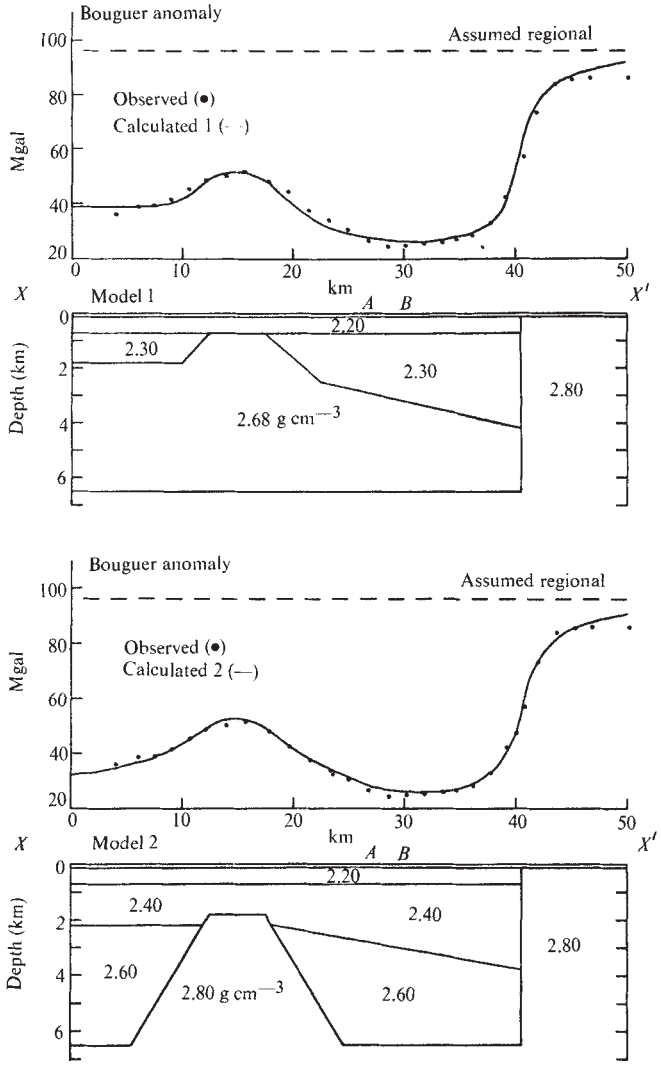

Fig. 5 Gravity profile across "low" *E* (profile *XX'*, Fig. 1) showing the interpretation. Densities are linked to an assumed value of 2.80 g cm^{-3} for the basement.

contrast for layer 2. The densities shown are linked to an assumed basement density of 2.80 g/cm^3 consistent with field measurements on Lewisian rocks[3,4].

The necessary density contrasts and observed seismic velocities support the interpretation of Bott and Watts that the basin probably contains Mesozoic–Tertiary sediments. The maximum thickness of low density sediments is 3 to 4 km which is less than that obtained previously, the gravity field being satisfied with an additional negative contribution from layer 3.

The probable density of layer 3, 2.6 to 2.7 g/cm^3, and its velocity of 4.7 km/s are within the ranges found for Palaeozoic rocks and for Torridonian Sandstone[3,5–7].

The structure of the basin is similar to that of the Cardigan Bay sedimentary basin. Both are probably fault-bounded and are structurally controlled along Caledonian trend directions. In Cardigan Bay, geophysical work[8,9] tied to the Mochras borehole[10] has established layers with seismic velocities of 2.3 and 3.5 km/s and the presence of Mesozoic and Tertiary sediments. The observed 70 mgal anomaly indicates an overall depth of 3.5–6.5 km. Neither the bottom of this basin nor a layer corresponding to the 4.7 km/s layer in the Shetland shelf basin has been detected by seismic methods.

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Atmospheric Ice Nuclei from Decomposing Vegetation

THE sources and the composition of atmospheric ice nuclei (particles initiating the phase transition to ice at temperatures between 0° C and −40° C) are still largely unidentified, chiefly because they make up an extremely small fraction (perhaps 1 in 10^6) of the total atmospheric aerosol and because they are a heterogeneous mixture of substances whose only common property is the ability to nucleate ice.

Oceans and deserts do not seem to make a major contribution, but other naturally occurring substances, such as clays and various soils, have been shown to be moderately good ice nucleators, and extraterrestrial sources may also contribute[1–3]. Various compounds, such as silver iodide and leucine, are effective ice nuclei in the laboratory but their atmospheric abundances are thought to be small. On the whole, no major sources of atmospheric ice nuclei have been identified and it seems especially difficult to explain the presence of nuclei acting in the temperature range between 0° C and −10° C.

Recent tests with derivatives of decaying vegetation suggest that a large source of active atmospheric ice nuclei might have

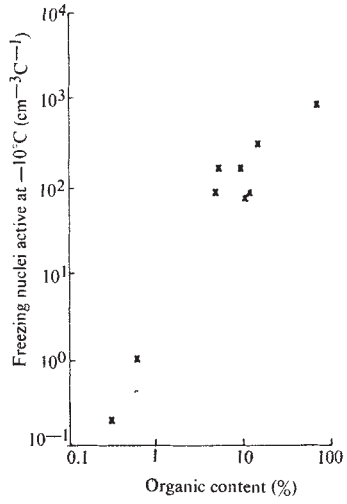

Fig. 1 Correlation of freezing nucleus concentrations with organic contents for sils of different origins.

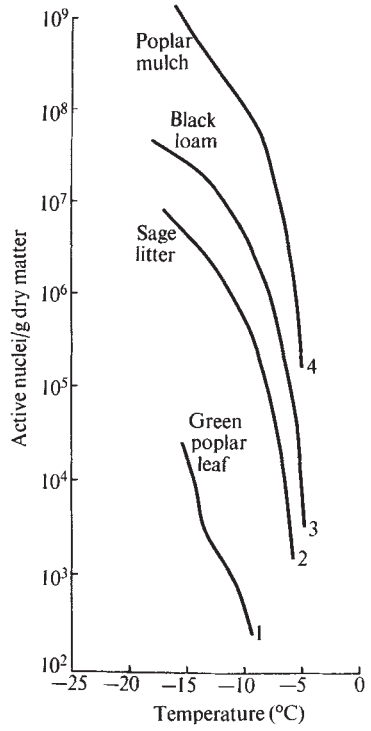

Fig. 2 Freezing nucleus spectra of four different sources. The numbers of nuclei as well as the warmest temperatures of activity increase in going from green leaves (1) to actively decomposing leaves (4).

been discovered. The starting point for this research was the finding[4] that soils having higher contents of organic matter are better nucleators than pure clays or sands. Soil samples from near the surface were found to contain more ice nuclei than samples from a few feet below the surface. Fig. 1 shows the correlation between freezing nucleus content and organic content for a selection of soil samples. Freezing nucleus contents were determined by the method of Vali[5]; the total organic contents were established by the methods of Peach *et al.*[6].

Because the organic contents of soils derive principally from decomposed vegetation, we attempted to trace the evolution of this matter with respect to nucleating ability. Samples were collected from different parts of trees and shrubs and at different times of the year, as well as from old litters that had been on the ground for one or more years. In addition, some leaves were collected, masticated, allowed to decay in the laboratory under either aerobic or anaerobic conditions and examined repeatedly during the decay process. Nucleus contents were determined in each case by immersing a small amount of lightly crushed matter in distilled water (1 part material to 100 parts of water). The solid content was then allowed to settle out and tests were made on the clear water above the sediment. After sedimentation the solid content of the water was estimated to be considerably less than 1 part in 10^4 parts of water. Freezing nucleation tests were run on the University of Wyoming automated nucleus spectrometer.

From the nucleation tests, it is evident that fresh green leaves or other parts of living plants do not provide large amounts of freezing nuclei. At the other end of the scale, the highest concentrations of nuclei were detected in poplar and spruce leaves undergoing active decomposition under aerobic conditions. Anaerobic decomposition leads to the development of considerably lower nucleus contents. Nucleus spectra for typical samples are shown in Fig. 2; it is apparent that the range of concentrations at $-10°$ C, for example, varies by as much as five orders of magnitude among these leaf samples, with the actively decomposing poplar mulch showing the highest activity. For comparison, the concentration of nuclei in purified clays, at $-10°$ C, is generally in the range 10^2 to 10^4 g^{-1}. The results thus clearly indicate that decomposing vegetation is much superior to clays as a source of freezing nuclei and that the nucleating abilities of soils are therefore related to their organic contents and not to their basic mineral constituents. Hence, an explanation for the results shown in Fig. 1 is readily available. Pending closer identification of the active ingredients, the nuclei found in decomposing leaves were termed "leaf-derived nuclei" or LDN.

Perhaps the clearest demonstration that the LDN result from active decomposition emerged from experiments in which nucleus contents were examined at various times during the decay process. Fig. 3 illustrates the results of these experiments; the temperatures at which the nucleus concentrations were 10 and 10^3 cm^{-3} are given for samples that had 1 part of solid to 100 parts of water. Brown and green poplar leaves both exhibited variations in activity during the decomposition process. Most significant is the occurrence of periods of very great activity, as evidenced by the high freezing temperatures of $-1.3°$ C on day 7 for the brown sample and $-2.2°$ C on day 22 for the green sample. The frequency of testing was insufficient in these experiments to pinpoint the changes in activity with greater detail. For nuclei derived from old well-decomposed litters, no change was apparent during a very long period of testing. The indication provided by these results is that the nuclei are by-products of active bacterial decomposition.

Can LDN contribute to atmospheric populations of ice nuclei? Mechanical contact between a clean surface and dry poplar litter was found to result in considerable numbers of active nuclei on the surface even though no visible residue was evident. Evaporation to dryness of water extracts has shown that essentially all activity remains in the dry residues. The materials constituting the LDN were also found to be volatile; heating of dry litters to temperatures somewhat in excess of 100° C and exposing a clean surface to these vapours resulted in high ice nucleation activity in the condensate on the surface. Hence, it appears that either mechanical lifting of aerosols (derived directly or by water extractions) or recondensation of vapours from the tree litters could lead to atmospheric ice nuclei.

These results refer mainly to litters from spruce and poplar trees. These are among the most abundant genera, especially

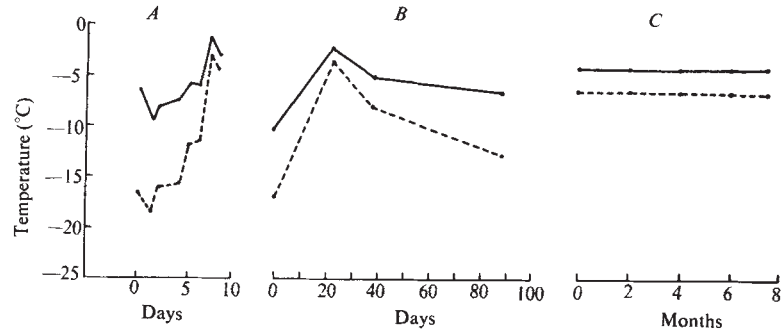

Fig. 3 Time variations of nucleus contents for poplar leaves which were brown (*A*) and green (*B*) when collected and for litter of earlier years (*C*). The points represent the temperatures at which the nucleus concentrations of water suspensions had indicated values. ——, $K=10$ cm^{-3}; - - -, $K=10^3$ cm^{-3}. .

at mid-latitudes, and were selected for testing for that reason. But work now in progress indicates that our findings are not restricted to the two species mentioned but are quite probably much more general in nature.

Decomposing vegetation is a common and extensive constituent of the surface coverage of the Earth. Because of the great abundance of nuclei that these materials provide, decomposing vegetation may indeed be an important source of atmospheric ice nuclei. The warm temperatures at which the LDN are active are remarkable because such very active nuclei are of pronounced importance for many precipitation processes. A further possibility is that LDN might become useful for artificial cloud seeding instead of silver iodide which is in common use today. The activities shown in Fig. 2 are about 10^3 lower than those typically reported for silver iodide seeding generators, but it must be recognized that the magnitudes given in Fig. 2 refer to the unrefined bulk leaf matter, of which only a minute fraction acts as freezing nuclei. By separation or by manufacturing (after identification) of the active ingredients, activities exceeding those of silver iodide are almost certain to be reached. The use of such natural substances for cloud seeding would be far preferable than the use of even mildly toxic heavy metals.

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Lowering of the Saturation Solubility of Oxygen by the Presence of Another Gas

THE solubility properties of gas mixtures dissolved in water have been much neglected in spite of the importance of the role of dissolved gases to a wide range of ecological and physiological problems. It has been generally accepted that for a gas mixture the variation of the solubility of each component with pressure can be fairly well estimated using the Henry's law relationship. It is quite generally assumed that the presence of a second gas does not affect the saturation solubility value.

Our results do not support this assumption. Fig. 1 shows the saturation solubility diagram for an oxygen–nitrogen mixture. The data are measured at 25.00° C and at a total pressure of 1 atmosphere. The actual amount of gas dissolved in a 1 cm³ sample of the saturated water was measured using a helium-stripping gas chromatographic technique. It is seen that the saturation solubility of each gas is depressed well below the expected Henry's law line. The lowering of the saturation solubility of oxygen is by 25% at $P_{O_2}=0.25$, 26% at $P_{O_2}=0.5$ and 12% at $P_{O_2}=0.75$. A similar mutual lowering of saturation solubility is observed for O_2–CH_4 and N_2–CH_4 mixtures.

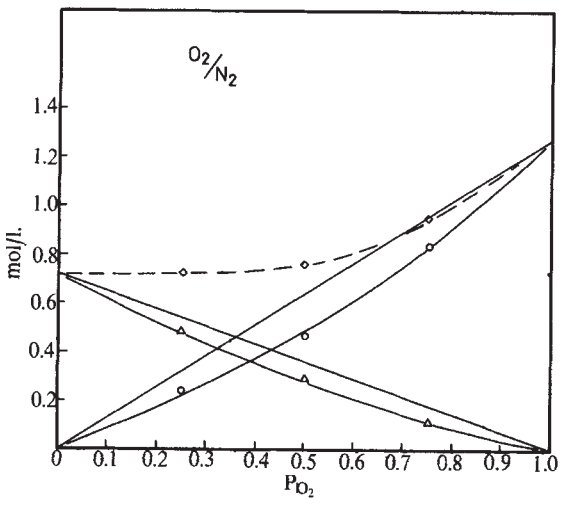

Fig. 1 Saturation solubility curves for O_2 and N_2 gas mixtures at various partial pressures of O_2 at a total pressure of 1 atmosphere. Data at 25.00 (±0.01°) C. Solvent, water. ○, Oxygen solubility (mol/l.); △, nitrogen solubility (mol/l.); ◇, total mol/l. solubility.

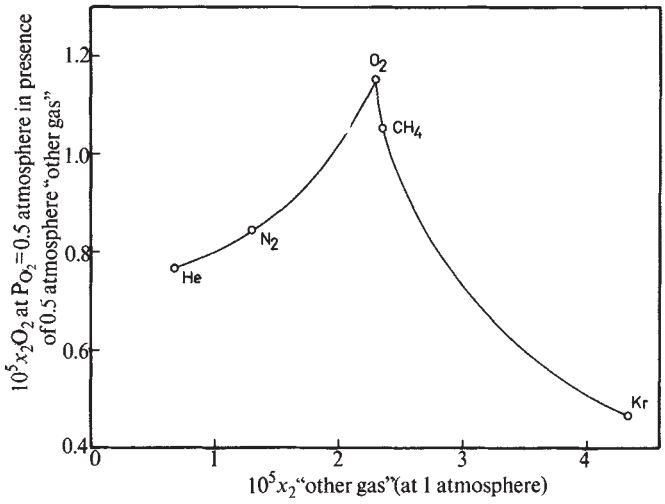

Fig. 2 Dependence of saturation solubility of oxygen (at 0.5 atmosphere partial pressure in mixture with "other" gas at 0.5 atmosphere partial pressure) on the saturation solubility of "other" gas (as pure gas at 1 atmosphere pressure). Data in water solvent at 25.00° C.

The depression of oxygen saturation solubility is of particular interest and Fig. 2 is a plot of the saturation solubility of oxygen at 0.5 atmosphere partial pressure, as a function of the saturation solubility of the second gas when dissolved in water as a pure gas at 1 atmosphere. Both gases more soluble than oxygen (saturation mol fraction solubility as pure gas at 1 atmosphere ($\chi_2=2.31\times10^{-5}$)) and gases less soluble than oxygen cause a lowering of oxygen saturation solubility. Thus, helium ($\chi_2=0.68\times10^{-5}$) depresses the saturation solubility from the expected Henry's law value by 34% and krypton ($\chi_2=4.32\times10^{-5}$) by 60%.

We emphasize that the reported data are for a total gas pressure of 1 atmosphere and at an oxygen partial pressure of 0.5 atmosphere. The inference of the effect of the "other gas" depressing oxygen saturation solubility as an alternative theory for non-reactive gas anaesthesia is worthy of note. Further studies at lower oxygen partial pressures and at higher pressures of the "other" gas are being made.

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