sounds by the shape. When we looked directly at the picture tube it was clear that some sounds were distinctive, but in order to prove this, photographs that could be studied were needed. Figure 2 shows that certain of the sounds are easy to recognize, but certainly not all. The consonants *th, v, z, m,* and *n* all show a difference from subject to subject. When we compared the photographs with a new attempt at production of the figures on the calligraphone, we found that there was a real difference among subjects in pronunciation of the sounds *m* and *n*, and the subject could control this by controlling the amount of nasal quality. In the case of *th, v,* and *z* the change could be explained away by the presence of braces or absence of teeth. These make a real difference in enunciation. At any rate the differences among our subjects are no greater than the differences in their handwriting. Note that the differences in pitch do not show up strongly when presented on the calligraphone.

Thus it has been shown that the patterns formed by the calligraphone form a natural phonetic alphabet with which one can capture nuances of pronunciation. In contrast to the more conventional sound spectrograph, which plots amplitude of the frequency components versus time, the calligraphone maintains phase information as well as amplitude information, though losing the time duration of the sounds.

The potential use which we find most exciting is the possibility that the calligraphone can be of help in the teaching of children with impaired hearing. It would enable the teacher to present to the deaf child a graphical illustration of the inadequacies of the child's enunciation. It has the particular virtue of low inherent cost, since all the unusual parts can be purchased for less than $60 (including the oscilloscope kit) and a clever teen-ager can assemble them in a couple of evenings.

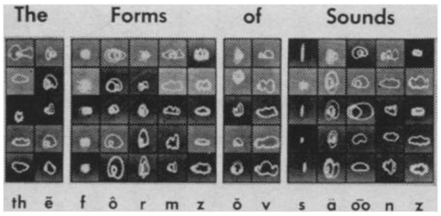

Fig. 2. Oscilloscope pictures of the sounds of the phrase printed at the top and repeated in phonetic symbols at the bottom (*3*). Top row, speech of adult male; second row, adult female; third row, 11-year-old male; fourth row, 9-year-old female; fifth row, 8-year-old male. (Picture of the *d* sound was omitted, because that sound is not maintained.)

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References and Notes

1. This experiment was submitted with a different text by one of us (S.H.B.) to the 1963 Alamo Science Fair.
2. J. F. Rider and S. D. Uslan, *Encyclopedia of Cathode Ray Oscilloscopes and Their Uses* (Rider, New York, 1959), in particular, chap. 4.
3. *Webster's New Collegiate Dictionary* (Merriam, Springfield, Mass., 1961), p. vii.

8 October 1963

Carbonate Rocks: Cleaning with Suspensions of Hydrogen-Ion Exchange Resin

Abstract. *The surface of carbonate rocks may be cleaned by etching or polishing or both, with hydrogen-ion exchange resin. This treatment reveals details in texture and fossil morphology so clearly that thin sections may be often dispensed with. Of four cleaning methods, (i) allowing resin to settle around the sample, (ii) stirring with a magnetic stirrer, (iii) agitating with an ultrasonic generator, and (iv) directing a jet stream at the sample, the first method was best for large specimens and the second method was best for well cuttings and chips.*

A method of cleaning calcareous fossils by means of ion-exchange resin has been described by Groth (*1*). He circulated a suspension of "colloidal" Dowex-50 cation exchange resin in the Na^+ form over the macrofossils to be cleaned. By a similar technique we have used commercial 200 to 400 mesh resin in the H^+ form to study carbonate rocks. The differential solution and polishing resulting from agitation of the suspension reveals the morphology of calcareous fossils and emphasizes the texture of the rock. These features are normally observed in the sample after thin sectioning, polishing, or acid etching.

The resin suspension can be used on chips, well cuttings, or on sawed or polished surfaces. Contact of the resin suspension is accomplished (i) by allowing the resin to settle around the sample in water, (ii) by stirring with a magnetic stirrer, (iii) by agitating with an ultrasonic generator, or (iv) by using a jet stream directed at the sample. The etching and polishing produced is controlled mainly by the time of treatment and the amount of agitation.

Samples having varying textures, fossil contents, and degrees of lithification were used in comparing these four techniques. Allowing the sample to rest undisturbed up to 24 hours in a bed of resin appears to be the best treatment for large specimens. The surface of the specimen is deeply etched with little polishing. A few pits may develop as a result of the resin beads remaining in one place. Stirring well cuttings or rock chips in the resin suspension for 10 minutes to several hours with a magnetic stirrer appears to be the best treatment for them. The surfaces are highly polished and greatly aid in the identification of microfossils. Agitating samples with an ultrasonic generator for 5 minutes to 2 hours results in some pitting and moderate polishing. Directing a jet of the resin suspension at a specimen is very unsatisfactory because the resin suspension acts slowly and many pits develop. Use of any one of the above methods depends upon the particular specimen being studied and upon the effect desired (etching or polishing).

The advantages of the method result from the chemical action which is limited to the rock surface, and the mechanical action of the beads on the rock surface when the suspension is agitated. The relief that is produced greatly aids in identifying fossils and seeing relationships between grains. Rough surfaces, such as those of cuttings, can be etched and the complete surface may be viewed. In many cases this eliminates the need for thin sections. Samples may be sawed in thin slices, etched, and the etched surfaces viewed. This minimizes the sampling problem and allows better selection of samples for thin sections, if desirable.

The main advantages over etching with acid alone are nonpenetration of H^+-ions into fractures and joints of the sample, smoother surfaces produced by H^+-resin, and convenience of control and handling of the resin. The used resin may be regenerated by treatment with acid, either in batches or in columns, and washing.

The main limitation is that the resolution is of the order of the size of the resin beads. This is related to the artifacts (pitting, irregularities) which may be produced in some of the agitation methods.

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Reference

1. A. Groth, Stockholm Contrib. in Geology **1**, No. 2, 31–34 (1957).

23 August 1963

Fresh Water: Temperature of Maximum Density Calculated from Compressibility

Abstract. *Measurement of sonic velocities in water provides an accurate method for determining the equation of state for water. A simple equation of state for fresh water yields the temperature of maximum density as a function of pressure.*

Fresh water at atmospheric pressure is most dense at about 4°C. The temperature of maximum density decreases with increasing pressure. Wright (*1*) first pointed out that some observed decreases in temperature with increasing depth in deep lakes are associated with this property, and are not due to faulty measurement as may have been thought.

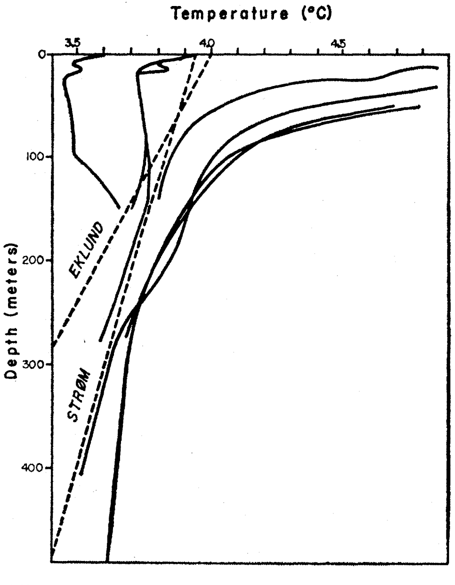

Fig. 1. Selected temperature profiles in deep lakes, and proposed lines of maximum density. [Adapted from Strøm]

Many investigators have tried by direct measurement to determine the effect of pressure on the temperature of maximum density. Dorsey (*2*, p. 276) reviewed their work and concluded that Lussana's result, a decrease of 0.0225°C per atmosphere, "probably is as good as we can do."

Reliable data for the compressibility of water have been made available in recent years by the measurement of sonic velocities. By applying compressibility data to the specific volume of water at atmospheric pressure, I have obtained a simple equation of state which is valid near the temperature of maximum density. By differentiating the equation of state with respect to temperature, I have computed the decrease of the temperature of maximum density with increasing pressure to be 0.021°C/bar (10^6 dyne/cm^2).

The adiabatic compressibility β_s is defined as

$$\beta_s = -\frac{1}{v}\left(\frac{\partial v}{\partial p}\right)_s$$

Similarly, the isothermal compressibility β_T is defined as

$$\beta_T = -\frac{1}{v}\left(\frac{\partial v}{\partial p}\right)_T$$

In these expressions, v is specific volume, p is pressure, T is temperature, and S is entropy.

I have calculated the adiabatic compressibility at 4° and 3°C with the data of Greenspan and Tschiegg (*3*) and the equation

$$\beta_s = \frac{v}{u^2}$$

where u is the velocity of sound, and the isothermal compressibility by using the equation

$$\beta_T = \beta_s + \frac{T}{v\,Cp}\left(\frac{\partial v}{\partial T}\right)_p^2$$

where Cp is the heat capacity at constant pressure. The computations are summarized in Table 1. A straight line connecting these points has the equation:

$$\beta_T = a + b\,\theta$$

where

$$a = 49.458 \times 10^{-6}/\text{bar}$$
$$b = 0.327 \times 10^{-6}/\text{bar, °C}$$

and θ is a temperature scale

$$\theta = (4.00 - T)\ \text{°C}$$

defined to simplify subsequent equations. The effect of the pressure on specific volume is therefore given by

$$v = v_0\,(1 - \beta_T\,p)$$

or

$$v = v_0\,[1 - (a + b\,\theta)\,p]$$

where p is to be considered "gauge" or "lake" pressure, and $v_0 = 1.000027$ cm^3/g at 4°C and atmospheric pressure.

Table 1. Summary of computations of compressibility at 4°C and 3°C.

Measure	$T = 4$°C	$T = 3$°C
u (cm/sec)	142,196	141,732
v (cm^3/g)	1.000027	1.000035
β_s (bar^{-1})	49.458×10^{-6}	49.783×10^{-6}
β_T (bar^{-1})	49.458×10^{-6}	49.785×10^{-6}

The specific volumes at atmospheric pressure between 4° and 3°C, as recorded by Dorsey (*2*, p. 204), fit the equation

$$v = v_0\,(1 + c\,\theta^2)$$

where $c = 7.8 \times 10^{-6}/(\text{°C})^2$.

The foregoing effects of pressure and temperature on the specific volume of water can be combined to give an equation of state near the temperature of maximum density

$$v = v_0\,[1 - p\,(a + b\,\theta) + c\,\theta^2]$$

This approximate equation of state is the simplest equation which satisfies, to the lowest relevant order, the following conditions known from experiment: (i) in the neighborhood of $\theta = 0$, v is quadratic in θ; (ii) u is known experimentally to be linear in θ if $\Delta\ \theta$ is small, and computations show that β_T can also be considered linear if $\Delta\ \theta$ is small; and (iii) u, and therefore β_T, changes only slightly over moderate pressure ranges.

At an arbitrary pressure p, the specific volume will be minimum when $\partial v/\partial\theta = 0$. By performing this differentiation, we get an expression for the temperature of maximum density as a function of pressure

$$\theta = \frac{b}{2c}\,p \qquad \text{°C}$$

The slope of this line, $b/2c$, has the value 0.021°C/bar. This result agrees well with the value determined by Lussana.

Strøm (*4*), after careful review of recorded temperatures in deep lakes, noted that a line could be drawn which would lie between summer and winter temperature profiles and would not in-