bubbling. However, the ice tube continued to grow in diameter by formation of a layer of transparent argon ice on the outside (Fig. 3*C*); this occurred because the solid argon on the inside of the tube had a high vapor pressure (0.68 atm) and sublimed into the helium-gas stream to furnish additional cooling. The initially formed tube contained many trapped bubbles of helium that gave it a more opaque, white appearance. When the helium flow was increased markedly, small ice particles dispersed throughout the liquid, which rapidly became full of mushy ice and finally froze solid.

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4. From data from E. I. du Pont de Nemours & Co.
5. We thank G. D. Halsey, Jr., University of Washington, for helpful discussion; M. Grosser, H. Harrison, and G. L. Hollingsworth, Boeing, for discussion and technical assistance. A 16-mm color film showing formation and growth of the argon ice tubes is available from the authors.

29 March 1965

Carbonates: Association with Organic Matter in Surface Seawater

Abstract. *Carbonate mineral particles suspended in surface seawater in tropical and subtropical areas do not interact measurably with the water. Identical complex mineral assemblages occur in waters in various states of saturation. Drastic alterations of temperature and* p*H in the laboratory do not affect the composition of the suspended carbonates. It appears that the mineral grains are protected from the water by resistant organic coatings.*

Surface seawater in tropical and subtropical areas contains carbonates and other minerals in suspension. The amount of suspended matter is variable. A concentration of five or more milligrams of $CaCO_3$ per liter is common near the shore, and far less occurs in the open sea. The mineralogy of the suspended carbonates is normally complex, with aragonite and a variety of magnesium calcites being present.

Samples of surface water from five areas in Bermuda, Jamaica, and western Florida have been studied. One to eight liters of water were filtered through an 0.8-μ Millipore filter. The filter was usually rinsed with a small amount of distilled water to remove sea salts, and was then dried and dissolved in acetone. The resultant slurry was centrifuged, and the centrifugate smeared on a glass microscope slide for x-ray diffraction analysis.

Over 100 samples from the different study areas were analyzed. One striking conclusion can be drawn from the data—there is no obvious evidence of chemical interaction between the carbonates and the seawater.

Aragonite and magnesium calcites exhibit a wide range of solubilities at constant temperature and pressure (*1*). In surface seawater, solubilities are further influenced by changes in temperature, salinity, and CO_2 pressure. However, in Bermuda, for instance, there is no significant change in the mineralogy of the suspended carbonates from summer (29° to 30°C) to winter (15° to 19°C). Surface water in summer has been demonstrated to be supersaturated with respect to all but the most soluble suspended phases of carbonate by use of *p*H-sensing techniques (*2*). By means of similar techniques, water in winter has been shown to be undersaturated with respect to the mineral phases present in the water. Thus it appears that the suspended particles are not acting as nuclei for selective precipitation, nor are they being selectively dissolved.

Off Cedar Key, in northwestern Florida, water in late summer (20° to 22°C) contains suspended aragonite, magnesium calcites, and quartz. Waters from this area with salinities about 30 per mill are oversaturated with respect to most of the carbonate phases present. However, near the mouth of the Suwannee River, where salinities are below 10 per mill and the water is undersaturated with respect to all calcium carbonate species, suspended carbonates are still abundant.

Laboratory experiments were conducted in Bermuda in which attempts were made to induce interactions between the suspended carbonates and the water. Cold waters were warmed to above 30°C in an attempt to induce precipitation. Warm waters were cooled to below 5°C to favor solution. Waters were bubbled with air and stirred while being warmed and cooled in order to speed equilibration with atmospheric CO_2. Waters were acidified with HCl to a *p*H of 7.25, at which point reagent calcite that was added dissolved readily; yet as shown in Figs. 1 and 2, no changes in the mineralogy of the suspended carbonates could be detected.

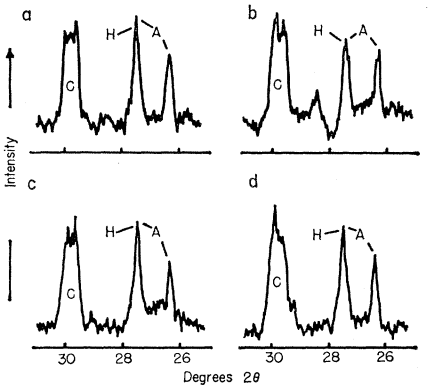

Fig. 1. X-ray diffraction patterns (CuKα) of carbonates suspended in samples (3 liters each) of nearshore Bermuda seawater as the water is cooled. *A*, aragonite peaks; *H*, halite (from dried salts); *C*, Mg-calcites, more magnesium at higher angles. (*a*) Fresh seawater 26.5°C; *p*H, 8.26. (*b*) Cooled 2.5 hours to 16°C; *p*H, 8.23. (*c*) Cooled 5 hours to 13°C; *p*H, 8.20. (*d*) Cooled 10 hours to 9°C; *p*H, 8.17. (*H* and one *A* peak overlap. These four samples were not rinsed with distilled water and thus the halite peak is large.) Samples obtained in September 1964.

The seawater used in these studies contains abundant organic aggregates (*3*). Microscopic examination of Millipore filters, cleared with oil having a refractive index of 1.500, showed that the aggregates, which ranged in size from 10 μ to 50 μ, contained abundant carbonate material. This material occurred as fine crystal clusters or as individual grains up to 20 μ in diameter. Mineral grains not in aggregates had a brownish coating, similar

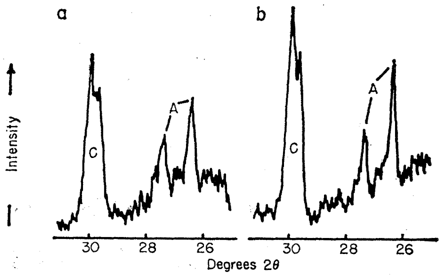

Fig. 2. X-ray diffraction patterns of carbonates suspended in samples (1.5 liters each) of nearshore Bermuda seawater, fresh and acidified. Diffraction peaks identified as in Fig. 1. (*a*) Fresh seawater at 17.3°C; *p*H, 8.21. (*b*) Acidified to *p*H 7.25 with HCl (17.3°C). Stirred for 10 minutes on magnetic stirrer after acidification. Samples obtained in March 1965.

in color to the aggregates and presumably consisting of organic material. The lack of chemical interaction between fine carbonate particles suspended in surface seawater appears to be the result of protection of the grains from the water by resistant organic coatings.

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8 April 1965

Jupiter's Decametric Emission Correlated with the Longitudes of the First Three Galilean Satellites

Abstract. *An analysis of data obtained at a variety of frequencies since 1957 has confirmed Bigg's observation that the satellite Io appears to control the emission of decametric radio energy by Jupiter. The correlation is stronger when intensity, rather than simple probability, is included in the analysis. There is also evidence of a similar influence by the satellites Europa and Ganymede.*

In 1964, Bigg (*1*) found a striking dependence of Jupiter's decametric radio emission on the angular position of Io, the innermost Galilean satellite. The radio data were those obtained during 1961, 1962, and 1963 by J. W. Warwick of the High Altitude Observatory at Boulder, Colorado. At the same time, Bigg reported that he had as yet found no definite correlation between the decametric radiation and the positions of the remaining three Galilean satellites.

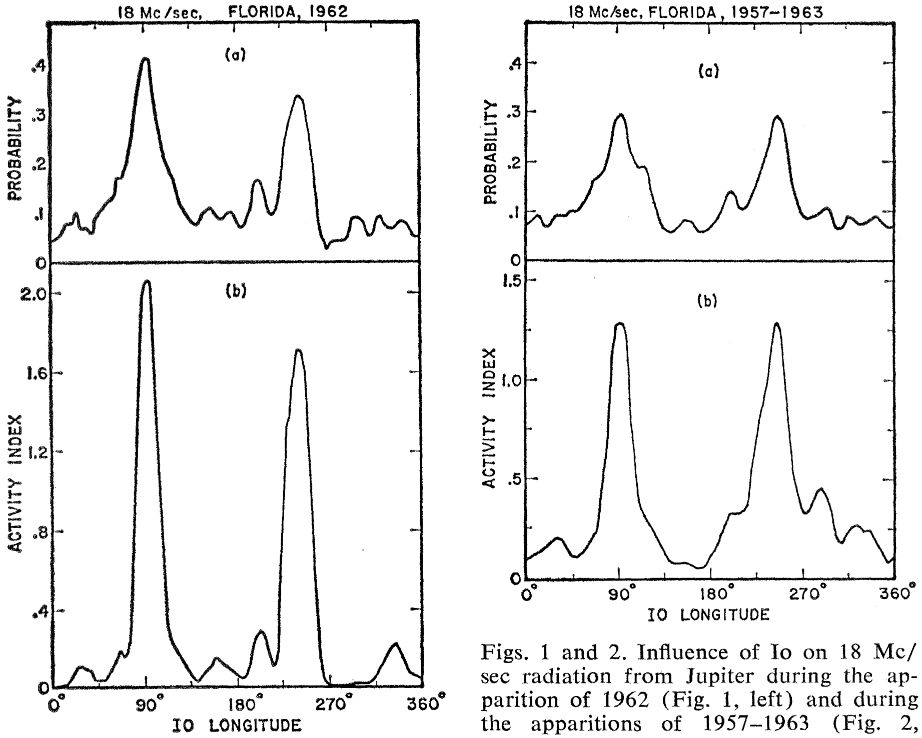
The University of Florida Radio Observatory has extensive multifrequency records of Jovian radio emission going back to 1957. These data are stored in punch-card form, so that a search for the satellite effect could be made merely by preparing a suitable computer program. As Fig. 1 indicates, the results of this search have amply verified Bigg's initial finding with respect to the influence of Io. Fig. 1*a* shows how the probability of receiving radiation at a frequency of 18 Mc/sec varied with the longitude of Io during the 1962 apparition of Jupiter. As usual, the longitude has been taken as zero when the satellite was at superior geocentric conjunction. The conspicuous probability peaks near 90° (western elongation) and 240° are in essential agreement with Bigg's work.

Figure 1*b* shows the same data, but here the ordinate is the Jovian "activity index" (*2*). In computing this index, the probability of occurrence is weighted through multiplication by the flux density of the received emission; thus the activity index reflects both the probability of receiving radiation and the intensity of that radiation. The fact that the peaks in Fig. 1*b* are far more pronounced than those in Fig. 1*a* suggests that Io imposes an intensity modulation on the emission, as well as controlling its occurrence.

Figure 2 is identical with Fig. 1, except that a computer program has been used to combine all of the 18 Mc/sec observations made during the seven apparitions from 1957 through 1963. The similarity of the two figures indicates that the Io influence is relatively stable in time. If, for example, gross changes occurred in the locations of the peaks, the peaks themselves would be broadened and degraded when data covering long periods of time are merged.

In the initial analysis emphasis was placed on the observations made at 18 Mc/sec. Since this frequency represents a kind of optimum compromise between the characteristics of the Jovian emission and the limitations imposed by the terrestrial ionosphere, the 18 Mc/sec data are generally the most abundant and the most reliable. The study has nevertheless been extended to a number of other frequencies, and the results for the 1962 apparition are shown in Fig. 3. The forms and locations of the two major peaks appear to be stable over this range of frequencies, although the relative amplitude of the peak at 240° decreases steadily as the frequency increases. On the other hand, data recorded at the lower frequencies (for example, 5 and 10 Mc/sec) at a field station in the southern hemisphere do not seem to conform to the pattern of Figs. 1 and 2. This is perhaps not surprising, since the apparent structure of the Jovian decametric sources themselves undergoes a radical change at frequencies below 15 Mc/sec (*3*).

It is well known that between 15 and 40 Mc/sec there are three major regions of activity on the planet, one of which often appears to be bifurcated (*4*). In a suitably defined longitude system (known as System III or λ_{III}) these



Figs. 1 and 2. Influence of Io on 18 Mc/sec radiation from Jupiter during the apparition of 1962 (Fig. 1, left) and during the apparitions of 1957–1963 (Fig. 2, right).