UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Geophysical investigations in southeastern Utah

by

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This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards

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Introduction

This report presents data collected from a geophysical survey by the U.S. Geological Survey in the Deer Flats area in southeastern Utah. The Survey area is located about 6 km north of Natural Bridges National Monument (fig. 1). Uranium deposits in the Deer Flats area are found in buried channels cut into the Moenkopi Formation (Lower and Middle (?) Triassic) and filled with sedimentary rocks of the Shinarump Member of the Chinle Formation (Upper Triassic). Exploration for uranium in this area consists of locating buried channels (usually by drilling) and drilling within their limits to detect possible ore bodies. In the early 1950's the U.S. Geological Survey demonstrated the usefulness of employing geophysical methods in exploration for buried channels in sedimentary environments (Black and others, 1962). During the past 25 or so years, since these earlier efforts, significant advances have been made in equipment design and construction, making it possible to measure physical properties in the field with a greater variety of techniques than before. In addition, interpretive methods have been greatly aided by the advent of digital computers which were not available to the earlier workers. Data presented in this report were taken with the present day state-of-the-art equipment and compiled using digital methods with the aid of a computer. It is the purpose of this report to present the field data and maps showing the results of the electrical measurements with a minimum of interpretation.

Electromagnetic measurements

The three electromagnetic (EM) methods used in the Deer Flats test area were very low frequency (VLF), slingram, and turam. Detailed descriptions of

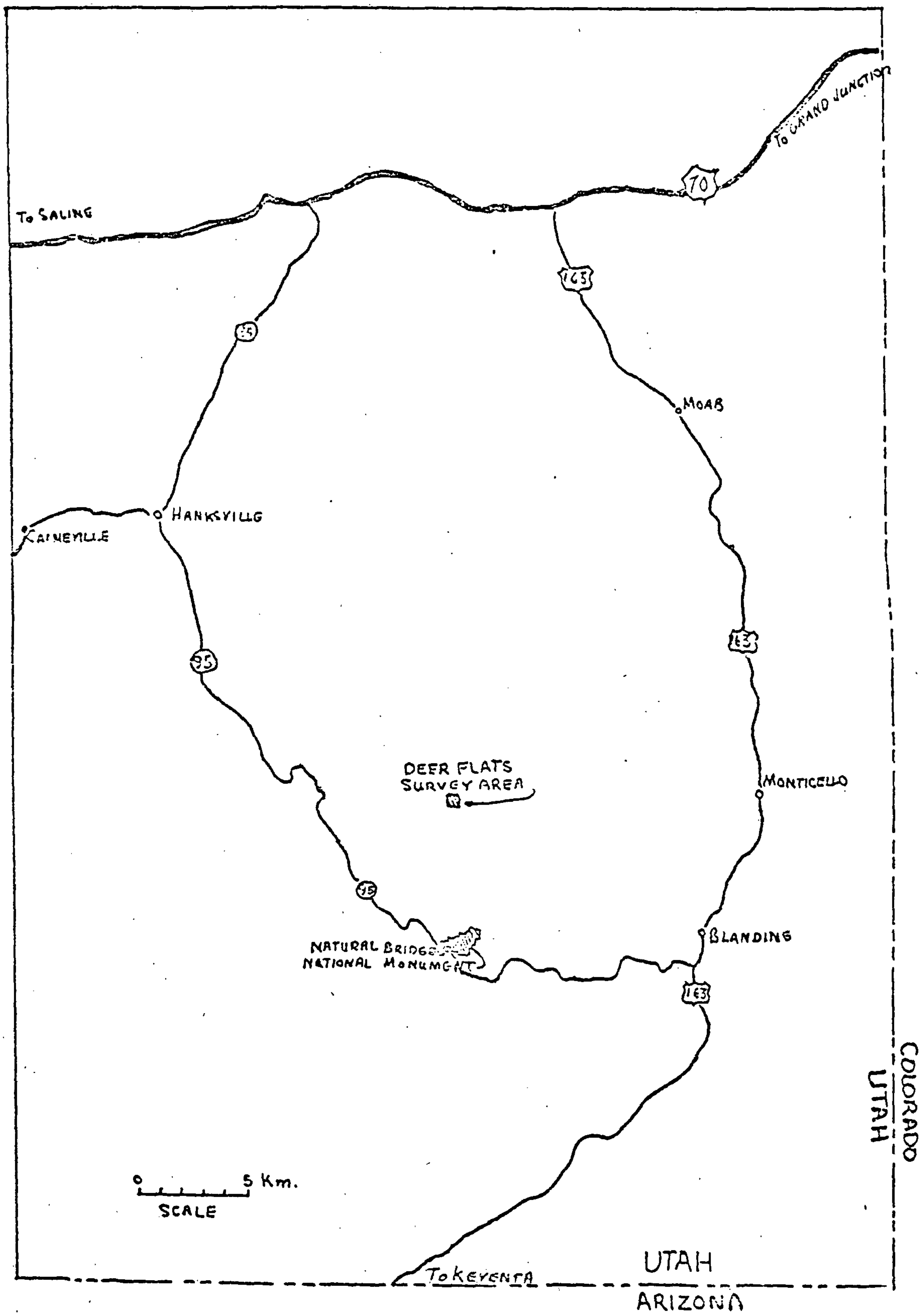


Figure 1. Index map showing location of the Deer Flats, Utah, survey area.

these methods are given by Telford (1976).

The VLF method measures components of the magnetic and electric fields associated with a transmitted radio wave originating from one of the powerful military VLF transmitters located in the western hemisphere. The transmitter used in this survey is located north of Seattle, Washington, and operates at a frequency of 18.6 KHz. The four components measured are the inclination or dip, ellipticity or quadrature (quad), apparent resistivity, and phase angle of the surface impedance. The VLF dip and quad are a measure of the VLF polarization ellipse in the vicinity of the measurement. The inclination and eccentricity reflect the relative field strength and phase of the primary and secondary magnetic fields at the transmitted frequency (Patterson and Ronka, 1971). The apparent resistivity of the earth beneath the measurement point is determined by measuring the relative field strength of the vertical magnetic and horizontal electric fields at the transmitted frequency. The phase of the surface impedance is useful in determining the relative resistivity of rock in a layered sequence. If the conductivity (inverse of resistivity) of the surface layer of the earth is higher than that of the underlying layer, the phase is generally somewhat less than 45 degrees. If the reverse is true, the phase is greater than 45 degrees. All of these parameters except the inclination are sensitive to changes of conductivity of the earth both laterally and vertically within the area of influence or roughly a skin depth. The skin depth is a function of the resistivity of the earth (a) and the frequency (F) of the transmitted signal, and is expressed as: SD (meters) = $503.29 \left(\frac{\rho a}{F}\right)^{1/2}$.

The slingram method, described in detail by Frischknecht (1967) and by Telford and others (1976) is a moving transmitter and receiver method.

Electromagnetic fields are induced in the earth by a transmitting coil. Components of the secondary field are measured by a receiving coil. The depth of exploration is a function of the resistivity of the upper layers of the earth, the coil separation, and the transmitting frequency. In the equipment employed, five frequencies from 222 to 3555 Hz and coil separations from 30.5 to 243 m are available for use. In this survey, measurements were taken at all five frequencies at a coil separation of 243 m. These data can be used to determine the resistivities of a layered earth by use of inversion programs producing geoelectric cross sections which can be related to the geologic cross section.

The turam method is a fixed-source EM method. The source used in this survey was a 1220-m-long wire grounded at both ends and energized by a transmitter at three frequencies (200,400,800 Hz). Two receiving coils at 30.5-m coil separation were used to measure the horizontal gradient and relative phase of the magnetic fields. Profiles were made normal to the transmitting wire; thus, the coils measure an amplitude ratio of the field at varying distances from the transmitter. The field data were normalized to the theoretical amplitude ratio, computed using a nearby resistivity well log for control (table 1).

Table 1. Near Here

Therefore, the amplitude ratios shown on the turam map reflect changes in the measured section that are different from the model assumed from the well log. The resistivity well log and model used to compute the normal amplitude are shown on figure 2. Included on figure 2 are data from a dc electrical

distance from transmitter (m)	amplitude ratio
45.7	.49
76.2	.65
106.7	.72
137.2	.76
167.6	.79
198.1	.81
228.6	.82
259.1	.83
289.6	.84
320.0	.8435
350.5	.8481
381.0	.8516
411.5	.8541
442.0	.8572
472.0	.8595
502.9	.8613
533.4	.8631
563.9	.8645

Table 1 Theoretical amplitude ratios used to normalize the turam data.

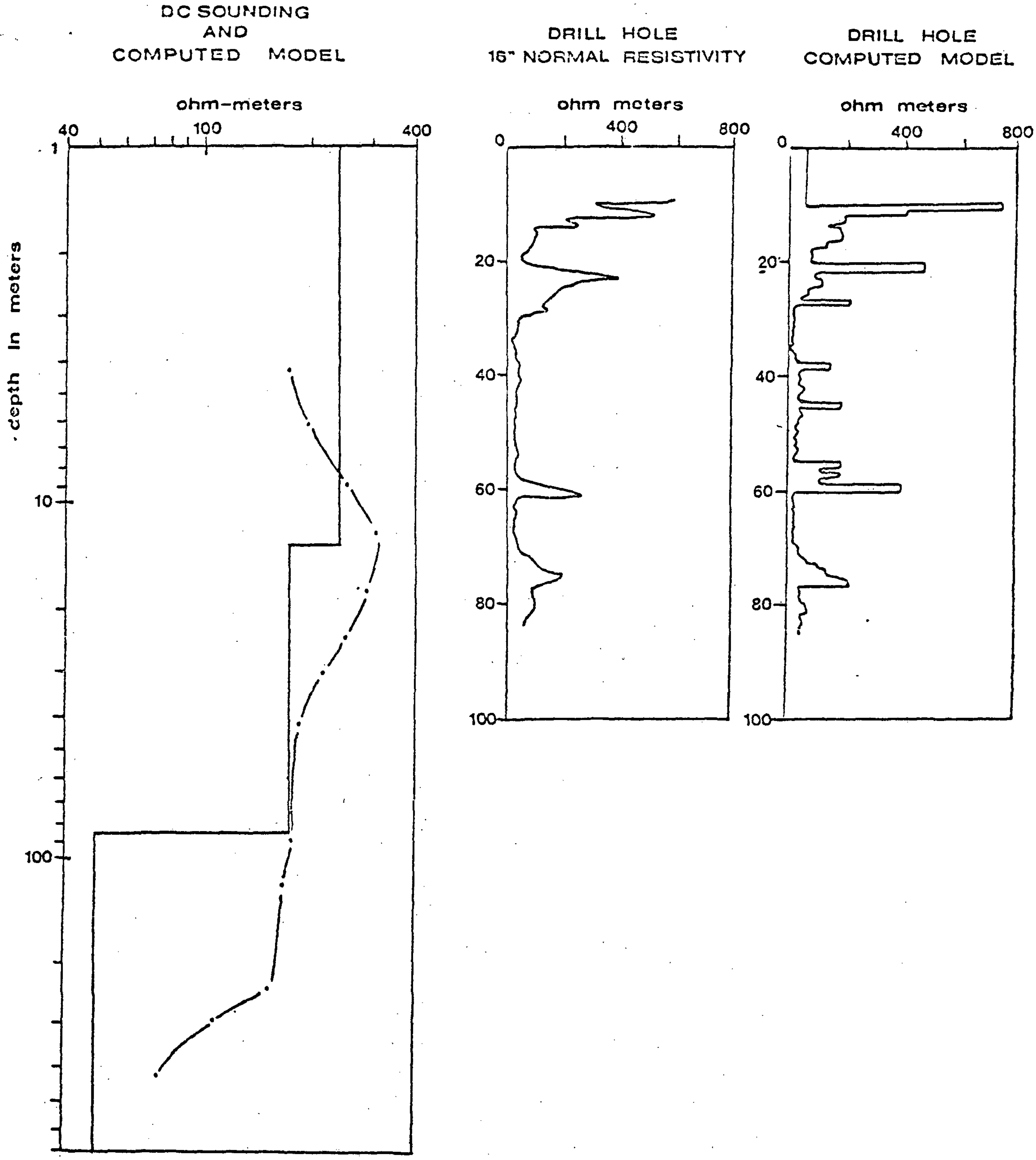


Figure 2. Geo-electric logs and models from the Deer Flats area.

sounding in the vicinity of the drill hole, along with an interpreted geoelectric section.

Measurements were made along east-west lines at 30.5- and 61-m intervals. Profile lines were spaced about 122 m apart. In the northwestern sector of the survey area, it was not possible to make measurements beyond the edge of the mesa. The mineralized zone does extend into this area below the edge of the rim rocks.

Data Presentation

The VLF data are presented as component contour maps (figs. 3-6) and as tables of field data (appendix, p. 23-25). The data show a variation of conductivity in the first 30 to 40 m (skin depth) of the earth's surface. Near-surface rocks are more resistive than the underlying layer (phase of the surface impedance is generally greater than 45 degrees). The most resistive rocks in the survey area are generally outlined by the 120 ohm-meter contour line in the center of the survey area (fig. 5). While the trend of mineralization in the survey area is shown on all the geophysical maps, it is not inferred that the VLF data reflect changes of physical properties associated with the buried channel which is at a depth of about 70 m. The VLF data provide a useful indication of lateral as well as vertical variation of conductivity in shallow rocks near the measurement point. This type of information is necessary to ascertain the degree of departure from a truly layered earth model assumed in modelling loop-loop data and to determine the near-surface effects on deeper penetration EM methods.

Two of the five frequencies of slingram data are shown on figures 7-10. The complete data set is shown in the appendix (p. 26, 27). The data variations reflect the more resistive near-surface rocks seen in the VLF data.

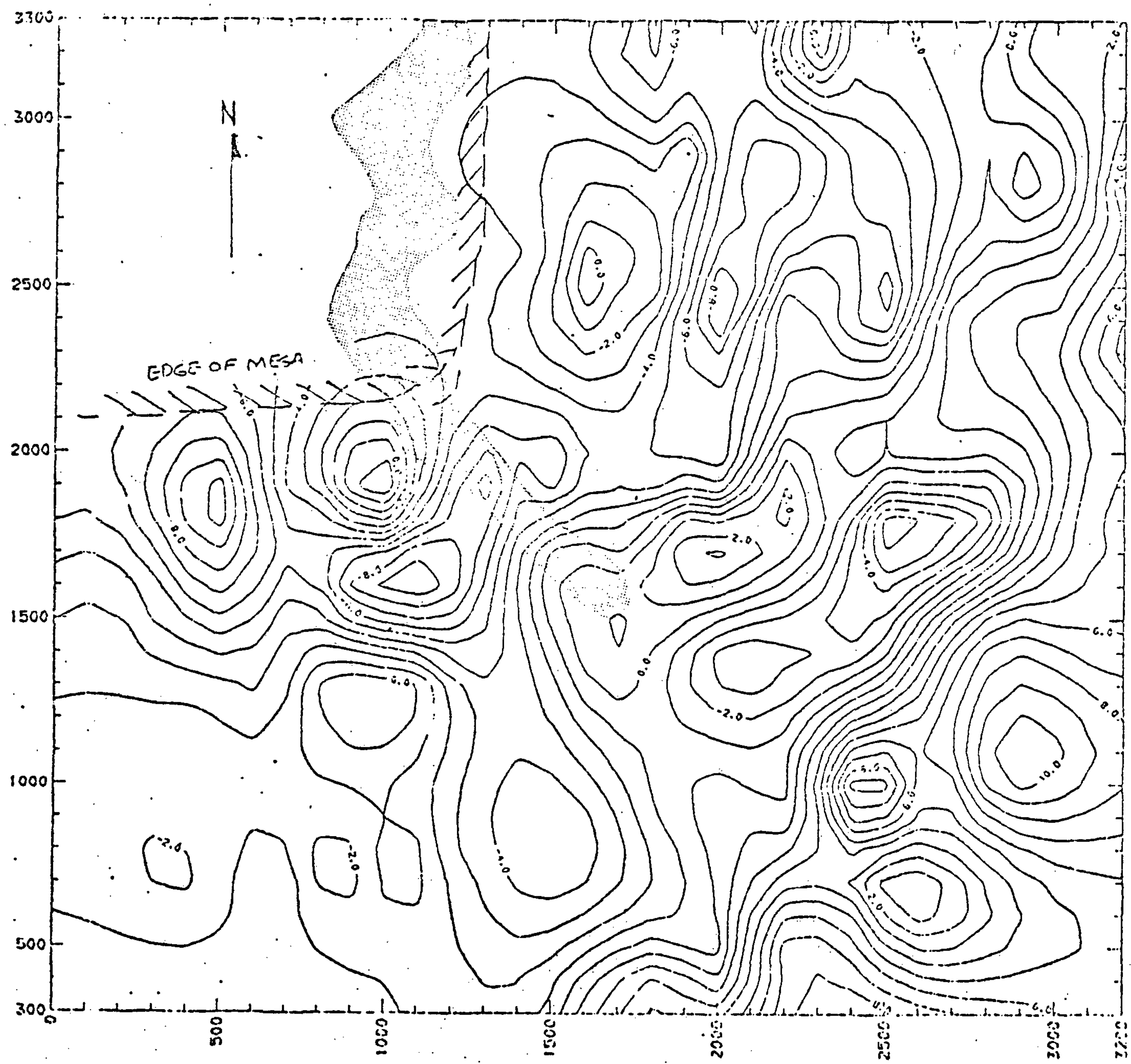


Fig. 3. VLF map of the Deer Flats, Utah, survey area showing values of the dip angle. Contour interval is 1 percent. Grid scale is in feet. Shaded area shows trend of uranium mineralization.

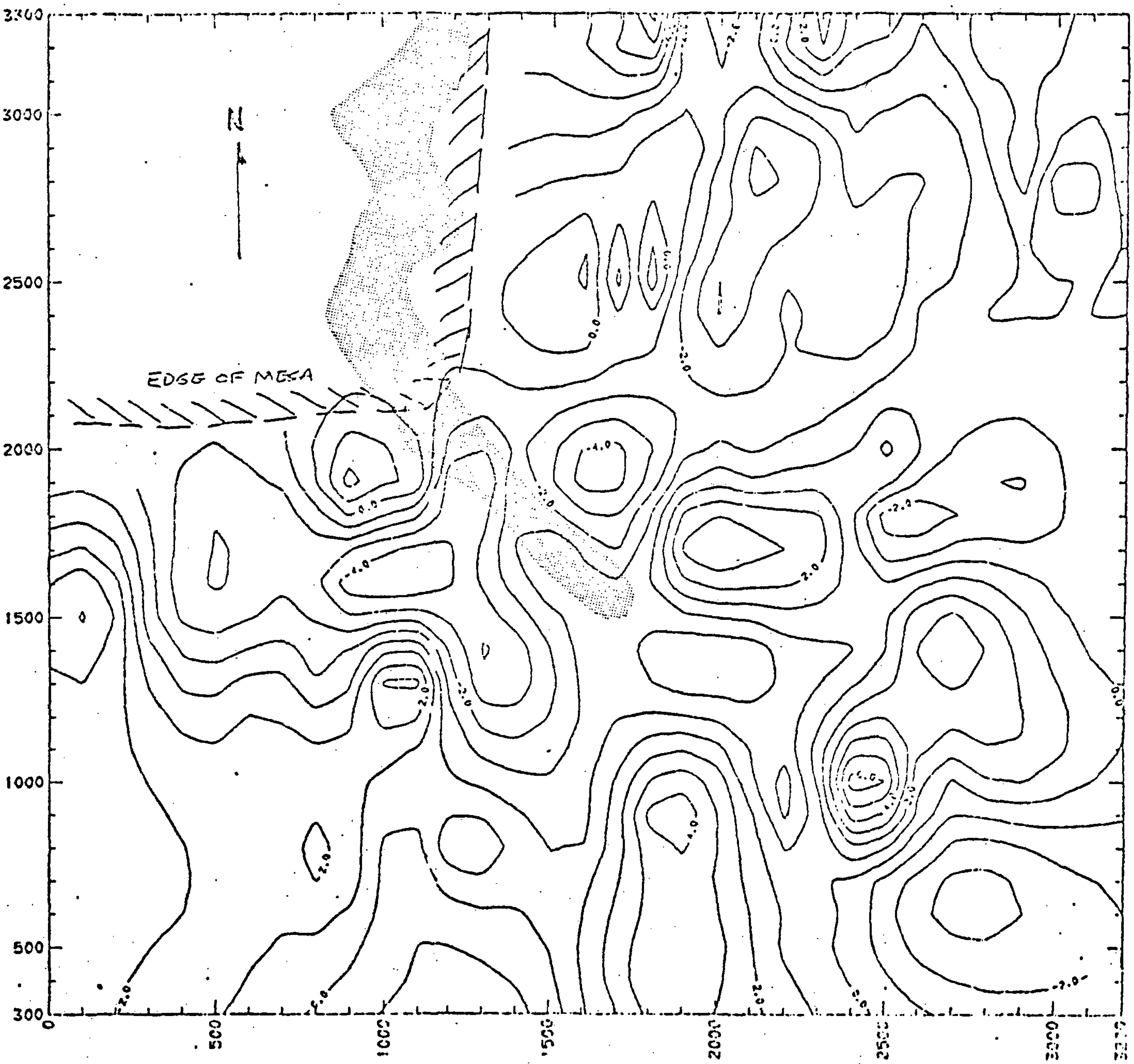
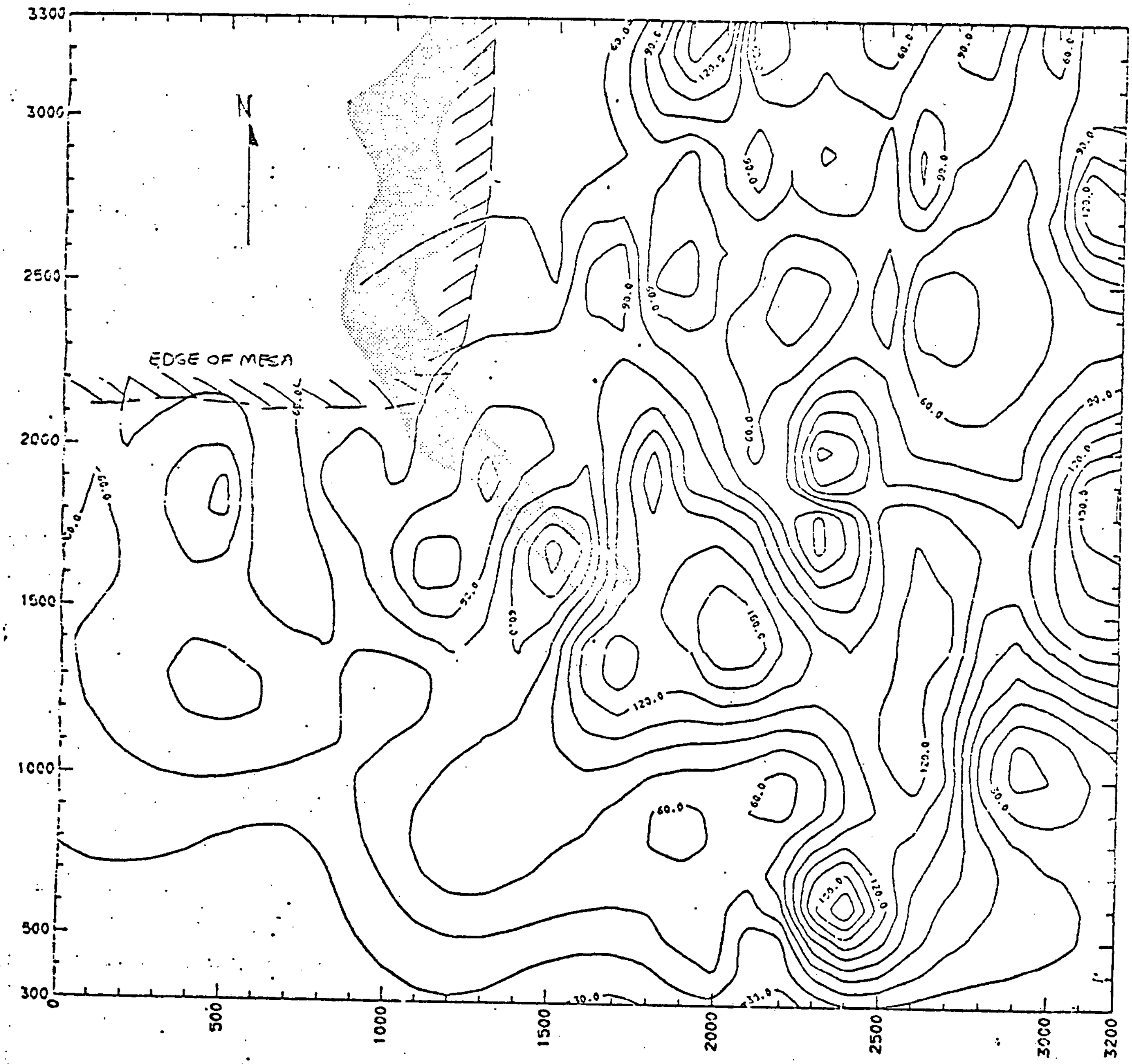


Figure 4. VLF map of the Deer Flats, Utah, area showing values of the quadrature field component. Contour interval is 1 percent. Grid scale is in feet. Shaded area shows trend of uranium mineralization.



gure 5. VLF map of the Deer Flats, Utah area showing values of apparent resistivity. Contour interval is 15 ohm-meters. Grid scale is in feet. Shaded area shows trend of uranium mineralization.

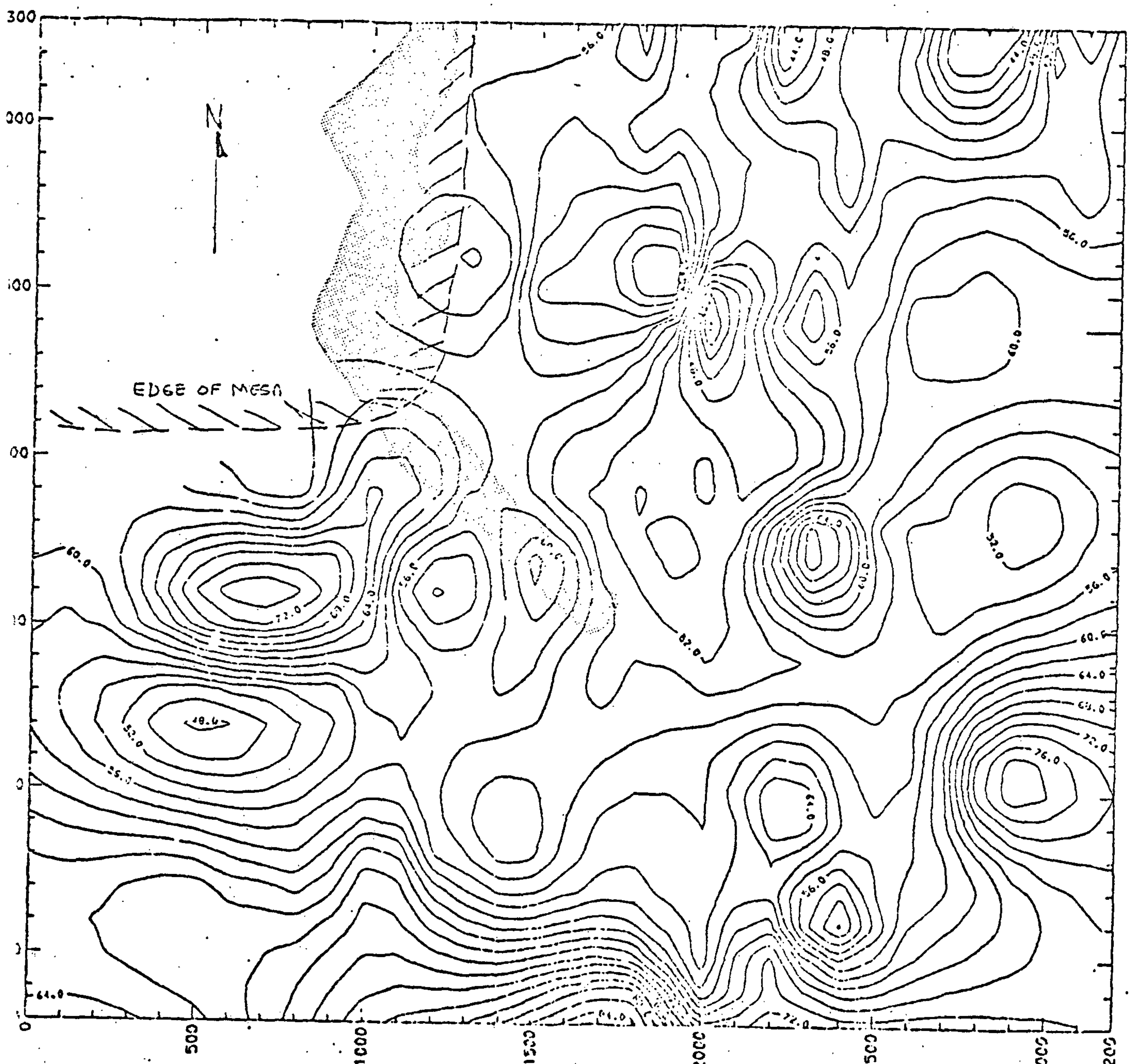
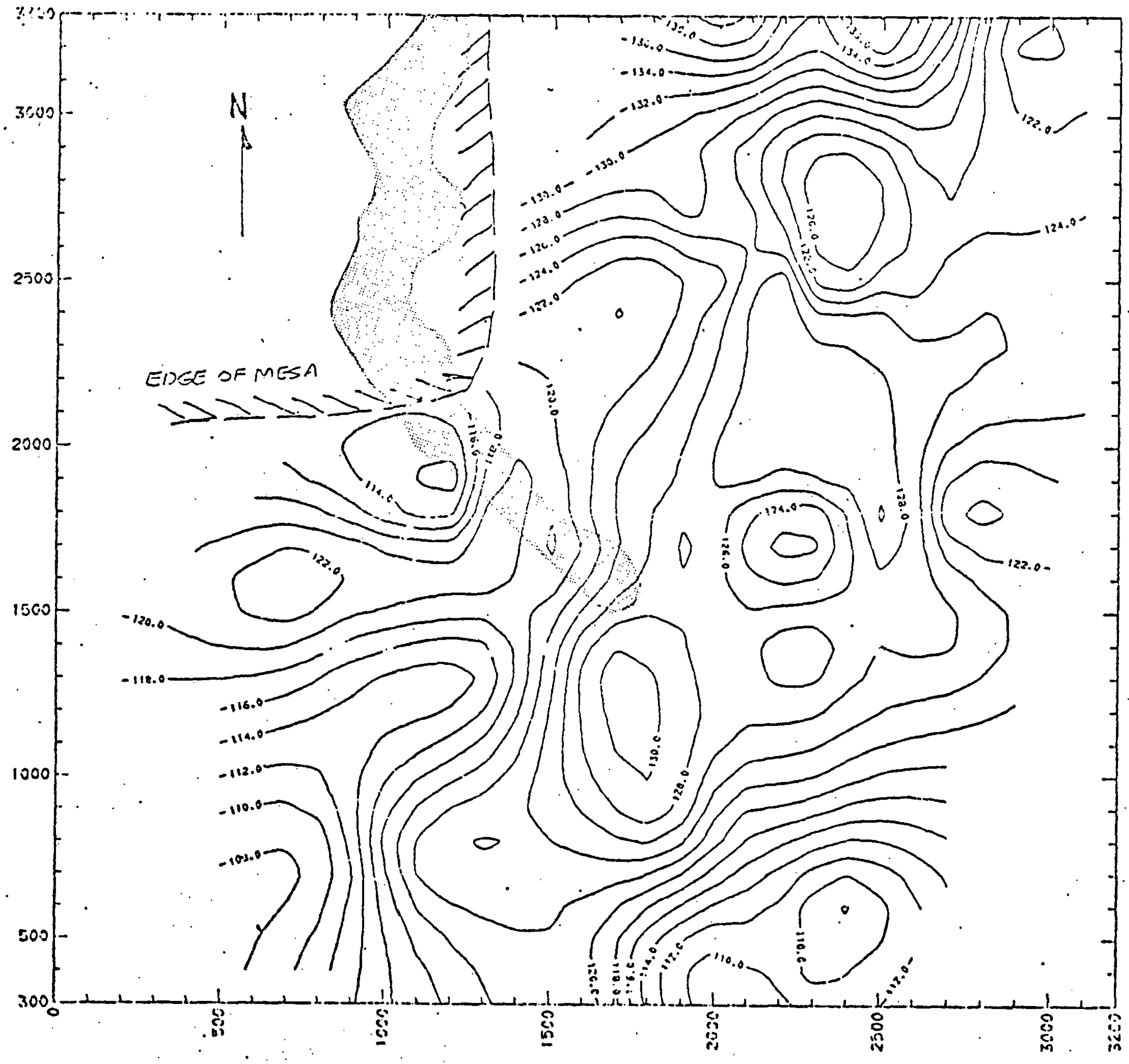
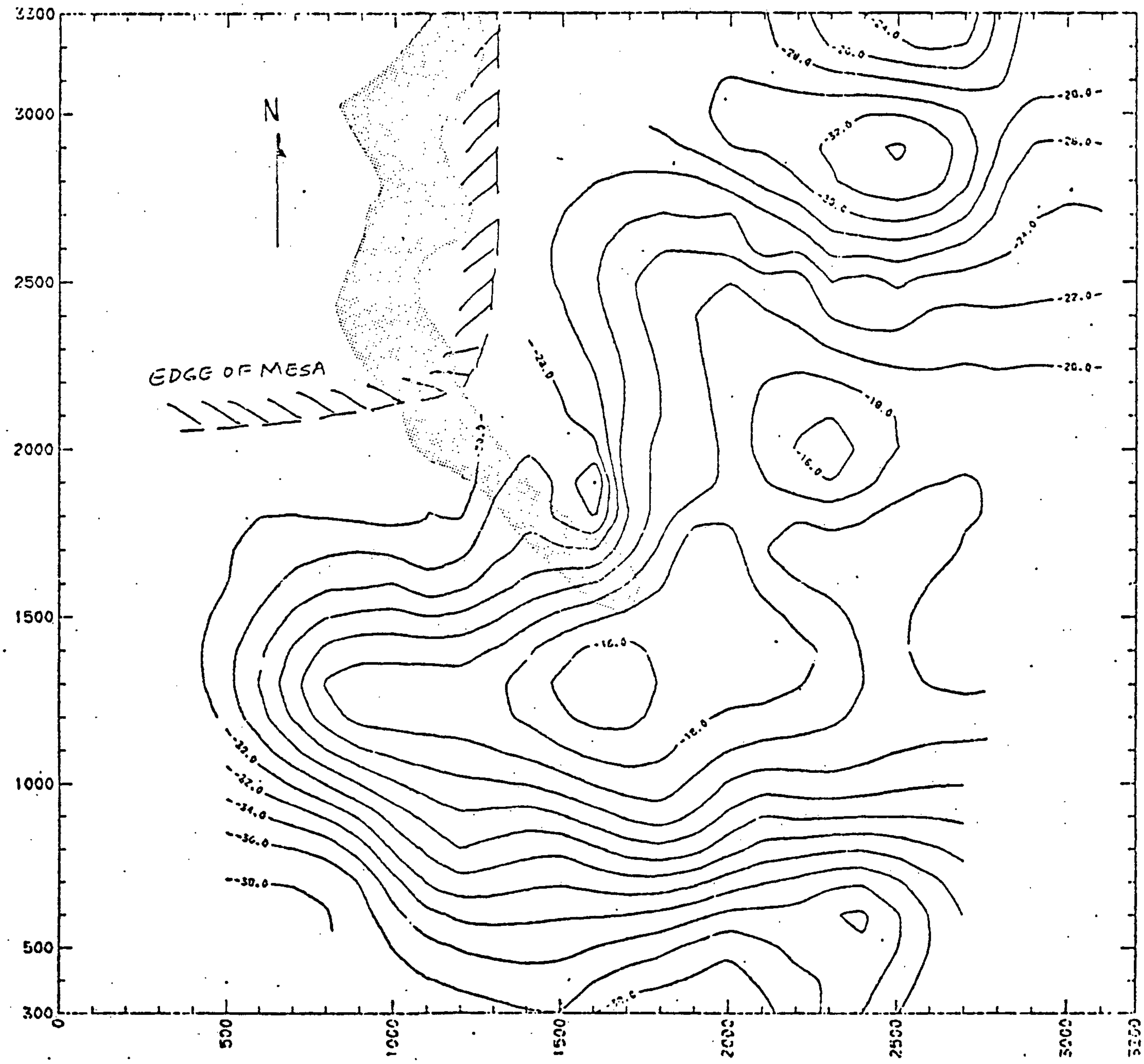


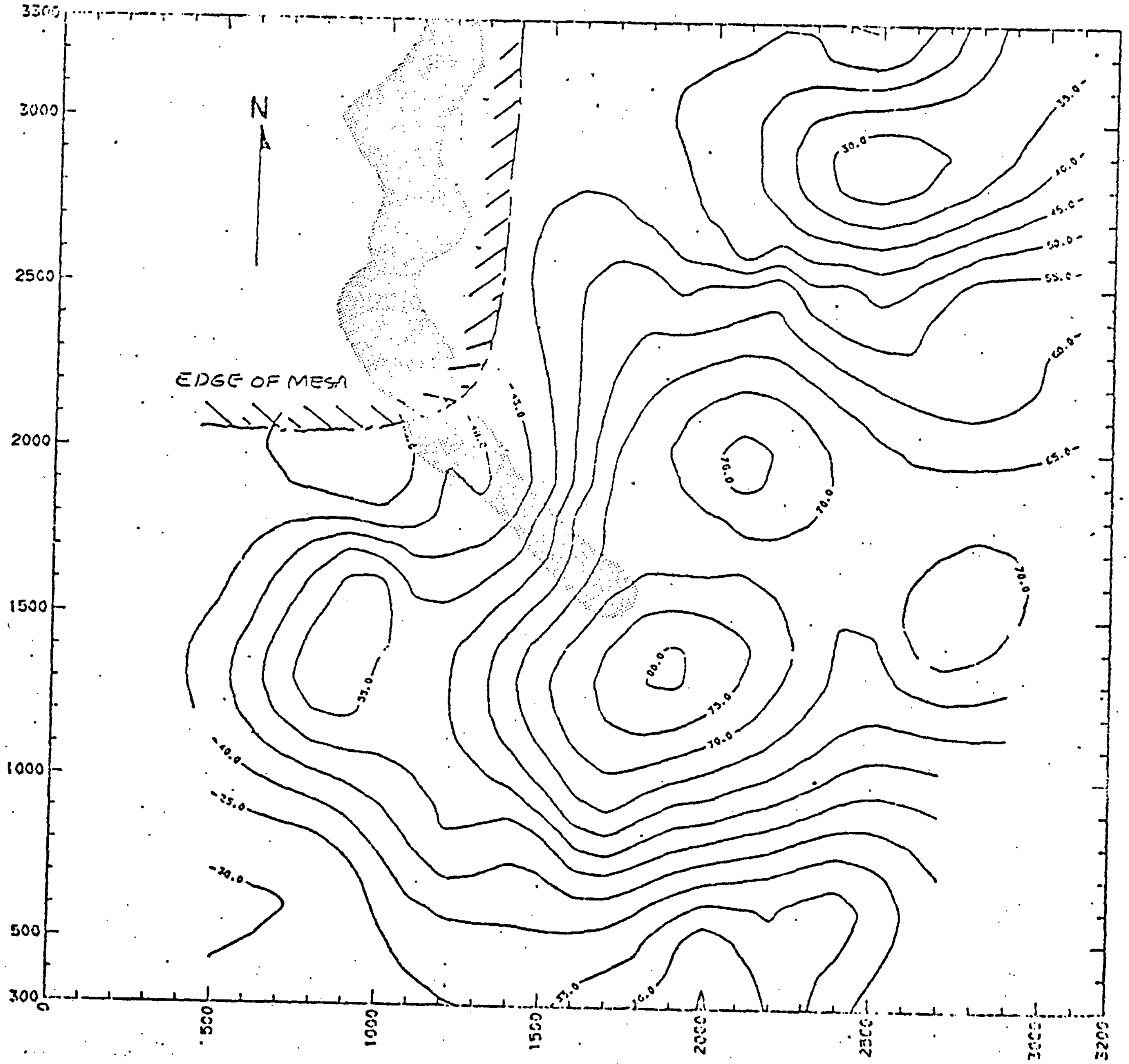
Figure 6. VLF map of the Deer Flats, Utah, survey area showing values of the phase angle of surface impedance. Contour interval is 2 percent. Grid scale is in feet. Shaded area shows trend of mineralization.



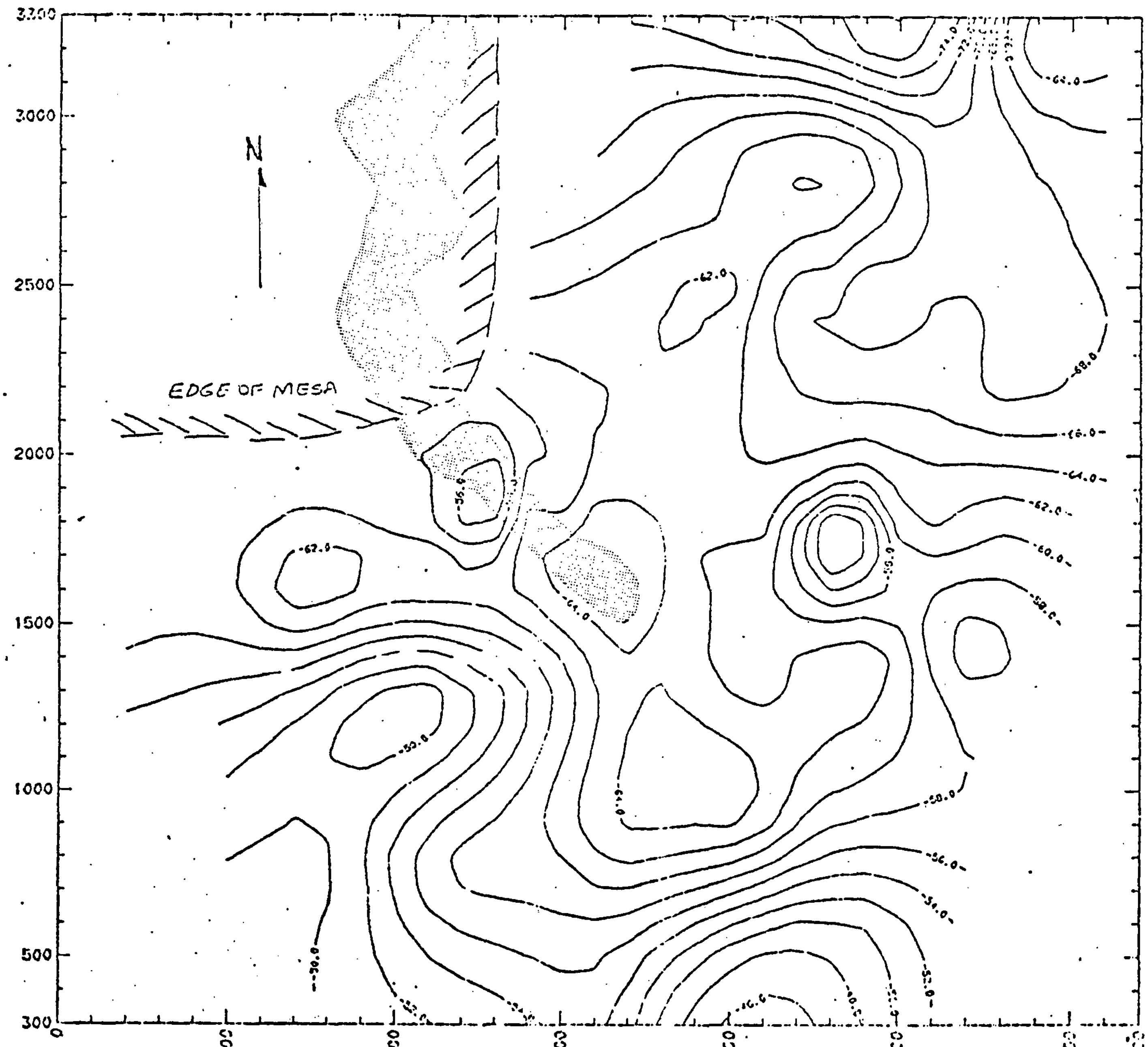
gure 7. Slingram map of the Deer Flats, Utah, survey area showing values of the real field component at 444 Hz. Contour interval is 2 percent. Grid scale is in feet. Shaded area shows trend of mineralization.



.gure 8. Slingram map of the Deer Flats, Utah, survey area showing the imaginary field component at 444 Hz. Contour interval is 2 percent. Grid scale is in feet. Shaded area shows trend of uranium mineralization.



ʒure 9. Slingram map of the Deer Flats, Utah, survey area showing the real field component of 1777 Hz. Contour interval is 5 percent. Grid scale is in feet. Shaded area shows trend of uranium mineralization.



igure 10. Slingram map of the Deer Flats, Utah, survey area showing the imaginary field component at 1777 Hz. Contour interval is 2 percent. Grid scale is in feet. Shaded area shows trend of mineralization.

While the coil separation was such as to be responding to changes of conductivity to a maximum depth of 120 m, without more interpretation it is impossible to determine whether or not the slingram data show trends that may be related to the buried channels. Preliminary model studies, using resistivity data from the drill hole penetrating the mineralized zone and from one that did not penetrate the mineralization for control, showed only a few percent difference in slingram readings over the two areas. The difference in slingram response in the model studies was attributed to a thin resistive layer overlying the mineralization. This resistive unit is not present in areas that are not mineralized. Inasmuch as the variations observed in the field are an order of magnitude higher than expected, the lateral variation of electrical resistivity in the near-surface rocks is assumed to be masking any expression that might be associated with the buried channels. Hence, the slingram contour maps probably cannot be interpreted as directly showing trends of the buried channels.

Turam measurements for one frequency (800 Hz) of the three measured in the field are shown as contour maps (figs. 11-12). The complete data set is shown in the appendix (p. 28,29). The turam data, like the VLF and slingram data, show considerable variation in measured values in the survey area. As mentioned earlier, the amplitude ratios measured in the field were normalized to amplitude ratios computed using a layered-earth model based on a resistivity well log. Thus, the values shown on the ratio map (fig. 11) indicate a certain degree of departure from the assumed model. Values of 1.0 outline areas where field data are in close agreement with the model parameters. Values above and below 1.0 indicate areas where the field electrical properties are somewhat different from the assumed layered-earth

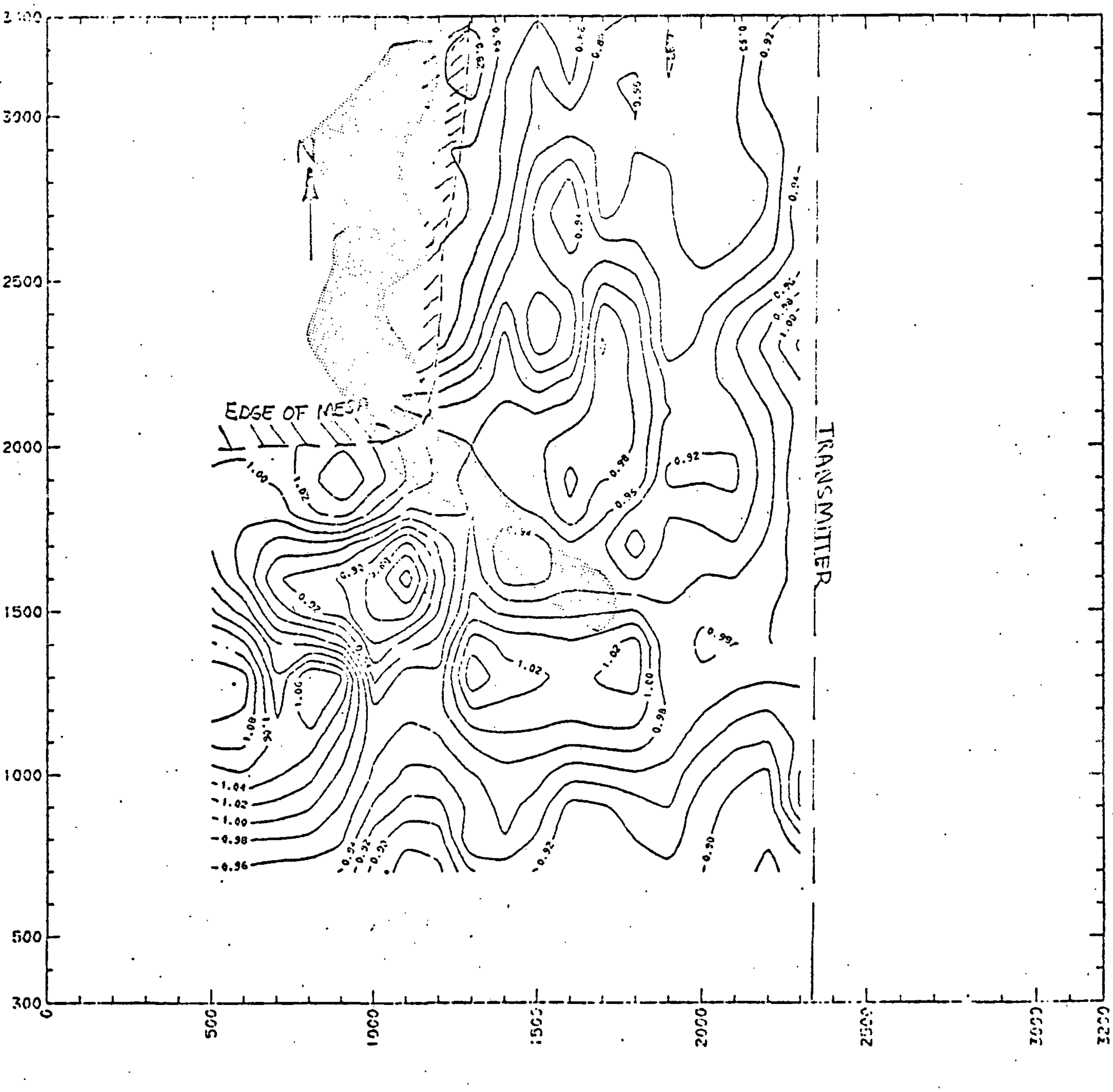
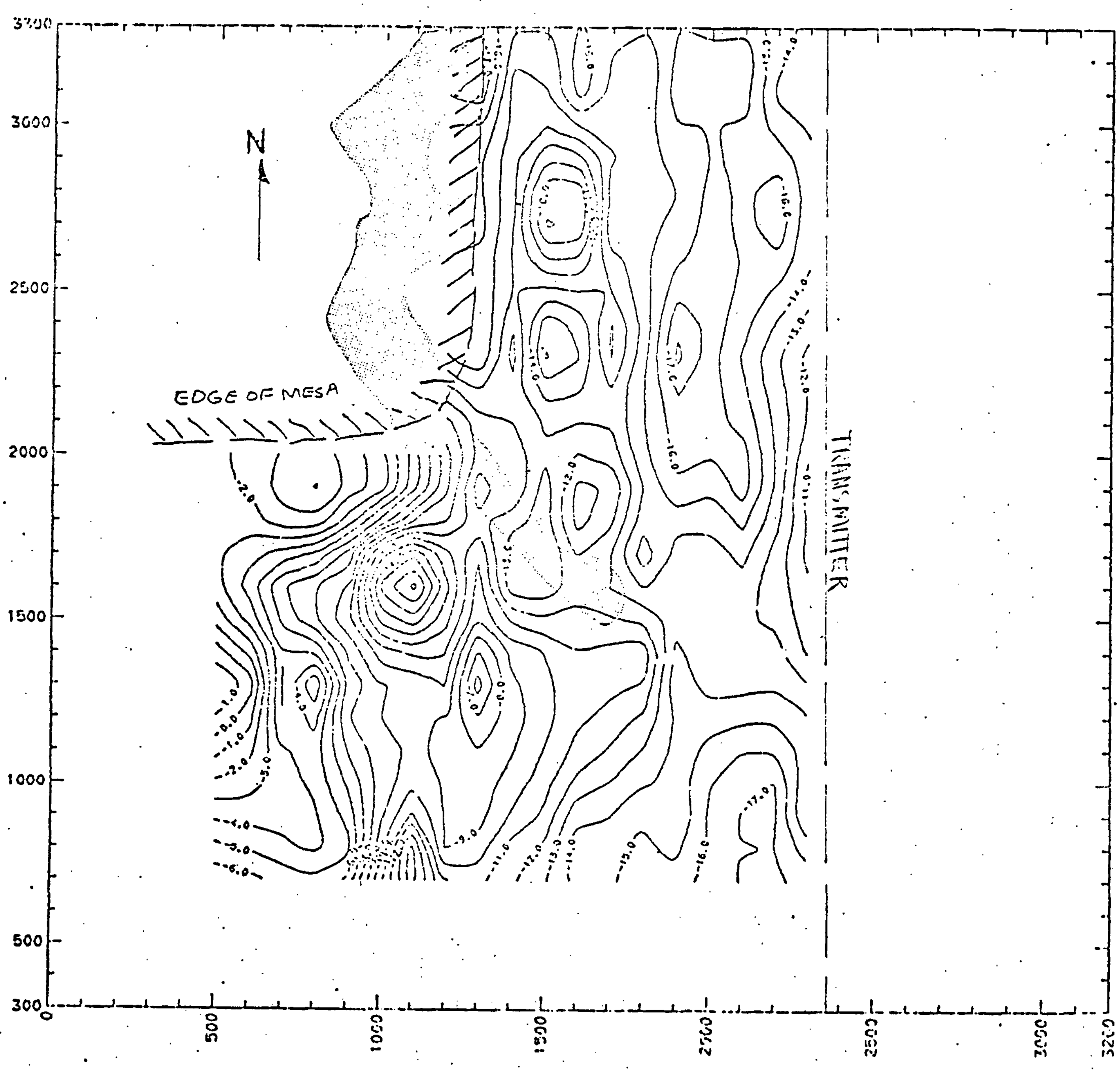


Figure 11. Turam map of the Deer Flats, Utah, survey showing values of the reduced amplitude ratio at 800 Hz. Contour interval is 0.02. Grid scale is in feet. Shaded area shows trend of uranium mineralization.



igure 12. Turam map of the Deer Flats, Utah, survey area showing the phase difference at 800 Hz. Contour interval is 1 degree. Grid scale is in feet. Shaded area shows trend of uranium mineralization.

model. Here, as with the VLF and slingram techniques, it is not known to what extent the departure from the assumed model is due to changes in the electrical properties of the near-surface rock or to deeper electrical changes associated with the buried channels. There is some indication that the trend of the mineralization follows ratio trends below 1.0, suggesting that the buried channels might extend to the southeast about 150 m and then turn to the south at about 2200 on the x grid coordinate. Just how valid this assumption is would have to be tested in the field by drilling. The turam phase map (fig. 12) shows the phase difference between the two detectors as measurements are made along the profile. The theoretical phase differences were not subtracted from the field data. Phase, as well as the amplitude measurements, is sensitive to the degree of conductivity of the rocks over which the measurements are being made. Conductive rocks are characterized by high inductance, and the phase lag between the induced voltage in the conductive zones and the secondary current is generally large, thus shifting the secondary field more out-of-phase with respect to the primary field. In a perfect conductor the secondary field is shifted a total of 180° from the primary field. The result is a strong in-phase or amplitude response, which may aid or oppose the primary field, depending on geometry and zero quadrature component or phase shift. Poorly conducting rocks are resistive, and the phase lag between the induced voltage and secondary current is small, so the secondary field approaches 90° out of phase with respect to the primary field. For turam, the largest phase shifts are encountered in rocks low enough in resistivity to allow large secondary currents to flow but not low enough to shift the phase close to 180°. Thus, the phase-difference map is indicating relative degrees of conductivity of the rocks over which the measurements are being made.

Conclusions

The three EM methods used in this survey indicate variations in response associated with the near-surface resistivity of the earth. While in a normal exploration program perhaps only one of the methods might be employed, the results can be compared and the method selected which is expected to yield the greatest amount of useful information. The selection of an optimum EM method must of necessity be geared to the geologic environment and the purpose and type of data interpretation to be used. The data presented in this report have not been subjected to numerical methods of interpretation, which can extract additional useful information.

References Cited

Black, R. A., Frischknecht, F. C., Hazelwood, R. M., and Jackson, W. H., 1962, Geophysical methods of exploring for buried channels in the Monument Valley area, Arizona and Utah: U.S. Geol. Survey Bulletin 1083-F, p. 161-228.

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Patterson, M. R., and Ronka, V., 1971, Five years of surveying with the very-low-frequency method: Geoexploration, v. 9, pg. 7-26.

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APPENDIX

Field data for EM methods

VLF DATA DEER FLATS, UTAH

Sta.	Line	x position	y position	Dip	Quad	Resistivity	Phase
1	8	1675.00	3290.00	-5.00	-4.00	50.00	55.00
2	8	1775.00	3290.00	-6.00	-9.00	75.00	63.00
3	8	1875.00	3290.00	-5.00	-1.00	135.00	55.00
4	8	1975.00	3290.00	-5.00	-3.00	160.00	55.00
5	8	2075.00	3290.00	-7.00	-2.00	40.00	59.00
6	8	2175.00	3290.00	-4.00	0.00	65.00	41.00
7	8	2275.00	3290.00	2.00	4.00	75.00	46.00
8	8	2375.00	3290.00	-3.00	1.00	65.00	50.00
9	8	2475.00	3290.00	-2.00	2.00	45.00	52.00
10	8	2575.00	3290.00	-2.00	0.00	65.00	51.00
11	8	2675.00	3290.00	-2.00	0.00	75.00	42.00
12	8	2775.00	3290.00	-2.00	2.00	110.00	40.00
13	8	2875.00	3290.00	0.00	1.00	85.00	39.00
14	8	2975.00	3290.00	2.00	2.00	35.00	55.00
15	8	3075.00	3290.00	1.00	0.00	95.00	48.00
16	8	3175.00	3290.00	2.00	1.00	75.00	55.00
17	8	3275.00	3290.00	4.00	2.00	65.00	50.00
18	7	1660.00	2925.00	-3.00	-2.00	55.00	59.00
19	7	1759.56	2915.67	-5.00	-1.00	80.00	54.00
20	7	1859.13	2906.33	-1.00	0.00	55.00	59.00
21	7	1958.69	2897.00	-5.00	-1.00	70.00	56.00
22	7	2058.25	2887.66	-7.00	-4.00	110.00	55.00
23	7	2157.82	2878.33	-8.00	-4.00	65.00	54.00
24	7	2257.38	2869.00	-7.00	-4.00	95.00	55.00
25	7	2356.94	2859.66	-5.00	-1.00	100.00	45.00
26	7	2456.51	2850.33	-5.00	-2.00	35.00	54.00
27	7	2556.07	2840.99	-4.00	-2.00	135.00	54.00
28	7	2655.63	2831.66	-3.00	-2.00	65.00	54.00
29	7	2755.20	2822.33	0.00	-1.00	80.00	55.00
30	7	2854.76	2812.99	-3.00	3.00	50.00	55.00
31	7	2954.32	2803.66	-2.00	-2.00	55.00	55.00
32	7	3053.89	2794.32	0.00	-2.00	140.00	52.00
33	7	3153.45	2784.99	5.00	1.00	110.00	55.00
34	7	3253.01	2775.65	5.00	1.00	150.00	55.00
35	5	1400.00	2550.00	-4.00	0.00	70.00	52.00
36	5	1499.65	2541.65	-3.00	0.00	50.00	62.00
37	5	1599.30	2533.30	1.00	2.00	90.00	62.00
38	5	1698.95	2524.95	-1.00	-3.00	110.00	62.00
39	5	1798.60	2516.60	-1.00	2.00	45.00	66.00
40	5	1898.25	2508.25	-5.00	-2.00	40.00	66.00
41	5	1997.90	2499.90	-9.00	-4.00	65.00	42.00
42	5	2097.56	2491.55	-7.00	-3.00	60.00	47.00
43	5	2197.21	2483.20	-3.00	-2.00	35.00	52.00
44	5	2296.86	2474.84	-3.00	-2.00	40.00	60.00
45	5	2396.51	2466.49	-4.00	-3.00	50.00	54.00
46	5	2496.16	2458.14	-7.00	-3.00	100.00	55.00
47	5	2595.81	2449.79	-3.00	-1.00	35.00	61.00
48	5	2695.46	2441.44	1.00	-1.00	35.00	60.00
49	5	2795.11	2433.09	2.00	0.00	50.00	62.00
50	5	2894.76	2424.74	3.00	0.00	45.00	60.00
51	5	2994.41	2416.39	3.00	0.00	60.00	60.00

VLF DATA DEEP FLATS, UTAH

Sta.	Line	x position	y position	Dip	Quad	Resistivity	Phase
52	5	3094.06	2408.04	5.00	0.00	70.00	60.00
53	5	3193.71	2399.69	7.00	0.00	70.00	60.00
54	1	545.00	1855.00	-11.00	-3.00	100.00	60.00
55	1	644.79	1861.42	-5.00	-2.00	30.00	60.00
56	1	744.59	1867.83	-3.00	-2.00	50.00	58.00
57	1	844.38	1874.25	-3.00	0.00	90.00	58.00
58	1	944.18	1880.66	1.00	3.00	90.00	64.00
59	1	1043.97	1887.08	2.00	0.00	70.00	68.00
60	1	1143.76	1893.49	-5.00	1.00	80.00	65.00
61	1	1243.56	1899.91	-7.00	-5.00	85.00	62.00
62	1	1344.94	1903.56	-9.00	-4.00	120.00	57.00
63	1	1444.87	1907.11	-4.00	0.00	80.00	58.00
64	1	1544.81	1910.67	-7.00	-4.00	90.00	54.00
65	1	1644.75	1914.23	-4.00	-5.00	75.00	50.00
66	1	1744.68	1917.78	-4.00	-4.00	120.00	52.00
67	1	1844.62	1921.34	-5.00	-2.00	160.00	49.00
68	1	1944.56	1924.90	-4.00	0.00	70.00	52.00
69	1	2044.49	1928.45	-5.00	0.00	80.00	54.00
70	1	2144.43	1932.01	0.00	-1.00	50.00	48.00
71	1	2244.37	1935.56	3.00	0.00	81.00	51.00
72	1	2344.30	1939.12	-2.00	0.00	180.00	54.00
73	1	2444.24	1942.68	1.00	0.00	120.00	56.00
74	1	2544.18	1946.23	-1.00	2.00	55.00	62.00
75	1	2644.11	1949.79	0.00	-1.00	80.00	56.00
76	2	130.00	1515.00	-3.00	4.00	60.00	58.00
77	2	328.64	1538.25	-5.00	-2.00	70.00	64.00
78	2	527.29	1561.51	-7.00	-3.00	65.00	74.00
79	2	725.93	1584.76	-4.00	-2.00	50.00	76.00
80	2	924.57	1608.01	-9.00	-5.00	75.00	70.00
81	2	1123.22	1631.26	-10.00	-5.00	120.00	52.00
82	2	1321.86	1654.52	-5.00	-2.00	80.00	54.00
83	2	1520.51	1677.77	0.00	0.00	15.00	64.00
84	2	1719.15	1701.02	-1.00	-2.00	120.00	52.00
85	2	1917.79	1724.27	3.00	4.00	130.00	49.00
86	2	2116.44	1747.53	2.00	3.00	110.00	54.00
87	2	2315.08	1770.78	0.00	2.00	20.00	72.00
88	2	2513.72	1794.03	-7.00	-3.00	120.00	55.00
89	2	2712.37	1817.28	-5.00	-2.00	100.00	54.00
90	2	2911.01	1840.54	1.00	-2.00	80.00	50.00
91	2	3109.66	1863.79	5.00	0.00	170.00	54.00
92	9	460.00	1260.00	-2.00	0.00	80.00	48.00
93	9	659.29	1276.86	-3.00	1.00	75.00	50.00
94	9	858.58	1293.73	1.00	-1.00	60.00	53.00
95	9	1057.86	1310.59	0.00	4.00	55.00	60.00
96	9	1257.15	1327.45	-4.00	-4.00	75.00	57.00
97	9	1456.44	1344.31	-3.00	-3.00	60.00	59.00
98	9	1655.73	1361.18	1.00	0.00	150.00	53.00
99	9	1855.01	1378.04	-1.00	-2.00	120.00	55.00
100	9	2054.30	1394.90	-4.00	-2.00	170.00	52.00
101	9	2253.59	1411.77	-3.00	0.00	120.00	54.00
102	9	2452.88	1428.63	-3.00	0.00	100.00	56.00

VLF DATA DEER FLATS, UTAH

Sta.	Line	x position	y position	Dip	Quad	Resistivity	Phase
103	9	2652.17	1445.49	3.00	4.00	140.00	54.00
104	9	2851.45	1462.35	7.00	2.00	70.00	58.00
105	9	3050.74	1479.22	6.00	0.00	120.00	60.00
106	3	460.00	680.00	-2.00	2.00	40.00	68.00
107	3	657.74	709.97	0.00	1.00	35.00	64.00
108	3	855.48	739.95	-3.00	2.50	50.00	62.00
109	3	1053.22	769.92	0.00	-1.00	70.00	70.00
110	3	1250.96	799.89	-3.00	2.00	90.00	58.00
111	3	1448.71	829.87	-5.00	0.00	80.00	52.00
112	3	1646.45	859.84	-4.00	0.00	75.00	58.00
113	3	1844.19	889.81	-1.00	5.00	55.00	60.00
114	3	2041.93	919.79	1.00	2.00	65.00	58.00
115	3	2239.67	949.76	0.00	-2.00	50.00	68.00
116	3	2437.41	979.73	11.00	8.00	100.00	58.00
117	3	2635.15	1009.71	5.00	0.00	125.00	60.00
118	3	2632.89	1039.68	11.00	2.00	10.00	80.00
119	4	910.00	-30.00	2.00	4.00	50.00	70.00
120	4	1093.41	49.75	4.00	3.00	120.00	54.00
121	4	1276.83	129.49	0.00	0.00	45.00	80.00
122	4	1460.24	209.24	-2.00	-2.00	30.00	84.00
123	4	1643.66	288.98	2.00	1.00	25.00	86.00
124	4	1827.07	368.73	4.00	4.00	40.00	82.00
125	4	2010.48	448.47	0.00	3.00	70.00	57.00
126	4	2193.90	528.22	7.00	1.00	30.00	72.00
127	4	2377.31	607.96	5.00	0.00	190.00	48.00
128	4	2560.73	687.71	0.00	-2.00	100.00	60.00
129	4	2744.14	767.45	3.00	-3.00	80.00	62.00

sta.	line	x pos.	y pos.	222 real	222 imag	444 real	444 imag	888 real	888 imag	1777 real	1777 imag	3555 real	3555 imag
1	1	985.00	1075.00	112.44	-7.58	113.59	-31.88	76.69	-60.15	29.25	-54.60	18.28	-23.94
2	1	1084.90	1074.56	114.38	-7.63	111.74	-29.92	77.61	-58.26	32.00	-54.78	16.69	-28.75
3	1	1184.79	1077.12	112.41	-6.55	108.82	-31.74	78.82	-55.47	36.63	-52.39	25.60	-26.66
4	1	1284.69	1085.68	118.28	-6.75	117.49	-29.13	84.42	-55.63	35.97	-49.07	8.35	-27.60
5	1	1384.59	1088.24	119.28	-5.61	120.40	-27.30	86.34	-53.82	38.30	-57.93	1.56	-26.75
6	1	1484.48	1092.80	116.31	-5.78	117.51	-28.17	88.21	-53.88	45.04	-56.36	19.85	-35.55
7	1	1584.38	1097.36	124.26	-3.99	120.08	-33.97	95.76	-51.28	52.06	-60.60	44.51	-44.56
8	1	1684.27	1101.92	116.38	-2.87	123.40	-22.62	98.61	-49.49	61.31	-61.15	34.58	-46.61
9	1	1884.06	1111.04	119.39	-0.96	125.31	-22.67	103.33	-47.76	65.93	-61.43	37.30	-49.69
10	1	2083.86	1120.16	123.28	-1.05	128.27	-18.90	109.99	-43.27	73.32	-61.07	43.47	-54.37
11	1	2283.65	1129.27	121.41	1.91	128.36	-16.08	106.12	-43.22	68.61	-59.74	35.21	-51.54
12	2	530.60	1560.00	121.17	-7.60	121.27	-30.19	83.36	-60.28	36.57	-55.97	13.37	-33.67
13	2	728.06	1583.11	121.19	-6.83	123.26	-27.38	90.93	-56.76	44.67	-60.17	19.85	-35.55
14	2	927.32	1606.22	120.22	-6.60	120.40	-27.30	86.13	-56.68	52.17	-50.76	21.52	-37.61
15	2	1125.58	1629.33	119.25	-6.78	120.35	-29.21	85.33	-56.60	41.08	-58.10	17.96	-35.33
16	2	1324.84	1652.44	116.51	-7.68	120.43	-26.35	90.08	-53.93	44.78	-56.32	16.82	-37.11
17	2	1523.30	1675.55	117.35	-2.90	116.68	-25.29	96.67	-52.24	51.95	-62.45	16.59	-46.82
18	2	1721.56	1698.66	120.38	-1.95	123.40	-22.62	102.40	-47.73	63.04	-63.11	26.00	-47.67
19	2	1920.82	1721.77	121.36	-0.03	126.33	-17.03	106.21	-45.03	63.26	-59.41	30.72	-49.14
20	2	2119.28	1744.88	120.32	-2.92	121.52	-21.61	105.33	-43.14	66.64	-59.58	30.51	-51.02
21	2	2317.94	1766.00	116.47	-0.69	121.55	-20.65	101.60	-43.04	66.75	-47.56	29.98	-47.15
22	2	2516.20	1791.11	115.40	-1.90	130.11	-21.85	99.68	-44.85	63.26	-59.41	27.08	-50.70
23	2	2715.26	1814.22	113.53	-2.76	116.68	-20.57	102.53	-43.06	64.19	-59.47	27.69	-46.62
24	3	2462.00	973.00	111.51	-5.62	118.57	-24.39	89.27	-49.23	47.71	-55.71	27.37	-36.38
25	3	2264.21	943.32	116.31	-5.78	120.48	-24.43	90.08	-53.93	52.28	-56.91	17.03	-35.23
26	3	2060.43	913.64	117.28	-5.61	120.46	-25.39	91.94	-53.98	54.78	-61.69	30.51	-33.88
27	3	1858.64	883.96	121.33	-1.00	120.17	-22.75	101.31	-53.31	53.91	-60.71	25.91	-40.56
28	3	1656.86	854.28	123.18	-4.93	125.25	-24.57	97.63	-51.34	59.46	-61.04	20.52	-43.19
29	3	1455.07	824.60	124.18	-3.98	123.26	-27.38	94.77	-53.12	44.89	-56.47	20.73	-41.59
30	3	1255.29	794.92	121.17	-7.60	123.26	-27.38	89.14	-53.90	45.67	-55.60	31.14	-36.60
31	3	1057.50	765.24	122.99	-12.69	120.32	-39.16	82.55	-55.58	38.63	-52.39	13.79	-30.11
32	3	859.72	735.56	110.24	-8.70	108.69	-30.51	71.32	-56.21	29.72	-46.29	19.01	-25.93
33	4	1275.00	132.00	120.98	-15.56	117.21	-39.66	75.94	-58.20	32.55	-45.53	23.51	-26.33
34	4	1450.56	211.42	120.02	-7.91	120.13	-35.04	77.75	-60.12	34.23	-40.41	27.48	-26.67
35	4	1662.11	290.83	123.18	-4.93	120.07	-39.68	78.66	-62.00	27.64	-49.68	11.29	-26.47
36	4	1875.67	370.25	113.50	-12.46	110.54	-39.47	74.62	-60.02	29.77	-45.37	21.04	-26.24
37	4	2064.23	449.67	115.02	-17.43	106.63	-38.42	68.47	-57.99	22.49	-43.10	0.52	-21.61
38	4	2192.78	529.08	121.17	-7.81	110.62	-35.60	73.14	-58.14	31.71	-43.65	21.20	-23.31
39	4	2376.34	608.50	116.26	-9.60	106.75	-30.45	71.32	-56.21	29.72	-46.29	2.40	-21.22
40	5	2765.00	2433.00	122.23	-3.98	125.31	-22.57	100.43	-52.35	56.41	-65.51	4.88	-41.50
41	5	2560.74	2497.14	116.58	-2.87	123.40	-22.02	95.76	-51.32	48.09	-65.02	0.42	-36.95
42	5	2319.47	2466.29	121.36	-0.03	120.54	-22.53	100.40	-52.35	50.72	-67.02	2.18	-40.24
43	5	2190.21	2491.43	124.32	0.87	130.10	-20.90	105.10	-51.54	57.39	-64.63	5.75	-42.55
44	5	1970.94	2490.57	120.34	-1.95	122.50	-20.68	99.53	-48:59	52.17	-58.76	16.50	-39.93
45	5	1791.08	2515.72	120.33	-2.92	119.58	-21.56	97.63	-51.34	53.95	-59.79	10.01	-37.13
46	6	1930.00	2712.00	123.20	-3.46	126.06	-25.00	94.07	-56.86	40.91	-60.89	11.70	-31.78
47	6	2105.37	2615.65	122.23	-2.97	125.20	-26.48	91.63	-65.17	38.19	-59.78	5.64	-33.03
48	6	2280.74	2519.70	119.25	-6.78	120.48	-25.39	93.79	-54.97	45.43	-62.99	4.07	-31.88
49	6	2456.11	2423.55	122.23	-3.94	125.25	-24.57	96.59	-55.04	46.19	-65.62	6.77	-40.96
50	6	2631.48	2327.39	117.59	0.06	125.33	-21.72	98.56	-51.36	50.92	-64.25	6.78	-41.71
51	6	2806.85	2231.24	121.33	-1.00	125.36	-20.76	101.36	-51.44	52.66	-60.21	10.33	-44.01
52	7	2660.00	2010.00	115.43	-3.77	121.37	-25.41	86.99	-59.49	32.39	-64.08	-3.46	-31.04
53	7	2660.88	2020.78	123.06	-9.78	124.05	-33.13	80.03	-65.01	25.01	-65.54	-14.04	-20.14
54	7	2661.77	2897.57	120.19	-8.74	118.27	-30.87	79.43	-60.72	22.42	-59.19	-2.02	-25.52
55	7	2662.65	2966.35	123.11	-7.04	119.31	-32.65	82.42	-60.25	30.69	-57.49	3.96	-24.25
56	7	2663.54	2585.14	124.18	-3.49	125.09	-30.50	88.99	-59.49	40.04	-59.09	6.35	-27.60
57	8	2460.00	3247.00	126.03	-5.05	139.42	-29.75	107.64	-60.96	42.23	-70.22	-6.17	-29.77
58	8	2460.00	3267.75	126.18	-1.12	131.67	-26.68	102.01	-61.76	40.51	-71.06	-16.47	-34.09
59	8	2460.00	3288.50	126.20	-0.15	137.65	-24.92	100.59	-60.99	40.56	-75.13	-6.49	-41.18

sta.	line	x pos.	y pos.	222 real	222 imag	444 real	444 imag	888 real	888 imag	1777 real	1777 imag	3555 real	3555 imag
60	8	2680.00	3287.25	121.33	-1.00	132.90	-22.89	101.05	-62.65	40.31	-71.04	-7.75	-35.33
61	8	2679.49	3290.00	119.23	-6.78	120.37	-29.21	83.36	-60.28	30.60	-59.34	-3.04	-27.28
62	9	2660.00	1438.90	117.37	-1.93	120.36	-18.88	105.28	-45.01	70.14	-53.33	24.52	-44.64
63	9	2469.72	1421.06	121.31	-1.97	125.33	-21.67	105.20	-47.81	59.51	-60.12	19.65	-44.12
64	9	2261.40	1404.12	123.30	-0.08	129.23	-18.97	109.93	-45.14	65.98	-60.50	24.38	-40.52
65	9	2062.16	1397.18	124.29	0.07	126.41	-16.98	117.50	-42.55	74.39	-59.15	40.12	-50.19
66	9	1862.67	1370.28	122.38	1.88	126.28	-17.99	116.43	-42.57	77.94	-62.14	34.48	-49.56
67	9	1665.59	1353.31	123.57	2.83	130.28	-15.18	115.59	-43.43	70.54	-61.70	34.09	-47.67
68	9	1464.51	1336.57	116.42	-9.93	120.70	-16.01	103.49	-42.15	64.39	-55.79	26.15	-39.10
69	9	1265.43	1319.43	113.51	-3.73	112.99	-19.46	94.13	-42.63	53.59	-50.49	24.07	-33.25
70	9	1065.75	1302.40	113.54	-2.76	112.99	-19.46	88.55	-41.74	49.19	-46.52	24.35	-29.37
71	9	860.47	1285.55	112.58	-1.76	113.95	-19.48	94.20	-40.02	55.60	-47.83	25.29	-29.48

TURAM DATA DEER FLATS, UTAH

sta	line	x	y	200 Hz. phase	200 Hz. ratio	400 Hz. phase	400 Hz. ratio	800 Hz. phase	800 Hz. ratio
1	1	2280.00	1925.00	-4.50	1.06	-6.60	1.03	-10.70	1.00
2	1	2180.10	1920.61	-7.70	1.00	-10.30	0.97	-14.50	0.94
3	1	2080.19	1916.21	-6.50	1.03	-11.00	0.97	-17.00	0.91
4	1	1980.29	1911.82	-6.00	1.03	-10.50	0.98	-15.00	0.92
5	1	1880.39	1907.42	-7.50	1.00	-12.00	0.97	-16.00	0.91
6	1	1780.48	1903.03	-6.50	1.02	-9.00	1.01	-14.00	0.99
7	1	1680.58	1898.63	-7.00	1.00	-8.50	0.99	-10.70	0.98
8	1	1580.68	1894.24	-5.50	1.02	-6.80	1.02	-10.70	1.01
9	1	1480.77	1889.84	-6.80	1.00	-10.50	1.00	-14.20	0.96
10	1	1380.87	1885.45	-5.00	1.02	-8.80	1.01	-10.00	0.97
11	1	1280.97	1881.05	-8.00	0.99	-11.50	0.98	-13.30	0.94
12	1	1181.06	1876.66	-7.30	0.99	-9.00	1.00	-8.00	0.98
13	1	1081.16	1872.27	-6.30	1.00	-9.30	0.98	-5.80	1.00
14	1	981.26	1867.87	-4.30	1.03	-4.00	1.06	-2.50	1.03
15	1	881.35	1863.48	-8.00	0.97	-8.00	0.98	-2.00	1.06
16	1	781.45	1859.08	-8.50	0.97	-9.50	0.95	0.00	1.02
17	1	681.55	1854.69	-8.80	0.98	-8.30	0.99	-1.00	0.99
18	1	581.64	1850.29	-7.00	1.00	-17.50	0.89	-2.50	0.99
19	2	2275.00	1760.00	-5.20	1.04	-7.30	1.01	-11.10	0.99
20	2	2175.64	1748.66	-6.00	1.03	-9.20	0.99	-13.50	0.95
21	2	2076.29	1737.33	-7.60	1.01	-10.40	0.96	-15.00	0.93
22	2	1976.93	1725.99	-7.90	0.99	-10.60	0.97	-13.30	0.95
23	2	1877.58	1714.66	-7.10	1.03	-11.50	0.95	-13.50	0.95
24	2	1778.22	1703.32	-8.00	1.00	-11.30	0.95	-16.00	0.90
25	2	1678.87	1691.98	-6.20	1.04	-10.30	0.97	-12.50	0.95
26	2	1579.51	1680.65	-6.90	1.04	-10.90	0.97	-12.20	0.95
27	2	1480.16	1669.31	-9.00	0.98	-11.80	0.95	-14.30	0.92
28	2	1380.80	1657.98	-10.50	0.96	-12.00	0.94	-14.00	0.92
29	2	1281.45	1646.64	-8.00	1.00	-12.00	0.94	-8.50	0.98
30	2	1182.09	1635.31	-9.50	0.96	-11.50	0.95	-14.50	0.89
31	2	1082.74	1623.97	-11.00	0.94	-17.00	0.84	-18.00	0.81
32	2	983.38	1612.63	-11.50	0.94	-11.00	0.95	-15.00	0.89
33	2	884.02	1601.30	-7.00	1.01	-9.50	0.95	-8.50	0.90
34	2	784.67	1589.96	-8.50	1.01	-13.00	0.91	-8.00	0.91
35	3	2295.00	955.00	-5.50	1.04	-9.50	1.00	-14.00	0.97
36	3	2196.13	940.01	-7.50	1.00	-13.00	0.93	-18.00	0.87
37	3	2097.26	925.02	-7.30	1.02	-12.30	0.94	-16.80	0.90
38	3	1998.39	910.03	-9.30	0.99	-10.30	0.98	-16.00	0.91
39	3	1899.52	895.04	-7.00	1.00	-10.50	0.97	-14.00	0.94
40	3	1800.65	880.06	-7.50	1.00	-10.80	0.96	-15.00	0.93
41	3	1701.78	865.07	-8.60	0.99	-10.60	0.96	-14.00	0.92
42	3	1602.91	850.08	-7.00	1.01	-13.20	0.94	-14.60	0.90
43	3	1504.04	835.09	-7.30	1.02	-11.00	0.95	-11.80	0.94
44	3	1405.17	820.10	-9.50	0.97	-11.80	0.95	-11.40	0.96
45	3	1306.30	805.11	-8.00	0.98	-9.30	0.99	-9.40	0.96
46	3	1207.43	790.12	-10.80	0.94	-11.00	0.94	-9.00	0.89
47	3	1108.56	775.13	-8.80	1.00	-10.70	0.95	-15.40	0.88
48	3	1009.69	760.14	-10.60	0.95	-13.20	0.91	-10.80	0.89
49	3	910.82	745.16	-11.00	0.93	-14.00	0.89	-5.50	0.95
50	5	2280.00	2345.00	-5.50	1.04	-6.00	1.05	-11.60	1.03

TURAM DATA DEER FLATS, UTAH

sta	line	x	y	200 Hz. phase	200 Hz. ratio	400 Hz. phase	400 Hz. ratio	800 Hz. phase	800 Hz. ratio
51	5	2160.00	2344.10	-5.60	1.01	-11.00	0.99	-14.00	0.97
52	5	2060.01	2343.19	-6.50	1.01	-10.00	1.00	-15.40	0.95
53	5	1960.01	2342.29	-8.20	0.99	-11.00	0.97	-16.50	0.92
54	5	1860.02	2341.38	-7.50	0.99	-11.50	0.98	-18.70	0.90
55	5	1760.02	2340.48	-10.00	0.97	-12.50	0.97	-13.50	0.99
56	5	1660.02	2339.57	-6.00	1.03	-10.50	1.00	-11.00	1.01
57	5	1580.03	2338.67	-7.50	0.96	-13.00	0.91	-16.20	0.87
58	5	1480.03	2337.76	-6.60	0.95	-12.50	0.93	-16.80	0.88
59	5	1380.04	2336.86	-7.50	0.96	-9.70	0.97	-9.80	0.97
60	5	1260.04	2335.95	-8.80	0.96	-10.30	0.97	-16.20	0.86
61	5	1160.05	2335.05	-7.20	0.95	-12.00	0.92	-13.60	0.84
62	6	2260.00	2735.00	-5.20	1.02	-9.00	0.98	-14.00	0.96
63	6	2160.00	2735.55	-6.60	0.97	-11.30	0.94	-17.80	0.88
64	6	2060.00	2736.11	-6.50	0.99	-10.00	0.94	-14.90	0.90
65	6	1930.00	2736.66	-6.90	0.97	-11.30	0.94	-16.90	0.88
66	6	1880.01	2737.22	-6.90	0.97	-10.60	0.93	-14.50	0.91
67	6	1780.01	2737.77	-7.40	0.96	-11.30	0.93	-14.30	0.91
68	6	1680.01	2738.33	-7.00	0.96	-11.50	0.92	-15.20	0.88
69	6	1580.01	2738.88	-4.00	1.01	-8.00	0.96	-7.20	0.98
70	6	1480.01	2739.43	-7.00	0.93	-9.80	0.92	-9.00	0.91
71	6	1350.01	2739.99	-6.50	0.92	-13.60	0.86	-14.60	0.85
72	7	2215.00	3138.00	-4.80	0.98	-8.30	0.95	-13.00	0.94
73	7	2115.00	3137.67	-6.00	0.95	-10.50	0.94	-16.60	0.89
74	7	2015.00	3137.34	-6.20	0.96	-10.20	0.94	-15.50	0.90
75	7	1915.00	3137.01	-7.40	0.95	-12.50	0.89	-17.50	0.87
76	7	1815.00	3136.67	-7.20	0.95	-10.20	0.94	-14.20	0.90
77	7	1715.00	3136.34	-6.50	0.96	-9.60	0.96	-14.00	0.91
78	7	1615.00	3136.01	-8.00	0.93	-11.40	0.91	-17.50	0.84
79	7	1515.00	3135.68	-6.60	0.95	-11.50	0.91	-14.50	0.89
80	7	1415.00	3135.35	-8.50	0.92	-10.00	0.92	-12.50	0.87
81	7	1315.00	3135.02	-10.50	0.89	-13.60	0.87	-18.00	0.80
82	9	2280.00	1410.00	-5.80	1.05	-8.00	1.02	-11.70	0.99
83	9	2180.32	1401.99	-6.00	1.05	-9.50	1.01	-13.50	0.98
84	9	2080.64	1393.98	-7.00	1.03	-10.00	1.00	-13.20	0.98
85	9	1980.96	1385.97	-7.00	1.04	-10.50	0.99	-13.00	0.99
86	9	1881.29	1377.96	-7.70	1.02	-11.30	0.98	-14.80	0.95
87	9	1781.61	1369.95	-6.90	1.05	-9.20	1.02	-9.00	1.06
88	9	1681.93	1361.94	-5.60	1.09	-8.00	1.05	-10.80	1.01
89	9	1582.25	1353.93	-6.90	1.05	-8.20	1.02	-10.80	1.01
90	9	1482.57	1345.92	-5.70	1.08	-7.80	1.05	-9.00	1.03
91	9	1382.89	1337.91	-5.50	1.08	-9.50	1.01	-9.00	1.02
92	9	1283.21	1329.90	-7.00	1.04	-7.80	1.04	-4.50	1.07
93	9	1183.53	1321.89	-8.50	1.01	-11.00	0.95	-11.50	0.94
94	9	1083.86	1313.88	-7.00	1.04	-7.80	1.01	-9.00	0.98
95	9	984.18	1305.87	-6.80	0.99	-10.00	0.97	-9.00	0.92
96	9	884.50	1297.86	-5.00	1.07	-8.00	1.02	-7.00	1.08
97	9	784.82	1269.85	-6.50	0.99	0.00	1.13	-1.00	1.09
98	9	685.14	1261.84	-5.50	1.04	5.00	1.15	-6.00	1.01
99	9	585.46	1273.83	-4.00	1.04	-9.00	0.97	2.00	1.13