gerina quinqueloba living in polar and subpolar regions have narrow constricted apertures that would not greatly enhance the porosity of their shells. Thus, the omission in my measurements of the open area contributed by apertures would further substantiate the observation that shell porosity can be related to the regional and climatic occurrences of the foraminiferal species.

Wiles (*5*) has demonstrated that variations in the pore concentrations of *Globigerina eggeri* Rhumbler [same as *Globoquadrina dutertrei* (d'Orbigny)] in Atlantic Ocean deep-sea cores can be correlated with Pleistocene climatic changes. His results show that high pore counts were associated with interglacial periods, when tropical-subtropical faunal assemblages prevailed. Low pore concentrations coincided with the glacial ages. Since Wiles did not measure pore diameters, variations in shell porosity of this species could not be determined. If it is assumed that the pore diameters of *G. eggeri* remained relatively constant throughout the core sequences studied by Wiles, then the low pore counts during glacial ages would reduce its shell porosity. Conversely, high pore counts during interglacial times would yield a more porous shell. If this assumption is correct my results would agree with those of Wiles and may perhaps help to explain the climatic influence upon variations in pore concentrations of *G. eggeri.*

The function of the pores in planktonic Foraminifera is little known. They serve as an outlet of the pseudopodia, and it has been suggested (*7*) that they play a role in buoyancy. I propose that the degree of porosity might also be influenced by the availability of light or heat. Planktonic Foraminifera spend their juvenile stages in the upper part of the euphotic zone when their small shells have relatively low porosity. As most species mature below the euphotic zone, the size increase of their shells is accompanied generally by a corresponding increase in shell porosity. Perhaps the lower light intensities at these depths necessitate a more porous shell structure. Calcification in later stages, however, is known to reduce shell porosity to a considerable extent (*2*).

Shell porosities of planktonic foraminiferal species can therefore become useful indices for charting climatic fluctuations during the geological past, as based on the findings that tropical and subtropical species build high-porosity shells and polar and subpolar species construct low-porosity shells.

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Activity Coefficients of Aqueous Sodium Chloride from 15° to 50°C Measured with a Glass Electrode

Abstract. *Values of the mean activity coefficient of sodium chloride at 15°, 25°, 38° and 50°C were determined for aqueous NaCl solutions of 0.01 to 1.0 molal from electromotive force measurements on the cell: (sodium-sensitive glass electrode, aqueous sodium chloride, silver chloride-silver).*

Mean activity coefficients of aqueous sodium chloride ($\gamma_{\pm\mathrm{NaCl}}$) have been determined by means of sodium-amalgam electromotive force (EMF) cells from 0° to 40°C (*1*); by means of concentration cells at 25°C (*2*), from 15° to 45°C (*3*), and from 0° to 50°C (*4*); by boiling-point depression from 60° to 100°C (*5*); and from freezing point data at 25°C (*6*). Most of the values obtained by these methods agree. The relatively new sodium-sensitive glass electrode (*7*) has been used by Lanier to determine the activity coefficient of sodium chloride at 25°C in partially aqueous solutions (*8*) and in concentrated three-component aqueous solutions (*9*). Measurements of $\gamma_{\pm\mathrm{NaCl}}$ in concentrated (1 to 5 molal) NaCl solutions at 0°, 25°, and 50°C have also been reported by Eisenman (*10*). I now report precise measurements of $\gamma_{\pm\mathrm{NaCl}}$ from 15° to 50°C in concentrations from 0.01 to 1.0 molal. The purpose of my investigation was to demonstrate the accuracy of the experimental arrangements in the determination of $\gamma_{\pm\mathrm{NaCl}}$ preliminary to studies of sodium-ion complexes with the same arrangements. The values of $\gamma_{\pm\mathrm{NaCl}}$ at 50°C may be a useful supplement to values obtained in earlier studies.

The cell employed may be represented

$$\mathrm{Na^{+}\text{-sensitive glass}}|\mathrm{NaCl}(m)|\mathrm{AgCl\text{-}Ag} \qquad \mathbf{(I)}$$

The glass electrode was made by the Corning Glass Company from a glass having the following composition (mole percent): Na_2O, 11; Al_2O_3, 18; and SiO_2, 71. This composition was recommended by Eisenman (*10*) for stability and high Na^+ selectivity relative to K^+ and H^+.

Although potassium-ion interference was not a problem in these experiments, the sensitivity of these electrodes to hydrogen ions limits their range of usefulness in dilute solutions. The hydrogen-ion sensitivity of the sodium-sensitive glass electrode that was used in these experiments is relatively low. The EMF of the Corning electrode in 0.1 molal NaCl is unaffected by hydrogen ion for *p*H values greater than 4.5 and the effect at *p*H 4 is only 1.2 mv. The hydrogen-ion effect on other sodium-sensitive glass electrodes is 2 to 20 times greater (*11*).

The AgCl-Ag electrodes were of the thermal-electrolytic type (*12*). Several electrodes were prepared simultaneously, and those with bias potentials greater than 0.03 mv were rejected. These electrodes proved satisfactorily stable in dilute NaCl solutions and, provided the solution was already saturated with AgCl, in concentrated solutions as well.

The reagent grade NaCl used was dried but was not otherwise purified, because the electrodes are unaffected by the small amounts (< 0.005 percent) of impurities present. The cell was filled with a weighed amount of water, freshly demineralized by passage through a mixed-bed ion exchanger. The *p*H of this water was > 6, and access of air to the cell was minimized to avoid lowering of *p*H through CO_2 absorption. Weighed amounts of NaCl were added and the molality was increased from 0.01 to 1.0 by small increments. This procedure minimizes exposure of the glass electrode to thermal and chemical shocks.

The potential of the cell was measured with a high-impedance electrometer (Keithley 601) and a potentiometer (Leeds and Northrup 7552). The glass electrode was disconnected from the circuit while the electrometer was zeroed to avoid polarization of the electrode by the relatively low resistance (10^7 ohms) of the zero circuit of the electrometer. At 25°C or higher, stable potentials were achieved rapidly. The EMF was usually within 0.1 mv of the final value 2 to 5 minutes after the concentration was changed, and all readings were stable to ±0.02 mv for 10 to 20 minutes before the next change of concentration. The average time taken to obtain a stable reading was less than 10 minutes. At 15°C the time for stability was approximately quadrupled.

The cell was stirred magnetically and was then surrounded by a jacket through which water from a temperature-controlled bath was pumped. The temperature regulation was to ±0.05°C in the cell.

The thermodynamic behavior of sodium-sensitive glass electrodes and of AgCl-Ag electrodes has been discussed (*10, 12*), and it can be shown that the electrode equation of cell shown in **I** is

$$E = C + S \log (\gamma^2_{\pm\mathrm{NaCl}}\, m^2_{\mathrm{NaCl}}) \qquad (1)$$

where C is a constant depending on the internal solution and construction of the glass electrode, S is the Nernst slope 2.303 RT/F (F is the faraday constant). With some types of glass electrode the value of C changes with time, and special methods of measurement and calculation have been devised to overcome this difficulty (*13*). Fortunately, for the electrode used in this experiment, C was found to be truly constant. This was indicated both by the stability in a single solution mentioned above and by the good agreement of derived $\gamma_\pm$ with values described in other reports.

The electrode equations (Eq. 2) for two measurements of NaCl solutions of molalities m_1 and m_2 and mean activity coefficients γ_1 and γ_2 may be subtracted to eliminate C, and the value of γ_2 may be determined from E_1, E_2, m_1, m_2, and γ_1:

$$\log \gamma_2 = \log \gamma_1 + \log (m_1/m_2) + (E_2 - E_1)/(2S) \qquad (2)$$

The only remaining problem is the choice of a standard solution (m_1) with a known activity coefficient (γ_1). The equation of Davies (*14*) for a uniunivalent electrolyte,

$$-\log \gamma_\pm = A \left(\frac{m^{1/2}}{1 + m^{1/2}} - 0.2m \right) \qquad (3)$$

in which A is a temperature-dependent constant, was used to determine $\gamma_\pm$ of a 0.01 molal NaCl solution. This value at 25°C is 0.9027, which is equal to the mean of all reported values of $\gamma_{\pm\mathrm{NaCl}}$ at this molality.

In practice, a graph of E plotted against log m (molality) over the range 0.005 to 0.05 molal was made, the best (least squares) line was drawn, and the value of E corresponding to $m = 0.01$ was determined. Values of $\gamma_{.01}$, A, and S at various temperatures are given in Table 1 (*15*).

Experimental values of $\gamma_{\pm\mathrm{NaCl}}$ obtained from Eq. 2 with $\gamma_1 = \gamma_{.01}$ are compared in Table 1 with values from the literature. Agreement with literature values is very good for solutions more dilute than 0.5 molal. Small positive deviations occur at higher molalities.

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Table 1. Comparison of $\gamma_{\pm\mathrm{NaCl}}$ values determined in this study (*18*) with values from the literature and constants used in Eqs. 1–3.

Ref.	Molality of NaCl								
	0.01	0.02	0.05	0.10	0.20	0.30	0.50	0.70	1.00
				Temperature, 15°C					
18	(0.904_3)	0.875_0	0.824_5	0.781_0	0.734_5	0.709_5	0.680_5	0.664_5	0.650_0
1			0.823	0.782	0.735		0.680		0.654
3	0.904_5	0.874_0	0.824_5	0.780_5					
*4**	0.902_5		0.823	0.774_5	0.729		0.674		0.647
				Temperature, 25°C					
18	(0.902_7)	0.872_0	0.822_0	0.778_0	0.733_0	0.709_0	0.683_5	0.672_5	0.664_0
1			0.821	0.779	0.733		0.681		0.658
2	0.902_2	0.870_7	0.819_2	0.774_4					
*3**	0.903_0	0.872_0	0.822_5	0.778_0					
4	0.901		0.823	0.774	0.729		0.676		0.653
6				0.784	0.740	0.715	0.687	0.672	0.663
16				0.778_5	0.735	0.710	0.681	0.667	0.657
17	0.903_2	0.872_4	0.821_5	0.778_4	0.734	0.710	0.682	0.668	0.658
				Temperature, 38°C					
18	(0.900_5)	0.870_5	0.819_5	0.774_5	0.726_5	0.702_5	0.676_5	0.664_0	0.652_0
1			0.817_5	0.774	0.728		0.676		0.655_5
*3**	0.901_0	0.870_0	0.819_0	0.775_0					
*4**	0.898_5		0.821	0.771_5	0.725_5		0.672_5		0.652_5
				Temperature, 50°C					
18	(0.898_3)	0.866_0	0.816_0	0.770_0	0.726_0	0.702_0	0.677_0	0.668_0	0.661_5
3†	0.898_5	0.866_5	0.815_0	0.770_0					
4	0.896		0.820	0.768	0.721		0.668		0.649
*5, 1**				0.771	0.727		0.675		0.658

Constants

T (°C)	S (mv)	A	$\gamma_{.01}$
15	57.17	0.492	0.904_3
25	59.16	.500	$.902_7$
38	61.74	.512	$.900_5$
50	64.12	.524	$.898_3$

* Interpolated. † Extrapolated.

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Fissure Basalts and Ocean-Floor Spreading on the East Pacific Rise

Abstract. *A basalt pavement outcrops almost continuously in a band along the crestal region of the East Pacific Rise from about 14°S to 6°S, that is, for more than 800 kilometers; the outcrop may well extend beyond the above limits along the axis of the rise. The basalt band is generally between 40 and 60 kilometers wide and is replaced laterally by sediment. The lavas are fresh, "oceanic tholeiites" which were emplaced less than 1 million years ago by fissure eruptions. These findings can be explained by the hypothesis of ocean-floor spreading; the basalts are the expression of material originating from the mantle and rising through fissures along the axis of the ridge. The absence of an axial rift valley on the East Pacific Rise may be explained by the fact that large volumes of lava are being outpoured along its crest.*

According to the hypothesis of ocean-floor spreading (*1*), formation of new crust due to injection of material from the mantle takes place along the axis of active oceanic ridges. In this connection it may be of interest to report some findings obtained on the East Pacific Rise by the R.V. *Pillsbury* of the University of Miami's Institute of Marine Sciences during cruise P6702 (March–April 1967).

The field work, which included bathymetric and magnetic surveys, deep-sea photography, sediment coring, and hard-rock dredging, was concentrated in the crestal region of the East Pacific Rise, between 14°S and 6°S. In the course of the surveys it was found that hard rock with no sediment cover invariably outcrops on the crest of the rise. The areal extension of such outcrops was determined with the aid of an echosounding system including a 12 kc precision depth recorder. The type of sound record obtained with this instrument depends on the nature of the material outcropping at the bottom (*2*); there was usually no difficulty in distinguishing reflections returned by soft pelagic sediments from those given back by hard, dense rocks (such as basalts), owing to the wide difference in acoustic impedance and scattering between the two materials. Information derived from the recorder was checked and complemented by direct sampling and photos of the sea floor.

It was thus established that the area where the hard rock outcrops is in the shape of a relatively narrow but apparently continuous band along the crestal zone of the rise (Fig. 1). The width of the band as measured in various transects across the crest of the rise is generally between 40 and 60 km; in one case it reached about 80 km. The bathymetry in some of the transects is shown in Fig. 2. The band appears to be continuous for at least 800 km along the ridge axis; it probably extends on the axis beyond the limits of the areas we surveyed.

The only hint that a break in the continuity of the band may exist was obtained at a latitude of about 9°S. Here the outcrop may be displaced laterally by about 30 km; alternatively, it is possible that two parallel bands are present at this latitude. More field work is needed to clarify this. The topography along the length of the lava band is remarkably constant in the portion of the rise we explored: gently rolling hills prevail at a depth varying between narrow limits (generally from 2600 to 3000 m below sea level).

The lateral contact between the hard rock and the sediment is not sharp: photographs show patches of sediment appearing more and more frequently toward the edges of the hard-rock band, until the sediment cover becomes continuous.

Samples of the rock were obtained by dredging at several sites along the outcrop (Fig. 1). They all consist of fragments and boulders of basalt which on visual observation appeared to be quite fresh. The original surface of the flows is marked by a crust of dark fresh glass; the thickness of such crust varies from a couple of millimeters to more than 1 cm. Below the glass crust, the rock is at least partially crystalline. The glassy crust of the flows must have been formed by the instant chilling of the melt upon effusion into seawater; as such, the crust acted as an insulator below which the basalt could be maintained warm and could flow on the ocean floor. This type of "quiet" deep-sea effusion contrasts with the volcanism which gives rise to seamounts, where evidence is commonly found of thermal shattering of the basalt due to extensive lava-water interaction during the eruption (*3*).

Some of the dredge hauls contain platy boulders which are limited by two parallel glass surfaces, which shows that the thickness of some of the individual flows can be as small as 5 cm. This, and the scarcity of first-generation phenocrysts, suggest that the lavas were very fluid when they were erupted. Deep-sea photos indicate that "pillow" structures are present occasionally (Fig. 3).

Microscopic examination indicates that the samples contain plagioclases ranging in composition from 65 percent An (labradorite) to 80 percent An (bytownite); clinopyroxenes, scarce olivine, titanomagnetite, and glass. First-generation phenocrysts are extremely scarce or absent. The basalts from the various stations have similar chemical composition. The results of a representative analysis of a moisture-free sample (P6702-39) are as follows (*4*): SiO_2, 49.57 percent; Al_2O_3, 15.44 percent; Fe_2O_3, 1.75 percent; FeO, 8.01 percent; CaO, 11.49 per-