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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References and Notes

1. M. Dubin and C. W. McCracken, *Astron. J.* **67**, 248 (1962).
2. W. M. Alexander, O. E. Berg, C. W. McCracken, L. Secretan, in *Space Research III*, W. Priester, Ed. (North-Holland, Amsterdam, 1963), p. 891.
3. F. L. Whipple, *Nature* **189**, 127 (1961).
4. S. F. Singer, *ibid.* **192**, 321 (1961).
5. V. I. Moroz, *Am. Inst. Aeronaut. Astronaut. J.* **1**, 2212 (1963).
6. S. H. Dole, *Planetary Space Sci.* **9**, 541 (1962).
7. D. P. Hale and J. J. Write, *J. Geophys. Res.* **69**, 3709 (1964).
8. R. B. Southworth, *Planetary Space Sci.* **11**, 499 (1963).
9. G. S. Hawkins, *Astron. J.* **67**, 241 (1962).
10. S. F. Singer, a remark made at the International Symposium on Meteor Orbits and Dust, Smithsonian Astrophysical Observatory, Cambridge, Mass. (1965).
11. C. S. Nilsson, W. M. Alexander, C. W. McCracken, O. E. Berg, L. Secretan, *Nature* **208**, 673 (1965).
12. L. Secretan, unpublished work.
13. W. M. Alexander, C. W. McCracken, H. E. LaGow, *J. Geophys. Res.* **66**, 3970 (1961).
14. M. Dubin, in *Space Research*, H. Kallmann Bijl, Ed. (North-Holland, Amsterdam, 1960), p. 1042.
15. M. Dubin, W. M. Alexander, O. E. Berg, *Smithsonian Contrib. Astrophys.* **7**, 109 (1961).
16. H. Jaffe, "Piezoelectricity," in the *Encyclopaedia Britannica* (1961).
17. R. Wlochowicz, *Can. J. Phys.* **44**, 1 (1966).
18. S. J. Peale, *J. Geophys. Res.* **71**, 911 (1966).
19. W. M. Alexander, C. W. McCracken, J. L. Bohn, *Science* **149**, 1240 (1965).
20. I wish to acknowledge the work of the other four experimenters on the OGO micrometeoroid project, in particular, that of the principal investigator, W. M. Alexander, for the original proposal and electronic design, and C. W. McCracken for help in the data reduction. Grateful acknowledgement is also made to these experimenters for permission to use the Explorer VIII prototype sensor in the tests presented here, and to L. Secretan for use of unpublished data. I am indebted to Dr. J. A. O'Keefe for valuable discussion and assistance in presenting this work, which was done at the Goddard Space Flight Center under a NAS-NASA Research Associateship.

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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

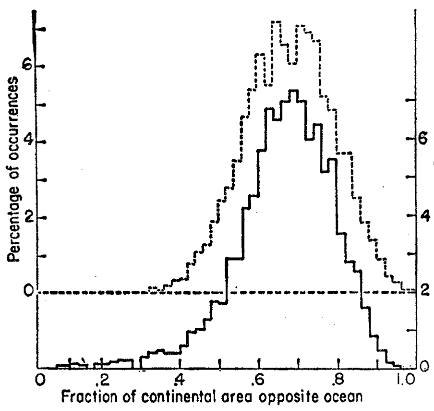

Fig. 1. Histograms of the fraction of continental area opposite ocean. The upper histogram is for circular continents and the lower histogram is for triangular continents. The ordinate shows the percentage of the total number of tries within each range; left-hand label is for upper histogram; right-hand label is for lower.

earth. Evison and Whittle (*4*) have attempted to discover whether the observed amount of continent opposite to ocean is likely to have occurred by a random process. By using an analytical probability method they calculated that the expected fraction of continental area opposite to ocean was about three-fourths. They concluded that the observed value of about five-sixths was so close to the expected value as to require no special explanation.

The antipodal relation is less marked than is generally believed, and we may take the figure of Vening Meinesz (*2*), who stated that only 6 percent of the earth's surface did not obey the "antipodal rule." This means that 82.6 percent of the total continental area is antipodal to oceanic area. The

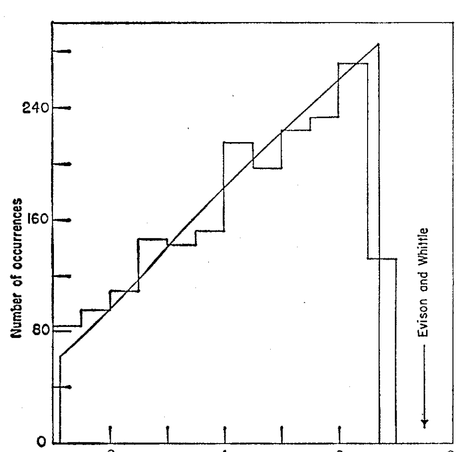

Fig. 2. Histogram of the fraction of continental area opposite ocean for two circular continents 0.25 and 0.2 of the earth's area, respectively.

continental areas, the edge of the continental shelf being used as the limit of each continent, are taken from Daly (*5*): Eurasia, 13.1 percent of the earth's surface; Africa, 6.1 percent; North America, 6.0 percent; South America, 4.0 percent; Antarctica, 2.9 percent; Australia, 2.3 percent; total for continents, 34.4 percent.

We wish to examine whether a random distribution of continents over the surface of the earth will give, with any likelihood, an antipodal arrangement where 82.6 percent of the continental area is antipodal to ocean. The method used was a calculation by digital computer in which random numbers were generated to produce the latitude and longitude of six continents, all of which were assumed to be circular in outline, but equal in area to the actual continents. To obtain an even distribution per unit solid angle, the colatitude, θ, was calculated from $\cos \theta = R-1$, where R is a random number varying between 0 and 2.

If one continent overlapped another one, a new pair of random numbers was used for that continent and the process repeated until all the continents were placed on the sphere without any overlapping taking place. The continents were placed on the sphere in a random order. The percentage of continent with ocean opposite was then calculated for that particular distribution of continents, and the whole process repeated 2000 times. Figure 1 is a histogram showing the number of times each antipodal percentage arose.

The median percentage of continent opposite ocean to be expected from a random distribution of circular continents is 68.0 percent of the continental area. The observed figure of 82.6 percent is exceeded in 192 cases out of 2000, or in 9.6 percent of all cases. Thus from this evidence alone it would appear that there is a probability of only 0.096 that the present distribution of continents is random over the surface of the earth.

It was thought that the irregular shape of the actual continents might reduce the probability of the observed amount of ocean opposite continent being exceeded. So the experiment was done again, this time using continents in the shape of equilateral triangles, whose sides were great circles and whose areas corresponded to the areas of the actual continents. In this case the median was 67.8 percent, and the observed value of 82.6 percent was exceeded in 178 cases out of 2400.

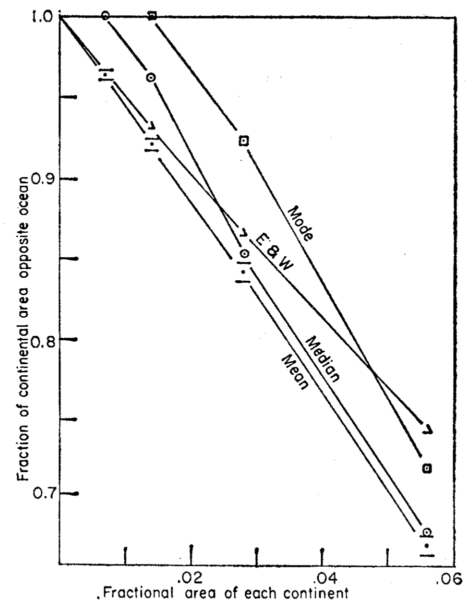

Fig. 3. Variation of various central measurements of the fraction of continental area opposite ocean for six circular continents of equal size, as this size is increased. The horizontal bars show the standard error of the mean value. "E & W" shows the most likely value calculated by the method of Evison and Whittle (*4*).

As the calculation was done in 16 groups of 150 tries each, it was possible to calculate a standard error for the probability of the observed figure being exceeded. The probability is 0.0742 ± 0.0042, which is significantly less than the probability obtained for circular continents. A histogram for the triangular continents is also shown in Fig. 1.

Because of the decrease in probability on going from circular to triangular continents it is reasonable to assume that if the actual shapes of the present-day continents were used instead of triangular continents, the probability would be less than 0.0742 that the present arrangement is random.

This method of obtaining a random distribution of continents was checked in the following way. The same calculation was done for two circular continents of fractional area 0.25 and 0.2 of the earth's surface. The theoretical frequency distribution curve for the antipodal percentage may be calculated for this set of continents and compared with the frequency histogram for the Monte Carlo method (done 2000 times). The two frequency distributions are shown in Fig. 2. A χ^2 test for goodness of fit did not reveal any significant difference between the two distributions.

As I have already quoted, Evison and Whittle (*4*) said that the present antipodal distribution of continents and oceans could easily have been caused by a random process, whereas the results described in this paper show that there is less than 1 chance in 14 that the present distribution has been caused by a random process. Thus there is some disagreement between the two methods.

One factor which Evison and Whittle may not have accounted for fully is the possibility of the continents overlapping each other. They attempted to allow for this, but it is not clear that the method they used was adequate. Their method seems to give a value for the mode (the most likely value) which is too high. For instance, in the case where two circular continents were used, of area 0.25 and 0.2 of the earth's surface, Evison and Whittle's method gives a mode of 75 percent, which is impossible for circular continents (Fig. 2). Even with triangular continents of this size, the *maximum* amount of continent opposite ocean is scarcely greater than 75 percent. Thus Evison and Whittle's method gives a mode which is much too high. In order to check that Evison and Whittle's method gives consistently high readings, a set of Monte Carlo calculations was done for six circular continents of equal size. Each continent was made 0.007, 0.014, 0.028, and 0.056 of the earth's area, in turn. In each of the four calculations, the continents were placed on the sphere 2000 times. The means, medians, and modes were calculated for each. The results are shown in Fig. 3. As can be seen, the most likely value calculated with Evison and Whittle's method becomes progressively larger than the values of the mean, median, and mode from the Monte Carlo method as the size of the continents is increased. It may be concluded that Evison and Whittle's method gives a good estimate of the mean percentage when the total continental area is small, but values which are too large when the continental area is an appreciable fraction of the earth's area.

The conclusion which can be drawn from this work is that there is less than 1 chance in 14 that the present antipodal distribution of continents and oceans is the result of a random process. Thus it appears probable that a nonrandom process, such as the presence of large-scale convection currents in the earth's mantle, has caused the present distribution of continents over the earth's surface.

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References and Notes

1. A. Holmes, *Principles of Physical Geology* (Ronald, New York, ed. 2, 1965).
2. F. A. Vening Meinesz, *Geol. Mijnbouw* **14**, 373 (1952).
3. W. M. Elsasser, "Early history of the Earth," in *Earth Science and Meteoritics*, compiled by J. Geiss and E. D. Goldberg (North-Holland, New York, 1963).
4. F. F. Evison and P. Whittle, *Geol. Mag.* **98**, 377 (1961).
5. R. A. Daly, *The Changing World of the Ice Age* (Yale Univ. Press, New Haven, Conn., 1934).
6. I thank J. D. Mudie for many helpful suggestions. This work was supported by NSF grant GP-4003. Contribution from the Scripps Institution of Oceanography.

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Ciliastatic Components in the Gas Phase of Cigarette Smoke

Abstract. *The gas phase of cigarette smoke, separated into its components by gas chromatography, was passed across a ciliated specimen. The acetaldehyde, acrolein, and hydrogen cyanide produced strong inhibition of the ciliary beat. A filter which removed most of the acetaldehyde and acrolein from smoke did not reduce the inhibitory effect of the gas phase of that smoke, whereas a filter that removed most of the hydrogen cyanide did reduce inhibition.*

The inhibitory effect of cigarette smoke on cilia movement was first demonstrated more than two decades ago. In recent years attempts have been made to identify and eliminate the components of smoke which cause ciliastasis. A number of compounds known to be present in cigarette smoke have been reported to affect the cilia of such animals as rabbits, cows, clams, frogs, and cats. These compounds include the acids, formic, acetic, propionic (*1*), and hydrocyanic (*2*), and the aldehydes, formaldehyde, acetaldehyde, propionaldehyde, acrolein, and crotonaldehyde (*3*).

The activity of a compound when pure is not necessarily its activity in the presence of smoke, as Bernfeld and co-workers (*4*) showed with phenol. They found that while pure phenol vapor showed little or no ciliastatic activity, it was markedly ciliastatic in the presence of smoke. Ideally then, one would like to remove each component of smoke selectively to determine its part in ciliastasis.

The work presented here deals only with the gas phase of cigarette smoke which is separated from the particulate phase by a glass-fiber filter. This work was planned to obtain more information about the ciliastatic components of the gas phase and to determine the changes in activity of the gas phase when some of the ciliastatic agents are selectively removed. (*Ciliastasis* herein means inhibition of the ciliary beat, rather than complete loss of motion.)

The Lamellibranch, *Anodonta cataracta*, which is a freshwater mussel, was chosen as test specimen. For exposure to smoke, 4-mm by 20-mm sections of the reflected lamellae of the inner gill plates were placed in temperature-controlled physiological solutions (*5, 6*). The method for measuring the ciliary beat is well known and is used by many investigators (*5, 7*). A stroboscope was synchronized with the metachronic wave of in vitro mussel cilia permitting quantitative measurement of any change in ciliary frequency. The frequency was measured with an error of less than 1 percent.

The puffing machine, consisting of a stainless-steel piston attached to a motor, drew a 35-ml puff in 2 seconds at a frequency of one puff per minute. It automatically diluted the puff with air to 100 ml and pushed it across the specimen. Eight puffs were taken on each cigarette. The glass-fiber filter used to separate the gas phase from the particulate phase was about 2 mm thick and 45 mm in diameter. Touey has reported that a filter of this type removes 99 percent of the liquid/solid phase of cigarette smoke and that the low-boiling aldehydes and ketones are not retained by the filter (*8*). Since the ciliary beat is sensitive to changes in temperature, the specimen temperature was controlled at 30°C to 31°C by passing water from a constant-temperature tank through coils in the base of the exposure chamber which was mounted on a microscope.

The gas phase was separated into two fractions, condensable gases and permanent gases, distinguished by whether they condense at dry ice/alcohol temperature. To determine the activity of the permanent gases as re-