in the vicinity of a well, the axes of the velocity ellipse at any

given depth are vertical and horizontal, then two functions, $V_v(z)$ and $V_h(z)$, define the velocity behavior. In this special case, Snell's Law for elliptically anisotropic media is

$$p = \frac{V(\theta, z) \sin \theta}{V_h^2(z)}, \quad (20)$$

where

$$V(\theta, z) = \frac{V_v(z) V_h(z)}{\sqrt{V_v^2(z) \sin^2 \theta + V_h^2(z) \cos^2 \theta}}$$

is the velocity, at a given depth, for a ray travelling at an angle θ with respect to vertical (Levin 1978).

The parametric ray equations for this case are

$$t(z) = \int_0^z \frac{d\xi}{V_v(\xi) \sqrt{1 - p^2(z) V_h^2(\xi)}} \quad (21)$$

and

$$x = p(z) \int_0^z \frac{V_h^2(\xi) d\xi}{V_v(\xi) \sqrt{1 - p^2(z) V_h^2(\xi)}}, \quad (22)$$

and the well shoot integral is

$$t(z) = \int_0^z \left\{ 1 - V_h^2(\xi) \left[\frac{1 - V_v^2(z) \left(\frac{dt}{d\xi} \right)^2}{V_h^2(z)} \right] \right\}^{-\frac{1}{2}} \frac{d\xi}{V_v(\xi)}. \quad (23)$$

Now, using equation (1), $V_v(z)$ may be determined using travel time data from a series of shots at stations near the

well head. $V_h(z)$ can then be determined in much the same manner, using equation (23) and travel time data from shot stations located at greater distances from the well.

The limitation of this solution is that lateral velocity gradients can cause a worse problem than those encountered in the direct solution and interpretation of data with equation (1). Therefore, it would not be advisable to attempt an application of this equation to data collected in a well where significant lateral gradients are known to exist.

CONCLUSIONS

Three principal conclusions have been drawn from this study:

- Azimuthal velocity variations were observed in the vicinity of Well 9-1, but they have been attributed primarily to the irregular, west-dipping alluvium-bedrock unconformity, and not to oriented fracture sets.

- Velocity lows correlate strongly with zones which display fracture-related effects in other geophysical logs conducted in Well 9-1. On this basis, three fracture zones, intersecting the well at approximate depths of 1000, 1600, and 2050 ft, were identified.

- Crack density and aspect ratios for these zones were estimated using the self-consistent velocity theory of

O'Connell and Budiansky (1974). The estimated values compare favorably with laboratory observations of fractured igneous rocks (Hadley 1976). Relatively large estimated crack densities and corresponding isothermal segments in a temperature log suggest that these zones may have sufficient permeability to be points of fluid entry in the well. It is suggested that the fracture zones have been structurally isolated from the primary geothermal reservoir, since Well 9-1 is considered to be a non-producer.

The areal well shoot method may be a powerful tool for reconnaissance of fractured regions in the vicinity of a well. The method's potential for estimating fracture parameters and delineating fault trends is evident, even though less than the desired information was obtained at the Roosevelt Hot Springs site. The method and its development clearly merit continued interest in both the academic and commercial sectors of the geophysical community.

The collection of supplemental geophysical data may be necessary to corroborate interpretations of the velocity profiles. Appropriate choices of such logs and surveys will depend upon the well site. Improved recording hardware, field methodology, and data reduction and analysis techniques are needed to refine the method, and are presently attainable.

Recommendations for Future Work

The technology required to make the areal well shoot a viable method for reconnaissance of fractured reservoirs is at hand. As with any method tested for the first time, both the deployment and execution phases were a learning process. Experience mandates at least four steps to improve the method:

- Increase the timing resolution to at least ± 0.1 millisecond, as follows:

- Use a more reproducible source. A vibroseis, weight drop, air gun in a water pit, sparker, or land airgun would minimize source variation and enable shot stacking to improve resolution of the first break. High frequency sources are preferred, as a faster rise time will allow more precise P-wave travel time determinations.
- Minimize timing errors by eliminating the FM tape recorder and interfacing directly with a digital recorder or minicomputer.
- Increase the record sampling rate to 10,000 Hz. Examination of the Well 9-1 records indicates that more precise picks could have been made if the sampling rate had been increased.

- Decrease the depth sampling interval. Given a timing resolution of ± 0.1 msec, the sampling interval may be reduced to as little as 20 ft. With the function $V(z)$ viewed as a waveform, sampling theory states that acceptable resolution of the velocity behavior in a layer requires a sampling interval $1/2\pi$ times the layer thickness (Nyquist's frequency). Thus, to satisfactorily measure the velocity behavior in a fracture zone 150 ft thick, the sampling interval should be no more than 25 ft.
- Measure the time-depth derivative directly with two sensors separated by a fixed vertical distance (say 20 ft). The time differential would be determined by autocorrelation of the two signals.
- Acquire detailed information on the near-surface velocity structure. At greater shot distances, structural effects on dt/dz may severely limit the resolving power of the areal well shoot method. Accurate estimates of near-surface velocities for the zones beneath distant shotpoints are needed to correct the travel times recorded from shallow-incident-angle rays. Closely spaced, reversed refraction profiling along the shot

azimuths seems the most prudent method, as the inverted velocity data could be easily incorporated into the velocity reduction program.

Coupled with analysis of P-wave data, studies of S-wave and attenuation data from the areal well shoot would further enhance the estimation of fracture parameters. Of particular interest is the possibility of detecting fractures from the S-wave polarization effects occurring in transversely anisotropic media (Crampin 1981). The addition of S-wave data would also allow unique, independent interpretations of crack density and porosity (O'Connell and Budiansky 1974).

REFERENCES

- Anderson, D. L. and J. H. Whitcomb, 1973. The dilatancy diffusion model of earthquake prediction, in Proceedings of the Conference on Tectonic Problems of the San Andreas Fault System, edited by R. L. Kovach and A. Nur, Stanford University Press, Stanford CA., pgs. 417-426.
- Anderson, D. L., B. Minster, and D. Cole, 1974. The effect of oriented cracks on seismic velocities, J. Geophys. Res. 79, 4011-4015.
- Archuleta, J. R., and B. E. Todd, 1978. Hot dry rock geothermal energy development project cablehead assembly: equipment development report, Los Alamos Scientific Laboratory Rept. No. LA-7325-MS, Los Alamos, N. M., 8 pgs.
- Bachman, R. T., 1979. Acoustic anisotropy in marine sediments and sedimentary rocks, J. Geophys. Res. 84, 7661-7663.
- Bamford, D. and K. R. Nunn, 1979. In situ seismic measurements of crack anisotropy in the Carboniferous limestone in Northwest England, Geophys. Prosp. 27, 322-338.
- Brace, W. F., B. W. Paulding, and C. Schloz, 1966. Dilatancy in the fracture of crystalline rocks, J. Geophys. Res. 71, 3939-3953.
- Carlson, R. L., and N. I. Christensen, 1979. Velocity anisotropy in semi-indurated calcareous deep sea sediments, J. Geophys. Res. 84, 205-211.
- Cheng, C. H., and M. N. Toksoz, 1979. Inversion of seismic velocities for the pore aspect ratio spectrum of a rock, J. Geophys. Res. 84, 7533-7544.
- Crampin, S., 1977. A review of the effects of anisotropic layering on the propagation of seismic waves, Geophys. J. R. astr. Soc. 49, 9-27.
- Crampin, S., 1978. Seismic-wave propagation through a cracked solid: polarization as a possible dilatancy diagnostic, Geophys. J. R. astr. Soc. 53, 467-496.
- Crampin, S. and D. Bamford, 1977. Inversion of P-wave velocity anisotropy, Geophys. J. R. astr. Soc. 49, 123-132.

Crampin, S., R. McGonigle, and D. Bamford, 1980. Estimating crack parameters from observations of P-wave velocity anisotropy, Geophysics 45, 345-360.

Crampin, S. and R. McGonigle, 1981. The variation of delays in stress-induced anisotropic polarization anomalies, Geophys. J. R. astr. Soc. 64, 115-131.

Dobrin, M. B., 1976. Introduction to Geophysical Prospecting (3rd ed.), McGraw-Hill Inc., Ch.7, 226-227.

Garbin, H. D. and L. Knopoff, 1973. The compressional modulus of a material permeated by a random distribution of circular cracks, Quart. Appl. Math. 30, 453-464.

Garbin, H. D. and L. Knopoff, 1975a. The shear modulus of a material permeated by a random distribution of free circular cracks, Quart. Appl. Math. 33, 296-300.

Garbin, H. D. and L. Knopoff, 1975b. Elastic moduli of a medium with liquid-filled cracks, Quart. Appl. Math. 33, 301-303.

Gertson, R. C., and R. B. Smith, 1979. Interpretation of a seismic refraction profile across the Roosevelt Hot Springs, Utah and vicinity, Univ. of Utah, Dept. of Geology and Geophysics, 119 pgs., DOE/DGE Contract No. DE-AC07-78ET28392.

Glenn, W. E., and J. B. Hulen, 1979a. Interpretation of well log data from four drill holes at Roosevelt Hot Springs KGRA, Univ. of Utah Res. Inst., Earth Science Laboratory Rept. 28, Salt Lake City, 74 pgs.

Glenn, W. E., J. B. Hulen, and D. L. Nielson, 1981. A comprehensive study of LASL Well C/T-2 Roosevelt Hot Springs KGRA, Utah, and applications to geothermal well logging, Los Alamos Scientific Laboratory Rept. No. LA-8686-MS, Los Alamos, N. M., 175 pgs. DOE/DGE Contract No. 4-N29-4988H-1.

Grant, F. S. and G. F. West, 1965. Interpretation Theory in Applied Geophysics, McGraw-Hill Inc., Ch. 5, 133-138.

Hadley K., 1976. Comparison of calculated and observed crack densities and seismic velocities in Westerly granite, J. Geophys. Res. 81, 3484-3494.

Julian, B. R. and D. L. Anderson, 1968. Travel times, apparent velocities and amplitudes of body waves, Bull. Seis. Soc. Am. 58, 339-366.

- Keith, C. M. and S. Crampin, 1977. Seismic body waves in anisotropic media: reflection and refraction at a plane interface, Geophys. J. R. astr. Soc. 49, 181-208.
- Keith, C. M. and S. Crampin, 1977. Seismic body waves in anisotropic media: propagation through a layer, Geophys. J. R. astr. Soc. 49, 209-223.
- Keith, C. M. and S. Crampin, 1977. Seismic body waves in anisotropic media: synthetic seismograms, Geophys. J. R. astr. Soc. 49, 225-243.
- Levin, F. K., 1978. The reflection, refraction, and diffraction of waves in media with an elliptical velocity dependence, Geophysics 43, 528-537.
- Levin, F. K., 1979. Seismic velocities in transversely isotropic media, Geophysics 44, 918-936.
- Mazzella, A. and H. F. Morrison, 1974. Electrical resistivity variations associated with earthquakes on the San Andreas Fault, Science 185, 855-857.
- Michaels, P., 1977. Computer program: seismic raypath migration with the pocket calculator, Geophysics 42, 1056-1063.
- Nielson, D. L., B. S. Sibbett, D. B. McKinney, J. B. Hulen, J. N. Moore, and S. M. Samberg, 1978. Geology of Roosevelt Hot Springs KGRA, Beaver County, Utah, Univ. of Utah Res. Inst., Earth Science Laboratory Rept. 12, Salt Lake City, 121 pgs.
- O'Connell, R. J. and B. Budiansky, 1974. Seismic velocities in dry and saturated cracked solids, J. Geophys. Res. 79, 5412-5426.
- O'Connell, R. J. and B. Budiansky, 1977. Viscoelastic properties of fluid-saturated cracked solids, J. Geophys. Res. 82, 5719-5735.
- Rothman, R. L., 1975. Crack distribution under uniaxial load and associated changes in seismic velocities prior to failure, Ph. D. Thesis, Penn. State Univ., 131 pgs.
- Simmons, G., T. Todd, and W. S. Baldrige, 1975. Toward a quantitative relationship between elastic properties and cracks in low porosity rocks, Am. J. of Sci. 275, 318-345.
- Talwani, M., J. L. Worzel, and M. Landisman, 1959. Rapid gravity calculations for two-dimensional bodies with application to the Mendicino submarine fracture zone, J. Geophys. Res. 64, 49-59.

Telford, W. M., L. P. Geldart, R. E. Sheriff, and D. A. Keys, 1976. Applied Geophysics, Cambridge University Press, 7-104, 347-350, and 798-799.

Vander Stoep, D. M., 1966. Velocity anisotropy measurements in wells, Geophysics 31, 900-916.

Ward, S. H., W. T. Parry, W. P. Nash, W. R. Sill, K. L. Cook, R. B. Smith, D. S. Chapman, F. H. Brown, J. A. Whelan, and J. R. Bowman, 1978. A summary of the geology, geochemistry, and geophysics of the Roosevelt Hot Springs thermal area, Utah, Geophysics 43, 1515-1542.

Waters, K. H., 1978. Reflection Seismology: A Tool for Energy Resource Exploration, John Wiley and Sons Inc., Ch. 7, 187-207.

Appendix A - FORTRAN programs

These programs were written to be used on a Digital PDP RSX-11/34 computer system. Therefore, some of the commands appearing in them (particularly those affecting input and output files) are system-specific. They may be adapted for use on other systems with minor modifications.

A brief description of each program is given below. Included in the description are explanations of how the programs are related to one another. The variables for inputs and outputs are described in the comment headers of the individual program listings.

Data reduction programs

TZINT.FTN--fits a Chebyshev polynomial to the measured travel time data (TZM.DAT).

input: TZM.DAT; TZINT.DAT

output: FOR006.DAT = tofz.dat (digital $t(z)$ values from fit curve).

FOR004.DAT--error analysis of fit

TZPLOT.FTN--plots tofz.dat and tzm.dat on HP plotter.

input: TZM.DAT; TOFZ.DAT; TZPLOT.DAT (plot parameters)

output: $T(z)$ plot on HP-plotter

Note: TZ2PLOT.FTN is same program but does not plot and label axes. This allows plotting more than one curve on the same set of axes without a redundant axes plot.

VELRED.FTN--computes $V(z)$ from $t(z)$ data.

input: TZM.DAT (not required); TOFZ.DAT;
VELRED.DAT

output: Constructed surface velocity function and digital $V(z)$ data (velocity assumed linear between sampled depths--digital interval = DELZ from tofz.dat; DELZ = 20 ft was used for Well 9-1 data). Output file is FOR006.DAT and is copied to a record file and to vofz.dat. Before vofz.dat can be used as input to subsequent programs, its header (1st 3 lines) must be deleted. Also, output to write (5,??) [set=ti:=screen] are $V_k(z)$, $T_k(z)$, and k so that progress of VELRED can be monitored in case it gets stuck (which it sometimes does when intolerable data values are input!).

VHZRED.FTN--(not fully developed) similar to VELRED but for elliptically anisotropic case. Can be used to find $V_h(z)$ given distant shot station travel time data (TOFZ.DAT) and $V_v(z)$ from shots near well head (VVOFZ.DAT = vzref.dat).

input: TOFZ.DAT; VVOFZ.DAT; VHZRED.DAT output:
FOR006.DAT = vofz.dat or vhofz.dat

VZPLOT.FTN--plots vofz.dat (digital $V(z)$ values resulting from velocity reduction programs).

input: VOFZ.DAT, TZM.DAT (for ZM only);
VZPLOT.DAT (plot parameters)

output: $V(z)$ plot w/ measured depths (ZM) also given adjacent to z-axis.

VZPDIG.FTN--digitizes patched (constructed) velocity function values at same interval as the data in VOFZ.DAT. This allows comparison of functions in averaging and residual analysis. Can also be performed before plotting vofz.dat.

input: VOFZ.DAT; VZPDIG.DAT

output: FOR006.DAT can be copied to:

vofz.dat (for vzplot.ftn)

vz1.dat or vz2.dat (for vavrg.ftn)

vzref.dat or vofz.dat (for vresid.ftn)

VAVRG.FTN--averages two digitized velocity functions (VZ1.DAT and VZ2.DAT). Both input fcns. must have same monotonic depth values and, therefore, may require editing after output from VZPDIG and before input to VAVRG.

input: VZ1.DAT; VZ2.DAT; VZPDIG.DAT

output: FOR006.DAT - copy to: vzref.dat,
vofz.dat (to plot), or any other appropriate
filename for future reference.

VRESID.FTN--compares a velocity function (VOFZ.DAT)
w.r.t. VZREF.DAT. Can calculate %-diff., absolute
diff., or ratio of the values of each function
versus depth.

input: VZREF.DAT; VOFZ.DAT; VRESID.DAT

output: FOR006.DAT - copy to dvozf.dat (for
input to vrplot.ftn)

Note: The comment applied to vz1.dat and vz2.dat
under VAVRG.FTN applies to VZREF.DAT and VOFZ.DAT
here.

VRPLOT.FTN--plots output of VRESID.DAT (DVOFZ.DAT)
if in %-diff.

input: DVOFZ.DAT; VRPLOT.DAT

output: Residual plot on HP-plotter.

Forward modelling programs

FWDMDL.FTN--produces travel time data by ray
tracing through a layered velocity model between
specified shot distances and sensor depths. Layers
can be elliptically anisotropic ($V_h \neq V_v$) or

isotropic ($V_h = V_v$). This model can be used to check VELRED; VHZRED output, or to check validity of layered models.

input: FWDMDL.DAT (model parameters and shot and sensor coordinates)

output: FOR006.DAT - copy to tofz.dat or tzm.dat to check velocity reduction programs.

DIPUNC.FTN--models $t(z)$ data (from specified shot distance) given a simple 2-layer velocity model having a dipping interface. Dip (δ) and depth at which the interface intersects the well are specified in the model. Using output $t(z)$ data as input to velred, this model can be used to demonstrate the effect on calculated $V(z)$ data when significant lateral velocity gradients are present.

input: DIPUNC.DAT (model parameters)

output: FOR006.DAT - can copy to tzm.dat or tofz.dat to check velred.

Assign write(5,??) to screen to monitor progress during run.


```

C      TZINT.FTN - - FITS LEAST SQUARES CHEBYSHEV POLYNOM-
C      IAL TO MEASURED T(Z) DATA IN ORDER TO CALCULATE
C      SMOOTHED T(Z) VALUES AT REGULAR INTERVALS (DELZ).
C      THIS PROGRAM USES IBM/SCIENTIFIC SUBROUTINES.
C
C      NZM = # OF MEASURED DATA POINTS TM(NZM)
C      ZCA = INITIAL DEPTH FOR CALCULATION OF TC(Z)
C      DELZ = DEPTH INTERVAL FOR OUTPUT DATA (TC(Z))
C      IP = DIMENSION OF LEAST SQUARES FIT (IP<NZM)
C      IOP = OPERATING PARAMETER FOR SUBR DAPFS (USE -2)
C      EPS = RELATIVE TOLERANCE FOR LOSS OF SIGNIFICANCE
C      TEST USED IN DAPFS
C      ETA = RELATIVE TOLERANCE FOR SQUARE SUM OF ERRORS
C
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      DIMENSION ZMTM(41),ZM(20),TM(20),B(20),WORK(231)
      CALL ASSIGN(1,'TZM.DAT',7)
      CALL ASSIGN(2,'TZINT.DAT',8)
      CALL ASSIGN(6,'XY:',3)
      CALL ASSIGN(5,'AB:',3)
      CALL ASSIGN(4,'XY:',3)
100    READ(2,100)NZM,IP,IOP,ZCA,DELZ,EPS,ETA
      FORMAT(3I3/3F8.2/2E10.2)
101    READ(1,101)((ZM(I),TM(I)),I=1,NZM)
      FORMAT(F6.2,F8.5)
      DO 1 I=1,NZM
        ZMTM(I)=ZM(I)
1      CONTINUE
      NZA=NZM+1
      NZE=2*NZM
      DO 2 I=NZA,NZE
        ZMTM(I)=TM(I-NZM)*10000.
2      CONTINUE
      NZE=2*NZM+1
      ZMTM(NZE)=-1.
      CALL DAFCH(ZMTM,NZM,IP,XD,XO,WORK,IER)
      CALL DAPFS(WORK,IP,IRES,IOP,EPS,ETA,JER)
      WRITE(5,200)IRES,IER,JER
200    FORMAT(2X,3I3)
      II=IRES-1
      NRES=0
      DO 3 K=1,II
        NRES=NRES+K
3      CONTINUE
      DO 4 I=1,IRES
        B(I)=WORK(NRES+I)
4      CONTINUE
      ZC=ZCA
      XC=XD*ZC+XO
5      CALL DCNFS(TC,XC,B,IRES)
      TC=TC/10000.
      WRITE(6,201)ZC,TC
201    FORMAT(1X,F6.2,F8.5)
      ZC=ZC+DELZ
      IF(ZC.LT.ZM(NZM)) GO TO 5
      WRITE(4,202)
202    FORMAT(T8,'ZM',T15,'TM',T24,'TC',T32,'DELT')
      SERSQ=0.
      DO 6 J=1,NZM
        XC=XD*ZM(I)+XO
        CALL DCNFS(TC,XC,B,IRES)
        TC=TC/10000.
        DELT=TM(I)-TC
        WRITE(4,203)ZM(I),TM(I),TC,DELT
203    FORMAT(T3,F8.2,T12,F8.5,T21,F8.5,T30,F8.5)
        SERSQ=SERSQ+DELT**2
6      CONTINUE
      AERSQ=SERSQ/NZM
      AER=SQRT(AERSQ)
      WRITE(4,204)AER
204    FORMAT(/T3,'MEAN ERROR:',F8.5,1X,'SECONDS')
      STOP -END

```

```

TZPLOT.FTN USES HP PLOTTER AND SUBROUTINES TO CON-
STRUCT A PLOT OF MEASURED AND CALCULATED T(Z) DATA.

NZC; NZM = # OF CALCULATED; MEASURED DATA POINTS
NBTX, NETY = # OF EIG (LAAELED) TICKS ON X-, Y-AXIS
XOF, YOF = PAGE OFFSET (INCHES) FROM LOWER LT CORNER
XSZ, YSZ = PAGE SIZE (INCHES)
XOR, YOR = ORIGIN (INCHES) FROM LOWER LT OF PG
XSC; YSC = SCALES (DATA UNITS PER INCH)
XL, YL = AXIS LENGTH (INCHES)
XLBLX, YLBLX = COORD'S OF X-AXIS LABEL (IN) W.R.T. P
XLELY, YLELY = Y-AXIS LABEL COORD'S FROM L.L. OF PG
XBT, YBT = SPACE BETWEEN LAAELED TICKS (DATA UNITS)
XTIC; YTIC = DATA UNIT LENGTHS OF X = Y TICKS
WIDE, HIGH, SLANT = CHARACTER SFECs (IN. IN. DEG)
ZM(1), TM(1) = MEASURED TRAVEL TIME DATA
Z(K), T(K) = DIGITAL T(Z) DATA FROM TZINT

DIMENSION T(200),Z(200),TM(20),ZM(20),X(2),Y(2)
CALL ASSIGN(2,'TOFZ.DAT',6)
CALL ASSIGN(3,'TZM.DAT',7)
CALL ASSIGN(4,'TZPLOT.DAT',10)
1 READ(4,104) NZC,NZM,NBTX,NBTY,XOF,YOF,XSZ,YSZ,XCR,
1 YOR,XSC,YSC,XL,YL,XLELX,YLELX,XLELY,YLELY,XBT,YBT,
1 XTIC,YTIC,WIDE,HIGH,SLANT
104 FORMAT(4I4/9(2F8.2/),3F8.2)
102 READ(2,102) ((Z(K),T(K)),K=1,NZC)
FORMAT(F8.2,F8.5)
READ(3,102) ((ZM(I),TM(I)),I=1,NZM)
CALL INITIA
CALL OFFSET(XOF,YOF)
CALL SIZE(XSZ,YSZ)
CALL ORIGIN(XOR,YOR)
CALL SCALE(XSC,YSC)
CALL COLOUR(1)
CALL TXTDEF(WIDE,HIGH,SLANT)
CALL ANGLE(0.)
CALL PLIFT
X(1)=0.
X(2)=0.
Y(1)=0.
Y(2)=-YSC*YL
CALL PLOT(X,Y,2,NC)
CALL PLIFT
Y(2)=0.
X(2)=XSC*XL
CALL PLOT(X,Y,2,NC)
CALL PLIFT
X(1)=0.
X(2)=0.
Y(1)=XTIC
Y(2)=-XTIC
NLTX=NBTX*10
NLTY=NETY*10
XLT=XBT/10.
YLT=YBT/10.
DO 1 I=1,NLTX
X(1)=X(1)+XLT
X(2)=X(1)
CALL PLOT(X,Y,2,NC)
CALL PLIFT
1 CONTINUE
X(1)=0.
X(2)=0.
Y(1)=2.*XTIC
Y(2)=-2.*XTIC

```

```

DO 2 I=1,NETX
    X(1)=X(1)+XET
    X(2)=X(1)
    CALL PLOT(X,Y,2,NC)
    CALL FLIFT
2  CONTINUE
    CALL TEXT(XLBLX,YLBLX,'TRAVEL TIME (milliseconds)@')
    Y(1)=0.
    Y(2)=0.
    X(1)=YTIC
    X(2)=-YTIC
    DO 3 I=1,NLTY
        Y(1)=Y(1)-YLT
        Y(2)=Y(1)
        CALL PLOT(X,Y,2,NC)
        CALL FLIFT
3  CONTINUE
    Y(1)=0.
    Y(2)=0.
    X(1)=2.*YTIC
    X(2)=-2.*YTIC
    DO 4 I=1,NETY
        Y(1)=Y(1)-YET
        Y(2)=Y(1)
        CALL PLOT(X,Y,2,NC)
        CALL FLIFT
4  CONTINUE
    XX=XOR-6.*WIDE
    YY=YOR
    ZZ=0.
    N=NETY+1
    DO 5 I=1,N
        CALL HFNUMD(XX,YY,ZZ,0)
        CALL FLIFT
        YY=YY-YET/YSC
        ZZ=ZZ+YET
5  CONTINUE
    XX=XOR-WIDE
    YY=YOR+XTIC/XSC
    ZZ=0.
    DO 6 I=1,NETX
        XX=XX+XET/XSC
        ZZ=ZZ+XET
        CALL HFNUMD(XX,YY,ZZ,0)
        CALL FLIFT
6  CONTINUE
    CALL ANGLE(90.)
    CALL TEXT(XLBLV,YLBLV,'DEPTH (feet)@')
    DO 7 I=1,NZM
        TM(I)=TM(I)*1000.
        ZM(I)=-ZM(I)
7  CONTINUE
    DO 8 I=1,NZC
        T(I)=T(I)*1000.
        Z(I)=-Z(I)
8  CONTINUE
    CALL PLOT(T,Z,NZC,NC)
    CALL FLIFT
    CALL SYMBOL(4)
    DO 9 I=1,NZM
        CALL PLOT(TM(I),ZM(I),1,NC)
        CALL FLIFT
9  CONTINUE
    CALL ANGLE(0.)
    CALL BORDER
    CALL PAGE
    STOP
    END

```

```

C      TZ2PLOT.FTN IS SAME AS TZPLOT BUT DOES NOT PLOT AND
C      LABEL AXES.  ALLOWS DATA FROM ANOTHER SHOT GROUP TO
C      BE PLOTTED ON A PLOT CONSTRUCTED BY TZPLOT.

      DIMENSION T(200),Z(200),TM(20),ZM(20)
      CALL ASSIGN(2,'TOFZ.DAT',8)
      CALL ASSIGN(3,'TZM.DAT',7)
      CALL ASSIGN(4,'TZPLOT.DAT',10)
      READ(4,104) NZC,NZM,NBTX,NBTY,XOF,YOF,XSZ,YSZ,XOR,
1      YOR,XSC,YSC,XL,YL,XLBLX,YLBLX,XLBLY,YLBLY,XBT,YBT.
1      XTIC,YTIC,WIDE,HIGH,SLANT
104    FORMAT(4I4/9(2F8.2/),3F8.2)
102    READ(2,102) ((Z(K),T(K)),K=1,NZC)
      FORMAT(F8.2,F8.5)
      READ(3,102) ((ZM(I),TM(I)),I=1,NZM)
      CALL INITIA
      CALL OFFSET(XOF,YOF)
      CALL SIZE(XSZ,YSZ)
      CALL ORIGIN(XOR,YOR)
      CALL SCALE(XSC,YSC)
      CALL COLOUR(1)
      CALL TXTDEF(WIDE,HIGH,SLANT)
      CALL PLIFT
      DO 7 I=1,NZM
          TM(I)=TM(I)*1000.
          ZM(I)=-ZM(I)
7      CONTINUE
      DO 6 I=1,NZC
          T(I)=T(I)*1000.
          Z(I)=-Z(I)
6      CONTINUE
      CALL PLOT(T,Z,NZC,NC)
      CALL PLIFT
      CALL SYMBOL(4)
      DO 5 I=1,NZM
          CALL PLOT(TM(I),ZM(I),1,NC)
          CALL PLIFT
5      CONTINUE
      CALL ANGLE(0.)
      CALL BORDER
      CALL PAGE
      STOP
      END

C      VELRED SOLVES EQUATION (1) (THIS PAPER) FOR V(Z)
C      GIVEN A DATA SET--T(Z)--OF P-WAVE TRAVEL TIMES
C      FROM A SURFACE SHOT STATION (FIXED HORIZONTAL DIS-
C      TANCE) TO A VARIABLE-DEPTH BOREHOLE SEISMOMETER.

C      NFIT = 1 (FOR DTDZ CALCULATED BY IBM SUBR DDGT3)
C      NUNITS = 1 (IN=OUT UNITS); 2 (FT IN; M OUT)
C      NZC; NZM = NO. OF DATA PTS IN TOFZ.DAT; TZM.DAT
C      A, B, V0 = NEAR-SURFACE VELOCITY FCN  $V(Z)=A*Z**B+V0$ 
C      DELZ = DIGITAL DEPTH INTERVAL FOR TOFZ.DAT
C      EPSX, EPST = ITER. TOLERANCE FOR COMPUTED T, XSHOT
C      XSHOT = HORIZ. SHOT STATION DIST. FROM WELL
C      ZSHOT = SHOT GROUP ELAVATION W.R.T. WELL HEAD
C      ZPATCH = INITIAL VALUE OF PATCH DEPTH TRIED FOR
C      CONSTRUCTED NEAR-SURFACE CORRECTION FCN
C      Z(K), T(K) = TOFZ.DAT
C      ZM(I), TM(I) = TZM.DAT

```

```

      IMPLICIT DOUBLE PRECISION (A-D,F-H,O-Z)
      DIMENSION Z(200),T(200),DTDZ(200),V(200),GR(200),
1      ZM(25),TM(25),AUX(200)
      EXTERNAL FVWT,FVWX
      CALL ASSIGN(1,'VELRED.DAT',10)
      CALL ASSIGN(2,'TOF2.DAT',8)
      CALL ASSIGN(3,'T2M.DAT',7)
      CALL ASSIGN(6,'XY',3)
      CALL ASSIGN(5,'AB',3)
      READ(1,101)NFIT,NUNITS,NZC,NZM,A,B,V0,DELZ,EPSX,
1      EPST,XSHOT,ZSHOT,ZPATCH
101      FORMAT(4I4/2F11.8/F8.2/2F8.2/F8.6/3F8.2)
      READ(2,102)((Z(K),T(K)),K=1,NZC)
102      WRITE(5,102)((Z(K),T(K)),K=1,NZC)
      FORMAT(F8.2,F8.6)
      READ(3,102)((ZM(I),TM(I)),I=1,NZM)
      WRITE(5,102)((ZM(I),TM(I)),I=1,NZM)
      EPSTI=EPST/10.
      EPSXI=EPSX/10.
      IF(NFIT.EQ.1) GO TO 10
      DO 19 K=2,NZC
          DTDZ(K)=(T(K)-T(K-1))/(Z(K)-Z(K-1))
19      CONTINUE
      GO TO 21
10      CALL DDGT3(Z,T,DTDZ,NZC,IER)
      C
      C
      C
      START OF ITERATIONS TO FIND V(Z)
      1ST FIND V(2) & ZPATCH SUCH THAT XC=XSHOT & TT=T(2)
21      WRITE(6,220)
220      FORMAT(T5,'Z',T15,'V',T25,'T',T35,'DTDZ',T50,'P',
1      T65,'XC',T75,'THTA'//)
      K=2
      VZP=FVEXP(A,B,V0,ZPATCH)
15      V(2)=VZP
      VMN=300.
      VMX=100000.
      GO TO 25
20      THTA=ASIN(P*V(K))*180./3.1415926535897932
      IF(NUNITS.EQ.1) GO TO 55
          V(K)=.3048*V(K)
          P=P/.3048
          DTDZ(K)=DTDZ(K)/.3048
          XC=XC*.3048
          Z(K)=Z(K)*.3048
55      WRITE(6,221)Z(K),V(K),T(K),DTDZ(K),P,XC,THTA
221      FORMAT(T3,F8.2,T12,F5.2,T23,F7.5,T32,E11.4,T47,E11.4
1      ,T60,F8.2,T72,F8.5)
      K=K+1
      IF(K.GT.NZC) GO TO 60
      V(K)=V(K-1)
      VMN=300.
      VMX=100000.
      TT=0.
25      WRITE(5,125)K,V(K)
125      FORMAT(2X,I3,T10,F8.2)
      C
      C
      C
      FIND P(Z)**2
      PSQ=1./V(K)**2-DDTZ(K)**2
      IF(PSQ.LT.0.) GO TO 50
      C0=1.-(V0**2)*PSQ
      IF(C0.LT.0.) GO TO 40
      C1=1.-(VZP**2)*PSQ
      IF(C1.LT.0.) GO TO 40
      DO 30 I=2,K
          CC=1.-(V(I)**2)*PSQ
          IF(CC.LT.0.) GO TO 40
30      CONTINUE
      P=SQRT(PSQ)
      C

```

```

C      FIND TT FOR WEATHERING LAYER
C
      IF(VZF.NE.V0) GO TO 31
      CALL DTVCON(TT,P,PSQ,0.,ZPATCH,V0)
      GO TO 32
31      CALL DGATRC(0.,ZPATCH,EPSTI,200,FVWT,TT,JER,AUX,A.B.
1      V0,PSQ)
C
C      FIND DT FOR DZFTCH
32      IF(K.GT.2) GO TO 29
      DZFTCH=Z(2)-ZPATCH+ZSHOT
      GR(2)=(V(2)-VZF)/DZFTCH
29      IF(V(2).NE.VZF) GO TO 33
      CALL DTVCON(DT,P,PSQ,0.,DZFTCH,V(2))
      GO TO 34
33      CALL DTLIN(DT,P,PSQ,GR(2),VZF,V(2))
34      TT=TT+DT
      IF(K.EQ.2) GO TO 37
C
C      COMPUTE TT FOR DEPTHS > Z(2)
      GR(K)=(V(K)-V(K-1))/(Z(K)-Z(K-1))
      DO 37 I=3,K
      IF(V(I).NE.V(I-1)) GO TO 35
      CALL DTVCON(DT,P,PSQ,Z(I-1),Z(I),V(I))
      GO TO 36
35      CALL DTLIN(DT,P,PSQ,GR(I),V(I-1),V(I))
36      TT=TT+DT
37      CONTINUE
      WRITE(5,126) TT
126     FORMAT(T30,F9.5)
      IF(ABS(TT-T(K)).LT.EPST) GO TO 31
      IF((TT-T(K)).GT.0.) GO TO 40
50      VMX=V(K)
      V(K)=(2.*VMN+VMX)/3.
      GO TO 25
40      VMN=V(K)
      V(K)=(2.*VMN+VMX)/3.
      GO TO 25
C
C      CALCULATE XC. IF AT Z(2), COMPARE WITH XSHOT AND
C      ADJUST ZPATCH IF NECESSARY.
C
C      CALCULATE XC IN WEATHERING LAYER
51      XC=0.
C
      IF(V0.NE.VZF) GO TO 41
      CALL DXVCON(XC,P,PSQ,0.,ZPATCH,V0)
      GO TO 42
41      CALL DGATRC(0.,ZPATCH,EPSTI,200,FVWX,XC,KER,AUX,A.B.
1      V0,PSQ)
C      FIND DX FOR DZFTCH
42      IF(V(2).NE.VZF) GO TO 43
      CALL DXVCON(DX,P,PSQ,0.,DZFTCH,VZF)
      GO TO 44
43      CALL DXLIN(DX,P,PSQ,GR(2),VZF,V(2))
44      XC=XC+DX
      IF(K.EQ.2) GO TO 52
C
C      CALCULATE XC FOR DEPTHS > Z(2)
      DO 47 I=3,K
      IF(V(I).NE.V(I-1)) GO TO 45
      CALL DXVCON(DX,P,PSQ,Z(I-1),Z(I),V(I))
      GO TO 46
45      CALL DXLIN(DX,P,PSQ,GR(I),V(I-1),V(I))
46      XC=XC+DX
47      CONTINUE
      WRITE(5,127) XC
127     FORMAT(T40,F10.2)
      GO TO 20
52      WRITE(5,127) XC

```



```

FUNCTION FVWX(ZETA,A,B,V0,PSQ)
VWZ=A*ZETA**B+V0
FVWX=SQRT(PSQ)*VWZ/SQRT(1.-PSQ*VWZ**2)
RETURN
END

```

```

C      DQATRC IS A MODIFIED VERSION OF THE IBM NUMERICAL
C      QUADRATURE SCIENTIFIC SUBROUTINE DGATR. IT HAS BEEN
C      CHANGED TO INTEGRATE FUNCTIONS HAVING MORE THAN ONE
C      LISTED VARIABLE, BUT ONLY THE PRINCIPAL VARIABLE (X)
C      IS THE VARIABLE OF INTEGRATION.

```

```

C      SUBROUTINE DGATRC(XL,XU,EPS,NDIM,FCT,Y,IER,AUX,A,B,C,PSQ)
C

```

```

C      DIMENSION AUX(1)
C      DOUBLE PRECISION AUX,XL,XU,X,Y,H,HH,HD,F,O,SM,FCT,A,B,C,PSQ
C

```

```

C      PREPARATIONS OF ROMBERG-LOOP
C      AUX(1)=.500*(FCT(XL,A,B,C,PSQ)+FCT(XU,A,B,C,PSQ))
C      H=XU-XL
C      IF(NDIM-1)8,8,1
C      IF(H)2,10,2

```

```

C      NDIM IS GREATER THAN 1 AND H IS NOT EQUAL TO 0.
C      2

```

```

C      HH=H
C      E=EPS/DABS(H)
C      DELT2=0.00
C      F=1.00
C      JJ=1
C      DO 7 I=2,NDIM
C      Y=AUX(1)
C      DELT1=DELT2
C      HD=HH
C      HH=.500*HH
C      F=.500*F
C      X=XL+HH
C      SM=0.00
C      DO 3 J=1,JJ
C      SM=SM+FCT(X,A,B,C,PSQ)
C      X=X+HD

```

```

C      3
C      AUX(I)=.500*AUX(I-1)+F*SM
C      A NEW APPROXIMATION OF INTEGRAL VALUE IS COMPUTED BY
C      MEANS OF TRAPEZOIDAL RULE.
C

```

```

C      START OF ROMBERG'S EXTRAPOLATION METHOD.
C

```

```

C      Q=1.00
C      JI=1-1
C      DO 4 J=1,JI
C      II=1-J
C      Q=Q+Q
C      Q=Q+Q
C      4
C      AUX(II)=AUX(II+1)+(AUX(II+1)-AUX(II))/(Q-1.00)
C      END OF ROMBERG STEP
C

```

```

C      DELT2=DABS(Y-AUX(1))
C      IF(I-5)7,5,5
C      IF(DELT2-E)10,10,6
C      IF(DELT2-DELT1)7,11,11
C      JJ=JJ+JJ
C      IER=2
C      Y=H*AUX(1)
C      RETURN
C      IER=0
C      GO TO 3
C      IER=1
C      Y=H*Y
C      RETURN
C      END

```



```

C      INCREASE VH(K)
C
40     VMN=VH(K)
      VH(K)=(VMX+VMN)/2.
      GO TO 25
60     DO 45 K=NA,NZ
          F(K)=DSQRT(PSQ(K))
45     CONTINUE
      WRITE(6,202)NA,NZ,X
202    FORMAT(T5,'VH(K) COMPUTED FOR K = ',I2,' TO ',I2,
1      ' FROM SHOTS AT X = ',F8.2,' METERS. '//T5,'Z',T15,
1      'T',T25,'DTDZ',T40,'P',T55,'VV',T65,'VH'//)
      WRITE(6,203)((Z(K),T(K),DTDZ(K),F(K),VV(K),VH(K)),
1      K=1,NZ)
203    FORMAT(T3,F8.2,T13,F6.4,T22,E11.4,T37,E11.4,T52,
1      F8.2,T62,F8.2)
      GO TO 60
70     WRITE(6,150)K
150    FORMAT(T5,'PSQ(K) NEG. AT K = ',I2,'. CHECK VV(K)
1      IN DATA SET...SHOULD BE LESS?')
80     STOP
      END

```

```

C      VZPLOT.FTN USES HP PLOTTER AND SUBROUTINES TO
C      CONSTRUCT PLOTS OF CALCULATED V(Z) DATA.
C
C      NZT = TOTAL # OF V(Z) DATA PTS IN VOFZ.DAT
C      NZM = # OF DATA PTS IN TZM.DAT
C      NETX, NETY =
C      XOF, YOF =
C      XSZ, YSZ =
C      XOR, YOR =
C      XSC, YSC = SEE TZPLOT.FTN
C      XL, YL =
C      XLBLX, YLELX =
C      XLBLY, YLELY =
C      XET, YET =
C      XTIC, YTIC =
C      WIDE, HIGH, SLANT =
C
1      DIMENSION V(150),Z(150),TM(25),ZM(25),X(2),Y(2),
      VC(150),ZC(150)
      CALL ASSIGN(2,'VOFZ.DAT',8)
      CALL ASSIGN(3,'TZM.DAT',7)
      CALL ASSIGN(1,'HPO:',4)
      CALL ASSIGN(4,'VZPLOT.DAT',10)
      READ(4,104) NZT,NZM,NETX,NETY,XOF,YOF,XSZ,YSZ,XOR,
1      YOR,XSC,YSC,XL,YL,XLBLX,YLELX,XLBLY,YLELY,XET,YET,
1      XTIC,YTIC,WIDE,HIGH,SLANT
104    FORMAT(4I4/8(2F8.2/),3F8.2)
102    READ(2,102) ((Z(K),V(K)),K=1,NZT)
      FORMAT(2X,F8.2,1X,F8.2)
103    READ(3,103) ((ZM(I),TM(I)),I=1,NZM)
      FORMAT(F8.2,F8.5)
      NZB=ZM(1)/(Z(2)-Z(1))
      NZC=NZT-NZB
      CALL INITIA
      CALL OFFSET(XOF,YOF)
      CALL SIZE(XSZ,YSZ)
      CALL ORIGIN(XOR,YOR)
      CALL SCALE(XSC,YSC)
      CALL COLOUR(1)
      CALL TXTDEF(WIDE,HIGH,SLANT)
      CALL ANGLE(0.)
      CALL PLIFT

```

```

X(1)=0.
X(2)=0.
Y(1)=0.
Y(2)=-YSC*YL
CALL PLOT(X,Y,2,NC)
CALL PLIFT
Y(2)=0.
X(2)=XSC*XL
CALL PLOT(X,Y,2,NC)
CALL PLIFT
X(1)=0.
X(2)=0.
Y(1)=XTIC
Y(2)=-XTIC
NLTX=NETX*10
NLTY=NETY*10
XLT=XBT/10.
YLT=YBT/10.
DO 1 I=1,NLTX
    X(1)=X(1)+XLT
    X(2)=X(1)
    CALL PLOT(X,Y,2,NC)
    CALL PLIFT
1 CONTINUE
X(1)=0.
X(2)=0.
Y(1)=2.*XTIC
Y(2)=-2.*XTIC
DO 2 I=1,NETX
    X(1)=X(1)+XBT
    X(2)=X(1)
    CALL PLOT(X,Y,2,NC)
    CALL PLIFT
2 CONTINUE
CALL TEXT(XLBLX,YLBLX,'VELOCITY (feet/second) x
1 1000@')
Y(1)=0.
Y(2)=0.
X(1)=YTIC
X(2)=-YTIC
DO 3 I=1,NLTY
    Y(1)=Y(1)-YLT
    Y(2)=Y(1)
    CALL PLOT(X,Y,2,NC)
    CALL PLIFT
3 CONTINUE
Y(1)=0.
Y(2)=0.
X(1)=2.*YTIC
X(2)=-2.*YTIC
DO 4 I=1,NETY
    Y(1)=Y(1)-YBT
    Y(2)=Y(1)
    CALL PLOT(X,Y,2,NC)
    CALL PLIFT
4 CONTINUE
XX=XOR-6.*WIDE
YY=YOR
ZZ=0.
N=NETY+1
DO 5 I=1,N
    CALL HPNUMD(XX,YY,ZZ,0)
    CALL PLIFT
    YY=YY-YBT/YSC
    ZZ=ZZ+YBT
5 CONTINUE
XX=XOR-2.*WIDE
YY=YOR+HIGH
ZZ=0.

```

```

DO 6 I=1,NEX
    XX=XX+XBT/XSC
    ZZ=ZZ+XBT/1000.
    CALL HFNUMD(XX,YY,ZZ,0)
    CALL PLIFT
6  CONTINUE
    CALL ANGLE(90.)
    CALL TEXT(XLBY,YLBY,'DEPTH (feet)e')
    DO 7 I=1,NZM
        ZM(I)=-ZM(I)
7  CONTINUE
    DO 8 I=1,NZT
        Z(I)=-Z(I)
8  CONTINUE
    CALL LINE(2)
    CALL PLOT(V,Z,NZB,NC)
    DO 10 I=1,NZC
        VC(I)=V(I+NZB)
        ZC(I)=Z(I+NZB)
10 CONTINUE
    CALL LINE(1)
    CALL PLOT(VC,ZC,NZC,NC)
    CALL PLIFT
    CALL SYMBOL(4)
    DO 9 I=1,NZM
        TM(I)=1000.
        CALL PLOT(TM(I),ZM(I),1,NC)
        CALL FLIFT
9  CONTINUE
    CALL ANGLE(0.)
    CALL BORDER
    CALL PAGE
    STOP
    END

```

```

C      VZPDIG.FTN--PROVIDES DIGITAL V(Z) VALUES FOR
C      CONSTRUCTED VELOCITY FCN. VZPATCH(Z). SAMPLE SFACING
C      = DELZ.
C
C      NZC = # OF CALCULATED DATA PTS IN VOFZ.DAT
C      A,B,V0 = NEAR-SURFACE FCN.  $V(Z)=A*Z**B+V0$ 
C      ZPATCH = COPY FROM OUTPUT OF VELRED
C      ZSHOT = " "
C      Z(1), V(1) = INPUT FROM VOFZ.DAT
C      ZF(1), VP(1) = DIGITIZED NEAR-SURFACE V(Z) VALUES
C
      DIMENSION ZF(50),VP(50),Z(100),V(100)
      CALL ASSIGN(1,'VZPDIG.DAT',10)
      CALL ASSIGN(2,'VOFZ.DAT',8)
      CALL ASSIGN(6,'XY:',3)
      READ(1,101)NZC,A,B,V0,ZPATCH,ZSHOT,DELZ
101    READ(2,102)((Z(1),V(1)),I=1,NZC)
102    FORMAT(13/2F11.9/3(F8.2/),F8.2)
      FORMAT(1X,F8.2,1X,F8.2)
      VZF=FVW(A,B,V0,ZPATCH)
      GF=(V(1)-VZF)/(Z(1)-ZPATCH+ZSHOT)
      IF(ZSHOT.GT.0.) GO TO 11
          NA=-ZSHOT/DELZ+1
          ZF(1)=NA*DELZ
          NZF=Z(1)/DELZ-NA
          GO TO 12
11     NZF=Z(1)/DELZ
      ZF(1)=0.
12     DO 10 I=1,NZF
          IF(ZF(1).GT.(ZPATCH-ZSHOT)) GO TO 20
          ZZ=ZF(1)+ZSHOT
          VP(I)=FVW(A,B,V0,ZZ)
          GO TO 15
20     VP(I)=GF*(ZF(1)-ZPATCH+ZSHOT)+VZF
15     ZF(I+1)=ZF(1)+DELZ
10     CONTINUE
      WRITE(6,200)((ZF(1),VP(1)),I=1,NZF)
      WRITE(6,200)((Z(1),V(1)),I=1,NZC)
200    FORMAT(3X,F8.2,1X,F8.2)
      STOP
      END

C
C      FUNCTION FVW(A,B,V0,ZZ)
      FVW=A*ZZ**B+V0
      RETURN
      END

```

```

C      VAVRG.FTN AVERAGES TWO DIGITIZED V(Z) FCNS
C
C      Z1(I), V1(I) = V(Z) DATA FROM VZ1.DAT
C      Z2(I), V2(I) = V(Z) DATA FROM VZ2.DAT
C      NOTE: Z1(I) = Z2(I) FOR ALL I
C      NZ = TOTAL # OF DATA PTS IN VZ1.DAT OR VZ2.DAT
C      W1; W2 = RELATIVE WEIGHTS ASSIGNED TO VZ1; VZ2
C
      DIMENSION Z1(200),V1(200),Z2(200),V2(200),VAV(200)
      CALL ASSIGN(1,'VAVRG.DAT',8)
      CALL ASSIGN(2,'VZ1.DAT',7)
      CALL ASSIGN(3,'VZ2.DAT',7)
      CALL ASSIGN(6,'XY:',3)
      READ(1,101)NZ,W1,W2
101    FORMAT(I3/2F5.3)
      READ(2,102)((Z1(I),V1(I)),I=1,NZ)
102    FORMAT(2X,F8.2,1X,F8.2)
      READ(3,102)((Z2(I),V2(I)),I=1,NZ)
      DO 10 I=1,NZ
          VAV(I)=(W1*V1(I)+W2*V2(I))/(W1+W2)
10     CONTINUE
      WRITE(6,200)((Z1(I),VAV(I),Z2(I)),I=1,NZ)
200    FORMAT(3X,F8.2,1X,F8.2,1X,F8.2)
      WRITE(6,201)W1,W2
201    FORMAT(3X,F5.3)
      STOP
      END

```

```

C      VRESID.FTN COMPUTES %-DIFF OR ABSOLUTE DIFF OF
C      VOFZ.DAT VS VZREF.DAT.
C
C      NZ = TOTAL # OF DATA PTS IN SMALLEST OF VOFZ; VZREF
C      NCALC = 1 (ABS DIFF.); GT.1 (%-DIFF.)
C      ZREF(I), VREF(I) = VZREF.DAT
C      Z(I), V(I) = VOFZ.DAT
C
      DIMENSION ZREF(200),VREF(200),Z(200),V(200),DV(200)
      CALL ASSIGN(1,'VRESID.DAT',10)
      CALL ASSIGN(2,'VZREF.DAT',5)
      CALL ASSIGN(3,'VOFZ.DAT',8)
      CALL ASSIGN(6,'XY:',3)
      READ(1,101)NZ,NCALC
101    FORMAT(I3)
      READ(2,102)((ZREF(I),VREF(I)),I=1,NZ)
      READ(3,102)((Z(I),V(I)),I=1,NZ)
102    FORMAT(2X,F8.2,1X,F8.2)
      IF(NCALC.GT.1) GO TO 11
      DO 10 I=1,NZ
          DV(I)=V(I)-VREF(I)
          WRITE(6,200) Z(I),DV(I)
10     CONTINUE
      GO TO 20
11     DO 20 I=1,NZ
          DV(I)=100.*(V(I)-VREF(I))/VREF(I)
          WRITE(6,200) Z(I),DV(I)
20     CONTINUE
200    FORMAT(3X,F8.2,1X,F8.2)
      STOP
      END

```

```

C      VRPLOT.FTN USES HP PLOTTER AND SUBROUTINES TO
C      CONSTRUCT PLOTS OF RESIDUAL VELOCITY DATA.
C
C      NZC, NZM = # DATA PTS IN VOFZ.DAT, TZM.DAT
C      NETX, NETY =
C      XOF, YOF =
C      XSZ, YSZ =
C      XOR, YOR =
C      XSC, YSC =
C      XL, YL =
C      XLBLX, YLBLX =
C      XLBLY, YLBLY =
C      XET, YET =
C      XTIC, YTIC =
C      WIDE, HIGH, SLANT =
C
C      SEE TZPLOT.FTN
C
C      DV(1), Z(1) = % DIFF. BETWEEN FCNS VS DEPTH FROM
C      VRESID.FTN
C
C      DIMENSION DV(200), Z(200), TM(20), ZM(20), X(2), Y(2)
C      CALL ASSIGN(2, 'DVOFZ.DAT', 8)
C      CALL ASSIGN(3, 'TZM.DAT', 7)
C      CALL ASSIGN(1, 'HFO.', 4)
C      CALL ASSIGN(4, 'VRPLOT.DAT', 10)
C      READ(4, 104) NZC, NZM, NETX, NETY, XOF, YOF, XSZ, YSZ, XOR,
1      YOR, XSC, YSC, XL, YL, XLBLX, YLBLX, XLBLY, YLBLY, XET, YET,
1      XTIC, YTIC, WIDE, HIGH, SLANT
104  FORMAT(4I4/8(2F6.2/), 3F8.2)
102  READ(2, 102) ((Z(K), DV(K)), K=1, NZC)
102  FORMAT(2X, F8.2, 1X, F8.2)
103  READ(3, 103) ((ZM(I), TM(I)), I=1, NZM)
103  FORMAT(F8.2, F8.5)
C      CALL INITIA
C      CALL OFFSET(XOF, YOF)
C      CALL SIZE(XSZ, YSZ)
C      CALL ORIGIN(XOR, YOR)
C      CALL SCALE(XSC, YSC)
C      CALL COLOUR(1)
C      CALL TXTDEF(WIDE, HIGH, SLANT)
C      CALL ANGLE(0.)
C      CALL PLIFT
C      X(1)=0.
C      X(2)=0.
C      Y(1)=0.
C      Y(2)=-YSC*YL
C      CALL PLOT(X, Y, 2, NC)
C      CALL PLIFT
C      Y(2)=0.
C      X(2)=XSC*XL
C      CALL PLOT(X, Y, 2, NC)
C      CALL PLIFT
C      X(1)=0.
C      X(2)=0.
C      Y(1)=XTIC
C      Y(2)=-XTIC
C      NLTX=NETX*10
C      NLTY=NETY*10
C      XLT=XET/10.
C      YLT=YET/10.
C      DO 1 I=1, NLTX
C          X(1)=X(1)+XLT
C          X(2)=X(1)
C          CALL PLOT(X, Y, 2, NC)
C          CALL PLIFT
1  CONTINUE
X(1)=0.

```

```

      X(2)=0.
      Y(1)=2.*XTIC
      Y(2)=-2.*XTIC
      DO 2 I=1,NETX
          X(1)=X(1)+XBT
          X(2)=X(1)
          CALL PLOT(X,Y,2,NC)
          CALL FLIFT
2      CONTINUE
      CALL TEXT(XLBLX,YLBLX,'RESIDUAL VELOCITY (%-diff.
1      W.F.T. VZREF)@')
      Y(1)=0.
      Y(2)=0.
      X(1)=YTIC
      X(2)=-YTIC
      DO 3 I=1,NLTY
          Y(1)=Y(1)-YLT
          Y(2)=Y(1)
          CALL PLOT(X,Y,2,NC)
          CALL FLIFT
3      CONTINUE
      Y(1)=0.
      Y(2)=0.
      X(1)=2.*YTIC
      X(2)=-2.*YTIC
      DO 4 I=1,NETY
          Y(1)=Y(1)-YBT
          Y(2)=Y(1)
          CALL PLOT(X,Y,2,NC)
          CALL FLIFT
4      CONTINUE
      XX=XOR-6.*WIDE
      YY=YOR
      ZZ=0.
      N=NETY+1
      DO 5 I=1,N
          CALL HPNUMD(XX,YY,ZZ,0)
          CALL FLIFT
          YY=YY-YBT/YSC
          ZZ=ZZ+YBT
5      CONTINUE
      XX=XOR-2.*WIDE
      YY=YOR+HIGH
      ZZ=-100.
      N=NETX+1
      DO 6 I=1,N
          CALL HPNUMD(XX,YY,ZZ,0)
          XX=XX+XBT/XSC
          ZZ=ZZ+XBT
          CALL FLIFT
6      CONTINUE
      CALL ANGLE(90.)
      CALL TEXT(XLBLY,YLBLY,'DEPTH (feet)@')
      DO 7 I=1,NZM
          ZM(I)=-ZM(I)
7      CONTINUE
      DO 8 I=1,NZC
          Z(I)=-Z(I)
          DV(I)=DV(I)+100.
8      CONTINUE

```



```

X(1)=100.
X(2)=100.
Y(1)=0.
Y(2)=-YL*YSC
CALL LINE(2)
CALL PLOT(X,Y,2,NC)
CALL PLIFT
CALL LINE(1)
CALL PLOT(DV,Z,NZC,NC)
CALL PLIFT
CALL SYMBOL(4)
DO 8 I=1,NZM
      TM(I)=1000.
      CALL PLOT(TM(I),ZM(I),1,NC)
      CALL PLIFT
8  CONTINUE
CALL ANGLE(0.)
CALL BORDER
CALL PAGE
STOF
END

C  FWDMDL.FTN PRODUCES TRAVEL TIMES & INCIDENT ANGLES
C  FOR DIRECT ARRIVALS FROM SHOTS AT POINTS X(I)
C  ARRIVING AT SENSOR DEPTHS Z(K) GIVEN A LAYERED MODEL
C  WITH LAYER THICKNESSES H(L) AND LAYER VELOCITIES
C  VV(L) & VH(L).
C  NO SENSOR DEPTH SHOULD EXCEED TOTAL DEPTH OF SECTION
C  WHICH IS SUM OF H(L)'S.
C
C  NX = # OF DIFFERENT SHOT DISTANCES CONSIDERED (LE.5)
C  NZ = # OF SENSOR DEPTHS CONSIDERED
C  NL = TOTAL # OF LAYERS IN MODEL
C  H(L) = LAYER THICKNESSES
C  VV(L) = VERTICAL VELOCITIES IN LAYERS
C  VH(L) = HORIZONTAL VELOCITIES IN LAYERS
C  Z(K) =
C  X(I) =
C
1  DIMENSION H(20),VV(20),VH(20),VDIR(20),THETA(20),VEF(20),
      XL(20),R(20),X(5),Z(50),T(5,50),ALPHA(5,50)
      CALL ASSIGN(1,'FWDMDL.DAT',10)
      CALL ASSIGN(5,'XY',3)
      READ(1,100)NX,NZ,NL,(H(L),L=1,20),(VV(L),L=1,20),(VH(L),
100 1 L=1,20),(Z(K),K=1,50),(X(I),I=1,5)
      FORMAT(3I3/11(10F8.2//),5F8.2)
      WRITE(5,200)NX,NZ,NL,(H(L),L=1,NL),(VV(L),L=1,NL)
200 1 FORMAT(T5,'NX',T15,'NZ',T25,'NL',T5,I2,T15,I2,T25,I2//
      T5,'L',T15,'H',T25,'VV',T35,'VH',T20,T4,I2,T10,F6.2,T22
1  ,F8.2,T32,F8.2//)
      K=1
      I=1
      L=1
C
C  WHAT LAYER (LS) IS SENSOR IN?
C
30  TH=H(L)
      IF(TH.GE.Z(K)) GO TO 38
      L=L+1
      TH=TH+H(L)
      GO TO 30
35  R(I)=X(I)
      VDIR(LS)=VH(LS)
      THETA(I)=90.*.017453293
      GO TO 85
45  T(I,K)=0.
      DO 55 LB=1,LU
          T(I,K)=T(I,K)+H(LB)/VV(LB)
55  CONTINUE

```

```

      T(I,K)=T(I,K)+D/VV(LS)
      THETA(LS)=0.0
      GO TO 15
50    THETA(1)=ATAN(X(1)/Z(K))
      R(1)=SQRT(X(1)**2+Z(K)**2)
      GO TO 5
39    LS=L
      LU=L-1
      D=H(LS)+Z(K)-TH
40    IF(Z(K).EQ.0.) GO TO 35
      IF(LS.EQ.1) GO TO 50
      IF(X(1).EQ.0.) GO TO 45
      TTAMN=0.
      TTAMX=90.*.017453283
60    THETA(LS)=(TTAMX+TTAMN)/2.
      L=LS
61    VEF(L)=VH(L)*SQRT((1.-(VH(L)/VV(L))**2)*SIN(THETA(L))
1      **2+(VH(L)/VV(L))**2)
      B=(SIN(THETA(L))*VH(L)-1)/VEF(L)**2
      AV=(VH(L)-1)/VV(L)-1)**2
      C=SQRT(B*AV/(1.-B*(1.-AV)))
      IF (C.GT.1.) GO TO 80
      THETA(L-1)=ASIN(C)
      XL(L-1)=H(L-1)*TAN(THETA(L-1))
      L=L-1
      IF(L.GT.1) GO TO 61
      XT=0.
      R(LS)=D/COS(THETA(LS))
      XL(LS)=R(LS)*SIN(THETA(LS))
      DO 70 LC=1,LS
          XT=XT+XL(LC)
70    CONTINUE
      IF(ABS(XT-X(1)).LT.0.5) GO TO 80
      IF((XT-X(1)).GE.0.5) GO TO 80
          TTAMN=THETA(LS)
          GO TO 60
          TTAMX=THETA(LS)
          GO TO 60
90    DO 5 LD=1,LU
          R(LD)=H(LD)/COS(THETA(LD))
5    CONTINUE
      VEF(1)=VH(1)*SQRT((1.-(VH(1)/VV(1))**2)*SIN
1      (THETA(1))**2+(VH(1)/VV(1))**2)
      DO 95 LE=1,LS
          VDIR(LE)=VH(LE)**2/VEF(LE)
95    CONTINUE
      T(I,K)=0.
      DO 15 LG=1,LS
          T(I,K)=T(I,K)+R(LG)/VDIR(LG)
15    CONTINUE
      ALPHA(I,K)=THETA(LS)/.017453283
      I=I+1
      IF(I.LE.NX) GO TO 40
      K=K+1
      IF(K.LE.NZ) GO TO 25
      WRITE(5,210) (X(I),I=1,5)
210   FORMAT(T5,'T=DIRECT ARRIVAL TIMES'/T5,'ALPHA=INCIDENT
1     'ANGLE AT SENSOR'//T5,'SHOT DISTANCE X',T22,F6.2,T42,
1     'F8.2,T62,F8.2,T82,F8.2,T102,F8.2//T5,'SENSOR DEPTH Z',
1     'T22,'T',T27,'ALPHA',T42,'T',T47,'ALPHA',T62,'T',T67,
1     'ALPHA',T82,'T',T87,'ALPHA',T102,'T',T107,'ALPHA'//)
      WRITE(5,220) (Z(K),(T(I,K),ALPHA(I,K),I=1,5),K=1,NZ)
220   FORMAT(T7,F6.2,T20,F6.4,2X,F4.1,T40,F6.4,2X,F4.1,
1     'T60,F6.4,2X,F4.1,T80,F6.4,2X,F4.1,T100,F6.4,2X,F4.1)
      STOP
      END

```

```

C      DIPUNC.FTN-- CALCULATE T(Z) FOR DOWNHOLE SENSOR IN
C      A MODEL W/ 2 LAYERS AND DIPPING INTERFACE BETWEEN
C      THEM.
C
C      DIP = DIP IN DEGREES OF LAYER INTERFACE
C      H = DEPTH TO INTERFACE IN WELL
C      V1, V2 = VELOCITIES FOR LAYER 1, LAYER 2
C      RSHOT = HORIZONTAL SHOT DISTANCE
C      ZA, ZB = UPPER, LOWER BOUNDS OF DEPTHS IN WELL
C      DELZ = DEPTH INCREMENT FOR CALCULATED T(Z)'S
C      EPSR = ITERATIVE TOLERANCE FOR COMPUTED RSHOT
C
      CALL ASSIGN(1,'DIPUNC.DAT',10)
      CALL ASSIGN(5,'AB',3)
      CALL ASSIGN(6,'XY',3)
      READ(1,100)DIP,H,V1,V2,RSHOT,ZA,ZB,DELZ,EPSR
100    FORMAT(8F8.2/F8.2)
      WRITE(6,200)DIP,H,V1,V2,RSHOT
200    FORMAT(T5,'DIP',T15,'H',T25,'V1',T35,'V2',T45,'RSHOT'//
1      1X,F8.2,T12,F8.2,T22,F8.2,T32,F8.2,T42,F8.2//
1      T5,'Z',T15,'T',T25,'TH1',T35,'TH2',T45,'HPR'//)
      DIP=DIP/57.2857785
      IF(DIP.GE.0.0)GO TO 20
      R=ABS(H/TAN(DIP))
      IF(R.GT.RSHOT)GO TO 20
      WRITE(5,205)
205    FORMAT(T5,'SHOTPOINT BEYOND OUTCROP')
      GO TO 70
20    Z=ZA
      TH2=45./57.2857785
30    IF(Z.GT.H)GO TO 40
      TH1D=ATAN(RSHOT/Z)*57.2857785
      T=SQRT(RSHOT**2+Z**2)/V1
      WRITE(6,210)Z,T,TH1D
210    FORMAT(1X,F8.2,T12,F8.5,T22,F8.2)
      Z=Z+DELZ
      GO TO 30
40    THMIN=DIP-3.141592654/2.
      THMAX=3.141592654/2.+DIP
41    HPR=(H+Z*TAN(TH2)*TAN(DIP))/(1.+TAN(TH2)*TAN(DIP))
      TH1=ASIN((V1/V2)*SIN(TH2-DIP))+DIP
      R1=HPR*TAN(TH1)
      R2=(Z-HPR)*TAN(TH2)
      R=R1+R2
      TH1D=TH1*57.2857785
      TH2D=TH2*57.2857785
      WRITE(5,215)R,TH1D,TH2D
215    FORMAT(T5,F8.2,T15,F8.2,T25,F8.2)
      IF(ABS(RSHOT-R).LT.EPSR)GO TO 60
      IF(RSHOT.GT.R)GO TO 50
      THMAX=TH2
      TH2=(2.*THMIN+THMAX)/3.
      GO TO 41
50    THMIN=TH2
      TH2=(2.*THMIN+THMAX)/3.
      GO TO 41
60    T=HPR/(V1*COS(TH1))+(Z-HPR)/(V2*COS(TH2))
      TH1D=TH1*57.2857785
      TH2D=TH2*57.2857785
      WRITE(6,220)Z,T,TH1D,TH2D,HPR
220    FORMAT(T2,F8.2,T12,F8.5,T22,F8.2,T32,F8.2,T42,F8.2)
      Z=Z+DELZ
      IF(Z.LE.ZB)GO TO 40
70    STOP
      END

```

Appendix B

Gravity reduction and modelling programs for the Hewlett-Packard HP-34C pocket calculator

Gravity reduction. This program computes Bouguer gravity values (without terrain corrections) with input station coordinates (R, ϕ , H) w.r.t. base station, g (gravity reading in dial divisions), and T (time of reading in hours). Time corrections are made via a linear extrapolation between two readings at the same base station. The program also computes latitude and elevation (Bouguer + free air) corrections.

Input to storage registers:

R0 - (station azimuth w.r.t. base)
 R1 - g1 = 1st reading at base station (dial divisions)
 R2 - g2 = 2nd gravimeter reading at base (dial divisions)
 R3 - gb = normalized base reading (mgal; e.g., 100 mgal)
 R4 - T1 = time of first base reading (hours)
 R5 - T2 = time of 2nd base reading (hours)
 R.0 - Free air constant = 0.09406
 R.1 - Bouguer constant = -0.01277
 R.2 - Latitude constant = $(1.307/5280)\sin 2\Delta$ (mgal/ft)
 R.3 - ρ = density (gm/cc)
 R.4 - gravimeter dial constant (ours was 0.086945 mgal/division)
 R.5 - depth to datum (ft)
 R.6 - $(g_2 - g_1)/(T_2 - T_1)$, calculated before program run to save time
 R.7 - $gb - g_1 \times$ (dial constant) calculated before program run

Program:

-001 h LBL A -002 STO 6 -003 g R+ -004 STO 7 -005 g R+ -006 STO 8 -007 g R+ -008 STO 9 * make secular * correction -009 RCL 4 -010 RCL 7 -011 g $\rightarrow$ H -012 - -013 RCL .6 -014 X -015 STO + 6 -016 RCL .4 -017 STO X 6	* make latitude * correction -018 RCL 0 -019 f COS -020 CHS -021 RCL 8 -022 X -023 RCL .2 -024 X -025 STO + 6 * elevation * correction -026 RCL .5 -027 STO + 9 -028 RCL .1 -029 RCL .3 -030 X -031 RCL .0 -032 +	-033 RCL 9 -034 X -035 STO + 6 * normalize to * base = gb -036 RCL .7 -037 RCL 6 -038 + -039 h RTN
---	---	--

Usage:

ϕ STO 0
 H ENTER
 R ENTER
 T ENTER
 g A
 On return display
 corrected g in
 mgal.

Gravity model. To find the dip angle of the basement into the Milford Valley Graben west of Well 9-1 a forward modelling program was written. To begin, we consider the following polygon:

To calculate the difference in measured gravity $\Delta g = g - g'$ between the well head and the field station given δ , d , $\Delta \rho$, and L (or H) the method introduced by Talwani and others (1959) was used. The solution for Δg was found to be

$$\Delta g = H(\theta' - \theta) + (b+d) \sin \delta \cos \delta \left[\theta' + \tan \delta \cdot \ln \left(\frac{\cos \theta' (\tan \delta - \tan \theta')}{\tan \delta} \right) \right] - b \sin \delta \cos \delta \left[\theta + \tan \delta \cdot \ln \left(\frac{\cos \theta (\tan \delta - \tan \theta)}{\tan \delta} \right) \right],$$

where

$$b = z_b / \tan \delta,$$

$$\theta' = \tan^{-1} \left[\frac{H}{(b-L)} \right] + \pi,$$

and

$$\theta = \tan^{-1} \left[\frac{H}{(b+d-L)} \right] + \pi.$$

Program:

-001 h LBL A	-037 RCL .2	-073 +
-002 ENTER	-038 RCL 2	-074 RCL 6
-003 ENTER	-039 RCL 4	-075 X
-004 f TAN	-040 -	-076 RCL 3
-005 STO 5	-041 $\div$	-077 X
-006 g R↓	-042 g TAN ⁻¹	-078 STO + 0
-007 f SIN	-043 1	-079 RCL 5
-008 STO 6	-044 8	-080 RCL 7
-009 g R↓	-045 0	-081 f TAN
-010 f COS	-046 +	-082 -
-011 STO X 6	-047 STO 7	-083 RCL 7
-012 g R↓	-048 -	-084 f COS
-013 STO 1.	-049 RCL .2	-085 X
-014 RCL f I	-050 X	-086 RCL 5
-015 RCL 5	-051 RCL .0	-087 $\div$
-016 $\div$	-052 X	-088 f LN
-017 STO 2	-053 STO 0	-089 RCL 5
-018 +	-054 1	-090 X
-019 STO 3	-055 CHS	-091 RCL 7
-020 RCL 9	-056 STO X 5	-092 RCL .0
-021 RCL 2	-057 STO X 6	-093 X
-022 +	-058 RCL 5	-094 +
-023 STO 4	-059 RCL 8	-095 RCL 6
-024 RCL 5	-060 f TAN	-096 X
-025 X	-061 -	-097 RCL 2
-026 STO .2	-062 RCL 8	-098 X
-027 RCL 3	-063 f COS	-099 STO - 0
-028 RCL 4	-064 X	-100 RCL .1
-029 -	-065 RCL 5	-101 STO X 0
-030 $\div$	-066 $\div$	-102 RCL 3
-031 g TAN ⁻¹	-067 f LN	-103 RCL 5
-032 1	-068 RCL 5	-104 X
-033 8	-069 X	-105 CHS
-034 0	-070 RCL 8	-106 RCL 0
-035 +	-071 RCL .0	-107 h RTN
-036 STO 8	-072 X	

Usage:

STO R.0 - $2\pi/360$

STO R.1 - $2\Delta\rho G$ (cgs units; G = gravitational constant = 6.67×10^{-8})

STO R9 - $(L - b)$ = distance from Well 9-1 along station azimuth to the center of the Milford Graben (~ 10 km West)

STO RI - z_b = depth to basement in Well 9-1 = 750 ft

d ENTER (d is distance from well head to field station)

δ A (δ is guessed dip of alluvium-bedrock interface in degrees)

On return:

$Y = z_b'$ = calculated depth to basement beneath field station

X = calculated Δg ; change δ iteratively until this agrees with measured Δg

Appendix C - Roosevelt Hot Springs gravity data

The following table lists data from a gravity survey conducted in Fall 1980 in the vicinity of Utah State Geothermal Well 9-1, Roosevelt Hot Springs KGRA, Beaver County, Utah (Plate I). Included are station coordinates (cylindrical coordinates R , ϕ , H) with respect to the well head, calculated Bouguer gravity values (station NV1 = 100.00 mgal), and estimated depths to the alluvium-bedrock interface at selected stations (z_{basement}). The method and program used to determine z_{basement} appear in Appendix B.

Appendix C - Roosevelt Hot Springs gravity data

Station	R	ϕ	H	g	z_{basement}
	ft	deg	ft	mgal	ft
Well 9-1	0	0	0	100	750.0
NV1	51.0	24.67	.14	100.00	
NV30	370.6	25.06	9.95	100.15	704.9
NV50	555.2	23.57	10.83	100.29	665.0
NE1	302.0	68.39	14.0	100.19	
NE2	568.5	58.90	23.2	100.71	
NE3	791.6	56.00	35.8	100.99	
NE4	1124.9	53.38	45.6	101.39	
NE5	1380.6	52.31	52.2	101.83	263.0
NE6	1583.9	52.17	64.8	102.01	
NE7	1809.3	51.53	80.3	102.08	
NE8	2066.1	51.32	92.1	102.12	
NE9	2322.5	51.14	100.7	102.38	109.0
NE10	2582.3	51.62	113.8	102.25	
NE11	2831.8	50.62	113.9	102.56	
NE12	3097.6	48.77	117.8	102.60	40.6
NE13	3280.4	49.18	127.8	102.47	
NE14	3594.9	49.75	127.1	102.08	
NE15	3795.3	49.51	130.3	102.09	
NE16	4021.3	49.33	139.7	101.92	
NE17	4253.1	49.38	149.4	101.81	
NE18	4501.0	49.08	159.0	101.61	
NE19	4780.4	48.89	170.9	101.68	
NE20	4942.6	48.86	176.6	101.52	
NE21	5193.5	48.64	185.3	101.57	
NE22	5426.3	45.86	192.1	101.57	
NE23	5651.6	48.13	204.9	101.36	
NE24	5872.3	48.64	214.8	101.33	
NE25	6145.7	48.71	227.8	101.46	
NE26	6356.5	48.67	236.6	101.41	
NE27	6627.7	48.51	245.6	101.60	
NE28	6803.3	48.46	250.9	102.01	
NE29	7146.7	48.56	267.6	102.36	
NE30	7341.3	48.62	274.6	102.78	
NE31	7530.8	48.45	280.7	103.56	
E1	364.	110.	17.	-----	641.0
E5	1200	116	50	-----	303.7
SE1	248.0	148.08	11.1	99.92	
SE2	582.6	144.52	14.0	100.46	
SE3	815.4	144.11	-7.9	100.81	
SE4	1064.3	144.99	-15.1	101.00	
SE5	1322.9	144.33	-18.3	101.20	415.0
SE6	1564.3	144.93	-25.7	101.37	
SE7	1808.1	143.81	-32.9	101.46	
SE8	2097.9	142.31	-26.5	101.43	
SE9	2317.6	143.95	-21.6	100.89	

Appendix C - Roosevelt Hot Springs gravity data

Station	R	ϕ	H	g	z _{basement}
	ft	deg	ft	mgal	ft
SE10	2492.3	151.06	-0.6	101.36	
SE11	2625.3	155.08	-0.8	101.13	
SE12	2748.4	159.05	10.8	100.70	
SE13	2911.0	164.72	5.2	100.30	
SE14	3208.5	159.46	14.9	99.74	
SE15	3405.4	156.56	24.1	99.44	
SE16	3606.0	154.01	32.3	99.64	
SE17	3812.1	151.90	41.4	99.62	
SE18	4045.7	149.81	54.4	99.73	
SE19	4241.6	148.20	64.4	99.90	
SE20	4467.5	146.53	76.5	-----	
SE21	4681.0	145.14	90.2	100.11	
SE22	4951.2	143.48	106.1	100.44	
SE23	5173.1	142.37	118.2	-----	
SE24	5535.9	141.46	137.1	-----	
SE25	5770.3	140.83	152.0	98.84	
SE26	6044.8	140.11	168.8	98.67	
SE27	6250.9	139.64	182.7	98.44	
SE28	6479.0	139.93	195.4	98.55	
SE29	6712.1	140.28	208.7	98.70	
SE30	6973.5	140.57	224.3	98.71	
SE31	7242.4	140.51	242.4	-----	
SE32	7516.8	139.82	262.8	99.67	
SE33	7715.6	139.08	278.9	99.96	
SE34	7912.4	137.74	297.2	100.32	
SE35	8062.7	136.02	307.2	99.46	
SE36	8180.9	134.63	318.7	98.83	
SE37	8332.8	133.21	336.6	98.78	
SE38	8471.6	131.45	355.8	-----	
SE39	8657.2	130.94	372.5	98.48	
SE40	8967.3	130.73	394.9	98.36	
SSW1	254.5	201.57	-1.4	99.86	
SSW2	525.5	201.11	-8.5	99.82	802.4
SSW3	-----	-----	-----	-----	
SSW4	1044.4	198.79	-61.2	99.82	805.6
SSW5	1341.0	198.36	-94.8	99.81	810.0
SSW6	1569.6	199.54	-96.3	99.34	
SSW7	1857.5	198.35	-85.3	99.34	
SSW8	2184.6	198.50	-71.3	98.95	
SSW8A	2355.1	199.07	-74.0	98.97	
SSW9	2447.6	198.68	-81.8	98.78	1105.3
SSW10	2697.2	196.88	-65.1	98.80	
SSW11	2881.2	192.94	-48.0	98.53	
SSW12	3147.0	190.38	-23.9	98.50	1190.6
SSW13	3230.7	187.73	-17.2	98.55	
SSW14	3487.8	187.65	-14.4	98.37	

Appendix C - Roosevelt Hot Springs gravity data

Station	R	ϕ	H	g	z basement
	ft	deg	ft	mgal	ft
SSW15	3752.9	187.78	-17.5	98.15	
SSW16	3938.4	189.52	-22.2	97.95	
SSW17	4107.4	191.59	-32.1	97.73	
SSW18	4356.1	194.18	-45.3	97.51	
SSW19	4534.1	195.91	-56.5	97.24	
SSW20	4754.7	197.74	-67.3	97.01	1617.5
SSW21	4987.5	199.45	-78.6	96.70	
SSW22	5239.6	198.17	-77.7	96.71	
SSW23	5475.2	197.14	-77.6	96.61	
SSW24	5721.9	196.29	-86.6	96.64	
SSW25	5999.6	195.48	-84.3	96.55	
SSW26	6264.5	194.63	-94.4	96.43	
SSW27	6515.9	194.18	-102.6	96.60	
SSW28	6886.8	193.53	-112.2	96.61	
SSW29	7144.4	193.07	-116.3	96.57	
SSW30	7364.3	192.79	-115.7	96.47	1796.8
SSW31	7600.3	193.46	-119.4	96.33	
SSW32	7669.1	195.64	-120.3	95.87	
SSW33	7880.0	196.38	-121.2	95.66	
SSW34	8108.5	196.29	-123.8	95.34	
SSW35	8299.6	196.15	-115.5	95.35	
SSW36	8561.8	196.04	-110.6	95.05	
SSW37	8828.9	195.93	-105.3	94.72	
SSW38	9145.1	195.80	-100.9	94.61	
SSW39	9352.1	195.75	-95.9	94.55	
SSW40	9629.4	195.62	-91.4	94.24	2452.3
SW1	277.6	214.91	-4.2	99.76	
SW2	536.6	220.52	-16.7	99.51	
SW3	806.2	224.51	-27.1	99.32	
SW4	1036.6	225.49	-39.7	99.09	
SW5	1350.7	226.60	-64.0	98.76	1110.2
SW6	1587.2	226.83	-77.6	98.51	
SW7	1953.5	226.75	-109.7	98.30	
SW8	2238.7	226.77	-119.2	98.09	
SW9	2528.7	225.69	-144.3	97.88	1375.8
SW10	2896.1	226.97	-156.3	97.48	
SW11	3109.7	229.38	-161.1	97.22	
SW12	3319.6	230.74	-164.5	96.99	1638.9
SW13	3457.2	228.25	-137.5	96.88	
SW14	3695.4	227.54	-140.2	96.67	
SW15	3971.1	227.67	-148.1	96.35	
SW16	4375.9	227.79	-160.5	95.84	
SW17	4713.1	227.81	-171.9	95.48	
SW18	4821.4	227.94	-175.5	95.36	
SW19	5047.4	228.05	-182.7	-----	
SW20	5362.9	228.10	-193.2	94.76	2324.3

Appendix C - Roosevelt Hot Springs gravity data

Station	R	ϕ	H	g	z_{basement}
	ft	deg	ft	mgal	ft
SW21	5555.9	228.14	-198.8	94.58	
SW22	5881.3	228.22	-211.3	94.15	
SW23	6118.8	228.31	-217.4	93.84	
SW24	6404.7	228.33	-226.1	93.56	
SW25	6625.8	228.41	-234.5	93.39	
SW26	6963.7	228.45	-243.4	93.01	
SW27	7252.2	228.48	-252.5	92.63	
SW28	7465.6	228.43	-259.5	92.46	
SW29	7734.0	228.44	-267.0	92.07	
SW30	8002.3	228.52	-273.7	91.78	3279.3
SW31	8248.3	228.50	-275.8	91.46	
SW32	8515.3	228.52	-277.9	91.27	
SW33	8783.2	228.55	-283.2	90.95	
SW34	8971.5	229.18	-288.2	90.73	
SW35	9256.3	228.74	300.7	90.62	
SW36	9573.7	228.52	-301.7	90.21	
SW37	9796.6	228.53	-305.9	89.91	
SW38	10090.0	228.57	-309.8	89.60	
SW39	10347.1	228.62	-312.3	89.36	
SW40	10557.4	228.64	-317.0	89.19	4147.7
W1	145.0	273.14	-6.5	99.63	
W2	331.1	271.53	-17.3	99.45	910.1
W3	646.1	279.01	-24.7	99.07	
W4	869.2	277.61	-34.5	98.79	
W5	1146.6	275.14	-50.2	98.38	1229.6
W6	1424.7	273.89	-64.4	97.94	
W7	1710.0	273.08	-80.0	97.67	
W8	1950.1	272.64	-92.6	97.41	
W9	2215.2	272.18	-106.2	97.02	1653.6
W10	2412.5	273.81	-117.0	96.80	
W11	2771.0	273.30	-136.5	96.50	
W12	2991.2	272.98	-146.9	96.19	1919.2
W13	3247.9	272.58	-158.5	95.83	
W14	3499.6	272.29	-168.8	95.55	
W15	3798.5	272.15	-179.0	95.17	
W16	4038.7	272.11	-190.3	94.96	
W17	4363.2	271.98	-207.9	94.45	
W18	4590.3	272.00	-221.9	94.29	
W19	4843.2	272.00	-234.1	94.13	
W20	5077.4	271.94	-243.9	93.91	2678.7
W21	5413.7	271.89	-259.1	93.55	
W22	5617.6	271.84	-267.2	93.39	
W23	5900.8	271.72	-281.1	93.04	
W24	6182.5	271.71	-292.8	92.80	
W25	6449.0	271.70	-305.6	92.50	3167.6
W26	6720.9	271.75	-317.7	92.27	

Appendix C - Roosevelt Hot Springs gravity data

Station	R	ϕ	H	g	z_{basement}
	ft	deg	ft	mgal	ft
W27	7041.8	271.64	-333.9	91.97	
W28	7309.7	271.43	-343.5	91.68	
W29	7554.9	271.50	-353.5	91.50	
W30	7718.0	271.42	-358.4	91.30	3595.8
W31	7995.0	271.57	-368.2	91.03	
W32	8221.0	271.58	-379.6	90.72	
W33	8513.5	271.53	-387.2	90.42	
W34	8762.5	271.51	-396.8	90.33	
W35	9052.2	271.58	-404.9	89.90	
W36	9206.4	271.49	-409.1	89.92	
W37	9538.6	272.31	-422.1	89.57	
W38	9767.1	272.80	-430.8	89.45	
W39	10046.9	273.12	-439.2	89.26	
W40	10292.6	273.74	-449.7	89.03	4435.3
NW1	274.9	307.11	-7.2	99.63	
NW2	523.4	304.87	-19.7	99.49	
NW3	774.9	305.93	-30.6	99.09	
NW4	1030.8	305.45	-42.0	99.04	
NW5	1289.7	305.52	-51.5	98.50	1188.3
NW6	1579.0	305.73	-61.3	98.38	
NW7	1853.1	305.84	-78.7	97.98	
NW8	2107.6	304.11	-91.8	97.85	
NW9	2374.9	303.39	-102.3	97.52	1487.4
NW10	2642.8	303.49	-111.3	97.35	
NW11	2916.0	303.58	-122.7	97.14	
NW12	3172.6	303.91	-137.8	97.05	1646.0
NW13	3488.6	304.30	-145.3	96.71	
NW14	3803.0	304.62	-159.3	96.48	
NW15	4024.7	305.12	-171.1	96.37	
NW16	4253.4	306.32	-185.3	96.25	
NW17	4517.1	307.60	-200.3	96.16	
NW18	4750.8	307.98	-209.0	96.02	
NW19	5068.1	308.46	-222.5	95.74	
NW20	5340.9	308.90	-235.4	95.55	2120.3
NW21	5581.6	309.30	-246.8	95.53	
NW22	5809.7	309.36	-256.1	95.34	
NW23	6104.2	309.75	-269.2	95.20	
NW24	6300.9	309.95	-278.5	95.05	
NW25	6548.6	310.06	-288.9	94.89	
NW26	6788.4	310.36	-296.4	94.71	
NW27	7086.4	310.29	-309.4	94.44	
NW28	7324.6	310.27	-320.4	94.23	
NW29	7692.1	310.37	-336.8	94.05	
NW30	7920.9	310.40	-346.7	93.83	
NW31	8183.1	310.50	-356.4	93.71	
NW32	8401.1	310.58	-366.5	93.48	

Appendix C - Roosevelt Hot Springs gravity data

Station	R	ϕ	H	g	z basement
	ft	deg	ft	mgal	ft
NW33	8671.0	310.78	-375.0	93.37	3042.3
NW34	8904.5	310.84	-383.4	93.13	
NW35	9163.9	311.02	-395.0	93.02	
NW36	9410.4	311.03	-403.7	92.77	
T1	4957.9	229.35	-185.3	94.88	
T2	4571.8	225.02	-161.3	95.66	
T3	4420	224	-150.5	95.88	
T4	4211.8	220.92	-135.3	96.22	
T5	4070	219	-123.9	96.45	
T6	3930	216.5	-110.0	96.72	
T7	3780	212.5	-97.3	97.09	
T8	3635	209	-78.5	97.38	
T9	3540	205	-64.5	97.69	
T10	3465	201	-51.0	97.85	
T11	3390	196.5	-39.8	98.08	
T12	3258.5	190.00	-23.3	98.46	
T13	3177.1	185.38	-17.5	98.82	
T14	3100.8	180.93	-16.6	99.20	
T15	3037.8	176.34	-8.4	99.61	
T16	3010.5	169.34	0.5	100.01	
T17	2800.7	160.61	12.6	100.58	
T18	2717.2	156.24	-2.5	100.57	
T19	2674.6	150.31	-5.3	100.56	
T20	2653.8	145.36	2.5	100.46	
T21	2670.4	139.85	10.6	100.31	
T22	2647.9	134.52	14.8	100.40	
T23	2612.6	129.17	12.9	100.66	
T24	2669.4	122.33	22.7	100.86	
T25	2792.6	117.05	36.5	101.03	
T26	2994.0	112.19	48.7	101.09	
SS13-10	3095.6	110.10	56.8	101.14	
T27	3311.3	104.90	72.3	101.31	
T28	3519.9	100.60	88.3	101.53	
T29	3686.4	97.67	100.2	100.95	
T30	3895.0	94.59	113.7	100.79	
T31	4057.8	92.53	124.1	100.80	
T32	4321.7	89.54	143.9	100.95	
T33	-----	-----	-----	-----	
T34	4472.4	87.94	151.7	101.05	
T35	4691.0	86.14	167.6	101.02	
T36	4844.5	84.91	176.2	100.98	
T37	5040.1	83.45	188.5	101.13	
T38	5253.6	82.00	197.9	101.32	
T39	5514.2	80.43	214.4	101.50	
T40	5741.7	79.25	227.7	101.66	
T41	6003.8	77.97	239.3	101.31	

Appendix C - Roosevelt Hot Springs gravity data

Station	R ft	ϕ deg	H ft	g mgal	z _{basement} ft
T42	6193.3	77.17	251.4	101.07	
T43	6441.6	76.13	266.2	100.96	
T44	6659.4	75.24	275.8	101.10	
T45	6903.4	74.36	291.0	101.46	
T46	7108.5	73.70	304.7	101.92	
T47	7369.4	72.88	321.4	101.99	
T48	7572.0	72.29	327.9	101.43	
T49	7785.7	71.70	334.8	100.71	
T50	8210.3	70.62	355.0	99.87	
T51	8453.9	70.06	365.7	99.61	
T52	8796.7	69.39	391.6	99.42	
T53	9072.4	68.81	400.3	99.54	
EW1	9850.5	195.39	-89.1	94.09	
EW2	9875.0	193.99	-83.8	94.38	
EW3	9811.2	192.39	-73.0	94.48	
EW4	9757.1	190.91	-61.1	94.64	
EW5	9691.5	188.78	-53.2	95.01	
EW6	9655.3	187.25	-47.3	95.31	
EW7	9623.8	185.77	-37.9	95.55	
EW8	9604.0	184.45	-35.3	95.84	
EW9	9586.9	183.11	-26.6	96.14	
EW10	9574.5	181.58	-20.3	96.51	
EW11	9587.1	179.98	-11.9	96.94	
EW12	9789.8	179.16	-2.4	96.78	
EW13	10049.4	178.72	5.4	96.54	
EW14	10252.8	177.89	14.8	96.47	
EW15	10391.2	176.70	22.5	96.52	
EW16	10619.3	176.67	31.4	96.48	
EW17	10652.6	175.15	35.0	96.85	
EW18	10676.5	173.62	43.1	97.48	
EW19	10686.1	172.26	50.8	97.98	
EW20	10700	171.3	-----	-----	
EW21	10710	170.1	-----	-----	

Appendix D - Travel time data logged in Well 9-1

The data given here was collected during an areal well shoot of Utah State Geothermal Well 9-1 in late October 1980. The following tables list the shot-to-sensor travel times determined from seismograms (e.g., Figure 8) from the downhole (vertical and horizontal) and surface geophones. Each arrival time is followed by a confidence rating:

- + $\rightarrow \delta t < 1$ millisecond
- / $\rightarrow 1 \text{ msec} < \delta t < 2 \text{ msec}$
- $\rightarrow \delta t > 2 \text{ msec}$

Shots having refracted first arrivals, determined from the first motion of the vertical downhole seismometer, are denoted by "refr".

Coordinates of the surface geophone (R, ϕ , H) with respect to the well head were R = 77 ft, ϕ = N62°W = 298°, and H = -5 ft. The coordinates of the shot station markers are given in Appendix C; because the shots were buried, an appropriate correction (ΔH = -5 to -8 ft) should be made to get approximate shotpoint locations.

Appendix D - Travel time data logged in Well 9-1

Station	Shot #	Sensor depth	Travel Times		
			Vert.	Horiz.	Surface
		ft	msec	msec	msec
NV24	1	2019.0	198+	199+	158+
NV23	12	1936.8	197+	201/	158+
NV22	14	1936.8	197+	197/	157/
NV21	20	1853.8	191+	193-	156+
NV20	27	1768.6	188+	192/	158+
NV19	34	1686.2	181+	183/	154+
NV18	48	1608.2	179/	181/	155+
NV17	49	1608.2	178+	181/	155+
NV16	55	1484.0	169+	171+	153+
NV15	62	1361.4	166-	168-	151+
NV14	69	1238.4	159+	160+	150+
NV13	76	1113.6	153+	156/	148+
NV12	77	1113.6	---	---	150+
NV11	84	991.7	138??	---	148+
NV9	85	991.7	147/	149/	149+
NV10	94	908.7	137+	138+	143/
NV8	102	705.5	129/	133/	143/
NV7	103	705.5	131+	133/	143/
NV6	104	580.3	121+	121+	137+
NV5	105	501.1	108+?	109+?	141+
NV4	106	380.6	114/?	113/?	140+
NV3	107	298.9	88+	88+	101+
NV2	108	176.8	54+	59/	54+
NV1	109	95.3	28+	29/	36+
NV26	123	2183.4	210+	214/	160/
NV25	137	2100.0	201/	199/	153/
NV39	152	2019.0	197+	197/	163+
NV38	168	1936.8	195+	197-	165+
NV37	180	1853.8	190+	190/	163+
NV36	191	1768.6	187+	188/	164+
NV35	199	1686.2	182+	183+	164+
NV34	210	1568.3	175+	176+	161+
NV33	213	1484.0	169+	171+	161+
NV32	220	1361.4	164+	165+	160+
NV30	233	1238.4	154/	154/	158+
NV29	237	1113.6	147+	150/	156+
NV28	245	1032.2	146+	147+	159+
NV27	251	908.7	139+	141/	157+

Appendix D - Travel time data logged in Well 9-1

Station	Shot#	Sensor depth	Travel Times		
			Vert.	Horiz.	Surface
		ft	msec	msec	msec
W2	122	2183.4	208+	208-	121+
	136	2100.0	202/	201-	121+
	150	2019.0	201+	201+	129+
	165	1936.8	198+	195-	120+
	178	1853.8	191+	192+	119+
	189	1768.6	189+	189+	126+
	198	1686.2	187+	186+	132+
	202	1568.3	179+	179+	130+
	214	1484.0	175+	175/	130+
	221	1361.4	165+	165/	119+
	234	1238.4	159+	160+	129+
	238	1113.6	151+	151+	124+
	246	1032.2	147+	147+	124+
	252	908.7	141+	142+	124+
	255	746.7	133+	133+	117/
	256	663.4	128+	127+	119+
E1	140	2100.0	187+	189/	154+
	151	2019.0	182+	194--	156+
	166	1936.8	180-	180-	156+
	167	1936.8	177+	177/	155+
	179	1853.8	174+	175/	157+
	190	1768.6	172+	172+	157/
	201	1686.2	165+	165/	158/
	208	1568.3	158+	159+	160/
	211	1484.0	154+	155+	158+
	226	1361.4	146+	148+	165+
	231	1238.4	141+	142+	160/
	239	1113.6	136+	137+	151+
	244	1032.2	130+	130+	151+
	249	908.7	123+	124+	159+
	254	746.7	119+	119+	160+
	257	663.4	122--	118/	161+
	258	580.3	117+	117+	162+
	259	501.1	114+	114+	164+
	260	380.6	115+	113-	164+ refr
	261	298.9	114+	114/	165+ refr
	262	176.8	118/	117+	160+ refr

Appendix D - Travel time data logged in Well 9-1

Station	Shot#	Sensor depth	Travel Times		
			Vert.	Horiz.	Surface
		ft	msec	msec	msec
NE5	Cal 1	2019.0	201+	201+	285-
	Cal 2	2019.0	201+	201+	281/
	13	1936.8	198+	198/	279+
	21	1853.8	194+	195/	279+
	28	1768.6	190+	190+	279+
	35	1686.2	187+	188+	281/
	36	1608.2	182+	182+	279+
	37	1608.2	181+	181+	277/
	56	1484.0	178+	177+	278+
	63	1361.4	172+	172+	276/
	70	1238.4	167+	167+	276+
	78	1113.6	168-	165+	276/
	86	991.7	166+	166+	282+
	95	908.7	160+	161+	278+
	101	705.5	158+	160+	275+ refr
E5	182	1853.8	192+	192+	269/
	183	1768.6	188+	188+	268+
	193	1686.2	185+	186/	269/
	207	1567.8	179+	180+	270/
	218	1484.0	176+	176+	268/
	225	1361.4	172+	172+	270/
	230	1238.4	169+	168+	270+
	240	1113.6	166+	167+	272/
	243	1032.2	161+	159+	269/
	248	908.7	155+	155+	267+
	253	746.7	153-	153+	269+
SE5	2	2019.0	187/	191/	269+
	7	1936.8	184+	184+	267+
	15	1853.8	183+	184/	268+
	22	1768.6	178+	180-	264+
	29	1686.2	177+	178+	268/
	38	1608.2	172+	174+	266+
	39	1608.2	173+	173+	267+
	50	1484.0	168+	168-	269+
	57	1361.4	166+	166+	272+
	64	1238.4	161+	161+	268+
	71	1113.6	157+	157+	267-
	79	991.7	155+	155+	268/
	89	908.7	152+	152+	268+
	96	705.5	151+	151+	270+ refr

Appendix D - Travel time data logged in Well 9-1

Station	Shot #	Sensor depth	Travel Times		
			Vert.	Horiz.	Surface
		ft	msec	msec	msec
SSW5	3	2019.0	201+	---	304+
	8	1936.8	198+	200/	304+
	16	1853.8	197+	197+	303+
	23	1768.6	195+	195+	305+
	30	1686.2	193+	193+	305+
	40	1608.2	191+	191+	303+
	41	1608.2	192+	192+	304+
	51	1484.0	188+	190+	305+
	58	1361.4	186+	189+	303+
	65	1238.4	184+	184+	305+
	72	1113.6	184+	185/	304+
	80	991.7	181+	181+	305+
	90	908.7	180-	181/	305/
	97	705.5	182+	182+	304+
					refr
SW5	4	2019.0	223+	224+	323+
	9	1936.8	223+	223+	324+
	17	1853.8	221+	221+	321+
	24	1768.6	217+	218/	321/
	31	1686.2	216+	216+	324+
	42	1608.2	214+	214+	324+
	43	1608.2	214+	214+	324+
	52	1484.0	209+	209+	321+
	52R	1484.0	209+	209+	321+
	59	1361.4	204+	204+	315+
	66	1238.4	201+	201+	318+
	73	1113.6	201/	201+	316+
	81	991.7	198+	198+	316+
	91	908.7	199-	199+	315-
	98	705.5	200+	200/	316+
	110	95.3	279+	282+	317/
					refr
					refr
W5	5	2019.0	231+	231+	311+
	10	1936.8	223+	---	307/
	18	1853.8	223+	224-	305+
	25	1768.6	223+	223/	309+
	32	1686.2	219+	219+	311+
	44	1608.2	216+	217+	311+
	45	1608.2	217+	216+	311+
	53	1484.0	211+	211+	311+
	60	1361.4	203+	203+	305+
	67	1238.4	201+	202+	309+
	74	1113.6	202+	202+	314+
	82	991.7	200-	198+	312+
	92	908.7	196+	196+	307+
	99	705.5	198+	198+	309+
					refr

Appendix D - Travel time data logged in Well 9-1

Station	Shot #	Sensor depth ft	Travel Times		
			Vert. msec	Horiz. msec	Surface msec
NW5	6	2019.0	236+	238/	327+
	11	1936.8	234+	237/	325+
	19	1853.8	232+	235-	329+
	26	1768.6	230+	228+	327+
	33	1686.2	226+	226+	326+
	46	1608.2	225+	226+	326+
	47	1608.2	225+	225/	326+
	54	1484.0	222+	222/	326+
	61	1361.4	217+	218+	326+
	68	1238.4	215+	216+	329+
	75	1113.6	213+	213+	325+
	83	991.7	214-	212+	328+
	93	908.7	208+	208+	324+ refr
	100	705.5	208+	208/	322/ refr
NE9	88	908.7	196+	196+	312-
	124	2183.4	232+	232+	315+
	139	2100.0	229+	229+	315+
	153	2019.0	223+	224+	311/
	169	1936.8	223+	222/	315+
	181	1853.8	218+	218+	313+
	192	1768.6	216+	216+	315/
	200	1686.2	215+	215+	317-
	209	1568.3	211+	212+	313/
	212	1484.0	208+	208+	315+
	219	1361.4	206+	206/	316/
	235	1238.4	203+	204/	315+
	250	908.7	198+	197/	316/
SE9	112	2183.4	216+	216+	312/
	126	2100.0	211/	211+	319--
	141	2019.0	210/	210/	314/
	155	1936.8	211/	---	314+
	173	1853.8	208+	208-	312/
SSW9	115	2183.4	257+	257+	371+
	129	2100.0	249+	249+	369/
	144	2019.0	251+	251+	369/
	171	1936.8	253+	253+	371/
	172	1853.8	245+	247+	367/
	185	1768.6	245/	244+	365+
	194	1686.2	250/	248/	375/
	206	1568.3	250+	249+	374/
	217	1484.0	250-	248+	376-
	224	1361.4	244/	244-	366/
	227	1238.4	243??	243-	366-

Appendix D - Travel time data logged in Well 9-1

Station	Shot #	Sensor depth	Travel Times			
			Vert.	Horiz.	Surface	
		ft	msec	msec	msec	
SW9	117	2183.4	283+	283+	409+	
	131	2100.0	281+	282+	412-	
	146	2019.0	278+	278+	404+	
	160	1936.8	280+	278-	407+	
	174	1853.8	278+	278+	406/	
	186	1768.6	276-	276+	405/	
	195	1686.2	277/	277/	406/	
	205	1568.3	275/	275+	405+	
	216	1484.0	273-	273+	403-	
	223	1361.4	274-	274+	402-	
	228	1238.4	275-	276+	402+	refr
	241	1113.6	280/	278/	404/	refr
	242	1032.2	280-	275/	406-	refr
	247	908.7	280-	280-	406+	refr
W9	118	2183.4	298+	301/	424+	
	132	2100.0	292+	293+	416/	
	147	2019.0	291/	292+	415+	
	161	1936.8	291/	291/	414+	
	175	1853.8	289+	290+	418+	
	187	1768.6	288+	290+	417/	
	196	1686.2	286/	286+	419+	
	204	1568.3	---	---	419+	
	215	1484.0	281/	280+	413+	
	222	1361.4	274/	273+	400+	
NW9	120	2183.4	320+	320+	440/	
	134	2100.0	317+	318/	443+	
	148	2019.0	317+	317/	439+	
	163	1936.8	315+	315/	439+	
	177	1853.8	315+	315+	443+	
	188	1768.6	314/	313/	440/	
	197	1686.2	314-	314/	446+	
	203	1568.3	315/	315/	446/	
NE12	125	2183.4	268+	269+	363-	
	138	2100.0	270+	271+	363+	
	154	2019.0	265+	267+	363+	
	170	1936.8	263+	264+	361/	

Appendix D - Travel time data logged in Well 9-1

Station Shot#		Sensor depth	Travel Times		
			Vert.	Horiz.	Surface
		ft	msec	msec	msec
SE12	113	2183.4	241+	241+	348+
	127	2100.0	239+	239+	347/
	142	2019.0	236+	236/	344+
	156	1936.8	237+	238-	347+
SSW12	114	2183.4	291/	292+	407/
	128	2100.0	288+	288+	407-
	143	2019.0	288+	286+	409+
	157	1936.8	286+	286/	409+
SW12	116	2183.4	329/	329/	474+
	130	2100.0	328/	328/	473/
	145	2019.0	328/	328+	460/
	159	1936.8	328/	328-	459-
W12	119	2183.4	349+	348+	484/
	133	2100.0	348+	348/	487/
	162	1936.8	341/	340/	478/
	176	1853.8	346/	345+	484+
NW12	121	2183.4	377+	374+	511/
	135	2100.0	379/	379+	516+
	149	2019.0	377/	---	514+
	164	1936.8	372+	372+	510+

Appendix E - Velocity reduction program outputs

Following are the output files from the operation of the programs TZINT and VELRED on travel time data obtained by the areal well shoot conducted at Utah State Geothermal Well 9-1. All of the printouts are labelled by station and by the order of the Chebyshev polynomial fit to the travel times recorded in the well from the given station.

Shown first are outputs from TZINT which compare the measured travel time values with those calculated by the least-squares-fit polynomial. The error for each point (ΔT) and the mean error ($\sum_i^N (|\Delta T_i| / N)$) are given.

The second set of printouts are those obtained by the operation of VELRED on the calculated travel time values. Given as a function of depth in the well (Z) are: calculated velocity (V), calculated travel time (T), dt/dz , ray parameter (P), calculated shot distance (XC), and the incident angle of the direct ray at the well bore (θ).

VELRED automatically corrects for the shot elevation so that the depths (Z) are given with respect to the well head. However, the near-surface (weathering) function and Z_{patch} are given with respect to the shotpoint (i.e., Z_{shot} is the origin for these values).

ZM	TM	TC	DELT
380.60	0.10850	0.10853	-0.00003
501.10	0.11400	0.11368	0.00032
580.30	0.12100	0.12170	-0.00070
705.50	0.13000	0.12614	0.00386
838.70	0.13700	0.13873	-0.00173
891.70	0.14600	0.14437	0.00163
1113.60	0.15300	0.15203	0.00097
1238.40	0.15900	0.15888	-0.00012
1361.40	0.16600	0.16486	0.00114
1484.60	0.16900	0.16988	-0.00088
1608.20	0.17800	0.17683	0.00117
1688.20	0.18100	0.18195	-0.00095
1768.80	0.18800	0.18732	0.00068
1853.80	0.19100	0.19208	-0.00108
1938.80	0.19700	0.19577	0.00123
2018.00	0.19850	0.19922	-0.00072
2100.00	0.20400	0.20370	0.00030
2183.40	0.21000	0.21002	-0.00002

NV - 10°

MEAN ERROR: 0.00084 SECONDS

ZM	TM	TC	DELT
380.60	0.10850	0.10853	0.00000
501.10	0.11400	0.11363	0.00037
580.30	0.12100	0.12118	-0.00018
705.50	0.13000	0.12971	0.00029
838.70	0.13700	0.13887	-0.00187
891.70	0.14600	0.14450	0.00150
1113.60	0.15300	0.15358	-0.00058
1238.40	0.15900	0.15968	-0.00068
1361.40	0.16600	0.16443	0.00157
1484.60	0.16900	0.17037	-0.00137
1608.20	0.17600	0.17715	0.00085
1688.20	0.18100	0.18171	-0.00071
1768.80	0.18800	0.18693	0.00107
1853.80	0.19100	0.19227	-0.00127
1938.80	0.19700	0.19616	0.00084
2018.00	0.19850	0.19881	-0.00031
2100.00	0.20400	0.20384	0.00016
2183.40	0.21000	0.21000	0.00000

NV - 13°

MEAN ERROR: 0.00086 SECONDS

ZM	TM	TC	DELT
501.10	0.11400	0.11388	0.00012
580.30	0.11750	0.11788	-0.00038
664.00	0.11650	0.11838	0.00188
747.30	0.11850	0.11888	0.00038
808.70	0.12500	0.12388	0.00112
1032.20	0.13050	0.13052	-0.00002
1113.60	0.13600	0.13506	0.00094
1238.40	0.14150	0.14154	-0.00004
1361.40	0.14650	0.14744	-0.00094
1484.60	0.15450	0.15361	0.00089
1568.20	0.15800	0.15636	0.00164
1688.20	0.16500	0.16538	-0.00038
1768.80	0.17200	0.17053	0.00147
1853.80	0.17400	0.17503	-0.00103
1938.80	0.17650	0.17683	-0.00033
2018.00	0.18250	0.18108	0.00142
2100.00	0.18750	0.18761	-0.00011

E1 - 8°

MEAN ERROR: 0.00068 SECONDS

ZM	TM	TC	DELT
501.10	0.11400	0.11402	-0.00002
580.30	0.11750	0.11736	0.00014
664.00	0.11850	0.11888	-0.00038
747.30	0.11950	0.11938	0.00012
808.70	0.12500	0.12333	0.00167
1032.20	0.13050	0.13058	-0.00008
1113.60	0.13600	0.13548	0.00052
1238.40	0.14150	0.14173	-0.00023
1361.40	0.14650	0.14708	-0.00058
1484.60	0.15450	0.15334	0.00116
1568.20	0.15800	0.15648	0.00152
1688.20	0.16500	0.16538	-0.00038
1768.80	0.17200	0.17062	0.00138
1853.80	0.17400	0.17471	-0.00071
1938.80	0.17650	0.17638	0.00012
2018.00	0.18250	0.18247	0.00003
2100.00	0.18750	0.18751	-0.00001

E1 - 11°

MEAN ERROR: 0.00063 SECONDS

ZM	TM	TC	DELT
665.00	0.12800	0.12788	0.00012
747.30	0.13300	0.13335	-0.00035
808.70	0.14200	0.14140	0.00060
1032.20	0.14700	0.14722	-0.00022
1113.60	0.15100	0.15138	-0.00038
1238.40	0.15900	0.15848	0.00052
1361.40	0.16500	0.16614	-0.00114
1484.60	0.17500	0.17383	0.00117
1568.20	0.17800	0.17838	-0.00038
1688.20	0.18650	0.18563	0.00087
1768.80	0.18900	0.18964	-0.00064
1853.80	0.19150	0.19338	-0.00188
1938.80	0.19600	0.19654	-0.00054
2018.00	0.20000	0.19972	0.00028
2100.00	0.20300	0.20328	-0.00028
2183.40	0.20800	0.20803	-0.00003

W2 - 6°

MEAN ERROR: 0.00079 SECONDS

ZM	TM	TC	DELT
665.00	0.12800	0.12792	0.00008
747.30	0.13300	0.13322	-0.00022
808.70	0.14200	0.14162	0.00038
1032.20	0.14700	0.14726	-0.00026
1113.60	0.15100	0.15124	-0.00024
1238.40	0.15900	0.15829	0.00071
1361.40	0.16500	0.16608	-0.00108
1484.60	0.17500	0.17414	0.00086
1568.20	0.17800	0.17834	-0.00034
1688.20	0.18650	0.18571	0.00079
1768.80	0.18900	0.18950	-0.00050
1853.80	0.19150	0.19301	-0.00151
1938.80	0.19600	0.19634	-0.00034
2018.00	0.20000	0.19987	0.00013
2100.00	0.20300	0.20371	-0.00071
2183.40	0.20800	0.20778	0.00022

W2 - 8°

MEAN ERROR: 0.00077 SECONDS

ZM	TM	TC	DELT
888.70	0.16050	0.16072	-0.00022
891.70	0.16400	0.16353	0.00047
1113.60	0.16550	0.16556	-0.00006
1238.40	0.16700	0.16777	-0.00077
1361.40	0.17200	0.17142	0.00058
1484.00	0.17700	0.17658	0.00042
1608.20	0.18200	0.18267	-0.00067
1686.20	0.18700	0.18654	0.00046
1768.60	0.19000	0.19040	-0.00040
1853.00	0.19400	0.19409	-0.00009
1936.80	0.19800	0.19753	0.00047
2018.00	0.20160	0.20120	-0.00040

NE5 - 6°

MEAN ERROR: 0.00045 SECONDS

ZM	TM	TC	DELT
888.70	0.15200	0.15214	-0.00014
891.70	0.15500	0.15454	0.00046
1113.60	0.15700	0.15764	-0.00064
1238.40	0.16100	0.16083	0.00017
1361.40	0.16500	0.16437	0.00063
1484.00	0.16800	0.16846	-0.00046
1608.20	0.17250	0.17311	-0.00061
1686.20	0.17700	0.17617	0.00083
1768.60	0.17800	0.17838	-0.00038
1853.00	0.18300	0.18247	0.00053
1936.80	0.18450	0.18503	-0.00053
2018.00	0.18700	0.18684	0.00016

SE5 - 5°

MEAN ERROR: 0.00051 SECONDS

ZM	TM	TC	DELT
888.70	0.18000	0.17986	0.00014
891.70	0.18100	0.18123	-0.00023
1113.60	0.18350	0.18328	0.00022
1238.40	0.18450	0.18469	-0.00019
1361.40	0.18600	0.18595	0.00005
1484.00	0.18800	0.18806	-0.00006
1608.20	0.19150	0.19118	0.00032
1686.20	0.19300	0.19326	-0.00026
1768.60	0.19500	0.19517	-0.00017
1853.00	0.19700	0.19669	0.00031
1936.80	0.19800	0.19815	-0.00015
2018.00	0.20100	0.20088	0.00012

SSW5 - 7°

MEAN ERROR: 0.00019 SECONDS

ZM	TM	TC	DELT
891.70	0.19850	0.19860	-0.00010
1113.60	0.20150	0.20115	0.00035
1238.40	0.20250	0.20283	-0.00033
1361.40	0.20500	0.20522	-0.00022
1484.00	0.20900	0.20872	0.00028
1608.20	0.21350	0.21289	0.00061
1686.20	0.21550	0.21570	-0.00020
1768.60	0.21750	0.21831	-0.00081
1853.00	0.22100	0.22057	0.00043
1936.80	0.22250	0.22228	0.00022
2018.00	0.22350	0.22364	-0.00014

SW5 - 6°

MEAN ERROR: 0.00038 SECONDS

ZM	TM	TC	DELT
747.30	0.15300	0.15302	-0.00002
808.70	0.15550	0.15512	0.00038
1032.20	0.15800	0.16075	-0.00275
1113.60	0.16650	0.16434	0.00216
1238.40	0.16800	0.16876	-0.00076
1361.40	0.17200	0.17221	-0.00021
1484.00	0.17600	0.17586	0.00014
1567.00	0.17800	0.17901	-0.00101
1686.20	0.18500	0.18452	0.00048
1768.60	0.18800	0.18858	-0.00058
1853.00	0.19200	0.19162	0.00038

ES - 6°

MEAN ERROR: 0.00051 SECONDS

ZM	TM	TC	DELT
888.70	0.18000	0.17995	0.00005
891.70	0.18100	0.18131	-0.00031
1113.60	0.18350	0.18265	0.00085
1238.40	0.18450	0.18454	-0.00004
1361.40	0.18600	0.18631	-0.00031
1484.00	0.18800	0.18845	-0.00045
1608.20	0.19150	0.19102	0.00048
1686.20	0.19300	0.19281	0.00019
1768.60	0.19500	0.19482	0.00018
1853.00	0.19700	0.19690	0.00010
1936.80	0.19800	0.19885	-0.00085
2018.00	0.20100	0.20057	0.00043

SSW5 - 5°

MEAN ERROR: 0.00040 SECONDS

ZM	TM	TC	DELT
891.70	0.19850	0.19911	-0.00061
1113.60	0.20150	0.20027	0.00123
1238.40	0.20250	0.20250	-0.00000
1361.40	0.20500	0.20566	-0.00066
1484.00	0.20900	0.20925	-0.00025
1608.20	0.21350	0.21312	0.00038
1686.20	0.21550	0.21554	-0.00004
1768.60	0.21750	0.21789	-0.00039
1853.00	0.22100	0.22031	0.00069
1936.80	0.22250	0.22228	0.00022
2018.00	0.22350	0.22387	-0.00037

SW5 - 4°

MEAN ERROR: 0.00056 SECONDS

ZM	TM	TC	DELT
888.70	0.18600	0.18560	0.00040
891.70	0.18750	0.18657	0.00093
1113.60	0.20100	0.20084	0.00016
1238.40	0.20200	0.20170	0.00030
1361.40	0.20400	0.20517	-0.00117
1484.00	0.21100	0.21031	0.00069
1608.20	0.21600	0.21607	-0.00007
1686.20	0.21800	0.21840	-0.00040
1768.60	0.22300	0.22239	0.00061
1853.00	0.22500	0.22489	0.00011
1936.80	0.22700	0.22746	-0.00046
2018.00	0.23100	0.23089	0.00011

W5 - 6°

MEAN ERROR: 0.00064 SECONDS

ZH	TH	TC	DELT
888.70	0.18500	0.18504	0.00006
891.70	0.18750	0.18772	-0.00020
1113.60	0.20100	0.20068	0.00032
1238.40	0.20200	0.20206	-0.00006
1361.40	0.20400	0.20408	-0.00008
1484.00	0.21100	0.20983	0.00107
1608.20	0.21600	0.21632	-0.00032
1686.20	0.21900	0.21874	-0.00026
1768.60	0.22300	0.22246	0.00054
1853.80	0.22500	0.22474	0.00026
1936.00	0.22700	0.22734	-0.00034
2018.00	0.23100	0.23062	0.00038

W5 - 7°

MEAN ERROR: 0.00049 SECONDS

ZH	TH	TC	DELT
881.70	0.21200	0.21188	0.00012
1113.60	0.21350	0.21366	-0.00016
1238.40	0.21500	0.21453	0.00047
1361.40	0.21700	0.21768	-0.00068
1484.00	0.22200	0.22158	0.00042
1608.20	0.22500	0.22471	0.00029
1686.20	0.22600	0.22637	-0.00037
1768.60	0.22600	0.22840	-0.00240
1853.80	0.23200	0.23125	0.00075
1936.00	0.23400	0.23441	-0.00041
2018.00	0.23600	0.23582	0.00018

NW5 - 7°

MEAN ERROR: 0.00043 SECONDS

ZH	TH	TC	DELT
888.70	0.18750	0.18750	0.00000
1238.40	0.20300	0.20304	-0.00004
1361.40	0.20600	0.20578	0.00022
1484.00	0.20800	0.20848	-0.00048
1567.80	0.21100	0.21072	0.00028
1686.20	0.21450	0.21416	0.00034
1768.60	0.21600	0.21642	-0.00042
1853.80	0.21650	0.21872	-0.00222
1936.00	0.22200	0.22138	0.00062
2018.00	0.22450	0.22483	-0.00033
2094.60	0.22600	0.22888	-0.00288
2178.00	0.23200	0.23201	-0.00001

NE9 - 8°

MEAN ERROR: 0.00032 SECONDS

ZH	TH	TC	DELT
1361.40	0.27300	0.27283	0.00017
1484.00	0.28000	0.28005	-0.00005
1686.20	0.28600	0.28583	0.00017
1768.60	0.28800	0.28804	-0.00004
1853.80	0.28950	0.28982	-0.00032
1936.00	0.29100	0.29078	0.00022
2018.00	0.29150	0.29131	0.00019
2100.00	0.29250	0.29273	-0.00023
2183.00	0.29800	0.29784	0.00016

W9 - 6°

MEAN ERROR: 0.00017 SECONDS

ZH	TH	TC	DELT
881.70	0.21200	0.21212	-0.00012
1113.60	0.21350	0.21309	0.00041
1238.40	0.21500	0.21516	-0.00016
1361.40	0.21700	0.21789	-0.00089
1484.00	0.22200	0.22182	0.00018
1608.20	0.22500	0.22441	0.00059
1686.20	0.22600	0.22660	-0.00060
1768.60	0.22800	0.22892	-0.00092
1853.80	0.23200	0.23135	0.00065
1936.00	0.23400	0.23375	0.00025
2018.00	0.23600	0.23618	-0.00018

NW5 - 5°

MEAN ERROR: 0.00066 SECONDS

ZH	TH	TC	DELT
888.70	0.18750	0.18751	-0.00001
1238.40	0.20300	0.20296	0.00004
1361.40	0.20600	0.20583	0.00017
1484.00	0.20800	0.20870	-0.00070
1567.80	0.21100	0.21075	0.00025
1686.20	0.21450	0.21383	0.00067
1768.60	0.21600	0.21618	-0.00018
1853.80	0.21650	0.21888	-0.00238
1936.00	0.22200	0.22182	0.00018
2018.00	0.22450	0.22504	-0.00054
2094.60	0.22600	0.22831	-0.00231
2178.00	0.23200	0.23223	-0.00023

NE9 - 6°

MEAN ERROR: 0.00042 SECONDS

ZH	TH	TC	DELT
1361.40	0.27300	0.27303	-0.00003
1484.00	0.27400	0.27406	-0.00006
1567.80	0.27500	0.27485	0.00015
1686.20	0.27600	0.27605	-0.00005
1768.60	0.27700	0.27696	0.00004
1853.80	0.27800	0.27786	0.00014
1936.00	0.27900	0.27900	0.00000
2018.00	0.28000	0.28003	-0.00003
2094.50	0.28100	0.28114	-0.00014
2178.00	0.28200	0.28235	-0.00035

SW9 - 3°

MEAN ERROR: 0.00009 SECONDS

NV - 10°

Z	V	T	GT0Z	P	XC	TKTA
440.00	8938.68	0.10786	0.6250E-04	0.0723E-04	308.54	54.37823
460.00	8165.66	0.10844	0.8875E-04	0.0373E-04	306.22	43.33497
480.00	7618.46	0.11141	0.1033E-03	0.0105E-04	300.77	38.13057
500.00	7458.61	0.11357	0.1086E-03	0.7866E-04	301.25	35.07717
520.00	7561.04	0.11576	0.1000E-03	0.7634E-04	301.58	35.25406
540.00	7686.82	0.11769	0.1020E-03	0.7401E-04	301.89	35.76622
560.00	8434.66	0.11867	0.9450E-04	0.7160E-04	302.14	37.14830
580.00	8101.86	0.12167	0.6550E-04	0.6880E-04	302.03	38.06232
600.00	8914.01	0.12329	0.7600E-04	0.6632E-04	302.37	41.10863
620.00	10860.43	0.12471	0.6675E-04	0.6342E-04	302.32	43.53665
640.00	11867.89	0.12596	0.5875E-04	0.6040E-04	302.30	45.79415
660.00	12655.84	0.12768	0.5175E-04	0.5727E-04	302.10	47.66667
680.00	14045.30	0.12803	0.4625E-04	0.5413E-04	302.05	48.48895
700.00	15016.75	0.12891	0.4275E-04	0.5106E-04	301.86	50.66141
720.00	15886.83	0.12874	0.4050E-04	0.4819E-04	301.93	48.85284
740.00	16651.77	0.13059	0.3825E-04	0.4545E-04	301.39	49.18766
760.00	17070.88	0.13131	0.3875E-04	0.4303E-04	301.32	47.56787
780.00	17182.27	0.13212	0.4130E-04	0.4090E-04	301.35	44.58501
800.00	17056.36	0.13287	0.4575E-04	0.3803E-04	301.31	41.73631
820.00	16708.40	0.13387	0.4675E-04	0.3737E-04	301.64	36.63699
840.00	16186.73	0.13484	0.5025E-04	0.3584E-04	301.61	35.57221
860.00	15578.61	0.13588	0.5460E-04	0.3470E-04	301.25	32.75248
880.00	14871.79	0.13703	0.5775E-04	0.3358E-04	300.82	30.16057
900.00	14457.34	0.13818	0.6160E-04	0.3261E-04	300.34	28.12785
920.00	13956.24	0.13944	0.6425E-04	0.3168E-04	301.19	26.25724
940.00	13512.31	0.14076	0.6725E-04	0.3089E-04	301.45	24.67331
960.00	13241.70	0.14213	0.6925E-04	0.3015E-04	301.37	23.51039
980.00	13012.89	0.14353	0.7100E-04	0.2940E-04	301.23	22.49663
1000.00	12897.17	0.14497	0.7260E-04	0.2877E-04	301.76	21.78288
1020.00	12837.66	0.14641	0.7200E-04	0.2812E-04	301.69	21.33586
1040.00	13013.17	0.14785	0.7175E-04	0.2752E-04	302.85	20.88164
1060.00	13212.05	0.14928	0.7075E-04	0.2688E-04	301.59	20.61164
1080.00	13541.33	0.15068	0.6800E-04	0.2632E-04	301.76	20.67636
1100.00	13833.24	0.15204	0.6760E-04	0.2573E-04	301.79	21.00851
1120.00	14385.28	0.15336	0.6475E-04	0.2516E-04	301.86	21.23620
1140.00	15046.21	0.15463	0.6175E-04	0.2458E-04	301.82	21.76451
1160.00	15755.57	0.15583	0.5875E-04	0.2404E-04	302.53	22.25276
1180.00	16532.66	0.15698	0.5575E-04	0.2347E-04	302.76	22.62686
1200.00	17536.66	0.15806	0.5225E-04	0.2284E-04	302.37	23.61481
1220.00	18505.58	0.15907	0.4925E-04	0.2224E-04	302.33	24.30646
1240.00	19410.27	0.16003	0.4675E-04	0.2165E-04	302.57	24.64738
1260.00	20506.20	0.16094	0.4400E-04	0.2103E-04	302.33	25.54153
1280.00	21517.23	0.16179	0.4175E-04	0.2042E-04	302.20	26.05874
1300.00	22481.88	0.16261	0.4000E-04	0.1982E-04	302.34	26.35725
1320.00	23127.61	0.16339	0.3875E-04	0.1918E-04	301.51	26.93669
1340.00	23627.28	0.16416	0.3800E-04	0.1864E-04	301.89	26.12486
1360.00	24026.93	0.16491	0.3750E-04	0.1805E-04	301.21	25.70885
1380.00	23886.86	0.16566	0.3800E-04	0.1757E-04	301.68	24.60990
1400.00	23493.67	0.16643	0.3900E-04	0.1705E-04	301.00	23.61901
1420.00	23086.67	0.16722	0.4000E-04	0.1650E-04	300.71	22.53662
1440.00	22327.25	0.16803	0.4175E-04	0.1622E-04	301.14	21.22552
1460.00	21362.85	0.16888	0.4400E-04	0.1585E-04	301.15	19.80565
1480.00	20488.08	0.16978	0.4625E-04	0.1552E-04	301.40	18.55180
1500.00	19495.93	0.17074	0.4900E-04	0.1518E-04	300.33	17.18565
1520.00	18568.54	0.17175	0.5175E-04	0.1480E-04	300.61	16.65979
1540.00	17719.78	0.17281	0.5450E-04	0.1465E-04	300.75	15.86362
1560.00	16836.40	0.17383	0.5725E-04	0.1440E-04	300.55	14.12146
1580.00	16281.71	0.17510	0.5875E-04	0.1422E-04	301.94	13.38502
1600.00	15732.55	0.17632	0.6200E-04	0.1401E-04	301.17	12.73028
1620.00	15271.64	0.17756	0.6400E-04	0.1385E-04	301.83	12.20833
1640.00	14845.77	0.17888	0.6550E-04	0.1366E-04	301.76	11.77744
1660.00	14738.82	0.18026	0.6650E-04	0.1346E-04	301.20	11.44937
1680.00	14681.18	0.18154	0.6675E-04	0.1333E-04	302.18	11.28941

NV - 10° (cont'd)

1700.00	14751.87	0.10287	0.6650E-04	0.1317E-04	302.34	11.20268
1720.00	14864.97	0.10420	0.6600E-04	0.1302E-04	302.67	11.16081
1740.00	15148.67	0.10551	0.6475E-04	0.1285E-04	302.97	11.22312
1760.00	15620.37	0.10679	0.6275E-04	0.1268E-04	303.29	11.42688
1780.00	16247.54	0.10802	0.6025E-04	0.1257E-04	303.61	11.70686
1800.00	16929.77	0.10928	0.5775E-04	0.1241E-04	303.63	12.12433
1820.00	17625.26	0.11033	0.5475E-04	0.1223E-04	303.57	12.55551
1840.00	18305.83	0.11139	0.5150E-04	0.1207E-04	303.83	13.10242
1860.00	18930.82	0.11238	0.4875E-04	0.1187E-04	303.26	13.67881
1880.00	19567.58	0.11334	0.4600E-04	0.1171E-04	303.88	14.27638
1900.00	20230.09	0.11423	0.4350E-04	0.1146E-04	302.42	14.75832
1920.00	20921.33	0.11508	0.4175E-04	0.1129E-04	303.10	15.13266
1940.00	21620.68	0.11590	0.4050E-04	0.1105E-04	301.77	15.26088
1960.00	22345.18	0.11676	0.4050E-04	0.1088E-04	302.47	15.84327
1980.00	23205.84	0.11752	0.4175E-04	0.1067E-04	301.56	16.33983
2000.00	23223.82	0.11837	0.4375E-04	0.1052E-04	301.88	17.51911
2020.00	23886.43	0.11927	0.4675E-04	0.1033E-04	300.87	18.46168
2040.00	19231.45	0.12024	0.5100E-04	0.1014E-04	299.35	19.24457
2060.00	17489.17	0.12131	0.5625E-04	0.1008E-04	301.22	19.15692
2080.00	15827.84	0.12249	0.6200E-04	0.9985E-05	299.28	20.87720
2100.00	14555.12	0.12378	0.6800E-04	0.9813E-05	299.41	22.21123
2120.00	13577.08	0.12521	0.7300E-04	0.9780E-05	301.49	23.63834
2140.00	13051.25	0.12671	0.7600E-04	0.9744E-05	302.31	25.28628
2160.00	12867.88	0.12825	0.7650E-04	0.9704E-05	303.81	27.22936
2180.00	13138.13	0.12977	0.7550E-04	0.9651E-05	304.73	29.28444

SHOTPOINT DISTANCE= 300.00FEET.

SHOTPOINT ELEVATION= 0.00FEET.

WEATHERING FUNCTION FROM SHOTPOINT TO ZPATCH (W.R.T. SHOT).

FVEXF=A*Z**B+VC

A= 0.201618841

B= 1.020170658

VC= 2065.34

ZPATCH= 106.28

NV - 13°

Z	V	T	DTDZ	F	XC	THTA
520.00	8886.83	0.11536	0.8275E-04	0.7625E-04	299.82	42.85973
540.00	8354.82	0.11717	0.8450E-04	0.7345E-04	300.27	37.85756
560.00	8178.58	0.11814	0.8950E-04	0.7104E-04	300.74	35.52428
580.00	8352.18	0.12115	0.8800E-04	0.6878E-04	301.33	39.06358
600.00	8841.75	0.12306	0.8150E-04	0.6648E-04	301.58	35.89873
620.00	8627.20	0.12481	0.8175E-04	0.6408E-04	301.86	36.89160
640.00	10734.31	0.12633	0.7000E-04	0.6147E-04	301.82	41.28805
660.00	12689.40	0.12762	0.5625E-04	0.5663E-04	302.10	45.16743
680.00	13683.68	0.12866	0.4750E-04	0.5347E-04	301.89	49.42444
700.00	15467.18	0.12851	0.3875E-04	0.5207E-04	301.62	53.36265
720.00	17147.77	0.13021	0.3225E-04	0.4859E-04	301.53	58.42565
740.00	18717.85	0.13088	0.2850E-04	0.4518E-04	301.34	57.76055
760.00	19773.64	0.13135	0.2800E-04	0.4211E-04	301.88	56.36139
780.00	20226.07	0.13182	0.2875E-04	0.3848E-04	300.73	53.06641
800.00	18844.51	0.13254	0.3350E-04	0.3731E-04	300.19	48.07824
820.00	18938.28	0.13326	0.3900E-04	0.3568E-04	300.43	42.38628
840.00	17573.10	0.13410	0.4550E-04	0.3416E-04	300.17	38.81038
860.00	16067.07	0.13588	0.5275E-04	0.3203E-04	300.25	32.85514
880.00	14699.84	0.13621	0.6000E-04	0.3206E-04	300.11	28.11588
900.00	13609.74	0.13748	0.6650E-04	0.3125E-04	300.34	23.17628
920.00	12785.16	0.13887	0.7200E-04	0.3056E-04	300.78	22.89608
940.00	12175.58	0.14036	0.7650E-04	0.2888E-04	300.73	21.34187
960.00	11769.87	0.14183	0.7875E-04	0.2838E-04	300.87	20.17302
980.00	11603.54	0.14355	0.8125E-04	0.2873E-04	301.86	18.47494
1000.00	11595.89	0.14518	0.8150E-04	0.2818E-04	301.19	18.87868
1020.00	11778.46	0.14681	0.8025E-04	0.2771E-04	302.83	18.85188

NV - 13° (cont'd)

1040.00	12141.53	0.14839	0.7775E-04	0.2717E-04	302.00	10.26471
1060.00	12675.96	0.14982	0.7423E-04	0.2667E-04	302.45	10.75522
1080.00	13386.68	0.15136	0.7000E-04	0.2608E-04	302.83	10.43517
1100.00	14223.90	0.15272	0.6530E-04	0.2534E-04	302.42	11.30403
1120.00	15262.07	0.15398	0.6050E-04	0.2492E-04	302.61	12.30886
1140.00	16437.40	0.15514	0.5575E-04	0.2435E-04	302.56	13.59620
1160.00	17707.00	0.15621	0.5125E-04	0.2372E-04	302.50	14.83451
1180.00	19023.23	0.15718	0.4725E-04	0.2304E-04	302.23	15.69302
1200.00	20349.32	0.15810	0.4375E-04	0.2236E-04	302.44	17.00120
1220.00	21677.97	0.15894	0.4100E-04	0.2165E-04	301.75	17.83914
1240.00	22466.41	0.15974	0.3825E-04	0.2099E-04	302.00	18.13895
1260.00	23083.97	0.16051	0.3625E-04	0.2034E-04	302.05	17.89625
1280.00	23372.71	0.16127	0.3400E-04	0.1966E-04	301.28	17.35669
1300.00	23392.18	0.16203	0.3225E-04	0.1895E-04	301.64	16.52357
1320.00	23046.11	0.16280	0.3025E-04	0.1830E-04	300.93	15.23588
1340.00	22442.08	0.16360	0.4075E-04	0.1802E-04	301.41	13.65645
1360.00	21753.12	0.16443	0.4250E-04	0.1752E-04	300.68	12.40577
1380.00	21075.66	0.16530	0.4425E-04	0.1712E-04	301.14	11.15653
1400.00	20426.49	0.16620	0.4600E-04	0.1674E-04	301.18	10.09702
1420.00	19718.86	0.16714	0.4800E-04	0.1636E-04	300.83	10.02545
1440.00	19213.75	0.16812	0.4950E-04	0.1608E-04	301.75	17.83555
1460.00	18734.58	0.16912	0.5100E-04	0.1575E-04	301.40	17.16407
1480.00	18351.75	0.17016	0.5225E-04	0.1547E-04	301.49	16.48806
1500.00	18063.10	0.17121	0.5325E-04	0.1514E-04	300.48	15.07424
1520.00	17848.01	0.17229	0.5400E-04	0.1483E-04	301.55	15.45597
1540.00	17718.56	0.17337	0.5450E-04	0.1466E-04	301.10	15.05830
1560.00	17584.31	0.17447	0.5500E-04	0.1446E-04	302.01	14.72846
1580.00	17456.03	0.17557	0.5550E-04	0.1420E-04	301.30	14.34775
1600.00	17331.08	0.17669	0.5625E-04	0.1399E-04	301.76	13.87092
1620.00	17205.80	0.17782	0.5700E-04	0.1373E-04	300.61	13.56497
1640.00	16788.05	0.17897	0.5800E-04	0.1357E-04	301.58	13.17787
1660.00	16464.47	0.18014	0.5925E-04	0.1336E-04	302.14	12.70366
1680.00	16150.32	0.18134	0.6050E-04	0.1318E-04	301.27	12.26699
1700.00	15848.36	0.18258	0.6175E-04	0.1287E-04	300.65	11.86566
1720.00	15554.09	0.18381	0.6300E-04	0.1200E-04	300.62	11.48853
1740.00	15327.03	0.18508	0.6400E-04	0.1266E-04	301.14	11.19241
1760.00	15162.31	0.18637	0.6475E-04	0.1253E-04	301.60	10.84852
1780.00	15170.09	0.18767	0.6475E-04	0.1236E-04	301.25	10.80730
1800.00	15346.44	0.18896	0.6400E-04	0.1225E-04	302.24	10.83517
1820.00	15709.14	0.19023	0.6250E-04	0.1208E-04	301.77	10.84152
1840.00	16407.08	0.19146	0.5975E-04	0.1201E-04	303.91	11.36941
1860.00	17544.73	0.19262	0.5575E-04	0.1186E-04	303.90	12.00781
1880.00	19112.26	0.19369	0.5100E-04	0.1169E-04	303.78	12.60527
1900.00	21184.46	0.19466	0.4575E-04	0.1154E-04	304.45	14.15288
1920.00	23913.31	0.19552	0.4025E-04	0.1134E-04	304.42	15.73832
1940.00	27051.75	0.19627	0.3525E-04	0.1113E-04	304.50	17.52720
1960.00	29786.60	0.19699	0.3175E-04	0.1090E-04	304.30	18.84134
1980.00	30745.36	0.19754	0.3075E-04	0.1080E-04	302.46	19.01735
2000.00	29325.38	0.19816	0.3250E-04	0.1031E-04	306.40	17.59781
2020.00	25282.77	0.19884	0.3825E-04	0.1007E-04	298.83	14.74548
2040.00	20105.13	0.19969	0.4875E-04	0.9867E-05	287.27	11.44220
2060.00	15748.38	0.20079	0.6275E-04	0.9695E-05	285.45	8.78294
2080.00	12609.56	0.20220	0.7875E-04	0.9680E-05	287.76	7.00751
2100.00	10582.11	0.20394	0.8400E-04	0.9699E-05	300.64	5.89127
2120.00	8795.25	0.20596	0.1023E-03	0.9821E-05	306.52	5.48626
2140.00	8661.31	0.20803	0.8325E-04	0.1012E-04	318.13	6.19124
2160.00	10656.63	0.20969	0.5256E-04	0.1080E-04	343.85	11.62013
2180.00	74311.31	0.21013	-0.0500E-05	0.1043E-04	343.61	50.82832

SHOTPOINT DISTANCE= 300.00FEET.

SHOTPOINT ELEVATION= 0.00FEET.

WEATHERING FUNCTION FROM SHOTPOINT TO XPATCH (W.R.T. SHOT):

FVEFF=A*Z**E+Vc

A= 0.201618841

E= 1.829170680

Vc= 2065.36

XPATCH= 203.52

E1 - 8°

I	V	T	STDZ	P	XC	THTA
520.00	8683.77	0.11543	0.7075E-04	0.7660E-04	363.41	47.18700
540.00	11356.13	0.11668	0.4875E-04	0.7333E-04	363.41	56.36689
560.00	13142.12	0.11738	0.3175E-04	0.6813E-04	362.86	65.33813
580.00	14846.87	0.11787	0.1850E-04	0.6400E-04	362.87	73.83426
600.00	16876.02	0.11816	0.1075E-04	0.5827E-04	362.81	79.54712
620.00	18869.86	0.11830	0.5886E-05	0.5248E-04	362.72	84.53732
640.00	21161.14	0.11836	0.2250E-05	0.4720E-04	362.52	87.27897
660.00	23388.87	0.11839	0.1500E-05	0.4271E-04	362.48	87.88851
680.00	25581.10	0.11842	0.2250E-05	0.3883E-04	362.38	86.78036
700.00	27667.00	0.11848	0.4500E-05	0.3613E-04	362.06	82.60000
720.00	28723.61	0.11860	0.8600E-05	0.3388E-04	361.72	76.71536
740.00	28173.85	0.11880	0.1200E-04	0.3211E-04	361.61	68.58741
760.00	28816.05	0.11898	0.1625E-04	0.3066E-04	361.10	62.07642
780.00	27746.54	0.11845	0.2075E-04	0.2847E-04	360.85	54.84848
800.00	26158.88	0.11891	0.2550E-04	0.2848E-04	360.80	48.15783
820.00	24480.66	0.12047	0.3025E-04	0.2765E-04	361.02	42.42885
840.00	22850.26	0.12112	0.3450E-04	0.2693E-04	361.65	37.86992
860.00	21356.64	0.12185	0.3875E-04	0.2620E-04	361.16	34.15009
880.00	20120.32	0.12267	0.4250E-04	0.2572E-04	361.53	31.18543
900.00	18145.46	0.12355	0.4575E-04	0.2520E-04	361.65	28.84773
920.00	16286.43	0.12450	0.4875E-04	0.2471E-04	361.65	26.88058
940.00	17708.86	0.12550	0.5100E-04	0.2424E-04	361.65	25.42451
960.00	17276.51	0.12654	0.5275E-04	0.2383E-04	361.87	24.80836
980.00	16823.86	0.12761	0.5425E-04	0.2342E-04	361.85	23.34653
1000.00	16543.18	0.12871	0.5550E-04	0.2302E-04	362.02	22.52731
1020.00	16555.53	0.12883	0.5600E-04	0.2264E-04	362.12	22.81136
1040.00	16530.78	0.13085	0.5625E-04	0.2226E-04	362.63	21.58756
1060.00	16568.85	0.13268	0.5625E-04	0.2188E-04	361.77	21.23074
1080.00	16732.86	0.13320	0.5575E-04	0.2154E-04	362.32	21.12247
1100.00	16899.87	0.13431	0.5525E-04	0.2116E-04	362.47	20.87805
1120.00	17148.52	0.13541	0.5450E-04	0.2082E-04	362.38	20.80744
1140.00	17386.71	0.13649	0.5375E-04	0.2047E-04	362.30	20.84670
1160.00	17713.41	0.13756	0.5275E-04	0.2011E-04	362.18	20.87138
1180.00	18052.04	0.13868	0.5175E-04	0.1976E-04	362.14	20.80182
1200.00	18483.15	0.13963	0.5075E-04	0.1942E-04	362.18	20.83921
1220.00	18769.34	0.14063	0.4975E-04	0.1907E-04	361.85	20.86890
1240.00	18975.23	0.14162	0.4825E-04	0.1876E-04	362.57	20.84762
1260.00	19278.39	0.14268	0.4650E-04	0.1838E-04	361.81	20.76367
1280.00	19498.57	0.14356	0.4800E-04	0.1806E-04	361.85	20.82085
1300.00	19616.27	0.14452	0.4775E-04	0.1776E-04	362.71	20.42056
1320.00	19761.82	0.14547	0.4750E-04	0.1745E-04	362.42	20.17418
1340.00	19885.86	0.14642	0.4750E-04	0.1712E-04	361.70	18.81730
1360.00	19751.42	0.14737	0.4775E-04	0.1683E-04	361.80	18.41583
1380.00	19516.67	0.14833	0.4850E-04	0.1653E-04	361.39	18.81614
1400.00	19278.88	0.14931	0.4825E-04	0.1627E-04	361.73	18.28020
1420.00	19046.80	0.15030	0.5000E-04	0.1602E-04	362.06	17.76787
1440.00	18782.86	0.15131	0.5100E-04	0.1577E-04	361.88	17.18013
1460.00	18423.14	0.15234	0.5200E-04	0.1554E-04	362.28	16.64311
1480.00	18048.74	0.15339	0.5325E-04	0.1530E-04	361.88	16.03457
1500.00	17687.85	0.15447	0.5475E-04	0.1509E-04	362.00	15.41287
1520.00	17185.52	0.15558	0.5625E-04	0.1485E-04	362.12	14.83087
1540.00	16918.81	0.15672	0.5725E-04	0.1468E-04	361.89	14.38568
1560.00	16582.86	0.15787	0.5850E-04	0.1449E-04	361.47	13.91689
1580.00	16278.02	0.15886	0.5975E-04	0.1431E-04	361.50	13.47688
1600.00	16093.60	0.16026	0.6050E-04	0.1417E-04	362.23	13.17896
1620.00	15917.77	0.16148	0.6125E-04	0.1397E-04	361.36	12.84789
1640.00	15861.86	0.16271	0.6175E-04	0.1383E-04	362.47	12.63888
1660.00	15758.72	0.16395	0.6200E-04	0.1367E-04	361.87	12.43387
1680.00	15757.86	0.16518	0.6280E-04	0.1354E-04	362.42	12.31572
1700.00	15887.68	0.16643	0.6150E-04	0.1339E-04	362.71	12.28746

E1 - 8° (cont'd)

1728.00	16883.13	0.18763	0.6075E-04	0.1324E-04	362.65	12.28848
1740.00	16415.01	0.18886	0.5830E-04	0.1308E-04	362.89	12.38445
1768.00	16628.71	0.17003	0.5800E-04	0.1282E-04	361.08	12.56098
1780.00	17334.05	0.17118	0.5625E-04	0.1261E-04	363.84	12.82814
1800.00	17851.43	0.17228	0.5425E-04	0.1265E-04	362.81	13.12798
1820.00	18697.59	0.17335	0.5200E-04	0.1251E-04	363.18	13.52331
1840.00	18680.15	0.17436	0.4958E-04	0.1236E-04	363.56	14.02087
1860.00	20585.47	0.17533	0.4780E-04	0.1218E-04	363.21	14.53673
1880.00	21583.84	0.17624	0.4675E-04	0.1200E-04	362.55	15.01086
1900.00	22540.75	0.17712	0.4275E-04	0.1186E-04	363.44	15.58280
1920.00	23459.72	0.17785	0.4100E-04	0.1166E-04	362.68	15.87756
1940.00	24031.35	0.17876	0.4000E-04	0.1147E-04	362.89	16.80158
1960.00	24855.88	0.17855	0.4000E-04	0.1132E-04	362.63	15.78706
1980.00	23273.41	0.18036	0.4150E-04	0.1113E-04	361.83	15.81757
2000.00	21838.05	0.18121	0.4425E-04	0.1084E-04	368.52	13.88593
2020.00	18834.32	0.18213	0.4925E-04	0.1078E-04	358.83	12.35505
2040.00	17318.54	0.18318	0.5675E-04	0.1064E-04	358.60	16.61606
2060.00	14788.83	0.18440	0.6675E-04	0.1051E-04	357.67	8.85107
2080.00	12666.80	0.18565	0.7825E-04	0.1046E-04	358.82	7.61677

SHOTPOINT DISTANCE= 364.00FEET.

SHOTPOINT ELEVATION= 12.80FEET.

WEATHERING FUNCTION FROM SHOTPOINT TO ZPATCH (W.R.T. SHOT):

FVEXP=A*Z**B*VG

A= 0.281618941

B= 1.828170680

VG= 2885.34

ZPATCH= 236.77

E1 - 11°

Z	V	T	BTDX	F	XC	THTA
520.00	11888.65	0.11478	0.4325E-04	0.7206E-04	364.14	59.82817
540.00	12143.17	0.11571	0.4360E-04	0.6887E-04	364.66	58.87669
560.00	12885.28	0.11658	0.4100E-04	0.6588E-04	364.81	58.18956
580.00	14068.87	0.11735	0.3425E-04	0.6263E-04	365.16	61.32718
600.00	15488.37	0.11786	0.2625E-04	0.5889E-04	365.31	66.81046
620.00	17286.27	0.11840	0.1825E-04	0.5488E-04	365.22	71.60614
640.00	18336.37	0.11869	0.1150E-04	0.5042E-04	365.43	77.15162
660.00	21675.58	0.11886	0.6666E-05	0.4574E-04	365.39	82.52734
680.00	24236.84	0.11893	0.2500E-05	0.4118E-04	365.15	86.52620
700.00	28878.63	0.11856	0.1258E-05	0.3718E-04	365.11	88.87458
720.00	28445.86	0.11888	0.1750E-05	0.3382E-04	364.86	87.84621
740.00	31574.76	0.11893	0.4066E-05	0.3142E-04	364.43	82.74422
760.00	32834.36	0.11814	0.7500E-05	0.2852E-04	363.74	75.74362
780.00	32769.87	0.11833	0.1200E-04	0.2807E-04	363.31	66.85117
800.00	31118.25	0.11862	0.1758E-04	0.2685E-04	362.83	57.80475
820.00	28333.56	0.12063	0.2375E-04	0.2611E-04	363.30	47.78712
840.00	25426.76	0.12057	0.3000E-04	0.2343E-04	363.62	40.28808
860.00	22861.77	0.12123	0.3666E-04	0.2485E-04	363.33	34.61137
880.00	20586.46	0.12201	0.4200E-04	0.2435E-04	363.25	30.10162
900.00	18882.43	0.12281	0.4725E-04	0.2392E-04	363.39	26.84863
920.00	17588.86	0.12380	0.5175E-04	0.2354E-04	363.61	24.45587
940.00	16560.47	0.12498	0.5575E-04	0.2320E-04	364.23	22.58463
960.00	15883.35	0.12613	0.5875E-04	0.2285E-04	364.01	21.25579
980.00	13431.66	0.12733	0.6875E-04	0.2255E-04	364.51	20.36657
1000.00	15181.32	0.12856	0.6200E-04	0.2225E-04	364.65	19.79878
1020.00	15087.31	0.12881	0.6250E-04	0.2193E-04	364.46	19.33786
1040.00	15171.60	0.13106	0.6225E-04	0.2167E-04	363.24	18.18032
1060.00	15368.85	0.13236	0.6150E-04	0.2135E-04	364.85	18.14334
1080.00	15727.46	0.13352	0.6000E-04	0.2104E-04	364.78	18.82658
1100.00	16172.26	0.13478	0.5825E-04	0.2075E-04	365.83	18.68480

E1 - 11° (cont'd)

1120.00	16706.83	0.13385	0.5625E-04	0.2046E-04	365.64	18.88847
1140.00	17421.54	0.13695	0.5975E-04	0.2014E-04	365.67	20.54324
1160.00	18125.68	0.13809	0.5158E-04	0.1878E-04	365.82	21.81712
1180.00	18808.84	0.13901	0.4950E-04	0.1848E-04	365.28	21.46494
1200.00	19617.51	0.13998	0.4725E-04	0.1818E-04	365.41	22.83822
1220.00	20315.85	0.14080	0.4550E-04	0.1878E-04	365.35	22.42631
1240.00	20765.22	0.14180	0.4450E-04	0.1841E-04	364.86	22.47415
1260.00	21228.84	0.14268	0.4350E-04	0.1807E-04	365.00	22.55636
1280.00	21684.78	0.14354	0.4275E-04	0.1774E-04	365.44	22.54110
1300.00	21669.84	0.14439	0.4275E-04	0.1738E-04	364.72	22.12174
1320.00	21511.24	0.14525	0.4225E-04	0.1704E-04	364.48	21.50803
1340.00	21241.80	0.14612	0.4400E-04	0.1674E-04	364.62	20.83010
1360.00	20771.83	0.14701	0.4525E-04	0.1644E-04	364.46	18.86706
1380.00	20120.26	0.14763	0.4700E-04	0.1616E-04	364.43	16.87686
1400.00	19502.78	0.14809	0.4875E-04	0.1588E-04	364.12	18.85473
1420.00	18912.83	0.14908	0.5050E-04	0.1567E-04	364.56	17.23489
1440.00	18185.56	0.15001	0.5275E-04	0.1542E-04	364.20	16.28700
1460.00	17523.16	0.15106	0.5500E-04	0.1522E-04	364.50	15.46923
1480.00	16865.75	0.15311	0.5700E-04	0.1501E-04	364.12	14.74953
1500.00	16438.47	0.15427	0.5900E-04	0.1481E-04	363.80	14.88663
1520.00	16001.22	0.15547	0.6075E-04	0.1487E-04	364.81	13.57243
1540.00	15646.27	0.15670	0.6225E-04	0.1446E-04	364.64	13.09895
1560.00	15420.66	0.15786	0.6325E-04	0.1431E-04	364.20	12.74624
1580.00	15256.64	0.15823	0.6400E-04	0.1415E-04	364.20	12.46580
1600.00	15205.41	0.16052	0.6425E-04	0.1404E-04	365.58	12.32637
1620.00	15270.83	0.16188	0.6400E-04	0.1388E-04	365.37	12.33631
1640.00	15392.31	0.16308	0.6350E-04	0.1373E-04	365.38	12.20188
1660.00	15634.31	0.16434	0.6250E-04	0.1360E-04	365.85	12.27360
1680.00	15946.50	0.16558	0.6125E-04	0.1345E-04	365.85	12.38645
1700.00	16401.85	0.16678	0.5950E-04	0.1330E-04	365.80	12.68018
1720.00	16935.18	0.16786	0.5750E-04	0.1313E-04	365.20	12.85826
1740.00	17616.65	0.16909	0.5525E-04	0.1302E-04	366.81	13.26477
1760.00	18336.10	0.17017	0.5300E-04	0.1286E-04	366.49	13.63599
1780.00	18828.88	0.17121	0.5100E-04	0.1268E-04	366.11	13.86762
1800.00	18771.77	0.17221	0.4900E-04	0.1253E-04	366.35	14.34611
1820.00	20578.67	0.17317	0.4760E-04	0.1234E-04	365.67	14.71588
1840.00	21230.48	0.17409	0.4550E-04	0.1218E-04	365.76	14.98731
1860.00	21667.14	0.17499	0.4450E-04	0.1200E-04	365.27	15.88888
1880.00	22062.69	0.17587	0.4375E-04	0.1185E-04	365.73	15.15047
1900.00	22867.77	0.17674	0.4375E-04	0.1165E-04	364.55	14.80805
1920.00	21761.25	0.17762	0.4450E-04	0.1147E-04	363.71	14.44776
1940.00	21214.48	0.17852	0.4575E-04	0.1135E-04	364.88	13.83671
1960.00	20491.34	0.17945	0.4750E-04	0.1118E-04	364.38	13.26916
1980.00	20528.43	0.18042	0.5000E-04	0.1105E-04	364.13	12.46674
2000.00	18561.84	0.18145	0.5275E-04	0.1094E-04	364.58	11.72121
2020.00	17608.88	0.18253	0.5575E-04	0.1082E-04	364.88	10.87866
2040.00	16676.27	0.18368	0.5800E-04	0.1072E-04	364.31	10.28517
2060.00	15835.83	0.18489	0.6225E-04	0.1061E-04	363.89	8.67244
2080.00	15618.78	0.18617	0.6575E-04	0.1050E-04	363.38	8.67436

SHOTPOINT DISTANCE= 364.00FEET.

SHOTPOINT ELEVATION= 12.80FEET.

WEATHERING FUNCTION FROM SHOTPOINT TO XPATCH (W.R.T. SHOT).

FVEIP=A*Z**B+VC

A= 0.201618941

B= 1.626170688

VC= 2085.34

XPATCH= 182.49

W2 - 6°

I	V	T	DTLZ	P	IC	TMTA
700.00	11281.60	0.13040	0.6750E-04	0.5743E-04	330.38	40.40270
720.00	11833.48	0.13170	0.6306E-04	0.5525E-04	330.51	41.25258
740.00	12575.30	0.13292	0.5825E-04	0.5384E-04	330.26	41.83347
760.00	13217.69	0.13407	0.5686E-04	0.5687E-04	330.19	42.25233
780.00	13812.91	0.13518	0.5358E-04	0.4877E-04	330.25	42.35451
800.00	14413.77	0.13821	0.5125E-04	0.4876E-04	330.46	42.37672
820.00	14886.17	0.13721	0.4950E-04	0.4478E-04	330.26	42.13808
840.00	15463.84	0.13818	0.4825E-04	0.4283E-04	330.27	41.66019
860.00	16007.63	0.13914	0.4708E-04	0.4115E-04	330.14	41.20488
880.00	16395.85	0.14007	0.4650E-04	0.3847E-04	329.80	40.32271
900.00	16718.87	0.14100	0.4625E-04	0.3782E-04	330.81	39.34839
920.00	17032.50	0.14192	0.4600E-04	0.3648E-04	330.19	38.41831
940.00	17284.00	0.14284	0.4600E-04	0.3508E-04	328.82	37.33868
960.00	17567.51	0.14376	0.4650E-04	0.3364E-04	330.62	36.04851
980.00	17806.48	0.14470	0.4725E-04	0.3267E-04	329.84	34.65888
1000.00	17671.43	0.14565	0.4775E-04	0.3156E-04	329.65	33.46104
1020.00	17445.29	0.14661	0.4850E-04	0.3055E-04	329.74	32.21038
1040.00	17337.62	0.14758	0.4850E-04	0.2961E-04	329.62	30.68357
1060.00	17206.30	0.14859	0.5050E-04	0.2877E-04	330.65	29.66682
1080.00	17602.27	0.14961	0.5175E-04	0.2785E-04	329.88	28.37362
1100.00	18048.11	0.15066	0.5275E-04	0.2721E-04	330.17	27.28493
1120.00	18692.23	0.15172	0.5375E-04	0.2666E-04	329.52	26.20664
1140.00	19360.60	0.15281	0.5500E-04	0.2580E-04	329.62	25.13181
1160.00	19229.82	0.15392	0.5625E-04	0.2521E-04	330.83	24.14053
1180.00	19045.76	0.15506	0.5725E-04	0.2463E-04	330.81	23.27491
1200.00	18865.87	0.15621	0.5825E-04	0.2407E-04	329.84	22.45309
1220.00	18686.31	0.15739	0.5925E-04	0.2353E-04	329.57	21.65915
1240.00	18555.71	0.15858	0.6060E-04	0.2306E-04	330.21	21.03789
1260.00	18371.80	0.15979	0.6180E-04	0.2261E-04	330.20	20.33655
1280.00	18243.86	0.16102	0.6175E-04	0.2214E-04	329.84	19.72648
1300.00	18113.62	0.16226	0.6250E-04	0.2172E-04	329.83	19.16082
1320.00	18034.16	0.16351	0.6360E-04	0.2134E-04	330.27	18.71041
1340.00	18011.73	0.16478	0.6325E-04	0.2088E-04	329.51	18.28790
1360.00	18028.67	0.16605	0.6375E-04	0.2057E-04	330.17	17.87981
1380.00	18052.20	0.16733	0.6375E-04	0.2022E-04	330.45	17.58770
1400.00	18077.81	0.16860	0.6375E-04	0.1985E-04	330.11	17.29551
1420.00	18088.60	0.16986	0.6375E-04	0.1952E-04	330.36	17.02615
1440.00	18075.54	0.17115	0.6350E-04	0.1918E-04	330.62	16.80454
1460.00	18148.84	0.17242	0.6325E-04	0.1888E-04	330.44	16.61802
1480.00	18286.61	0.17368	0.6275E-04	0.1858E-04	330.67	16.48227
1500.00	18471.27	0.17495	0.6200E-04	0.1827E-04	330.65	16.41828
1520.00	18666.43	0.17626	0.6125E-04	0.1787E-04	330.58	16.34816
1540.00	18864.85	0.17738	0.6050E-04	0.1768E-04	330.87	16.28503
1560.00	19132.66	0.17858	0.5950E-04	0.1738E-04	330.53	16.28189
1580.00	19408.62	0.17976	0.5850E-04	0.1707E-04	330.09	16.26780
1600.00	19693.22	0.18092	0.5750E-04	0.1680E-04	330.35	16.28885
1620.00	19956.42	0.18206	0.5625E-04	0.1653E-04	330.52	16.37773
1640.00	19568.18	0.18327	0.5475E-04	0.1626E-04	330.58	16.53863
1660.00	17605.18	0.18425	0.5350E-04	0.1588E-04	330.64	16.63621
1680.00	18327.65	0.18531	0.5225E-04	0.1572E-04	330.69	16.74041
1700.00	18657.61	0.18634	0.5050E-04	0.1543E-04	330.37	16.88130
1720.00	18439.08	0.18733	0.4900E-04	0.1514E-04	329.80	17.16574
1740.00	18894.28	0.18830	0.4800E-04	0.1482E-04	331.82	17.26821
1760.00	19518.63	0.18925	0.4650E-04	0.1466E-04	331.86	17.49477
1780.00	21278.88	0.19016	0.4475E-04	0.1435E-04	330.10	17.78023
1800.00	21666.81	0.19104	0.4350E-04	0.1411E-04	330.68	17.87143
1820.00	22374.57	0.19190	0.4250E-04	0.1383E-04	330.24	18.02542
1840.00	23030.26	0.19274	0.4125E-04	0.1356E-04	329.82	18.19318
1860.00	23384.24	0.19355	0.4025E-04	0.1333E-04	330.75	18.32911
1880.00	24032.44	0.19435	0.3950E-04	0.1308E-04	330.81	18.32629
1900.00	24488.58	0.19513	0.3875E-04	0.1283E-04	330.66	18.31828

W2 - 6° (cont'd)

1020.00	24666.56	0.10380	0.3850E-04	0.1260E-04	328.06	18.11545
1040.00	24884.24	0.10667	0.3825E-04	0.1272E-04	328.01	17.85752
1060.00	25081.41	0.10743	0.3800E-04	0.1207E-04	328.02	17.61038
1080.00	24826.75	0.10810	0.3850E-04	0.1164E-04	328.70	17.69285
2060.00	24417.17	0.10897	0.3825E-04	0.1160E-04	328.49	16.58972
2020.00	23896.82	0.10976	0.4025E-04	0.1145E-04	328.06	15.87788
2040.00	22985.05	0.20858	0.4280E-04	0.1126E-04	328.41	15.02055
2060.00	22154.47	0.20144	0.4375E-04	0.1111E-04	328.39	14.24366
2080.00	21167.84	0.20233	0.4600E-04	0.1096E-04	328.72	13.39955
2100.00	19332.22	0.20320	0.4800E-04	0.1077E-04	328.44	12.39892
2120.00	18666.38	0.20428	0.5250E-04	0.1066E-04	328.25	11.48263
2140.00	17400.73	0.20538	0.5650E-04	0.1051E-04	328.11	10.53560
2160.00	16085.68	0.20635	0.6125E-04	0.1040E-04	328.27	9.63983
2180.00	14805.27	0.20783	0.6675E-04	0.1032E-04	328.07	8.78127

SHOTPOINT DISTANCE= 331.06FEET.

SHOTPOINT ELEVATION= -10.00FEET.

WEATHERING FUNCTION FROM SHOTPOINT TO ZPATCH (W.R.T. SHOT):

FVEIP=A*2+B*VG

A= 0.281618941

B= 1.828170693

VG= 2685.34

ZPATCH= 178.57

W2 - 8°

Z	V	T	ETDZ	P	XC	THTA
680.00	11182.33	0.12893	0.6675E-04	0.5851E-04	331.17	41.71841
700.00	11518.37	0.13023	0.6525E-04	0.5726E-04	331.31	41.26746
720.00	11824.08	0.13154	0.6325E-04	0.5506E-04	331.26	41.64018
740.00	12410.87	0.13278	0.6075E-04	0.5283E-04	331.25	41.06485
760.00	12800.23	0.13387	0.5850E-04	0.5086E-04	331.25	41.00402
780.00	13586.76	0.13512	0.5650E-04	0.4887E-04	331.31	40.85637
800.00	13838.08	0.13623	0.5425E-04	0.4694E-04	331.41	40.87004
820.00	14468.27	0.13728	0.5225E-04	0.4503E-04	330.36	40.75268
840.00	15038.36	0.13832	0.5050E-04	0.4326E-04	331.28	40.58538
860.00	15568.23	0.13931	0.4800E-04	0.4153E-04	331.23	40.26452
880.00	16071.81	0.14028	0.4775E-04	0.3889E-04	331.35	39.87602
900.00	16565.32	0.14122	0.4650E-04	0.3836E-04	331.24	39.45477
920.00	17031.78	0.14214	0.4575E-04	0.3660E-04	330.81	38.81227
940.00	17343.23	0.14305	0.4550E-04	0.3542E-04	330.87	37.88691
960.00	17643.57	0.14396	0.4525E-04	0.3413E-04	331.52	37.62513
980.00	17882.07	0.14466	0.4525E-04	0.3286E-04	330.69	35.88572
1000.00	17861.33	0.14577	0.4575E-04	0.3173E-04	330.83	34.74155
1020.00	17648.38	0.14668	0.4650E-04	0.3068E-04	331.04	33.42097
1040.00	17822.51	0.14763	0.4725E-04	0.2967E-04	330.67	32.13052
1060.00	17868.85	0.14856	0.4800E-04	0.2877E-04	330.02	30.84813
1080.00	17665.74	0.14955	0.4825E-04	0.2781E-04	330.55	29.53687
1100.00	17375.73	0.15055	0.5675E-04	0.2714E-04	330.78	28.15741
1120.00	17142.58	0.15158	0.5200E-04	0.2644E-04	331.20	26.84846
1140.00	16808.41	0.15263	0.5325E-04	0.2573E-04	330.60	25.78588
1160.00	16549.14	0.15371	0.5500E-04	0.2508E-04	330.32	24.51220
1180.00	16233.64	0.15483	0.5650E-04	0.2454E-04	331.07	23.47877
1200.00	15994.85	0.15587	0.5775E-04	0.2385E-04	330.41	22.32645
1220.00	15681.82	0.15714	0.5825E-04	0.2347E-04	330.85	21.60566
1240.00	15398.54	0.15834	0.6075E-04	0.2283E-04	330.37	20.69723
1260.00	15168.85	0.15957	0.6200E-04	0.2252E-04	330.74	19.86135
1280.00	14876.04	0.16082	0.6300E-04	0.2212E-04	331.23	18.34382
1300.00	14788.82	0.16209	0.6400E-04	0.2167E-04	330.61	18.78388
1320.00	14671.50	0.16338	0.6475E-04	0.2128E-04	330.81	18.18859
1340.00	14546.83	0.16468	0.6550E-04	0.2091E-04	330.71	17.70154
1360.00	14463.81	0.16600	0.6680E-04	0.2059E-04	331.52	17.32753
1380.00	14465.63	0.16732	0.6600E-04	0.2024E-04	331.48	17.04568
1400.00	14507.88	0.16864	0.6680E-04	0.1988E-04	331.16	16.76704

W2 - 8° (cont'd)

1428.00	14528.07	0.16986	0.6600E-04	0.1653E-04	336.57	16.47897
1440.00	14586.14	0.17128	0.6575E-04	0.1625E-04	331.45	16.32225
1460.00	14770.02	0.17250	0.6500E-04	0.1603E-04	331.25	16.23000
1480.00	14950.28	0.17380	0.6425E-04	0.1580E-04	330.76	16.14612
1500.00	15106.34	0.17516	0.6325E-04	0.1532E-04	331.06	16.15022
1520.00	15486.37	0.17641	0.6200E-04	0.1505E-04	331.58	16.32842
1540.00	15742.57	0.17764	0.6100E-04	0.1772E-04	336.87	16.18940
1560.00	16127.84	0.17885	0.5950E-04	0.1746E-04	331.47	16.35024
1580.00	16533.75	0.18002	0.5800E-04	0.1715E-04	331.13	16.47223
1600.00	16958.21	0.18117	0.5650E-04	0.1687E-04	331.28	16.62547
1620.00	17351.89	0.18228	0.5450E-04	0.1661E-04	331.76	16.84636
1640.00	18035.46	0.18335	0.5300E-04	0.1629E-04	331.87	17.08312
1660.00	18538.41	0.18440	0.5150E-04	0.1605E-04	332.02	17.30628
1680.00	19249.80	0.18541	0.4950E-04	0.1576E-04	332.81	17.66156
1700.00	19831.00	0.18638	0.4800E-04	0.1545E-04	331.50	17.04523
1720.00	20443.00	0.18733	0.4650E-04	0.1518E-04	331.86	18.08452
1740.00	21085.05	0.18828	0.4500E-04	0.1490E-04	331.82	18.32050
1760.00	21685.13	0.18913	0.4375E-04	0.1458E-04	330.82	18.42748
1780.00	22301.85	0.18999	0.4250E-04	0.1428E-04	336.70	16.58920
1800.00	22822.28	0.19083	0.4150E-04	0.1406E-04	331.68	18.71530
1820.00	23248.22	0.19165	0.4075E-04	0.1377E-04	331.25	18.67233
1840.00	23551.75	0.19246	0.4025E-04	0.1352E-04	331.56	18.56584
1860.00	23731.71	0.19326	0.4000E-04	0.1325E-04	331.28	18.32867
1880.00	23774.33	0.19406	0.4000E-04	0.1301E-04	331.43	18.81545
1900.00	23816.83	0.19486	0.4000E-04	0.1276E-04	331.27	17.68705
1920.00	23724.44	0.19566	0.4025E-04	0.1251E-04	336.75	17.27151
1940.00	23663.36	0.19647	0.4100E-04	0.1228E-04	330.56	16.68562
1960.00	23677.82	0.19730	0.4200E-04	0.1211E-04	331.33	16.68158
1980.00	23415.38	0.19815	0.4300E-04	0.1188E-04	330.55	15.45036
2000.00	21662.43	0.19902	0.4400E-04	0.1171E-04	330.84	14.88651
2020.00	21415.63	0.19981	0.4525E-04	0.1153E-04	330.58	14.28977
2040.00	20891.28	0.20063	0.4650E-04	0.1136E-04	330.51	13.72524
2060.00	20481.08	0.20177	0.4750E-04	0.1120E-04	330.41	13.26306
2080.00	20181.24	0.20273	0.4850E-04	0.1107E-04	331.27	12.86166
2100.00	19821.45	0.20371	0.4925E-04	0.1084E-04	331.58	12.52370
2120.00	19643.75	0.20470	0.4975E-04	0.1078E-04	331.26	12.23775
2140.00	18747.52	0.20570	0.4850E-04	0.1060E-04	332.88	12.17651
2160.00	20151.17	0.20668	0.4850E-04	0.1051E-04	336.74	12.22277
2180.00	20568.02	0.20764	0.4750E-04	0.1036E-04	330.32	12.30465

SHOTPOINT DISTANCE= 331.00 FEET.

SHOTPOINT ELEVATION= -10.00 FEET.

WEATHERING FUNCTION FROM SHOTPOINT TO ZPATCH (W.B.T. SHOT):

FVEXP=A*Z**B*V0

A= 1.201618941

B= 1.828170680

V0= 2685.34

ZPATCH= 177.76

NE5 - 6°

S	V	T	DTGZ	P	XC	THTA
000.00	17438.48	0.16324	0.2575E-04	0.5116E-04	1380.18	63.28316
1000.00	18079.86	0.16371	0.2208E-04	0.5677E-04	1378.83	66.57008
1020.00	18597.50	0.16412	0.1880E-04	0.5832E-04	1380.82	68.38748
1040.00	18844.58	0.16447	0.1675E-04	0.4577E-04	1378.64	71.38774
1060.00	18982.66	0.16478	0.1550E-04	0.4918E-04	1380.81	72.50718
1080.00	18730.14	0.16508	0.1450E-04	0.4857E-04	1380.84	73.37616
1100.00	20027.27	0.16537	0.1400E-04	0.4783E-04	1376.58	73.71788
1120.00	20208.18	0.16565	0.1450E-04	0.4731E-04	1378.75	72.86130
1140.00	20344.88	0.16595	0.1525E-04	0.4673E-04	1378.78	71.82513
1160.00	20430.43	0.16626	0.1625E-04	0.4617E-04	1378.63	70.61012
1180.00	20454.44	0.16660	0.1750E-04	0.4565E-04	1379.80	69.82548
1200.00	20411.26	0.16696	0.1800E-04	0.4516E-04	1378.60	67.18146
1220.00	20247.18	0.16736	0.2100E-04	0.4470E-04	1379.46	64.83728
1240.00	19835.79	0.16780	0.2325E-04	0.4426E-04	1378.35	62.28612
1260.00	19747.78	0.16828	0.2525E-04	0.4388E-04	1378.38	60.88048
1280.00	19472.89	0.16881	0.2725E-04	0.4353E-04	1378.27	57.85136
1300.00	18868.35	0.16938	0.2975E-04	0.4318E-04	1378.26	55.43682
1320.00	18684.23	0.17000	0.3200E-04	0.4287E-04	1378.60	53.25781
1340.00	18358.13	0.17066	0.3400E-04	0.4258E-04	1379.44	51.37823
1360.00	17958.38	0.17136	0.3625E-04	0.4227E-04	1378.64	48.38358
1380.00	17553.88	0.17211	0.3850E-04	0.4198E-04	1378.37	47.48181
1400.00	17248.63	0.17288	0.4025E-04	0.4173E-04	1378.62	46.63126
1420.00	16843.44	0.17372	0.4200E-04	0.4146E-04	1378.36	44.63274
1440.00	16636.52	0.17458	0.4375E-04	0.4122E-04	1378.61	43.28373
1460.00	16381.81	0.17547	0.4525E-04	0.4098E-04	1378.61	42.16277
1480.00	16174.83	0.17638	0.4650E-04	0.4074E-04	1378.82	41.22442
1500.00	15970.58	0.17733	0.4775E-04	0.4050E-04	1378.36	40.30646
1520.00	15661.46	0.17830	0.4850E-04	0.4028E-04	1378.76	38.71066
1540.00	15381.13	0.17927	0.4900E-04	0.4005E-04	1378.68	38.26242
1560.00	15092.31	0.18026	0.4975E-04	0.3982E-04	1378.41	38.67597
1580.00	14876.43	0.18126	0.5000E-04	0.3963E-04	1378.48	36.97888
1600.00	14663.40	0.18226	0.5025E-04	0.3938E-04	1378.89	38.86601
1620.00	14746.87	0.18327	0.5000E-04	0.3916E-04	1378.83	38.86575
1640.00	14879.72	0.18426	0.4950E-04	0.3893E-04	1378.85	38.18245
1660.00	14815.84	0.18523	0.4950E-04	0.3870E-04	1378.64	36.61600
1680.00	14643.67	0.18624	0.4875E-04	0.3846E-04	1378.67	38.27433
1700.00	14286.11	0.18728	0.4800E-04	0.3823E-04	1378.74	38.53633
1720.00	14433.15	0.18816	0.4725E-04	0.3798E-04	1378.85	38.68336
1740.00	14750.48	0.18909	0.4625E-04	0.3775E-04	1378.85	39.22128
1760.00	14959.81	0.19001	0.4550E-04	0.3750E-04	1378.81	38.48577
1780.00	17175.57	0.19091	0.4475E-04	0.3725E-04	1378.68	39.77107
1800.00	17653.24	0.19180	0.4375E-04	0.3700E-04	1380.18	40.21825
1820.00	17742.31	0.19266	0.4275E-04	0.3673E-04	1378.84	40.66829
1840.00	17818.26	0.19351	0.4225E-04	0.3646E-04	1378.84	46.78546
1860.00	18097.13	0.19435	0.4175E-04	0.3620E-04	1380.63	40.82608
1880.00	18261.46	0.19518	0.4125E-04	0.3592E-04	1378.78	41.65231
1900.00	20340.46	0.19600	0.4125E-04	0.3566E-04	1378.82	40.83853
1920.00	18336.84	0.19683	0.4150E-04	0.3538E-04	1378.52	40.44843
1940.00	18263.80	0.19766	0.4200E-04	0.3512E-04	1378.56	39.89975
1960.00	18065.85	0.19851	0.4300E-04	0.3486E-04	1378.39	38.02846
1980.00	17739.77	0.19938	0.4450E-04	0.3460E-04	1378.18	37.86867
2000.00	17283.80	0.20028	0.4650E-04	0.3437E-04	1378.64	36.47063

SHOTPOINT DISTANCE= 1380.00FEET.

SHOTPOINT ELEVATION= 47.00FEET.

WEATHERING FUNCTION FROM SHOTPOINT TO ZPATCH (W.R.T. SHOT):

FVEIP=A*Z**B*V8

A= 0.281618841

B= 1.829170690

V8= 2085.34

ZPATCH= 381.67

E5 - 6°

Z	V	T	STDZ	P	XC	THTA
020.00	10097.07	0.15253	0.1325E-04	0.5365E-04	1200.22	76.12608
040.00	17604.66	0.15285	0.2175E-04	0.5318E-04	1200.38	67.75601
060.00	18626.48	0.15340	0.2875E-04	0.5283E-04	1200.40	61.44444
080.00	15946.83	0.15404	0.3625E-04	0.5253E-04	1200.51	56.89449
090.00	15372.12	0.15477	0.3875E-04	0.5225E-04	1200.40	53.43862
020.00	14925.88	0.15558	0.4225E-04	0.5200E-04	1200.60	50.80424
040.00	14653.07	0.15646	0.4450E-04	0.5174E-04	1200.58	48.30278
060.00	14462.82	0.15737	0.4600E-04	0.5148E-04	1200.96	46.22482
080.00	14417.33	0.15830	0.4675E-04	0.5124E-04	1200.89	47.82268
1000.00	14422.64	0.15824	0.4700E-04	0.5097E-04	1200.72	47.32303
1020.00	14463.38	0.16010	0.4700E-04	0.5071E-04	1200.81	47.17363
1040.00	14613.87	0.16112	0.4625E-04	0.5043E-04	1201.03	47.47657
1060.00	14880.42	0.16203	0.4475E-04	0.5014E-04	1200.84	48.24868
1080.00	15118.57	0.16291	0.4350E-04	0.4983E-04	1200.87	48.87852
1100.00	15365.65	0.16377	0.4225E-04	0.4950E-04	1201.05	49.51877
1120.00	15738.74	0.16460	0.4025E-04	0.4916E-04	1201.30	50.68935
1140.00	16091.25	0.16538	0.3850E-04	0.4878E-04	1201.14	51.71941
1160.00	16457.64	0.16614	0.3675E-04	0.4838E-04	1201.21	52.78624
1180.00	16841.84	0.16685	0.3500E-04	0.4786E-04	1201.00	53.88148
1200.00	17185.18	0.16754	0.3350E-04	0.4752E-04	1201.20	54.81816
1220.00	17618.77	0.16819	0.3175E-04	0.4705E-04	1201.04	55.88586
1240.00	17869.26	0.16881	0.3050E-04	0.4655E-04	1200.88	56.76560
1260.00	18334.83	0.16941	0.2825E-04	0.4603E-04	1201.23	57.56610
1280.00	18673.77	0.16998	0.2625E-04	0.4548E-04	1201.02	58.16162
1300.00	18932.54	0.17054	0.2775E-04	0.4494E-04	1200.85	58.30631
1320.00	19188.32	0.17109	0.2725E-04	0.4439E-04	1201.03	58.45532
1340.00	19373.32	0.17163	0.2725E-04	0.4384E-04	1201.06	58.13476
1360.00	19551.18	0.17218	0.2725E-04	0.4328E-04	1200.73	57.80721
1380.00	19675.16	0.17272	0.2750E-04	0.4274E-04	1200.67	57.24370
1400.00	19836.82	0.17328	0.2650E-04	0.4222E-04	1200.72	55.86008
1420.00	19825.10	0.17386	0.2625E-04	0.4172E-04	1201.02	54.86787
1440.00	19554.55	0.17445	0.2625E-04	0.4123E-04	1200.62	53.73466
1460.00	19284.88	0.17507	0.2600E-04	0.4077E-04	1200.51	51.87271
1480.00	19070.21	0.17573	0.2550E-04	0.4034E-04	1200.82	50.29374
1500.00	18834.15	0.17641	0.2500E-04	0.3993E-04	1200.68	48.76147
1520.00	18468.86	0.17713	0.2475E-04	0.3953E-04	1200.67	46.88650
1540.00	18082.50	0.17788	0.2400E-04	0.3917E-04	1200.75	45.12137
1560.00	17712.37	0.17868	0.2100E-04	0.3881E-04	1200.64	43.43663
1580.00	17386.11	0.17933	0.275E-04	0.3848E-04	1200.63	41.89045
1600.00	17058.62	0.18049	0.4450E-04	0.3816E-04	1200.65	40.61431
1620.00	16731.50	0.18131	0.4625E-04	0.3786E-04	1200.77	39.30074
1640.00	16461.82	0.18225	0.4775E-04	0.3756E-04	1200.47	38.18547
1660.00	16242.40	0.18322	0.4800E-04	0.3728E-04	1200.78	37.26177
1680.00	16129.13	0.18421	0.4875E-04	0.3700E-04	1200.64	36.63775
1700.00	16066.88	0.18521	0.5025E-04	0.3673E-04	1200.60	36.16114
1720.00	16160.11	0.18622	0.5000E-04	0.3646E-04	1201.23	36.08646
1740.00	16471.85	0.18721	0.4875E-04	0.3618E-04	1201.15	36.58218
1760.00	16851.82	0.18817	0.4725E-04	0.3590E-04	1201.31	37.22890
1780.00	17486.67	0.18910	0.4475E-04	0.3561E-04	1201.24	38.50978
1800.00	18416.64	0.18998	0.4125E-04	0.3530E-04	1201.45	40.55616
1820.00	18712.88	0.19075	0.3675E-04	0.3487E-04	1201.87	43.57701
1840.00	21453.71	0.19145	0.3125E-04	0.3458E-04	1201.65	47.68685

SHOTPOINT DISTANCE= 1200.00FEET.
 SHOTPOINT ELEVATION= 43.00FEET.
 WEATHERING FUNCTION FROM SHOTPOINT TO ZPATCH (W.R.T. SHOT)
 FVEP=A*Z**B*VG
 A= 0.261618641
 B= 1.829170650
 VG= 2085.34
 ZPATCH= 367.78

SE5 - 5°

Z	V	T	DTDZ	P	XC	THTA
040.00	17367.00	0.15309	0.2950E-04	0.4845E-04	1323.42	59.18108
060.00	17623.48	0.15367	0.2825E-04	0.4921E-04	1323.42	60.14126
080.00	17846.01	0.15422	0.2725E-04	0.4895E-04	1323.43	60.89510
1000.00	18066.05	0.15476	0.2675E-04	0.4867E-04	1323.40	61.20469
1020.00	18211.08	0.15528	0.2600E-04	0.4837E-04	1323.40	61.73907
1040.00	18364.02	0.15580	0.2556E-04	0.4804E-04	1323.35	62.64256
1060.00	18525.05	0.15631	0.2525E-04	0.4771E-04	1323.42	62.11010
1080.00	18673.09	0.15661	0.2500E-04	0.4736E-04	1323.33	62.17015
1100.00	18828.00	0.15731	0.2475E-04	0.4689E-04	1323.31	62.22550
1120.00	18947.59	0.15780	0.2475E-04	0.4661E-04	1322.82	62.83365
1140.00	19025.03	0.15830	0.2500E-04	0.4623E-04	1323.07	61.59660
1160.00	19165.21	0.15866	0.2525E-04	0.4585E-04	1323.07	61.15736
1180.00	19104.52	0.15831	0.2550E-04	0.4546E-04	1323.21	60.71164
1200.00	19264.56	0.15882	0.2575E-04	0.4507E-04	1323.18	60.26017
1220.00	19248.07	0.16034	0.2650E-04	0.4468E-04	1323.51	59.32883
1240.00	19274.06	0.16088	0.2700E-04	0.4430E-04	1323.33	58.63949
1260.00	19347.02	0.16142	0.2725E-04	0.4392E-04	1323.25	58.18146
1280.00	19318.02	0.16107	0.2800E-04	0.4354E-04	1323.05	57.25304
1300.00	19261.39	0.16254	0.2875E-04	0.4317E-04	1323.28	56.33474
1320.00	19236.64	0.16312	0.2950E-04	0.4280E-04	1323.25	55.42238
1340.00	19108.38	0.16372	0.3025E-04	0.4244E-04	1323.16	54.31780
1360.00	19132.47	0.16433	0.3100E-04	0.4208E-04	1323.07	53.62223
1380.00	19070.35	0.16486	0.3175E-04	0.4173E-04	1323.00	52.73635
1400.00	19001.02	0.16560	0.3250E-04	0.4138E-04	1323.10	51.66190
1420.00	18926.26	0.16626	0.3325E-04	0.4106E-04	1323.05	50.89673
1440.00	18848.07	0.16683	0.3400E-04	0.4073E-04	1323.14	50.14390
1460.00	18764.15	0.16762	0.3475E-04	0.4041E-04	1323.32	49.30333
1480.00	18678.70	0.16832	0.3550E-04	0.4006E-04	1322.85	48.46828
1500.00	18582.27	0.16904	0.3625E-04	0.3977E-04	1323.26	47.65390
1520.00	18543.78	0.16977	0.3675E-04	0.3947E-04	1323.21	47.04027
1540.00	18502.13	0.17051	0.3725E-04	0.3918E-04	1323.24	46.43285
1560.00	18457.02	0.17126	0.3775E-04	0.3886E-04	1323.25	45.83055
1580.00	18410.09	0.17202	0.3825E-04	0.3856E-04	1323.23	45.23370
1600.00	18361.37	0.17278	0.3875E-04	0.3827E-04	1323.21	44.64267
1620.00	18316.02	0.17357	0.3925E-04	0.3798E-04	1323.30	44.05893
1640.00	18276.71	0.17436	0.3925E-04	0.3768E-04	1323.12	43.83827
1660.00	18444.44	0.17514	0.3925E-04	0.3740E-04	1323.02	42.61891
1680.00	18448.58	0.17583	0.3950E-04	0.3712E-04	1323.28	43.22089
1700.00	18577.04	0.17672	0.3925E-04	0.3683E-04	1323.31	43.18185
1720.00	18708.55	0.17756	0.3900E-04	0.3655E-04	1323.27	43.14106
1740.00	18842.58	0.17828	0.3875E-04	0.3626E-04	1323.43	43.10104
1760.00	19044.61	0.17805	0.3825E-04	0.3597E-04	1323.38	43.24265
1780.00	19252.24	0.17881	0.3775E-04	0.3568E-04	1323.16	42.38353
1800.00	19532.14	0.18056	0.3700E-04	0.3536E-04	1323.41	43.72366
1820.00	19893.26	0.18329	0.3600E-04	0.3508E-04	1323.39	44.26187
1840.00	20340.72	0.18200	0.3475E-04	0.3478E-04	1323.26	43.82160
1860.00	20607.94	0.18268	0.3350E-04	0.3446E-04	1323.20	43.80792
1880.00	21253.07	0.18334	0.3225E-04	0.3416E-04	1323.43	46.62839
1900.00	21865.01	0.18397	0.3050E-04	0.3360E-04	1323.53	47.83812
1920.00	22739.25	0.18456	0.2850E-04	0.3344E-04	1323.23	49.56886
1940.00	23595.02	0.18511	0.2650E-04	0.3308E-04	1323.77	51.28614
1960.00	24485.13	0.18562	0.2450E-04	0.3268E-04	1323.61	53.13830
1980.00	25612.46	0.18609	0.2200E-04	0.3226E-04	1323.04	55.70361
2000.00	27004.21	0.18658	0.1800E-04	0.3176E-04	1323.72	58.13078

SHOTPOINT DISTANCE= 1323.00 FEET.

SHOTPOINT ELEVATION= -25.00 FEET.

WEATHERING FUNCTION FROM SHOTPOINT TO ZPATCH (W.R.T. SHOT).

FVEIP=A*Z**B*V0

A= 0.281619941

B= 1.626176650

V0= 2083.34

ZPATCH= 411.67

SSW5 - 7°

Z	V	T	DTGZ	P	XC	THTA
040.00	14231.49	0.18027	0.1300E-04	0.6805E-04	1341.50	78.33832
050.00	14229.63	0.18057	0.1600E-04	0.6843E-04	1341.73	76.63983
060.00	14238.83	0.18081	0.1775E-04	0.6784E-04	1341.63	75.33813
1000.00	14307.10	0.18128	0.1800E-04	0.6726E-04	1341.78	74.32651
1020.00	14425.62	0.18167	0.1800E-04	0.6867E-04	1341.80	74.89240
1040.00	14563.05	0.18204	0.1850E-04	0.6803E-04	1341.77	74.34644
1060.00	14751.23	0.18241	0.1890E-04	0.6596E-04	1341.81	74.60200
1080.00	14876.45	0.18276	0.1675E-04	0.6464E-04	1341.87	75.47186
1100.00	15233.17	0.18398	0.1525E-04	0.6385E-04	1341.83	76.56713
1120.00	15459.25	0.18337	0.1460E-04	0.6301E-04	1341.63	77.47265
1140.00	15755.55	0.18364	0.1300E-04	0.6212E-04	1341.86	78.18091
1160.00	16046.44	0.18388	0.1175E-04	0.6120E-04	1341.83	78.13208
1180.00	16342.43	0.18411	0.1075E-04	0.6024E-04	1341.81	78.88170
1200.00	16624.76	0.18432	0.1025E-04	0.5927E-04	1341.88	80.18870
1220.00	16831.86	0.18452	0.8580E-05	0.5828E-04	1341.87	80.74405
1240.00	17238.45	0.18470	0.8000E-05	0.5731E-04	1341.85	81.67475
1260.00	17508.78	0.18488	0.8250E-05	0.5636E-04	1341.89	80.67800
1280.00	17777.78	0.18507	0.8500E-05	0.5544E-04	1341.86	80.27677
1300.00	18027.83	0.18526	0.1000E-04	0.5456E-04	1341.85	78.61450
1320.00	18251.25	0.18547	0.1075E-04	0.5373E-04	1341.88	78.68511
1340.00	18462.55	0.18568	0.1150E-04	0.5283E-04	1341.74	77.74168
1360.00	18617.87	0.18593	0.1275E-04	0.5218E-04	1341.68	76.26817
1380.00	18722.01	0.18620	0.1425E-04	0.5148E-04	1341.71	74.52674
1400.00	18822.26	0.18658	0.1550E-04	0.5082E-04	1341.73	73.83754
1420.00	18870.68	0.18682	0.1700E-04	0.5018E-04	1341.66	71.28858
1440.00	18888.66	0.18718	0.1850E-04	0.4960E-04	1341.76	68.54578
1460.00	18862.21	0.18756	0.2000E-04	0.4884E-04	1341.69	67.81216
1480.00	18849.73	0.18788	0.2156E-04	0.4850E-04	1341.43	66.88206
1500.00	18830.90	0.18842	0.2275E-04	0.4786E-04	1341.43	64.63375
1520.00	18783.28	0.18888	0.2400E-04	0.4748E-04	1341.78	63.18964
1540.00	18741.67	0.18938	0.2525E-04	0.4708E-04	1341.41	61.75602
1560.00	18758.64	0.18980	0.2600E-04	0.4654E-04	1341.74	60.80866
1580.00	18815.66	0.19042	0.2650E-04	0.4607E-04	1341.45	60.88158
1600.00	18866.53	0.19086	0.2768E-04	0.4561E-04	1341.76	59.37637
1620.00	18808.85	0.19150	0.2780E-04	0.4515E-04	1341.89	58.12162
1640.00	19152.69	0.19204	0.2760E-04	0.4469E-04	1341.83	58.86082
1660.00	19308.86	0.19258	0.2650E-04	0.4422E-04	1341.89	58.86611
1680.00	19783.87	0.19310	0.2575E-04	0.4373E-04	1341.62	59.51086
1700.00	20070.27	0.19361	0.2475E-04	0.4324E-04	1342.03	60.21550
1720.00	20437.86	0.19409	0.2375E-04	0.4272E-04	1341.58	60.93024
1740.00	20812.41	0.19456	0.2250E-04	0.4218E-04	1341.85	61.83134
1760.00	21443.56	0.19498	0.2100E-04	0.4164E-04	1341.64	63.23611
1780.00	21848.77	0.19540	0.1975E-04	0.4106E-04	1341.86	64.30860
1800.00	22536.21	0.19576	0.1825E-04	0.4045E-04	1341.77	65.71437
1820.00	23044.70	0.19613	0.1725E-04	0.3982E-04	1341.72	66.57660
1840.00	23521.55	0.19647	0.1650E-04	0.3918E-04	1341.68	67.16335
1860.00	23958.58	0.19678	0.1600E-04	0.3855E-04	1341.89	67.45843
1880.00	24231.84	0.19711	0.1625E-04	0.3783E-04	1341.85	66.81088
1900.00	24384.88	0.19744	0.1725E-04	0.3735E-04	1341.44	65.21207
1920.00	23893.66	0.19760	0.1850E-04	0.3683E-04	1341.18	62.18308
1940.00	23303.22	0.19812	0.2275E-04	0.3638E-04	1341.88	57.88452
1960.00	22072.56	0.19871	0.2750E-04	0.3680E-04	1340.70	52.62745
1980.00	20214.82	0.19932	0.3425E-04	0.3568E-04	1340.66	46.18298
2000.00	18259.68	0.20008	0.4175E-04	0.3544E-04	1340.76	40.32892

SHOTPOINT DISTANCE= 1341.00FEET.

SHOTPOINT ELEVATION= -102.00FEET.

WEATHERING FUNCTION FROM SHOTPOINT TO ZPATCH (W.R.T. SHOT).

FVEIP=A*Z**B*VC

A= 0.281618961

B= 1.629170660

VC= 2065.34

ZPATCH= 297.64

SW5 - 4°

I	V	T	DTDZ	P	XC	THTA
1048.00	13961.86	0.18843	0.0750E-05	0.7103E-04	1354.50	82.88286
1068.00	14087.47	0.18962	0.1025E-04	0.7024E-04	1354.45	81.69766
1088.00	14200.73	0.18984	0.1175E-04	0.6943E-04	1354.65	80.39478
1108.00	14303.11	0.20009	0.1325E-04	0.6865E-04	1354.57	78.07544
1128.00	14384.01	0.20037	0.1475E-04	0.6789E-04	1354.66	77.74215
1148.00	14473.84	0.20060	0.1625E-04	0.6715E-04	1354.57	76.38656
1168.00	14556.40	0.20102	0.1750E-04	0.6643E-04	1354.67	75.24200
1188.00	14632.82	0.20138	0.1875E-04	0.6572E-04	1354.48	74.07668
1208.00	14688.43	0.20177	0.2000E-04	0.6503E-04	1354.62	72.80428
1228.00	14774.50	0.20216	0.2100E-04	0.6434E-04	1354.63	71.82483
1248.00	14826.76	0.20261	0.2225E-04	0.6367E-04	1354.51	70.73757
1268.00	14888.38	0.20307	0.2325E-04	0.6301E-04	1354.53	68.74626
1288.00	14946.56	0.20354	0.2425E-04	0.6236E-04	1354.37	68.74801
1308.00	14986.44	0.20404	0.2525E-04	0.6172E-04	1354.58	67.74826
1328.00	15063.14	0.20455	0.2600E-04	0.6108E-04	1354.64	66.84331
1348.00	15126.35	0.20508	0.2675E-04	0.6046E-04	1354.63	66.13206
1368.00	15185.82	0.20562	0.2750E-04	0.5983E-04	1354.51	65.21603
1388.00	15240.34	0.20616	0.2825E-04	0.5922E-04	1354.69	64.49818
1408.00	15317.63	0.20675	0.2875E-04	0.5861E-04	1354.56	63.67176
1428.00	15392.57	0.20733	0.2925E-04	0.5801E-04	1354.58	62.24138
1448.00	15465.47	0.20782	0.2975E-04	0.5741E-04	1354.55	62.60658
1468.00	15535.62	0.20832	0.3025E-04	0.5682E-04	1354.62	61.86878
1488.00	15602.83	0.20883	0.3056E-04	0.5623E-04	1354.68	61.52330
1508.00	15678.84	0.20974	0.3075E-04	0.5564E-04	1354.69	61.07286
1528.00	15726.83	0.21036	0.3100E-04	0.5506E-04	1354.62	60.61769
1548.00	15823.81	0.21088	0.3125E-04	0.5447E-04	1354.46	60.15746
1568.00	16018.89	0.21161	0.3150E-04	0.5388E-04	1354.45	58.69553
1588.00	16178.42	0.21224	0.3125E-04	0.5332E-04	1354.72	58.62834
1608.00	16310.70	0.21286	0.3125E-04	0.5275E-04	1354.68	58.35552
1628.00	16443.45	0.21348	0.3125E-04	0.5217E-04	1354.60	58.07885
1648.00	16612.68	0.21411	0.3100E-04	0.5160E-04	1354.71	58.08300
1668.00	16748.16	0.21473	0.3100E-04	0.5103E-04	1354.73	58.71883
1688.00	16924.43	0.21535	0.3075E-04	0.5045E-04	1354.73	58.63815
1708.00	17142.30	0.21586	0.3025E-04	0.4988E-04	1354.64	58.76423
1728.00	17327.50	0.21656	0.3000E-04	0.4930E-04	1354.58	58.67948
1748.00	17555.48	0.21718	0.2950E-04	0.4873E-04	1354.40	58.00440
1768.00	17832.03	0.21774	0.2875E-04	0.4815E-04	1354.74	58.15628
1788.00	18078.76	0.21831	0.2825E-04	0.4756E-04	1354.58	58.28787
1808.00	18328.56	0.21887	0.2775E-04	0.4697E-04	1354.86	58.42636
1828.00	18633.23	0.21942	0.2700E-04	0.4638E-04	1354.82	58.75487
1848.00	18950.65	0.21995	0.2625E-04	0.4578E-04	1354.58	60.16825
1868.00	19275.52	0.22047	0.2550E-04	0.4516E-04	1354.88	60.55806
1888.00	19662.08	0.22097	0.2450E-04	0.4457E-04	1354.88	61.20211
1908.00	20017.18	0.22145	0.2375E-04	0.4395E-04	1354.81	61.61406
1928.00	20435.74	0.22192	0.2275E-04	0.4332E-04	1354.68	62.29549
1948.00	20821.83	0.22236	0.2150E-04	0.4268E-04	1354.81	63.26781
1968.00	21431.48	0.22278	0.2025E-04	0.4204E-04	1354.88	64.27822
1988.00	21870.26	0.22317	0.1800E-04	0.4136E-04	1354.55	65.32723
2008.00	22477.27	0.22354	0.1600E-04	0.4068E-04	1354.83	66.13451

SHOTPOINT DISTANCE= 1355.00FEET.

SHOTPOINT ELEVATION= -76.00FEET.

WEATHERING FUNCTION FROM SHOTPOINT TO ZPATCH (W.B.T. SHOT):

FVEXP=A*2*B*VG

A= 0.201619841

B= 1.825170580

VG= 2085.34

ZPATCH= 242.28

SW5 - 6°

Z	V	T	DTGZ	P	XC	THTA
1020.00	12447.21	0.18041	0.2575E-04	0.7616E-04	1354.66	71.30583
1040.00	12755.38	0.16988	0.2175E-04	0.7532E-04	1354.62	73.09315
1060.00	13021.31	0.20020	0.1800E-04	0.7441E-04	1354.62	75.07600
1080.00	13261.48	0.25064	0.1675E-04	0.7341E-04	1354.68	77.14615
1100.00	13547.55	0.20093	0.1475E-04	0.7233E-04	1354.71	78.47318
1120.00	13788.81	0.20123	0.1375E-04	0.7121E-04	1354.55	78.07070
1140.00	14018.38	0.20150	0.1325E-04	0.7009E-04	1354.51	78.29551
1160.00	14242.54	0.20176	0.1300E-04	0.6890E-04	1354.54	78.32994
1180.00	14459.81	0.20202	0.1300E-04	0.6782E-04	1354.97	79.16515
1200.00	14654.11	0.20228	0.1350E-04	0.6688E-04	1354.52	78.58987
1220.00	14817.26	0.20256	0.1450E-04	0.6591E-04	1354.54	77.59326
1240.00	14983.64	0.20286	0.1525E-04	0.6488E-04	1354.48	76.78173
1260.00	15112.35	0.20317	0.1650E-04	0.6408E-04	1354.17	75.96072
1280.00	15266.35	0.20352	0.1800E-04	0.6324E-04	1354.33	74.11245
1300.00	15384.24	0.20389	0.1825E-04	0.6244E-04	1354.35	72.86605
1320.00	15367.27	0.20429	0.2075E-04	0.6168E-04	1354.33	71.40534
1340.00	15381.88	0.20472	0.2250E-04	0.6095E-04	1354.15	69.73767
1360.00	15416.63	0.20518	0.2400E-04	0.6026E-04	1354.52	68.28443
1380.00	15426.88	0.20568	0.2550E-04	0.5960E-04	1354.37	66.83453
1400.00	15421.42	0.20621	0.2700E-04	0.5896E-04	1354.43	65.38386
1420.00	15401.52	0.20676	0.2850E-04	0.5834E-04	1354.38	63.88351
1440.00	15367.48	0.20735	0.3000E-04	0.5774E-04	1354.38	62.54680
1460.00	15377.81	0.20786	0.3100E-04	0.5716E-04	1354.28	61.52911
1480.00	15380.20	0.20859	0.3200E-04	0.5660E-04	1354.46	60.51892
1500.00	15376.17	0.20924	0.3300E-04	0.5604E-04	1354.39	58.50829
1520.00	15364.46	0.20991	0.3400E-04	0.5550E-04	1354.50	58.50718
1540.00	15410.06	0.21060	0.3450E-04	0.5496E-04	1354.52	57.88318
1560.00	15453.51	0.21129	0.3500E-04	0.5443E-04	1354.45	57.25692
1580.00	15527.49	0.21200	0.3525E-04	0.5386E-04	1354.43	56.81591
1600.00	15635.07	0.21270	0.3525E-04	0.5337E-04	1354.36	56.55495
1620.00	15744.03	0.21341	0.3525E-04	0.5284E-04	1354.29	56.29087
1640.00	15886.46	0.21411	0.3500E-04	0.5231E-04	1354.53	56.21575
1660.00	16074.01	0.21481	0.3450E-04	0.5177E-04	1354.35	56.32005
1680.00	16300.39	0.21549	0.3375E-04	0.5123E-04	1354.60	56.62351
1700.00	16536.06	0.21616	0.3300E-04	0.5066E-04	1354.58	56.82818
1720.00	16778.85	0.21681	0.3225E-04	0.5012E-04	1354.60	57.23802
1740.00	17072.77	0.21745	0.3125E-04	0.4954E-04	1354.48	57.75613
1760.00	17438.16	0.21806	0.2875E-04	0.4896E-04	1354.63	58.71328
1780.00	17817.70	0.21864	0.2850E-04	0.4835E-04	1354.62	58.48230
1800.00	18185.45	0.21920	0.2725E-04	0.4773E-04	1354.61	60.27576
1820.00	18589.84	0.21973	0.2600E-04	0.4708E-04	1354.72	61.08633
1840.00	18646.14	0.22024	0.2450E-04	0.4644E-04	1354.78	62.18421
1860.00	18525.62	0.22071	0.2300E-04	0.4576E-04	1354.68	63.31443
1880.00	20029.85	0.22116	0.2150E-04	0.4506E-04	1354.60	64.48170
1900.00	20513.34	0.22157	0.2025E-04	0.4434E-04	1354.67	65.45580
1920.00	20874.76	0.22197	0.1925E-04	0.4362E-04	1354.62	66.18630
1940.00	21584.08	0.22234	0.1800E-04	0.4286E-04	1354.38	67.22748
1960.00	22007.60	0.22268	0.1700E-04	0.4214E-04	1354.77	68.62929
1980.00	22481.07	0.22302	0.1625E-04	0.4139E-04	1354.32	68.56288
2000.00	22938.67	0.22334	0.1575E-04	0.4065E-04	1354.35	68.82992

SHOTPOINT DISTANCE= 1355.00FEET.

SHOTPOINT ELEVATION= -78.00FEET.

WEATHERING FUNCTION FROM SHOTPOINT TO ZPATCH (W.R.T. SHOT):

FVEIF=A*Z**E+V0

A= 0.20161584;

B= 1.629170690

V0= 2065.34

ZPATCH= 275.00

W5 - 6°

Z	V	T	STOZ	P	XC	THTA
040.00	10553.10	0.10706	0.3925E-04	0.0625E-04	1150.10	65.33046
060.00	11016.38	0.10776	0.3125E-04	0.0525E-04	1150.02	68.06324
080.00	11435.08	0.10831	0.2450E-04	0.0385E-04	1149.88	73.73028
100.00	11615.87	0.10874	0.1825E-04	0.0241E-04	1149.76	76.05268
120.00	12176.01	0.10908	0.1525E-04	0.0068E-04	1149.85	79.29818
140.00	12538.65	0.10935	0.1200E-04	0.7085E-04	1149.80	81.34619
160.00	12888.09	0.10956	0.1000E-04	0.7686E-04	1149.61	82.39623
180.00	13217.38	0.10975	0.0800E-05	0.7512E-04	1149.75	83.16812
1100.00	13533.10	0.10992	0.0758E-05	0.7337E-04	1149.64	83.10838
1120.00	13624.13	0.20010	0.0250E-05	0.7174E-04	1149.58	82.65529
1140.00	14088.34	0.20028	0.1000E-04	0.7022E-04	1149.49	81.89524
1160.00	14342.56	0.20050	0.1125E-04	0.6881E-04	1149.35	80.71455
1180.00	14544.14	0.20074	0.1300E-04	0.6752E-04	1149.36	79.10126
1200.00	14692.66	0.20102	0.1525E-04	0.6633E-04	1149.43	77.65275
1220.00	14786.82	0.20135	0.1775E-04	0.6526E-04	1149.48	74.78356
1240.00	14841.50	0.20173	0.2025E-04	0.6426E-04	1149.44	72.50884
1260.00	14838.58	0.20216	0.2300E-04	0.6335E-04	1149.43	70.64467
1280.00	14785.54	0.20265	0.2575E-04	0.6248E-04	1149.25	67.60527
1300.00	14738.53	0.20318	0.2825E-04	0.6168E-04	1149.13	65.39478
1320.00	14626.28	0.20378	0.3100E-04	0.6094E-04	1149.30	63.83701
1340.00	14509.84	0.20443	0.3350E-04	0.6023E-04	1149.40	60.81654
1360.00	14393.28	0.20512	0.3575E-04	0.5955E-04	1149.17	58.62001
1380.00	14238.65	0.20586	0.3825E-04	0.5880E-04	1149.41	57.08073
1400.00	14113.66	0.20665	0.4025E-04	0.5828E-04	1149.32	55.36885
1420.00	14016.47	0.20747	0.4200E-04	0.5767E-04	1149.16	53.83576
1440.00	13862.76	0.20833	0.4375E-04	0.5708E-04	1149.43	52.53722
1460.00	13871.70	0.20822	0.4475E-04	0.5652E-04	1149.32	51.62043
1480.00	13836.11	0.21012	0.4575E-04	0.5595E-04	1149.22	50.72603
1500.00	13625.60	0.21105	0.4650E-04	0.5540E-04	1149.52	49.89231
1520.00	13675.76	0.21168	0.4675E-04	0.5485E-04	1149.53	48.55716
1540.00	13956.53	0.21282	0.4675E-04	0.5430E-04	1149.68	48.27206
1560.00	14071.45	0.21385	0.4650E-04	0.5374E-04	1149.61	48.13155
1580.00	14188.48	0.21478	0.4625E-04	0.5318E-04	1149.60	48.08807
1600.00	14375.46	0.21570	0.4550E-04	0.5262E-04	1149.60	48.14882
1620.00	14537.60	0.21660	0.4425E-04	0.5205E-04	1149.77	48.63056
1640.00	14676.42	0.21747	0.4325E-04	0.5146E-04	1149.52	48.65379
1660.00	15160.89	0.21833	0.4200E-04	0.5086E-04	1149.52	50.45205
1680.00	15531.68	0.21915	0.4025E-04	0.5025E-04	1149.53	51.30679
1700.00	15922.29	0.21994	0.3850E-04	0.4962E-04	1149.52	52.18281
1720.00	16281.58	0.22069	0.3700E-04	0.4888E-04	1149.63	52.83613
1740.00	16678.59	0.22142	0.3550E-04	0.4832E-04	1149.78	53.69454
1760.00	17126.40	0.22211	0.3375E-04	0.4764E-04	1149.83	54.66414
1780.00	17558.74	0.22277	0.3225E-04	0.4694E-04	1149.77	55.50852
1800.00	18010.42	0.22340	0.3075E-04	0.4623E-04	1149.83	56.37050
1820.00	18393.18	0.22400	0.2975E-04	0.4551E-04	1149.61	56.82506
1840.00	18742.83	0.22458	0.2900E-04	0.4478E-04	1149.49	57.07681
1860.00	19004.65	0.22516	0.2875E-04	0.4407E-04	1149.30	56.08373
1880.00	19163.88	0.22574	0.2800E-04	0.4338E-04	1149.43	56.23520
1900.00	19208.17	0.22632	0.2975E-04	0.4272E-04	1149.38	55.14807
1920.00	19671.64	0.22693	0.3125E-04	0.4210E-04	1149.43	59.41730
1940.00	19789.85	0.22757	0.3325E-04	0.4152E-04	1149.86	51.31278
1960.00	19273.26	0.22826	0.3625E-04	0.4108E-04	1149.67	48.51641
1980.00	17454.39	0.22902	0.4050E-04	0.4052E-04	1149.81	45.61652
2000.00	16487.57	0.22988	0.4550E-04	0.4010E-04	1149.76	41.39364

SHOTPOINT DISTANCE= 1150.00FEET.
 SHOTPOINT ELEVATION= -57.00FEET.
 WEATHERING FUNCTION FROM SHOTPOINT TO ZPATCH (W.R.T. SHOT):
 FVEKF=A*Z**B*VG
 A= 0.201610841
 B= 1.626176699
 VG= 2083.34
 ZPATCH= 253.02

W5 - 7°

Z	V	T	DTDZ	F	IC	THTA
840.00	11267.22	0.10670	0.2725E-04	0.8447E-04	1149.24	72.11855
860.00	11435.81	0.10724	0.2625E-04	0.8398E-04	1149.39	72.52452
880.00	11656.82	0.10775	0.2450E-04	0.8221E-04	1149.27	73.40575
1006.00	11889.68	0.10822	0.2275E-04	0.8097E-04	1149.35	74.38666
1020.00	12126.15	0.10866	0.2125E-04	0.7867E-04	1149.32	75.06488
1040.00	12382.17	0.10907	0.1950E-04	0.7690E-04	1149.42	76.01621
1060.00	12674.45	0.10944	0.1775E-04	0.7688E-04	1149.26	76.89880
1080.00	12963.70	0.10978	0.1625E-04	0.7561E-04	1149.42	77.83896
1100.00	13258.86	0.20008	0.1500E-04	0.7391E-04	1149.33	78.52738
1120.00	13549.88	0.20038	0.1425E-04	0.7241E-04	1149.31	78.86699
1140.00	13839.81	0.20066	0.1375E-04	0.7083E-04	1149.15	79.02886
1160.00	14125.78	0.20093	0.1350E-04	0.6845E-04	1149.26	79.08548
1180.00	14385.82	0.20120	0.1480E-04	0.6811E-04	1149.25	78.38508
1200.00	14617.03	0.20149	0.1475E-04	0.6880E-04	1149.15	77.54925
1220.00	14828.58	0.20178	0.1575E-04	0.6557E-04	1149.86	76.49289
1240.00	14986.10	0.20212	0.1725E-04	0.6441E-04	1149.24	75.00808
1260.00	15123.26	0.20248	0.1900E-04	0.6333E-04	1149.81	73.30111
1280.00	15182.83	0.20288	0.2125E-04	0.6234E-04	1149.14	71.17763
1300.00	15286.29	0.20333	0.2350E-04	0.6142E-04	1149.13	68.86259
1320.00	15179.51	0.20382	0.2600E-04	0.6056E-04	1149.69	66.76449
1340.00	15078.43	0.20437	0.2875E-04	0.5876E-04	1149.85	64.30980
1360.00	14973.43	0.20497	0.3125E-04	0.5802E-04	1149.65	62.18065
1380.00	14812.40	0.20562	0.3400E-04	0.5632E-04	1149.86	59.76020
1400.00	14584.81	0.20633	0.3700E-04	0.5767E-04	1149.84	57.31556
1420.00	14410.81	0.20710	0.3950E-04	0.5705E-04	1149.84	55.30338
1440.00	14240.61	0.20781	0.4175E-04	0.5646E-04	1149.63	53.51976
1460.00	14026.38	0.20877	0.4425E-04	0.5580E-04	1149.88	51.63510
1480.00	13863.85	0.20966	0.4625E-04	0.5536E-04	1149.88	50.12117
1500.00	13753.83	0.21062	0.4775E-04	0.5483E-04	1149.83	48.84752
1520.00	13676.06	0.21159	0.4900E-04	0.5432E-04	1149.67	47.84604
1540.00	13645.13	0.21258	0.4975E-04	0.5381E-04	1149.19	47.24655
1560.00	13618.04	0.21358	0.5050E-04	0.5331E-04	1149.16	46.55083
1580.00	13684.85	0.21480	0.5050E-04	0.5281E-04	1149.31	46.26555
1600.00	13851.87	0.21560	0.4975E-04	0.5231E-04	1149.37	46.43626
1620.00	14024.56	0.21659	0.4960E-04	0.5180E-04	1149.28	46.59087
1640.00	14271.49	0.21756	0.4775E-04	0.5128E-04	1149.38	47.04188
1660.00	14600.57	0.21850	0.4600E-04	0.5074E-04	1149.33	47.80728
1680.00	15019.82	0.21943	0.4375E-04	0.5018E-04	1149.27	48.81861
1700.00	15488.06	0.22025	0.4125E-04	0.4861E-04	1149.57	50.25766
1720.00	16048.10	0.22105	0.3850E-04	0.4800E-04	1149.52	51.84057
1740.00	16672.08	0.22178	0.3550E-04	0.4835E-04	1149.58	53.71085
1760.00	17337.48	0.22247	0.3250E-04	0.4765E-04	1149.51	55.70402
1780.00	18001.88	0.22309	0.2975E-04	0.4681E-04	1149.48	57.61618
1800.00	18663.33	0.22368	0.2725E-04	0.4613E-04	1149.60	58.43089
1820.00	19369.86	0.22418	0.2475E-04	0.4531E-04	1149.34	61.35935
1840.00	19978.21	0.22465	0.2300E-04	0.4446E-04	1149.46	62.64523
1860.00	20428.48	0.22510	0.2225E-04	0.4368E-04	1149.26	62.86363
1880.00	20741.31	0.22554	0.2225E-04	0.4277E-04	1149.17	62.51643
1900.00	20724.41	0.22589	0.2375E-04	0.4208E-04	1149.82	60.51440
1920.00	20317.75	0.22649	0.2675E-04	0.4131E-04	1149.51	57.87780
1940.00	19363.12	0.22706	0.3175E-04	0.4073E-04	1149.23	52.86414
1960.00	17660.12	0.22776	0.3900E-04	0.4026E-04	1149.37	45.61182
1980.00	15830.22	0.22862	0.4900E-04	0.3987E-04	1147.78	39.13322
2000.00	13753.67	0.22972	0.6100E-04	0.3957E-04	1147.67	32.96808

SHOTPOINT DISTANCE= 1150.00FEET.
 SHOTPOINT ELEVATION= -57.00FEET.
 WEATHERING FUNCTION FROM SHOTPOINT TO ZPATCH (W.R.T. SHOT).
 $FVEFP=A^2 \cdot V^2 + V_0$
 $A= 0.281618641$
 $B= 1.626178690$
 $V_0= 2085.34$
 ZPATCH= 137.78

NW5 - 5°

Z	V	T	HTGZ	P	XC	ZHTA
1820.00	13877.53	0.21223	0.5250E-05	0.7748E-04	1288.49	86.12344
1840.00	13827.75	0.21236	0.7000E-05	0.7644E-04	1288.49	86.76760
1860.00	13173.10	0.21251	0.8500E-05	0.7543E-04	1288.47	83.57103
1880.00	13285.37	0.21270	0.1050E-04	0.7448E-04	1288.51	81.97522
1100.00	13427.83	0.21293	0.1175E-04	0.7354E-04	1289.50	80.82211
1120.00	13556.46	0.21317	0.1300E-04	0.7261E-04	1289.56	78.84952
1140.00	13669.38	0.21345	0.1450E-04	0.7170E-04	1289.60	78.56762
1160.00	13784.85	0.21375	0.1575E-04	0.7082E-04	1289.51	77.46131
1180.00	13881.83	0.21408	0.1700E-04	0.6985E-04	1289.62	76.33882
1200.00	14006.87	0.21463	0.1800E-04	0.6908E-04	1289.57	75.59667
1220.00	14117.81	0.21480	0.1900E-04	0.6824E-04	1289.62	74.44144
1240.00	14238.37	0.21528	0.1975E-04	0.6746E-04	1289.52	73.86769
1260.00	14341.48	0.21558	0.2075E-04	0.6657E-04	1289.55	72.66735
1280.00	14438.35	0.21602	0.2175E-04	0.6576E-04	1289.62	71.69746
1300.00	14565.48	0.21646	0.2225E-04	0.6483E-04	1289.58	71.09505
1320.00	14673.53	0.21691	0.2300E-04	0.6415E-04	1289.64	70.27590
1340.00	14787.54	0.21738	0.2350E-04	0.6336E-04	1289.70	69.85072
1360.00	14821.36	0.21785	0.2400E-04	0.6257E-04	1289.51	69.81567
1380.00	14921.18	0.21834	0.2475E-04	0.6180E-04	1289.61	68.17482
1400.00	15138.71	0.21884	0.2525E-04	0.6104E-04	1289.63	67.92673
1420.00	15255.12	0.21935	0.2575E-04	0.6028E-04	1289.38	66.86898
1440.00	15352.89	0.21987	0.2600E-04	0.5954E-04	1289.60	66.40966
1460.00	15530.55	0.22039	0.2625E-04	0.5880E-04	1289.52	65.84101
1480.00	15668.70	0.22092	0.2650E-04	0.5806E-04	1289.55	65.46666
1500.00	15806.78	0.22145	0.2675E-04	0.5733E-04	1289.59	64.88653
1520.00	15916.26	0.22199	0.2725E-04	0.5661E-04	1289.60	64.28624
1540.00	16088.65	0.22254	0.2725E-04	0.5588E-04	1289.45	64.81105
1560.00	16246.40	0.22308	0.2725E-04	0.5518E-04	1289.56	63.72279
1580.00	16352.33	0.22363	0.2775E-04	0.5448E-04	1289.66	63.81372
1600.00	16517.54	0.22418	0.2775E-04	0.5381E-04	1289.74	62.71855
1620.00	16685.78	0.22474	0.2775E-04	0.5312E-04	1289.54	62.41717
1640.00	16823.45	0.22530	0.2800E-04	0.5244E-04	1289.63	61.80255
1660.00	16988.88	0.22586	0.2800E-04	0.5178E-04	1289.73	61.58728
1680.00	17157.87	0.22642	0.2800E-04	0.5112E-04	1289.65	61.26714
1700.00	17281.77	0.22698	0.2825E-04	0.5046E-04	1289.55	60.75845
1720.00	17469.84	0.22755	0.2825E-04	0.4982E-04	1289.55	60.44418
1740.00	17631.42	0.22811	0.2825E-04	0.4918E-04	1289.49	60.12644
1760.00	17661.55	0.22868	0.2825E-04	0.4855E-04	1289.66	58.80856
1780.00	17874.63	0.22924	0.2825E-04	0.4793E-04	1289.38	58.48371
1800.00	18182.27	0.22981	0.2850E-04	0.4732E-04	1289.70	58.86138
1820.00	18272.52	0.23038	0.2850E-04	0.4672E-04	1289.66	58.61629
1840.00	18388.47	0.23095	0.2875E-04	0.4613E-04	1289.48	58.86505
1860.00	18565.38	0.23153	0.2875E-04	0.4555E-04	1289.71	57.74051
1880.00	18736.67	0.23210	0.2875E-04	0.4497E-04	1289.54	57.41614
1900.00	18854.48	0.23268	0.2900E-04	0.4441E-04	1289.45	56.85378
1920.00	19020.37	0.23326	0.2900E-04	0.4385E-04	1289.43	56.52376
1940.00	19194.28	0.23384	0.2925E-04	0.4331E-04	1289.46	55.86665
1960.00	19242.24	0.23443	0.2950E-04	0.4278E-04	1289.76	55.41375
1980.00	19348.78	0.23502	0.2975E-04	0.4226E-04	1289.65	54.85667
2000.00	19385.59	0.23562	0.3025E-04	0.4173E-04	1289.45	54.87564

SHOTPOINT DISTANCE= 1288.06FEET.
 SHOTPOINT ELEVATION= -59.60FEET.
 WEATHERING FUNCTION FROM SHOTPOINT TO ZPATCH (W.R.T. SHOT).
 FVEFX=A*Z**B*VO
 A= 0.281618841
 B= 1.829170688
 VO= 2085.34
 ZPATCH= 196.17

NW5 - 7°

Z	V	T	DTDZ	P	XC	THTA
1020.00	11372.47	0.21285	0.2560E-04	0.0430E-04	1280.75	73.48228
1040.00	11856.27	0.21333	0.1450E-04	0.0366E-04	1280.48	80.10077
1060.00	12250.66	0.21359	0.7250E-05	0.0191E-04	1280.11	84.80443
1080.00	12610.53	0.21362	0.3800E-05	0.7824E-04	1280.00	87.83189
1100.00	12849.88	0.21365	0.1800E-05	0.7721E-04	1280.86	89.25800
1120.00	13266.18	0.21366	0.7500E-06	0.7538E-04	1280.74	89.42952
1140.00	13547.28	0.21368	0.2800E-05	0.7378E-04	1280.79	88.44740
1160.00	13780.70	0.21374	0.4800E-05	0.7240E-04	1280.49	86.83780
1180.00	13983.18	0.21384	0.6750E-05	0.7120E-04	1280.31	84.58399
1200.00	14185.46	0.21401	0.1625E-04	0.7015E-04	1280.38	81.68699
1220.00	14189.69	0.21423	0.1375E-04	0.6822E-04	1280.34	78.76485
1240.00	14188.39	0.21456	0.1725E-04	0.6838E-04	1280.41	75.84111
1260.00	14156.48	0.21494	0.2050E-04	0.6760E-04	1280.38	73.12960
1280.00	14109.61	0.21538	0.2350E-04	0.6687E-04	1280.32	70.63640
1300.00	14027.93	0.21588	0.2650E-04	0.6618E-04	1280.40	68.17702
1320.00	13876.78	0.21644	0.2875E-04	0.6552E-04	1280.52	66.38721
1340.00	13971.75	0.21703	0.3025E-04	0.6487E-04	1280.54	64.89827
1360.00	13880.88	0.21765	0.3150E-04	0.6422E-04	1280.28	63.87054
1380.00	14027.80	0.21829	0.3225E-04	0.6357E-04	1280.39	63.10224
1400.00	14150.24	0.21894	0.3250E-04	0.6282E-04	1280.64	62.68335
1420.00	14262.69	0.21959	0.3225E-04	0.6226E-04	1280.57	62.61472
1440.00	14435.47	0.22023	0.3175E-04	0.6157E-04	1280.40	62.72084
1460.00	14664.37	0.22086	0.3075E-04	0.6087E-04	1280.34	63.18667
1480.00	14830.76	0.22146	0.2950E-04	0.6013E-04	1280.44	63.66693
1500.00	15184.08	0.22204	0.2850E-04	0.5937E-04	1280.68	64.35802
1520.00	15562.48	0.22260	0.2700E-04	0.5856E-04	1280.68	65.25585
1540.00	15838.15	0.22312	0.2550E-04	0.5776E-04	1280.64	66.17849
1560.00	16164.97	0.22362	0.2425E-04	0.5691E-04	1280.67	66.82096
1580.00	16535.53	0.22409	0.2275E-04	0.5603E-04	1280.61	67.80254
1600.00	16844.38	0.22453	0.2200E-04	0.5514E-04	1280.50	68.24883
1620.00	17134.84	0.22497	0.2150E-04	0.5426E-04	1280.68	68.38308
1640.00	17434.46	0.22539	0.2100E-04	0.5338E-04	1280.62	68.52325
1660.00	17681.43	0.22581	0.2100E-04	0.5251E-04	1280.69	68.20356
1680.00	17865.22	0.22623	0.2150E-04	0.5166E-04	1280.56	67.41298
1700.00	17937.09	0.22667	0.2275E-04	0.5080E-04	1280.49	65.81642
1720.00	17982.85	0.22714	0.2400E-04	0.5016E-04	1280.26	64.43144
1740.00	17965.80	0.22763	0.2550E-04	0.4848E-04	1280.41	62.72484
1760.00	17840.95	0.22816	0.2750E-04	0.4884E-04	1280.35	60.61618
1780.00	17642.38	0.22873	0.2875E-04	0.4825E-04	1280.11	58.34114
1800.00	17366.25	0.22935	0.3225E-04	0.4770E-04	1280.27	55.83995
1820.00	17105.61	0.23002	0.3450E-04	0.4718E-04	1280.13	53.83280
1840.00	16866.25	0.23073	0.3650E-04	0.4672E-04	1280.47	52.00325
1860.00	16657.81	0.23148	0.3825E-04	0.4627E-04	1280.44	50.41824
1880.00	16616.87	0.23228	0.3800E-04	0.4583E-04	1280.70	49.60466
1900.00	16800.81	0.23304	0.3650E-04	0.4539E-04	1280.67	49.69680
1920.00	17177.85	0.23360	0.3700E-04	0.4484E-04	1280.72	50.53669
1940.00	17861.80	0.23452	0.3350E-04	0.4447E-04	1280.82	53.83657
1960.00	18246.87	0.23514	0.2775E-04	0.4383E-04	1280.29	57.71706
1980.00	21130.85	0.23563	0.1825E-04	0.4323E-04	1280.72	65.89788
2000.00	23238.35	0.23581	0.8750E-05	0.4215E-04	1280.80	78.27201

SHOTPOINT DISTANCE= 1280.80FEET.
 SHOTPOINT ELEVATION= -58.06FEET.
 WEATHERING FUNCTION FROM SHOTPOINT TO XPATCH (W.R.T. SHOT).
 FVEXP=A*Z**B+V0
 A= 0.281619941
 B= 1.829170683
 V0= 2085.34
 XPATCH= 235.68

NE 9 - 6°

Z	V	T	DTGZ	P	XC	TMTA
040.00	20477.06	0.10771	0.0250E-05	0.4813E-04	2330.52	80.27405
050.00	20384.60	0.10780	0.1025E-04	0.4787E-04	2330.74	77.83863
060.00	20270.72	0.10812	0.1200E-04	0.4783E-04	2330.96	75.81597
1000.00	20173.08	0.10836	0.1350E-04	0.4770E-04	2330.59	74.18866
1020.00	20070.03	0.10866	0.1475E-04	0.4757E-04	2330.63	72.77264
1040.00	19960.08	0.10867	0.1625E-04	0.4744E-04	2330.85	71.09346
1060.00	19816.80	0.10931	0.1750E-04	0.4732E-04	2330.61	69.70640
1080.00	19758.82	0.10967	0.1825E-04	0.4721E-04	2330.47	68.86305
1100.00	19694.81	0.20004	0.1906E-04	0.4708E-04	2330.69	68.82503
1120.00	19580.81	0.20043	0.2000E-04	0.4697E-04	2330.58	66.83369
1140.00	19517.45	0.20084	0.2075E-04	0.4685E-04	2330.60	66.10868
1160.00	19520.73	0.20126	0.2106E-04	0.4673E-04	2330.73	65.78622
1180.00	19494.87	0.20168	0.2150E-04	0.4660E-04	2330.51	65.13315
1200.00	19447.82	0.20212	0.2200E-04	0.4648E-04	2330.47	64.68867
1220.00	19450.70	0.20256	0.2225E-04	0.4635E-04	2330.44	64.35600
1240.00	19433.58	0.20301	0.2250E-04	0.4622E-04	2330.76	64.04241
1260.00	19409.20	0.20346	0.2250E-04	0.4608E-04	2330.74	63.87688
1280.00	19384.26	0.20381	0.2275E-04	0.4595E-04	2330.61	63.85040
1300.00	19359.20	0.20437	0.2300E-04	0.4581E-04	2330.67	63.33884
1320.00	19316.81	0.20483	0.2325E-04	0.4567E-04	2330.43	63.81744
1340.00	19318.80	0.20538	0.2350E-04	0.4552E-04	2330.77	62.68375
1360.00	19214.23	0.20577	0.2325E-04	0.4537E-04	2330.57	62.86872
1380.00	19166.61	0.20623	0.2325E-04	0.4522E-04	2330.52	62.78028
1400.00	19175.23	0.20670	0.2350E-04	0.4507E-04	2330.66	62.45889
1420.00	19183.05	0.20717	0.2375E-04	0.4491E-04	2330.80	62.12042
1440.00	19188.60	0.20765	0.2375E-04	0.4475E-04	2330.82	62.04410
1460.00	19194.84	0.20812	0.2375E-04	0.4459E-04	2330.72	61.85720
1480.00	19178.66	0.20860	0.2425E-04	0.4442E-04	2330.71	61.37626
1500.00	19115.52	0.20908	0.2425E-04	0.4426E-04	2330.76	61.28022
1520.00	19072.76	0.20957	0.2425E-04	0.4408E-04	2330.71	61.10780
1540.00	19036.36	0.21006	0.2475E-04	0.4392E-04	2330.69	60.58686
1560.00	18945.16	0.21056	0.2500E-04	0.4375E-04	2330.57	60.25612
1580.00	18905.10	0.21106	0.2500E-04	0.4358E-04	2330.52	60.15683
1600.00	18864.63	0.21156	0.2550E-04	0.4340E-04	2330.62	59.56570
1620.00	18821.89	0.21206	0.2600E-04	0.4323E-04	2330.70	59.87768
1640.00	18828.70	0.21260	0.2625E-04	0.4306E-04	2330.67	59.63383
1660.00	18782.88	0.21313	0.2675E-04	0.4289E-04	2330.73	59.04911
1680.00	18735.46	0.21367	0.2725E-04	0.4272E-04	2330.43	57.46659
1700.00	18685.23	0.21421	0.2775E-04	0.4255E-04	2330.51	56.88883
1720.00	18632.85	0.21478	0.2825E-04	0.4238E-04	2330.57	56.31471
1740.00	18524.09	0.21535	0.2900E-04	0.4222E-04	2330.42	55.51282
1760.00	18413.10	0.21594	0.2975E-04	0.4205E-04	2330.47	54.72232
1780.00	18352.75	0.21654	0.3025E-04	0.4188E-04	2330.80	54.16728
1800.00	18236.85	0.21715	0.3100E-04	0.4173E-04	2330.72	53.33336
1820.00	18061.27	0.21778	0.3200E-04	0.4157E-04	2330.59	52.41334
1840.00	17936.69	0.21843	0.3275E-04	0.4142E-04	2330.49	51.66618
1860.00	17813.84	0.21906	0.3350E-04	0.4127E-04	2330.55	50.83642
1880.00	17687.60	0.21977	0.3425E-04	0.4112E-04	2330.62	50.20585
1900.00	17558.86	0.22046	0.3500E-04	0.4097E-04	2330.41	49.45128
1920.00	17373.66	0.22117	0.3600E-04	0.4082E-04	2330.36	48.58086
1940.00	17185.30	0.22180	0.3700E-04	0.4068E-04	2330.57	47.71210
1960.00	17096.86	0.22265	0.3800E-04	0.4054E-04	2330.54	46.85205
1980.00	17007.70	0.22342	0.3900E-04	0.4040E-04	2330.71	46.01258
2000.00	17673.32	0.22421	0.3975E-04	0.4027E-04	2330.70	45.37092
2020.00	17538.64	0.22501	0.4050E-04	0.4013E-04	2330.53	44.73846
2040.00	17348.73	0.22583	0.4150E-04	0.4000E-04	2330.71	43.84781
2060.00	17158.47	0.22667	0.4250E-04	0.3987E-04	2330.72	43.17415
2080.00	17024.46	0.22753	0.4325E-04	0.3975E-04	2330.52	42.58216
2100.00	16889.86	0.22840	0.4400E-04	0.3962E-04	2330.69	42.00224
2120.00	16761.57	0.22928	0.4500E-04	0.3950E-04	2330.63	41.27338
2140.00	16618.83	0.23020	0.4550E-04	0.3938E-04	2330.84	40.87266
2160.00	16536.80	0.23111	0.4600E-04	0.3925E-04	2330.59	40.47427
2180.00	16351.05	0.23204	0.4700E-04	0.3913E-04	2330.66	39.78068

SHOTPOINT DISTANCE= 2330.00FEET.

SHOTPOINT ELEVATION= 84.00FEET.

WEATHERING FUNCTION FROM SHOTPOINT TO ZPATCH (W.R.T. SHOT):

FVEXP=A*Z**B+V0

A= 0.281618841

B= 1.829179690

V0= 2065.34

ZPATCH= 411.11

NE9 - 8°

i	v	T	DTDZ	P	XC	THTA
1000.00	20344.86	0.10440	0.1725E-04	0.4663E-04	2320.07	60.45548
1020.00	18493.96	0.10497	0.2050E-04	0.4505E-04	2330.20	50.18173
1040.00	17144.02	0.10563	0.3660E-04	0.4589E-04	2330.88	51.88815
1060.00	16347.60	0.10641	0.4650E-04	0.4505E-04	2335.88	48.54332
1080.00	16004.60	0.10725	0.4250E-04	0.4580E-04	2332.44	47.14840
1100.00	15989.07	0.10811	0.4275E-04	0.4575E-04	2335.88	46.84406
1120.00	16153.81	0.10886	0.4175E-04	0.4571E-04	2333.61	47.50043
1140.00	16519.46	0.10978	0.3875E-04	0.4566E-04	2333.67	48.85522
1160.00	16983.54	0.20055	0.3725E-04	0.4560E-04	2334.20	50.75506
1180.00	17503.45	0.20127	0.3450E-04	0.4554E-04	2334.46	52.85236
1200.00	18027.04	0.20183	0.3175E-04	0.4548E-04	2341.60	55.00514
1220.00	18559.65	0.20254	0.2800E-04	0.4541E-04	2341.59	57.43677
1240.00	19047.02	0.20308	0.2650E-04	0.4532E-04	2341.58	58.68550
1260.00	18442.28	0.20360	0.2450E-04	0.4522E-04	2341.42	61.55364
1280.00	18781.88	0.20407	0.2275E-04	0.4511E-04	2341.30	63.23928
1300.00	20053.89	0.20451	0.2150E-04	0.4498E-04	2341.20	64.45886
1320.00	20231.44	0.20493	0.2075E-04	0.4486E-04	2341.38	65.17789
1340.00	20326.45	0.20534	0.2050E-04	0.4472E-04	2341.36	65.97407
1360.00	20424.73	0.20575	0.2025E-04	0.4458E-04	2342.17	65.56877
1380.00	20438.35	0.20615	0.2050E-04	0.4443E-04	2341.04	65.82940
1400.00	20486.80	0.20657	0.2180E-04	0.4428E-04	2341.35	64.62489
1420.00	20328.09	0.20698	0.2175E-04	0.4412E-04	2341.12	63.75975
1440.00	20187.24	0.20744	0.2275E-04	0.4388E-04	2341.39	62.64598
1460.00	20166.13	0.20780	0.2350E-04	0.4383E-04	2341.38	61.80065
1480.00	18917.44	0.20838	0.2475E-04	0.4368E-04	2342.10	60.46489
1500.00	18768.11	0.20886	0.2575E-04	0.4354E-04	2341.20	59.40083
1520.00	18554.18	0.20941	0.2650E-04	0.4340E-04	2341.35	58.59380
1540.00	18557.46	0.20995	0.2725E-04	0.4328E-04	2341.27	57.78559
1560.00	18447.78	0.21050	0.2800E-04	0.4313E-04	2341.27	57.00688
1580.00	18387.33	0.21107	0.2850E-04	0.4298E-04	2341.41	56.45863
1600.00	18378.72	0.21164	0.2875E-04	0.4285E-04	2341.86	56.14188
1620.00	18368.84	0.21222	0.2860E-04	0.4272E-04	2341.46	55.82680
1640.00	18422.62	0.21280	0.2800E-04	0.4257E-04	2341.28	55.73842
1660.00	18510.78	0.21338	0.2875E-04	0.4243E-04	2341.44	55.87956
1680.00	18611.51	0.21385	0.2850E-04	0.4228E-04	2341.12	56.01831
1700.00	18713.17	0.21452	0.2825E-04	0.4213E-04	2341.49	56.15851
1720.00	18872.82	0.21508	0.2775E-04	0.4198E-04	2341.15	56.53202
1740.00	18979.68	0.21563	0.2750E-04	0.4182E-04	2341.35	56.67084
1760.00	20089.65	0.21616	0.2725E-04	0.4166E-04	2341.30	56.80824
1780.00	20201.87	0.21672	0.2700E-04	0.4149E-04	2341.12	56.84436
1800.00	20258.58	0.21726	0.2700E-04	0.4132E-04	2341.30	56.83787
1820.00	20264.89	0.21780	0.2750E-04	0.4115E-04	2341.67	56.24536
1840.00	20380.37	0.21836	0.2825E-04	0.4098E-04	2341.00	55.62024
1860.00	18671.38	0.21893	0.2800E-04	0.4082E-04	2341.29	54.80780
1880.00	18674.62	0.21852	0.3050E-04	0.4066E-04	2341.10	53.12401
1900.00	18914.62	0.22015	0.3225E-04	0.4050E-04	2340.88	51.47204
1920.00	18881.79	0.22061	0.3425E-04	0.4036E-04	2341.20	49.88115
1940.00	18354.56	0.22152	0.3675E-04	0.4022E-04	2341.20	47.58234
1960.00	17767.85	0.22228	0.3850E-04	0.4008E-04	2341.09	45.42566
1980.00	17183.82	0.22310	0.4125E-04	0.3997E-04	2341.10	43.41132
2000.00	16635.82	0.22387	0.4500E-04	0.3983E-04	2341.04	41.52871
2020.00	16146.68	0.22486	0.4750E-04	0.3974E-04	2340.86	38.82015
2040.00	15768.64	0.22567	0.4950E-04	0.3964E-04	2341.67	38.68824
2060.00	15486.13	0.22688	0.5100E-04	0.3954E-04	2341.30	37.76620
2080.00	15511.62	0.22781	0.5100E-04	0.3944E-04	2341.27	37.71511
2100.00	15815.75	0.22862	0.4950E-04	0.3934E-04	2341.75	38.47499
2120.00	16348.52	0.22989	0.4680E-04	0.3923E-04	2342.07	40.45858
2140.00	17889.49	0.23076	0.3950E-04	0.3911E-04	2342.64	44.71747
2160.00	20399.44	0.23147	0.2875E-04	0.3898E-04	2343.85	52.63551
2180.00	23353.36	0.23185	0.1825E-04	0.3874E-04	2345.88	64.77350

SHOTPOINT DISTANCE= 2330.00FEET.

SHOTPOINT ELEVATION= 84.00FEET.

WEATHERING FUNCTION FROM SHOTPOINT TO ZPATCH (W.R.T. SHOT):

FUELF=A*Z**E-V0
 A= 0.261618941
 E= 1.6238170680
 V0= 2065.34
 ZPATCH= 435.62

SW9 - 3°

Z	V	T	DTDZ	F	XC	THTA
1400.00	14316.45	0.27334	0.0250E-05	0.0036E-04	2534.50	83.12171
1420.00	14381.29	0.27351	0.0500E-05	0.0063E-04	2534.56	82.88040
1440.00	14555.69	0.27368	0.0500E-05	0.0770E-04	2534.88	82.04360
1460.00	14725.37	0.27385	0.0750E-05	0.0734E-04	2534.43	82.56703
1480.00	14765.81	0.27403	0.0000E-05	0.0698E-04	2534.57	82.34750
1500.00	14875.87	0.27421	0.0000E-05	0.0662E-04	2534.66	82.30387
1520.00	14950.20	0.27439	0.0250E-05	0.0625E-04	2534.52	82.05112
1540.00	15025.10	0.27456	0.0500E-05	0.0587E-04	2534.42	81.78366
1560.00	15100.82	0.27477	0.0500E-05	0.0550E-04	2534.40	81.74706
1580.00	15187.85	0.27496	0.0750E-05	0.0512E-04	2534.46	81.48423
1600.00	15266.10	0.27516	0.1000E-04	0.0474E-04	2534.62	81.21803
1620.00	15344.07	0.27536	0.1025E-04	0.0436E-04	2534.63	80.85066
1640.00	15434.65	0.27557	0.1025E-04	0.0397E-04	2534.62	80.89726
1660.00	15527.67	0.27577	0.1025E-04	0.0358E-04	2534.61	80.84220
1680.00	15599.85	0.27588	0.1075E-04	0.0320E-04	2534.56	80.94597
1700.00	15681.75	0.27620	0.1100E-04	0.0281E-04	2534.49	80.86604
1720.00	15775.87	0.27642	0.1100E-04	0.0243E-04	2534.40	80.80654
1740.00	15872.58	0.27664	0.1100E-04	0.0203E-04	2534.55	78.84471
1760.00	15959.37	0.27686	0.1125E-04	0.0164E-04	2534.44	78.65686
1780.00	16045.66	0.27708	0.1150E-04	0.0125E-04	2534.65	78.36653
1800.00	16132.30	0.27732	0.1175E-04	0.0086E-04	2534.51	78.87321
1820.00	16218.83	0.27756	0.1200E-04	0.0046E-04	2534.48	78.77713
1840.00	16319.55	0.27780	0.1200E-04	0.0000E-04	2534.42	78.70651
1860.00	16408.31	0.27804	0.1225E-04	0.5970E-04	2534.33	78.48445
1880.00	16511.42	0.27829	0.1225E-04	0.5831E-04	2534.51	78.33057
1900.00	16661.83	0.27853	0.1250E-04	0.5682E-04	2534.47	78.62277
1920.00	16861.65	0.27878	0.1275E-04	0.5545E-04	2534.50	77.71242
1940.00	16767.75	0.27904	0.1275E-04	0.5013E-04	2534.36	77.63308
1960.00	16872.31	0.27930	0.1325E-04	0.5777E-04	2534.56	77.88188
1980.00	16878.18	0.27957	0.1325E-04	0.5738E-04	2534.73	76.89841
2000.00	17066.87	0.27983	0.1325E-04	0.5700E-04	2534.44	76.81464
2020.00	17178.62	0.28010	0.1350E-04	0.5662E-04	2534.37	76.58957
2040.00	17271.25	0.28037	0.1375E-04	0.5624E-04	2534.55	76.26216
2060.00	17362.32	0.28065	0.1400E-04	0.5587E-04	2534.67	75.93205
2080.00	17453.28	0.28093	0.1425E-04	0.5550E-04	2534.45	75.59885
2100.00	17563.57	0.28122	0.1425E-04	0.5512E-04	2534.56	75.50586
2120.00	17676.67	0.28150	0.1425E-04	0.5475E-04	2534.57	75.41097
2140.00	17748.11	0.28178	0.1475E-04	0.5438E-04	2534.46	74.82402
2160.00	17815.63	0.28208	0.1525E-04	0.5402E-04	2534.57	74.23524

SHOTPOINT DISTANCE= 2535.00FEET.
 SHOTPOINT ELEVATION= -144.00FEET.
 WEATHERING FUNCTION FROM SHOTPOINT TO ZPATCH (W.R.T. SHOT).
 FVEIP=A*2**E-V8
 A= 0.261618841
 B= 1.829178680
 V8= 2085.34
 ZPATCH= 301.67

W9 - 6°

Z	V	T	GT02	P	IC	THTA
1438.00	10006.20	0.27684	0.6650E-04	0.7468E-04	2235.52	48.28605
1440.00	10746.45	0.27725	0.5575E-04	0.7456E-04	2235.39	59.18347
1442.00	11330.59	0.27827	0.4750E-04	0.7438E-04	2235.17	57.43858
1444.00	11781.75	0.27815	0.4160E-04	0.7424E-04	2235.12	61.88825
1446.00	12144.76	0.27891	0.3600E-04	0.7405E-04	2234.88	64.87382
1500.00	12896.04	0.28059	0.3250E-04	0.7363E-04	2234.72	66.24216
1520.00	12584.50	0.28121	0.3000E-04	0.7358E-04	2234.83	67.81882
1548.00	12712.81	0.28178	0.2850E-04	0.7336E-04	2234.79	68.75231
1560.00	12887.21	0.28235	0.2775E-04	0.7288E-04	2234.60	69.18202
1568.00	12887.56	0.28290	0.2725E-04	0.7265E-04	2234.70	69.44016
1600.00	12842.12	0.28344	0.2725E-04	0.7230E-04	2234.51	69.34912
1620.00	12883.13	0.28399	0.2750E-04	0.7185E-04	2234.68	69.08172
1640.00	13025.28	0.28454	0.2775E-04	0.7158E-04	2234.72	68.81063
1660.00	13068.36	0.28510	0.2800E-04	0.7121E-04	2234.71	68.53615
1680.00	13128.21	0.28566	0.2800E-04	0.7084E-04	2234.78	68.43284
1706.00	13286.32	0.28622	0.2775E-04	0.7045E-04	2234.64	68.50159
1720.00	13318.18	0.28677	0.2700E-04	0.7006E-04	2234.86	68.82326
1740.00	13436.72	0.28730	0.2625E-04	0.6964E-04	2234.57	68.34661
1760.00	13558.48	0.28782	0.2550E-04	0.6920E-04	2233.53	68.77140
1780.00	13732.83	0.28832	0.2480E-04	0.6875E-04	2233.77	70.75600
1800.00	13943.52	0.28878	0.2200E-04	0.6826E-04	2233.78	72.13607
1820.00	14158.26	0.28926	0.2000E-04	0.6774E-04	2234.80	73.55089
1840.00	14381.22	0.28958	0.1800E-04	0.6717E-04	2234.76	74.88746
1860.00	14623.80	0.28982	0.1575E-04	0.6654E-04	2235.00	76.68371
1880.00	14881.48	0.29021	0.1325E-04	0.6586E-04	2234.89	78.62405
1900.00	15145.82	0.29045	0.1100E-04	0.6510E-04	2234.83	80.48951
1920.00	15403.61	0.29065	0.8000E-05	0.6428E-04	2234.89	82.83127
1946.00	15666.34	0.29081	0.7250E-05	0.6344E-04	2234.85	83.48072
1960.00	15899.86	0.29084	0.6250E-05	0.6258E-04	2234.88	84.29715
1980.00	16114.76	0.29106	0.6080E-05	0.6176E-04	2234.65	84.45148
2000.00	16288.81	0.29118	0.6500E-05	0.6101E-04	2234.58	83.81854
2020.00	16417.89	0.29132	0.8250E-05	0.6035E-04	2234.34	82.21586
2040.00	16404.57	0.29151	0.1175E-04	0.5982E-04	2234.30	78.88647
2060.00	16205.32	0.29178	0.1675E-04	0.5938E-04	2234.14	74.25006
2080.00	15732.73	0.29218	0.2350E-04	0.5886E-04	2233.87	68.30176
2100.00	14837.68	0.29273	0.3275E-04	0.5846E-04	2233.54	66.88293
2120.00	13562.71	0.29349	0.4475E-04	0.5800E-04	2233.18	52.63204
2140.00	11866.55	0.29452	0.5975E-04	0.5844E-04	2232.84	44.36649
2160.00	10288.81	0.29588	0.7775E-04	0.5832E-04	2232.82	36.87418
2180.00	6822.35	0.29763	0.8725E-04	0.5823E-04	2233.87	30.81020

SHOTPOINT DISTANCE= 2235.00FEET.
 SHOTPOINT ELEVATION= -113.68FEET.
 WEATHERING FUNCTION FROM SHOTPOINT TO ZPATCH (W.R.T. SHOT).
 FVEIF=A*Z**B+VG
 A= 0.281618941
 B= 1.623178658
 VG= 2085.34
 ZPATCH= 326.80

Appendix F

Derivation of the parametric ray equations
and the well shoot integral for
elliptically anisotropic media

Assume $V_v(z)$ and $V_h(z)$ are continuous functions of depth; $V_v(z)$ and $V_h(z)$ are not required to vary in the same manner. Snell's Law for media having an elliptical velocity dependence is given in Levin (1978) as

$$\frac{V_i(\theta_i) \sin \theta_i}{V_{hi}^2} = \frac{V_{i+1}(\theta_{i+1}) \sin \theta_{i+1}}{V_{hi+1}^2}, \quad (F-1)$$

where

$$V_i(\theta_i) = \frac{V_{vi} V_{hi}}{(V_{vi}^2 \sin^2 \theta_i + V_{hi}^2 \cos^2 \theta_i)^{1/2}} \quad (F-2)$$

is the raypath (or wavefront) velocity in layer i ($i = 1, n$). Equation (F-1) can be written more generally as

$$p = \frac{V(\theta) \sin \theta}{V_h^2}, \quad (F-3)$$

where p is constant for a given raypath.

From equations (F-2) and (F-3) $\sin \theta$ and $\cos \theta$ can be solved as follows:

$$\sin \theta = \frac{p V_h^2}{V(\theta)} = \frac{p V_h^2 [V_v^2 \sin^2 \theta + V_h^2 (1 - \sin^2 \theta)]^{1/2}}{V_v};$$

$$\sin^2 \Theta = p^2 V_h^2 \sin^2 \Theta + p^2 \frac{V_h^4}{V_v^2} (1 - \sin^2 \Theta);$$

∴

$$\sin \Theta = \left[\frac{p^2 V_h^4}{V_v^2 - p^2 V_v^2 V_h^2 + p^2 V_h^4} \right]^{\frac{1}{2}} \quad (F-4)$$

and

$$\cos \Theta = [1 - \sin^2 \Theta]^{\frac{1}{2}} = \left[\frac{V_v^2 - p^2 V_v^2 V_h^2}{V_v^2 - p^2 V_v^2 V_h^2 + p^2 V_h^4} \right]^{\frac{1}{2}} \quad (F-5)$$

Inserting (F-4) and (F-5) in (F-2) gives $V(\Theta)$ in terms of V_v , V_h , and p :

$$V(\Theta) = [V_v^2 - p^2 V_v^2 V_h^2 + p^2 V_h^4]^{\frac{1}{2}} \quad (F-6)$$

Now,

$$\frac{dz}{dt} = \cos \Theta V(\Theta) \quad (F-7)$$

and

$$\frac{dx}{dz} = \tan \Theta \quad (F-8)$$

can be written as

and

$$dt = \frac{dz}{V_v(z) \sqrt{1 - p^2 V_h^2(z)}} \quad (F-9)$$

$$dx = \frac{p V_h^2(z)}{V_v(z) \sqrt{1 - p^2 V_h^2(z)}} \quad (F-10)$$

Thus, for a ray traversing a path from a depth $z=z_1$ to $z=z_2$,

and

$$t = \int_{z_1}^{z_2} \frac{ds}{V_v(s) \sqrt{1 - p^2 V_h^2(s)}} \quad (F-11)$$

$$x = p \int_{z_1}^{z_2} \frac{V_h^2(s) ds}{V_v(s) \sqrt{1 - p^2 V_h^2(s)}} \quad (F-12)$$

are the raypath integrals. This pair of integrals constitutes an implied relationship between x , t , and p .

A continuous log of the velocities $V_v(z)$ and $V_h(z)$ may be reduced from borehole measurements of travel times from surface shots if the following assumptions are valid:

1. Snell's Law for elliptically anisotropic media is satisfied.

2. $V_v(z)$ and $V_h(z)$ do not vary significantly in the x-direction.

Note that p is a continuous function of z , as each new sensor position implies a different Fermat path from a fixed shot station. Also, $p(z)$ will be independent of ξ in the raypath integrals shown below.

Given the preceding assumptions,

$$t(z) = \int_0^z \frac{d\xi}{V_v(\xi) \sqrt{1 - p^2(z) V_h^2(\xi)}} \quad (F-13)$$

and

$$x = p(z) \int_0^z \frac{V_h^2(\xi) d\xi}{V_v(\xi) \sqrt{1 - p^2(z) V_h^2(\xi)}} \quad (F-14)$$

are the parametric equations for a ray travelling from a shotpoint x ($\xi=0$) to a borehole sensor at a depth z . $p(z)$ must be eliminated between equations (F-13) and (F-14) in order to obtain a relationship between t , V_v , and V_h .

If x is constant, then

$$\frac{dx}{dz} = \left(\frac{\partial x}{\partial p} \right)_p + \left(\frac{\partial x}{\partial p} \right)_z \left(\frac{\partial p}{\partial z} \right) = 0$$

$$= \frac{p(z) V_h^2(z)}{V_v(z) \sqrt{1 - p^2(z) V_h^2(z)}} + \frac{dp}{dz} \left[\frac{\int_0^z \frac{V_h^2(\xi) d\xi}{V_v(\xi) \sqrt{1 - p^2(z) V_h^2(\xi)}} + p^2(z) \int_0^z \frac{V_h^2(\xi) d\xi}{V_v(\xi) [1 - p^2(z) V_h^2(\xi)]^{\frac{3}{2}}} \right];$$

$$\frac{dx}{dz} = \frac{p(z) V_h^2(z)}{V_v(z) \sqrt{1 - p^2(z) V_h^2(z)}} + \frac{dp}{dz} \int_0^z \frac{V_h^2(s) - p^2(z) V_h^4(s) + p^2(z) V_h^4(s)}{V_v(s) [1 - p^2(z) V_h^2(s)]^{3/2}} ds ;$$

$$\frac{dx}{dz} = \frac{p(z) V_h^2(z)}{V_v(z) \sqrt{1 - p^2(z) V_h^2(z)}} + \frac{dp}{dz} \int_0^z \frac{V_h^2(s) ds}{V_v(s) [1 - p^2(z) V_h^2(s)]^{3/2}} \quad (F-15)$$

Differentiating equation (F-13) gives:

$$\begin{aligned} \frac{dt}{dz} &= \left(\frac{\partial t}{\partial z} \right)_p + \left(\frac{\partial t}{\partial p} \right)_z \left(\frac{dp}{dz} \right) \\ &= \frac{1}{V_v(z) \sqrt{1 - p^2(z) V_h^2(z)}} + \frac{dp}{dz} \int_0^z \frac{p(z) V_h^2(s) ds}{V_v(s) [1 - p^2(z) V_h^2(s)]^{3/2}} ; \end{aligned}$$

$$\frac{dt}{dz} = \frac{1}{V_v(z) \sqrt{1 - p^2(z) V_h^2(z)}} + p(z) \int_0^z \frac{V_h^2(s) ds}{V_v(s) [1 - p^2(z) V_h^2(s)]^{3/2}} \quad (F-16)$$

Substituting (F-15) into (F-16) gives

$$\frac{dt}{dz} = \frac{1}{V_v(z) \sqrt{1 - p^2(z) V_h^2(z)}} - \frac{p^2(z) V_h^2(z)}{V_v(z) \sqrt{1 - p^2(z) V_h^2(z)}} ;$$

$$\frac{dt}{dz} = \frac{\sqrt{1 - p^2(z) V_h^2(z)}}{V_v^2(z)} . \quad (F-17)$$

Now, equation (F-17) is rearranged,

$$p^2(z) = \frac{1 - \left[V_v(z) \frac{dt}{dz} \right]^2}{V_h^2(z)} , \quad (F-18)$$

and substituted into equation (F-13), giving the well shoot integral for elliptically anisotropic media,

$$t(z) = \int_0^z \left\{ 1 - V_h^2(s) \left[\frac{1 - \left(\frac{dt}{dz} \right)^2 V_v^2(z)}{V_h^2(z)} \right] \right\}^{-\frac{1}{2}} \frac{ds}{V_v(s)} . \quad (F-19)$$

This integral equation--equation (23) in the text of this paper--may be solved numerically for $V_h(z)$ given $t(z)$ measured from a distant shot station and $V_v(z)$ determined from a vertical well shoot.

Plate I EXPLANATION

Terrain corrected Bouguer gravity
 100 (contour interval=1 mgal)
 extrapolated contour

Faults
 previously mapped (Nielson et al, 1978)
 tentative location

SW40 Gravity station
 NES Shot site
 34-3 Producing geothermal well
 32-2/ Non-producing well
 + Section corner

GEOHERMAL WELL 9-1
 AND VICINITY
 ROOSEVELT HOT SPRINGS KGRA
 BEAVER COUNTY, UTAH

38°30'
 112°52'30"

SCALE
 feet 0 500 1000 2000 3000 4000 5000
 meters 0 500 1000 1500

Tim Jenkinson
 May 1981

Plate II

LOG COMPOSITE OF
UTAH STATE
GEOTHERMAL WELL 9-1

TEMPERATURE, NEUTRON, & GEOLOGY LOGS
from Glenn, Hulen, and Nielson (1981)
VELOCITY (Jenkinson, 1981)