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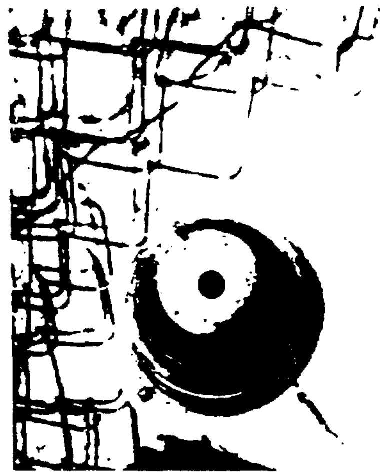

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IN SITU DETERMINATION OF STRESSES RAINIER MESA, NEVADA TEST SITE

REPORT

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RAINIER MESA,

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by

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COVER PHOTO:

Overcore in place, after stress relief in horizontal hole.

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Verne E. Hooker[1], James R. Aggson[2], and David L. Bickel[3]

ABSTRACT

Stress relief measurements were made in N tunnel (.07 by-pass) at the Nevada Test Site. The three-dimensional stress ellipsoid has been calculated from this data. The measurements were made at hole depths beyond the zone of tunnel opening influence; thus, calculated stresses are representative of in situ stress conditions.

The largest calculated principal stress is -1239 psi in a direction of N45°E. The vertical component of stress is in excellent agreement with estimates of the stress due to overburden. Calculated stresses are presented in two coordinate systems.

INTRODUCTION

This investigation was performed as part of a cooperative agreement between the U. S. Bureau of Mines and Special Projects branch of the U. S. Geological Survey.

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[3] Engineering Technician

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The determination of in situ stresses from stress-relief data has been significantly improved during the past few years. Relative measures of rock anisotropy are determined from the overcores and, if significant, included in the interpretation of results. Improved equipment and methods of overcoring have reduced time and cost for obtaining the necessary data to a minimum. Overcoring data are required from at least three holes of different orientations for a statistical stress ellipsoid determination. Subsequently one vertical and two horizontal holes were drilled near a site where measurements had been obtained by others several years previously. These data were obtained to provide a complete current determination of the state of stress and a measure of any significant changes of stress relative to earlier measurements.

The test site location is shown on the topographic map given in figure 1. The vertical depth to the test site, estimated from topographic surface contours, is 1250 feet. The drill holes and their orientations are shown in figure 2. Holes 2 and 3 were inclined 5 degrees upward to effect the release of drill water and cuttings during overcoring.

INSTRUMENTATION

Borehole deformations were measured with a three-component U. S. Bureau of Mines borehole gage (2)[4], using the techniques developed by the

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[4] Underlined numbers in parentheses refer to items in the list of references.

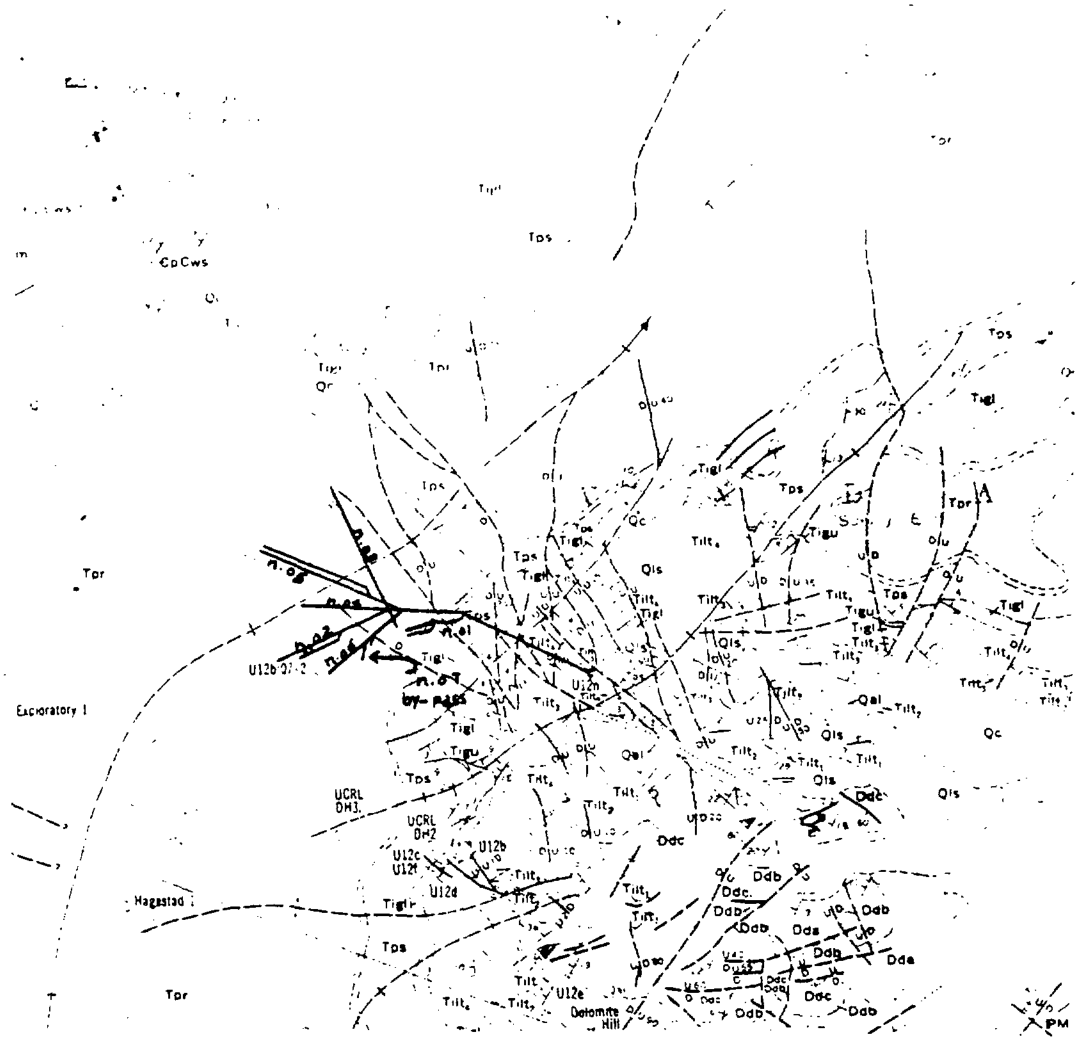

FIGURE 1.-Test Site Location

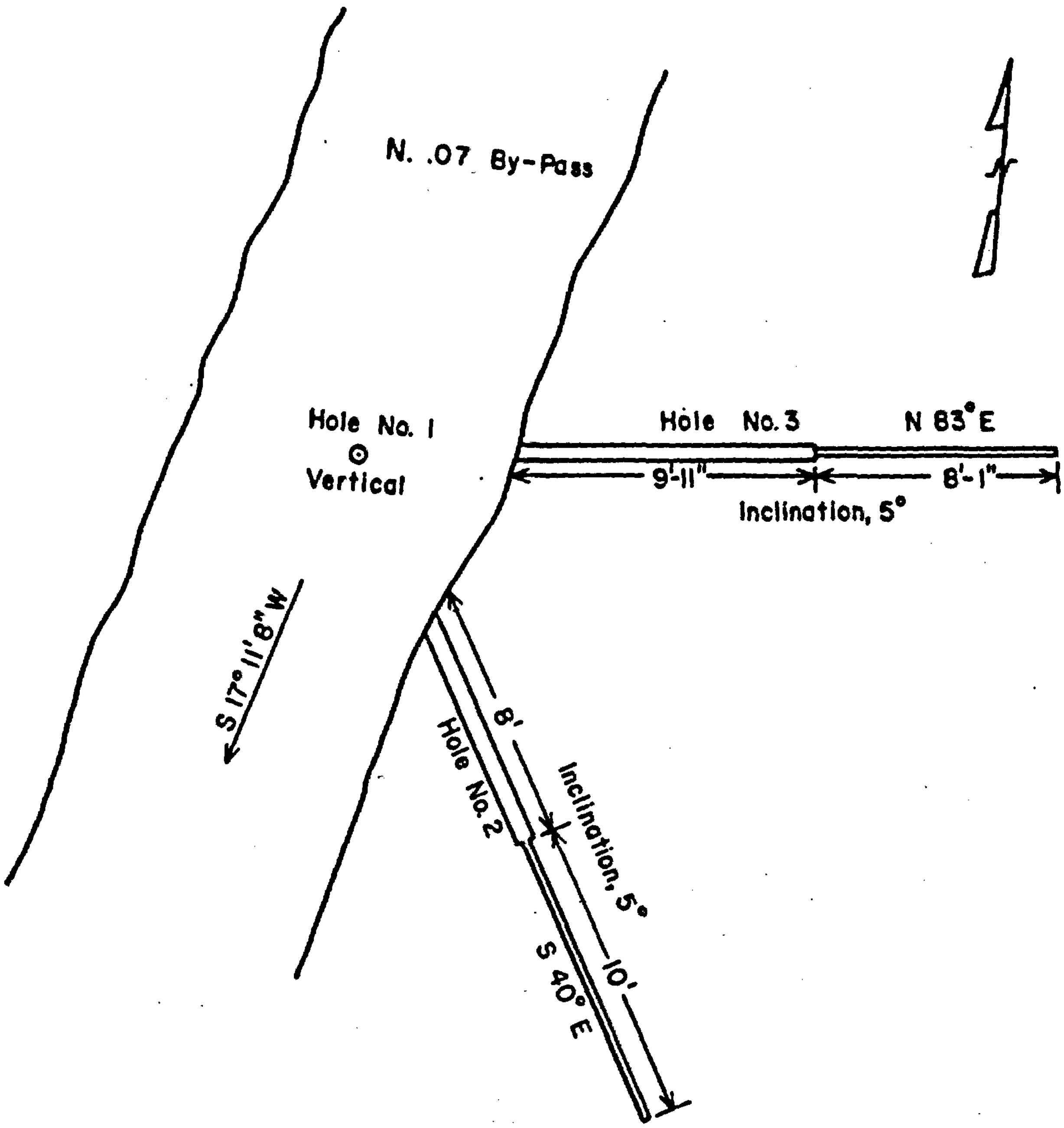

FIGURE 2.-Drill Hole Orientation

Bureau of Mines. Deformations were measured in a $1\frac{1}{2}$ inch diameter pilot gage hole as it was overcored with a 6 inch diameter overcoring bit. The readout sensitivity of the system for diametral deformations was one microinch. In order to continuously monitor the progress of overcoring, a separate strain indicator was used for each of the diametral elements. This procedure provides the maximum information for the interpretation of overcoring data.

EXPERIMENTAL RESULTS

The weight density, γ, of each overcore was obtained from weight-volume measurements. Static elastic constants, Young's modulus (E) and Poisson's ratio (ν), were obtained from representative overcores using triaxial testing procedures (1, 3). The results of the triaxial tests are presented in Table 1. The quantity, P_o, is the applied lateral pressure at which the constants were evaluated. Secant moduli were used for calculating stresses since these values more nearly represent conditions during overcoring. Tangent values are representative constants at a lateral pressure of P_o. Thus, tangent values represent in situ elastic constants.

TABLE 1. - Elastic constant determinations

Hole Number	γ lb/ft^3	P_o psi	Secant Modulus, E 10^6 psi	Secant ν	Tangent Modulus, E 10^6 psi	Tangent ν
1	102.7	1000	.911	.153	1.289	.178
2	97.3	1000	.582	.151	1.000	.169
3	83.9	500	.362	.195	.492	.201

A sample set of deformation data for a typical overcore is shown for the three different diameters as shown in figure 3. This particular relief was obtained in hole 5 at a hole depth of 16 feet 6 inches. The plane of measurement is at a distance of 9 inches (1½ diameters of the overcore) into the 1½-inch diameter gage hole. Overcoring proceeds to a distance of 9 inches beyond the plane of measurement. The observed difference in deformation at 0 and 18 inch overcore distances represents the deformation magnitudes from the applied stress. These are the values used for stress determinations.

The calculated stresses are given in Table 2. Three dimensional representations of the principal stress components are shown in figure 4. The normal and shear stress components for the rectangular coordinate system with Y aligned with north, X aligned with east and Z vertical are presented

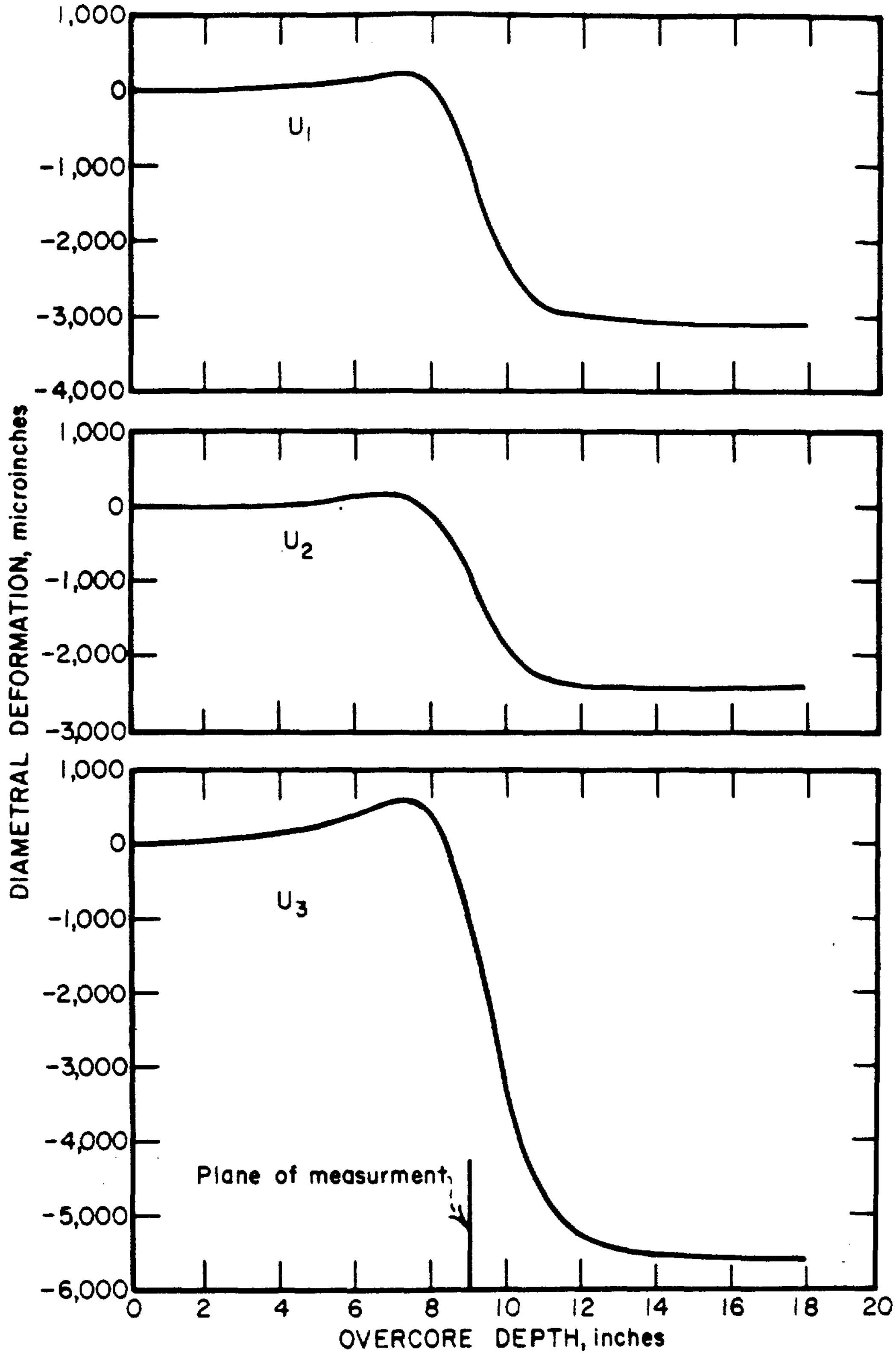

FIGURE 3.–Data for Three Diameters from Typical Overcoring Process

TABLE 2. - Stress Ellipsoid Calculations

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-STRESS ELLIPSOID CALCULATIONS-

NTS STRESS ELLIPSOID
39 DEFORMATION MEASUREMENTS

AVERAGE GROUND STRESS COMPONENTS WITH RESPECT TO THE X,Y,Z COORDINATE SYSTEM-
   SIGMA X =    -787 PSI      SIGMA Y =   -750 PSI      SIGMA Z =    -867 PSI
    TAU XY =    -422 PSI       TAU YZ =     83 PSI       TAU ZX =     106 PSI

PRECISION OF THE DATA-
   DEFORMATION SUM OF SQUARES                        =10.4464-004
   B1*G1 + B2*G2 + . . . + B6*G6                     =97.1656-005
   RESIDUAL SUM OF SQUARES                           =72.9882-006
   MULTIPLE CORRELATION COEFFICIENT SQUARED =           0.9301
   STANDARD DEVIATION OF THE FITTED DATA             =14.8720-004

STANDARD DEVIATIONS OF THE GROUND STRESS COMPONENTS-
   SD (X) =  141 PSI      SD (Y) =   61 PSI      SD (Z) =   56 PSI
   SD(XY) =   76 PSI      SD(YZ) =   37 PSI      SD(ZX) =   68 PSI

PRINCIPAL STRESSES S1, S2, AND S3 AND THEIR DIRECTIONS-
   S1 =   -345 PSI      BEARING = 136.0 DEG.      INCLINATION =  91.5 DEG.
   S2 =  -1239 PSI      BEARING = 226.6 DEG.      INCLINATION = 109.8 DEG.
   S3 =   -819 PSI      BEARING = 221.7 DEG.      INCLINATION =  19.9 DEG.

   STANDARD DEVIATION OF S1 =  133 PSI
   STANDARD DEVIATION OF S2 =   73 PSI
   STANDARD DEVIATION OF S3 =   64 PSI
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Note: A negative sign for principal stresses S1, S2, and S3 and secondary principal stresses σ_x, σ_y, and σ_z indicates compressive stress. A negative sign for shear stresses τ_{xy}, τ_{yz}, and τ_{zx} indicates the direction of the stress.

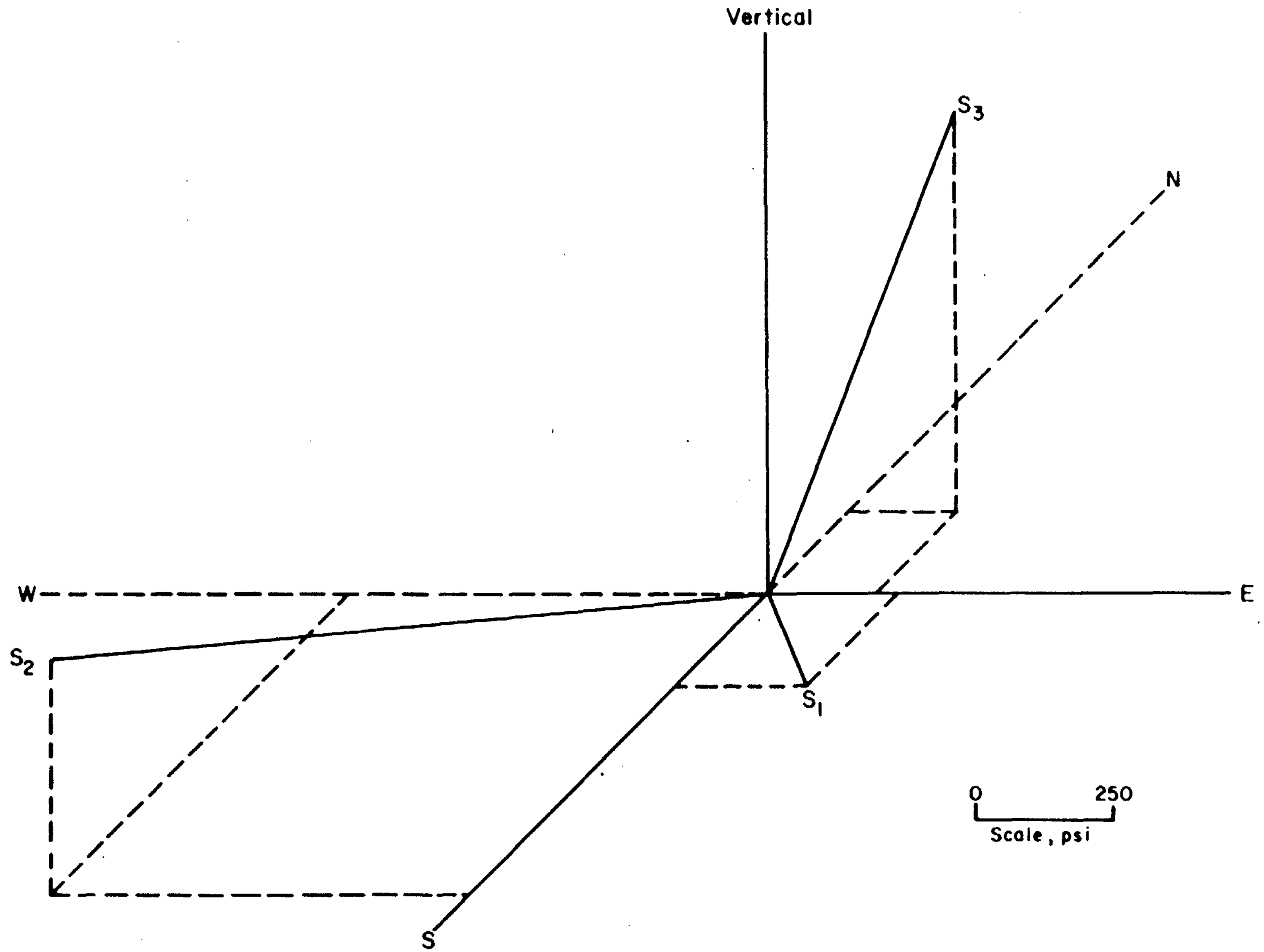

FIGURE 4.– Principal Stresses

in figure 5. For interpretation of principal stresses, S_1, S_2, and S_3 bearings are referenced using true north as 0° and increasing clockwise to 360°. Inclinations are referred to the vertical with down being 0° inclination and the horizontal being 90° inclination.

DISCUSSION OF RESULTS

The natural stress field at the test location is composed of both gravitational (due to the overburden of rock) and tectonic stresses. The vertical component of the stress field was measured to be -867 psi. The average weight density of the 1250 feet of overburden can be calculated from the measured vertical stress to be 99.9 lb/ft^3. The average weight density of the overcores that were tested triaxially after they were allowed to dry is 94.6 lb/ft^3.

The horizontal component of stress, S_h, due to overburden can be approximated from

$$S_h = \frac{\nu}{1-\nu}\sigma_z .$$

Using the static tangent Poisson's ratio the horizontal stress (due to overburden) is -194 psi. If the average horizontal ground stress $\left(\frac{\sigma_x + \sigma_y}{2}\right)$ is reduced by S_h, the remaining -575 psi is the average excess horizontal stress which is presumably of tectonic origin. The maximum excess horizontal tectonic stress in the largest principal stress (S_2) direction can be found by subtracting -194 psi from the horizontal component of S_2. The

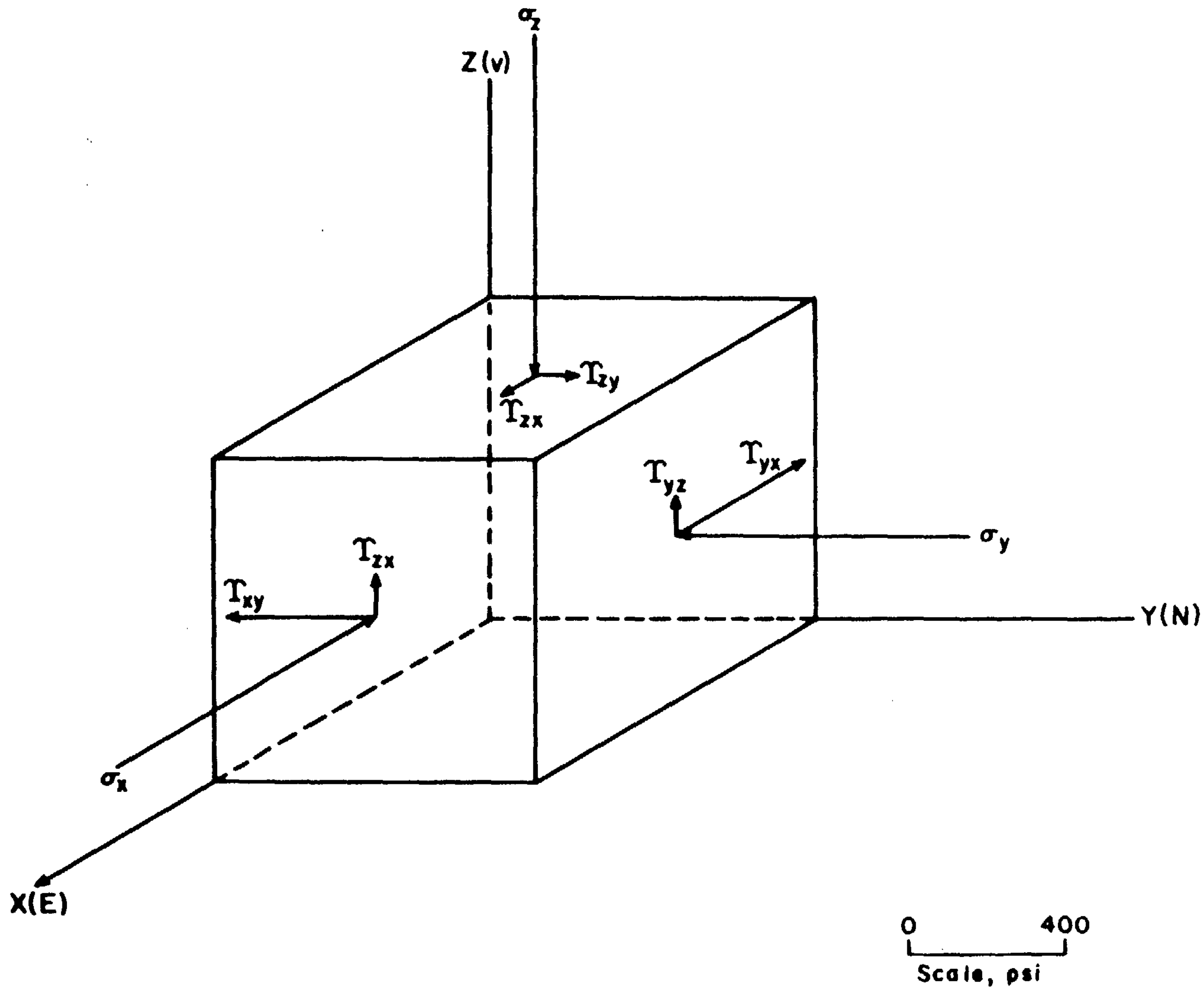

FIGURE 5.-Stress Components for X,Y,Z, Coordinate System

horizontal component of S_2 is -1166 psi. Therefore the maximum excess horizontal tectonic stress is -972 psi. The bearing of this stress is S46°W.

All overcores were tested biaxially (1). The ratios of biaxial anisotropy from each hole were used to calculate the directions and relative magnitudes of the 3 principal axes of anisotropic symmetry. These axes are shown in figure 6. E_L represents the direction of the largest Young's modulus. E_I represents the direction of the intermediate Young's modulus which is .86 x E_L. E_s represents the direction of the smallest Young's modulus which is .81 x E_L.

As can be seen by comparing Table 2 and figure 4, the largest principal stress -1239 psi, bearing 226.6° or S46.6°W conforms to the topological boundary of Rainier Mesa and parallels the axis of the plunging syncline through the mesa. The inclination of the largest principal stress is 109.8° or 19.8° above horizontal. This inclination indicates that this stress component is dipping with the syncline plunge shown in figure 1. The smallest principal stress -345 psi has a bearing of 136.0° or S44°E which is perpendicular to the topological boundary of Rainier Mesa. As this direction has the least confinement, one should expect to find the smallest horizontal compression in this direction. The inclination of this principal stress is only .7° from the horizontal.

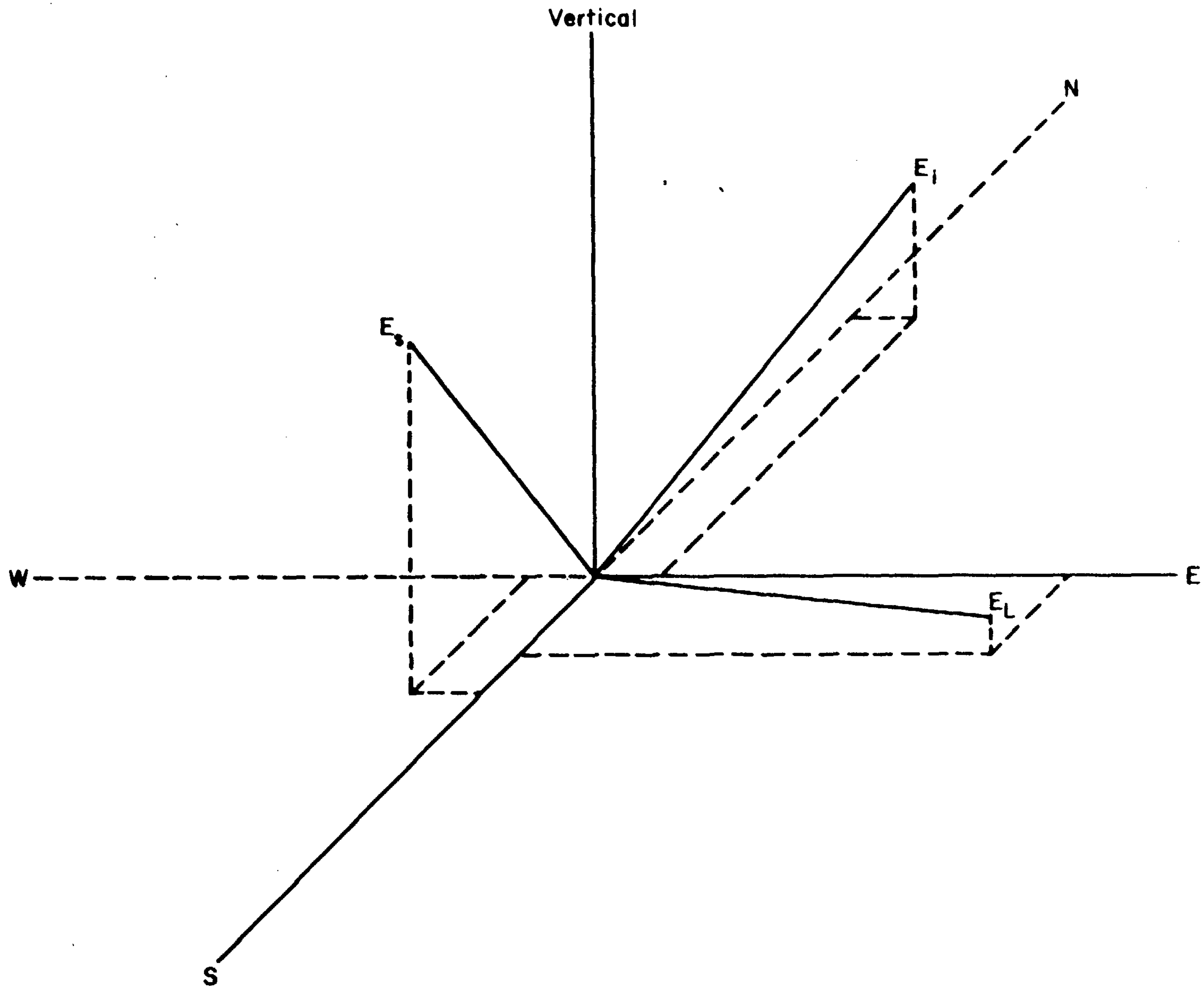

FIGURE 6.– Principal Axes of Anisotropy

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