illustrated in Fig. 6. The upper intersection in this figure gives an age of 4270 million years. The cases examined here, together with other evidence cited previously, strongly suggest an age of the earth of 4550 million years. Consequently, I conclude that the common lead emplaced into the Guadelupe rocks recently (due to the lower intercept in Fig. 6) was formed in at least a three-stage system as distinct from the essentially two-stage history of the common lead in the other suites.

The source of the basalt samples studied in this paper is the upper mantle. Superficially, the lead isotope and lead-uranium ratios for these samples tempt one to conclude that the upper mantle is heterogeneous with respect to lead-uranium and thorium on a global scale. Thus, Tatsumoto (*8*) has concluded that "the upper mantle is an open system chemically; thus, the lead in basalts extruded from the upper mantle could not have developed in a single closed system in contrast to the idea that conformable ore lead came from an isotopically homogeneous mantle." It is true that the immediate source rocks of many of these basalts are heterogeneous, but I believe that the model presented here shows that their association with such source rocks was relatively short lived (mostly less than 250 million years) and that they existed in closed systems for the greater part of the earth's history.

T. J. ULRYCH

Department of Geophysics,
University of British Columbia,
Vancouver 8, Canada

References and Notes

1. M. Tatsumoto, *J. Geophys. Res.* **71**, 1721 (1966).
2. R. L. Stanton and R. D. Russell, *Econ. Geol.* **54**, 588 (1959).
3. R. D. Russell and R. M. Farquhar, *Geochim. Cosmochim. Acta* **19**, 41 (1960).
4. G. R. Tilton and R. H. Steiger, *Science* **150**, 1805 (1965).
5. E. K. Gerling and Y. A. Shukolyukov, *Geokhimiya*, **1962**, 458 (1962).
6. V. R. Murthy and C. C. Patterson, *J. Geophys. Res.* **67**, 1161 (1962).
7. D. York, *Can. J. Phys.* **44**, 1079 (1966).
8. M. Tatsumoto, *Science* **153**, 1094 (1966).
9. H. Kurasawa, *Abstr. Geol. Soc. Am.* (1966); A. Masuda, *Geochim. Cosmochim, Acta* **28**, 291 (1964); H. Kuno, *Bull. Volcanol.* **20**, 37 (1959).
10. R. G. Ostic, R. D. Russell, P. H. Reynolds, *Nature* **199**, 1150 (1963).
11. The section dealing with the criticism of Tilton and Steiger's (*4*) calculation for the age of the earth has been written with the help of P. H. Reynolds.
12. R. G. Ostic, thesis, University of British Columbia (1963).
13. W. F. Slawson, E. R. Kanasewich, R. G. Ostic, R. M. Farquhar, *Nature* **200**, 413 (1963).
14. G. R. Tilton, *Sci. Terre* **10**, Nos. 3–4, 247 (1965).
15. E. J. Catanzaro, *J. Geophys. Res.* **68**, 2045 (1963).
16. T. J. Ulrych and P. H. Reynolds, *ibid.* **71**, 3089 (1966); R. E. Zartman, *ibid.* **70**, 965 (1965); R. E. Zartman, *J. Petrol.* **6**, 28 (1965).
17. B. R. Doe, G. R. Tilton, C. A. Hopson, *J. Geophys. Res.* **70**, 1947 (1965).
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Temperature-Dependence of the Polarity of Electrical Charges on Ice Crystals

Abstract. *The electrical polarity of ice crystals produced from a supercooled cloud is temperature-dependent. The charge polarity appears to be associated with the crystal habit. This phenomenon may be important in precipitation and cloud electrification processes.*

The relation between the crystal habit and the temperature of formation of ice crystals has been well documented (*1, 2*). Workman and Reynolds (*3*) observed the electrical potential produced across an ice-water interface during the freezing of dilute aqueous solutions and suggested the relation of this phenomenon to cloud electrification. Experimental results indicate a relation between these phenomena. The electrical polarity and crystal habit of ice crystals produced from a fog of supercooled water droplets are related and are dependent on temperature and saturation ratio during crystal growth. In this note we offer the experimental results, and, without attempting to explain the fundamentals of the phenomenon, we suggest that it be considered as possibly having a bearing on thunderstorm electrification.

A fog of supercooled water droplets, with a typical diameter of less than 10 μ, was produced in a 24-m^3 chamber by the addition of approximately 300 g of steam. The resulting visibility was less than 2 m. After thermal equilibrium was attained, the supercooled fog was nucleated by the adiabatic expansion of a small quantity of moist air. This nucleation produced a number of ice crystals that were large enough to settle out within a few minutes. An excess of nucleation produced a relatively stable ice fog. The crystals were collected on a microscope slide, coated with formvar, and placed 0.5 mm below a grid of four parallel

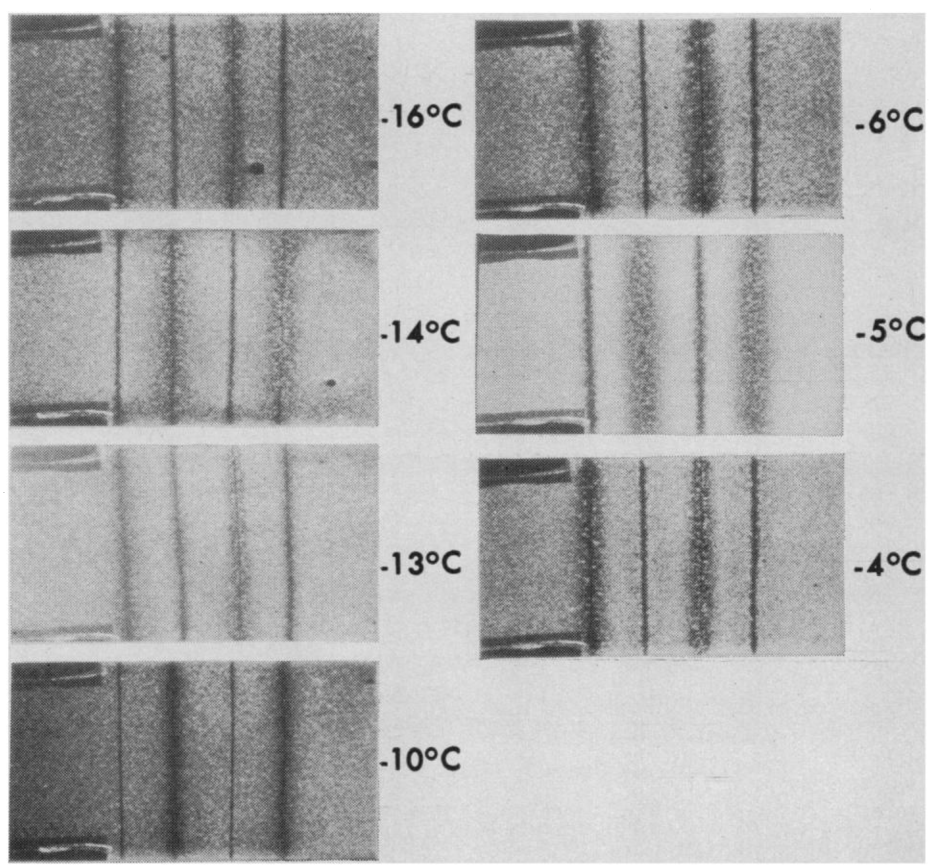

Fig. 1. Replicas of ice crystals collected in the presence of an electric field.

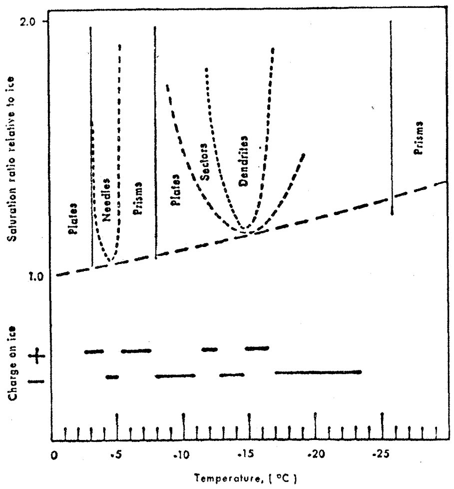

Fig. 2. Observed temperature-dependence of the charge of ice crystals compared with the temperature-dependence of the ice crystal habit [see Hallett and Mason (*1*)].

horizontal wires that were 0.2 mm in diameter and spaced 6.5 mm apart. For the slides in Fig. 1, the first and third wires from the right were maintained at +250 volts and the remaining wires at −250 volts with respect to the chamber walls. The ice crystals on the slide were replicated by the chloroform-vapor technique described by Schaefer (*4*). An examination of crystals that collected on the wires and the distribution and habit of those replicated on the slides indicated a relation between the charge and habit of the ice crystals. A series of these slides, photographed with dark-field illumination, and their corresponding temperatures are shown in Fig. 1. Satisfactory replication could not be obtained with fogs warmer than −1°C. The coldest supercooled fog obtained in the chamber was −24°C.

A charge separation was produced during the sublimation or condensation followed by freezing, or both. In these experiments, at nearly constant temperature, the majority of prisms and stars were found to be positively charged and the majority of the plates were negatively charged. A space charge of oppositely charged ions might possibly satisfy the charge conservation requirement, since there was no indication of variations of habit distribution in the chamber. The resultant charge and shape of an ice crystal were dependent on its growth history. Polarity of the charge, observed on the ice crystals as a function of temperature, is compared in Fig. 2 with the crystal habits observed by Hallett and Mason (*1*). Under the conditions of our experiment, most of the crystal growth occurs when the water-vapor pressure is near that of liquid water. This may account for the number of changes in the polarity of the charge. It might be expected from the habit-temperature data of Hallett and Mason (*1*) and Mason (*5*) that at lower vapor pressures, that is between those of water and ice, the ice crystals grown between −3° and −8°C would acquire a positive charge, and those grown between −8° and −25°C a negative charge.

The observed results suggest to us that the phenomenon responsible for the charge separation may have an important role in the processes of precipitation and cloud electrification.

F. KIRK ODENCRANTZ
ROGER W. BUECHER

Research Department,
Naval Weapons Center,
China Lake, California 93555

References

1. J. Hallett and B. J. Mason, *Proc. Roy. Soc. London Ser. A* **247**, 440 (1958).
2. U. Nakaya, *Compendium of Meteorology* (American Meteorological Society, Boston, 1951), p. 207.
3. E. J. Workman and S. E. Reynolds, *Phys. Rev.* **78**, 254 (1950).
4. V. J. Schaefer, *J. Appl. Meteor.* **3**, 413 (1962).
5. B. J. Mason, in *The Art and Science of Growing Crystals*, J. J. Gilman, Ed. (Wiley, New York, 1963), p. 136.

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X-rays from Sources 3C 273 and M 87

Abstract. *An x-ray survey of the Virgo region revealed signals from the directions of 3C 273 and M 87. Three other x-ray sources appear in the region scanned, but do not fit any known radio sources. The x-ray flux (1 to 10 angstroms) from the direction of 3C 273 is about 1000 times weaker than from the strongest x-ray source, Sco XR-1. If the source is located at the cosmological distance of 500 megaparsecs, the x-ray luminosity is 7.3 × 10^{45} ergs per second. The x-ray luminosity of M87 is 1.5 × 10^{43} ergs per second.*

An x-ray search of the Virgo region was performed from an Aerobee rocket, launched 17 May 1967 from White Sands, New Mexico. In order to attain high sensitivity and resolution, all available flight time was devoted to a single fan-beam scan along a strip of sky 14° long, which included the quasar 3C 273 and the radio galaxy Virgo A (M 87). The field of view was 1° wide in the scan direction by 8° long at right angles to the scan. Source positions were determined to about 0.1° by optical photography of the star field throughout the controlled portion of the flight. In addition to signals from the directions of 3C 273 and M 87, the survey detected three x-ray sources comparable in flux to 3C 273, but not coincident with any known quasar or radio galaxy. The high galactic latitudes of these unknown sources (about 70 degrees) favor their being extragalactic.

The instrumentation for this flight was similar to that used by Naval Research Laboratory (NRL) groups in previous surveys (*1*). Two proportional counters looked outward through the side of the rocket in the same direction and were baffled by an array of blades and honeycomb that limited the field of view to 1° by 8°, full width at half maximum (FWHM). The effective combined aperture through the collimator was 525 cm^2. Mylar film, ⅛ mil thick, was the window material, and the gas filling consisted of 90 percent argon and 10 percent methane at atmospheric pressure. Pulse amplitudes were sorted into six channels, and the outputs of the two counters were recorded independently. To reduce the cosmic ray background count, an anticoincidence counter was wrapped around the back and two sides of each soft x-ray counter. Above the atmosphere, the residual cosmic ray background count was 0.1 cm^{-2} sec^{-1}.

The Aerobee rocket was equipped with an ACS stabilizer (*2*) which was programmed to point to the Virgo region and then to perform a slow turn so that the detectors scanned along a line from 3C 273 to M 87. Figure 1 is a map of the region scanned. The orientation of the collimator is indicated at 10-second intervals from 140 seconds to 310 seconds after launch. The length of each bar represents the 8° FWHM of the baffled field of view, and the short vertical line marks the center of the field. The orientation of the collimator was determined from a succession of photographs of the field initiated every 10 seconds. The pointing directions determined in this way are accurate to 0.1°.

Figure 2 shows the observed combined counting rates from both counters as a function of time. The plotted counting rates are running means averaged over 10 seconds at intervals of 2 seconds. The controlled scan began to turn the rocket smoothly at