

## 32. DIFFUSIMETRY (DIFFUSION CONSTANT ESTIMATION) ON SEDIMENT CORES BY RESISTIVITY PROBE<sup>1</sup>

Frank T. Manheim, United States Geological Survey, Woods Hole, Massachusetts  
and

Lee S. Waterman, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts

### ABSTRACT

Measurement of formation factor (ratio of rock resistivity to interstitial water resistivity) from sediment cores provides an indirect measurement of the tortuosity of the fluid channels in the sediments. From these measurements one can estimate the diffusion coefficient of the sediment with depth. The  $F$  (formation factor) values for Indian Ocean sediments varied from 1.6 for a clayey diatom ooze having 87% porosity (70% water content) to 13.6 for a cemented limestone having 25% porosity (11% water content). These formation factors would yield diffusion coefficients for chloride ions in the corresponding sediments of  $6.4 \times 10^{-6}$  to  $1.5 \times 10^{-6}$  cm<sup>2</sup>/sec. In general, surficial sediments showed diffusion coefficients about one-half to one-third of those for free solution, values decreasing with depth and porosity.

### INTRODUCTION

The permeability of porous sediments to movement of ions and molecules is an important property since it governs the rate at which migration, loss or gain of dissolved constituents, may proceed via the interconnected fluid channels. The diffusive properties of relatively porous sediments are known to some degree through laboratory experiments (Manheim, 1970; Smirnov, 1971) and can be inferred indirectly by electrical measurements. However, whereas substantial data are available from electrical logging measurements in drill holes, particularly in oilfield work (Pirson, 1963) these data refer almost exclusively to reservoir, or permeable rocks such as sandstones and permeable limestones. Only a few studies have attempted to obtain data on relatively impermeable materials such as shales, shaly sands, or tight limestones. In particular, there appear to be only two systematic studies applicable to elucidating the diffusive permeability of sediments downward from the sea floor (Zatenatskaya, 1965; Keller, 1969). Such data are needed to understand the exchange of materials within the sediments and between the deposits and overlying ocean waters.

In principle, the manner in which electrolyte-saturated sediments transmit electrical current is analogous to their ability to allow molecular diffusion. The diffusivity of dissolved species within sediments is a function of the species themselves; the temperature, viscosity, and other physical properties of the solution; and the porosity and

tortuosity (geometry) of the free channels in the sediment. Since the electrical resistivity of many mineral particles is very large compared with electrolyte solutions, one can often ignore the proportion of current carried by the solids. Under such conditions the diffusion coefficient of a given molecule or ionic species within the sediment is given by

$$d = \frac{d_o}{F} = d_o R_w / R_s \quad (1)$$

where  $d_o$  is the diffusion coefficient for the given species in free solution at a given temperature and ionic strength solution,  $R_w$  is the electrical resistivity of the interstitial water of the sediment, and  $R_s$  is the bulk electrical resistivity of the sediment.  $F$ , or  $R_s/R_w$ , is the formation factor. Alternatively,

$$d = \frac{d_o}{F} = d_o C_s / C_w \quad (2)$$

where  $C_s$  and  $C_w$  are corresponding conductivities and  $F = C_w/C_s$ .

Where the sediments in question contain high proportions of clay with respect to fluid, the clays may conduct a significant part of the current, and the above relationship will no longer be applicable. Under these conditions

$$1/R_s = 1/R_c + 1/R_w \quad (3)$$

where  $R_c$  is the resistivity of the clay component, or

$$C_s = C_c + C_w \quad (4)$$

using conductivities.

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No simple correction can be made for clay resistivity or conductivity, however, because the total conductivity is a complex function of the geometry of the pore distribution and interaction of the electrolytes with the clay. For many sands and sandstones, the simple Archie relationship holds:

$$F = \frac{1}{\phi^2} \quad (5)$$

where  $\phi$  = porosity.

For clays, the exponent may vary from 2.5 to 5.4 (Atlan et al., 1968). However, these investigators also showed that the contribution by clay to rock resistivity can be quite well characterized by clay type and particularly base exchange capacity of the sediment. For example, the limiting conductivity for illites having a base exchange capacity of about 25 meq/100 g is on the order of 0.2 mho/m or 5 ohm/m resistivity for sediments permeated with saline solutions of seawater ionic strength or greater. This indicates that deriving diffusion coefficients for Leg 22 sediments from the electrical measurements will normally involve an error smaller than the scatter of values attributable to local variability in lithology and uncertainty due to temperature gradients. The actual error may sometimes exceed about 10%. In such instances, the apparent diffusion coefficients will be systematically higher than the true values.

Diffusion coefficients are sensitive to temperature. Because information on temperature gradients is not available, the diffusion coefficient cannot be corrected for in situ temperature. At the greatest depths, temperature may be significantly higher than 25° (perhaps reaching 35°) whereas at shallow depths, temperatures similar to those at the sea floor (1-2°) are anticipated. Such differences involve a change in diffusion coefficient on the order of a factor of 2½.

Preliminary experiments, using a two-electrode probe and a Beckman resistivity bridge to measure sediment and fluid resistivity, showed that polarization effects with stainless steel, copper, brass, and platinum electrodes rendered them useless for salinities above 0.1 N NaCl. Platinized platinum, commonly used for laboratory measurements, was regarded as unfeasible because of the delicacy of electrode surface and probable damage by abrasive sediments. However, 1/8-in. diameter spectrographic graphite electrodes, when pointed in a pencil sharpener, appear to yield acceptable results even with strong brines. This system was placed aboard *Glomar Challenger* for the special geochemical study on Leg 15. However, W. S. Broecker, who tested the system, reported that the graphite electrodes tended to break, and unexplainably large shifts in calibration resistivities occurred. Subsequently, a 4-electrode device was employed, which has proved much more successful and sturdy for the measurements made on Legs 22 and 23B.

## METHODS

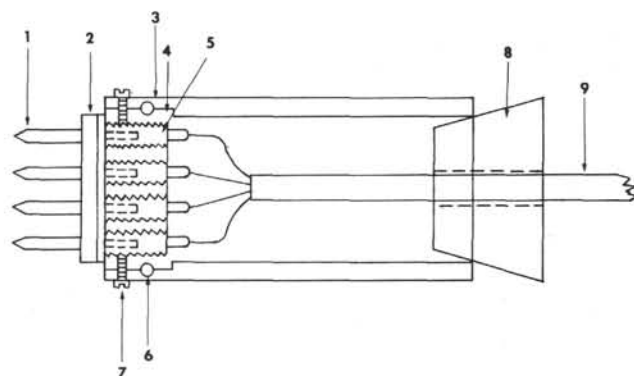
The construction of the probe and the 4-electrode test circuit are shown in Figures 1 and 2. The outer two electrodes supply the AC current (high frequency), whereas

the inner electrodes are used to measure the potential. With this system, polarization effects are minimized, since it is the relative potential drop between inner electrodes that determines the measured resistivity. Electrodes are inserted into a medium whose depth may be infinite with respect to investigative radius of the inner electrodes, or may be finite. In simplified form, the resistivity of an assumed semi-infinite medium is given by:

$$R = 2V/I \frac{(r_2 - r_1)}{r_2 r_1} \quad (6)$$

(Jakosky, 1950) where  $V$  is the potential difference,  $r_2$  and  $r_1$  are the respective distances of the inner electrodes from the power electrodes, and  $I$  is the current flowing between the power electrodes. The sediment medium is assumed to be isotropic. Thus, the specific resistance of any medium is directly proportional to the potential measured, if the current and spacing are held constant. The resistivities are measured on a Model EMT-C portable mud tester (Schlumberger Well Surveying Corp., Houston, Texas).

In principle, the electrodes' cell constant is first determined for the exact geometry of the container chosen to hold the sediment samples, using surface ocean water as reference fluid. Then the probe is inserted into the sediment and the resistivity measured. The resistivity of both the reference fluid and the interstitial water squeezed



1. Stainless steel pin, 3/32" (2.4 mm) diameter, inserted in push-in screw receptacle.
2. Polyvinyl chloride cover plate, 1/4" thickness, drilled to accommodate electrode pins.
3. Stainless steel housing.
4. PVC insert, holding (5).
5. Electrode contact receptacles, screwed into insert.
6. O-ring to prevent moisture from entering interior of housing.
7. Screws to grip PVC insert.
8. Rubber stopper bored and slit to accommodate electrical cable.
9. 4-conductor cable, soldered to electrode contacts.

Figure 1. Probe construction.

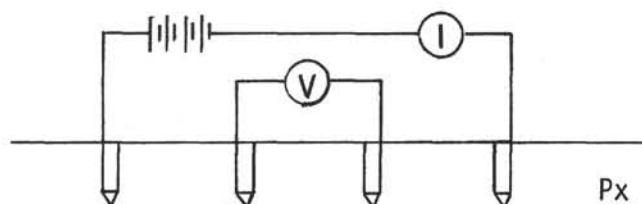


Figure 2. Electrode circuit.

from the same sediment (Waterman, 1970) are determined on a small, calibrated resistivity cell. Temperature corrections are applied to bring both sediment and interstitial water measurements to the same basis, and the formation factor is determined.

In practice the following steps are taken:

(1) Determine apparent resistivity of the sediment by inserting the probe into the end of a 10-cm mini-core cut from a standard 150-cm section of core. In cases where it is not possible to obtain a mini-core, e.g., core-catcher sample, the probe is inserted into a relatively flat surface on the sediment lump. The temperature is determined using a Weston stainless steel dial thermometer.

(2) Determine the resistivity of a volume of reference fluid which closely approximates the geometry and volume of the sediment. A container made from a length of plastic core liner is filled to the brim with the reference fluid and the electrodes submerged to the same depth as when inserted into the sediment. The probe is supported by a plate having a larger diameter than the top of the container. The temperature of the reference fluid is determined. A variety of small plastic cups is used to approximate the size and shape of sediment samples taken from the core catcher. A sufficiently large volume of surface ocean water is collected at the beginning of the leg so that the same reference fluid can be used throughout the cruise.

(3) Determine resistivity of the interstitial fluid using the small calibrated cell. The temperature of the pore water is determined with a glass laboratory thermometer attached to the cell. The salinity is determined from refractometer (index of refraction) measurements. About 1½ ml of pore fluid is necessary for the resistivity measurement.

(4) Determine resistivity of the reference fluid using the calibrated cell as described above.

(5) The probe assembly is partially disassembled for cleaning. The polyvinyl chloride plate is removed and the electrodes pulled out of their sockets. All pieces are washed with fresh water using tissues to rub off clinging sediment and salt accumulation, then rapidly dried with acetone dispensed from a wash bottle. The unit is reassembled.

(6) Calculations: The cell constant,  $k$ , is the true resistivity at  $t^\circ\text{C}$  for reference fluid (small cell) divided by the apparent resistivity in sample cup or configuration. Corrected resistivity of sediments is obtained by multiplying the apparent value (directly measured) by the cell constant. Temperature corrections are determined graphically (Figure 3). Find the apparent salinity corresponding to determined resistivity at the appropriate temperature. Move horizontally to the desired (interpolated) temperature. The new resistivity value will be found on the bottom scale directly below. Formation factor,  $F = R_s/R_{iw}$ , where  $R_s$  is the corrected sediment resistivity and  $R_{iw}$  is the resistivity of the interstitial water. Diffusion constants are obtained from Equation 1. Porosity is calculated from water content using the graph shown in Figure 4.

If the core is partly consolidated or lithified, preliminary holes are bored into the sediment using a 1/8-in. twist drill and a plastic template which serves both as a position and depth guide. Drills wear out and must be replaced often when drilling in hard sediment such as sandy carbonates. The apparent resistivity is determined as described above;

an additional measurement is made after checking the probe to firmly seat the electrodes. When there is doubt about adequate contact between the pins and the sediment, a few drops of ocean water may be placed in each of the holes. Precautions are taken when obtaining and storing mini-cores to minimize drying from exposure to the atmosphere before the resistivity measurements are carried out. The condition of the mini-core (e.g., state of consolidation, drilling slurry, obvious disruption of material by drilling, cracks resulting from the drilling of holes to insert the probes, etc.) is recorded when appropriate.

## RESULTS AND DISCUSSION

The data and calculations summarized in Tables 1 through 7 show that the lowest formation factors (1.6) occur in very porous diatom-radiolarian oozes near the surface of Site 215. Ordinary nannoplankton oozes and silts showed  $F$  factors of about 3 in the uppermost sections. The most marked increases in the  $F$  factor (decreases in diffusion coefficient) with depth occurred in nannofossil ooze-chalks at Site 217, where maximum  $F$  values of 13.6 were obtained. These values correspond to lithified limestones having a porosity of only 25% (water content of 11%). However, interspersed between the poorly permeable sediments are deposits showing lower  $F$  factors.

As indicated earlier, one can draw some conclusions about the nature of  $F$  factors and hence diffusive capacity of sediment from the proportion and kind of reactive clays or other minerals having appreciable ion exchange capacity. Conversely, from the porosity,  $F$  factor data, and the data of Atlan et al. (1968), the exchange capacity of the sediments can also be estimated in a rough way. Figure 5 is constructed from data relating exchange capacity of a series of clays including kaolinites, illites, and montmorillonites, with porosity and conductivity. Thus, for Site 215, the surficial diatom-radiolarian oozes are indicated to have an exchange capacity of somewhat more than 3 meq/100 g. On the other hand, between 68 and 76 meters an exchange capacity of between 30 and 40 meq/100 g is indicated, values which would be in agreement with the clayey-zeolitic nature of the sediments at that point.

The diffusion behavior of the sediments can be roughly interpreted if it is assumed that bottom waters are at  $2^\circ\text{C}$  and that room temperature conditions exist at depths of about 500 meters (temperature gradient of  $4^\circ\text{C}/100\text{ m}$ ). Then for chloride ion, a diffusion coefficient of  $3.4 \times 10^{-6}$  is obtained for surficial sediments at Site 214 and a value of  $2.9 \times 10^{-6}$  at 486 meters. The  $F$  factors increase from 2.9 to 6.3 for the two intervals, and the smaller change in calculated diffusion coefficient for free solution would be  $1.0$  and  $2.0 \times 10^5$  for temperatures of  $0^\circ\text{C}$  and  $25^\circ\text{C}$ , respectively.

Making the same assumptions for Site 217, formation factors of 2.5 and 13.6 at 7 and 547 meters depth, respectively, would yield diffusion coefficients of  $4 \times 10^{-6}$   $\text{cm}^2/\text{sec}$  and  $1.5 \times 10^{-6}$   $\text{cm}^2/\text{sec}$ . If temperature gradients were steeper, the diffusion coefficients at depth would be larger. On the other hand, we may reckon that some artificial increase in the apparent diffusion coefficient is caused not only by the presence of conductive clay, referred to earlier, but, by decompression of the sediments

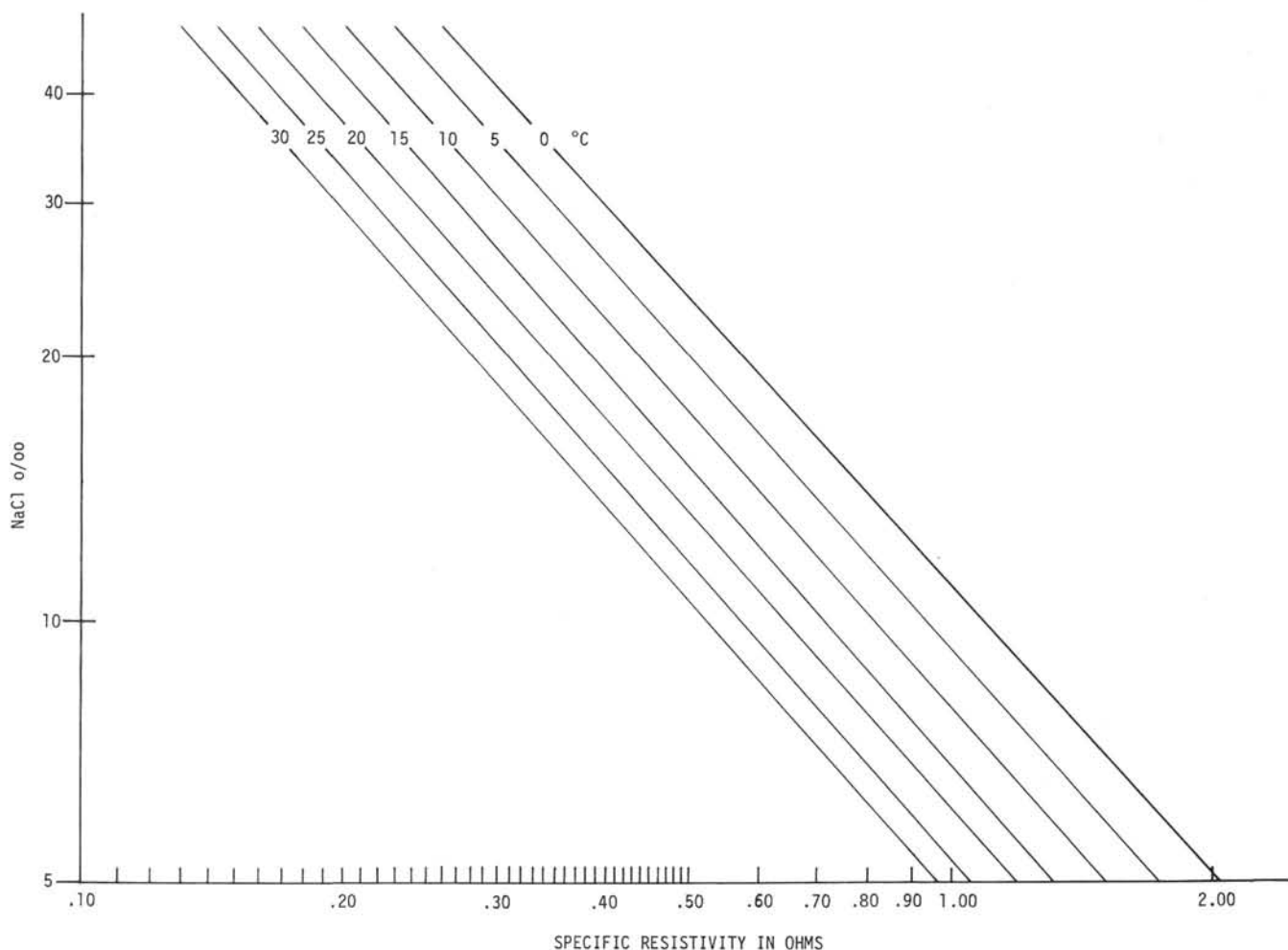


Figure 3. Graph for the determination of the temperature-corrected sediment resistivity.

when raising them to the surface. Nevertheless, the given values may be regarded as providing a first approximation to diffusion coefficients for dissolved species at depth in deep-sea sediments. The preceding discussion has referred only to the net diffusional velocity of free ions and molecules in the pore spaces of the sediments. Where reactive species are concerned, their reactions with host sediments introduce further complications.

#### ACKNOWLEDGMENTS

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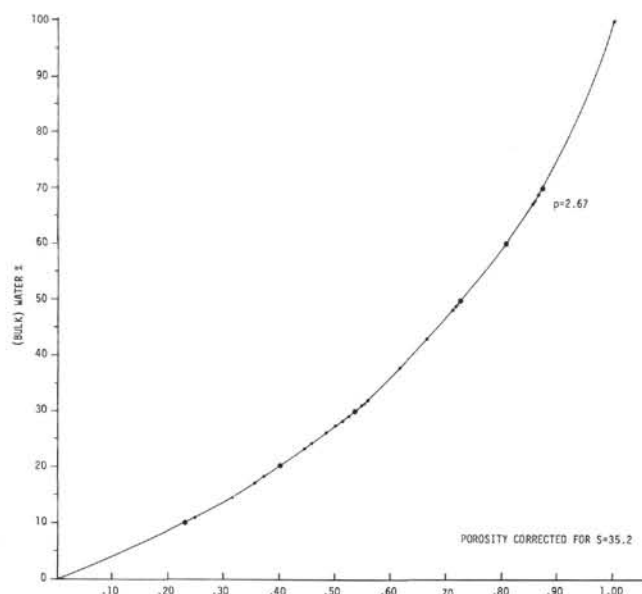


Figure 4. Water content versus porosity. The curve is drawn assuming the relationship

$$\phi(\text{porosity}) = \frac{W}{\frac{(100 - W_c) + W}{2.67}}$$

where  $W$  is water content,  $W_c$  is brine weight corrected for salinity of 35.2 ‰, obtained approximately by multiplying  $W$  by 1.03, and 2.67 is the assumed grain density of the sediments. For certain diatom- or radiolarian-rich samples, a separate calculation has been made, using the grain density of 2.4.

TABLE 1  
Resistivity Measurements, Site 212

Sample	Depth (m)	Water Content (%)	Porosity (%)	Corrected Pore Fluid (Cell)	Corrected Reference Fluid (Cell)	Reference Fluid (Cup)	Cell Constant	Corrected Sediment Resistivity	$F$
212-2-3	12	58.3	79	0.195 (23)	0.198 (24)	0.301 (24)	0.658	0.398	2.0
212-8-3	130	31.5	55	0.190 (24)	0.190 (25)	0.294 (25)	0.646	0.743	4.0
212-10-5	170	25.3	48	0.195 (24)	0.190 (25)	0.316 (25)	0.601	0.883	4.5
212-11-3	196	25.5	48	0.185 (24)	0.188 (25)	0.316 (25)	0.595	0.797	4.3
212-16-2	299	32.6	55	0.205 (22)	0.188 (26)	0.296 (26)	0.672	0.820	4.1
212-21-3	321	37.4	61.5	0.187 (24)	0.190 (25)	0.292 (25)	0.651	1.093	5.8
212-23-3	367	24.5	47	0.182 (25)	0.193 (25)	0.292 (25)	0.661	1.058	5.8
212-25-5	389	15.2	32.5	0.189 (25)	0.193 (25)	0.281 (25)	0.687	1.848	10
212-27-5	408	30.1	54	0.192 (25)	0.194 (25)	0.281 (25)	0.690	1.091	5.8 <sup>a</sup>
212-33-3	464	12.6	28	0.190 (25)	0.198 (25)	0.290 (25)	0.683	2.287	12.5
212-35-2	481	14.1	30	0.191 (25)	0.198 (25)	0.278 (25)	0.712	2.051	10.7

Note: (19° 11.3'S, 99° 17.8'E) water depth 6243 m; 521 m penetration. Values in parentheses refer to temperature of determination or correction basis. Cell refers to mini-cell. Cup refers to sediment container. All values except cell constant, are expressed in ohm-m.  $F$  refers to formation factor  $R_g/R_w$  (see text). Sediment consists of clayey nannoplankton ooze to 321 m, after which interlayered chalk and zeolitic clay occurred. Bottom two samples are chalk.

<sup>a</sup>The consistent trend observed at this site suggests that this value is erroneous, possibly resulting from drilling disturbance.

TABLE 2  
Resistivity Measurements, Site 213

Sample	Depth (m)	Water Content (%)	Porosity (%)	Corrected Pore Fluid (Cell)	Corrected Reference Fluid (Cell)	Reference Fluid (Cup)	Cell Constant	Corrected Sediment Resistivity	F
213-1-0	<1	70	87	0.202 (22)	0.187 (27)	0.266 (27)	0.703	0.328	1.6
213-2-5	15	68	86	0.199 (21)	0.186 (25)	0.282 (25)	0.660	0.342	1.7
213-3-5	24	70	87	0.225 (15)	0.190 (25)	0.279 (25)	0.681	0.424	1.9
213-5-5	44	62	80	0.223 (15)	0.190 (25)	0.287 (25)	0.662	0.455	2.05
213-7-5	62	69	84	0.245 (13)	0.193 (25)	0.281 (25)	0.687	0.418	1.7
213-9-6	83	63	83	0.270 (9)	0.190 (26)	0.280 (26)	0.679	0.664	2.5
213-11-5	100	54	76	0.272 (11)	0.196 (25)	0.283 (25)	0.693	0.783	2.9
213-13-6	121	54	76	0.247 (12)	0.192 (25)	0.283 (25)	0.678	0.685	2.8
213-15-6	140	31	54.5	0.240 (14)	0.193 (25)	0.283 (25)	0.682	0.709	2.9
213-16-4	146	29	52.5	0.193 (22)	0.193 (25)	0.282 (25)	0.684	0.612	3.2
213-1-0	<1	70	87	0.193 (24)	0.195 (25)	0.282 (25)	0.691	0.344	1.8 <sup>a</sup>
213-3-5	24	70	87	0.185 (24)	0.183 (27)	0.276 (27)	0.663	0.321	1.7 <sup>a</sup>
213-5-5	44	62	80	0.192 (22)	0.186 (26)	0.285 (26)	0.653	0.354	1.8 <sup>a</sup>

Note: (10° 12.5'S, 93° 53.8'E) water depth 5611 m; 172.5 m penetration. Notes as in Table 1. Sediments are clayey diatom ooze to 64 m, zeolitic clay to 121 m, and nannofossil ooze below 121 m.

<sup>a</sup>Measurements made on a contiguous mini-core.

TABLE 3  
Resistivity Measurements, Site 214

Sample	Depth (m)	Water Content (%)	Porosity (%)	Corrected Pore Fluid (Cell)	Corrected Reference Fluid (Cell)	Reference Fluid (Cup)	Cell Constant	Corrected Sediment Resistivity	F
214-1-5	6	44	68	0.201 (22)	0.187 (27)	0.276 (27)	0.678	0.575	2.9
214-3-5	25	47	70	0.209 (20)	0.196 (25)	0.284 (25)	0.690	0.569	2.7
214-5-6	44	43	66	0.226 (17)	0.196 (25)	0.283 (25)	0.693	0.627	2.8
214-7-5	63	44	68	0.221 (16)	0.197 (24)	0.286 (24)	0.689	0.608	2.7
214-9-5	82	48	71	0.214 (17)	0.192 (25)	0.286 (25)	0.671	0.524	2.5
214-11-5	101	42	66	0.233 (16)	0.199 (24)	0.289 (24)	0.689	0.592	2.5
214-15-3	136	43	66	0.202 (21)	0.197 (25)	0.285 (25)	0.692	0.530	2.6
214-19-5	178	37	61	0.216 (17)	0.195 (25)	0.284 (25)	0.687	0.566	2.6
214-23-5	216	32	56	0.256 (11)	0.192 (25)	0.275 (25)	0.698	0.705	2.8
214-27-5	254	24	47	0.250 (13)	0.196 (25)	0.275 (25)	0.713	0.927	3.7
214-31-5	292	—	—	0.208 (19)	0.195 (25)	0.275 (25)	0.709	0.709	3.4
214-35-5	330	—	—	0.204 (20)	0.197 (24)	0.277 (24)	0.711	0.740	3.7
214-36-4	338	31	55	0.199 (22)	0.199 (24)	0.283 (24)	0.703	1.027	5.1
214-37-2	344	32	56	0.210 (19)	0.199 (24)	0.285 (24)	0.698	0.838	4.0
214-41-3	384	25	48	0.210 (21)	0.188 (27)	0.268 (27)	0.701	1.403	6.7
214-46-3	424	36	60	0.254 (11)	0.186 (27)	0.262 (27)	0.710	2.250	8.9
214-52,CC	486	—	—	0.192 (21)	—	—	0.696	1.204	6.3

Note: (11° 20.2'S, 88° 43.1'E) water depth 1665 m; 500 m penetration. Notes as in Table 1. Sediments are foraminiferal ooze to 330 m, glauconitic calcarenite to 384 m, and clay pebble conglomerate to 486 m.

TABLE 4  
Resistivity Measurements, Site 215

Sample	Depth (m)	Water Content (%)	Porosity (%)	Corrected Pore Fluid (Cell)	Corrected Reference Fluid (Cell)	Reference Fluid (Cup)	Cell Constant	Corrected Sediment Resistivity	F
215-1-5	6	72	86	0.235 (13)	0.187 (26)	0.270 (26)	0.693	0.365	1.55
215-3-5	23	72	86	0.242 (13)	0.197 (25)	0.275 (25)	0.716	0.421	1.7
215-5-2	38	74	87.5	0.252 (12)	0.198 (25)	0.273 (25)	0.725	0.429	1.7
215-8-3	68	74	89.5	0.276 (9)	0.192 (26)	0.262 (26)	0.733	0.586	2.1
215-9-2	76	67	85	0.260 (11)	0.192 (26)	0.262 (26)	0.733	0.513	2.0
215-10-2	85	34	58	0.235 (14)	0.192 (26)	0.262 (26)	0.733	0.709	3.0
215-11-5	99	31	54.5	0.220 (17)	0.191 (26)	0.262 (26)	0.729	0.698	3.2
215-13-3	115	28	51	0.221 (17)	0.193 (26)	0.262 (26)	0.737	0.717	3.3
215-15-4	136	27	50	0.205 (20)	0.192 (26)	0.262 (26)	0.733	0.747	3.6 <sup>a</sup>
								0.953	4.7 <sup>b</sup>

Note: (8°07.3'S, 86°47.5'E) water depth 5319 m; 175 m penetration. Notes as in Table 1. Sediments are radiolarian-diatom ooze to 38 m, silty zeolitic clays occur at 68-76 m. Below that depth nannoplankton oozes prevail.

<sup>a</sup>"Soft" end of mini-core.

<sup>b</sup>"Firm" end of mini-core.

TABLE 5  
Resistivity Measurements, Site 216

Sample	Depth (m)	Water Content (%)	Porosity (%)	Corrected Pore Fluid (Cell)	Corrected Reference Fluid (Cell)	Reference Fluid (Cup)	Cell Constant	Corrected Sediment Resistivity	F
216-1-6	8	43	67	0.210 (20)	0.198 (25)	0.272 (25)	0.728	0.757	3.6
216-2-5	50	40	64	0.223 (17)	0.199 (24)	0.287 (24)	0.693	0.630	2.8
216-4-5	126	36	60	0.207 (20)	0.199 (24)	0.293 (24)	0.679	0.563	2.8
216-5-5	164	35	59	0.192 (23)	0.197 (25)	0.87 (25)	0.686	0.553	2.9
216-6-4	172	33	57	0.188 (24)	0.196 (25)	0.287 (25)	0.683	0.557	2.9
216-10-2	208	30	54	0.195 (22)	0.190 (26)	0.302 (26)	0.629	0.642	3.3
216-14-3	247	28	51	0.191 (22)	0.188 (26)	0.295 (26)	0.637	0.956	5.0

Note: (1°27.7'N, 90°12.5'E) water depth 2247 m; 477.5 m penetration. Notes as in Table 1. Sediments are foraminifera-bearing nannoplankton ooze and chalk.

TABLE 6  
Resistivity Measurements, Site 217

Sample	Depth (m)	Water Content (%)	Porosity (%)	Corrected Pore Fluid (Cell)	Corrected Reference Fluid (Cell)	Reference Fluid (Cup)	Cell Constant	Corrected Sediment Resistivity	F
217-1-6	7	49	72	0.198 (22)	0.202 (24)	0.304 (24)	0.664	0.503	2.5
217-2-2	42	43	66.5	0.215 (18)	0.201 (24)	0.286 (24)	0.703	0.649	3.0
217-3-2	72	42	65.5	0.230 (15)	0.199 (24)	0.284 (24)	0.701	0.676	2.9
217-4-4	120	38	62	0.218 (17)	0.196 (25)	0.280 (25)	0.700	0.728	3.3
217-6-5	188	31	54.5	0.227 (16)	0.201 (24)	0.287 (24)	0.700	0.798	3.5
217-8-5	274	27	50	0.238 (12)	0.208 (23)	0.293 (23)	0.710	1.207	5.0
217-9-6	314	26	49	0.192 (23)	0.200 (25)	0.283 (25)	0.707	1.611	8.3
217-10-4	348	24	46	0.185 (24)	0.191 (25)	0.283 (25)	0.675	1.458	7.9
217-12, CC	383	26	49	0.183 (24)	0.195 (25)	0.287 (25)	0.679	0.829	4.5
217-14-4	397	21	41	0.180 (24)	0.195 (25)	0.283 (25)	0.689	0.786	4.4
217-16-4	416	20	40	0.177 (24)	0.196 (25)	0.283 (25)	0.693	1.891	10.7
217-20-4	454	20	40	0.190 (22)	0.199 (24)	0.287 (24)	0.693	0.943	5.0
217-30-3	547	11	25	0.178 (25)	0.192 (25)	0.289 (25)	0.664	2.432	13.6

Notes: (8°55.6'N, 90°32.3'E) water depth 3020 m; 614.5 m penetration. Notes as in Table 1. Sediments are clay-rich nannofossil ooze to 120 m, a nanno ooze chalk to 348 m, foram-rich chalk and chert to 416 m, and Cretaceous micritic limestone to 547 m.

TABLE 7  
Resistivity Measurements, Site 218

Sample	Depth (m)	Water Content (%)	Porosity (%)	Corrected Pore Fluid (Cell)	Corrected Reference Fluid (Cell)	Reference Fluid (Cup)	Cell Constant	Corrected Sediment Resistivity	F
218-2-4	8	36	60	0.215 (18)	0.195 (24)	0.283 (24)	0.689	0.641	3.0
218-3-2	15	31	55	0.310 (14)	0.199 (24)	0.284 (24)	0.701	0.932	3.0
218-4-2	43	29	52.5	0.240 (14)	0.195 (24)	0.283 (24)	0.689	1.020	4.3
218-5-2	72	29	52.5	0.271 (10)	0.201 (24)	0.277 (24)	0.726	1.044	3.8
218-6-1	110	40	64	0.239 (15)	0.199 (24)	0.277 (24)	0.718	0.862	3.6
218-8-3	187	35	59	0.255 (13)	0.198 (24)	0.277 (24)	0.715	0.922	3.7
218-9,CC	232	23	44.5	0.233 (16)	0.199 (24)	0.277 (24)	0.718	1.351	5.8
218-11-2	300	32	56	0.198 (23)	0.198 (24)	0.281 (24)	0.705	0.631	3.2
218-13-2	376	25	47.5	0.206 (20)	0.199 (24)	0.279 (24)	0.713	1.377	6.8
218-14,CC	422	23	44.5	0.189 (23)	0.201 (24)	0.291 (24)	0.687	1.230	6.5
218-15-1	452	19	38	0.224 (18)	0.195 (24)	0.282 (24)	0.691	1.127	5.0
218-16-2	461	21	41	0.188 (23)	0.187 (25)	0.266 (25)	0.703	1.167	6.25
218-18,CC	488	21	41	0.189 (24)	0.190 (25)	0.266 (25)	0.714	1.407	7.5
218-21-3	538	18	37	0.192 (23)	0.192 (25)	0.266 (25)	0.722	1.061	5.5
218-22-2	575	23	44.5	0.192 (24)	0.191 (25)	0.266 (25)	0.718	0.991	5.2
218-23-2	613	21	41	0.187 (23)	0.190 (25)	0.269 (25)	0.706	1.300	6.8
218-24-2	651	19	38	0.211 (20)	0.194 (25)	0.283 (25)	0.686	1.638	7.9
218-25-2	689	25	47.5	0.221 (19)	0.198 (24)	0.286 (24)	0.692	1.073	4.8
218-26-2	727	17	35.5	0.226 (19)	0.199 (24)	0.267 (24)	0.745	1.878	8.3
218-27-2	765	20	40	0.289 (9)	0.194 (24)	0.281 (24)	0.690	1.360	6.0 <sup>a</sup>
								1.498	5.3 <sup>a</sup>

Note: (8°00.4'N, 86°17.0'E) water depth 3759 m; 773 m penetration. Notes as in Table 1. Sediments are sandy to clayey silts with interspersed nanno ooze.

<sup>a</sup>Two irregular shaped pieces were taken from this core.

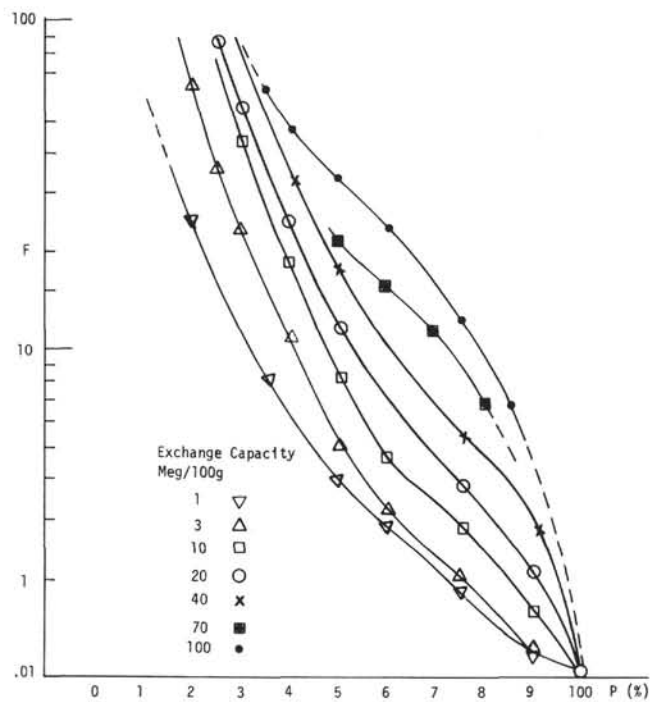


Figure 5. Relationships between formation factor, porosity, and exchange capacity for various sediments. Drawn from data in Atlan et al., 1968. Conductivity of the permeating solution (NaCl) is 15 mho/m.