EGG-NPR-10689
December 1991

GEOPHYSICAL INVESTIGATION
NEW PRODUCTION REACTOR COMPLEX
IDAHO NATIONAL ENGINEERING LABORATORY

by

F. P. Lipkowski, M. Blackey, D. Davies
E. N. Levine, and V. Murphy
Weston Geophysical Corporation
Westboro, MA 01581

Prepared for U.S. Department of Energy
Office of New Production Reactors
Under DOE Idaho Field Office
Contract No. DE-AC07-76ID01570

GEOPHYSICAL INVESTIGATION
NEW PRODUCTION REACTOR COMPLEX
IDAHO NATIONAL ENGINEERING LABORATORY

F. Filipkowski
M. Blackey
D. Davies
E.N. Levine
V. Murphy

Published December 1991

Weston Geophysical Corporation
Westboro, MA 01581

Prepared for EG & G Idaho, Inc.
Under Subcontract No. C91-103365-DCD-243-91

ABSTRACT

Seismic crosshole and downhole velocity measurements were performed for two borehole arrays approximately 300 feet deep in conjunction with verticality measurements and geophysical logging of borehole WO- 2 (to a depth of 4,960 feet) at the NPR site of the INEL under Task 2 of EG & G Subcontract No. C-91-103365. Past studies show that the site area is covered by a thin layer of soil which overlies numerous basalt flows interrupted by sandy and clayey interbeds.

Compressional and shear wave velocities computed for these arrays revealed low velocity zones at the following elevation ranges for crosshole array No. 1: 4,893 feet to 4873 feet (basalt rubble zone) and 4,705 feet to 4,686 feet (sediment interbed). Corresponding elevation ranges for crosshole array No. 2 include: 4,830 feet to 4,815 feet (sediment interbed), 4,785 feet to 4,765 feet (highly vesicular and fractured basalt), 4,715 feet to 4,705 feet (basalt rubble zone), and 4,672 feet to 4,667 feet (sediment interbed). In general, crosshole velocity data correlated between arrays with velocity differences possibly explained by localized lithologic changes. Due to scatter in the downhole velocity data, only velocity averages were computed. However, these downhole velocities correlated to the approximate mean crosshole velocity values and therefore independently confirmed the crosshole data.

Geophysical logging of well WO-2 included natural gamma, neutron, and compensated density logs to a depth of 4,960 feet at which a viscous borehole fluid inhibited further investigation. Second runs of small sections of these logs were repeated satisfactorily for confirmation of certain anomalous areas.

CONTENTS

FIGURES

TABLES

INTRODUCTION

Geophysical support services, provided by Weston Geophysical under subcontract C91-103365 for Task 2 of the FY91 work plan, consisted of geophysical surveys and measurements conducted at the New Production Reactor (NPR) site at the Idaho National Engineering Laboratory (INEL). These activities included: (a) borehole verticality measurements (performed by Strata Data, a Weston Geophysical subcontractor), (b) seismic crosshole measurements to a depth of approximately 300 feet, (c) seismic downhole measurements to a depth of approximately 300 feet, and (d) borehole geophysics performed (by Colog, Inc. under subcontract to Weston Geophysical) for deephole WO-2 to a depth of approximately 4,960 feet. This work was performed during the period of September 30 through October 18, 1991. The purpose of this investigation was to determine compressional and shear wave velocities which could be used to seismically identify and gage zones of weaker material such as sediment interbeds, and to use geophysical logging techniques to investigate deeper strata in borehole WO-2.

Methods of Investigation

Location and Survey Control

The general area of investigation and approximate location of the seismic survey area and deep hole WO-2 are shown on Figure 1. Borehole configurations for the two arrays designed for in-situ crosshole seismic measurements are illustrated on Figure 2. Horizontal and vertical survey control were provided by EG&G and are referenced to the Idaho State Grid and the National Geodetic Vertical Datum of 1929, respectively.

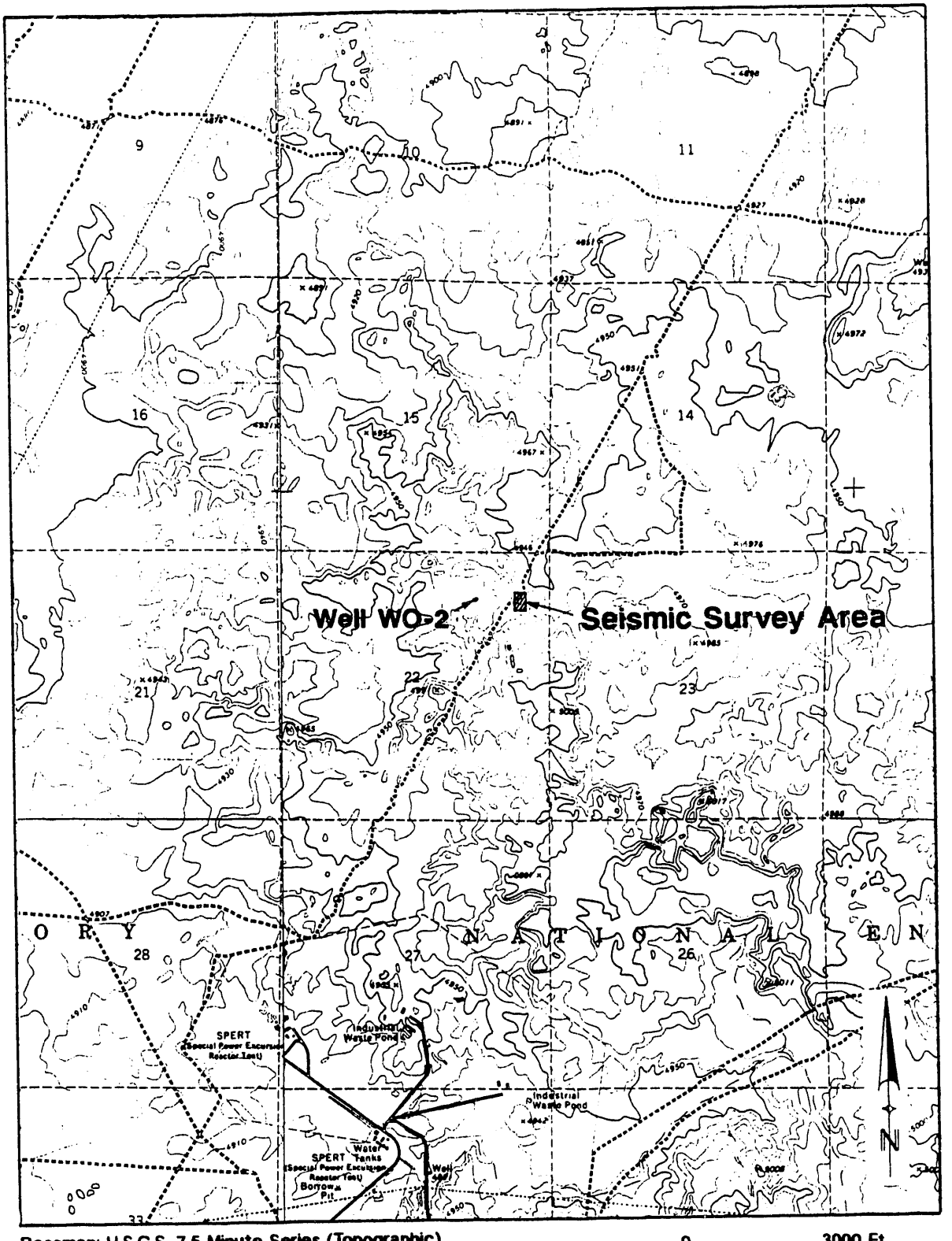


Figure 1. Area of investigation

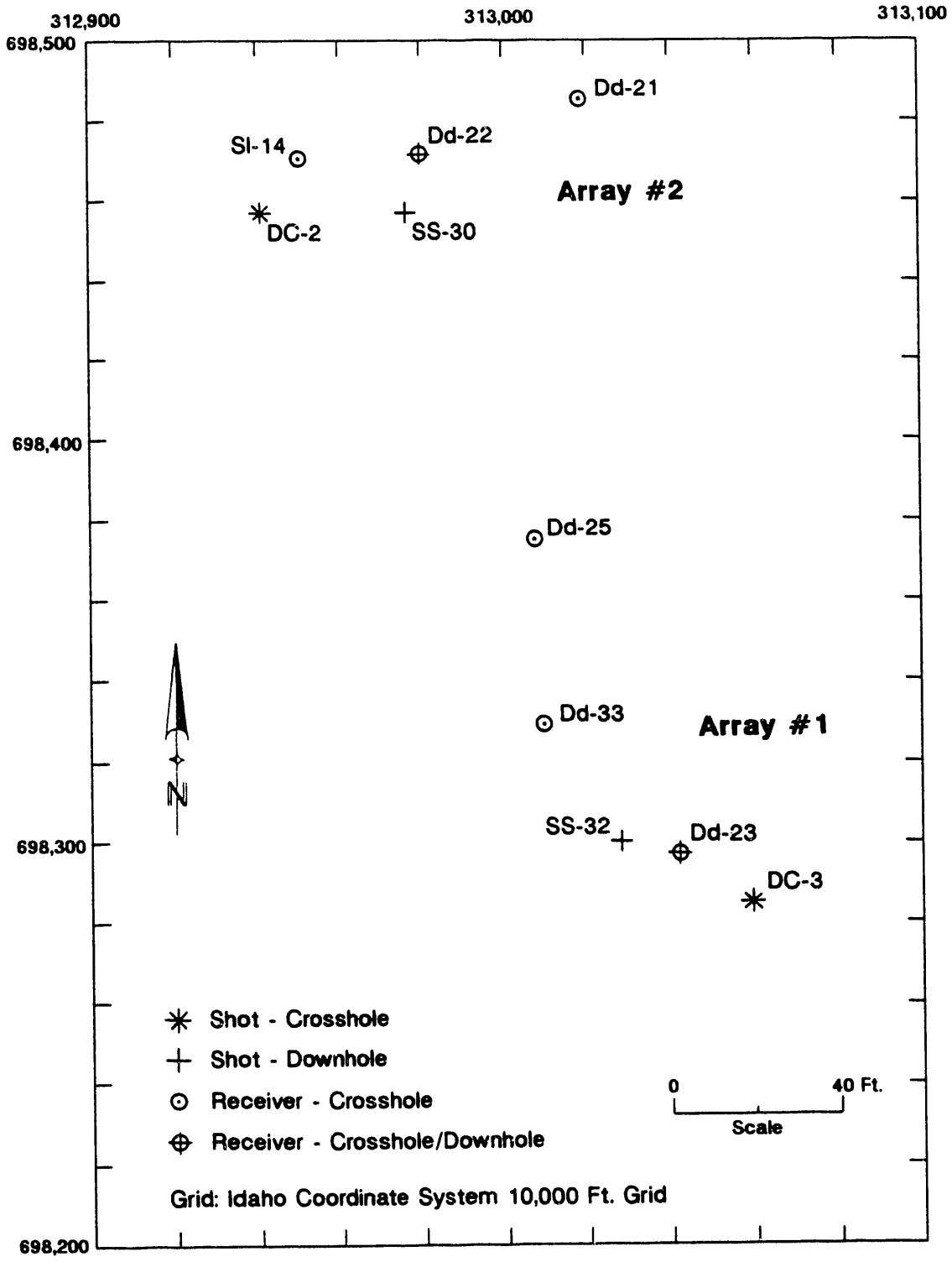


Figure 2. Borehole configurations for in-situ seismic surveys.

Borehole Verticality

The boreholes used for Task 2 geophysics (Figures 1 and 2) were as follows:

Crosshole Array No. 1 :	shot hole = Dc-3
	receiver holes = Dd-23, Dd-33, and Dd-25
Crosshole Array No. 2 :	shot hole = Dc-2
	receiver holes = SI-14, Dd-22, and Dd-21
Downhole Array No. 1 :	shot hole = SS-32
	receiver hole = Dd-23
Downhole Array No. 2 :	shot hole = SS-29
	receiver hole = Dd-22

Deep hole WO-2

Verticality measurements for all boreholes used for the crosshole program and the deep hole were provided by Strata Data. Boreholes SS- 29 and SS-32 were drilled specifically for use as shallow shot holes (approximately 15 feet deep) for the downhole program, thus rendering verticality measurements unnecessary. Verticality measurements were acquired every 25 feet for the seismic boreholes and every 100 feet for the deep hole to assure adequate sampling of borehole deviation. A discussion of the borehole verticality measurement program and borehole deviation plots are included in Appendix A.

Seismic Crosshole Survey

The seismic crosshole survey was performed using two arrays each consisting of four boreholes (three receiver holes and one shot hole), as shown on Figure 2. Velocity measurements were recorded with geophones containing three orthogonal components (one vertical and two horizontal). The boreholes were capped at the bottom and filled with water to assure good seismic energy and geophone coupling. Seismic wave energy was generated in the source borehole using Millidet zero delay blasting caps and Detaprime cap boosters.

Using pre-measured cables the explosive charge and geophones were lowered to common elevations (within one foot). The charge was detonated according to the stringent safety procedures enforced by an INEL blasting expert and seismic energy was recorded with a digital data acquisition system developed by Weston Geophysical. A sampling interval of 250 microseconds was employed to ensure adequate waveform resolution. Data were stored on hard disk and diskette with hardcopy printouts of the records accompanying the field notes.

In general, crosshole data were obtained every 10 feet. Gamma-gamma and lithologic logs made available by EG&G and Golder Associates Inc., for shot holes Dc-2 and Dc-3 respectively, enabled the Weston field geophysicist to identify interbed depths and reduce the recording interval to one to five feet within the interbeds. These logs were released as preliminary data unchecked and unreviewed but served as guidelines to plan the crosshole program. The lithologic logs were incorporated into Figures 3 and 4, which show the compressional and shear wave velocities computed for the crosshole arrays. An expanded discussion of the seismic crosshole method and data analysis is included in Appendix B.

Seismic Downhole Survey

The seismic downhole survey was performed using two arrays each consisting of two boreholes (one receiver hole and one shot hole per array) as shown on Figure 2. Initially, velocity measurements were attempted with a 12 hydrophone streamer. This instrumentation was lowered to the bottom of borehole SI-14 to be winched upwards in 50 foot intervals to assure one repeated record. However, the cable became snagged at a depth of approximately 230 feet. Although the streamer was retrieved it sustained severe damage and an alternate approach to acquire downhole data was used.

The alternate approach employed a three-component geophone positioned at 10 foot intervals with the shot depth fixed at 15 feet. As during the crosshole program, the boreholes were filled with water to provide geophone coupling and good seismic energy transmission. An additional geophone was positioned near the shot hole at the surface to monitor for spurious delays in data acquisition due to variable blasting cap delays. Further details of the seismic downhole method are listed in Appendix B.

Deephole Geophysical Logging

Geophysical logging was conducted in deephole WO-2 by Colog, Inc. under the supervision of Weston Geophysical. The logs consisted of natural gamma, neutron, and compensated density (gamma-gamma). The deephole was logged with these techniques to a depth of approximately 4,960 feet where viscous borehole fluid

inhibited further logging. Extended discussion and results of the geophysical logging performed in well WO-2 is included in Appendix C.

Results

Seismic crosshole velocity differences observed between the spatially close arrays and downhole data scatter may be caused by the complex lithology of the 300 foot section investigated. Previous studies show that a thin veneer of eolian deposits overlie numerous basalt flows which are sporadically interrupted by thin silty sand and clay interbeds. Weathering of the basalt varies from slight to extreme. Basalt vesicularity decreases from flow top to bottom and fractures are random throughout these strata. Water table is greater than 300 feet below ground surface.

Seismic Crosshole Survey

Seismic crosshole results are presented in Tables 1 and 2, with computed elastic moduli, and on Figures 3 and 4 as velocity profiles with lithologic logs. Tables 1 and 2 list compressional and shear wave velocities for each borehole array interval used to generate the velocity profiles shown on Figures 3 and 4. From these velocities dynamic elastic moduli were computed for each investigated depth interval. These moduli include Young's Modulus, Shear Modulus, Bulk Modulus, and Poisson's Ratio. The bulk densities provided by EG & G to compute elastic moduli were 1.90 and 2.44 grams per cubic centimeter (g/cc). A compressional wave velocity threshold of 8,000 ft/sec was selected to designate these densities for moduli computation. This velocity threshold is based on the minimum computed crosshole velocity which indicated "high velocity" strata. A density value of 1.90 g/cc was used for compressional wave

INEL Project
Elastic Moduli Calculations
December 20, 1991
Prepared by: D.M.Davies
Checked by: F.Filipkowski

TABLE 1

Array #1 (Hole DC-3)

Approx. Depth (ft)	Elevation (ft)	Density (gm/cc)	Average "P" Wave Velocity (ft/sec)	Average "S" Wave Velocity (ft/sec)	Poisson's Ratio	Young's Modulus (lbs/in2) (x10^4)	Shear Modulus (lbs/in2) (x10^4)	Bulk Modulus (lbs/in2) (x10^4)
10	4916	1.90	4000	2100	0.31	0.474	0.181	0.415
20	4906	1.90	4700	2400	0.32	0.625	0.236	0.591
30	4896	1.90	4500	2350	0.31	0.595	0.226	0.528
40	4886	1.90	2550	1025	0.40	0.121	0.043	0.209
50	4876	1.90	2400	1500	0.18	0.218	0.092	0.113
70	4856	1.90	4150	2350	0.26	0.573	0.226	0.404
80	4846	1.90	4250	2300	0.29	0.561	0.217	0.451
90	4836	1.90	5600	3200	0.26	1.056	0.420	0.726
95	4831	1.90	5800	2650	0.37	0.788	0.288	0.996
100	4826	1.90	6800	3150	0.36	1.110	0.407	1.354
105	4821	1.90	5800	3400	0.24	1.174	0.474	0.747
110	4816	1.90	5300	2700	0.32	0.792	0.299	0.753
120	4806	1.90	4650	2700	0.25	0.745	0.299	0.488
125	4801	1.90	3900	2250	0.25	0.519	0.208	0.347
130	4796	1.90	4850	2500	0.32	0.676	0.256	0.623
140	4786	1.90	4800	2650	0.28	0.738	0.288	0.561
150	4776	1.90	4800	2500	0.31	0.674	0.256	0.603
160	4766	1.90	4300	2450	0.26	0.620	0.246	0.430
170	4756	1.90	4800	2850	0.23	0.818	0.333	0.501
180	4746	1.90	7750	4250	0.28	1.904	0.741	1.475
190	4736	2.44	9900	4700	0.35	3.152	1.163	3.611
210	4716	1.90	6800	3400	0.33	1.264	0.474	1.264
220	4706	1.90	5550	2750	0.34	0.829	0.310	0.850
225	4701	1.90	4150	2150	0.32	0.499	0.190	0.454
230	4696	1.90	3600	1850	0.32	0.371	0.140	0.344
235	4691	1.90	1500	900	0.22	0.081	0.033	0.048
240	4686	1.90	2600	1400	0.30	0.208	0.080	0.170
250	4676	2.44	12150	4550	0.42	3.093	1.090	6.321
255	4671	2.44	12000	4700	0.41	3.279	1.163	6.033
260	4666	2.44	13150	5450	0.40	4.368	1.564	7.021
280	4646	2.44	11300	5600	0.34	4.417	1.652	4.523
290	4636	2.44	10100	5500	0.29	4.108	1.593	3.248
300	4626	2.44	10950	5200	0.35	3.858	1.424	4.416

TABLE 2

Array #2 (Hole DC-2)

Approx. Depth (ft)	Elevation (ft)	Density (gm/cc)	Average "P" Wave Velocity (ft/sec)	Average "S" Wave Velocity (ft/sec)	Poisson's Ratio	Young's Modulus (lbs/in2) (x10^4)	Shear Modulus (lbs/in2) (x10^4)	Bulk Modulus
15	4909	1.90	4300	2950	0.06	0.753	0.357	0.282
20	4904	1.90	6700	3300	0.34	1.197	0.447	1.245
30	4894	1.90	7900	3050	0.41	1.078	0.381	2.051
40	4884	2.44	8200	3200	0.41	1.521	0.539	2.822
45	4879	2.44	8600	2800	0.44	1.190	0.413	3.345
60	4864	1.90	7300	3200	0.38	1.160	0.420	1.625
70	4854	2.44	9500	4500	0.36	2.891	1.066	3.331
80	4844	2.44	9100	3700	0.40	2.020	0.721	3.400
90	4834	1.90	6350	2850	0.37	0.915	0.333	1.209
95	4829	1.90	3550	1700	0.35	0.320	0.119	0.359
100	4824	1.90	3250	2050	0.17	0.403	0.172	0.203
103	4821	1.90	1950	950	0.34	0.100	0.037	0.107
105	4819	1.90	2750	1700	0.19	0.282	0.119	0.152
120	4804	1.90	6200	3000	0.35	0.994	0.369	1.084
130	4794	2.44	8100	3950	0.34	2.209	0.822	2.360
140	4784	1.90	3650	2350	0.15	0.519	0.226	0.244
150	4774	1.90	3800	2400	0.17	0.552	0.236	0.277
170	4764	2.44	9450	4550	0.35	2.942	1.090	3.249
180	4754	2.44	9400	3600	0.41	1.930	0.683	3.743
190	4744	2.44	10500	4250	0.40	2.667	0.951	4.538
200	4734	2.44	10650	4400	0.40	2.849	1.020	4.614
210	4714	1.90	3250	1450	0.38	0.237	0.086	0.318
220	4704	1.90	3850	2200	0.26	0.499	0.198	0.343
225	4699	1.90	5800	2450	0.39	0.685	0.246	1.051
230	4694	1.90	5950	3250	0.29	1.115	0.433	0.874
235	4689	2.44	8300	3500	0.39	1.796	0.645	2.768
240	4684	2.44	12500	5700	0.37	4.684	1.711	5.947
245	4679	2.44	13000	6800	0.31	6.388	2.435	5.653
250	4674	2.44	10400	4650	0.38	3.132	1.139	4.178
253	4671	2.44	10700	4100	0.41	2.504	0.885	4.849
255	4669	1.90	3150	2000	0.16	0.381	0.164	0.188
256	4668	1.90	3600	1750	0.35	0.338	0.126	0.364
260	4664	2.44	13200	5700	0.39	4.741	1.711	6.895
270	4654	2.44	12000	6250	0.31	5.406	2.057	4.841
280	4644	2.44	9200	4250	0.36	2.596	0.951	3.189
290	4634	2.44	8300	5100	0.20	3.279	1.370	1.802
296	4628	2.44	8200	4200	0.32	2.457	0.929	2.303
300	4624	2.44	7850	4650	0.23	2.801	1.139	1.727

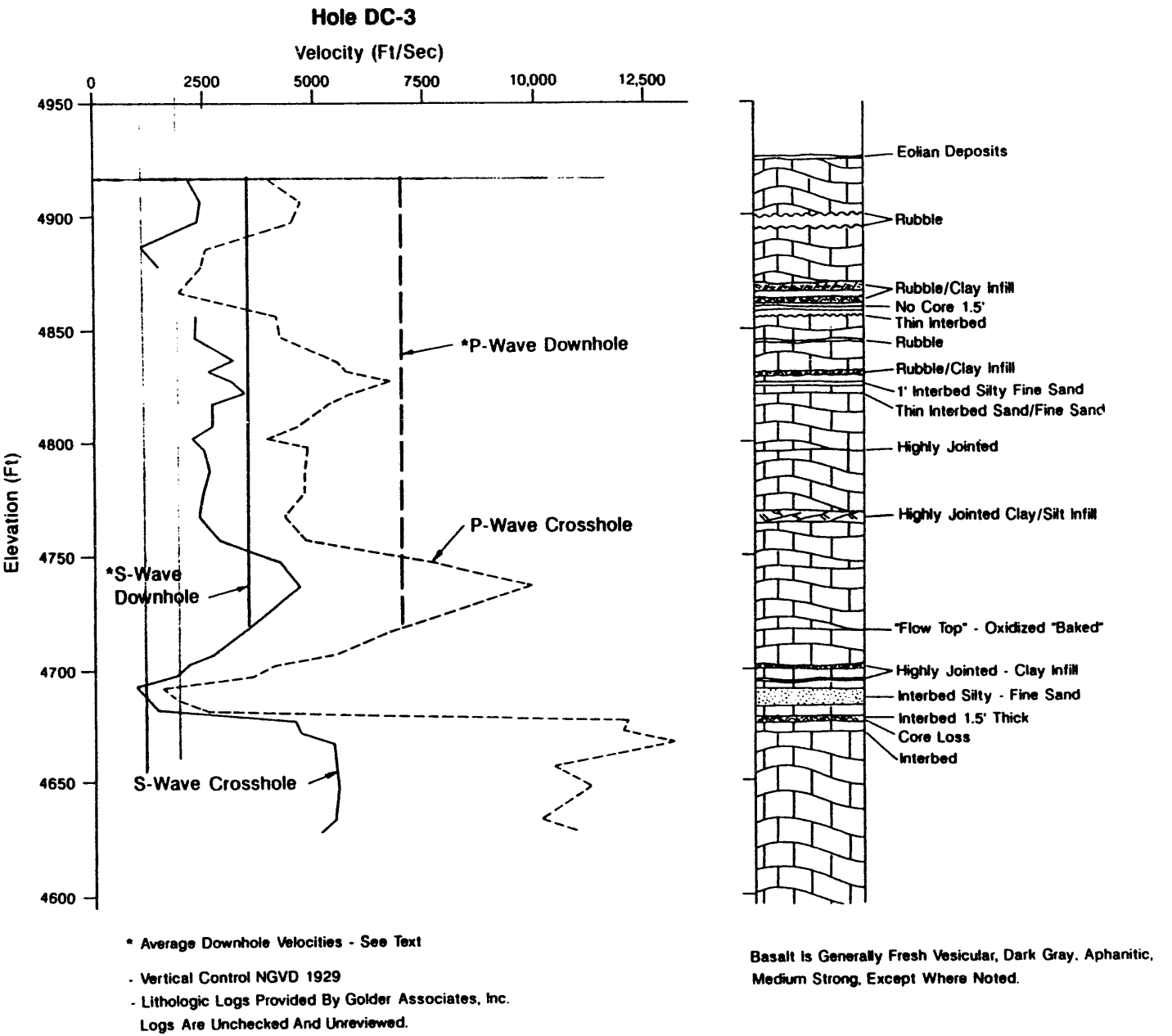


Figure 3. In-situ velocity profiles and lithologic log for Array #1 (Hole DC-3)

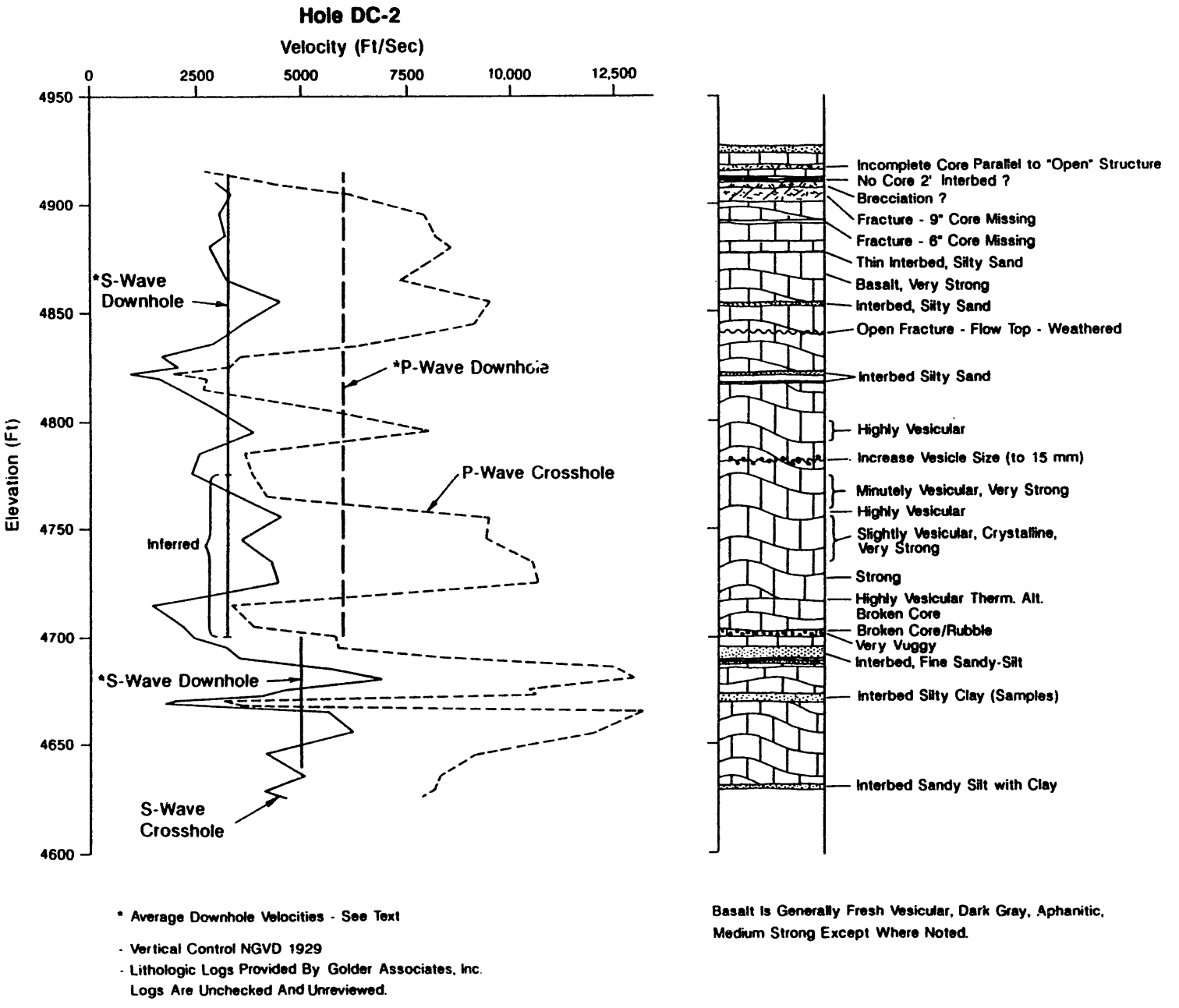


Figure 4. In-situ velocity profiles and lithologic log for Array #2 (Hole DC-2)

velocities under 8,000 ft/sec and a density of 2.44 g/cc was employed for those velocities greater than or equal to 8,000 ft/sec.

Using seismic velocities alone, materials can be placed into broad classifications. Seismic velocity values do not have unique material correlations, but based on available boring information and Weston Geophysical's experience the compressional velocities listed in Tables 1 and 2, and shown on Figures 3 and 4, are likely to correspond with materials listed below:

Compressional Velocity (ft/sec)	Material Correlation
1,500-3,600	Silty sand or silty clay interbed or highly weathered and fractured basalt.
3,600-13,200	Highly weathered, vesicular, and fractured basalt (3,600) to slightly weathered, aphanitic basalt with minor fracturing (13,200).

In general, there is good correlation of crosshole velocities to lithology as shown on Figures 3 and 4. Anomalously lower crosshole velocities were computed for depths approximately correlating to sediment interbeds and zones of highly fractured basalt. Sediment interbeds and these basalt "rubble" zones were seismically identifiable for layer thicknesses greater than approximately three feet. Crosshole velocities are lowest at or near the logged depth of identifiable sediment interbeds with velocities gradually increasing for depth intervals immediately above or below these strata. However, velocity changes for depth intervals abutting a low velocity basalt rubble zone appear to be much more abrupt.

Compressional and shear wave velocities computed for Crosshole Array No. 1 were significantly low between elevations ranging from 4,893 feet to 4,873 feet and 4,705 feet to 4,686 feet. These ranges approximately correlate to a basalt rubble zone and a silty sand interbed, respectively. The highest crosshole velocities measured at Array No. 1 were at elevations ranging from about 4,682 feet to approximately 4,635 feet. Lithology for this depth range shows basalt with very minor weathering and fracturing.

Four low velocity zones were identified for Crosshole Array No. 2. These zones are located at elevations ranging from 4,830 feet to 4,815 feet, 4,785 feet to 4,765 feet, 4,715 feet to 4,705 feet, and 4,672 feet to 4,667 feet. Lithology within these zones indicate, respectively: a sediment interbed, highly vesicular basalt with healed fractures, small basalt rubble zones, and another sediment interbed.

Spatially, the two crosshole arrays are a minimum of approximately 80 feet apart. In general, velocity peaks and troughs correlate between these arrays. Any velocity differences between arrays may be explained by localized velocity variations which could be generated by the complex lithology of the depth section investigated.

Seismic Downhole Survey

Results from the seismic downhole survey are illustrated on Figures 3 and 4. Average compressional and shear wave velocities were computed for each downhole array for most of the depth sections. No downhole interval velocities were calculated due to scatter in arrival times which may have been caused by inhomogeneities in the strata. One example of an inhomogeneity would be velocity inversions experienced

when seismic energy propagates downward through basalt into sediment. This effect is minimized during a crosshole program which utilizes direct seismic arrivals recorded from energy propagating laterally through material at an approximately constant depth. Therefore, crosshole velocities computed at regular intervals for Array Nos. 1 and 2 better define the strata seismically than the downhole data. The average computed downhole velocities serve as an independent check on the calculated crosshole velocities.

Average compressional and shear wave velocities calculated for Downhole Array No. 1 are 7,000 ft/sec and 3,500 ft/sec from ground surface to an elevation of 4,720 feet. Downhole data below this elevation were inconclusive due to considerable scatter of arrival times. These downhole velocities correspond to the approximate median of their counterpart crosshole velocities.

For Array No. 2, average velocities of 6,000 ft/sec for compressional waves and 3,250 ft/sec for shear waves are observed from ground surface to an elevation of 4,700 feet. Due to scatter in arrival times, the compressional wave velocity could not be determined below level 4,700 and the shear wave velocity is inferred from elevations ranging from 4,775 feet to 4,700 feet. An average shear wave velocity of 5,000 ft/sec was computed for elevations ranging from 4,700 feet to 4,640 feet and is interpreted to represent more competent strata. The average downhole velocities approximately correlate to median crosshole velocity over the previously mentioned elevation ranges. In addition, a compressional wave velocity of 6,000 ft/sec for Array No. 2 agrees within 1,000 ft/sec to the maximum velocity observed on downhole records collected independently and submitted to Weston Geophysical by EG&G.

APPENDIX A

BOREHOLE VERTICALITY

STRATA DATA, INC.
GYROSCOPIC DIRECTIONAL SURVEY - OPERATING PROCEDURE

TABLE OF CONTENTS

CHECKLIST - EQUIPMENT & SUPPLIES:

A) Running Gear.

1) 3 piece protective case (Includes instrument housing with swivel sub and 2 piece battery barrel).

2) Control sub (Including gyro housing for 3 inch).

3) Stabilizer guides with rubber fingers.

4) 2 Correctly sized centralizers with allen screws (For inside casing. Must be stout if in high angle).

5) 2 Stop collars with extra screws.

6) Allen wrench.

7) Top sub with 1" GOI connection.

8) Rope socket (Used only when running on sandline).

9) Landing plate with (4) legs.

10) Cavins counter with ears and bolts (For sandline).

11) Sinker bars (For checking for obstructions if running in open hole).

12) Optional - Battery spacer bar (Voltage regulator back up).

13) "D" size batteries (Enough for at least 2 runs).

14) Correct O-Rings for tool being used (Extras also).

15) Lubricant for O-Rings.

16) Emery cloth.

17) Rags.

If running single shots include:

1) Muleshoe stinger with lock ring.

2) Impression pins (Tattletales).

If running on land include:

1) Brunton compass.
2) Compass mount.
3) Non-magnetic tripod.
4) Lath stake or equivalent for reference.

If running single shots include:

1) Single Shot camera with light stop.
2) Timers.
3) Film loaders.
4) Developing tank.
5) Film Reader.

ODOMETER CALIBRATION CHECK:

As a check on the accuracy of the wireline odometer, the following calibration check shall be performed at the start and upon completion of fieldwork, and shall be so documented (see Attachment 1):

1) Reel off an amount of line such that the odometer indicates 100 feet.
2) Measure the length of line reeled off with a calibrated tape.
3) The odometer shall agree to within ± one foot of the measured line length.

NOTE: When surveying angle holes (more than 10° from vertical) the gyro must be oriented either in the direction of the hole angle, or 180° away from the hole direction. If it is not possible to set a stake to sight on in either direction, an oriented or surveyed stake or landmark must be used for the Benchmark shot, and some other object in the proper direction relative to the hole direction will be used to orient the gyro. The correct gyro orientation direction can then be calculated from the angle between the orientation shots and the benchmark shot.

2. Find a convenient spot at least 25 feet out and away from the rig and/or other metal objects where you can set up the compass on its stand so that it can readily be seen from the well. (CAUTION: If a rig is on the hole and they are going to be pulling pipe, don't set up your stake where the pipe would hide it after they trip out.)

3. Open the compass with the rear pointer and the mirror half at approximately 135° from the compass face. Use the circular bubble to level the compass. With the mirror away from you so that you can see your reflection, orient the compass by sighting through the peep sights to the well. Read the direction where the white or North end of the needle is pointing; for

RUNNING THE SURVEY:

When you are ready to run the survey, attach the landing plate to the control sub and lower the battery barrel into the hole until the landing plate rests on the top of the pipe. If conditions warrant, (4) legs can be screwed into the landing plate to support it above the ground or other stable surface. Attach the scope to the control sub and aim it at your reference point, using the inspection mirror if necessary. After the gyro has warmed-up, place it on the control sub and turn the switch ON. Listen to the gyro. It should sound like it is speeding up. Check voltage and current. Current should be reading about 300 M.A., voltage about 28 V. (Initially, current will be somewhat greater). Using the handle on the scope, rotate the tool to zero the gyro. With one hand on the gyro, cage it and observe that the "0" on the outer scale (called the primary index) is on the opposite side of the gyro as the reference point. The North on the gyro should line up with the primary index. Carefully and slowly turn the tool until the scope is again aimed at the reference point. Uncage and cover the gyro. Assemble the multishot camera and, after several timing sequences, obtain first flash and start stopwatches. Very carefully lower the protective barrel until it is even with the landing plate or the top of the stand, but not directly over the gyro. Then lock the brake on the wireline unit. Recheck the scope alignment and if necessary cage, carefully turn, then uncage the gyro so that it will again be oriented to the reference stake. Give the gyro a moment to settle to make sure the rotor is level.

Pull down on the line to lift the instrument slightly, then remove the stand or landing plate. If running in casing, be sure all B.O.P.s are open. Gyro surveys are generally taken 100 feet apart. On platforms they are 50 feet apart for the first 1,000 feet. On long surveys, stations may be further apart. Drift checks should not be more than 20 minutes apart and should last at least 5 minutes. Record first and last pictures of each drift check on the "surface time" column of the work sheet. Take the first survey picture with the tool just completely in the hole (5 to 15 feet). The instrument should not be raised or lowered at more than 250 feet per minute. Starts and stops should be smooth and easy. Constantly check the line speed to keep from running too fast, Beware of starting too quickly, or jerking to a stop. If instrument is stopped within 5 feet of the survey depth it is better to take the survey there than to move it. Continue running survey to bottom depth. On longer surveys it is generally a good idea to take a drift check on bottom unless excessive temperature is a variable. This is because the gyro may drift differently coming out of the hole. You should know where your bottom survey will be ahead of the time so you don't hit bottom. More often than not, due to contaminated mud, excessive cement in column, etc.., it's necessary to reduce line speed considerably when traversing near bottom. When total depth is requested by customer, it's good practice to gently tag bottom, then pull up several feet for bottom shot. This will eliminate erroneous readings of drift angle on bottom. Unless requested by customer, <u>never traverse into open hole.</u> After your bottom picture, usually with drift check, pull the

direction of drift. Check the voltage and current through the control sub and if possible, observe that the rotor is level (the design of some gyros does not permit viewing the spin motor). Turn off the power switch. Cover the gyro with a plastic bag, remove it from the control sub, and set it on the warm-up box. Zero and cage the gyro and turn the box off. The warm-up box should remain stationary for a minimum of 10 minutes. Record ending drift along with the last flash on the work sheet. After the gyro has "spun-down", store in a safe place. Develop the film in the usual manner. Wash it and let it dry. You are now ready to read and calculate the survey.

STRATA DATA, INC.
2080 FAIRGROUNDS RD., NO. 6 - P.O. BOX 4895
CASPER, WY 82604 (307) 265-7510
ELKO, NV 89801 - P.O. BOX 70 (702) 738-5579

GYROSCOPIC DIRECTIONAL SURVEY

DATE: 10/1/91 S.O. #: 5198F

FOR: WESTON GEOPHYSICAL CORPORATION
LYONS STREET
BOX 550
WESTBORO, MA 01581-0550

REFERENCE HOLE NO.: DD-3
REFERENCE HOLE COORDS.: 698297.00' N. & 313043.00' E.

CLOSURE - ZERO COORD.: 1.00 @ N69°35'W (350.65°)
COLLAR COORD.: 765282.00 @ N24°09'E

FLUID LEVEL - N/A
TIME - 14:30

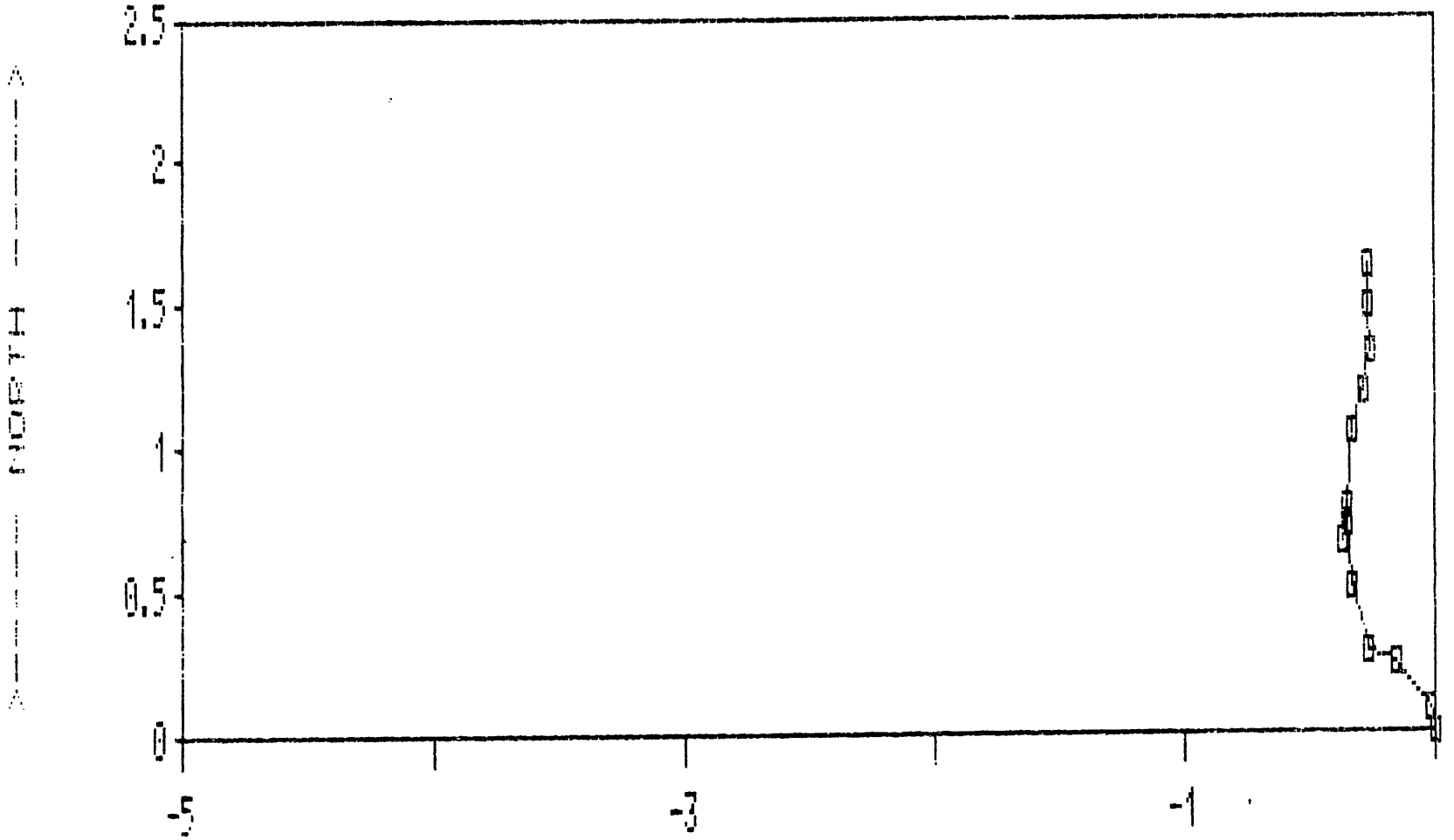
COMP. METHOD: BALANCED CURVATURE
PROJECT WGC NO. 18552-02
HOLE NO. DD-3
AREA INCL/NPR
COUNTY BUTTE
STATE IDAHO
LOCATION 698285.00' N. & 313060.00' E.
ELEVATION N/A
MAG. DECL. 15 DEG. E.
REF. HOLE AZIMUTH 315.12°
T.D. - DRILLER 399
T.D. - LOGGER 381
MAXIMUM TEMP. N/A
TRUCK NO. 102
ENGINEER WEIKUM, McDONALD

Meas. Depth	Direction Azimuth	Bearing	Incl.	Disp.	Dog-leg	### ZERO COORDINATES: ## TVD	North	East	##### COLLAR COORDINATES ##### TVD	North	East
0.0	100	S80E	0.18	0.00	0.0	0.00	0.00	0.00	NA	698285.00	313060.00
25.0	327	N33W	0.55	0.09	2.7	25.00	0.09	-0.02	NA	698285.09	313059.98
50.0	305	N55W	0.41	0.29	0.9	50.00	0.24	-0.16	NA	698285.24	313059.84
75.0	216	S86W	0.16	0.40	1.2	75.00	0.28	-0.22	NA	698285.28	313059.78
100.0	353	N07W	0.95	0.60	4.0	100.00	0.50	-0.32	NA	698285.50	313059.67
125.0	74	N74E	0.02	0.80	3.9	124.99	0.72	-0.35	NA	698285.72	313059.65
150.0	198	S18W	0.26	0.76	1.2	149.99	0.66	-0.37	NA	698285.66	313059.63
175.0	12	N12E	0.84	0.96	4.5	174.99	0.79	-0.35	NA	698285.79	313059.65
200.0	344	N16W	0.30	1.09	2.3	199.99	1.04	-0.37	NA	698286.04	313059.63
225.0	34	N34E	0.45	1.22	1.4	224.99	1.19	-0.25	NA	698286.19	313059.75
250.0	344	N16W	0.31	1.36	1.4	249.99	1.33	-0.25	NA	698286.33	313059.75
275.0	4	N04E	0.47	1.51	0.7	274.99	1.48	-0.25	NA	698286.48	313059.75
299.0	15o	N04W	0.7[illegible]	1.66	2.4	298.99	1.64	-0.27	NA	698286.64	313059.73

Data entered and computed 10/3/91

Checked 10/3/91

STRATA DATA GYRO DIRECTIONAL SURVEY
WESTON GEOPHYSICAL CORP. - HOLE # DC-3



□ 25 FT. STATIONS

STRATA DATA, INC.
2060 FAIRGROUNDS RD., NO. B - P.O. BOX 4599
CASPER, WY 82604 (307) 265-7717
ELKO, NV 89801 - P.O. BOX 70 (702) 738-5579

GYROSCOPIC DIRECTIONAL SURVEY

DATE: 10/1/91 S.O. #: 51986

FOR: WESTON GEOPHYSICAL CORPORATION
LYONS STREET
BOX 550
WESTBORO, MA 01581-0550

REFERENCE HOLE NO.: N/A
REFERENCE HOLE COORDS.: N/A

CLOSURE - ZERO COORD.: 2.81' @ S45°49'E (130.82')
COLLAR COORD.: 765253.80' @ N24°09'E

FLUID LEVEL - N/A
TIME - 15:30

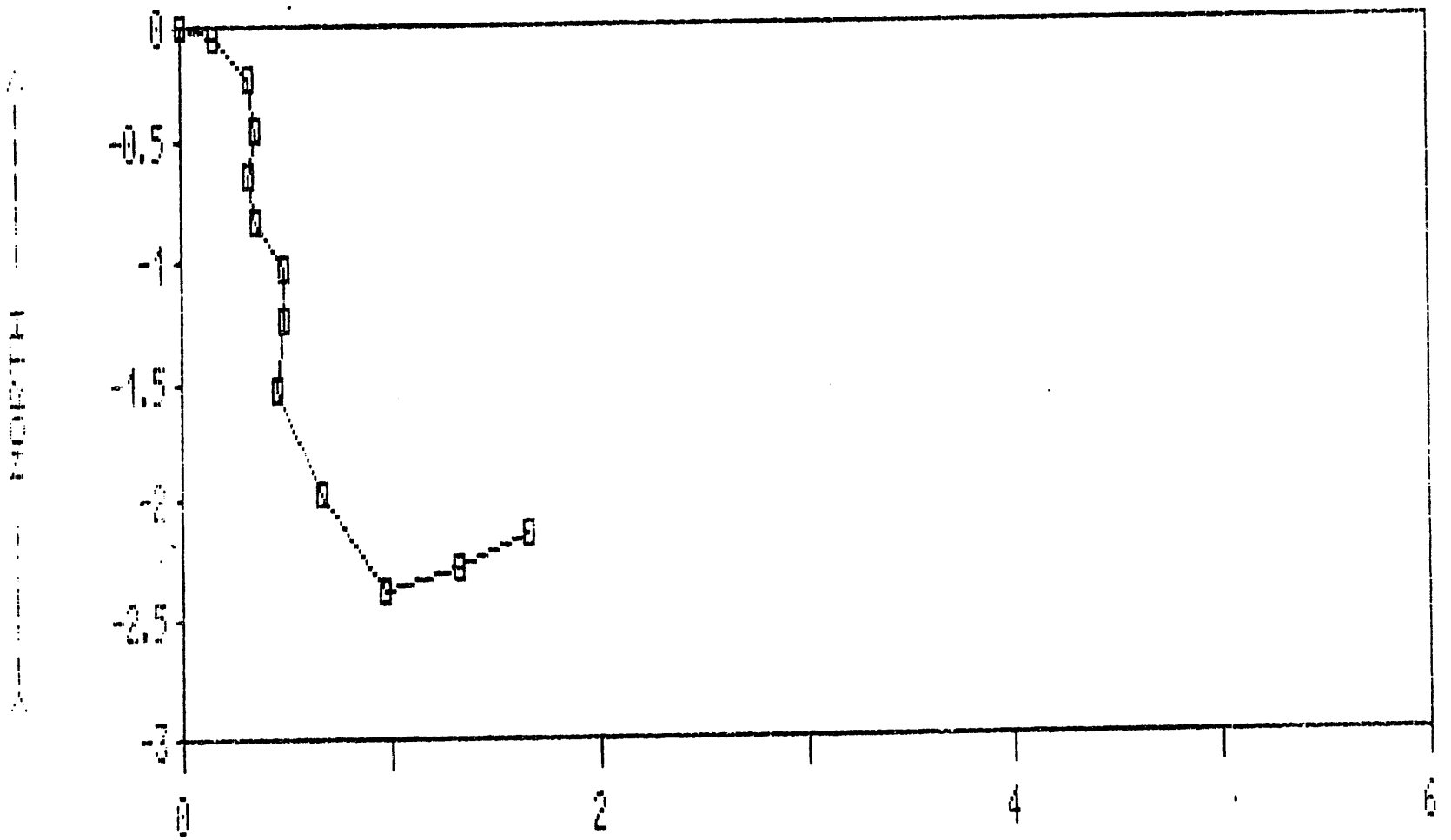
COMP. METHOD: BALANCED CURVATURE
PROJECT WGI NO. 19550-02
HOLE NO. II-27
AREA INEL/NPR
COUNTY BUTTE
STATE IDAHO
LOCATION 698297.00' N. & 313047.00' E.
ELEVATION N/A
MAG. DECL. 15 DEG. E.
REF. HOLE AZIMUTH N/A
T.D. - DRILLER 310
T.D. - LOGGER 283
MAXIMUM TEMP. N/A
TOOL NO. 112
ENGINEER WEIKUM, YODONALL

Meas. Depth	Direction Azimuth	Bearing	Incl.	Disp.	Dog-leg	### ZERO COORDINATES: ## TVD	North	East	##### COLLAR COORDINATES ##### TVD	North	East
0.0	105	S75E	0.22	0.00	0.0	0.00	0.00	0.00	NA	698297.00	313047.00
25.0	111	S69E	0.55	0.17	1.3	25.00	-0.05	0.16	NA	698296.95	313047.16
50.0	159	S21E	0.63	0.39	1.1	50.00	-0.22	0.24	NA	698296.72	313047.24
75.0	188	S06W	0.40	0.57	1.4	75.00	-0.44	0.26	NA	698296.56	313047.26
100.0	193	S13W	0.54	0.72	0.6	100.00	-0.64	0.22	NA	698296.36	313047.22
125.0	140	S40E	0.47	0.90	1.5	125.00	-0.82	0.35	NA	698296.18	313047.35
150.0	143	S37E	0.62	1.12	0.2	149.99	-1.01	0.49	NA	698295.99	313047.49
175.0	216	S36W	0.66	1.33	3.1	174.99	-1.24	0.48	NA	698295.76	313047.48
200.0	161	S19E	0.84	1.60	2.9	199.99	-1.53	0.46	NA	698295.47	313047.46
225.0	151	S29E	1.42	2.08	2.4	224.99	-1.97	0.67	NA	698295.03	313047.67
250.0	128	S52E	0.85	2.35	2.4	249.98	-2.26	0.87	NA	698294.64	313047.87
275.0	46	N49E	1.27	2.67	5.6	274.98	-2.25	1.16	NA	698294.72	313048.16
300.0	109	S71E	0.61	2.70	4.8	299.97	-2.14	1.63	NA	698294.86	313048.63
325.0	11	N43E	1.04	3.20	3.3	324.97	-2.02	1.93	NA	698294.98	313048.93
340.0	49	N49E	1.04	3.81	0.5	339.97	-1.98	2.17	NA	698295.02	313049.17

Data entered and computed 10/3/91

Checked 10/3/91

STRATA DATA GYRO DIRECTIONAL SURVEY
WESTON GEOPHYSICAL CORP. - HOLE # DD-23



□ 25 FT. STATIONS

STRATA DATA, INC.
2080 FAIRGROUNDS RD., NO. 6 - P.O. BOX 4898
CASPER, WY 82604 (307) 265-7717
ELKO, NV 89801 - P.O. BOX 70 (702) 738-5579

GYROSCOPIC DIRECTIONAL SURVEY

DATE: 10/1/91 S.G. #: 5198H

FOR: WESTON GEOPHYSICAL CORPORATION
LYONS STREET
BOX 550
WESTBORO, MA 01581-0550

REFERENCE HOLE NO.: N/A
REFERENCE HOLE COORDS.: N/A

CLOSURE - ZERO COORD.: 5.05' @ N48°21'E (48.45')
COLLAR COORD.: 000000.0' @ N00°00'E

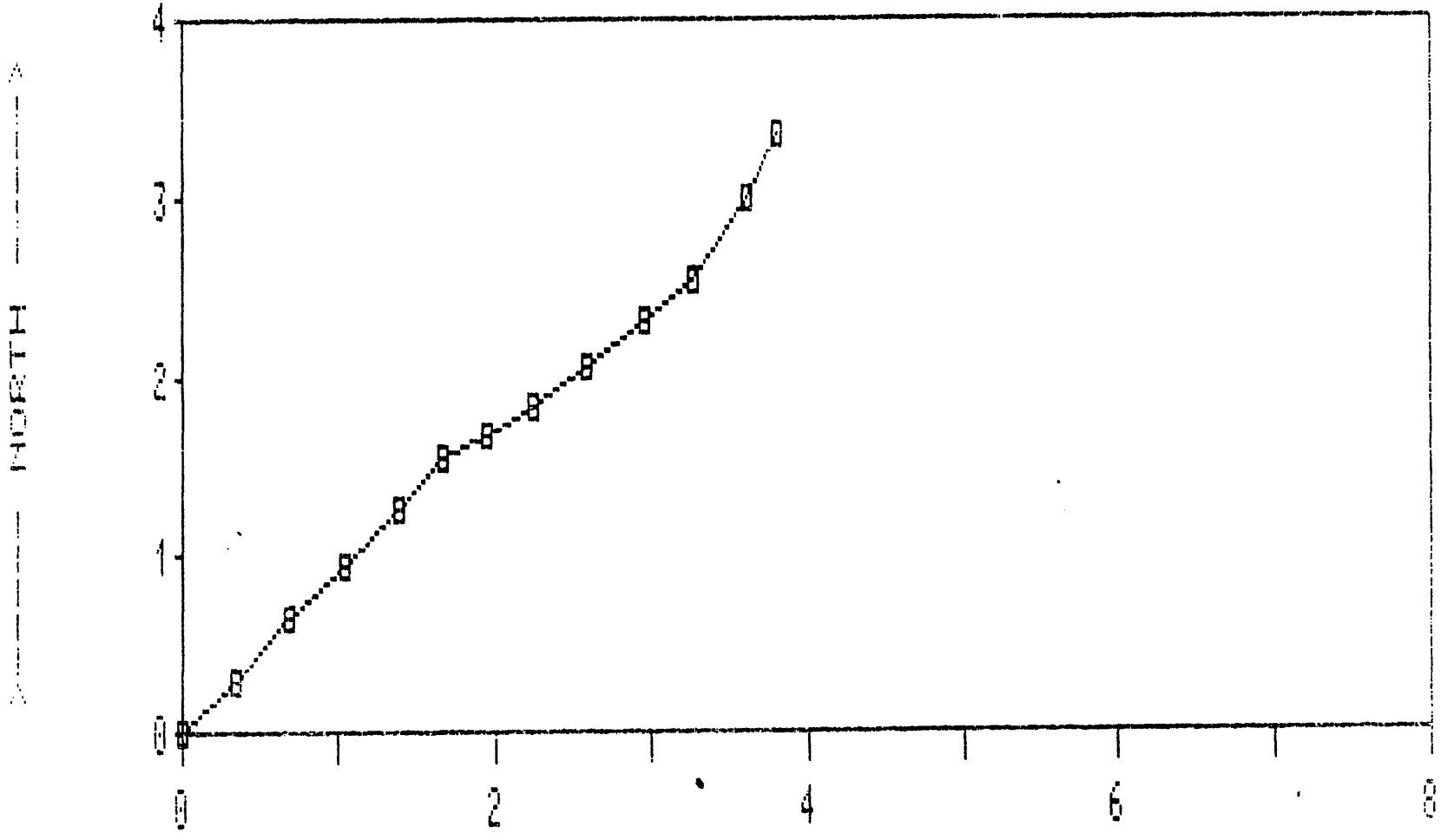
FLUID LEVEL - N/A
TIME - 16:30

COMP. METHOD: BALANCED CURVATURE
PROJECT WSG NO. 19552-02
HOLE NO. CO-23
AREA INEL.NPR
COUNTY BUTTE
STATE IDAHO
LOCATION N/A
ELEVATION N/A
MAG. DECL. 15 DEG. E.
REF. HOLE AZIMUTH N/A
T.D. - DRILLER 300
T.D. - LOGGER 300
MAXIMUM TEMP. N/A
TRUCK NO. 102
ENGINEER WEIKUM, McDONALD

Meas. Depth	Direction Azimuth	Bearing	Incl.	Disp.	Dog-leg	ZERO COORDINATES: TVD	North	East	COLLAR COORDINATES TVD	North	East
0.0	59	N59E	0.85	0.00	0.0	0.00	0.00	0.00	NA	NA	NA
25.0	44	N44E	1.22	0.44	1.8	25.00	0.29	0.34	NA	NA	NA
50.0	41	N41E	1.03	0.94	0.8	49.99	0.65	0.68	NA	NA	NA
75.0	59	N59E	1.10	1.39	1.4	74.99	0.94	1.08	NA	NA	NA
100.0	76	N76E	1.09	1.86	1.7	99.98	1.25	1.38	NA	NA	NA
125.0	51	N51E	0.75	2.26	1.7	124.98	1.54	1.65	NA	NA	NA
150.0	77	N77E	0.76	2.57	1.4	149.98	1.69	1.94	NA	NA	NA
175.0	52	N52E	0.79	2.89	1.4	174.97	1.83	2.24	NA	NA	NA
200.0	57	N57E	1.09	3.30	1.2	199.97	2.07	2.57	NA	NA	NA
225.0	56	N56E	0.94	3.74	0.6	224.97	2.31	2.94	NA	NA	NA
250.0	49	N49E	0.92	4.15	0.5	249.96	2.56	3.26	NA	NA	NA
275.0	29	N29E	1.66	4.68	3.4	274.96	3.01	3.63	NA	NA	NA
295.0	29	N29E	1.00	5.05	1.0	294.95	3.35	3.89	NA	NA	NA

Data entered and computed 10/3/91 B. McDonald
Checked 10/3/91

STRATA DATA GYRO DIRECTIONAL SURVEY
WESTON GEOPHYSICAL CORP. - HOLE # DD- 3



□ 25 FT. STATIONS

STRATA DATA, INC.
2020 FAIRGROUNDS RD., NO. B - P.O. BOX 4896
CASPER, WY 82604 (307) 265-7713
ELKO, NV 89801 - P.O. BOX 70 (702) 738-5579

GYROSCOPIC DIRECTIONAL SURVEY

DATE: 9/30/91 S.O. #: 5198A

FOR: WESTON GEOPHYSICAL CORPORATION
LYONS STREET
BOX 550
WESTBORO, MA 01581-0550

REFERENCE HOLE NO.: DC-2
REFERENCE HOLE COORD.: [illegible]

CLOSURE - ZERO COORD.: 4.75 @ N[illegible]W [illegible]
COLLAR COORD.: 765010.02 @ N24°08'E

FLUID LEVEL - N/A
TIME - 12:40

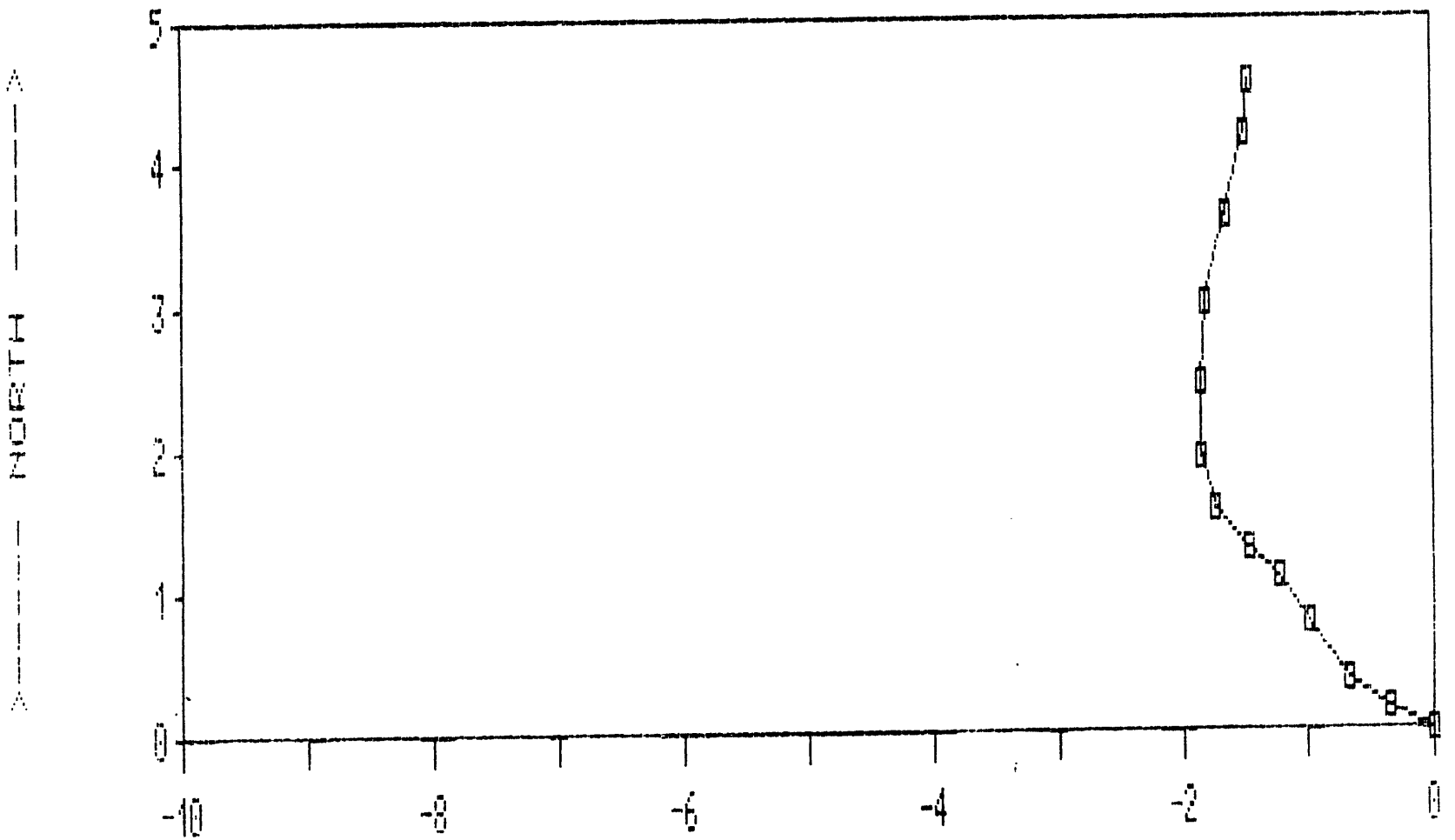
COMP. METHOD: BALANCED CURVATURE
PROJECT WGC NO. 12552-02
HOLE NO. DD-25
AREA INEL/NPR
COUNTY BUTTE
STATE IDAHO
LOCATION 698375.00' N. & 213009.0
ELEVATION N/A
MAG. DECL. 15 DEG. E.
REF. HOLE AZIM. [illegible]
T.D. - DRILLER 300
T.D. - LOGGER 302
MAXIMUM TEMP. N/R
PROB NO. 102
ENGINEER WEIKUM, McDONALD

Meas. Depth	Direction Azimuth	Bearing	Incl.	Dleg.	Deg-leg	ZERO COORDINATES: TVD	North	East	COLLAR COORDINATES Y.C.	Northing	Easting
0.0	295	N62W	0.96	0.00	0.0	0.00	0.00	0.00	NA	698375.00	213009.00
25.0	[illegible]	N72W	0.83	[illegible]	0.3	25.00	[illegible]	[illegible]	NA	[illegible]	[illegible]
50.0	317	N43W	1.08	[illegible]	2.2	49.99	0.09	-0.69	NA	[illegible]	[illegible]
75.0	325	N35W	1.12	[illegible]	0.7	74.99	0.77	-1.00	NA	698375.77	213007.00
100.0	311	N46W	0.61	[illegible]	2.4	99.99	1.07	-1.24	NA	698375.07	[illegible]
125.0	317	N43W	0.92	1.97	1.7	124.98	1.70	-1.48	NA	698376.30	213006.52
150.0	315	N45W	0.86	2.36	0.3	149.98	1.58	-1.75	NA	698376.58	213006.25
175.0	3	N03E	1.03	2.69	1.1	174.98	1.94	-1.97	NA	698376.94	213006.03
200.0	357	N03W	1.34	3.09	1.3	199.97	2.45	-1.97	NA	698377.45	[illegible]
225.0	11	N11E	1.41	3.55	1.4	224.96	3.04	-1.83	NA	698378.04	[illegible]
250.0	27	N27E	1.40	3.99	1.2	249.96	3.63	-1.66	NA	698378.63	213006.74
275.0	9	N09E	1.37	4.47	1.6	274.95	4.21	-1.51	NA	698379.21	[illegible]
290.0	5	N05E	1.21	4.75	1.1	289.95	4.55	-1.41	NA	[illegible]	[illegible]

Data entered and computed 10/2/91

Checked 10/2/91 [illegible]

STRATA DATA GYRO DIRECTIONAL SURVEY
WESTON GEOPHYSICAL CORP. - HOLE # DD-25



□ 25 FT. STATIONS

STRATA DATA, INC.

2090 FAIRGROUNDS RD., NO. 5 - P.O. BOX 4858
CASPER, WY 82604 (307) 265-7313
ELKO, NV 89801 - P.O. BOX 70 (702) 738-5579

GYROSCOPIC DIRECTIONAL SURVEY

DATE: 9/20/91 S.O. #: 5198E

FOR: WESTON GEOPHYSICAL CORPORATION
LYONS STREET
BOX 550
WESTBORO, MA 01581-0550

REFERENCE HOLE NO.: N/A
REFERENCE HOLE COORDS.: N/A

CLOSURE - ZERO COORD.: 6.29' @ N62°14 W (307.76'
DOLLAR COORD.: 765359.47' @ N24°[illegible] E

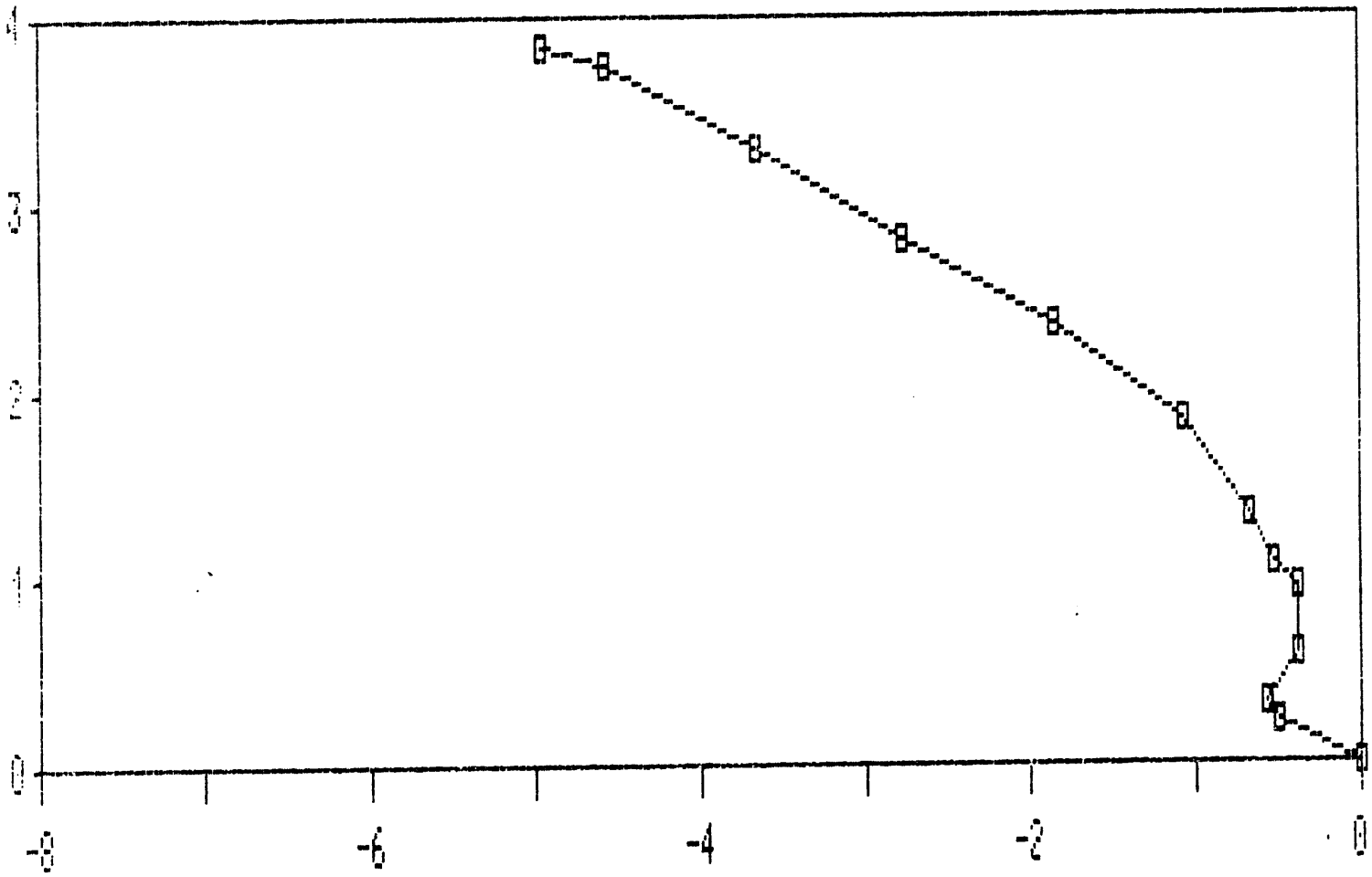
FLUID LEVEL - N/A
TIME - 19:55

COMP. METHOD:- BALANCED CURVATURE
PROJECT WGC NO. 8552-02
HOLE NO. DC-2
AREA INEL/NPR
COUNTY BUTTE
STATE IDAHO
LOCATION 698456.00' N, & 312941.00' E.
ELEVATION N/A
MAG. DECL. 15 DEG. E.
REF. HOLE AZIMUTH N/A
T.D. - DRILLER 720'
T.D. - LOGGER 287'
MAXIMUM TEMP. N/A
TRUCK NO. 102
ENGINEER WEIKUM, MCDONALD

Meas. Depth	Direction Azimuth	Bearing	Incl.	Disp.	Dog-leg	ZERO COORDINATES: TVD	North	East	DOLLAR COORDINATES TVD	North	East
0.0	291	N69W	1.63	0.00	0.0	0.00	0.00	0.00	NA	698456.00	312941.00
25.0	287	N73W	0.91	0.06	2.9	24.98	0.02	-0.51	NA	698456.02	312940.49
50.0	80	N80E	0.51	0.67	5.4	49.94	0.32	-0.58	NA	698456.33	312940.42
75.0	22	N22E	1.15	0.69	3.9	74.94	0.58	-0.39	NA	698456.58	312940.61
100.0	316	N44W	0.68	1.00	4.3	99.93	0.92	-0.72	NA	698456.92	312940.61
125.0	314	N46W	0.24	1.19	1.8	124.93	1.07	-0.53	NA	698457.07	312940.47
150.0	333	N27W	1.11	1.48	3.5	149.88	1.32	-0.68	NA	698457.32	312940.32
175.0	315	N45W	1.91	2.12	3.7	174.87	1.83	-1.08	NA	698457.83	312939.92
200.0	295	N65W	2.46	3.01	3.8	199.85	2.26	-1.87	NA	698458.26	312939.13
225.0	299	N61W	2.20	3.95	1.2	224.81	2.81	-2.78	NA	698458.81	312938.22
250.0	299	N61W	2.41	4.97	1.8	249.81	3.30	-3.66	NA	698459.30	312937.34
275.0	290	N70W	2.31	5.91	1.5	274.77	3.72	-4.55	NA	698459.73	312936.41
285.0	292	N68W	2.27	6.29	3.2	284.69	3.85	-4.97	NA	698459.85	312936.00

Data entered and computed [illegible]

STRATA DATA GYRO DIRECTIONAL SURVEY
WESTON GEOPHYSICAL CORP. - HOLE # DC-2



□ 25 FT. STATIONS

STRATA DATA, INC.
2080 FAIRGROUNDS RD., NO. 6 - P.O. BOX 4859
CASPER, WY 82604 (307) 265-7317
ELKO, NV 89801 - P.O. BOX 70 (702) 738-5579

GYROSCOPIC DIRECTIONAL SURVEY

DATE: 9/30/91 S.D. #: 5198D

FOR: WESTON GEOPHYSICAL CORPORATION
LYONS STREET
BOX 550
WESTBORO, MA 01581-0550

REFERENCE HOLE NO.: N/A
REFERENCE HOLE COORDS.: N/A

CLOSURE - ZERO COORD.: 2.20' @ N43°20'W (216.66')
DOLLAR COORD.: 765775.29' @ N24°06'E

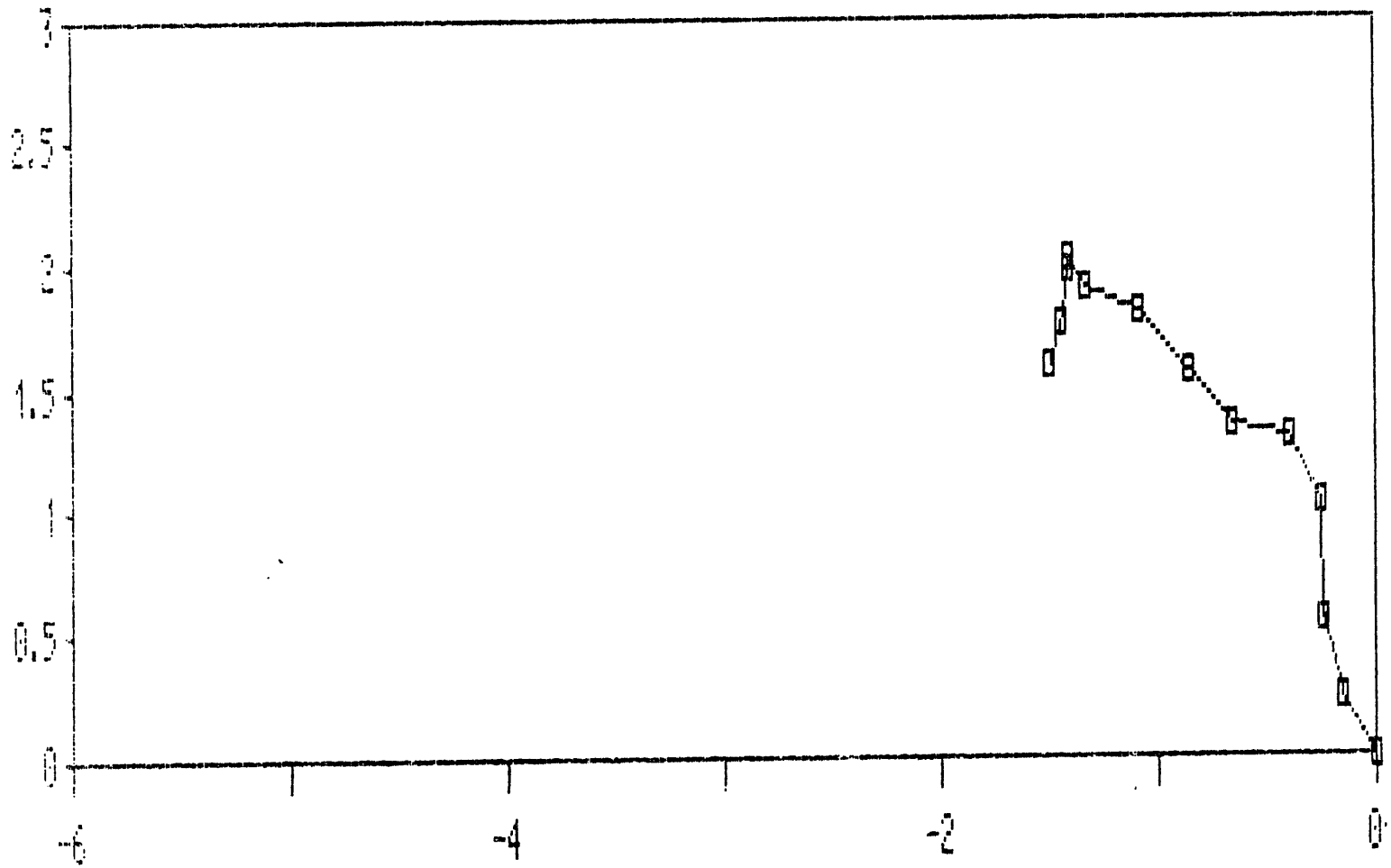
FLUID LEVEL - N/A
TIME - 18:50

COMP. METHOD: BALANCED CURVATURE
PROJECT WSI NO. 19552-12
HOLE NO. EI-1A
AREA INEL/NRF
COUNTY BUTTE
STATE IDAHO
LOCATION 698471.20' N. & 712950.00' E.
ELEVATION N/A
MAG. DECL. 15 DEG. E.
REF. HOLE AZIMUTH N/A
T.D. - DRILLER 700
T.D. - LOGGER 701
MAXIMUM TEMP. N/A
TRUCK NO. 102
ENGINEER WESLEY McDONALD

Meas. Depth	Direction Azimuth	Bearing	Incl.	Disc.	Dog-leg	### ZERO COORDINATES: ## TVD	North	East	##### DOLLAR COORDINATES ##### TVD	North	East
0.0	343	N17W	0.66	0.00	0.0	0.00	0.00	0.00	N/A	698471.20	712950.00
25.0	314	N46W	0.72	0.29	1.4	25.00	0.25	-0.19	N/A	698471.25	712949.85
50.0	9	N08E	0.98	0.61	3.2	50.00	0.56	-0.24	N/A	698471.56	712949.76
75.0	350	N10W	1.24	1.07	1.7	74.99	1.04	-0.26	N/A	698471.04	712949.74
100.0	265	S85W	0.47	1.26	5.1	99.99	1.31	-0.43	N/A	698471.30	712949.60
125.0	291	N69W	0.27	1.50	1.9	124.99	1.75	-0.65	N/A	698471.75	712949.34
150.0	345	N15W	0.77	1.69	2.9	149.98	1.88	-0.87	N/A	698471.88	712949.13
175.0	290	N70W	0.89	2.12	3.1	174.98	1.81	-1.10	N/A	698471.81	712948.90
200.0	302	N58W	0.34	2.34	2.2	199.98	1.93	-1.34	N/A	698471.92	712948.66
225.0	351	N09W	0.39	2.49	1.2	224.98	2.04	-1.42	N/A	698472.04	712948.58
250.0	176	S04E	0.61	2.44	4.0	249.98	1.99	-1.42	N/A	698471.99	712948.58
275.0	202	S22W	0.49	2.26	1.1	274.98	1.76	-1.45	N/A	698471.76	712948.55
299.0	192	S18W	1.85	2.20	2.8	298.98	1.80	-1.51	N/A	698471.80	712948.49

Data entered and computed 10/1/91 [illegible]
Checked 10/1/91, B. McDonald

STRATA DATA GYRO DIRECTIONAL SURVEY
WESTON GEOPHYSICAL CORP. - HOLE # SI-14



□ 25 FT. STATIONS

STRATA DATA, INC.
2060 FAIRGROUNDS RD., NO. 5 - P.O. BOX 4899
JASPER, WY 82604 (307) 265-7213
ELKO, NV 89801 - P.O. BOX 70 (702) 738-5579

GYROSCOPIC DIRECTIONAL SURVEY

DATE: 9/30/91 S.O. #: 5198C

FOR: WESTON GEOPHYSICAL CORPORATION
LYONS STREET
BOX 550
WESTBORO, MA 01581-0550

REFERENCE HOLE NO.: 81-14
REFERENCE HOLE COORDS.: 698470.00 N. & 312950.00 E.

CLOSURE - ZERO COORD.: 10.15' @ N27°10'E (27.20°)
COLLAR COORD.: 765398.68 @ N24°13 E

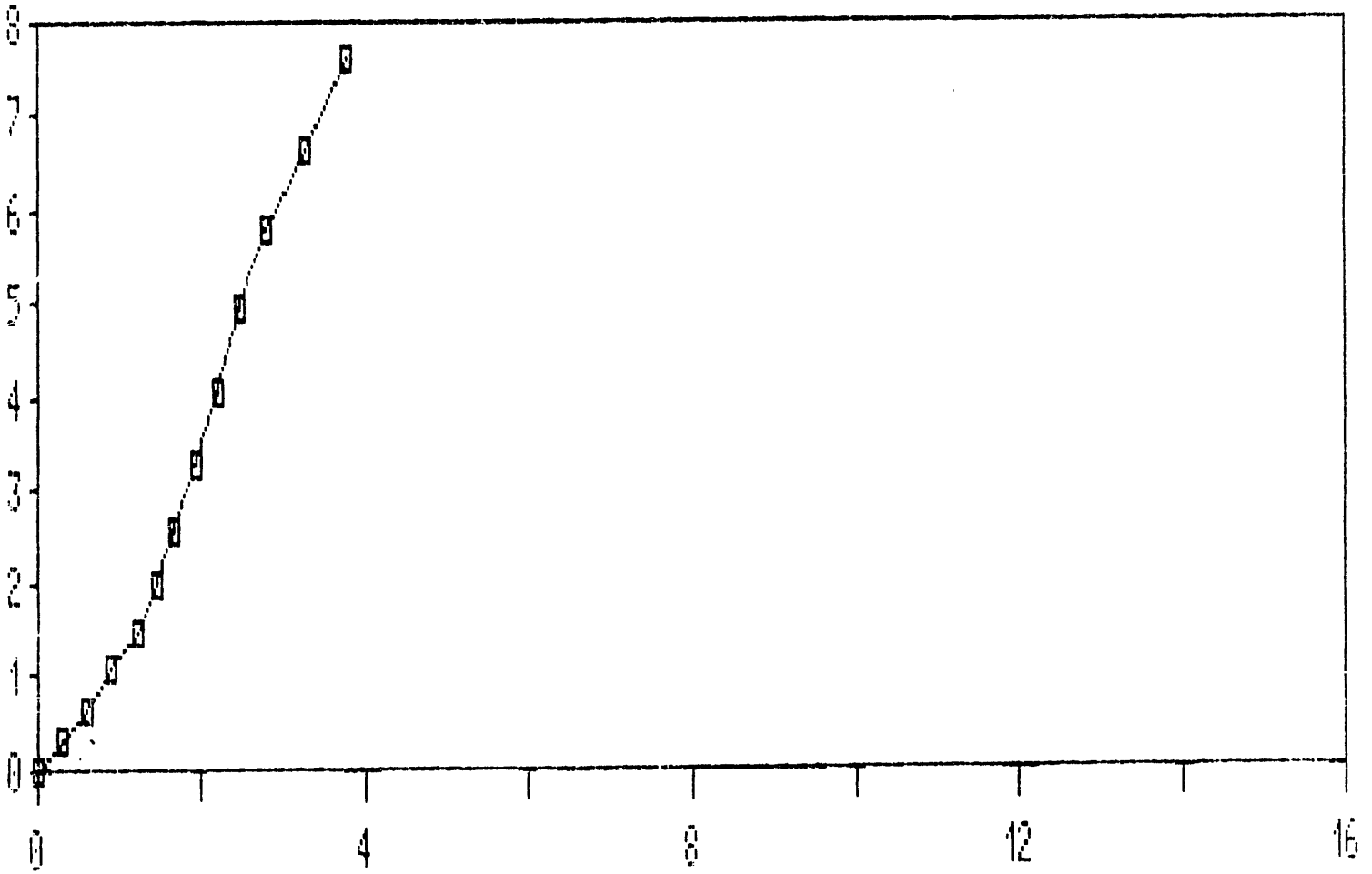
FLUID LEVEL - N/A
TIME - 17:30

COMP. METHOD: BALANCED CURVATURE
PROJECT WGE NO. 19553-02
HOLE NO. 20-22
AREA INEL,NPR
COUNTY BUTTE
STATE IDAHO
LOCATION 698472.00 N. & 312950.0
ELEVATION N/A
MAG. DECL. 15 DEG. E.
REF. HOLE AZIMUTH 2ec.2°
T.D. - DRILLER TBD
T.D. - LOGGER TBC
MAXIMUM TEMP. N/A
TRUCK NO. 10C
ENGINEER WEIRUM, McDONALD

Meas. Depth	Direction Azimuth	Bearing	Incl.	Dist.	Deg-leg	ZERO COORDINATES: TVD	North	East	COLLAR COORDINATES TVD	North	East
0.0	45	N45E	1.13	0.00	0.0	0.00	0.00	0.00	NA	698472.00	312950.00
25.0	48	N48E	0.97	0.45	0.5	25.00	0.32	0.71	NA	698472.32	312950.71
50.0	34	N34E	1.14	0.90	1.2	49.99	0.67	0.60	NA	698472.67	312950.60
75.0	39	N39E	1.14	1.39	0.4	74.99	1.07	0.89	NA	698473.07	312950.89
100.0	35	N35E	1.30	1.90	0.9	99.98	1.50	1.21	NA	698473.50	312951.21
125.0	20	N20E	1.15	2.41		124.96	1.98	1.46	NA	698473.98	312951.46
150.0	19	N19E	1.66	3.05	2.0	149.97	2.55	1.67	NA	698474.55	312951.67
175.0	20	N20E	1.77	3.78	0.5	174.96	3.26	1.92	NA	698475.26	312951.92
200.0	17	N17E	2.12	4.61	1.5	199.94	4.06	2.19	NA	698476.06	312952.19
225.0	16	N16E	2.13	5.52	0.1	224.92	4.95	2.45	NA	698476.95	312952.45
250.0	29	N29E	2.10	6.44	1.6	249.91	5.80	2.79	NA	698477.80	312952.79
275.0	26	N26E	2.32	7.42	1.2	274.89	6.67	3.24	NA	698478.67	312953.24
300.0	23	N23E	2.46	8.47	1.2	299.87	7.59	3.76	NA	698479.59	312953.76
325.0	27	N27E	2.09	9.57	1.7	324.84	8.53	4.34	NA	698480.53	312954.34
341.0	34	N34E	2.06	10.15	1.6	340.82	9.07	4.64	NA	698481.07	312954.64

Data entered and computed 10/2/91
checked 10/2/91

STRAIN GYRO DIRECTIONAL SURVEY
WESTON GEOPHYSICAL CORP. - HOLE # DD-22



□ 25 FT. STATIONS

STRATA DATA, INC.
2080 FAIRGROUNDS RD., NO. E - P.O. BOX 4899
CASPER, WY 82604 (307) 265-7317
ELKO, NV 89801 - P.O. BOX 70 (702) 738-5579

GYROSCOPIC DIRECTIONAL SURVEY

DATE: 9/30/91 O.O. #: 5198B

FOR: WESTON GEOPHYSICAL CORPORATION
LYONS STREET
BOX 550
WESTBORO, MA 01581-0550

REFERENCE HOLE NO.: DD-22
REFERENCE HOLE COORDS.: 698472.00' N. & 312960.00' E.

CLOSURE - ZERO COORD.: 3.57' @ N06°18'E (6.31°)
DOLLAR COORD.: 765419.23' @ N24°06'E

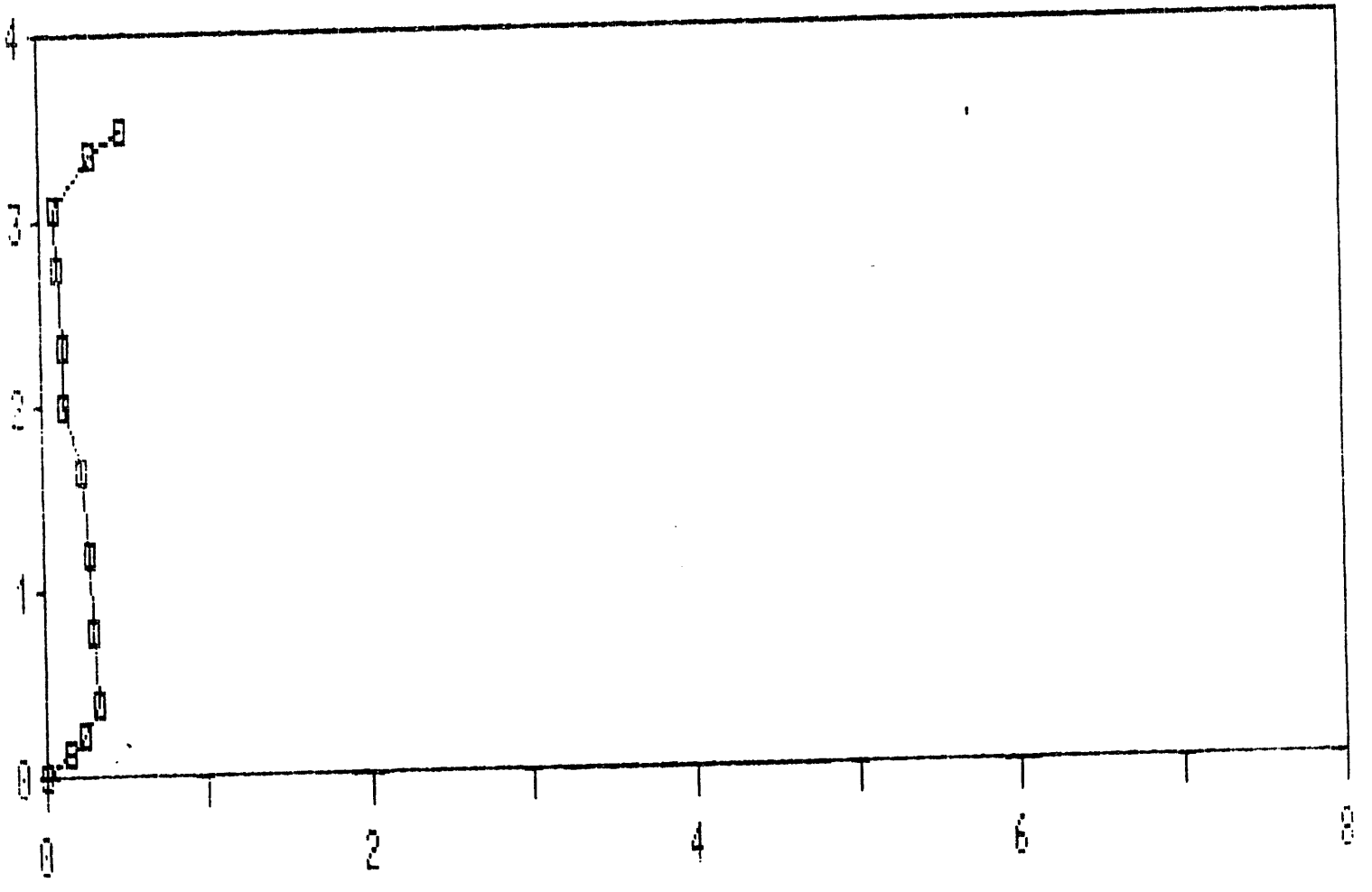
FLUID LEVEL - N/A
TIME - 16:30

COMP. METHOD: BALANCED CURVATURE
PROJECT WSC NO. 1955I-02
HOLE NO. DD-21
AREA INEL/NPR
COUNTY BUTTE
STATE IDAHO
LOCATION 698485.00' N. & 312019.0
ELEVATION N/A
MAG. DECL. 15 DEG. E.
REF. HOLE AZIMUTH 251.1°
T.D. - DRILLER 300
T.D. - LOGGER 302
MAXIMUM TEMP. N/A
TRUCK NO. 102
ENGINEER WEIKUM, McDONALD

Meas. Depth	Direction Azimuth	Bearing	Incl.	Disp.	Dog-leg	††† ZERO COORDINATES: †† TVD	North	East	††††† DOLLAR COORDINATES ††††† TVD	North	East
0.0	45	N49E	0.75	0.00	0.0	0.00	0.00	0.00	NA	698485.00	312019.00
25.0	70	N36E	0.18	0.21	2.0	25.00	0.14	0.16	NA	698485.14	312019.16
50.0	55	N55E	0.41	0.53	1.0	50.00	0.32	0.34	NA	698485.32	312019.34
75.0	45	N45E	0.55	0.52	1.7	75.00	0.48	0.44	NA	698485.48	312019.44
100.0	351	N09W	1.16	0.83	2.6	99.99	0.77	0.30	NA	698485.77	312019.30
125.0	4	N04E	0.84	1.23	1.6	124.99	1.20	0.28	NA	698486.20	312019.28
150.0	350	N10W	1.28	1.66	2.0	149.99	1.66	0.24	NA	698486.66	312019.24
175.0	322	N38W	0.38	2.00	3.8	174.98	2.00	0.14	NA	698487.00	312019.14
200.0	3	N03E	1.17	2.31	3.7	199.98	2.31	0.17	NA	698487.31	312019.17
225.0	339	N21W	0.91	2.74	2.3	224.98	2.74	0.10	NA	698487.74	312019.10
250.0	22	N22E	0.76	3.08	2.5	249.97	3.08	0.19	NA	698488.08	312019.19
275.0	41	N50E	0.97	3.37	1.9	274.97	3.31	0.31	NA	698488.31	312019.31
297.0	67	N67E	0.84	3.57	2.3	296.97	3.39	0.51	NA	698488.39	312019.51

Data entered and computed 10/2/91
Checked 10/2/91

STRAIN DATA GRID DIRECTIONAL SURVEY
WESTON GEOPHYSICAL CORP. - HOLE # DD-21



□ 25 FT. STATIONS

APPENDIX B

IN SITU
VELOCITY MEASUREMENTS

Detailed in situ measurements of compressional "P" and shear "S" wave velocities, their attenuation and anisotropic effects due to subsurface materials, particularly for thin layers, are best obtained by the cross-hole techniques. Measurements are made using geophones containing three orthogonal elements, one vertical and two horizontal. Seismic energy is generated in one hole and detected by the geophones in four other holes, usually with the seismic energy source and geophones at the same elevation level [Figure 1]. The borings are spaced apart at varying distances so that interchanging the seismic energy source and detectors yields different combinations of shot to detector distances, adding data points for velocity control. Borings which are proposed or existing for other disciplines may be included in the cross-hole array to minimize drilling effort. Field recordings are obtained using a multi-trace [usually 16] field computer system. The seismic signal is amplified, displayed, checked for quality, correlated and summed if desired and finally printed with Weston's field computer system, the WesComp™. Field parameters may be changed if required. Data are stored on magnetic disk or tape and the analog field record is retained for verification. Recordings are normally made at 10-foot intervals by simultaneously raising or lowering the source and detectors. Seismic energy is generated by one or more sources such as a small explosive charge, borehole airgun, mechanical device, etc.

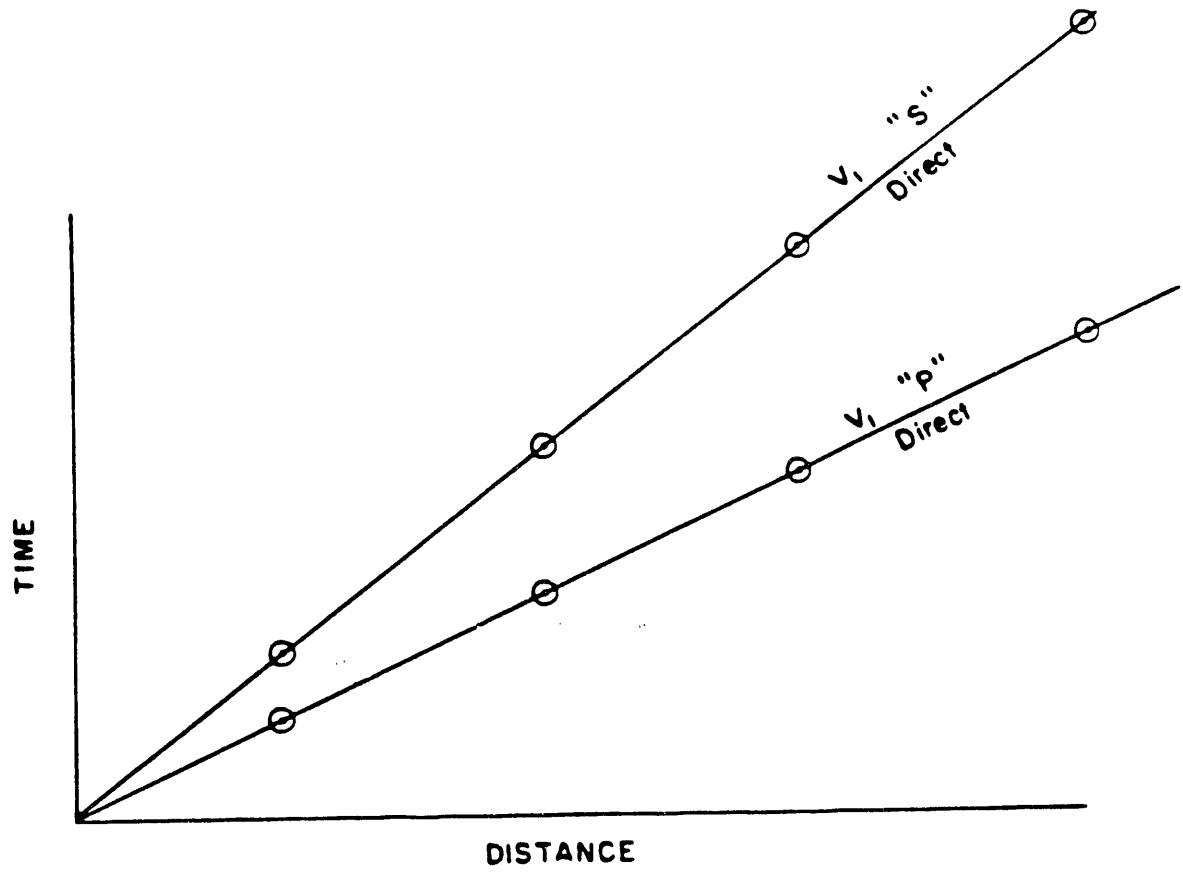
INTERPRETATION

Data obtained from cross-hole tests are the digitized wave forms and times required for both "P" compressional and "S" shear waves to travel from the source to each of the component geophones. The "P" wave is readily identified as the first arrival time to the detector. The arrival of the "S" wave is sometimes less apparent and may require some processing. Traces from all three components of each geophone are examined on the computer system for expected characteristics such as particle motion, amplitude ratios, etc.

For an accurate determination of the velocities, all distances between the source and the geophones must be corrected for drift or misalignment of boreholes. This is normally accomplished by a borehole verticality survey.

Velocity is the direct distance traveled divided by the travel time. A plot of seismic wave arrival times vs. source to detector distance is shown on Figure 1. It should be noted that the velocity lines drawn through the individual arrival times tie to time zero at the energy source indicating that seismic waves have propagated through the same velocity layer.

If a nearby higher velocity layer exists the wave will refract and travel along that layer. At some distance from the source the least time path from source to detector will become the refracted wave path rather than the direct wave path as shown on Figure 2. The velocities for each layer are shown on the time dis- tance plot. It should be noted that the velocity lines through the layer in which the source is located tie into time zero; however, the velocity lines for the refracted arrivals tie in at a time related to the distance of the refracting layer above or below the source. In such instances, calculations based on Snell's law may be used to compute the distance above or below the source for the adjacent zones of higher velocity material.


TIME
DISTANCE
V_1 "S" Direct
V_1 "P" Direct

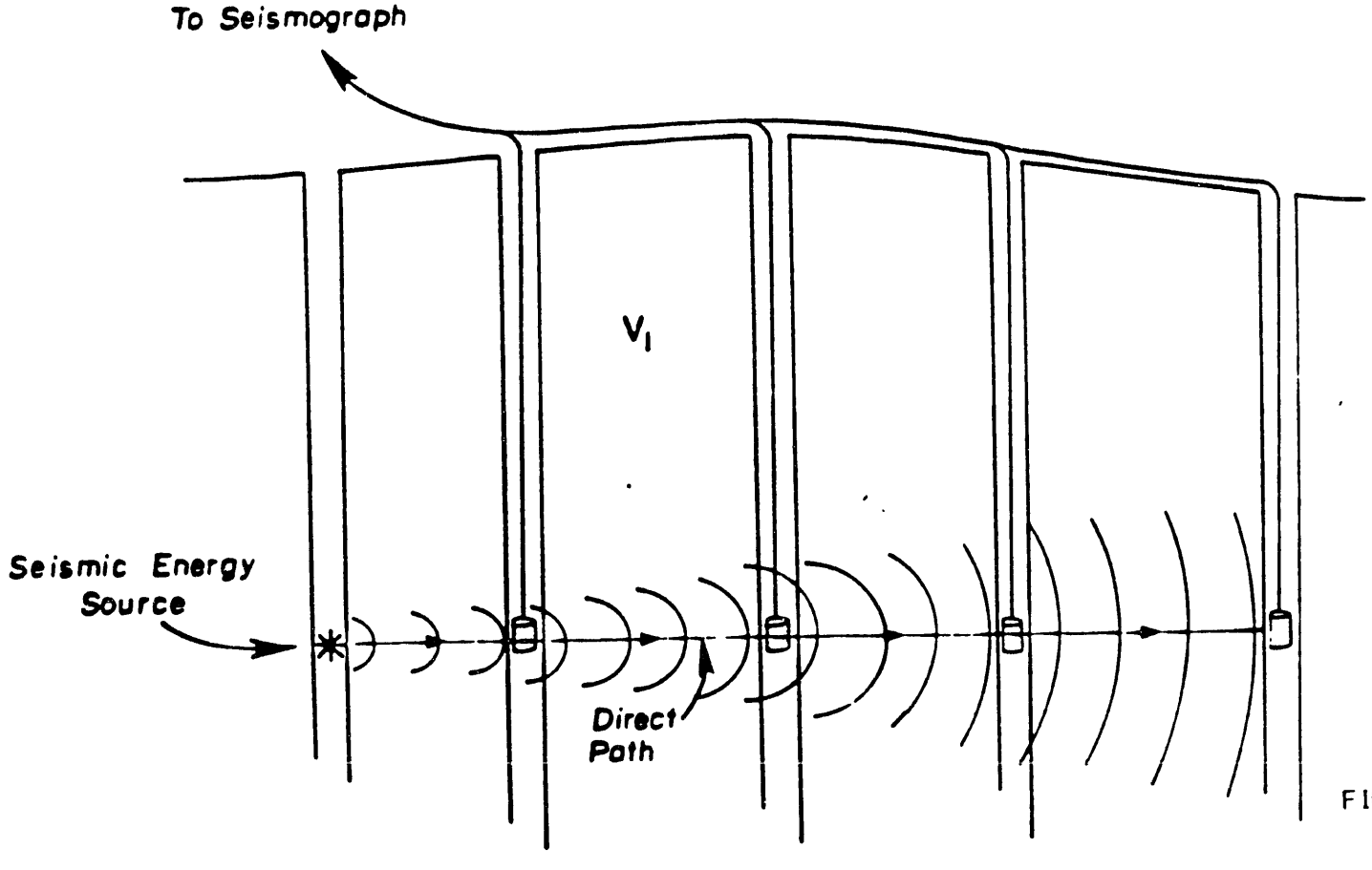
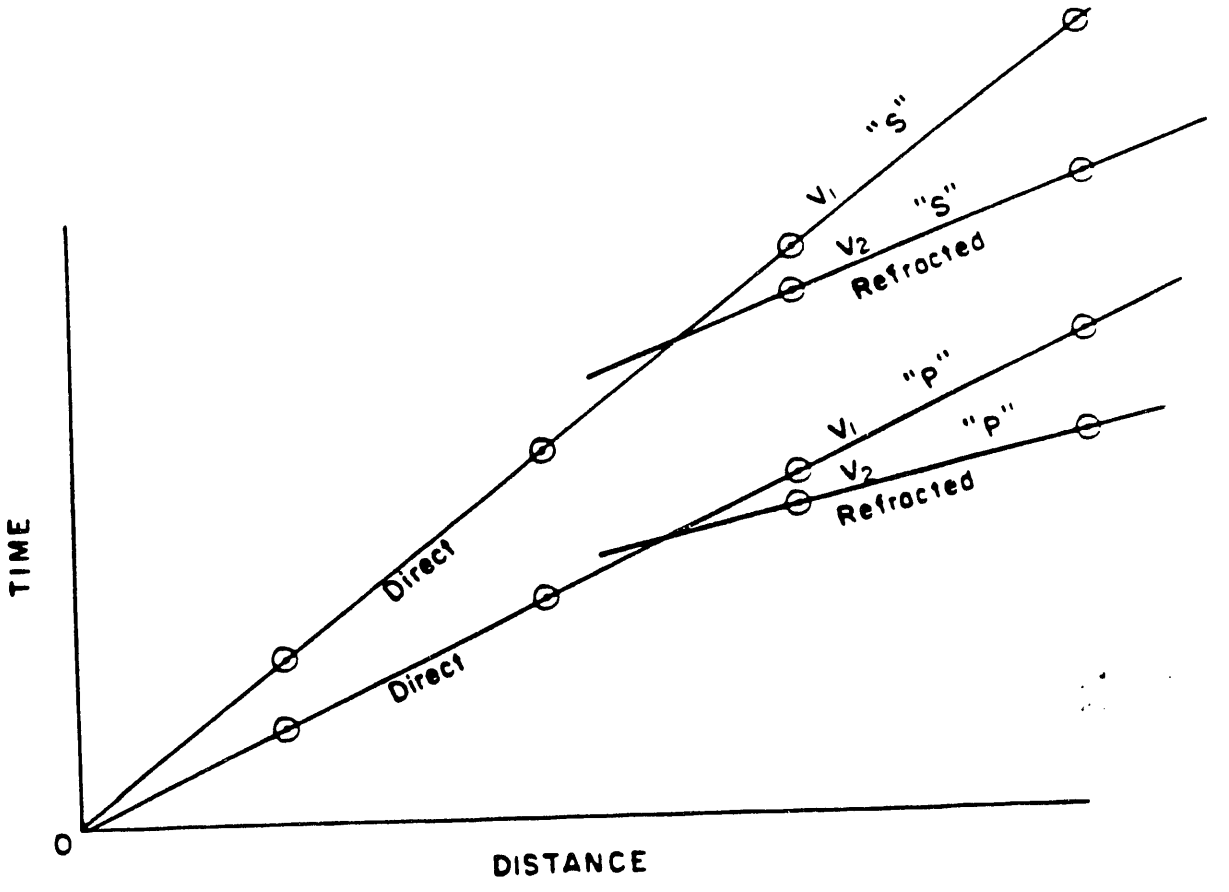

To Seismograph
V_1
Seismic Energy Source
Direct Path

FIGURE 1


"S"
V_1
"S"
V_2
Refracted
"P"
V_1
"P"
V_2
Refracted
Direct
Direct
TIME
0
DISTANCE

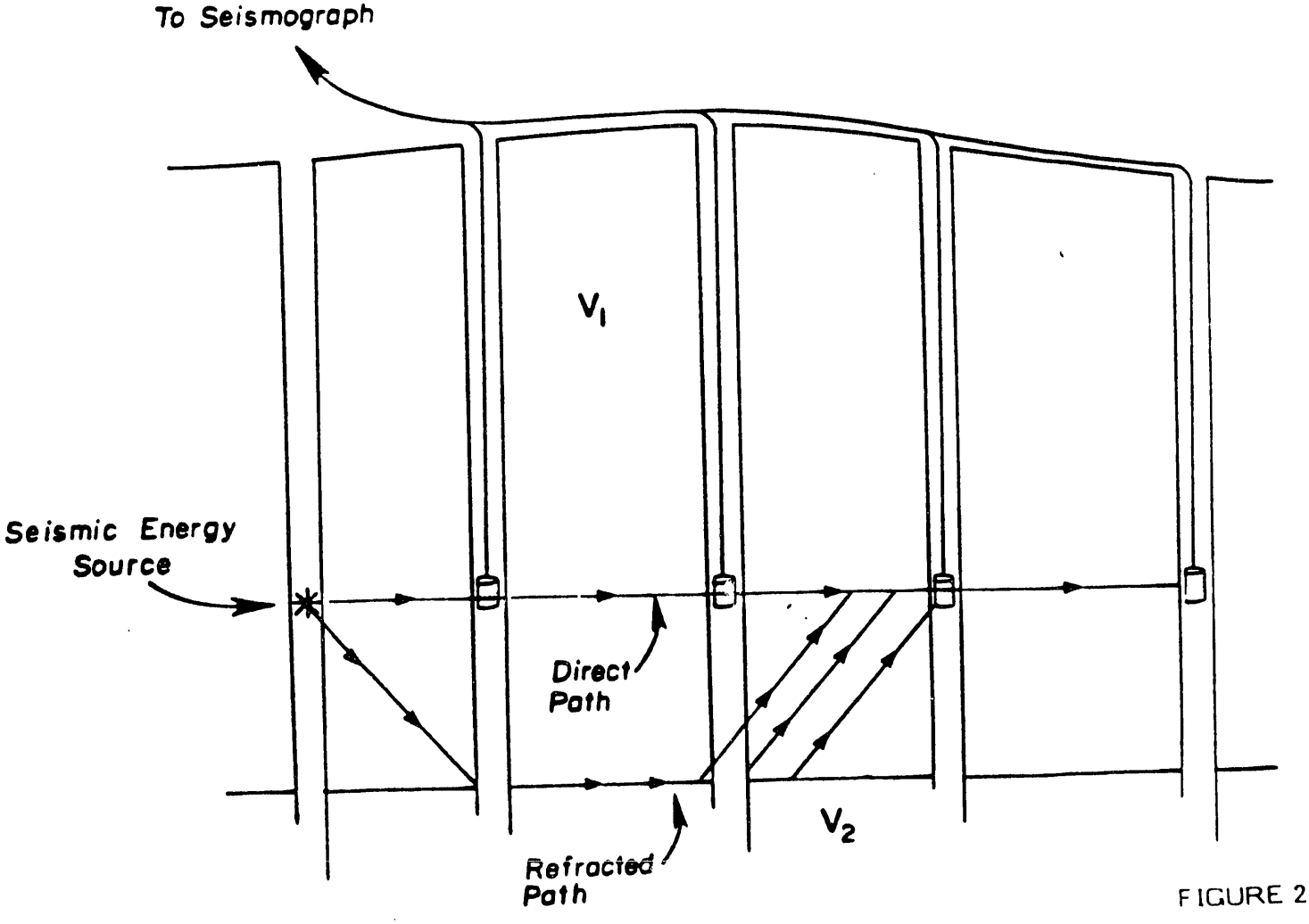

To Seismograph
V_1
Seismic Energy Source
Direct Path
V_2
Refracted Path

FIGURE 2

APPENDIX C

DEEPHOLE GEOPHYSICAL LOGGING

GEOPHYSICAL LOGGING PROCEDURES FOR WELL W0-2 AT THE INEL/NPR IDAHO FALLS, IDAHO.

COLOG, Inc.
17301 West Colfax, Suite 265
Golden CO 80401

SUMMARY

Borehole geophysical logging procedures for Well W0-2 at the NPR Site of the INEL comply with COLOG's Standard Operating Procedures and Quality Assurance Program as prepared for Weston Geophysical/Baker Environmental on September 3, 1991. COLOG's final scope of work for this project included an XAP-GGC (compensated density and single-arm caliper) and an XAP-GN (natural gamma and neutron) logging run with repeat sections.

These geophysical logs were acquired on September 30 and October 1, 1991. Daily logs documenting chronological events appear in Appendix A of this report and are signed/initialed by Weston and COLOG personnel in the field. A copy of the field logging report (2 pages) is also included in Appendix A. General information including digital data file names, calibration file names, and on site witnesses are recorded by the Field Engineer on this document; comments and remarks about the job are also noted. Appendix B is a paper original of the final merged log with repeat sections on separate sheets. A floppy diskette with the final data file, header file and raw data files is included in Appendix B (the transparent pocket). The XAP-GN probe system was run in the well first followed by the XAP-GGC.

GAMMA-NEUTRON (XAP-GN)

Calibration data, including a document review by Mt. Sopris Instrument Company, and equipment checkout information can be found in Appendix C. The 1 Curie AmBe neutron source and He-3 detector system COLOG used at W0-2 responded with a count rate of approximately 260 CPS (counts per second) in a large water barrel (100% porosity). In air at W0-2, the probe responded by counting at a rate of 15-20 CPS. Neutron deflection in the borehole environment increases as moisture content decreases. Neutron deflection information at the Denver Federal Center Test Pits is listed on the neutron-thermal-neutron checkout/calibration sheet in Appendix C. Published information about the petrophysical properties of these pits, including porosity data, is available in COLOG's Standard Operating Procedures and Quality Assurance Program of September 3, 1991. The natural gamma function was checked in the field with COLOG's gamma calibration sleeve. Count rates from this sleeve when placed directly over the scintillation crystal ranges from 4200 to 4500 CPS. In the field at W0-2, the sleeve calibration was at 4200-4250 CPS. Background natural gamma on site was less than 10 CPS.

Gamma-Neutron data was collected at 15 feet per minute while moving down the well. After reaching a depth of 4961 feet, the wireline lost tension and no data was collected beyond this depth. A 200 foot repeat section (see Appendix A) was recorded from 2750 feet to 2550 feet. An after survey depth error (ASDE) of 5.7 feet was recorded on the logging report for the Gamma-Neutron logging run; most of this depth error likely occurred as the wireline was

winched uphole (90 to 100 feet/min.). At this high speed, spurious depth pulses can enter the system and create some very minor depth discrepancies. The raw gamma-neutron data was digitized at 0.25-foot depth intervals. The time constant for this logging run can be calculated by dividing the depth digitize interval by the logging speed as follows:

$$TC = DDI/LS$$

where; TC = Time constant
DDI = Depth digitize interval
LS = Logging speed.

For well W0-2: DDI = 0.25 feet
LS = 15 feet/min or 0.25 feet/second

TC = 0.25 ft/0.25 ft./sec

TC_{W0-2} = 1 second.

Unusual condsitions or problems encountered

No unusual conditions or problems were encountered during the gamma-neutron logging run.

GAMMA-GAMMA DENSITY (XAP-GGC)

After the gamma-neutron logging run was completed, the density/caliper probe functions were connected to the wireline cablehead and caliper ring calibrations were performed. Figure one is a graphical representation of density calibrations performed at COLOG prior to mobilization. Post-calibration readings were within 3 percent of these values. Aluminum (ρ = 2.62 gm/cc) and Lucite (ρ = 1.28 gm/cc) blocks are utilized in the calibration process. A water barrel (ρ = 1.1 gm/cc) is also used for calibrations. Compton-scattered gamma rays are counted at two cesium activated NaI detectors at 7.87 (short detector) and 13.83 (long detector) inches from the 100 mC, Cs137 source. The calibrations used to compute bulk density at each detector and subsequently compensated density for well W0-2 follow:

	Short Detector	Long Detector
Aluminum Block	3015 CPS	82 CPS
Lucite Block	7404 CPS	1088 CPS
Water Barrel	8030 CPS	1440 CPS

The compensated density algorithm used by COLOG is derived from "spine and rib" curves generated by plotting short detector versus

long detector densities. Apparent matrix density used in the density porosity calculation for basalt is 2.95 gm/cc.

Unusual conditions or problems encountered

The density/caliper log was collected while logging uphole at a rate of 15 feet per minute. Due to borehole temperatures exceeding probe manufacturer specifications, data could only be collected from 4200 feet. After completing the repeat section from 950 to 850 feet, the probe became lodged in the borehole at 520 feet. Several attempts to pull the probe from the well initially failed; one fishing attempt with a sandline overshot device failed. Finally, after applying 1368 pounds of tension, the probe pulled free. The ASDE after these procedures was 6.2 feet.

The final log is depth referenced to the gamma-neutron log because it was run first while moving down hole when depth errors are considered minimal. Raw data was filtered with a 5-point weighted average filter to produce the final logs as presented in this report.

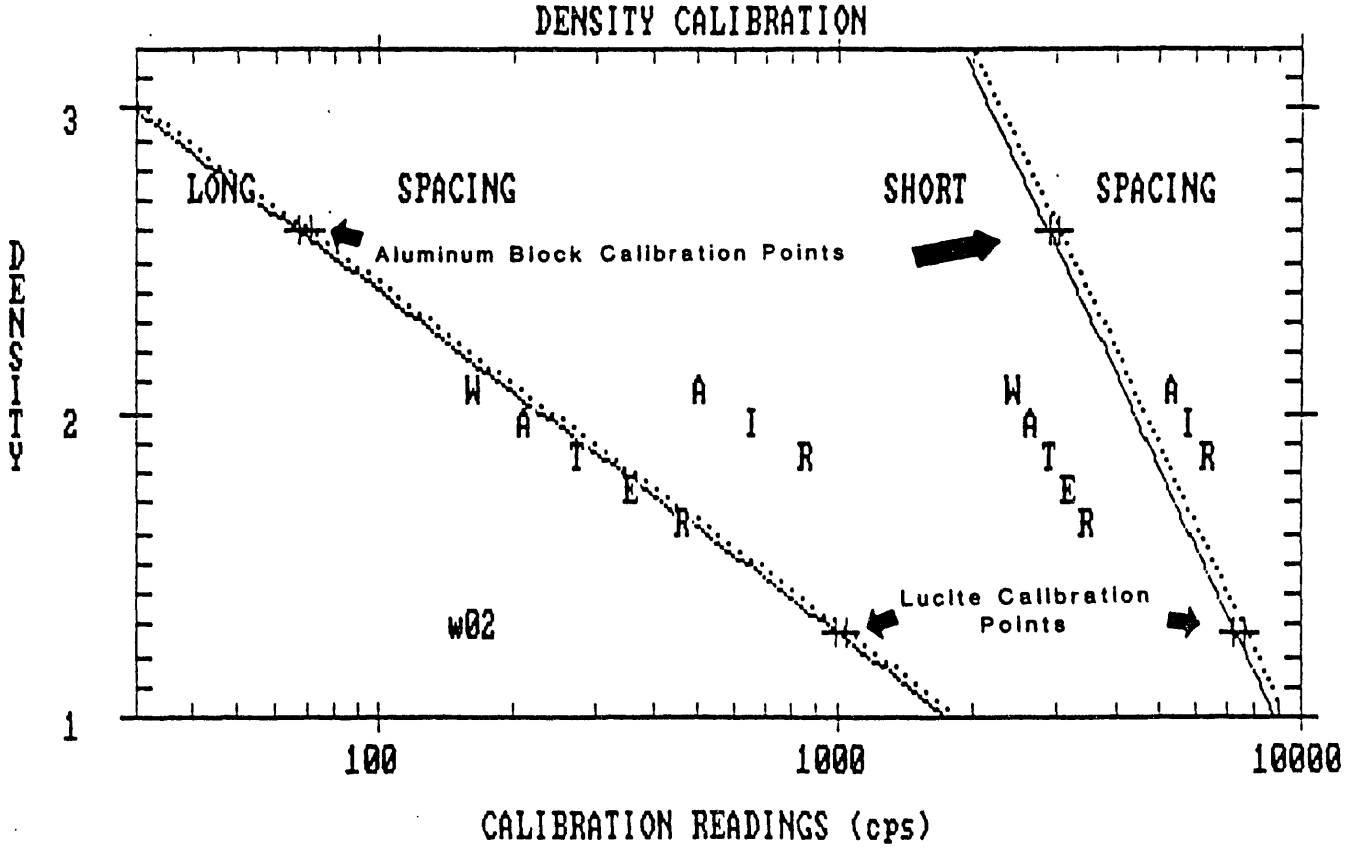


Figure 1. Graphical representation of density calibrations for INEL/NPR well WO-2

COLOG INC

BOREHOLE GEOPHYSICS

17301 W. COLFAX, STE. 265, GOLDEN, CO 80401

PHONE: (303) 279-0171 FAX: 279-2730

GAMMA, NEUTRON DENSITY/CALIPER

WELL: **WO-2**

PROJECT: **INEL-NEW PRODUCTION REACTOR** DATE: **SEPT. 30, 1991**

CLIENT: **WESTON GEOPHYSICAL WESTBORO, MASS** COLOG ID NO:

LOCATION:

STATE: IDAHO COUNTY: BUTTE ELEV: DEPTH REF: SURFACE

BOREHOLE DATA

DRILLING CONTRACTOR: TONTO DRILLING SALT LAKE CITY,UT

CUSTOMER TD: 5000 FT COLOG TD: 4961 FT

RUN	BIT RECORD			CASING RECORD		
NO.	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	NX CORE	SURFACE	TD	NX	SURF.	TD
2	101mm RD	SURF.	1825 FT	4" ID	SURF.	608 FT
3	6" ID	SURF.	10 FT			
4						

HOLE MEDIUM: AIR (SURF-460'); MUD/GEL (460'-TD) DRILL METHOD: NX CORE

MUD TYPE: Bentonite TIME SINCE CIRC: 5 DAYS

VISCOSITY: WEIGHT: Rmf at Deg

GENERAL DATA

INSTRUMENTATION: SERIES III UNIT/TRUCK: 705/12

LOGGING ENGINEER: JJL-ALC

CLIENT REP: CHARLENE L. SULLIVAN - WESTON; FIL J. FILIPKOWSKI - WESTON

OTHER SERVICES: TEMPERATURE, DEVIATION

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR	SPACING		SOURCE		LOGGED INTERVAL		
		MODEL	PROBE S.N.	UPHOLE S.N.	DIG INT FEET	SPEED FT./MIN	TYPE	Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
NEUTRON	1	JLM	4683	980	0.25	15 Dn	HE-3	13.7"	N/A	AmBe	1 Cu	8.7'	4961'	4952.3
GAMMA	1	JLM	1743	908	0.25	15 Dn	SCINT.	N/A	N/A	N/A	N/A	3.9'	4956.2	4952.3
CALIPER	2	JLM	1380	908	0.25	15 Up	N/A	N/A	N/A	N/A	N/A			
DENSITY	2	HPF	1380	908	0.25	15 Up	Csl	7.87"	13.8"	Cs137	100mC	4200'	600'	3600'

CALIBRATION FACTOR(S):

DIGITAL FILE NAME(S): W02FIN.DAT, W02FINAL.PLP, INEL.HDP

REMARKS:

MAXIMUM BOREHOLE TEMP = 172.5 DEG. F

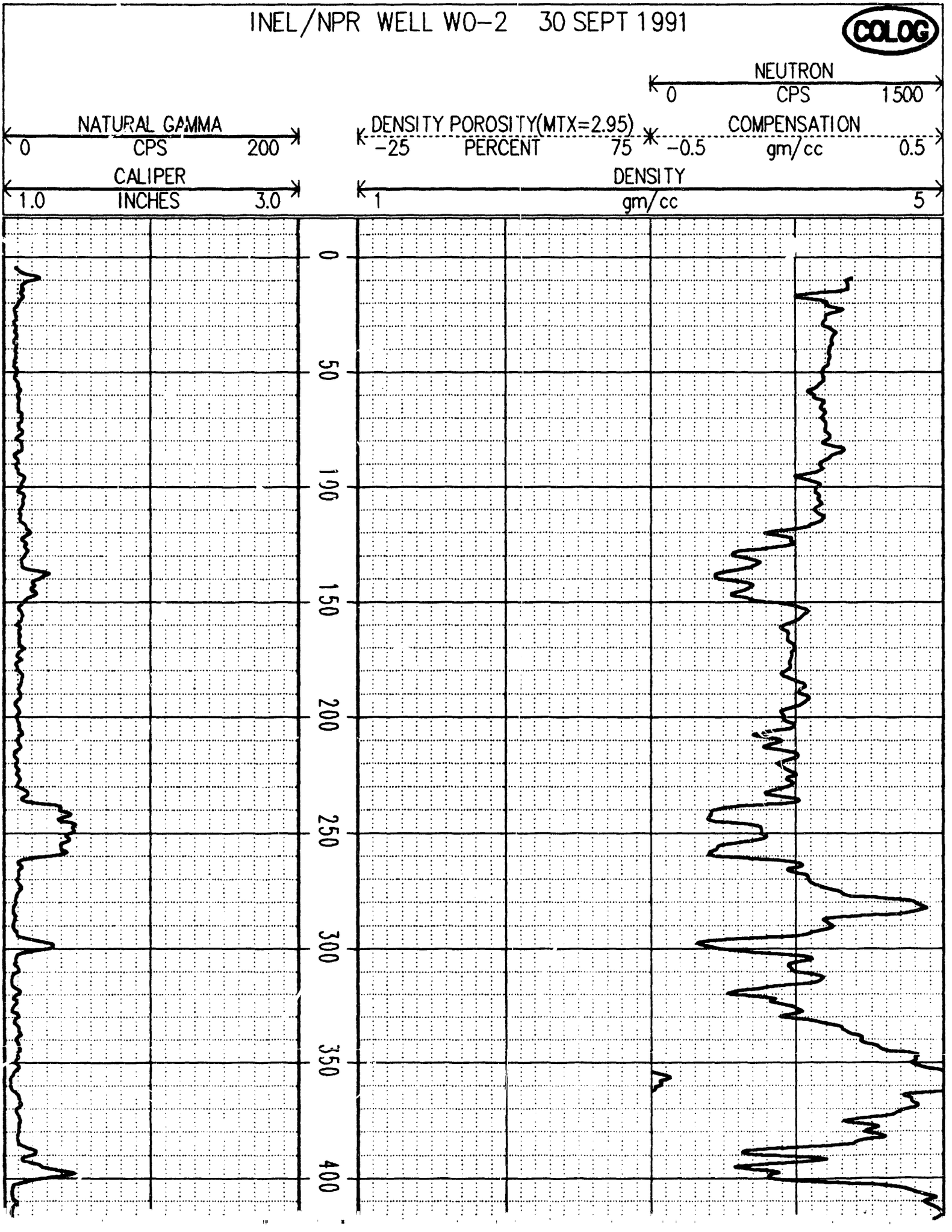
Well Owner: EG&E, Idaho Falls

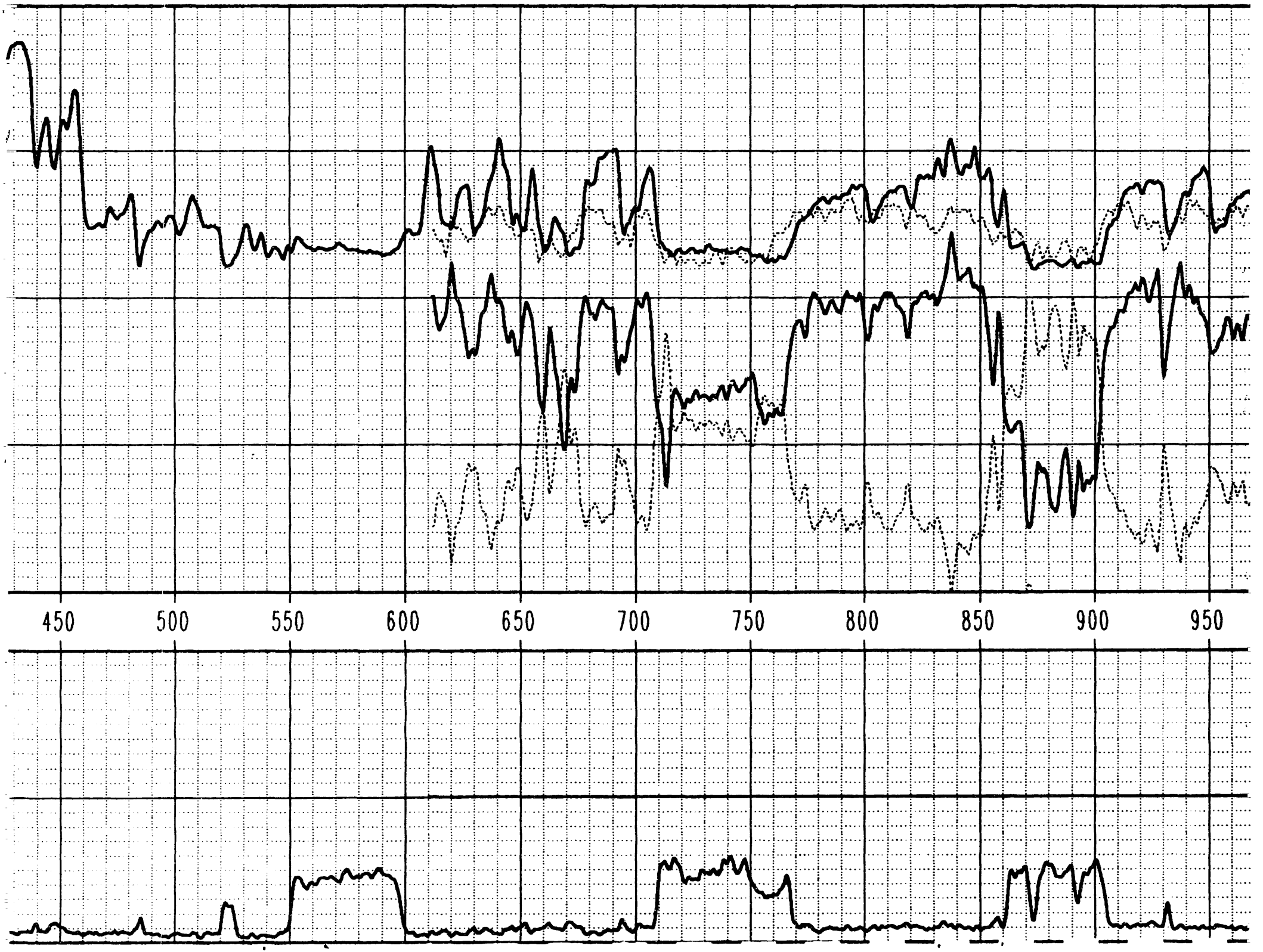
Casing @ 0.75' above surface

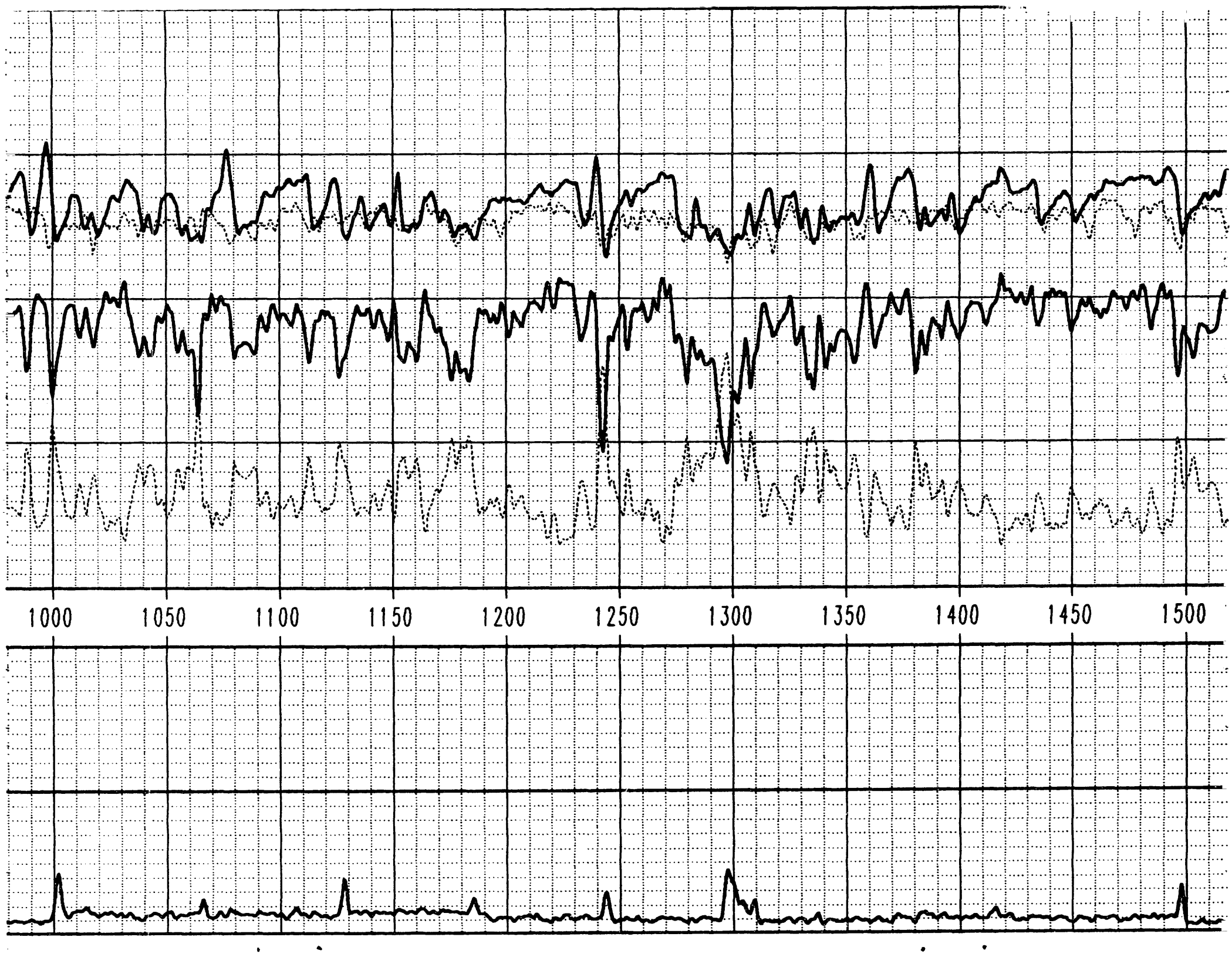
Shop Calibrations: 9/28/91

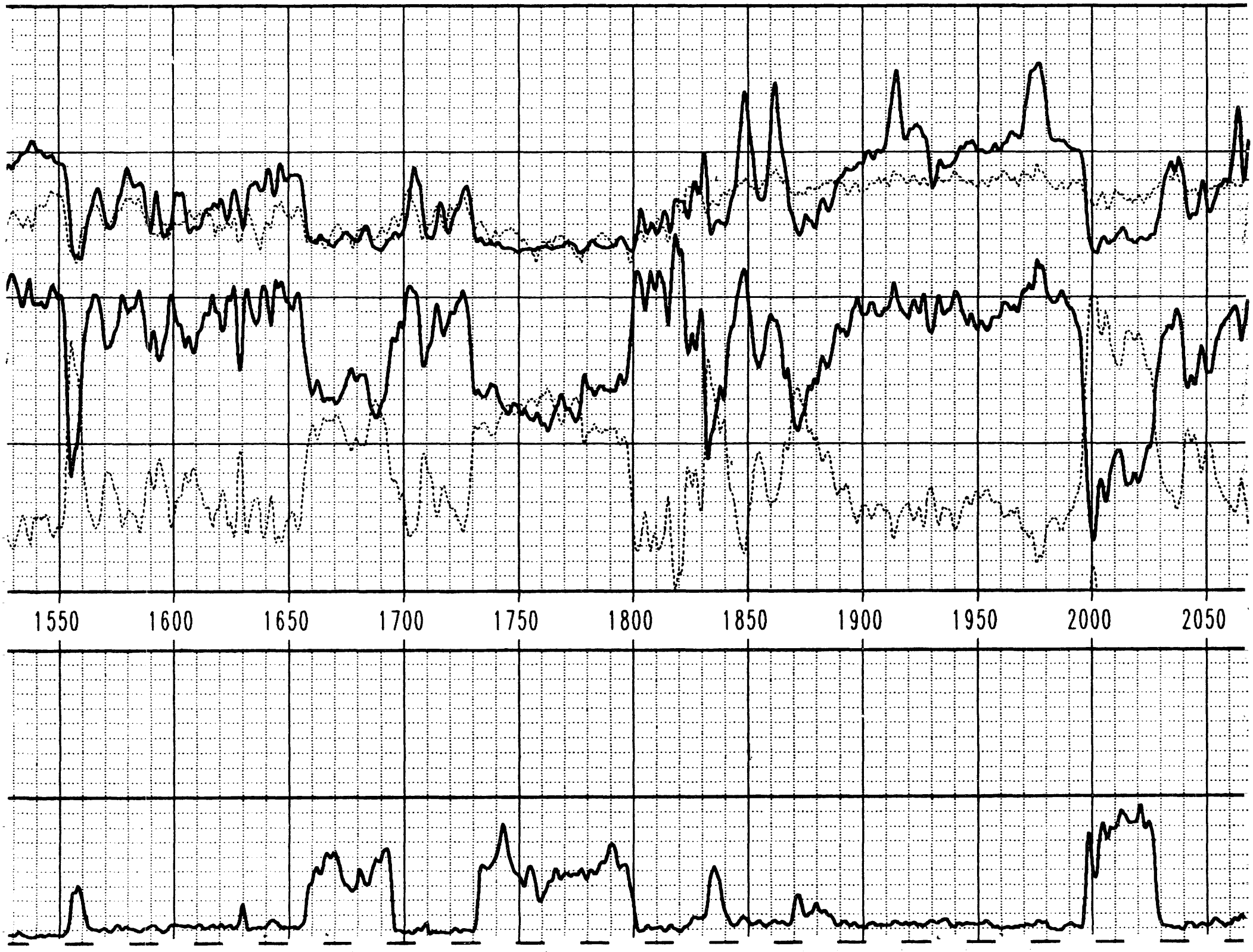
Site Calibrations: 9/30/91

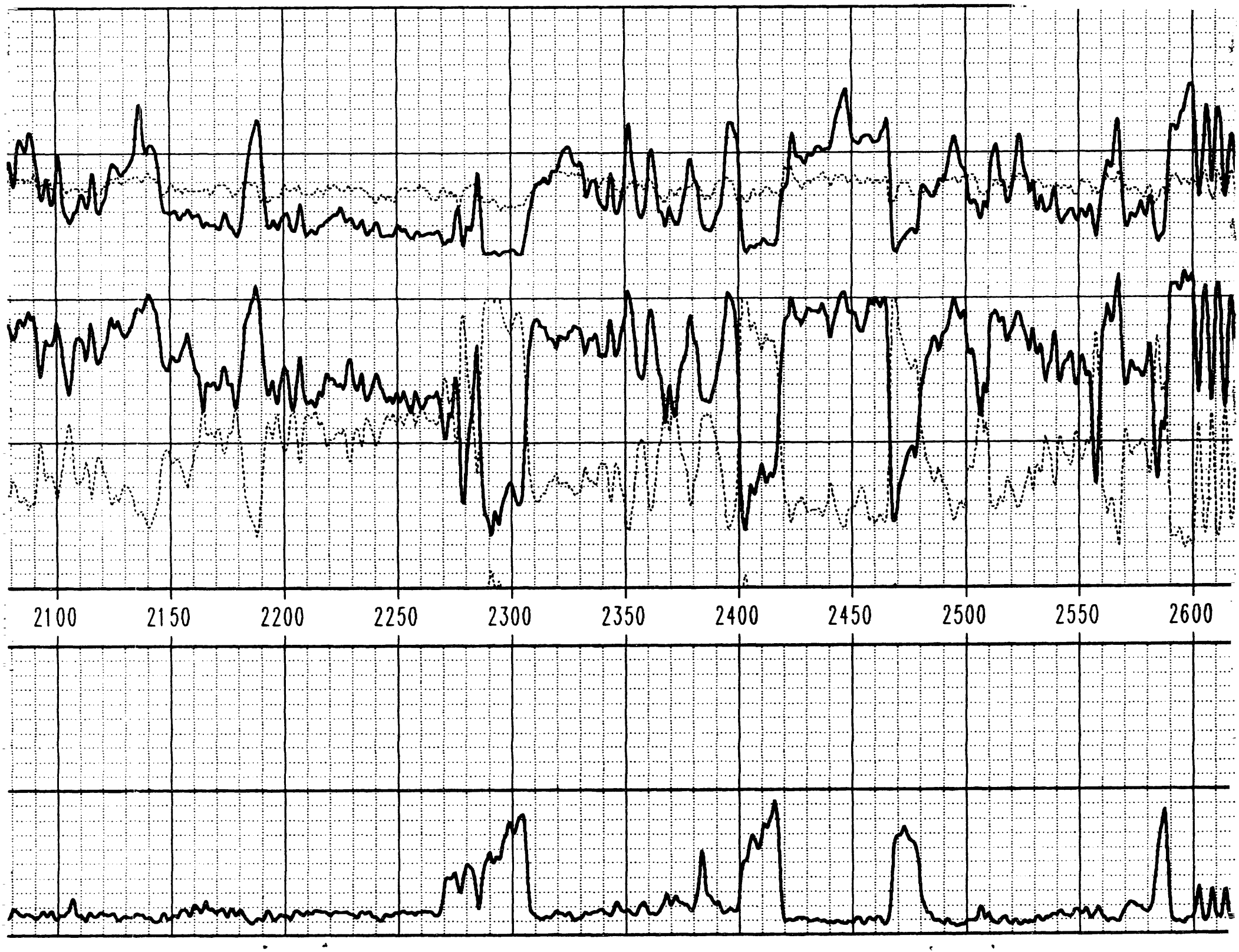
Post Calibrations: 10/3/91

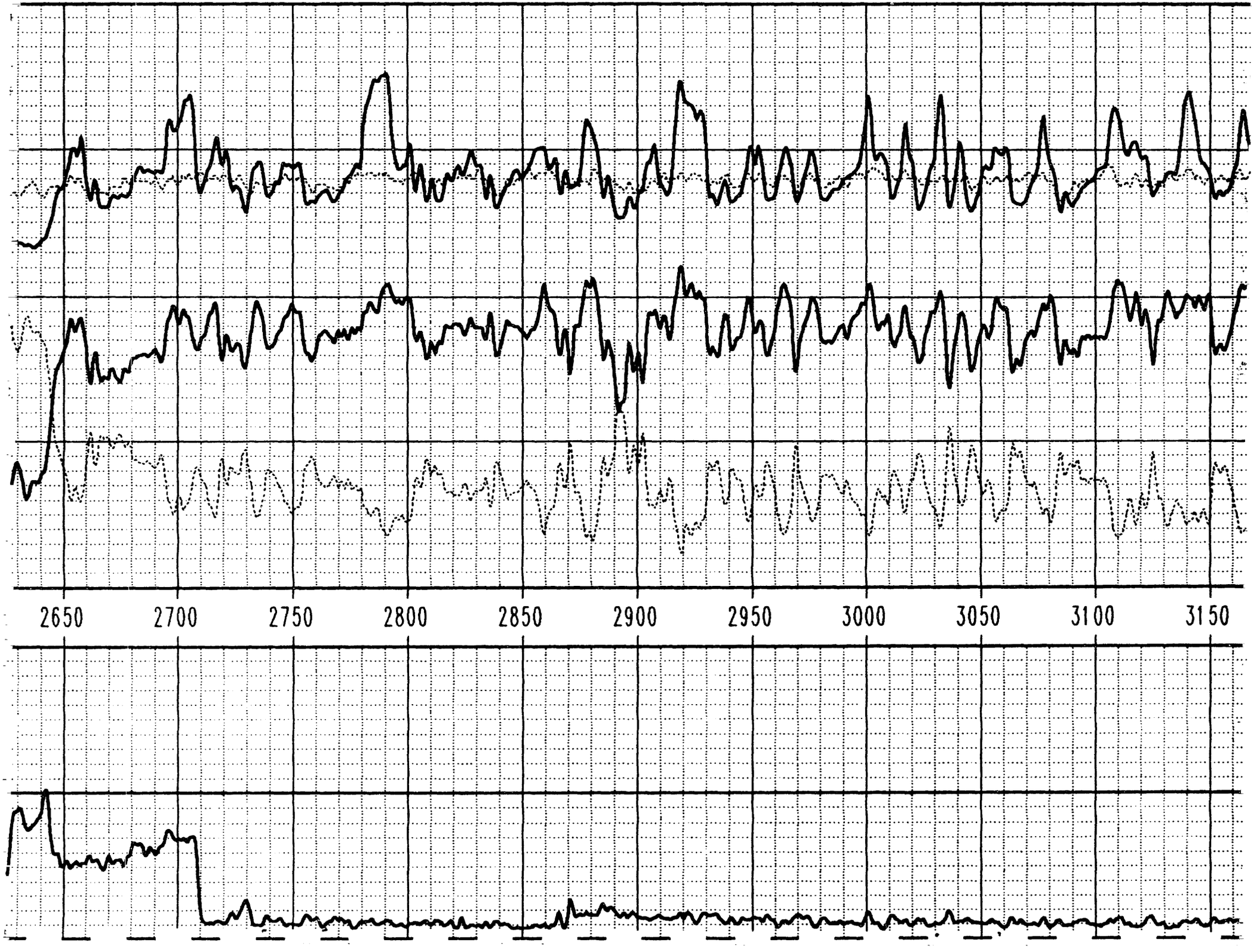

INEL/NPR WELL WO-2 30 SEPT 1991
COLOG
NEUTRON
0 CPS 1500
NATURAL GAMMA
0 CPS 200
DENSITY POROSITY(MTX=2.95)
-25 PERCENT 75
COMPENSATION
-0.5 gm/cc 0.5
CALIPER
1.0 INCHES 3.0
DENSITY
1 gm/cc 5
0
50
100
150
200
250
300
350
400

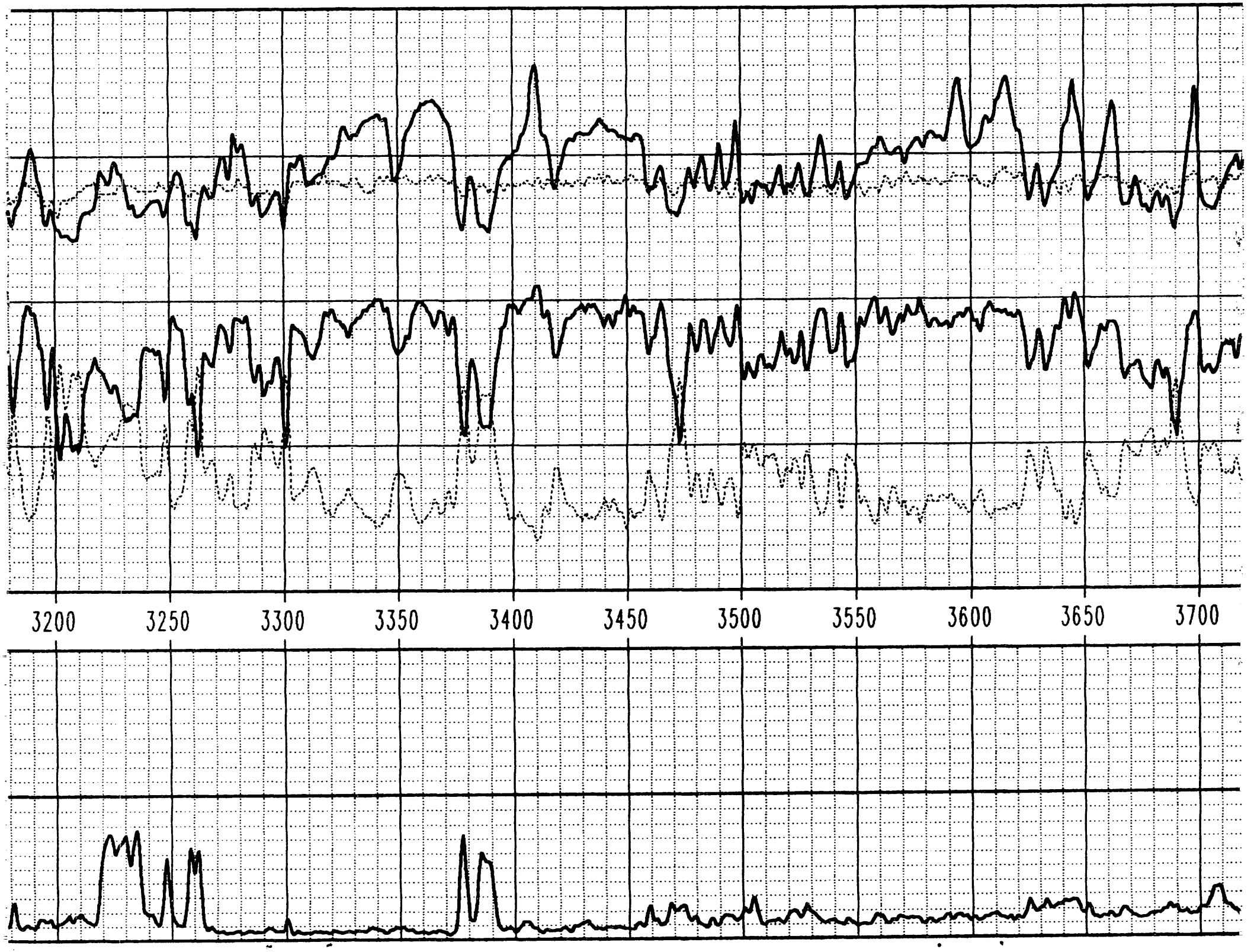

450
500
550
600
650
700
750
800
850
900
950

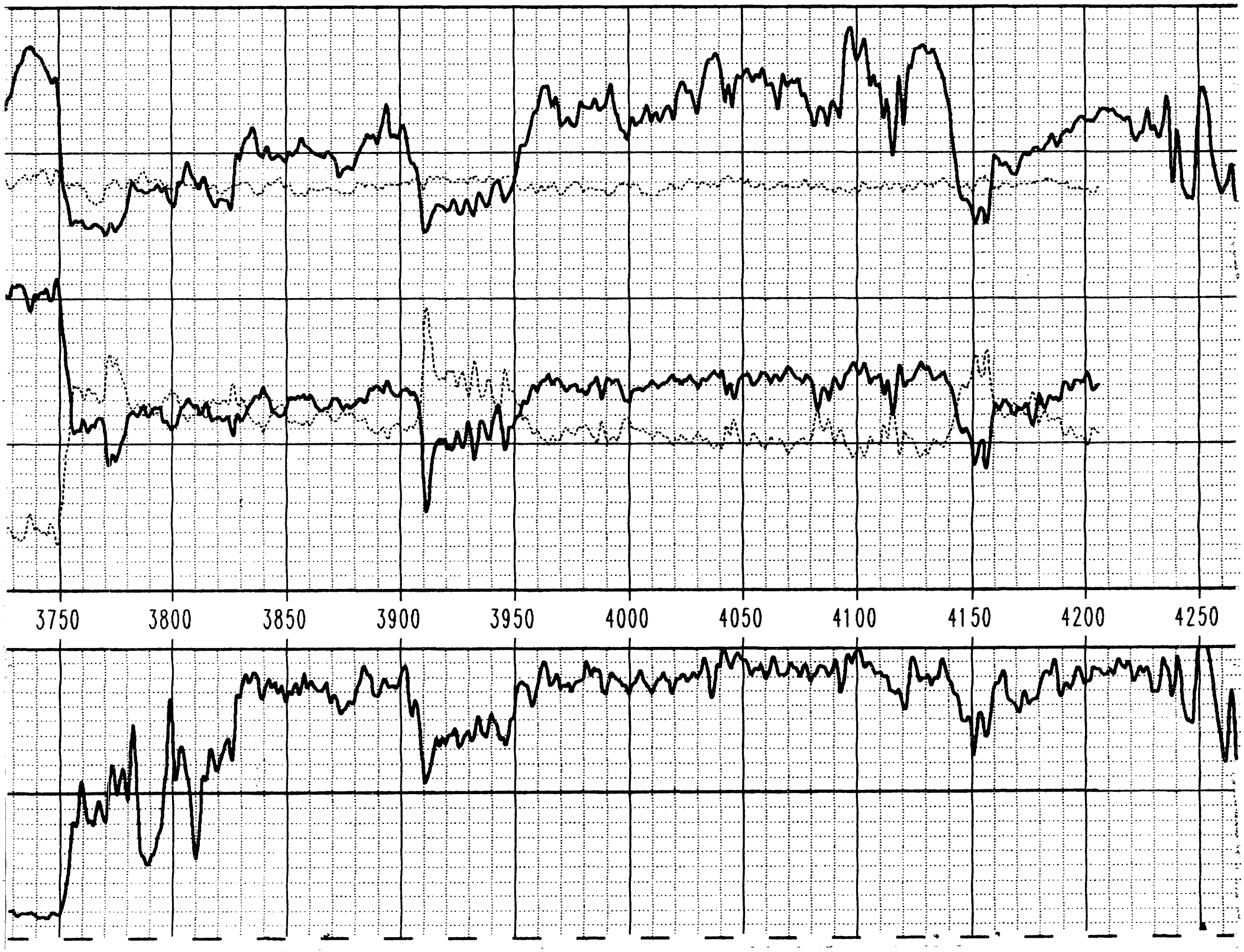

1000
1050
1100
1150
1200
1250
1300
1350
1400
1450
1500

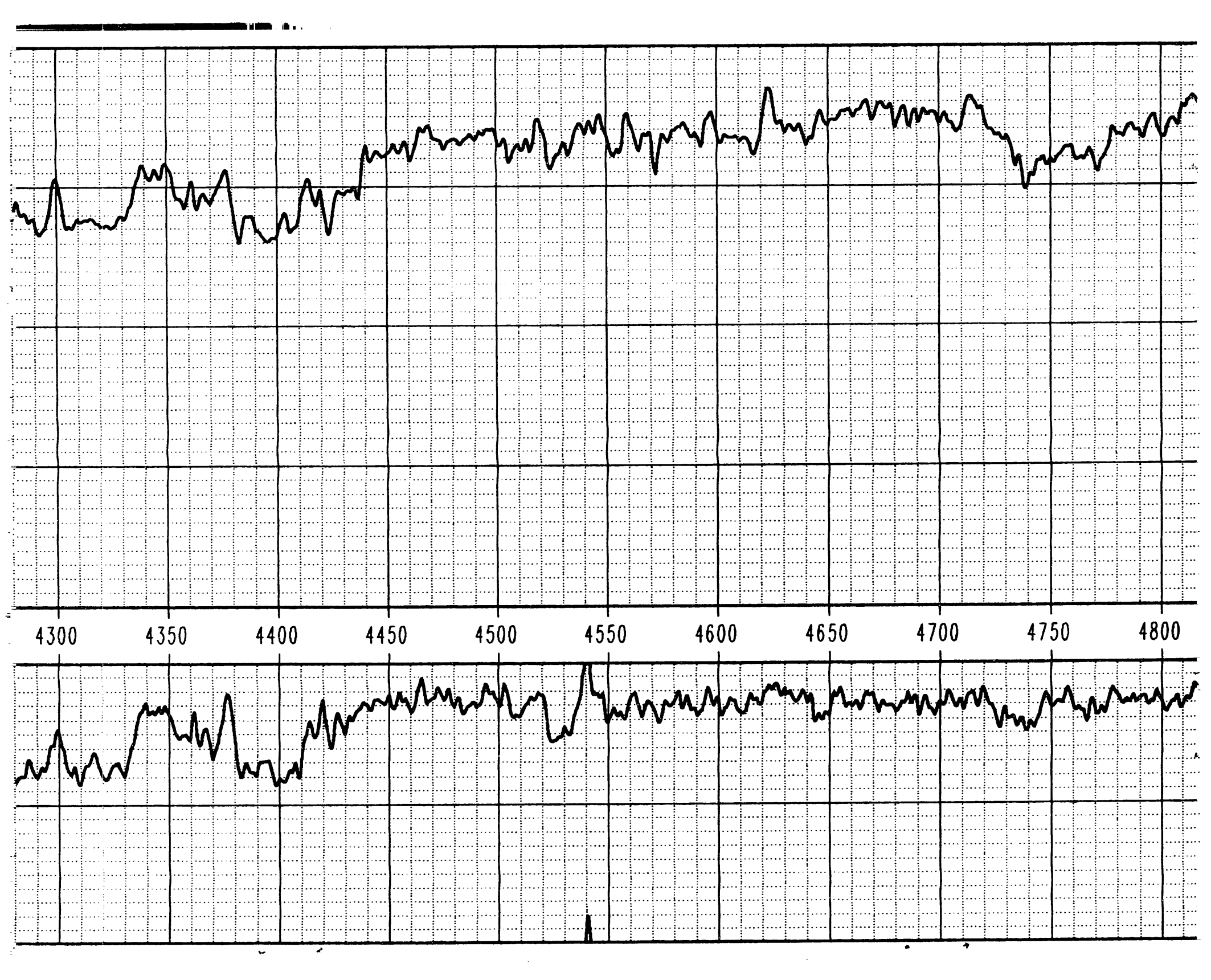

1550
1600
1650
1700
1750
1800
1850
1900
1950
2000
2050

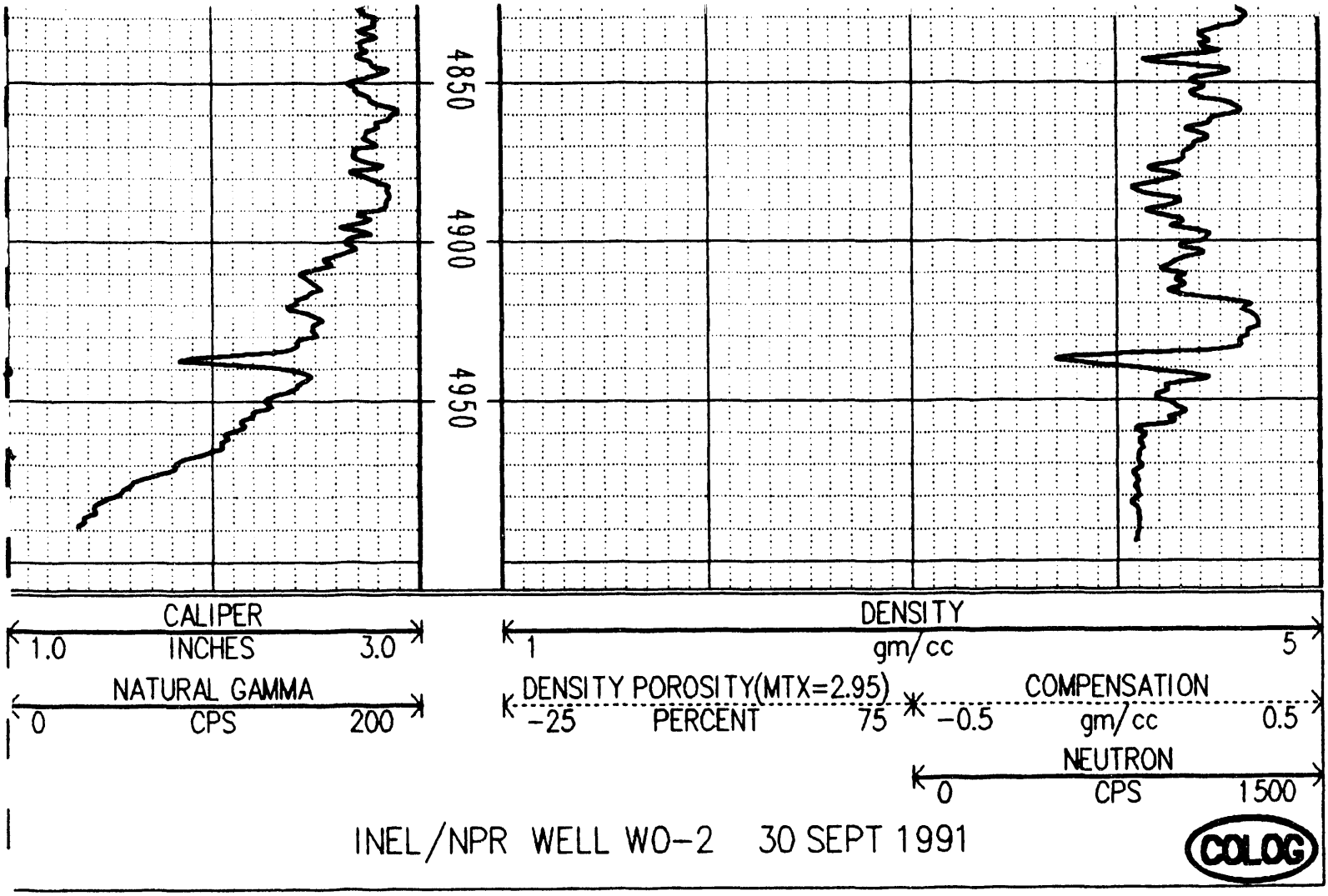

2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
2600


2650
2700
2750
2800
2850
2900
2950
3000
3050
3100
3150


3200
3250
3300
3350
3400
3450
3500
3550
3600
3650
3700


3750
3800
3850
3900
3950
4000
4050
4100
4150
4200
4250


4300
4350
4400
4450
4500
4550
4600
4650
4700
4750
4800


4850
4900
4950
CALIPER
1.0
INCHES
3.0
NATURAL GAMMA
0
CPS
200
DENSITY
1
gm/cc
5
DENSITY POROSITY(MTX=2.95)
-25
PERCENT
75
COMPENSATION
-0.5
gm/cc
0.5
NEUTRON
0
CPS
1500
INEL/NPR WELL WO-2 30 SEPT 1991
COLOG

END

DATE
FILMED
10/7/93