

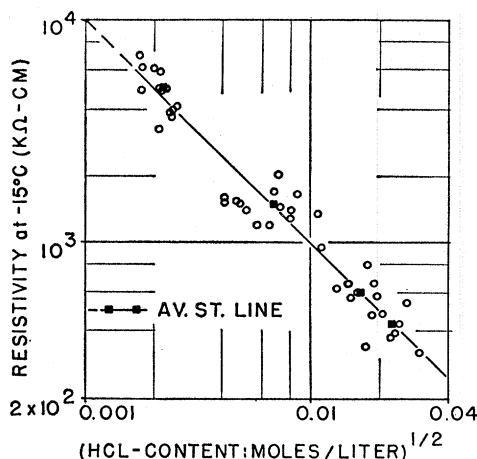


Fig. 1. Resistivities at -15°C plotted against the square roots of the concentrations for 43 ice samples doped with hydrochloric acid. The four points of the average straight line were computed by averaging melt concentrations and resistivities for each subgroup of samples prepared from the following four mother solutions: 0.01N, 0.005N, 0.001N, and 0.0001N.

or 41, on one side of which has been condensed an electrically coherent layer of finely divided palladium under vacuum, at pressure of about 10^{-3} mm-Hg. These disks, prior to use, are saturated in a solution of dilute hydrofluoric acid (at strength of about 100 to 1000 times the effective concentration of ionic impurities in the ice). Hydrofluoric acid is most suitable because it enters the ice structure easily and apparently does not stimulate anodic oxidation as actively as other acids do. A connection with the current circuit is provided by a circular electrode of spectrographic carbon, platinum, or palladium pressed against each palladium-coated disk. Care is taken to prevent an ice film from forming at this interface. An alternative method consists of growing ice samples on a clean palladium or platinum surface and using this undisturbed surface as the cathode, the anode being prepared in the manner described.

The potential electrodes are cross hairs made of 0.0126-inch or 0.02-inch platinum or palladium wire suspended in a circular Teflon frame and frozen into the sample during its preparation. Separation of these wires is 2.5 mm. The sample is thus divided into three sections of known thickness. The drop in potential across each section is measured by means of a Keithley electrometer, model 610. A comparison of these drops in potential suggests that the field-disturbing effect of the potential

electrodes may be neglected in the calculation of resistivities.

Samples were grown in a thin Teflon sleeve press-fitted onto a platinum or palladium disk about 5 mm thick. The solution to be frozen was degassed under vacuum (with a water aspirator). The cup was filled and frozen onto a refrigerated copper block. Average sample-growth velocity was about 1 mm/min. The freezing solution was hand-stirred with a Teflon rod. When the sample had reached the desired thickness the supernatant liquid was pipetted off and the free sample surface was rinsed with cold conductivity water. At once the palladium-coated paper disk and the upper current electrode were affixed, and the latter was weighted down with a weight of a few hundred grams until it was well frozen in. About 3 cm³ of cold conductivity water were then added and frozen. The sample could then be taken out *in toto* and its lower surface could be frozen onto a similar electrode assemblage. After preparation, the samples were stored with shunted current electrodes at -15°C for at least 12 hours before measurements were made.

Currents in the range between 0.01 and 2 ma were obtained from batteries (floating circuit) or from an electronic power supply. Currents of several magnitudes were applied to a given sample, the magnitudes depending on the sample's resistivity; this, at -15°C , varies between 10^{10} ohm-cm for "pure" ice and a few hundred thousand ohm-cm for the most highly doped samples studied. If prepared properly, these electrodes showed a perfectly ohmic behavior and, equally important, insured a uniform potential gradient within the sample. Measurement procedures were carried out during as many as 3 hours before appreciable polarization occurred at the current electrodes. Reversal of polarity afforded an additional check on the reliability of results.

Current measurements were accurate to within 1 to 10 percent; those of potential drops to within about $\frac{1}{2}$ percent. Results from a series of measurements on a given sample with currents of the same magnitude or of different magnitudes (on the same day or on different days) placed the reproducibility roughly in a range between an average of ± 3.5 percent for samples of resistivity of 3×10^6 to 6×10^6 ohm-cm and an average of ± 10 percent for samples of resistivity of 3×10^5 to 6×10^5 ohm-cm.

The effective acid content of doped samples was determined by means of pH and conductivity measurements on the melt. The scatter shown in Fig. 1 is probably caused by two main factors: slight variations in the impurity-concentration gradient in different samples and the difficulty of avoiding some contamination of the melted sample prior to determination of its impurity content.

Measurements have been made at temperatures between -10° and -86°C in the experiments thus far completed.

The results indicate that the direct-current conductivity of ice at constant temperature is directly proportional to the square root of the acid concentration of the melted sample, as required by the mass-action law if conduction is due primarily to protons (see the "average straight line" of Fig. 1). Furthermore, the conductivity appears to be independent of the anion to a first approximation (5).

Note added in proof. After this report went to press, I learned of two papers (6) that describe such a series of experiments, carried out by a somewhat different method, for ice samples doped with several acids, bases, and salts. In particular, their results for HCl-doped ice agree well with those shown in Fig. 1.

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References and Notes

1. M. Gourley, unpublished laboratory reports (1956).
2. H. Gränicher *et al.*, *Discussions Faraday Soc.* **23**, 53 (1957).
3. C. Jaccard, *Helv. Phys. Acta* **32**, 89 (1959).
4. A. Steinemann, *ibid.* **30**, 584 (1957).
5. The research discussed in this report is being carried out under Office of Naval Research contract No. Nonr 815 (01).
6. J. V. Iribarne *et al.*, *J. Chim. Phys.* **58**, 208 (1961); L. Levi and L. Lubart, *ibid.*, p. 863, 2 August 1962.

Natural Occurrence of Amino Acids in Virgin Crocidolite Asbestos and Banded Ironstone

The detection of fluorescent oils containing polycyclic aromatic hydrocarbons and amino acids in crocidolite and amosite asbestos but not in chrysotile has been reported by Harington (1). The present report provides further details about the amino acids found in natural association with virgin crocidolite asbestos taken from the North-

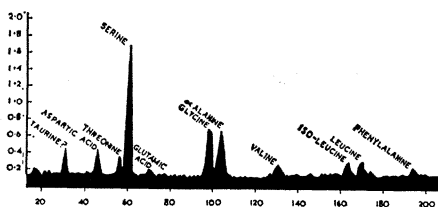


Fig. 1. Ion-exchange analysis of amino acids in an aliquot of crocidolite asbestos oil. Abscissa, effluent (ml); ordinate, absorbance.

Western Cape, Republic of South Africa.

Samples of fiber were taken from cobs of asbestos in such a way that contamination of any sort was extremely unlikely (1) and were extracted under reflux for 1 hour with boiling 80 percent (vol/vol) ethanol-water. The clear, faint yellow solution was then decanted and dried in a flash evaporator, giving a yield of 0.025 percent of the sample of asbestos taken. The final extract was a brownish-yellow, oily mass. Similar extractions of the country rock of crocidolite gave yields of virgin oil of 123 mg/100 g and 42 mg/100 g of pulverized material. Paper chromatography of samples of crocidolite and country rock extracts—downward development in butanol, acetic acid, and water (125:30:125)—showed the presence of three amino acids in both of the latter extracts and eight in the crocidolite extract. These have been tentatively identified as alanine, glycine, aspartic acid, leucine or isoleucine, glutamic acid, lysine, histidine, and cystine. A quantitative amino acid estimation by the column chromatographic method of Moore, Spackman, and Stein (2) was next undertaken (3) and gave the results shown in Table 1 and Fig. 1.

With the exception of serine, all of the amino acids found in crocidolite asbestos have been found by previous

Table 1. Amino acid composition of organic extract of crocidolite asbestos.

Amino acid*	Concentration (mg/100 g of fiber)
Serine	0.095
α -Alanine	.038
Glycine	.035
Aspartic acid	.024
Threonine	.017
Leucine	.014
Isoleucine	.014
Valine	.014
Phenylalanine	.010
Glutamic acid	.007
Total	0.268†

* Amino N: 0.025 mg/100 of fiber. † This represents 0.00027 percent, or 0.027 μ mole/g of fiber.

workers in various situations, for example, from fossils found from Pliocene to Devonian periods (4), from Oligocene marine mud (5), and from sedimentary rocks ranging in age from Ordovician to Tertiary periods (6). Virtually the same amino acids were found by Barghoorn (7) in samples of uncontaminated Gunflint chert. These last findings are particularly relevant because, like the crocidolite ones, they refer to a banded ironstone formation.

The concentration of amino acids found in crocidolite (0.00027 percent) is low compared with that found in other situations, for example, 0.0026 to 0.03 percent in various fossils from Pliocene to Devonian periods (4), 0.005 percent in Oligocene mud (5), and 0.02 percent from Middle Huronian ironstones (7).

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References and Notes

1. J. S. Harington, *Nature* **193**, 43 (1962).
2. S. Moore *et al.*, *Anal. Chem.* **30**, 1185 (1958).
3. I am very grateful to Paul Baily of the Chamber of Mines Research Laboratory, Johannesburg, for performing the quantitative amino acid analysis on my behalf, and to Marianne Smith for her skilled assistance.
4. P. H. Abelson, in *Researches in Geochemistry*, P. H. Abelson, Ed. (Wiley, New York, 1959), p. 79; —, *Science* **119**, 576 (1954).
5. J. G. Erdman, E. M. Marlett, W. E. Hanson, *Science* **124**, 1026 (1956).
6. J. G. Palacas and F. M. Swain, *Nature* **185**, 234 (1960).
7. E. S. Barghoorn, *Bull. Geol. Soc. Am.* **67**, 75 (1957).

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Impedance to Water Movement in Soil and Plant

Abstract. The total impedance to water movement from the soil into the plant was compared with that predicted for the soil alone. When soil suction was below 0.6 bar, the impedance was largely in the plant. When suction was greater than 1 or 2 bars, the soil became the limiting factor. Water movement to the plant roots takes place primarily in the liquid phase.

Bonner has suggested that, during even moderate transpiration, a large portion of the water transfer from soil to plant roots takes place in the vapor phase, across a vapor gap (1). This conclusion is based upon calculations by Philip of the soil moisture gradients in the vicinity of the plant root (2). From a more extensive analysis along the lines of Philip's, Gardner concluded that the soil suction gradi-

ents near the plant root are probably small until the lower limit of available water is approached (3). We have now compared the impedance to water movement in the soil near the root with the impedance in the entire plant.

Impedance in the plant and soil is defined by the equation:

$$q = (\delta - \tau)/(I_s + I_p), \quad (1)$$

where q is the volume of water taken up per unit time per unit volume of soil, δ is the potential energy,—that is, the diffusion pressure deficit—of the water at some point in the plant, τ is the total potential energy of water in the soil, and I_s and I_p are the impedance to water movement in the soil and plant, respectively (3). The total impedance I is

$$I = I_s + I_p = (\delta - \tau)/q. \quad (2)$$

It has been shown that I_s can be represented by the expression

$$I_s = A/kL, \quad (3)$$

where A is a constant, k is the conductivity of unsaturated soil, which is a function of the water content or soil suction, and L is a measure of the effective length of roots per unit volume (3). If we substitute Eq. 3 into Eq. 2,

$$I = I_p + A/kL. \quad (4)$$

In question is the relative magnitude of the two terms on the right-hand side of Eq. 4. If this equation represents the water uptake process even approximately, then the relative importance of the impedance to water movement in the soil to that in the plant is reflected in the relative magnitudes of I_s and I_p . Equation 4 is based on the assumption that the water flux is proportional to the free energy gradient, and the impedance in the plant, for lack of data, is assumed to be constant. Neither assumption may be precisely correct.

Total impedance $I = I_s + I_p$ was measured for single pepper plants (*Capsicum frutescens* L. var. *grossum*, "California Wonder") growing in 3-gallon crocks of Pachappa sandy loam in a greenhouse. The diffusion pressure deficit of detached leaves was measured by the vapor pressure method of Richards and Ogata (4), as described by Ehlig (5). Soil suction was measured with tensiometers and gypsum resistance blocks. The transpiration rate was determined from daily weighings of the crocks. Values which had been obtained earlier by the outflow method were used for k (6).