UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Petrophysical Measurements Across a Uranium Roll Feature: Rajah-49 Mine, Gateway, Colorado

by

Jeffrey C. Wynn and Robert A. Brooks

Open-File Report 78-565

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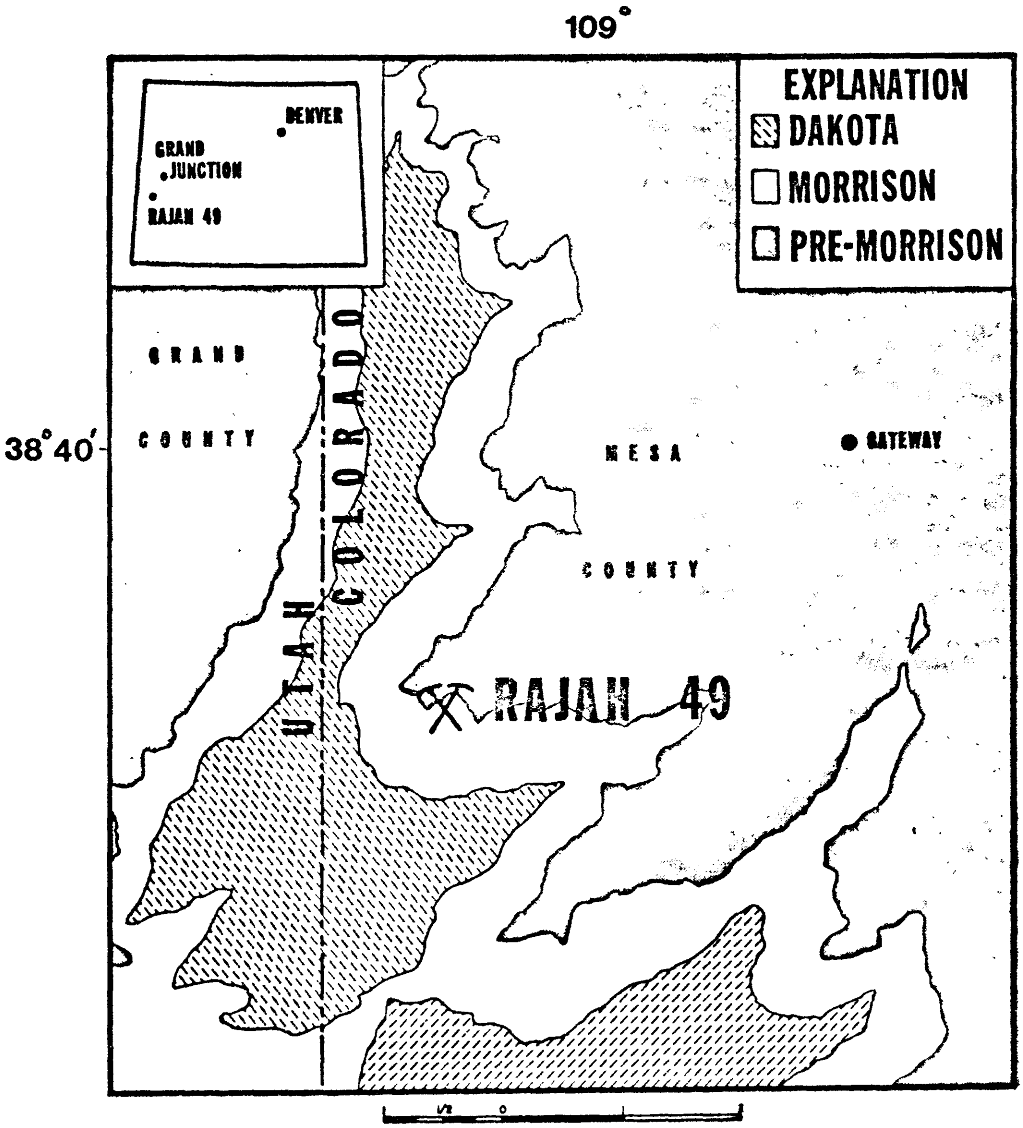
INTRODUCTION

Samples of rock were obtained from a uranium roll feature exposed on the wallrock of a drift in the Rajah-49 mine, near Gateway, Mesa County, Colorado (Figure 1). These samples were measured for magnetic susceptibility, porosity, specific gravity, and complex resistivity (multispectral induced polarization). In addition, after one week of submersion, pH measurements were made of the distilled water used to soak the samples.

These measurements were made to determine if any of these physical properties were diagnostic of the mineralization and therefore might be applicable in an exploration program. These results will be used for comparison with results for corresponding properties of uranium ore from Texas and Wyoming. Petrophysical measurements of uranium ores from these and other environments are in progress as part of a U.S. Geological Survey research program on uranium ore genesis and exploration strategies.



109°
EXPLANATION
DAKOTA
MORRISON
PRE-MORRISON
DENVER
GRAND JUNCTION
RAJAH 49
GRAND
COUNTY
38°40′
UTAH
COLORADO
MESA
COUNTY
GATEWAY
RAJAH 49
SCALE IN MILES

Figure 1.

THE GEOLOGIC ENVIRONMENT

The Rajah 49 mine lies in the west Gateway Uranium district (Fig. 1) at the north end of the Uravan Mineral Belt, on the southwestern flank of the Sagers Wash syncline. The crest of the Uncompahgre uplift lies about 8 km to the east of the mine, and the intrusive of Eocene age that constitutes the La Sal Mountains lies 3 km to the west. Uranium deposits in this area occur in the Salt Wash Member of the Morrison Formation of Late Jurassic age, which at this location consists of three prominent sandstone ledges separated by intervening mudstones (Hausen, 1959). The Salt Wash Member, which locally attains thicknesses of as much as 100 m, lies directly on the Middle Jurassic Summerville Formation and is capped by the Brush Basin Member of the Morrison Formation. The Morrison is overlain by the Dakota Sandstone of Late Cretaceous age.

The occurrence of uranium ore in the mine is similar to that of the well-known roll front deposits of south Texas and Wyoming (Childers, 1974). Most of the ore occurs within the upper sandstone ledge (called the third rim by local miners) of the Salt Wash, along the edges of a fluvial paleochannel. This concentration of uranium is especially pronounced in places where there are large accumulations of organic detritus. The visible ore shown in Figure 2 marks the paleointerface between altering-mineralizing fluids and the connate fluids that were encountered as the former moved down the permeable channel (Hausen, 1959). The movement of this solution interface resulted in an alteration interface that often cannot be traced by cursory observation of altered and unaltered facies. The electrical studies were designed to sample this interface and relate the two sides (if possible) to different electrical

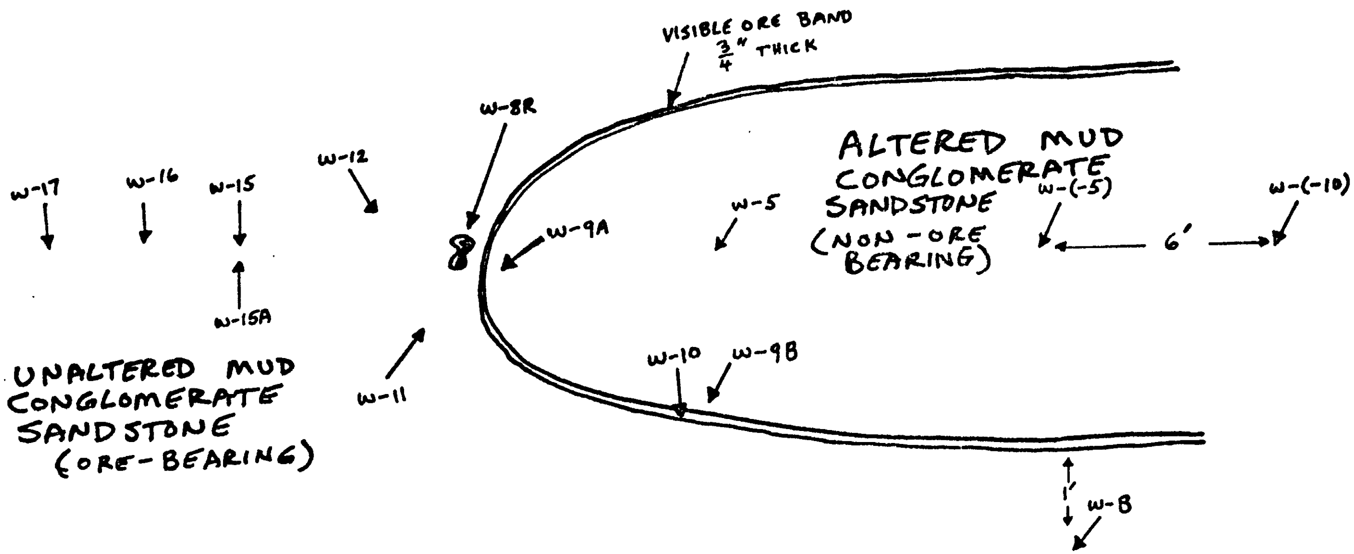


Figure 2.--SAMPLE LOCATIONS AT "8-R" ROLL FEATURE, RAJAH-49 MINE

spectral signatures.

Uranium in the visible ore zone reaches a maximum concentration, determined by chemical analysis, of about 15,000 ppm (1.5%), while vanadium reaches a maximum concentration of about 30,000 ppm (3%). The distribution of pyrite is difficult to interpret in the samples (and in the Colorado Plateau in general) owing to the presence of several generations of pyrite. In this roll feature, pyrite concentrations of 1.5% by weight were measured. Information about the clay content through the roll is not now available and would be somewhat suspect anyway, considering the processing history of the samples that is discussed later. We think that most of the anomalous phase shifts described later are caused by pyrite and clays, and probably not by the uranium itself. This conclusion is based upon the lack of correlation between uranium concentration (and sample site) and the electrical spectra, both in this sample suite and in other (proprietary) suites that one of the authors (JCW) has worked on. We had not seriously anticipated an electrical response from the uranium, but had begun this study mainly hoping to determine if the oxidized-reduced alteraton contact could be identified by electrical methods.

SAMPLING AND PREPARATION

The rock samples were obtained from the points labeled in figure 2 using a hammer and chisel. The rock wall had been exposed to humid air for several months. The samples were removed to Denver, dried, cored, and trimmed to 0.96-inch diameter and 0.7- to 1.1-inch-thick cylinders, depending on the size of the hand specimens collected. Two samples (not listed) were so friable that they could not be cored, one on the visible ore line and one inside the altered zone. Magnetic susceptibility was measured in all remaining samples.

The prepared samples were encased in plexiglass cylinders using silicon cement as shown in figure 3. The cement was applied to cover the entire cylindrical surface of each sample, leaving only the end faces exposed, and allowed to set for 48 hours. Following encasement, the samples were soaked in double-distilled water for 48 hours; toward the end of the soak period, the samples were put under a 15-lb vacuum for 2 hours to remove the interstitial air. The volume of the soak fluid for each sample was 125 ml, which was kept separate in individual plastic bottles for each sample.

Electrical measurements were carried out on the rocks for a period of 10 days, after which the pH of the soak fluid of each sample was measured. At the conclusion of the electrical measurements, the samples were removed from the plexiglass and silicon holders and again soaked under a 15-lb vacuum for 24 hours. During this soak period the samples were submerged. Porosity, dry density, and specific gravity were then measured by the water displacement method and weighed after drying for 24 hours under a vacuum at 70°C.

 (page 8 follows)

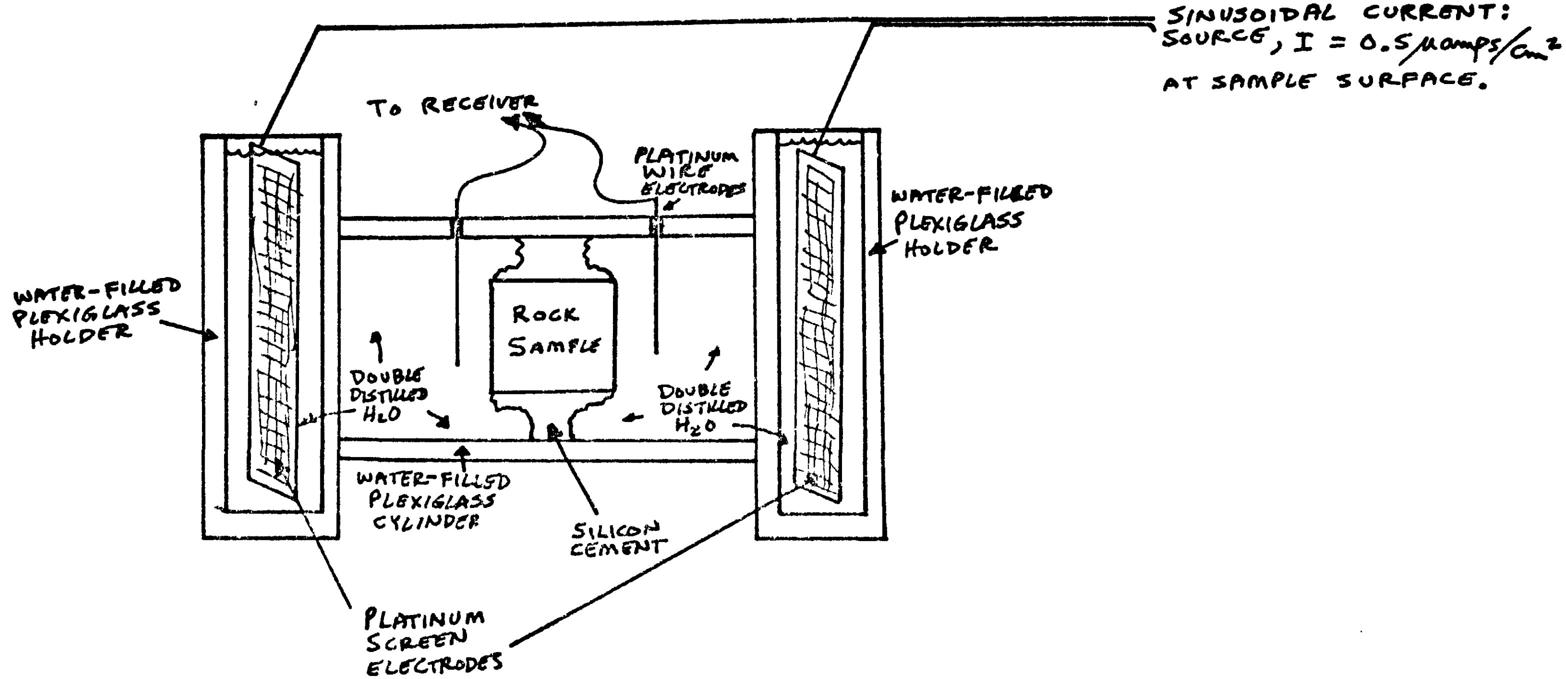


Figure 3.--ELECTRICAL MEASUREMENTS SAMPLE HOLDER (4-ELECTRODE)

MEASUREMENTS AND RESULTS

Magnetic Susceptibility:

Magnetic susceptibility was measured using a Bison[1/] susceptibility meter. The measurements were adjusted for the different sizes of the samples, and the results are presented in Table 1. These measurements showed a 30-40% decrease in susceptibility in the ore zone and immediately adjacent to it on the altered side. These values are barely above the noise threshold of the instrument, however, and the data are only accurate to ±10-15%. The data in the following figures will be shown against an ordinate of locations going from altered (top) to unaltered rock (bottom) in approximate order of physical distance from the ore zone.

pH:

After the samples reached electrical equilibrium with the double-distilled soak fluid, the fluid was analyzed using an ORION pH meter and sodium-ion probe. The sodium-ion measurements showed a 300%-400% increase in ion content in the water from, and immediately adjacent to, the ore zone, approximately coincident with the decrease in magnetic susceptibility. These sodium-ion measurements were susceptible to bias from other ions in the water and, therefore, are not included in the table. The pH values are shown in Table 1. In the ore zone and on the altered side of the ore zone, pH varied roughly from about 6 to 7. On the unaltered side of the ore zone, pH varied from

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1/ Use of brand names does not imply endorsement by the U.S. Geological Survey.

Table 1.

Sample No.	Magnetic susceptibility x10 -6EMU/cm 3	Soak fluid ph	Porosity (Percent)	Dry density (g/cm 3)	Specific gravity (g/cm 3)
W-(-10)-1	0.31	5.53	22.20	2.179	2.401
W-(-10)-2	.41	6.23	24.44	2.165	2.410
W-(-5)-1	.53	7.06	23.33	2.171	2.404
W-(-5)-2	.53	nd	nd	nd	nd
W-5-1	.48	7.09	22.30	2.184	2.407
W-5-2	.49	nd	22.52	2.167	2.392
W-9A	.57	4.63	28.82	2.182	2.470
W-9B-1	.32	7.02	23.13	2.164	2.396
W-9B-2	.32	5.45	23.44	2.178	2.412
W-8R-1	.33	6.44	26.72	2.091	2.358
W-8R-2	.31	6.91	25.41	2.111	2.365
W-11-1	.48	7.04	23.01	2.236	2.466
W-11-2	.44	5.27	25.03	2.204	2.455
W-12	.33	5.55	25.46	2.116	2.370
W-15-1	.46	5.38	26.79	2.119	2.387
W-15-2	.38	nd	21.06	2.233	2.444
W-15A-1	.34	5.25	22.902	2.196	2.425
W-15A-2	.32	nd	nd	nd	nd
W-16	.40	5.68	23.58	2.168	2.404
W-17-1	.49	5.28	25.05	2.142	2.392
W-17-3	.37	5.07	21.46	2.203	2.417
W-17-4	.48	nd	nd	nd	nd
W-B-1	.31	5.12	24.43	2.151	2.396
W-B-2	.39	nd	24.92	2.120	2.369

nd, no data [sample of insufficient size or otherwise unusable]; -1, -2, -3 -4 following sample number indicate different samples from the same hand specimen about 5.1 to 5.6. These results are different from those of Childers (1974), who noted that pH, measured in situ in Tertiary roll fronts in Wyoming, decreased in an ore zone and were higher on both sides; this was for a different geochemical setting however. The model proposed by Hagmaier (1974), also for Wyoming rocks, has a pH of 7 on the oxidized (altered) side.

Porosity, Dry Density, and Specific Gravity:

The samples were soaked in a vacuum to remove interstitial air; weighed on a Mettler PN2210 balance while submerged, (W_{sub}); then weighed saturated with the surface dry, (W_{sat}). The samples then were dried at 70°C for 24 hours under a vacuum and weighed again, (W_{dry}). The following relationships (International Society for Rock Mechanics, 1972) were used to give:

$$\text{Porosity} = \frac{W_{sat} - W_{dry}}{W_{sat} - W_{sub}} \times 100\%$$

$$\text{Dry Density} = \frac{W_{dry}}{W_{sat} - W_{sub}} \times 100\%$$

$$\text{Specific Gravity} = \frac{W_{sat}}{W_{sat} - W_{sub}} \times 100\%$$

These equations assume water = 1.0 g/cm^3.

The results of these measurements are also included in Table 1. Sample W-9A gave anomalous results, as it did in susceptibility and pH. The porosity was higher in and immediately beyond the ore zone on the unaltered side; the specific gravity was also higher just beyond the ore zone on the unaltered side. In general, however, the correlations were not very meaningful.

Electrical Spectra:

Electrical magnitude and phase measurements were made on the wet rocks for a frequency range of 0.01 through 1000 Hz, using a current density of about 0.5 μ-amp/cm^2 to avoid any current density-caused non-linear phenomena. The measurements utilized two Hewlett-Packard (HP) digital multimeters, HP3490A; a calculator/controller, HP9830B; a frequency synthesizer, HP1B and HP59308A; and a Nicolet 1090AR digital oscilloscope. Complex resistivity measurements have been described previously by Zonge and Wynn (1975), Olhoeft (1975), Olhoeft (1977), and Sumner (1976).

The results are presented in Table 3 in complete form, and some specific features are tabulated in Table 2. The equipment used and the data precision to be expected are described in Olhoeft (1977).

Unusually large phase-shifts relative to fresh sandstone (see Zonge and Wynn, 1975) were observed in most of the rocks. These phase-shifts ranged as high as 53 miliiradians (MRAD) at 0.1 Hz and 1500 MRAD at 1000 Hz. There were increases in DC resistivity on both sides of the ore zone; the increase in porosity in the ore itself probably accounts for the fact that the DC resistivity high is broken up into two parts. Relaxations in the AC spectra occurred around 0.1 Hz and 100 Hz, and did not appear to be directly related to either alteration or visible ore. To date the samples have not been petrographically analyzed, and more specific correlations between spectral shape and mineralogy cannot be made at this time.

TABLE 2. Summary of Low-Frequency (Wet) Electrical Spectra from the Rajah-49 Mine

Sample No.	$-\phi_{.1}$	$-\phi_{1.0}$	$-\phi_{10.}$	$-\phi_{100.}$	$\frac{10.}{100.}$	$\phi_{1000.}$		$\rho_{.01}$
W-(-10)1	5.6	12.3	37	60	0.66	320	11.6	95
W-(-10)2	8.7	37.7	64	209	.31	1522	32	309
W-(-5)-1	7.7	15.0	28	69	.41	476	3.6	183
W-5-1	53	89.6	92	109	.84	678	3.8	248
W-5-2	nd	nd	nd	nd	nd	nd	nd	nd
W-9A	0.6	24.7	36	68	.53	396	36	611
W-9B-1	2.9	0.3	8.5	31	.27	285	17-25	104
W-9B-2	33	32.5	42	49	.86	138	1.75	77
5 -amps	29	30.3	41	49				
W-8R-1	3.1	39.8	84	94	.89	471	46	64
W-8R-2	12		31	88	.28	637		238
W-11-1	5.6	7.5	17	94	.18	581	3.9	536
W-11-2	22	23.3	22	83	.27	551	1.0	399
W-12	2.4	14.4	44	61	.72	386	27	177
W-15-1	5.1	6.2	19	49	.39	360	4.7	257
W-15-2	nd	nd	nd	nd	nd	nd	nd	nd
W15A-1	11.6	68.5	155	272	.57	1454	26	150
W-16	6.6	16.7	116	124	.94	407	Noise	90
W-17-1	29	53.7	70	86	.81	356	4.7	87
W-17-3	15	41.7	72	78	.92	270	5.9	105
W-B-1	8.3	21.7	50	35	1.43	85	14.3	109
W-B-2	nd	nd	nd	nd	nd	nd	nd	nd

ϕ_a : Phase angle in milliradians at frequency a, where a ranges from 0.1 to 1000;

ρ_a : Resistivity in ohm-meters at frequency a, where a equals 0.01; and

nd: No data [Sample of insufficient size or otherwise unusable].

Table 3

Electrical spectra for samples from the Rajah-49 mine, near Gateway, Colorado.

Summary of column headings:

F (Hz)	Frequency in Hz
K	Dielectric Constant
D	Loss Tangent
R′(OHM-M)	Real Resistivity
MRAD	Phase Shift in Milliradians

PLOTS ARE:

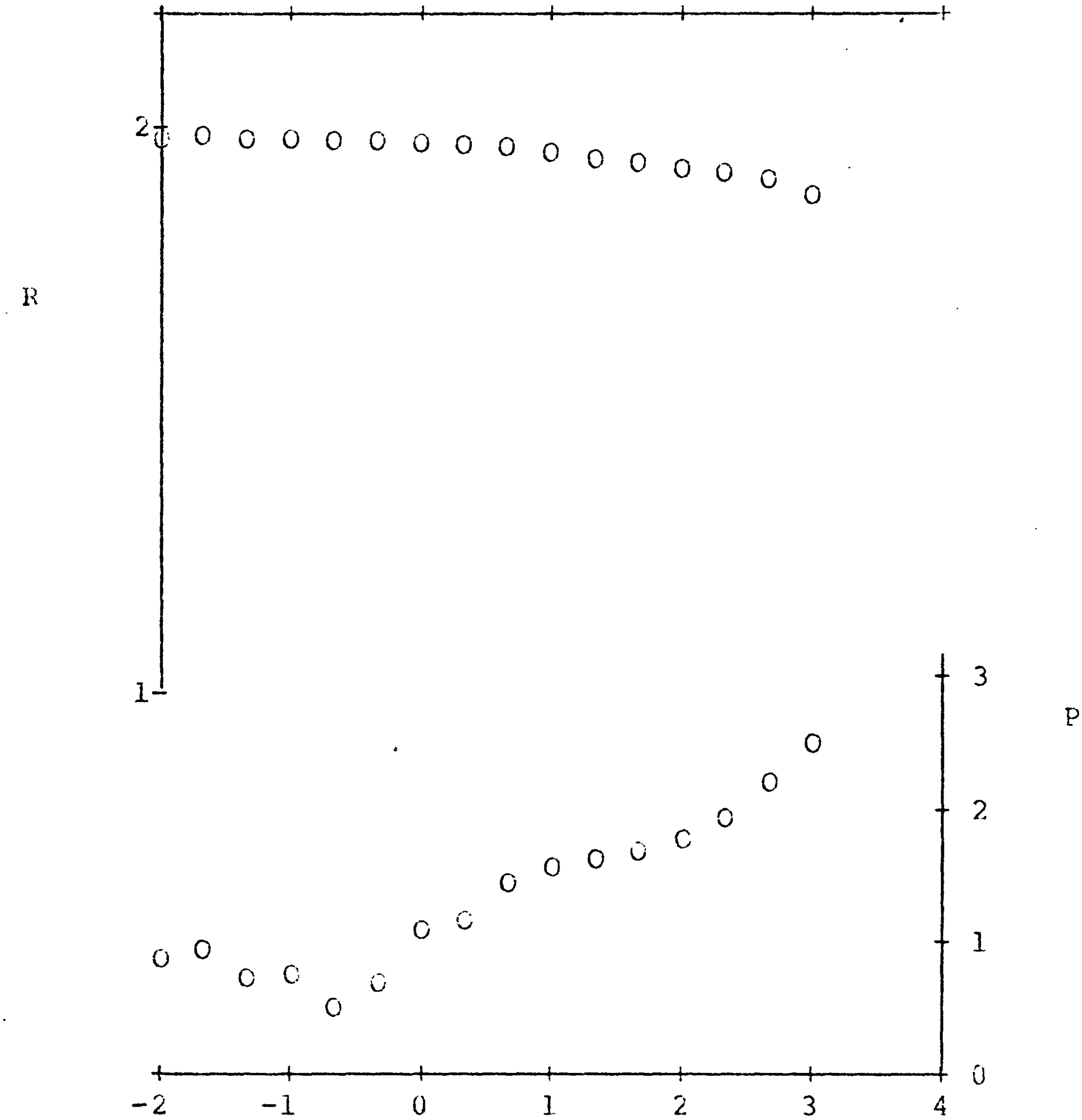
R	Log(Real Resistivity)
P	Log(Phase)

Ordinate is in Log(Frequency).

RAJAH 49 GATEWAY, COLO
12/28/76 10:53:32

F(HZ)	K	D	R´(OHM-M)	MPAD
1.00E-02	1.392E+08	135.9200	95.0243	-7.4
2.10E-02	7.895E+07	112.5940	96.2821	-8.9
4.60E-02	2.161E+07	190.2620	95.0331	-5.3
1.00E-01	1.061E+07	178.5580	94.9133	-5.6
2.15E-01	2.858E+06	310.0200	94.3450	-3.2
4.64E-01	2.034E+06	202.0200	94.2530	-4.9
1.00E+00	2.358E+06	81.3641	93.6798	-12.3
2.15E+00	1.350E+06	66.5565	92.8808	-15.0
4.64E+00	1.202E+06	34.9207	92.2253	-28.6
1.00E+01	7.435E+05	26.8213	90.0119	-37.3
2.15E+01	4.099E+05	23.1196	87.8701	-43.2
4.64E+01	2.209E+05	20.3025	86.1210	-49.2
1.00E+02	1.268E+05	16.6959	84.6006	-59.8
2.15E+02	88228.600	11.2720	83.2358	-88.5
4.64E+02	76253.200	6.0937	81.1532	-162.7
1.00E+03	70703.400	3.0157	75.9526	-320.2

W-(-10)-1



LOGR (OHM-M) & LOGP (MR) VS LOGF

O = DATA

RAJAH 49 GATEWAY, COLO

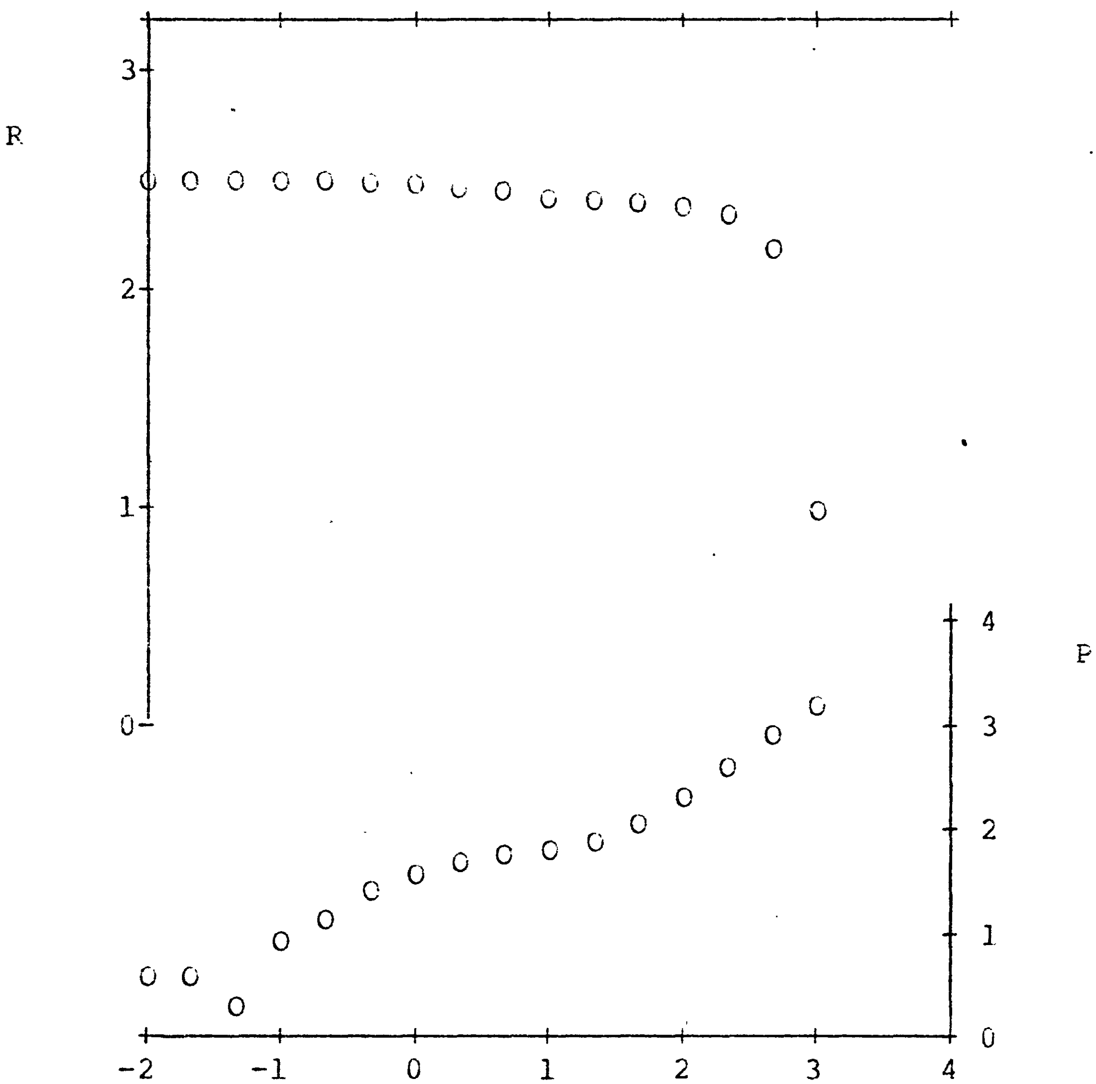
12/28/76 10:53:32

W-(-10)-2

RAJAH 49 GATEWAY, COLO
12/30/76 12:49:50

F(HZ)	K	D	R´(OHM-M)	MRAD
1.00E-02	2.226E+07	260.8840	309.5241	-3.8
2.10E-02	1.045E+07	266.7210	307.0391	-3.7
4.60E-02	2.485E+06	510.9180	307.7362	-2.0
1.00E-01	5.071E+06	115.5740	306.7029	-8.7
2.15E-01	3.934E+06	69.7252	304.7478	-14.3
4.64E-01	3.452E+06	37.3737	300.0758	-26.8
1.00E+00	2.316E+06	26.5103	292.2866	-37.7
2.15E+00	1.410E+06	20.7601	284.4875	-48.1
4.64E+00	8.362E+05	16.7029	276.3108	-59.8
1.00E+01	4.481E+05	15.6552	255.1798	-63.8
2.15E+01	2.626E+05	12.7413	247.8549	-78.3
4.64E+01	1.874E+05	8.4785	240.4107	-117.4
1.00E+02	1.579E+05	4.7134	231.1422	-209.1
2.15E+02	1.426E+05	2.3174	212.8290	-407.4
4.64E+02	1.290E+05	0.9073	149.3550	-834.0
1.00E+03	91490.400	0.0483	9.4593	-1522.6

W-(-10)-2



LOGP (OHM-M) & LOGP (mF) VS LOGF

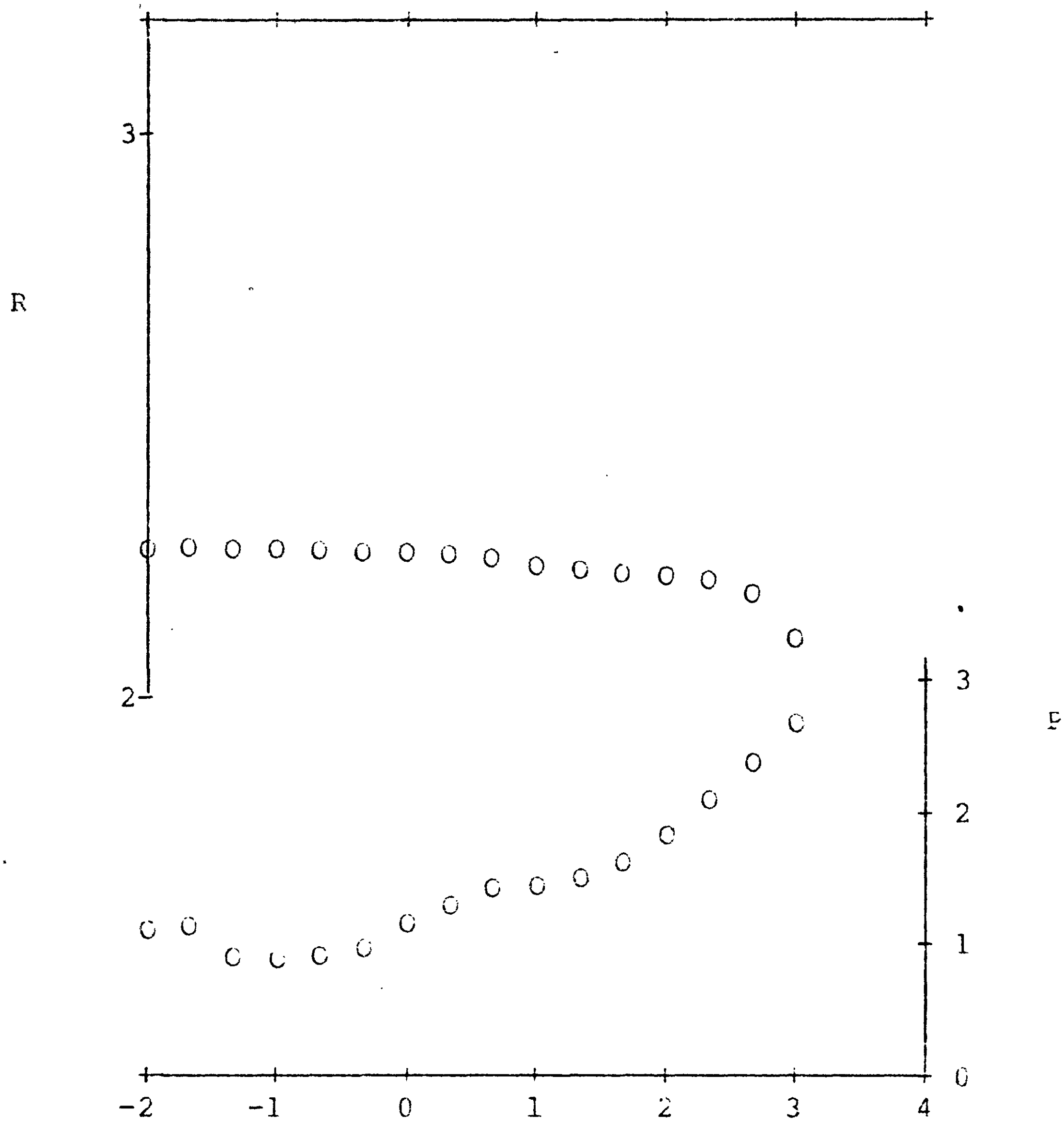
O = DATA
W-(-10)-2

RAJAH 49 GATEWAY, COLO

12/30/76 12:49:50

RAJAH 49   GATEWAY, COLO
12/28/76   13:01:55

F(HZ)	K	D	R´(OHM-M)	MRAD
1.00E-02	1.250E+08	78.4893	183.1342	-12.7
2.10E-02	6.339E+07	73.1815	184.4683	-13.7
4.60E-02	1.727E+07	123.8500	182.6762	-8.1
1.00E-01	7.613E+06	129.5020	182.3083	-7.7
2.15E-01	3.795E+06	121.2550	181.6570	-8.2
4.64E-01	2.034E+06	105.6220	180.3251	-9.5
1.00E+00	1.506E+06	66.4789	179.5477	-15.0
2.15E+00	9.349E+05	50.0958	178.1027	-20.0
4.64E+00	5.959E+05	36.9705	175.6685	-27.0
1.00E+01	2.981E+05	35.2809	170.7812	-28.3
2.15E+01	1.629E+05	30.5068	167.7061	-32.8
4.64E+01	1.008E+05	23.1878	165.3639	-43.1
1.00E+02	75687.100	14.4363	163.7250	-69.2
2.15E+02	64508.300	7.9232	160.6739	-125.5
4.64E+02	60234.700	3.9722	152.0755	-246.6
1.00E+03	58004.400	1.9395	126.2633	-476.3
0.00E+0				



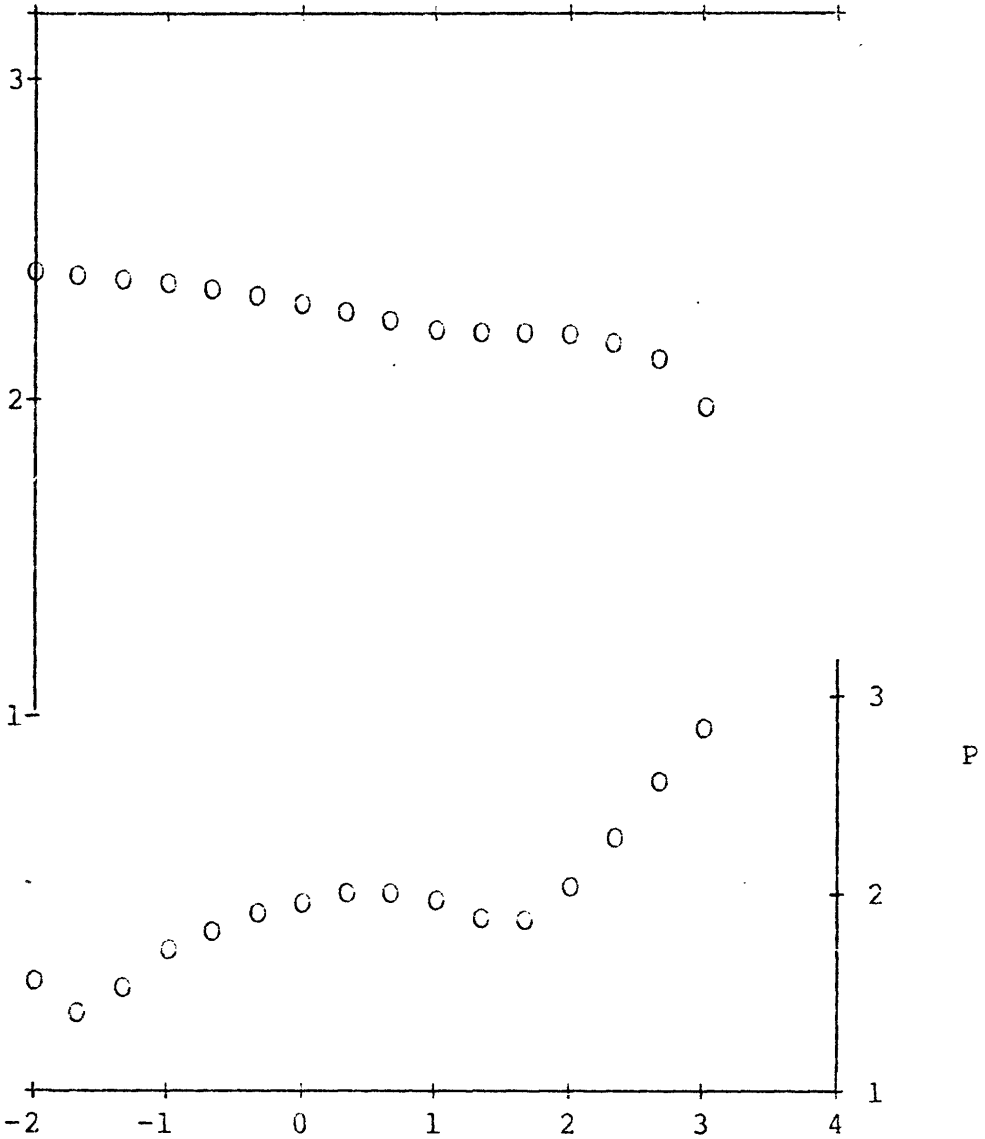
LOGR (OHM-M) & LOGP (mR) VS LOGF
O = DATA

RAJAH 49 GATEWAY, COLO

12/28/76 13:01:55

RAJAH 49 GATEWAY, COLO
12/28/76 14:20:05

F(HZ)	K	D	R´(OHM-M)	MRAD
1.00E-02	2.625E+08	27.5151	248.4974	-36.3
2.10E-02	8.790E+07	40.1804	242.2048	-24.9
4.60E-02	5.614E+07	29.6111	234.7999	-33.3
1.00E-01	4.190E+07	18.7778	227.8213	-53.2
2.15E-01	2.511E+07	15.1625	218.6466	-65.9
4.64E-01	1.487E+07	12.3704	209.1640	-80.7
1.00E+00	9.052E+06	11.1305	198.9524	-89.6
2.15E+00	4.516E+06	9.7752	187.0657	-101.9
4.64E+00	2.210E+06	9.8647	175.8738	-101.0
1.00E+01	1.009E+06	10.8312	163.0976	-92.1
2.15E+01	3.864E+05	13.3411	160.9209	-74.8
4.64E+01	1.784E+05	13.4429	160.5429	-74.3
1.00E+02	1.226E+05	9.1602	158.1456	-108.7
2.15E+02	1.042E+05	5.1575	149.5560	-191.5
4.64E+02	97314.900	2.6004	133.3131	-367.1
1.00E+03	94118.700	1.2402	93.3208	-678.6



LOGF (OHM-M) & LOGP (mF) VS LOGF
= DATA

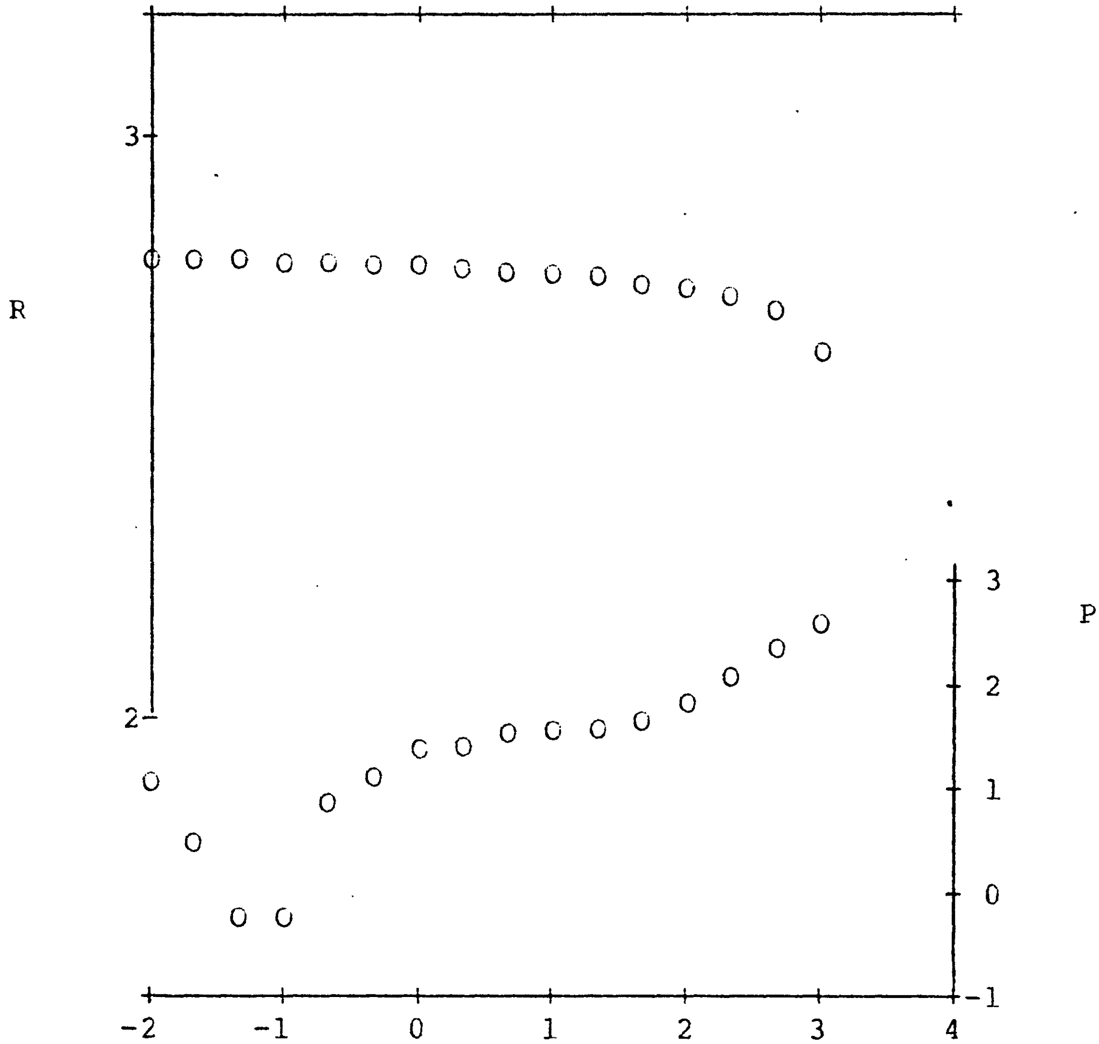
UAH 49 GATEWAY, COLO

12/28/76 14:20:05

RAJAH 49 GATEWAY, COLO
12/29/76 16:17:59

F(HZ)	K	D	R´(OHM-M)	MRAD
1.00E-02	3.381E+07	86.9075	611.5988	-11.5
2.10E-02	4.209E+06	331.8440	612.8264	-3.0
4.60E-02	3.697E+05	1732.0900	610.2566	-0.6
1.00E-01	1.697E+05	1752.6200	604.4718	-0.6
2.15E-01	1.006E+06	138.3430	600.4281	-7.2
4.64E-01	8.441E+05	76.7922	597.5703	-13.0
1.00E+00	7.452E+05	40.4742	595.6034	-24.7
2.15E+00	3.635E+05	38.9485	589.0720	-25.7
4.64E+00	2.359E+05	28.2578	580.1984	-35.4
1.00E+01	1.136E+05	27.5930	572.6306	-36.2
2.15E+01	55282.900	26.3646	571.5953	-37.9
4.64E+01	32076.300	21.8205	552.1092	-45.8
1.00E+02	22521.700	14.5908	544.4476	-68.4
2.15E+02	19302.700	8.0756	527.1349	-123.2
4.64E+02	17101.000	4.3051	499.0704	-228.2
1.00E+03	15129.300	2.3930	422.6641	-395.8
0.00E				

W-9A



LOGR (OHM-M) & LOGP (mR) VS LOGF

O = DATA

W-9A

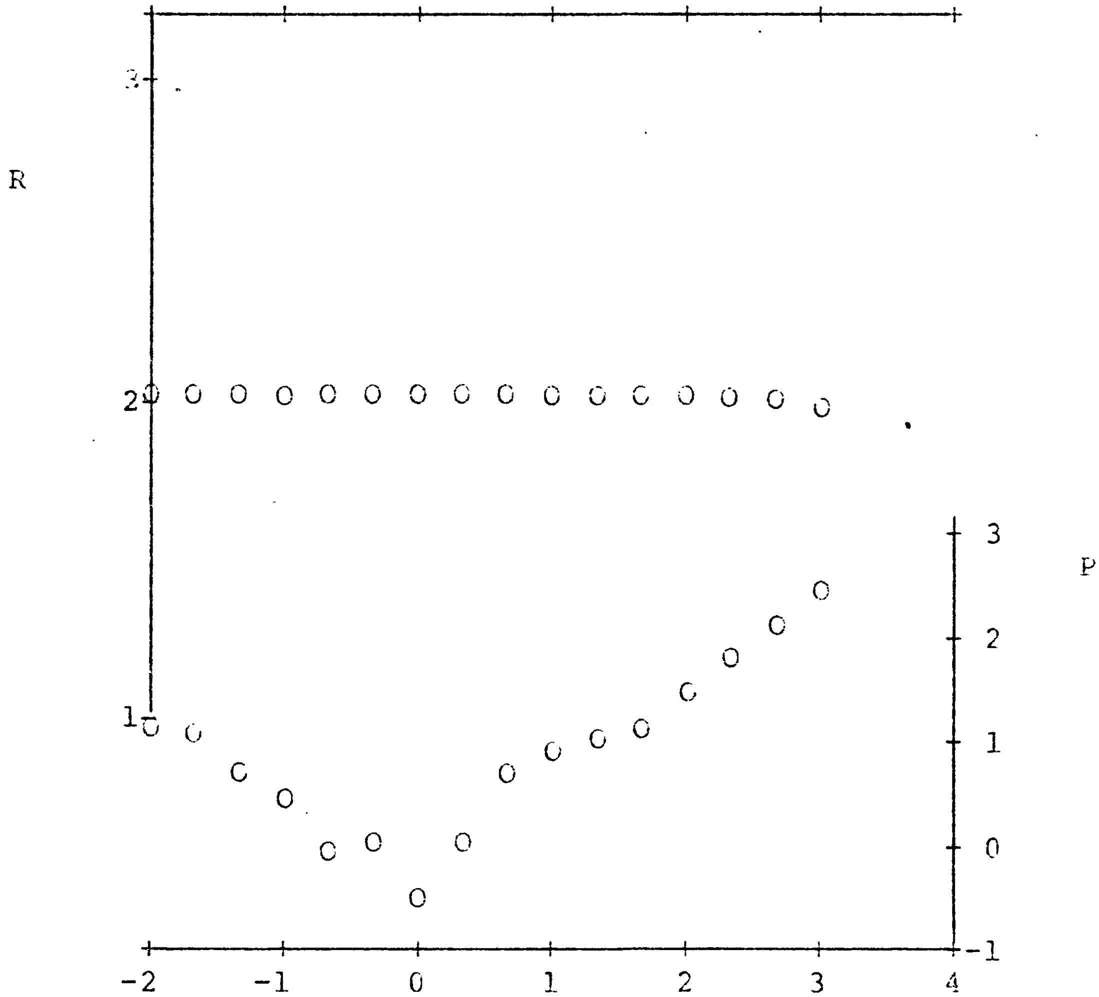
RAJAH 49 GATEWAY, COLO

12/29/76 16:17:59

RAJAH 49 GATEWAY, COLO
12/31/76 10:02:39

F(HZ)	K	D	R´(OHM-M)	MRAD
1.00E-02	2.331E+08	73.8383	104.4126	-13.5
2.10E-02	9.962E+07	82.5166	103.9909	-12.1
4.60E-02	1.919E+07	197.5230	103.0766	-5.1
1.00E-01	5.060E+06	346.1010	102.6432	-2.9
2.15E-01	7.273E+05	1114.2700	103.1681	-0.9
4.64E-01	4.256E+05	831.4000	103.2652	-1.1
1.00E+00	54787.480	3178.9800	103.2055	-0.35
2.15E+00	91880.700	877.6160	103.4895	-1.1
4.64E+00	1.891E+05	197.6320	103.6428	-5.1
1.00E+01	1.484E+05	117.9190	102.7393	-8.5
2.15E+01	89035.900	91.7127	102.1595	-10.9
4.64E+01	52837.200	71.9355	101.8634	-13.9
1.00E+02	54151.600	32.5690	101.8232	-30.7
2.15E+02	53091.100	15.4648	101.1922	-64.6
4.64E+02	53001.900	7.2040	99.5023	-137.9
1.00E+03	51834.900	3.4104	93.6321	-235.2

0.00



LOGR (CRM-M) & LOGP (rF) VS LOGF
O = DATA
W-9B-1

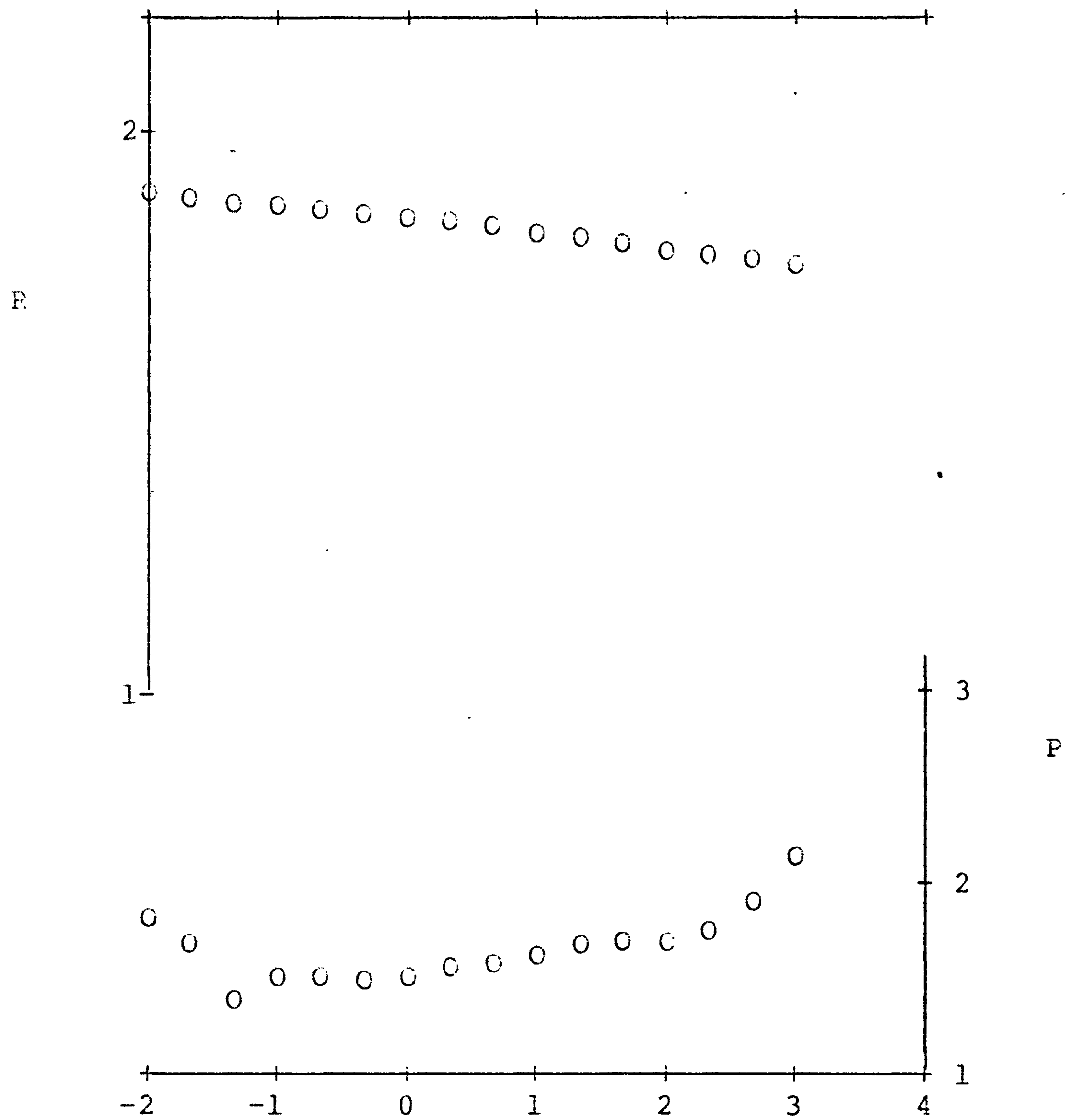
RAJAH 49 GATEWAY, COLO

12/31/76 10:02:39

RAJAH 49 GATEWAY, COLO
01/03/77 10:41:51

F(HZ)	K	D	R´(OHM-M)	MRAD
1.00E-02	1.510E+09	15.2202	77.8744	-65.6
2.10E-02	5.400E+08	20.8085	76.0039	-48.0
4.60E-02	1.280E+08	41.0535	74.2928	-24.4
1.00E-01	7.965E+07	30.7650	73.2784	-32.5
2.15E-01	3.705E+07	31.1551	72.3525	-32.1
4.64E-01	1.664E+07	32.6974	71.1513	-30.6
1.00E+00	8.329E+06	30.7455	70.1214	-32.5
2.15E+00	4.423E+06	27.2459	69.1602	-36.7
4.64E+00	2.183E+06	26.1851	67.6716	-38.2
1.00E+01	1.144E+06	23.7529	66.0259	-42.1
2.15E+01	6.280E+05	20.5369	64.5402	-48.7
4.64E+01	3.005E+05	20.4025	63.0033	-49.0
1.00E+02	1.429E+05	20.4951	61.2233	-48.8
2.15E+02	77950.500	17.7383	60.1473	-56.3
4.64E+02	51894.400	12.4977	59.3284	-79.8
1.00E+03	42326.900	7.2006	57.8614	-138.0

W-9B-2



LOGR (OHM-M) & LOGP (MR) VS LOGF

O = DATA
W-9B-2

RAJAH 49 GATEWAY, COLO

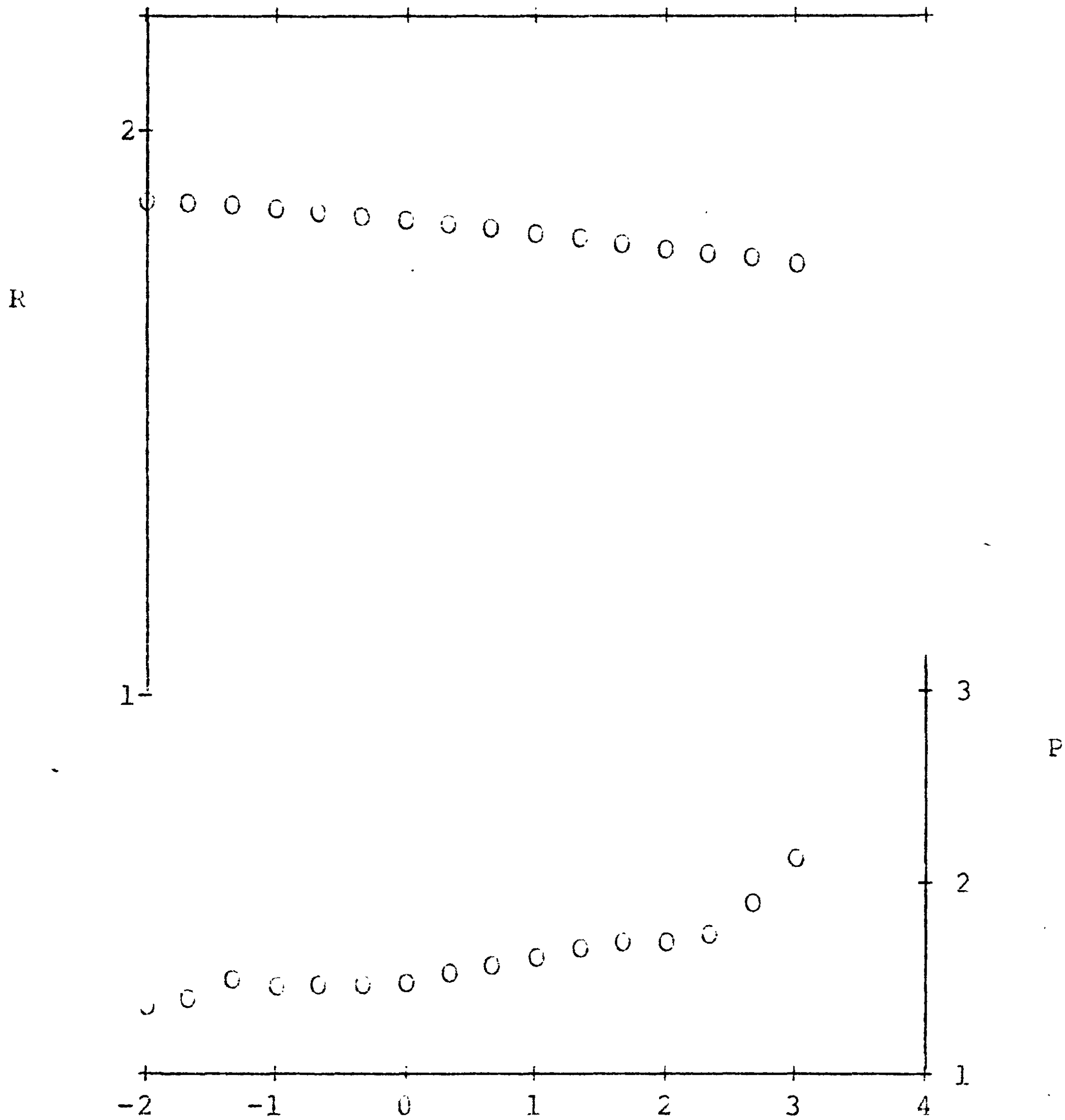
01/03/77 10:41:51

W-9B-2 @ 5 microamps/cm^2

RAJAH 49 GATEWAY, COLO
01/03/77 13:37:47

F(HZ)	K	D	P´(OHM-M)	MRAD
1.00E-02	5.440E+08	44.0439	74.9830	-22.7
2.10E-02	2.390E+08	39.8743	74.2343	-25.1
4.60E-02	1.700E+08	31.3250	73.3189	-31.9
1.00E-01	7.195E+07	34.6032	72.1421	-28.9
2.15E-01	3.416E+07	34.3636	71.1519	-29.1
4.64E-01	1.614E+07	34.1918	70.1355	-29.2
1.00E+00	7.863E+06	32.9845	69.2431	-30.3
2.15E+00	4.115E+06	29.7084	68.1764	-33.6
4.64E+00	2.171E+06	26.5810	67.0345	-37.6
1.00E+01	1.123E+06	24.4699	65.3085	-40.8
2.15E+01	6.006E+05	21.6815	63.9990	-46.1
4.64E+01	3.018E+05	20.4645	62.5424	-48.8
1.00E+02	1.438E+05	20.3929	61.1479	-49.0
2.15E+02	75740.000	18.2642	60.1311	-54.7
4.64E+02	50862.800	12.7679	59.2665	-78.2
1.00E+03	41594.900	7.3262	57.9080	-135.7

W-9B-2 @ 5 microamps/cm^2



LOGF (CHM-M) & LOGF (MR) VS LOGF

O = DATA

W-9B-2 5-MICRO-A/CM^2

PAJAH 49 GATEWAY, COLO

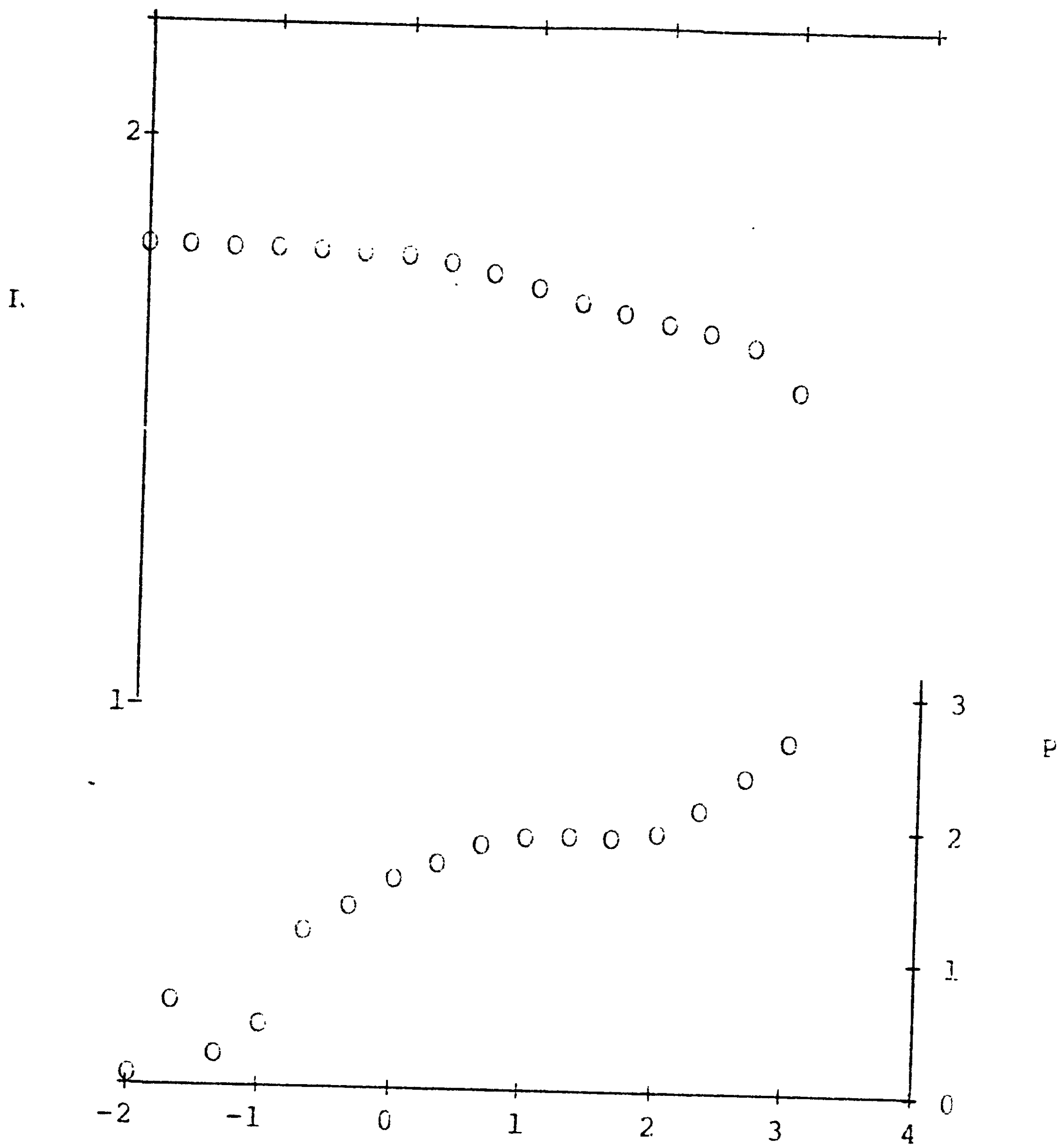
01/03/77 13:37:47

W-8R-1

AH 49 GATEWAY, COLO
2/29/76 10:47:24

(HZ)	K	D	R´(OHM-M)	MRAD
00E-02	3.428E+07	815.5250	64.2934	-1.2
10E-02	6.058E+07	220.6050	64.0505	-4.5
60E-02	1.105E+07	554.8460	63.7430	-1.8
00E-01	8.661E+06	327.0820	63.4524	-3.1
15E-01	2.076E+07	63.8342	63.0600	-15.7
64E-01	1.509E+07	40.8803	62.7790	-24.5
00E+00	1.153E+07	25.0907	62.0489	-39.8
15E+00	7.278E+06	18.7980	60.8206	-53.1
64E+00	4.850E+06	13.5920	58.4413	-73.4
00E+01	2.711E+06	11.9199	55.2301	-83.7
15E+01	1.395E+06	11.4109	52.0271	-87.4
64E+01	6.609E+05	11.6357	49.9855	-85.7
00E+02	3.501E+05	10.5818	48.0858	-94.2
15E+02	2.498E+05	6.9926	46.8106	-142.0
64E+02	2.102E+05	3.9339	43.9953	-248.9
00E+03	1.962E+05	1.9650	37.0377	-470.7

W-8R-1



LOGR (OHM-M) & LOGP (MR) VS LOGF

O = DATA
W-8R-1

RAJAH 49 GATEWAY, COLO

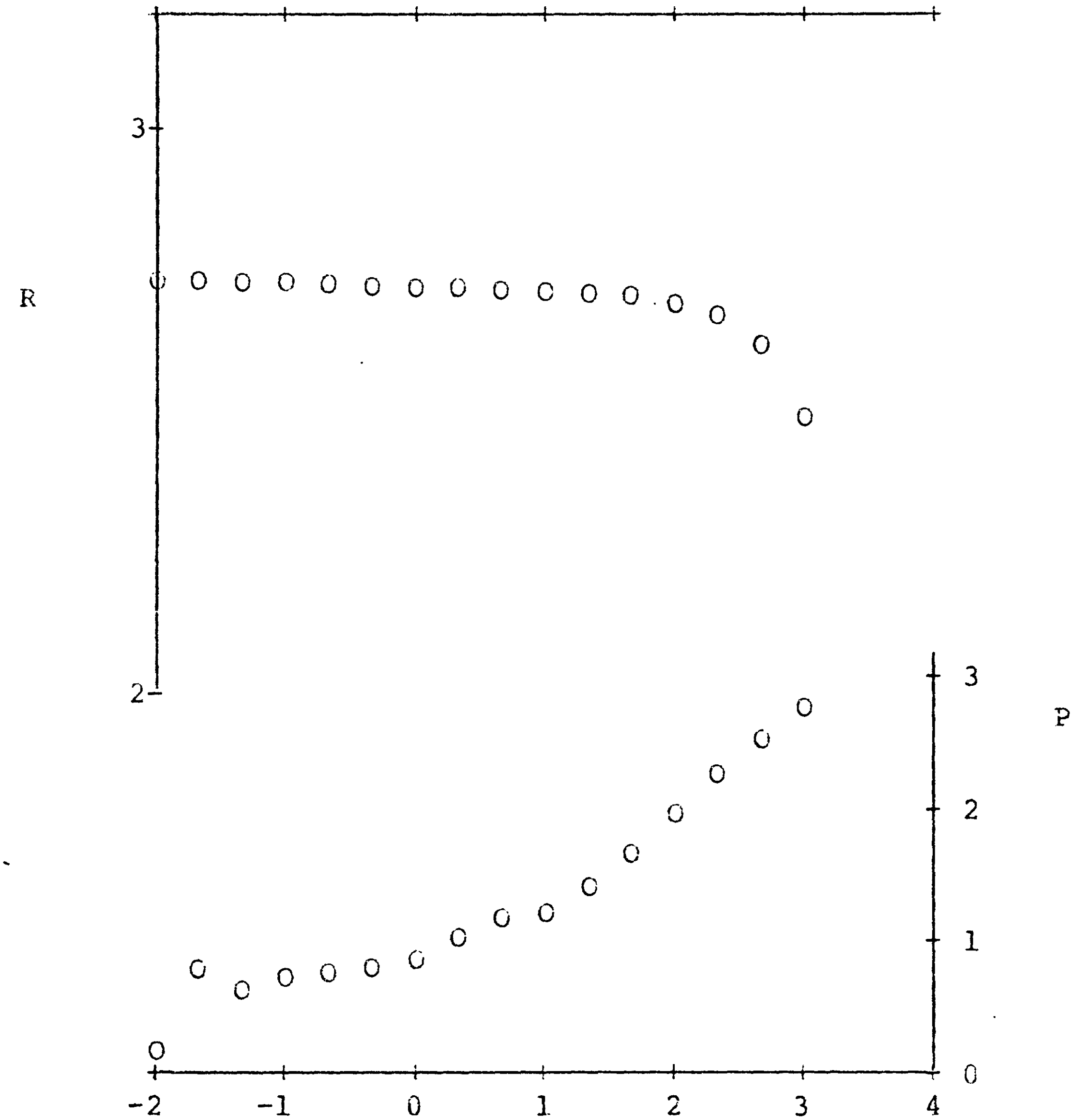
12/29/76 10:47:24

RAJAH 49 GATEWAY, COLO
12/31/76 11:16:14

F(HZ)	K	D	R´(OHM-M)	MRAD
1.00E-02	5.018E+06	667.3690	536.7758	-1.5
2.10E-02	1.010E+07	157.3460	538.6478	-6.4
4.60E-02	3.117E+06	233.8170	536.1908	-4.3
1.00E-01	1.889E+06	178.6280	532.5739	-5.6
2.15E-01	9.174E+05	172.0560	529.6262	-5.8
4.64E-01	4.833E+05	152.1710	526.7745	-6.6
1.00E+00	2.590E+05	132.5720	523.5166	-7.5
2.15E+00	1.727E+05	92.8478	520.2336	-10.8
4.64E+00	1.131E+05	66.1161	518.0385	-15.1
1.00E+01	58645.200	59.4858	515.1136	-16.8
2.15E+01	42751.600	38.1607	511.0439	-26.2
4.64E+01	36143.300	21.1751	504.8523	-47.2
1.00E+02	34237.400	10.6523	488.5588	-93.6
2.15E+02	32051.200	5.4182	464.6024	-182.5
4.64E+02	29814.600	2.7857	413.0298	-344.7
1.00E+03	26880.800	1.5234	306.7694	-580.9

0.

W-11-1



LOGR (OHM-M) & LOGP (mE) VS LOGF

O = DATA
W-11-1

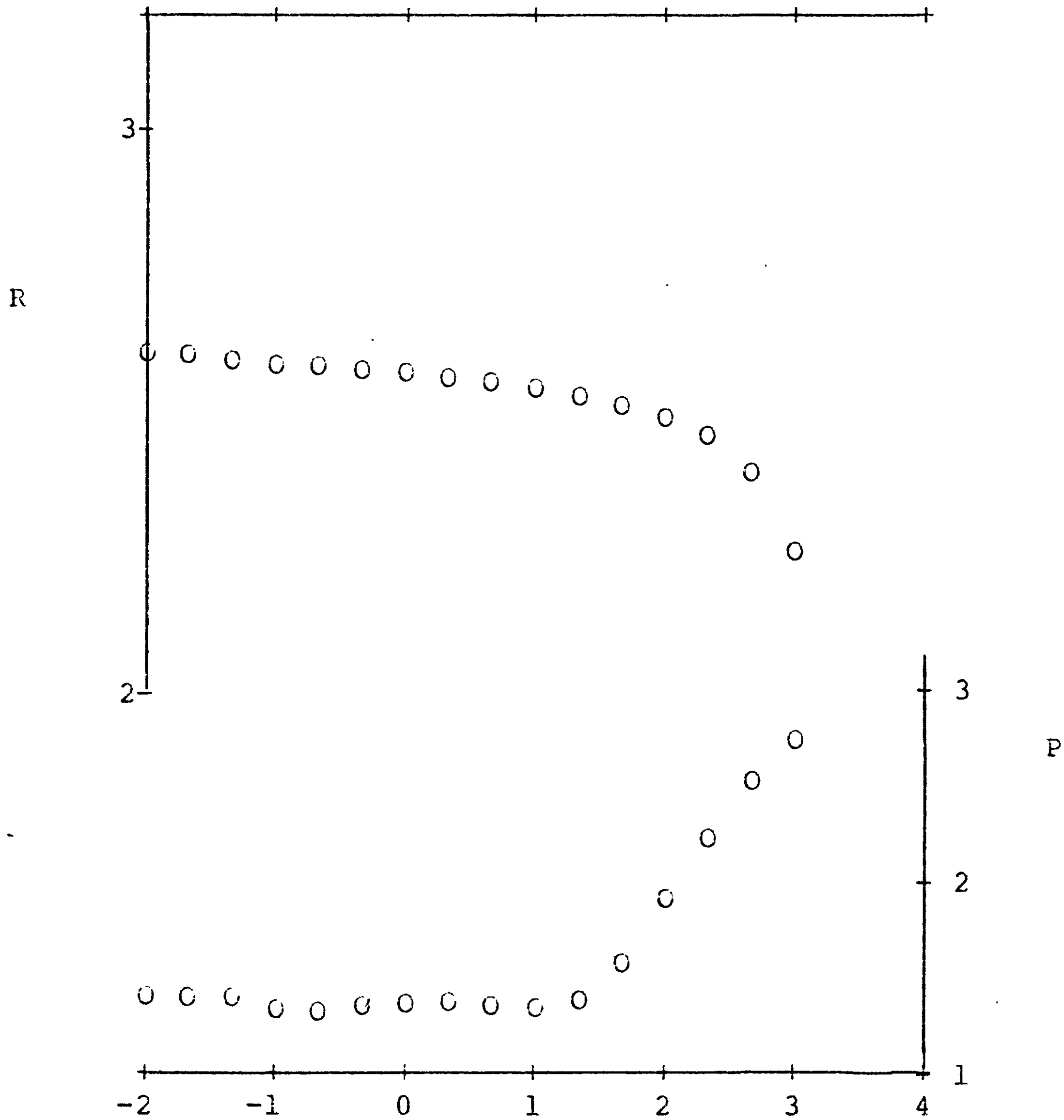
RAJAH 49 GATEWAY, COLO

12/31/76 11:16:14

RAJAH 49 GATEWAY, COLO
12/31/76 14:29:47

F(HZ)	K	D	R´(OHM-M)	MRAD
1.00E-02	1.148E+08	39.1270	399.8505	-25.6
2.10E-02	5.419E+07	39.8477	396.1405	-25.1
4.60E-02	2.521E+07	39.8694	388.5470	-25.1
1.00E-01	1.014E+07	46.3139	382.6420	-21.6
2.15E-01	4.622E+06	47.7181	378.8861	-21.0
4.64E-01	2.338E+06	44.3365	373.6030	-22.6
1.00E+00	1.136E+06	42.8734	368.7203	-23.3
2.15E+00	5.548E+05	41.5741	361.5819	-24.0
4.64E+00	2.479E+05	43.8560	356.0602	-22.8
1.00E+01	1.142E+05	45.2471	347.7531	-22.1
2.15E+01	60861.700	40.7050	336.5667	-24.6
4.64E+01	45620.100	26.3159	322.0950	-38.0
1.00E+02	48487.900	11.9952	306.9183	-83.2
2.15E+02	49051.600	5.7870	285.3895	-171.1
4.64E+02	49302.100	2.8500	245.3858	-337.5
1.00E+03	44747.100	1.6230	179.1523	-550.8

W-11-2



LOGR (OHM-M) & LOGP (mR) VS LOGF

O = DATA
W-11-2

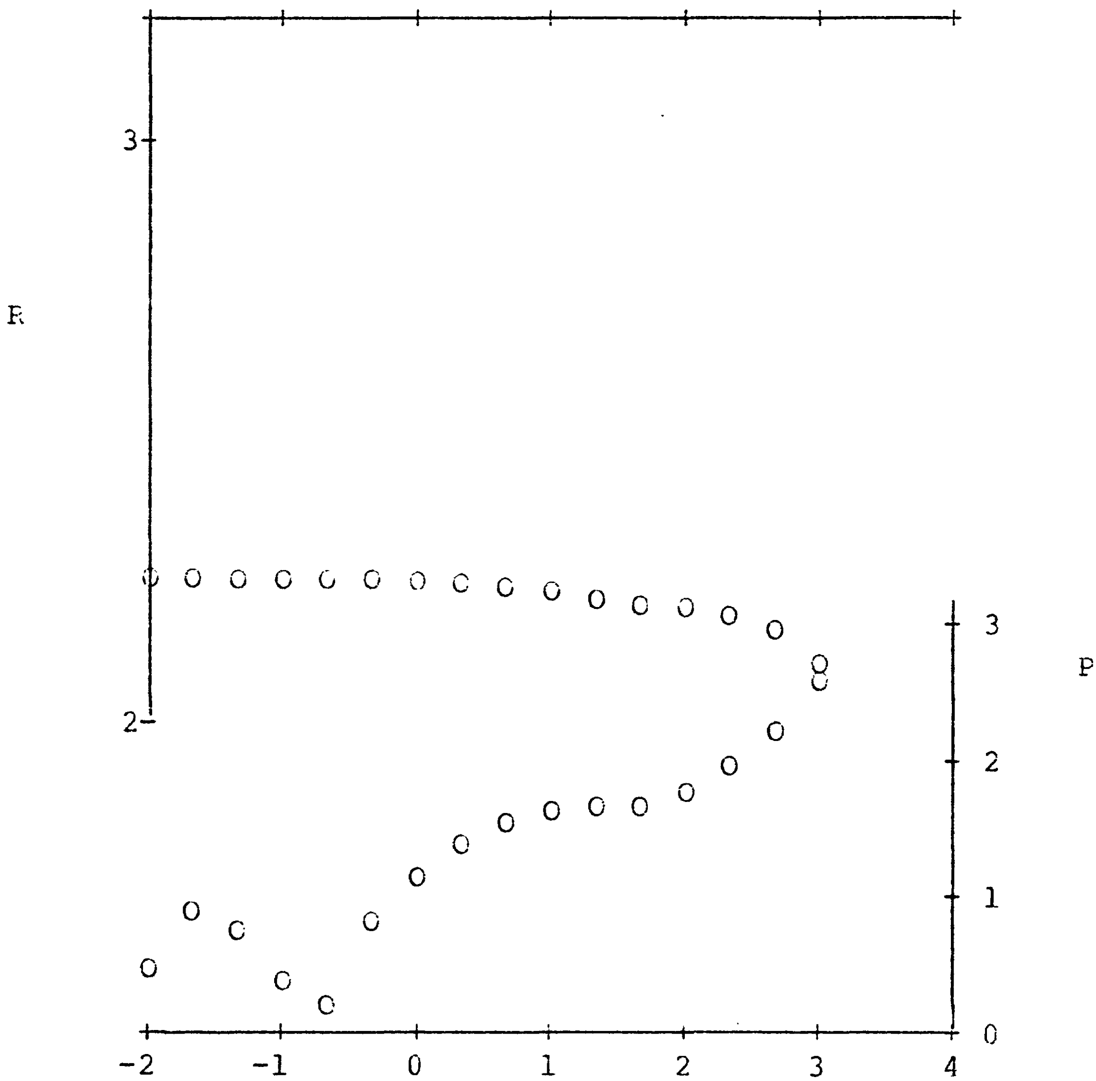
RAJAH 49 GATEWAY, COLO

12/31/76 14:29:47

RAJAH 49 GATEWAY, COLO
12/30/76 10:13:06

F(HZ)	K	D	R´(OHM-M)	MRAD
1.00E-02	3.059E+07	330.7430	177.6765	-3.0
2.10E-02	3.861E+07	125.2870	176.9164	-8.0
4.60E-02	1.278E+07	173.5610	176.1085	-5.8
1.00E-01	2.465E+06	415.1360	175.6633	-2.4
2.15E-01	7.746E+05	614.1190	175.7427	-1.6
4.64E-01	1.480E+06	149.1130	175.5002	-6.7
1.00E+00	1.478E+06	69.5274	174.8880	-14.4
2.15E+00	1.190E+06	40.4580	173.2012	-24.7
4.64E+00	8.275E+05	27.3477	170.9171	-36.5
1.00E+01	4.682E+05	22.9336	167.0789	-43.6
2.15E+01	2.399E+05	21.3980	162.1646	-46.7
4.64E+01	1.146E+05	21.2381	158.8019	-47.1
1.00E+02	69475.100	16.4311	156.8809	-60.8
2.15E+02	51028.900	10.6275	152.4928	-93.8
4.64E+02	44643.000	5.8651	143.7190	-168.9
1.00E+03	49980.600	2.4545	125.6662	-386.9

W-12



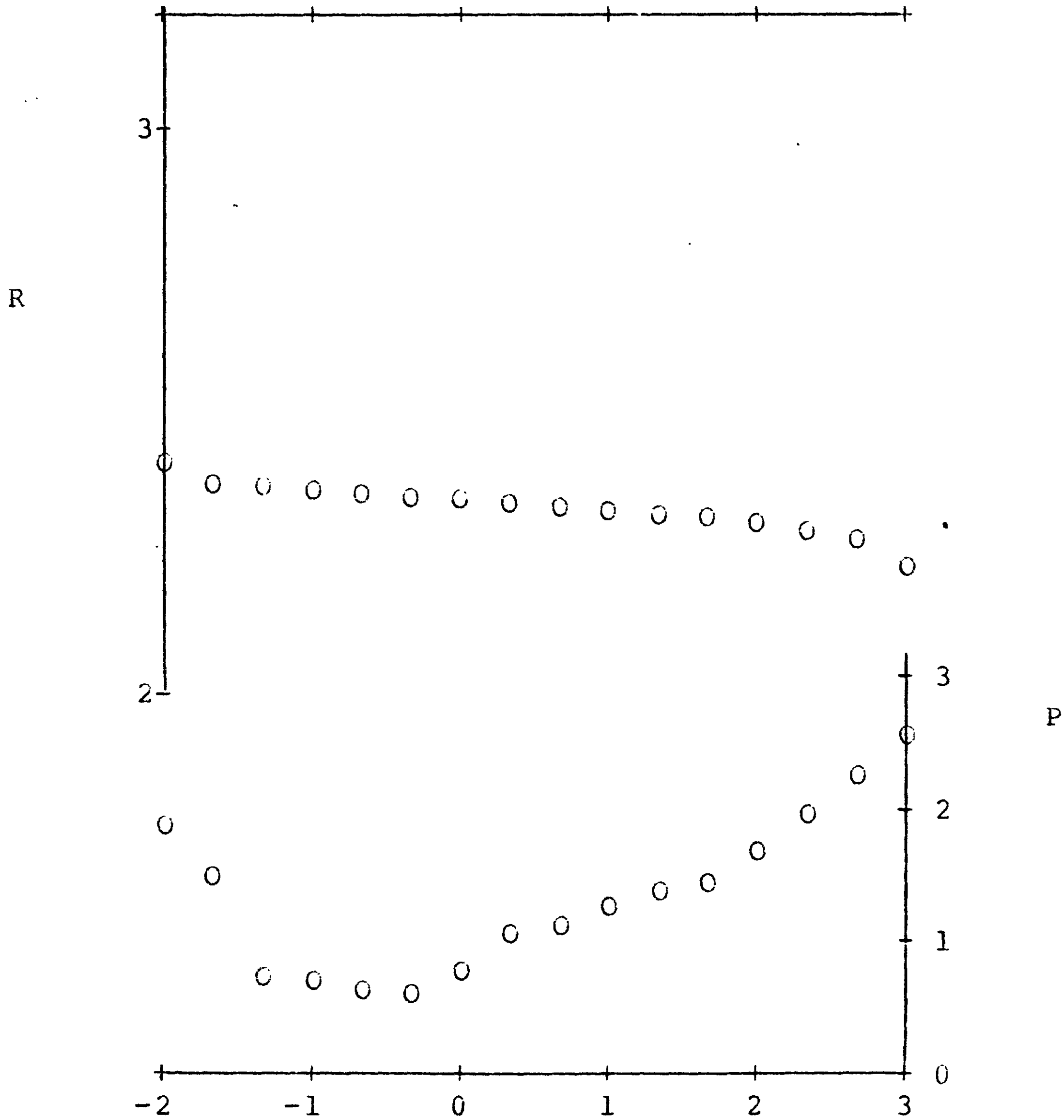
LOGR (OHM-M) & LOGP (mR) VS LOGF
O = DATA
W-12

RAJAH 49 GATEWAY, COLO

12/30/76 10:13:06

RAJAH 49 GATEWAY, COLO
12/31/76 12:34:52

F(HZ)	K	D	R´(OHM-M)	MRAD
1.00E-02	5.285E+08	13.1548	257.0423	-75.9
2.10E-02	1.153E+08	31.6351	234.4540	-31.6
4.60E-02	9.156E+06	183.2270	232.9191	-5.5
1.00E-01	3.965E+06	196.7190	229.2920	-5.1
2.15E-01	1.595E+06	232.4240	225.5545	-4.3
4.64E-01	6.993E+05	249.1500	222.3379	-4.0
1.00E+00	5.032E+05	162.5350	219.7643	-6.2
2.15E+00	4.444E+05	86.7042	216.5425	-11.5
4.64E+00	2.420E+05	74.8483	213.7739	-13.4
1.00E+01	1.609E+05	53.3857	209.1484	-18.7
2.15E+01	1.009E+05	40.0746	206.2906	-24.9
4.64E+01	54391.300	34.8932	203.9426	-28.7
1.00E+02	43779.300	20.5047	199.8241	-48.7
2.15E+02	39749.500	10.7885	192.9559	-92.4
4.64E+02	37039.400	5.4130	186.8356	-182.7
1.00E+03	35258.000	2.6600	167.9775	-359.6



LOGR (OHM-M) & LOGP (mF) VS LOGF
O = DATA
W-15-1

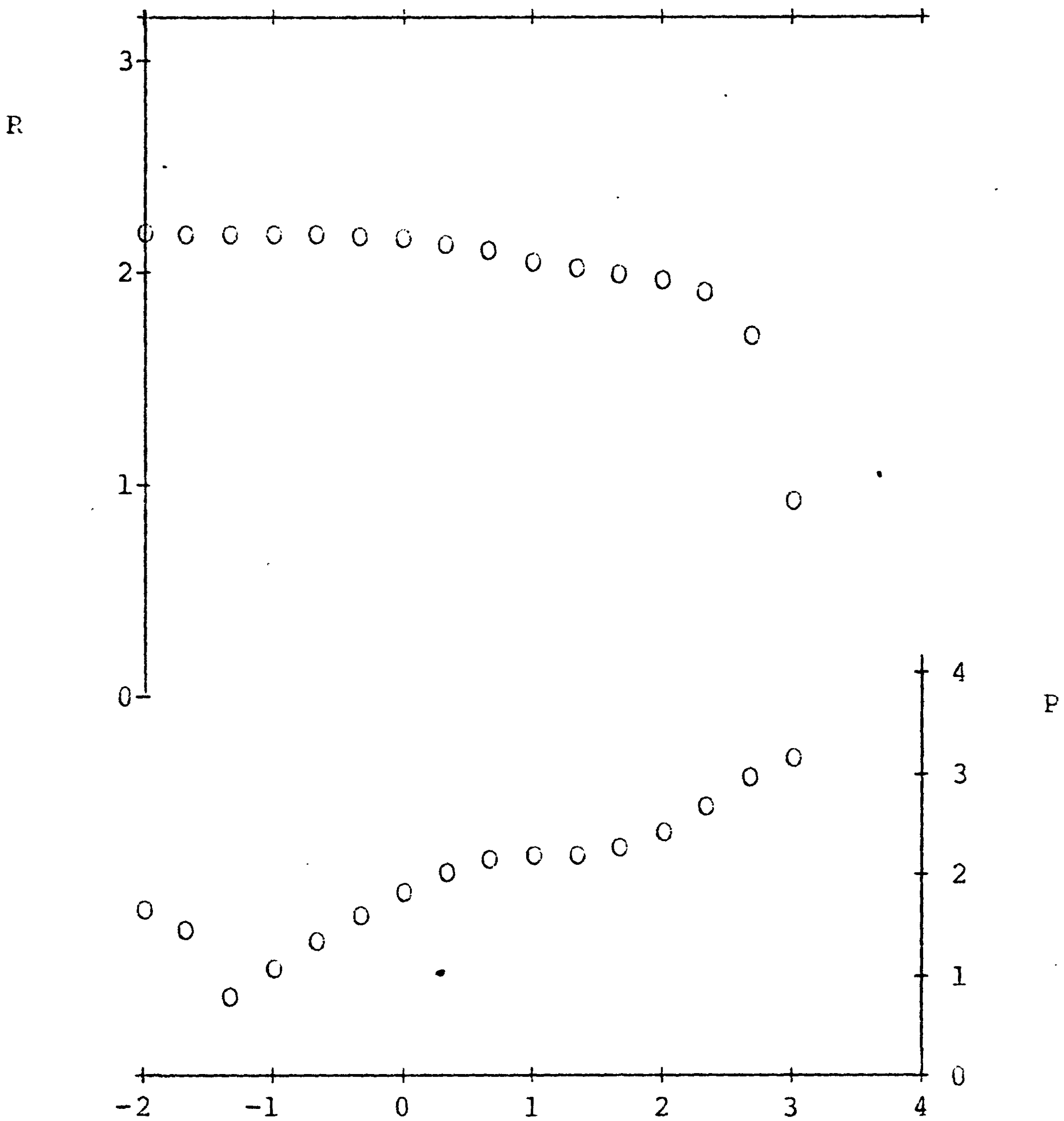
RAJAH 49 GATEWAY, COLO

12/31/76 12:34:52

RAJAH 49 GATEWAY, COLO
12/29/76 14:23:13

F(HZ)	K	D	R´(OHM-M)	MRAD
1.00E-02	5.030E+08	23.6813	150.6455	-42.2
2.10E-02	1.570E+08	36.6385	148.6697	-27.3
4.60E-02	1.562E+07	168.3620	148.5673	-5.9
1.00E-01	1.413E+07	85.9987	147.9465	-11.6
2.15E-01	1.240E+07	45.6827	147.4786	-21.9
4.64E-01	1.064E+07	25.0692	144.9962	-39.9
1.00E+00	8.643E+06	14.5675	142.1022	-68.5
2.15E+00	6.629E+06	9.2691	134.2464	-107.5
4.64E+00	4.434E+06	6.8913	124.1343	-144.1
1.00E+01	2.458E+06	6.4148	111.2787	-154.6
2.15E+01	1.232E+06	6.3446	104.1871	-156.3
4.64E+01	7.201E+05	5.3550	97.0357	-184.6
1.00E+02	5.149E+05	3.5844	90.3630	-272.1
2.15E+02	4.322E+05	1.8658	80.3682	-492.0
4.64E+02	3.686E+05	0.7527	50.4829	-925.6
1.00E+03	2.477E+05	0.1173	8.3931	-1454.1

W-15A-1



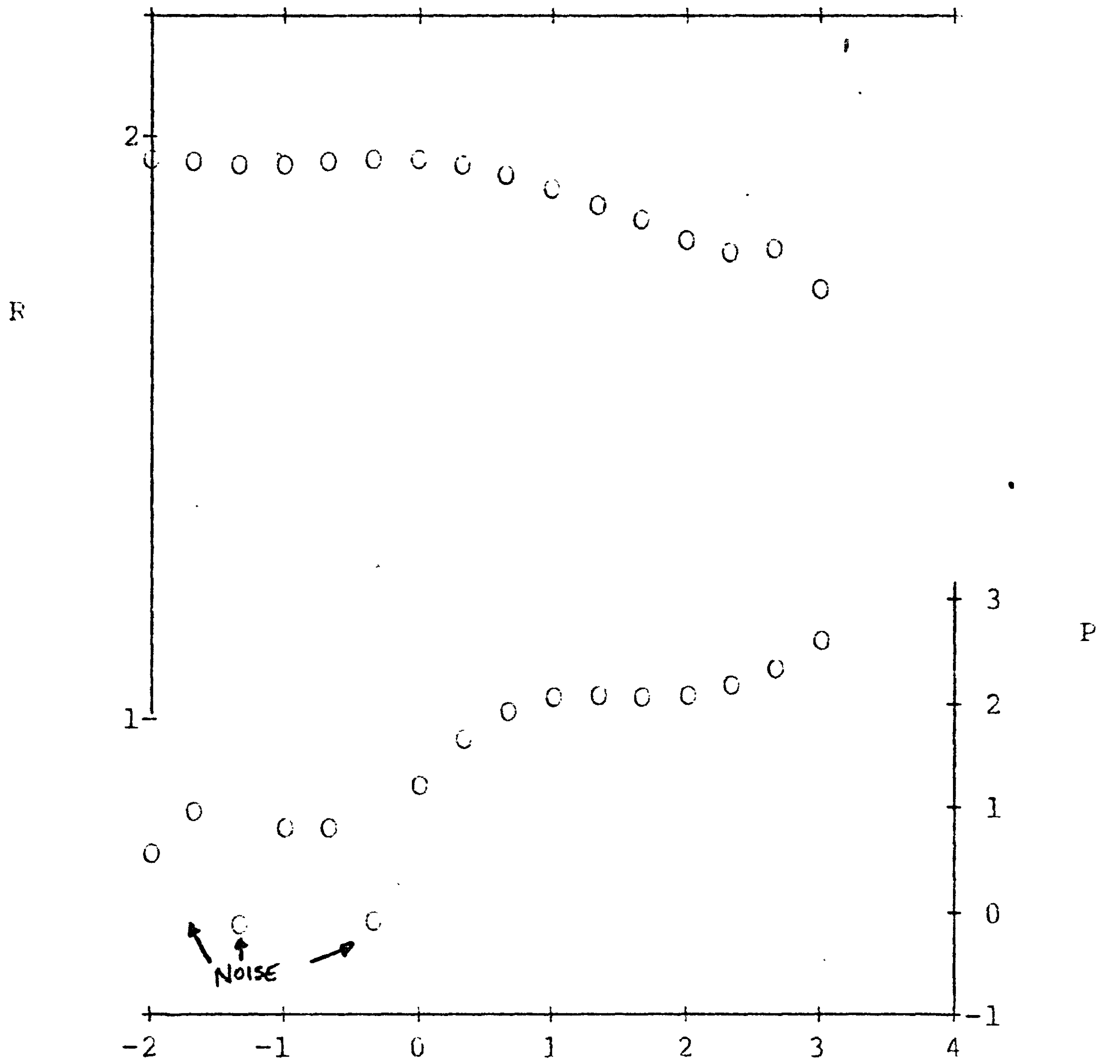
LOGR (OHM-M) & LOGP (mR) VS LOGF
O = DATA
W-15A-1

RAJAH 49 GATEWAY, COLO

12/29/76 14:23:13

RAJAH 49 GATEWAY, COLO
12/30/76 16:02:37

F(HZ)	K	D	R´(OHM-M)	MRAD
1.00E-02	6.946E+07	284.4930	90.9599	-3.5
2.10E-02	8.793E+07	107.4500	90.5889	-9.3
4.60E-02	3.243E+06	1349.8100	89.2604	-0.7
1.00E-01	1.324E+07	152.0680	89.2764	-6.6
2.15E-01	5.897E+06	157.1400	90.2142	-6.4
4.64E-01	3.513E+05	1206.8700	91.3799	-0.8
1.00E+00	3.281E+06	59.8977	91.4518	-16.7
2.15E+00	4.407E+06	21.2817	88.7882	-47.0
4.64E+00	3.943E+06	11.3882	85.5927	-97.6
1.00E+01	2.541E+06	8.6109	81.0478	-115.6
2.15E+01	1.354E+06	8.0001	75.8266	-124.4
4.64E+01	6.395E+05	3.2939	71.9633	-120.0
1.00E+02	3.318E+05	3.0575	66.2236	-123.5
2.15E+02	2.032E+05	6.3574	63.0162	-156.0
4.64E+02	1.313E+05	4.3785	64.0392	-224.5
1.00E+03	1.193E+05	2.3195	54.7903	-407.1



LOGR (CHM-M) & LOGP (MF) VS LOGF
O = DATA
W-16

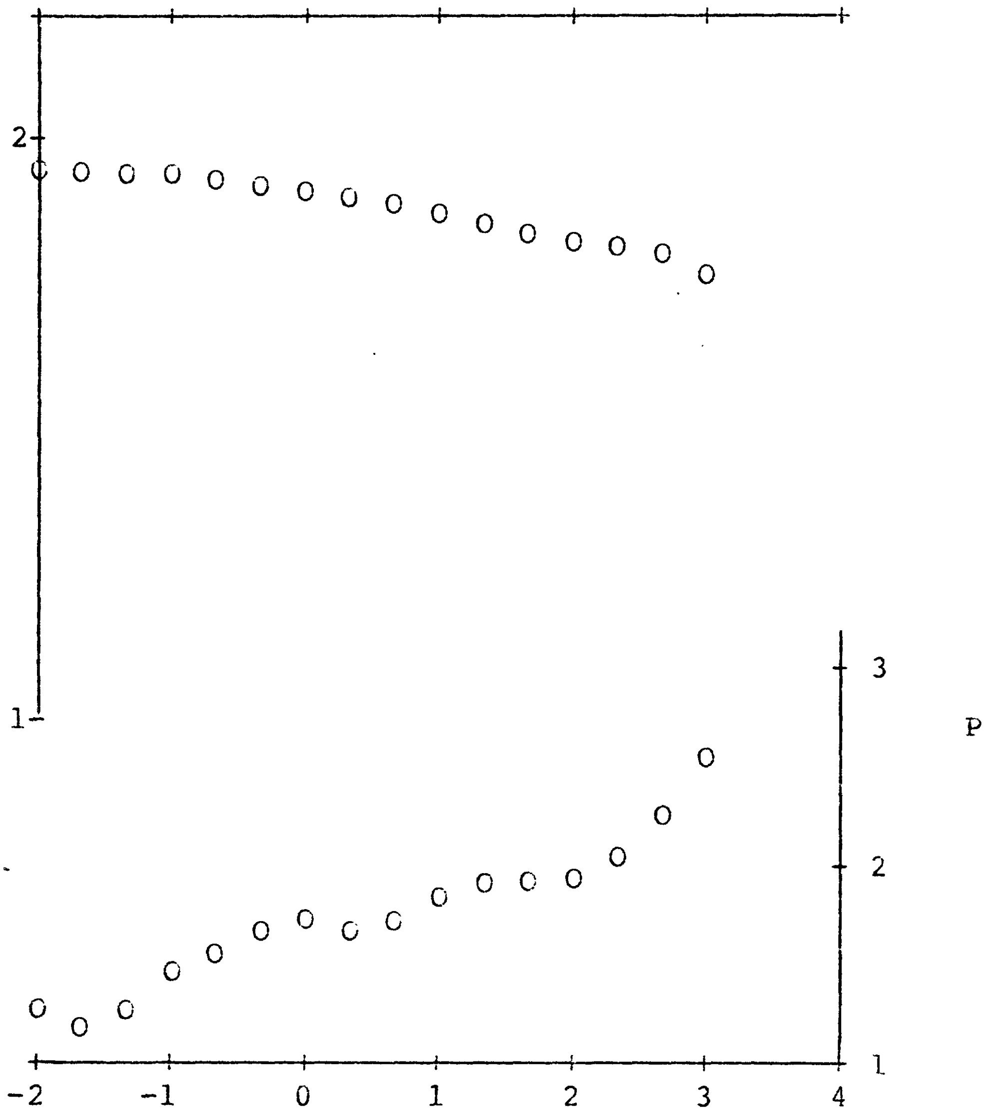
RAJAH 49 GATEWAY, COLO

12/30/76 16:02:37

RAJAH 49 GATEWAY, COLO
12/29/76 09:14:53

F(HZ)	K	D	R´(OHM-M)	MRAD
1.00E-02	3.847E+08	53.3672	87.5338	-18.7
2.10E-02	1.483E+08	66.2646	87.1106	-15.1
4.60E-02	8.551E+07	52.7933	86.5284	-18.9
1.00E-01	6.111E+07	34.1774	85.9928	-29.3
2.15E-01	3.634E+07	27.2297	84.3676	-36.7
4.64E-01	2.192E+07	21.4886	82.0761	-46.5
1.00E+00	1.200E+07	18.6197	80.2231	-53.7
2.15E+00	5.019E+06	21.1053	78.6058	-47.3
4.64E+00	2.643E+06	19.0632	76.6736	-52.4
1.00E+01	1.708E+06	14.1802	73.8541	-70.4
2.15E+01	9.650E+05	12.1721	70.5490	-82.0
4.64E+01	4.813E+05	11.7299	68.0987	-85.0
1.00E+02	2.332E+05	11.5936	65.9874	-86.0
2.15E+02	1.422E+05	8.9853	64.4911	-110.8
4.64E+02	1.113E+05	5.3784	62.5366	-183.8
1.00E+03	1.018E+05	2.6902	57.6677	-355.9

W-17-1



LOGR (OHM-M) & LOGP (mR) VS LOGF
) = DATA
7-1

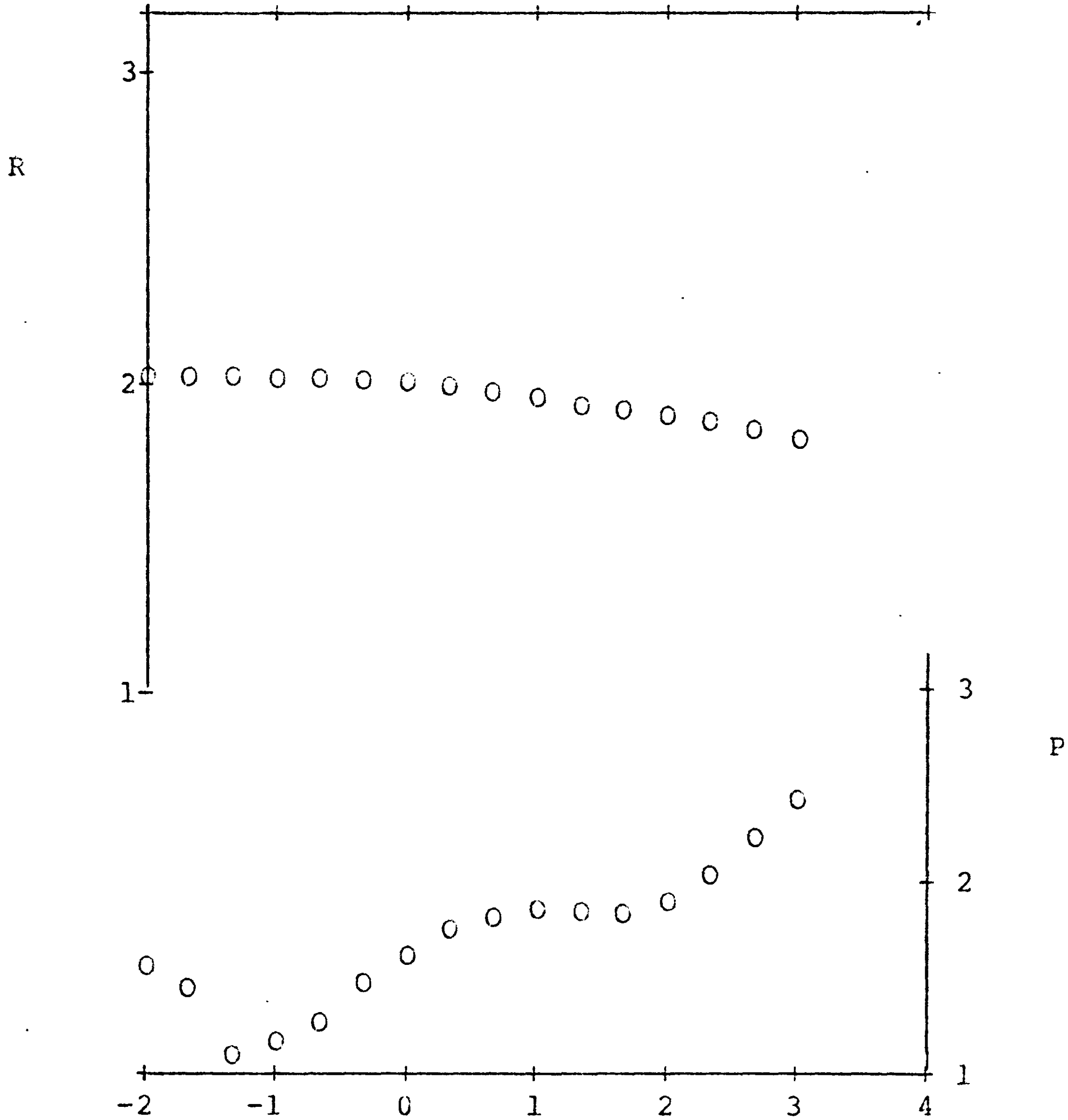
PAJAH 49 GATEWAY, COLO

12/29/76 09:14:53

RAJAH 49 GATEWAY, COLO
12/29/76 13:13:35

F(HZ)	K	D	R´(OHM-M)	MRAD
1.00E-02	6.159E+08	27.5889	105.6459	-36.2
2.10E-02	2.260E+08	35.9808	105.1806	-27.8
4.60E-02	4.683E+07	79.6349	104.7705	-12.6
1.00E-01	2.567E+07	67.1125	104.3233	-14.9
2.15E-01	1.510E+07	53.3554	103.7178	-18.7
4.64E-01	1.138E+07	33.0563	102.8766	-30.2
1.00E+00	7.418E+06	23.9454	101.0218	-41.7
2.15E+00	4.840E+06	17.4744	98.3464	-57.2
4.64E+00	2.669E+06	15.3855	93.9437	-64.9
1.00E+01	1.433E+06	13.9526	89.4284	-71.5
2.15E+01	6.877E+05	14.2303	84.8356	-70.2
4.64E+01	3.233E+05	14.6221	81.5396	-68.3
1.00E+02	1.795E+05	12.7571	78.0076	-78.2
2.15E+02	1.107E+05	9.1844	75.0257	-108.5
4.64E+02	91552.800	5.7670	71.2029	-171.7
1.00E+03	70188.300	3.6188	65.7481	-269.6

W-17-3



LOGF (OHM-M) & LOGP (mF) VS LOGF

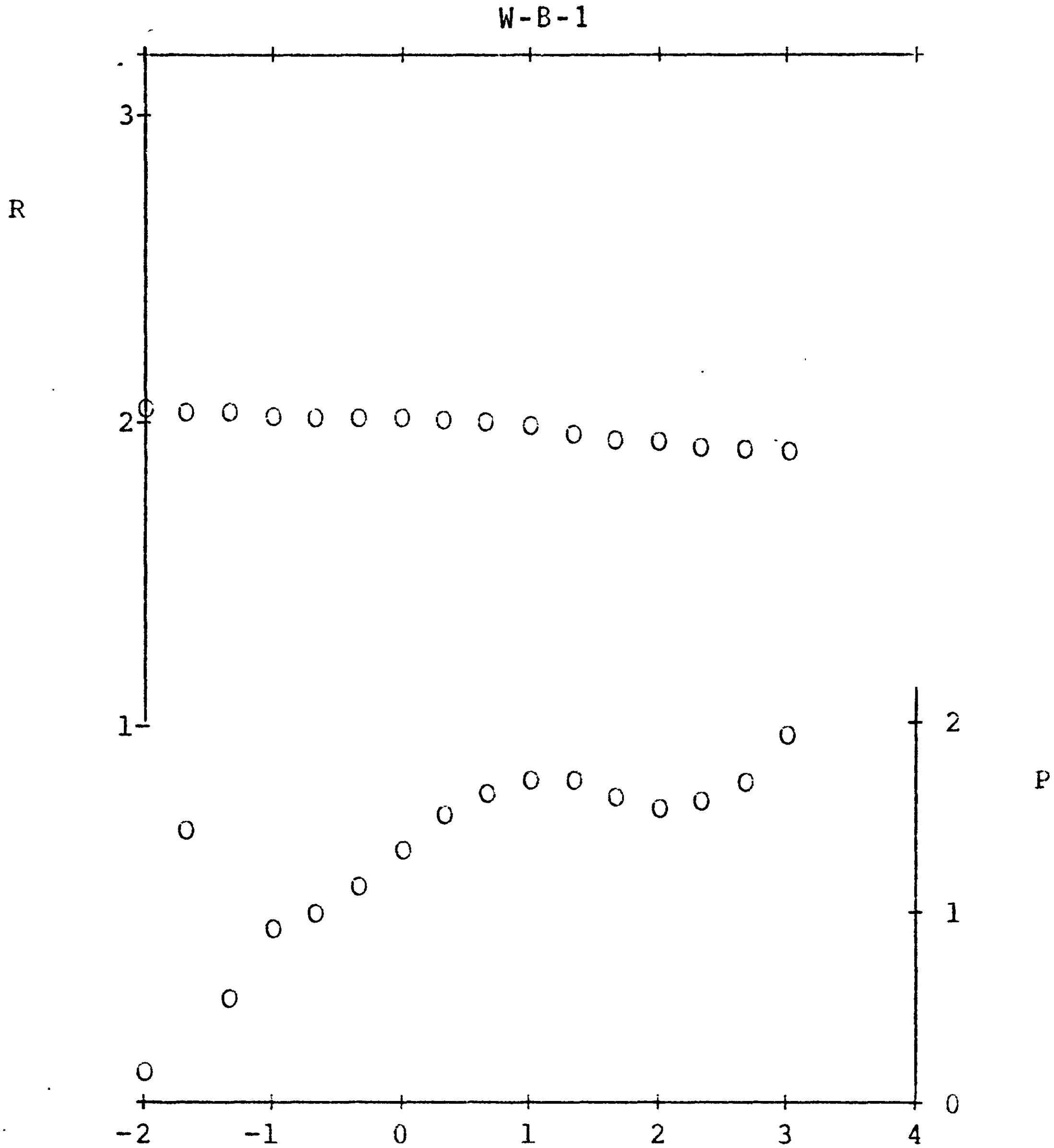
O = DATA
W-17-3

RAJAH 49 GATEWAY, COLO

12/29/76 13:13:35

RAJAH 49 GATEWAY, COLO
12/28/76 15:50:35

F(HZ)	K	D	R´(OHM-M)	MRAD
1.00E-02	2.370E+07	693.6560	109.3615	-1.4
2.10E-02	2.175E+08	36.6072	107.4001	-27.3
4.60E-02	1.296E+07	282.3720	106.7475	-3.5
1.00E-01	1.427E+07	120.6980	104.3729	-8.3
2.15E-01	8.147E+06	99.6512	102.9756	-10.0
4.64E-01	5.186E+06	72.7609	102.6378	-13.7
1.00E+00	3.822E+06	46.0395	102.1105	-21.7
2.15E+00	2.687E+06	30.6463	101.2260	-32.6
4.64E+00	1.667E+06	23.3918	99.1259	-42.7
1.00E+01	9.394E+05	19.8831	95.9930	-50.3
2.15E+01	4.581E+05	19.8423	91.5497	-50.4
4.64E+01	1.808E+05	24.4453	87.4722	-40.9
1.00E+02	74618.900	28.2634	85.1246	-35.4
2.15E+02	38997.700	26.0594	81.9752	-38.4
4.64E+02	23573.500	20.3322	80.5986	-49.1
1.00E+03	19272.900	11.6977	79.1520	-85.3



LOGR (OHM-M) & LOGP (mR) VS LOGF
O = DATA

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CONCLUSIONS

A correlation was observed between visible ore and a decrease in magnetic susceptibility. The relative contrast involved may justify use of a portable susceptibility meter in exploration, but only in underground or down-hole configurations. The pH measurements are probably not useful in an exploration context owing to the complexity of variables involved, but could be used in a borehole as part of a larger research program.

Porosity, dry density, and specific gravity measurements are difficult to understand, however, when combined with careful petrographic and x-ray analyses of the samples, they may show more reasonable correlations with mineralogy. This information might provide insights into ore placement; considering the size of the target, however, these data show that it would be difficult to use gravimetry in a reasonable exploration approach.

The electrical data were disappointing in that no clear phenomenological behavior was observed that might prove amenable to measurements made using surface exploration techniques. The limited results here are due at least in part to the lack of petrographic information.

The data presented here should be considered in light of the processing history of the samples and the inhomogeneities in the host rock. The wallrock from which they were taken may have been altered or oxidized following the blasting-removal process. (This contamination would certainly not be as severe as drill-mud contamination however.) Additionally, the samples were exposed to oxygen in the drift for months before they were collected, and for some time afterwards.

The somewhat inconclusive results of this study might be alleviated if further sampling of this type was made using a small coring device and then hermetically sealing the samples in plastic containers. Samples collected from several meters inside the wallrock should give the most faithful representation of the original conditions. We are unable to make any conclusions concerning the applicability of electrical spectral measurements to uranium exploration until careful sampling of roll features exposed in drifts from many different environments are undertaken. Furthermore, careful petrographic examinations would also have to be made on all samples.

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