

15. PRELIMINARY ELECTRICAL MEASUREMENTS OF CORE SAMPLES, DSDP LEG 37

T.J. Katsube, J. Frechette, and L.S. Collett, Geological Survey of Canada, Ottawa, Canada

INTRODUCTION

Preliminary measurements have been completed on the electrical properties of core samples from the Deep Sea Drilling Project (6 samples from Hudson Deep Drill '74 site survey, and 10 samples from *Glomar Challenger* Leg 37). The frequency range of measurement is from 1.0 to 10^6 Hz, and the measured parameters are parallel resistivity (ρ_p) or resistivity and dissipation factor (D). Because the thickness of the core samples measured ranges from 2.0-3.0 cm, measurement problems occurred at the higher frequencies (mainly above 10^4 Hz). And because to date only the two electrode system has been applied, not all measurements are free from electrode effects at the lower frequencies. It is also not certain whether the samples have been measured under adequate conditions, since some of them have been saturated with seawater (*Glomar Challenger* samples), and others with ground water (Hudson samples). However, the measurements at the frequencies ranging from 10 to 10^4 Hz are generally free from erroneous effects and indicate the general trend of the electrical properties of these core samples.

SAMPLES AND PREPARATION

Samples measured in this study are cores taken from the grab samples from Hudson Deep Drill '74 site (6 samples) and from *Glomar Challenger* Leg 37 (10 samples). The samples were cut into cylinders with two parallel surfaces. Sample dimensions geometrical factor (k) and other information is given in Tables 1 and 2. *Glomar Challenger* samples were received and measured in seawater saturated condition, and the Hudson samples were received in room-dry condition but measured under ground water (Ottawa River water) saturated condition.

The geometrical factor (k) is determined from the equation:

$$k = \frac{\text{area}}{\text{sample length}}$$

Each sample diameter is 2.54×10^{-2} m and area is 5.067×10^{-4} m².

MEASURING SYSTEM AND PARAMETERS

An automatic high impedance measuring system, controlled by a mini-computer, is used to measure the core samples. The measurement principles and electronic setup of the system are described in the paper by Gauvreau and Katsube (1975). This system makes

direct measurement of the complex resistivity (ρ^*) and dissipation factor (D), and the parallel resistivity (ρ_p) is calculated from these measurements:

$$\rho_p = \frac{D}{\rho^* \sqrt{1 + D^2}}$$

The interrelationship between the various parameters and their significance are described by Katsube (1975a, b). Parallel resistivity (ρ_p) is a parameter usually referred to as "Resistivity."

RESULTS

Typical results are shown in Figures 1 and 2 for a high impedance sample and a low impedance sample. These results are similar to the usual trends seen in the past work which is briefly summarized by Katsube (1975a), except for the increase of D above 10^5 Hz. For the low impedance sample (Figure 2) there is a rapid rise of ρ_p and rapid decrease of D with decreasing frequency below 10^2 Hz. The rise of D at the maximum frequencies is due to stray capacitive effects of the system caused by the large length. Cole-Cole diagrams in the complex resistivity plane for the same two samples are shown in Figures 3 and 4. Methods of analysis of the Cole-Cole diagrams are discussed in Cole and Cole (1941) and Katsube (1975c). The analysis of Figure 4 suggests that the rapid decrease in D at low frequencies (Figure 2) is due to electrode effects. The trend of the electrode effects being visible in Figure 2 (low impedance sample) but not in Figure 1 (high impedance sample) coincides with the results shown in the paper by Katsube (1975d). Results for ρ_p and D which are thought to be free from erroneous effects (electrode and stray effects) are tabulated in Tables 3 and 4.

DISCUSSION

Resistivity or parallel resistivity (ρ_p) usually show little variation with frequency below the critical frequency (Katsube, 1975a; Katsube and Collett, 1973, 1974). This "little variation with frequency" is seen in all the results shown in Tables 3 and 4. The large variation of resistivity with frequency is not seen in these results because the applied frequencies are not high enough.

Under the conditions where the resistivity shows a "little variation with frequency," Cole-Cole diagrams can be used to determine a single resistivity (ρ_{p1}) value which represents a characteristic of the rock, and which does not contain any electrode or membrane polarization effects. According to Katsube (1975c), three zones:

TABLE 1
Information on Samples from *Glomar Challenger* Leg 37

Core	Section	Depth (m)	Sample Length (cm)	Geometric Factor (k)	Rock Type	
Hole 332A						
	7	2	113	3.375	0.015	Sparsely phyric basalt
	11	1	151	2.885	0.0176	Sparsely phyric basalt
	17	1	208	3.22	0.0157	Aphyric basalt
	23	1	264	2.83	0.018	Aphyric basalt
	30	2	332	3.00	0.0169	Plagioclase phyric basalt
Hole 332B						
	6	1	284	3.46	0.0146	Aphyric basalt
	31	1	556	3.265	0.0155	Sparsely plagioclase phyric basalt
Site 334						
	22	2	321	3.13	0.0162	Serpentinized plagioclase peridotite
	24	4	343	2.42	0.0209	Olivine-rich gabbro
Site 335						
	6	1	458	3.535	0.0143	Sparse to moderate phyric basalt

TABLE 2
Information on Grab Samples
from Hudson Deep Drill '74 Site

Sample	Sample Length (cm)	Factor (k)	Rock Type
74-003, 2-1c	2.13	0.0305	Tholeiite (basalt)
74-003, 6-1c	2.11	0.0221	Tholeiite (basalt)
74-003, 10-1b	2.098	0.0223	Tholeiite (basalt)
74-003, 10-2a	2.248	0.0202	Tholeiite (basalt)
74-003, 10-3a	2.088	0.0224	Tholeiite (basalt)
74-003, 10-4b	2.083	0.0229	Tholeiite (basalt)

critical frequency zone, membrane polarization, and electrode polarization zone, can be seen as a result of analyzing the Cole-Cole diagrams. From Katsube (1975c) or Katsube and Collett (1974), it is evident that the left-hand side arc in Figure 3 (high impedance sample) is the critical frequency zone, and the small right-hand side arc is, perhaps, the membrane polarization zone with the electrode polarization zone further to the right not appearing. Thus the right-hand side interception of the arc and horizontal axis determines ρ_{p1} . The left hand side arc in Figure 4 (low impedance sample) is perhaps the membrane polarization zone with part of the electrode polarization zone seen on the right-hand side of it. The critical frequency zone cannot be seen in the figure, but can be expected to be seen on the left-hand side of the arc, if the measurements at higher frequencies were shown. Thus, the left-hand side interception of the arc and horizontal axis determines ρ_{p1} . ρ_{p1} and the approximate frequency at which it is determined for all the samples are shown in Tables 3 and 4.

If four electrode systems were used at the lower frequencies, and the minimum frequency was extended to 10^{-2} Hz, it is expected that the effect of membrane polarization (expressed by $\rho_{p2} - \rho_{p1}$ in Figure 4) and elec-

trode polarization effects of metallic minerals in the rock sample (if they do exist) could be measured. And if the maximum frequency range was extended to 10^8 Hz, it is expected that further details of the critical frequency zone can be determined: values of the dielectric constant. This laboratory is set up to do these measurements, and these measurements will be the next step to be taken in this study.

The resistivity of rocks is dependent upon not only rock type, but also the type of liquid, type and amount of alteration in the pores, porosity, and other textural features. That is, two rocks which are identical in mineral and chemical composition can differ in resistivity due to differences in texture or type of pore liquid. At present, work is being carried out to standardize the type of liquid for saturating the rocks so that interlaboratory and regional comparisons can be made. However, in general, it is reasonable to expect resistivity values of basalt to be on the order of 500 to 10^4 ohm-meters. The basalts from *Glomar Challenger* Leg 37 range from about 9 to 60 ohm-meters, and those from Hudson Deep Drill '74 range from about 70 to 540 ohm-meters. These values are smaller than the usual values, perhaps, due to the pores being saturated with seawater, or due to salt-water deposits in the pores dissolving into the pore water. Resistivity values of gabbro can be expected to be on the same order or larger than those of basalts. Thus, the 55 ohm-meter value for the gabbro Sample 334-24-4 is very low, perhaps for the same reason that the basalt samples show low resistivities. Serpentinized periodites show resistivities ranging from 5 to 10^5 ohm-meters, and thus the 95 ohm-meter value for Sample 334-22-2 is normal.

Four sources of measurement error can be considered. The first source is instrumental error of the electronic measuring equipment which is in the order of $\pm 3.0\%$. The second source is the sample-holder

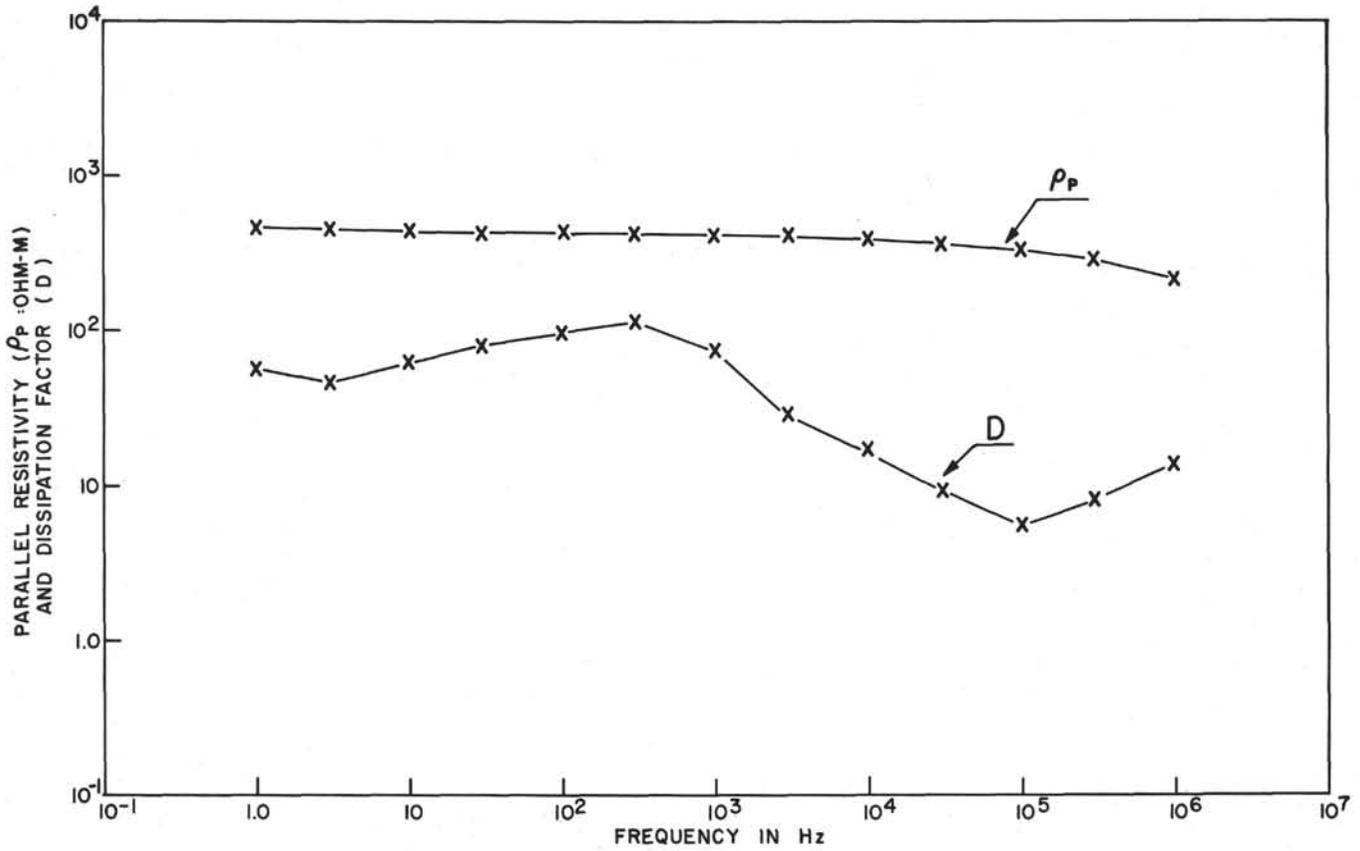


Figure 1. Parallel resistivity (ρ_p) or resistivity and dissipation factor (D) vs. frequency for a high impedance sample (74003, 2-1c).

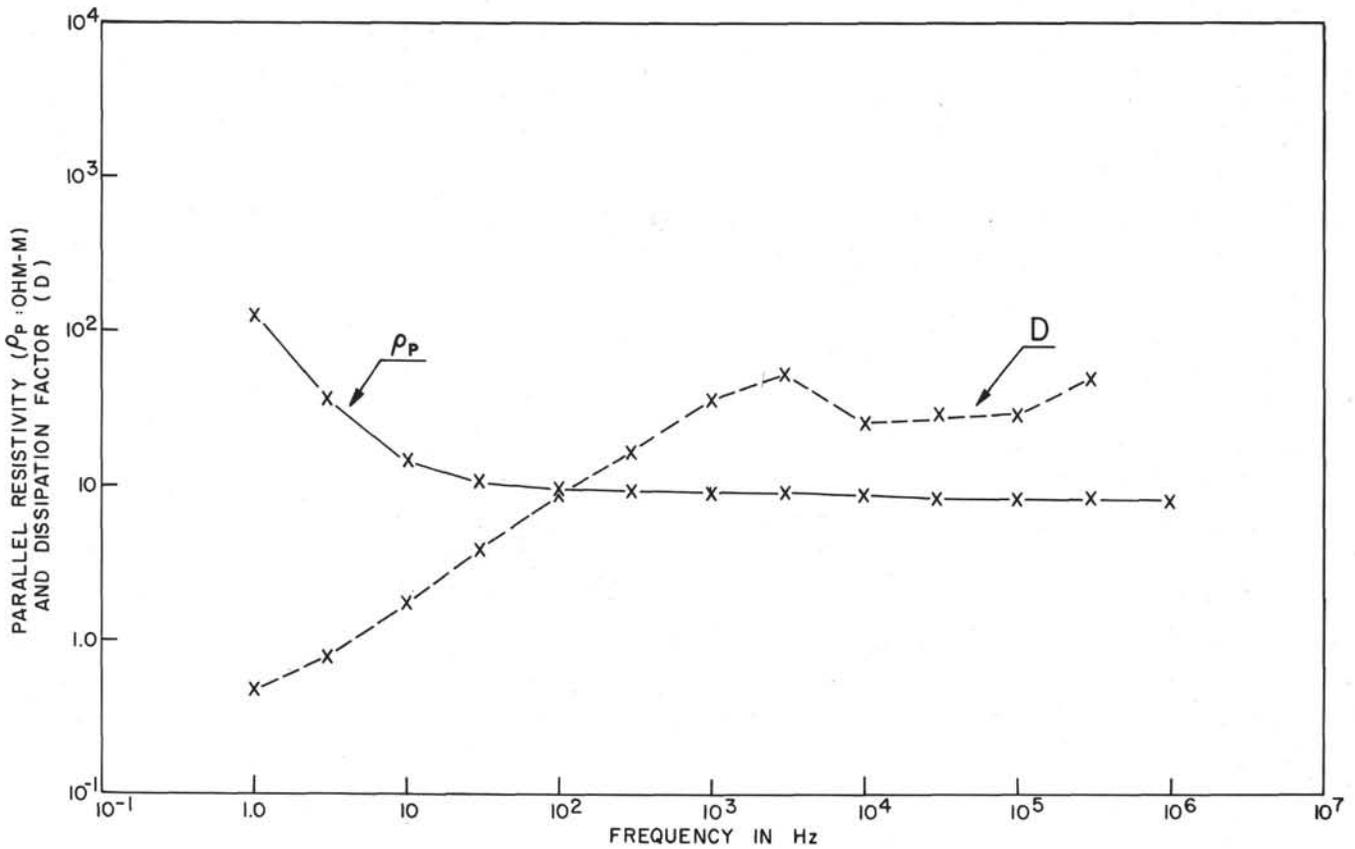


Figure 2. Parallel resistivity (ρ_p) or resistivity and dissipation factor (D) vs. frequency for a low impedance sample (332A-40-2).

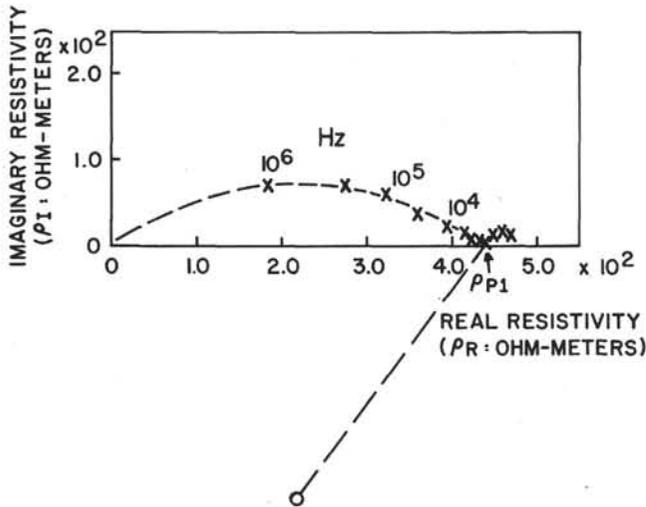


Figure 3. Cole-Cole diagram of the complex resistivity plane (ρ_R : real resistivity, ρ_i : imaginary resistivity) for Sample 74003, 2-1c.

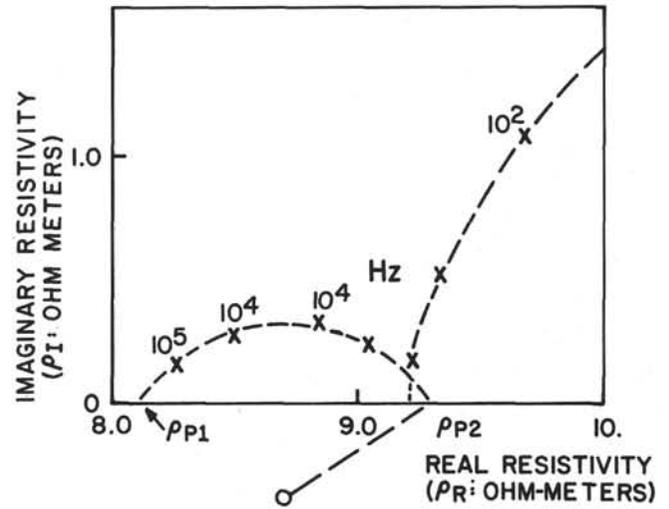


Figure 4. Cole-Cole diagram of the complex resistivity plane for Sample 332A-40-2.

system's error which is mainly caused by the electrochemical double-layer forming on the electrodes that contact the sample. This error is significant at the lower frequencies when the resistivity is low, but theoretically it is not contained in the value of ρ_{p1} in Tables 3 and 4. The third source is sample handling error, which is mainly caused by evaporation of water from the surface of the specimen when moving it from container to sample holder or during measurement. Efforts are made to keep this error to a minimum, but empirically it is in the order of $\pm 3\%$ to 6% . The fourth source is due to the type of liquid used to saturate the rock specimens. The difference in pore liquids can cause the resistivity to vary by a factor of 10 to 100. This is the reason that standardization of the type of liquids to saturate the rock is essential for making comparisons.

CONCLUSION

Preliminary measurements of the electrical properties for 16 deep-sea samples have been carried out over the frequency range from 1.0 to 10^6 Hz. One of the parameters (ρ_{p1}) which represents the resistivity of the samples is seen to range from 9.3 to 95 ohm-meters for the samples from *Glomar Challenger* Leg 37 drill holes, and from 120 to 540 ohm-meters for the grab samples from Hudson Deep Drill '74 site. The dissipation factor (D) ranges from 1.0 to about 700 for these samples.

Four electrode measurements at the lower frequencies, measurement at frequencies above 10^6 Hz and below 1.0 Hz measurements with different salinities are planned for the future using samples with smaller thicknesses. Petrographical correlation studies are also planned for the future.

TABLE 3
Parallel Resistivity (ρ_p) or Resistivity and Dissipation Factor (D) for Samples from *Glomar Challenger* Leg 37

Sample	Parameter	Frequency				ρ_{p1} (Freq.)
		10^1	10^2	10^3	10^4 Hz	
332A-7-2 (42)	ρ_p	6.21 E 1	5.90 E 1	5.83 E 1	5.56 E 1	57
	D	9.8	50.9	644	52	(10^4)
332A-12-1 (123)	ρ_p	3.31 E 1	2.95 E 1	2.81 E 1	2.61 E 1	28.8
	D	5.2	20	38.7	21.9	(10^3)
332A-27-1 (129)	ρ_p	2.49 1	2.28 E 1	2.14 E 1	1.99 E 1	22
	D	13.8	23.3	35.7	23.5	(10^2)
332A-34-1 (89)	ρ_p	4.55 E 1	4.22 E 1	4.02 E 1	3.07 E 1	41.8
	D	10.6	22.9	39.4	24.5	(10^3)
332A-40-2 (96)	ρ_p	1.46 E 1	9.80 E 0	8.10 E 0	8.8 E 0	9.3
	D	1.8	8.8	37.2	27	(10^2)
332B-6-1 (100)	ρ_p	6.41 E 1	6.10 E 1	5.89 E 1	5.49 E 1	61.1
	D	16.5	32.9	63.1	43.9	(10^2)
332B-31-1 (109)	ρ_p	2.50 E 1	2.31 E 1	2.17 E 1	2.01 E 1	22.5
	D	9.3	22.4	33.5	24.6	(10^3)
334-22-2 (44)	ρ_p	1.06 E 2	9.19 E 1	8.16 E 1	7.25 E 1	94.7
	D	8	11.2	17.1	23.9	(10^2)
334-24-4 (87)	ρ_p	7.46 E 2	6.51 E 1	5.83 E 1	5.37 E 1	55
	D	7.8	12.6	24.2	26.1	(10^3)
335-6-1 (6)	ρ_p	5.79 E 2	5.44 E 1	5.37 E 1	5.06 E 1	53.9
	D	11.6	46.6	298	43.6	(10^3)

TABLE 4
Parallel Resistivity (ρ_p) or Resistivity and Dissipation Factor (D)
for Grab Samples from Hudson Deep Drill '74 Site

Sample	Parameter	Frequency				ρ_p (Freq.)
		10 ¹	10 ²	10 ³	10 ⁴ Hz	
2-1, c	ρ_p	4.49 E 2	4.39 E 2	4.24 E 2	3.96 E 2	430
	D	63.2	95.7	76.3	17.8	(10 ³)
6-1, c	ρ_p	1.28 E 2	1.21 E 2	1.09 E 2	9.24 E 1	74
	D	31.3	20.8	14.8	13.8	(10 ⁴)
10-1, b	ρ_p	1.29 E 2	1.25 E 2	1.23 E 2	1.18 E 2	120
	D	51.2	142	722	56.8	(10 ³)
10-2, a	ρ_p	3.62 E 2	3.53 E 2	3.41 E 2	3.19 E 2	348
	D	81.5	116	68.4	17.9	(10 ²)
10-3, a	ρ_p	1.53 E 2	1.49 E 2	1.48 E 2	1.39 E 2	147
	D	70.6	142	325	30.4	(10 ³)
10-4, b	ρ_p	5.54 E 2	5.41 E 2	5.29 E 2	4.95 E 2	539
	D	71.4	116	70.7	18.8	(10 ²)

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