and resulting isotopic, heterogeneities in the upper mantle source material of the rocks on Oahu; the detailed nature of such heterogeneities and of the magma-producing process remain unknown. As Gast (*18*) has pointed out, the isotopic data indicate that at least some chemical differences among spatially related volcanic rocks may reflect differences in the chemistry of their source materials, rather than the effects of contamination or igneous differentiation.

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Some Doubts about the Earth's Dust Cloud

Abstract. *Considerable doubt is cast on the validity of past satellite measurements of micrometeoroid fluxes in which piezoelectric microphones have been used as detectors. Data have been obtained from satellite and laboratory experiments which show that the microphone crystals emit noise when subject to slowly varying temperatures. The rate of noise is consistent with past flight data which have previously been interpreted on the basis of micrometeoroid impacts. These measurements have given rise to the theory that the earth is surrounded by a cloud of dust, although no satisfactory mechanism has yet been found to explain this apparent phenomenon. On the basis of the results reported here, it now appears that whether or not a concentration of dust exists in the vicinity of the earth, the data from satellite microphone measurements should not be used to support such a hypothesis.*

Over the last 7 years there has been a considerable volume of literature concerning the apparent existence of a concentration of dust in the vicinity of the earth. Evidence for this concentration consists primarily of the direct measurements reported by Dubin and McCracken (*1*) and Alexander *et al.* (*2*). Whipple (*3*) and Singer (*4*) have examined various possible sources of this dust, but no satisfactory mechanism has yet been found to account for the apparent increase in the flux of particles of masses between 10^{-7} and 10^{-13} g over fluxes deduced from photometric measurements of zodiacal light. Moroz (*5*) has presented arguments to show that debris splashed from the moon by meteoric impact cannot be a sufficient source of these dust particles. Many attempts have been made to explain the enhancement by the gravitational attraction of the earth. Dole (*6*), and also Hale and Wright (*7*), are among those who have studied this, but as Southworth (*8*) has pointed out, gravitational attraction can only increase the flux near the earth if the particles in heliocentric orbits have very small velocities relative to the earth. This implies an orbital distribution for these particles which is not realistic. The data of Hawkins (*9*) from ratio meteor studies show no evidence for such a confined distribution of orbits.

The measurements themselves seem to rule out the possibility that the dust particles are in long-term closed orbits around the earth. Rapid temporal variations of particle flux have been observed on nearly every satellite and these variations could not possibly exist if these particles were in geocentric orbits with periods of many days. The results of direct measurements of dust particles near the earth are difficult to explain theoretically, and this has prompted Singer (*10*) to announce his disbelief in the existence of the earth's dust cloud. Experimental evidence has now accumulated to support this view by throwing grave doubts on the validity of the direct measurements. The data presented below suggest that the microphone measurements consist largely, if not completely, of noise generated by the experiments themselves under changing temperature conditions. Thus the prime evidence for the existence of the earth's dust cloud is negated, and there is no longer any need for a theoretical explanation of such a large apparent enhancement of particle flux.

Direct evidence of the noise generated by microphone experiments has been obtained both in interplanetary space and in the laboratory. The former evidence was obtained from the flight of the OGO II interplanetary dust particle experiment. The basic sensor for this experiment has been previously described in connection with an earlier experiment on the OGO I satellite (*11*), and only a brief description need be given here. A micrometeoroid is detected through its impact on a thin film capacitor plate after it has passed through two very thin (1500-Å) films. A lead zirconate microphone crystal is bonded to the back of each glass capacitor plate to provide a measure of the impulse imparted to the plate by the impact of the particle. Figure 1 shows the basic sensor.

One hundred hours of data from the OGO II experiment have been analyzed to date. Two major conclusions to be drawn from these data are: first, there have been no detectable signals from the sensors that could have been caused by micrometeoroid impact, and second, the microphone systems have been emitting noise. It is this second aspect of the data that will be considered here. A low background rate of microphone events has manifested itself throughout these 100 hours of data, this rate being a little less than one event per hour. At one time when the experiment was slowly cooling after the heater failed, the microphone event rate rose nearly two orders of magnitude, to about one event per minute. This lasted for at least 10 hours.

The first question asked was whether or not these events were due to micrometeoroids or noise. There are very good reasons why they could not be due to micrometeoroid impacts. The limiting sensitivity of each transducer is about 1×10^{-4} dyne-sec. For a particle impacting at 30 km/sec, this threshold corresponds to a particle mass of about 3×10^{-11} g, if one assumes a simple momentum response. Particles of this order of mass would generate a signal either from the front thin film sensor, or the back plate capacitor, or both sensors, if they were able to reach the threshold sensitivity of the microphone system. Not one microphone event observed so far has been accompanied by a response from the other sensors, although a continuous in-flight calibration system has indicated no malfunction of either the sensors or the electronics. Furthermore, a similar experiment built for the OGO-D spacecraft has been subjected to slowly varying temperatures inside a thermal-vacuum chamber, and it too has emitted microphone noise for several hours at rates exceeding one event per minute, with occasional events corresponding to impulses greater than 2.5×10^{-3} dyne-sec. This phenomenon could not have been seen on the OGO-I experiment because, unlike the case with OGO-II, data were not read out from the experiment unless the rear sensor capacitor had been triggered. Thus, events emanating from the microphones alone would never have appeared in the telemetered data. One of the important features of the OGO series of interplanetary dust particle experiments is the fact that each experiment is surrounded by a thermal blanket and the temperature gradients with time suffered by the microphones are very small. This was not the case with the earlier microphone experiments such as those on Explorer I, Vanguard III, and Explorer VIII, the data from which form the basis of the theory that the micrometeoroid flux near the earth is much higher than that in interplanetary space. If the OGO II experiment suffered from microphone noise, it is indeed pertinent to ask whether or not these earlier experiments could also have been subject to noise from the transducer systems. The noise on these other experiments could have been much greater, as the temperature gradients during flight were much more severe. That this appears to be the case is shown below.

A sensor that was a prototype of the Explorer VIII dust detector has been subjected to varying thermal gradients in some rather simple laboratory

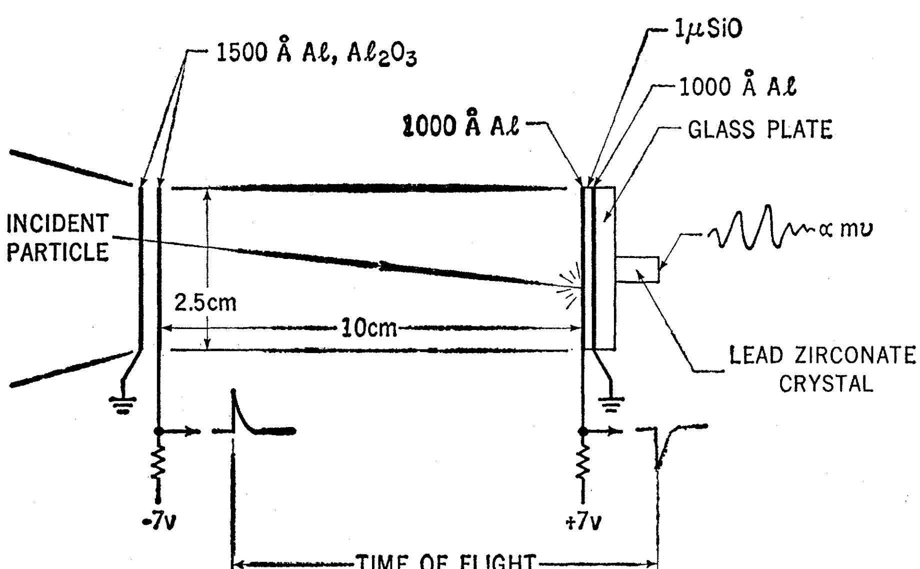

Fig. 1. The OGO-II micrometeoroid detector. The rear sensor employs a lead zirconate transducer bonded to a glass plate 2.5 cm in diameter.

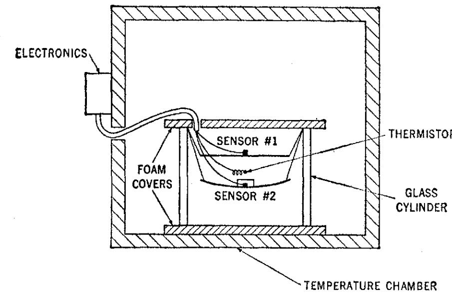

Fig. 2. The laboratory setup used to determine the noise rate figures given in Fig. 3.

tests. Because of the importance of the experimental details in tests of this type, the test setup needs to be briefly described. A dual unit system was arranged to detect any outside interference. A monitor sensor (unit No. 1) and the Explorer VIII sensor (unit No. 2) were hung by light thread close together inside a glass cylinder and the assembly was placed inside a temperature chamber. Figure 2 shows the experimental arrangement. The monitor sensor consisted simply of a lead zirconate crystal bonded to an aluminum plate. The electronic amplifiers, separate for each unit, were battery powered and mounted outside the temperature chamber. Each amplifier system was similar to that used on OGO II and was tuned to about 100 kcy/sec. The outputs from each amplifier were used to trigger a cathode-ray oscilloscope and the gate pulses thus generated were fed into a chart recorder. A calibrated thermistor placed close to, but not touching, the two plates gave a temperature measurement which was also recorded.

The level at which an event was recorded on unit No. 2 corresponded to an impulse on the sensor plate of approximately 5×10^{-3} dyne-sec. However, the monitor unit was set at a more sensitive level so that it triggered on an impulse of about 5×10^{-4} dyne-sec. This was to insure that either electrical noise or mechanical noise external to the experiments would trigger the monitor unit before the unit specifically under test. Noise of sufficient intensity to trigger the test unit No. 2 would trigger both simultaneously, and this event would be recognizable on the chart. This precaution proved rather academic, as the tests were carried out late at night and no outside interference was recorded other than that deliberately generated to test the system. Both units produced noise when subjected to variations in temperature. The individual output pulses for the two units were obviously independent of each other, but both showed a dependence on temperature gradient. The general form of the results from several tests on different occasions was the same. Data from one series of tests are shown in Fig. 3. The number of output pulses per 10-minute interval for each system is given in each temperature/temperature gradient cell as a number pair. The first figure is that from the monitor unit; the second of the pair is that from the Explorer VIII prototype. The star which appears twice for the latter unit is the result of a curious feature: on a number of occasions the amplifier output for this system would be shaken by sudden bursts of large pulses occuring every second or less. As the gate pulses from the cathode-ray oscilloscope were several seconds long it was not possible during these initial tests to count the number of pulses.

The minimum sample time used to obtain a number pair was 10 minutes, but sometimes during periods of low event rate the sample time was as much as 40 minutes. Numbers from such samples have been scaled down to 10-minute rates. Thus, in all cases the numbers of events actually counted are no less than the figures shown. Also important is the fact that during periods when the temperature did not change measurably with time, the event rate from both units was zero. Several hours of such data were obtained, indicating again that outside interference was negligible. The fact that the rates from the two units are of the same order although the sensitivities were an order of magnitude apart appears to be fortuitous and due to the Explorer VIII sensor being inherently more noisy than the monitor sensor. This point is discussed in more detail below.

Temperature gradients were obtained by changing the environment outside the glass cylinder and then switching the heating or cooling mechanism off. Data were taken while the air inside the cylinder slowly reached equilibrium with that outside. It is noteworthy that the noise-burst phenomenon associated with the Explorer VIII sensor never occurred on the monitor unit even when the amplifiers were changed around. Another feature of the data, to which reference is made later, is that the number of noise pulses is greater when the temperature gradient is negative. This is so for both units. It can also be seen from Fig. 3

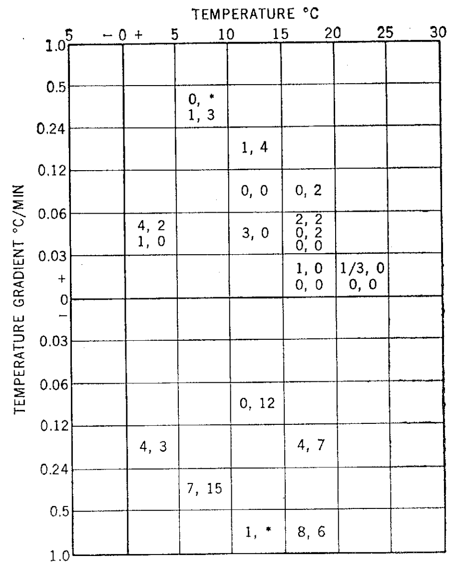

Fig. 3. Noise rates determined from laboratory tests. The rates, in events per 10 minutes, are given as number pairs for the two sensors. The first figure is that from the monitor sensor; the second is the rate simultaneously obtained from the less sensitive Explorer VIII sensor. The * represents a noise burst from the latter unit.

that under any specific temperature/temperature gradient conditions the noise rate can be highly variable. The variability of event rate with time from actual flight experiments is a feature to which past experimenters, for example, Dubin and McCracken (*1*), have repeatedly drawn attention.

Having presented the experimental data from both OGO II and laboratory tests concerning the noise output from microphone detectors, it remains to show how this fits into the pattern of past results which have been interpreted on the basis of micrometeoroid impacts. The micrometeoroid sensor on the Vanguard III satellite consisted of four lead zirconate crystals attached to the skin of the satellite. Secretan (*12*) has studied the temperature variations of the skin of this vehicle. He shows that the satellite skin cools and warms by as much as 25°C as the satellite passes in and out of the earth's shadow. The equatorial skin temperature can exceed that of the polar skin by more than 10°C, doubtless leading to differential expansion of the skin itself, a fact that is not even considered in the experimental noise results presented here.

The satellite skin cools in about 30 minutes, thus average temperature gradients exceeding 0.6°C per minute are common. Furthermore, the maximum and minimum temperatures reached by any part of the skin vary from day to day. For example, for the polar skin the range is from about 38°C to 13°C on 23 October but only 7°C to −3°C on 25 September. The range of the equatorial skin temperature reaches a maximum of 26°C during the period 16–21 November, which coincides in time with the November 1959 dust particle shower reported by Alexander *et al.* (*13*). This may not be significant, however, as the magnitude of the temperature variation on other occasions is very little less. In fact, the daily impact rate does not appear to be simply correlated with the daily temperature difference plotted in Fig. 4.

The flight impact data show an average rate of about two events per hour over the period 18 September to 9 October 1959, but the rate reaches about 40 events per hour over the period 16 November to 18 November. At one stage 200 ± 10 events were observed during 6.3 minutes of real time telemetry at 2237 hours satellite local time on 17 November. Alexander *et al.* (*13*) suggested that the high rate during these few days was probably associated with the Leonid meteor stream. The sensitivity of the system is given as about 1×10^{-2} dyne-sec. Because of the attenuation between each crystal face and the skin which was used as an impact area, however, the sensitivity at the face of each crystal was considerably greater than this. In fact, due to the method of mounting, this attenuation was probably greater than that between the Explorer VIII plate and its crystal, so that the noise data shown in Fig. 3 may even have been taken at a lower crystal sensitivity than that of the Vanguard III flight experiment. Because of factors such as these, the quoted sensitivities cannot be used exactly in comparing absolute noise rates, and one can only say that the noise data given here appear to be generally applicable to the Vanguard III experiment. Also, four crystals contributed to the flight data, whereas the noise data given here were obtained with only one crystal per system. It is obvious that rates of 40 events per hour, or, to use the units of Fig. 3, 7 events per 10 minutes, are quite consistent with the hypothesis that they were caused by noise either emanating from the crystals or the total experimental package. A rate of 200 events in 6 minutes is quite consistent with a noise burst such as those observed in the tests of the prototype Explorer VIII unit.

A cosmic dust shower was also observed in the data from Explorer I. This experiment was very similar to that on Vanguard III, although the limiting sensitivity was slightly higher, about 2.5×10^{-3} dyne-sec, according to Dubin (*14*). Once again, it should be noted that the sensitivity at each crystal face would have been considerably higher than the figure given. The average rate from 1 to 12 February 1958 was about 5 events per hour, but for a 10-hour period starting on 2 February, Dubin *et al.* (*15*) state: "It is quite evident that the impact rates during the shower period were nearly two orders of magnitude greater than the average of the latter two-thirds [last 8 days] of the measurement period."

An examination of the table of Dubin *et al.* (*15*) showing hits as a function of time reveals that the highest significant rate is based on 12 events in 261 seconds. Periods of noise at this rate were commonly observed in the test data shown in Fig. 3. It is noteworthy that both the dust showers from Explorer I and Vanguard III were observed primarily during the hours 1800 to 2400 satellite local time. This is just the period during which the microphone experiments were subject to maximum cooling rates. In view of the greater number of noise events noted during periods of negative temperature gradient in Fig. 3, this fact may be significant.

The microphone dust particle experiment aboard the Explorer VIII satellite seems to have been regarded by Alexander *et al.* (*2*) as the most significant of the three experiments discussed in any detail in this report. About 3700 events of equivalent momenta greater than 2.5×10^{-3} dyne-sec were recorded in nearly 1000 hours. Rate data were obtained at three different momentum levels and, by assuming an average velocity of impact of 30 km/sec, the fluxes of micrometeoroids at three different mass levels were obtained. A cumulative flux-versus-mass plot could thus be made, and it was quickly apparent that the data from the microphone experiments on Explorer I and Vanguard III fitted rather well with the Explorer VIII data. It was found that the flux (I) versus mass (m) distribution was best described by the equation $\log I = -17.0 - 1.7 \log m$. From the high negative slope, Alexander *et al.* (*2*) deduced that: "First, the distribution departs markedly from what is expected from extrapolations of meteor data, and second, the accretion of interplanetary matter by the earth is dominated by the small dust particles."

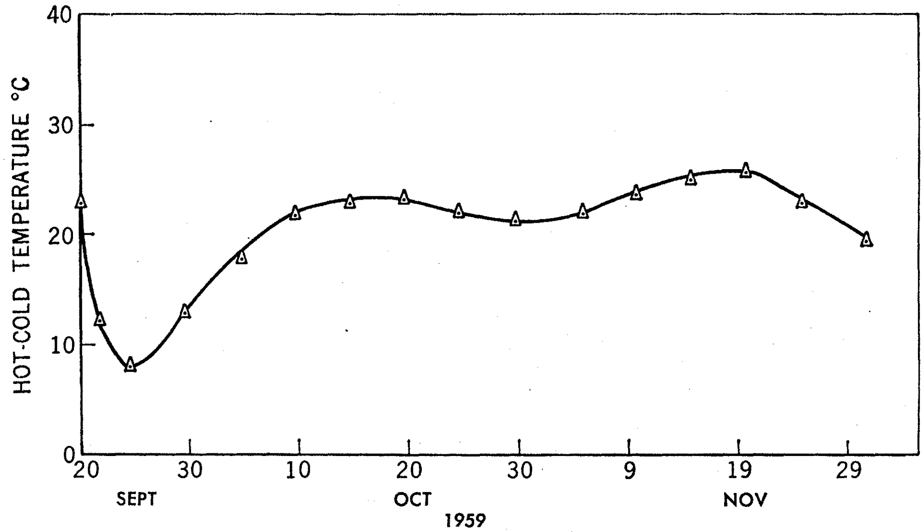

Fig. 4. The daily variation of the equatorial skin temperature on the Vanguard III satellite (1959 eta). The skin went through a complete temperature cycle of this amplitude once every 130 minutes.

The flight experiment carried two sensors attached to a conical section of the spin-stabilized satellite. The temperature gradients observed on the skin of Vanguard III would certainly have been suffered by the metallic sounding plates on Explorer VIII. In fact, the gradients could have been even more severe, as the mass of each sounding plate was less than that of the shell of Vanguard III. One would thus expect gradients of up to 1°C per minute over ranges similar to those shown for Vanguard III, hence the data in Fig. 3 are applicable to the flight conditions of the experiment. One cannot, however, compare the rates directly, as the sensor under test was not identical in every respect to that flown, and has been subjected to different environmental conditions and suffered various tests over the last 6 years. Assuming each sensor contributed half the data, the rate per sensor averages a little less than 2 events per hour over the entire flight. Temperature noise is more than sufficient to account for this rate and is quite capable of accounting for sudden large increases in the observed rate.

In conclusion, it seems that there is considerable evidence that the micrometeoroid impact data obtained by microphone experiments largely consists of noise. Not only are the average rates consistent with thermal noise but the erratic behavior with time is also common to both the previous flight data and the test data presented here. The question naturally arises as to why this noise problem was not detected during prelaunch tests of the experiments. It is unfortunate that the experiment tests consisted in the past, and still do, of quiet runs at various fixed temperatures inside a thermal-vacuum environment. Test data are not normally obtained while satellite temperatures are changing. It is my understanding that this situation applied to both the Vanguard III and the Explorer VIII satellites, but that data were obtained from the Explorer I experiment while temperatures were being cycled. No noise was observed. This would appear to be contradictory to the data presented here and as such is quite important. It is necessary, however, to know the experimental details of such a test before it can be properly evaluated.

Little has been said concerning the physical nature of the noise involved. Rates have been plotted as a function of temperature and temperature gradient, as there seems to be some correlation between them. In view of the erratic nature of the data, it may well be that some other parameter is involved. The tests to date indicate that the transducers themselves are a source of noise quite apart from any thermal creaking of the attached plates. The transducers used have been barium titanate and lead zirconate ceramics, which owe their piezoelectric nature to the polarization of the electric domains under applied direct current voltage at elevated temperatures (*16*). It seems quite conceivable that the physical changes that must accompany changes of temperature would give rise to sudden changes in total polarization, thus giving rise to events at the output of the attached amplifiers.

Every experiment utilizing piezoelectric crystals, and every crystal that I have tested, has shown temperature-dependent noise to some significant degree. A second prototype sensor of the Explorer VIII experiment has recently been tested, and while the event rate appears to be nearly an order of magnitude less than that shown in Fig. 3, it nevertheless produces sufficient noise to account for the flight data. This variability of rate from one unit to another suggests that more than one source of noise may be present, and indeed there is evidence to support this view. Some years ago Secretan (*12*) obtained noise data on crystals mounted in various ways. A crystal clamped to a plate in a manner similar to that used on Explorer VIII was subjected to a temperature rise of 43°C in 50 minutes; 270 events of magnitude greater than 10^{-2} dyne-sec (plate sensitivity) were recorded in that period. When the temperature rise ceased, so did the events. This work was not known to me at the time the data in Fig. 3 were taken, and thus it can be regarded as confirmation of this more recent work. However, when a crystal was cemented to the plate, rather than mechanically clamped, the event rate was several orders of magnitude lower, about 16 events being recorded in 95 hours of temperature cycling. Thus there is good reason to believe that the mechanical crystal mounts used on these early experiments have been major contributors to the observed event rates. Possibly this accounts for the fact that the rates given in Fig. 3 for unit No. 1 and unit No. 2 are about the same, although the former was an order of magnitude more sensitive. The crystal on No. 1 was bonded to the plate, whereas the Explorer VIII crystal was clamped. Quite independent evidence of the role of the transducers themselves in generating noise comes from yet another microphone experiment aimed at detecting micrometeoroids. Wlochowicz (*17*) has flown a number of rockets with acoustic detectors and has refined his experiments to take into account in a quantitative way the attenuation of the impact in the rocket skin. He attached three crystals to the inner surface of the rocket shroud and, by comparing the magnitude of the response from each crystal, hoped to obtain some information about the actual point of impact on the rocket nose. The results are difficult to interpret in terms of random impacts, as he himself states:

"According to pre-flight calibration curves for the system on AD-II-44, assumed impacts producing the large responses from M1 and not recorded by M2 are possible, providing that relatively large particles impacted over a very small area around the microphone. There appears to be an unlikely number of such occurrences. By assuming some deterioration in the sensitivity in M2, particularly due to the contact between the microphone and the sensing surface, the probable impact area responsible for the larger responses on M1 increases, and the record becomes more realistic. One would still expect, however, to see a few more small responses on M2."

A possible explanation of this data is that the output pulses originated from noise generated within the crystal M1 itself, not from micrometeoroid impacts over the rocket shroud.

The data from all these flight experiments have been widely used. Peale (*18*), for example, has devoted a considerable study to the question of whether the zodiacal light can be partly or wholly explained by a dust belt around the earth. In the light of the evidence presented above on the probable noise output of these experiments, it would seem advisable to reexamine such studies with less weight being placed on the microphone data. It is also worth noting that the control system (No. 1) used in the noise tests presented here closely approximated the sensor of the Mariner IV dust particle experiment (*19*). The rate of change of crystal temperature on this flight unit would have been almost negligible as the satellite moved slowly out towards the orbit of Mars. Nevertheless, because of the extremely low event rate (about one per day), the results of this experiment should be considered suspect, along with all the other satellite microphone measurements discussed above.

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Antipodal Location of Continents and Oceans

Abstract. *The percentage of continent antipodal to ocean on the earth is compared with a distribution obtained by a Monte Carlo method. It is concluded that the present antipodal arrangement of continents and oceans has less than 1 chance in 14 of being caused by a random process.*

An occurrence which has puzzled geophysicists for many years is the apparent antipodal arrangement of continents and oceans (*1*). The theories which have attempted to explain a possible correlation of continent at one point and ocean at its antipode originated with Lowthian Green's tetrahedral hypothesis; today theories have been advanced by Vening Meinesz (*2*), who explains the occurrence by convection currents, and by Elsasser (*3*), who believes that it was caused during the main period of differentiation in the