up 20 percent of the total foraminiferal assemblage. Benthonic Foraminifera make up 3 percent of the Pleistocene foraminiferal assemblage. *Inoceramus* prisms and echinoid spines were present. Cretaceous forms make up 80 percent of the foraminiferal assemblage.

Between 4 and 8 cm, Cretaceous microfauna, mixed with Pleistocene microfauna, were present.

At 8 to 240 cm, the following planktonic index fossils were seen: *Globigerinelloides eaglefordensis, Hedbergella brittonensis, Hedbergella delrioensis, Guembelina complanata, Guembelina globulosa* (*4*). Benthic Foraminifera make up 3 to 4 percent of the washed foraminiferal fauna. In addition, Ostracoda, Radiolaria, *Inoceramus* prisms, coccolithophorid plates, and echinoid spines were identified.

Variation with depth in the amount of the coarse fraction of sediment (Fig. 1) suggests conditions different from the present at the time of deposition of the old sediments. The high percentage of fine fraction in the old sediments is characteristic of deposits in deep and broad basins remote from strong bottom currents. The presence of manganese nodules and the larger percentage of coarse fraction (Fig. 1) of recent sediments are due to removal of the finer fraction by bottom currents (*5*). The induration of the old sediments is probably due to compaction under a former sediment cover and not cementation (*6*). If the stratigraphic unconformity is due to slumping of sediments which occurred as a result of local instability triggered by post-Paleocene tectonic uplift, then the missing sediments might be recovered on the slopes of the rise (*7*).

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Ozone Damage: Protection for Plants

Abstract. *Tobacco plant leaves treated with dried particulate charcoal, diatomaceous earth, and powdered ferric oxlde so that a covering formed on the leaves were relatively undamaged by comparison with untreated controls when exposed to as much as 0.9 part of ozone per million in the atmosphere. A theory is offered to explain the results.*

Ozone in the atmosphere can damage plant leaf structure. Pathological lesions on the upper leaf surfaces and premature falling of leaves occur on grape vines in areas polluted by airborne ozone. The damage is designated as ozone stiple of grape leaf (*1*). The leaf stiple occurs in the vicinity of Los Angeles and San Francisco, areas where the concentration of ozone is high. In Connecticut and Massachusetts (*2*) weather fleck of tobacco has been identified with ozone injury. In New Jersey ozone damage has been observed on spinach, alfalfa, cereals, red clover, beans, parsley, and grapes (*3*). Many species of common plants can be readily injured by exposure to ozone. Certain compounds, utilized as fungicides, can protect tomato foliage in the field from damage apparently caused by excessive atmospheric ozone (*4*). Other chemical agents preventing ozone damage have been used in an experimental program to impregnate field tents for shade-grown tobacco (*4*). These "antiozonants" apparently protect the tobacco and tomato plant by destroying the ozone in the atmosphere surrounding the plants.

The polyvalent metals such as iron, cobalt, nickel, manganese, chromium, vanadium, and the platinum metals are excellent catalysts for the destruction of peroxides. In this case, I believe that the shade cloth was effectively treated with polyvalent metal ions which were responsible for the catalytic decomposition of the ozone. If one considers the reactions

$$O_3 \rightarrow O_2 + O \qquad \Delta H_1 = 24.1 \text{ kcal} \qquad (1)$$

$$M + 2O \rightarrow O_2 + M \qquad \Delta H_2 = -116.4 \text{ kcal} \qquad (2)$$

it becomes apparent that it is undesirable to have these reactions taking place directly at the surface of the leaf. ΔH is the heat of reaction and M is a third body.

Instead, it would be desirable to decompose the ozone at some distance away from the leaf surface. The endothermic decomposition of ozone by Eq. 1 is well known. The exothermic formation of oxygen molecules, according to Eq. 2 yields 116.4 kcal/mole. It would be undesirable to have the oxygen atom recombination of Eq. 2 take place directly on the leaf of the plant, since the reaction is a three-body collision in which the leaf surface could be the third body. This exothermic reaction would be expected to burn the leaf and to produce lesions.

In view of this theory, some further experiments were made on the effect of using finely powdered material such as diatomaceous earth, powdered charcoal, powdered ferric oxide, and other particulates as dispersions that would be reasonably effective catalysts for the decomposition of ozone. Such particulate matter, sprayed on the plants and dried, would produce an extremely high surface to volume ratio of catalytic surface substance, capable, by heterogeneous catalysis, of destroying the ozone at some distance from the surface of the plant leaf, so that the heat of reaction of Eq. 2 would leave the surface of the catalyst by radiation.

A glass-lined cube-shaped chamber for experimental fumigation, approximately 3 feet on edge, was equipped with an air-exhaust fan, a Welsbach-type of ozone generator, and flow meters for regulating the ozone concentration in the air at room temperature. Clean air was introduced into the chamber through a carbon filter; a hydrating device maintained the air humidity in the fumigation chamber at approximately 60 to 70 percent. The concentration of ozone was measured continuously and recorded by a potassium iodide–ozone measuring meter. The flow rate of gas to the chamber was

Table 1. Protection of plants by particular agents from damage by ozone. Injury scale: none, N; slight, S; moderate, M; heavy, H.

Protectant	Injury
3¾ hours at 0.4 part O_3 per million	
Diatomaceous earth	N–S
Charcoal	N–S
Fe_2O_3	N–S
Tulare clay	S
S	S
Kaolin	S
None	H
3½ hours at 0.9 part O_3 per million	
Diatomaceous earth	S–M
Fe_2O_3	N–S
Charcoal	N–S
Tulare clay	S
Kaolin	S
S	M
None	H

approximately 27 ft^3/min; this rate caused a change in atmosphere in the chamber in about 1 minute. The general test procedure was to select plants of a specific variety of uniform age and condition, to spray them with test solutions, to allow them to dry for 1 hour, and then to place them in the fumigation chamber. Before placing the plants in the chamber, the air was brought to a constant ozone concentration. After exposure to the ozonized air for a specific period of time, the plants were removed and placed in a greenhouse for observation.

After preliminary work, experiments were made on tobacco plants (*Nicotiana glutinosa*) about 8 weeks old and with only the upper six fully expanded leaves left on the plant. One-half of each leaf (right hand on two replicates and left hand on two replicates) was painted with a dispersion (2 percent by weight) of a solid catalyst under test and air dried. Four drops of a wetting agent (polyethylene sorbitan monooleate) were used in each 500 ml of solution. The dispersion was shaken and dabbed on one-half of each leaf, top and bottom, with disposable paper tissue. The dry particles tested were powdered sulfur, kaolin, diatomaceous earth, powdered clay from Tulare County, powdered ferric oxide, and powdered charcoal (Norit A); they were of a size that passed through 325-mesh screen.

Four experiments were performed where six plants were exposed to ozone in the fumigation chamber. Six leaves on each plant were treated by the systematic Latin square method. In this manner the effects of orientation and age of the leaf on the plant were minimized. In the final experiments a second measurement of ozone concentration was made by passing the exhaust gas from the chamber through a long-path (40 meter) Perkin-Elmer No. 21 infrared spectrophotometer. Before placing the plants in the chamber, the air was brought to a constant ozone concentration. After exposure to the fumigating atmosphere for a specific period of time, the plants were removed and placed in the greenhouse for recovery and observation. Typically, lesions resulting from the ozone were sometimes visible at the end of the fumigation period, at high ozone concentrations. At lower ozone concentrations, the lesions were readily visible the next morning.

The experimental results (Table 1) clearly indicate that diatomaceous earth, powdered charcoal, and powdered ferric oxide are excellent particulate protectants against ozone damage. At the typical ozone concentrations likely to be found in the field, clay—as exemplified by Tulare clay—is also effective.

Thus plants can be protected by a heterogeneous catalyst sprayed or dusted on the plant which will promote the decomposition of ozone at a regulated distance above the actual surface of the leaf (*5*).

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Groundwater: Flow Toward an Effluent Stream

Abstract. *Hydrodynamic, topographic, and geologic factors control flow of groundwater toward an effluent stream. Features of such flow are illustrated by a hydraulic model that simulates the stream and surrounding consolidated rocks. Colored ink in the flow system marks progress toward the stream. Visual analysis shows that groundwater moves into the effluent stream along curvilineal flow lines. The total head of groundwater beneath the stream increases with depth.*

One of the most interesting groundwater flow-patterns in nature occurs in the vicinity of an effluent stream, a stream which is supplied by the surrounding groundwater. Legal disputes have arisen from misinterpretation of information about the flow patterns near such streams. Water levels in wells drilled along an effluent stream can be higher than the water level of the stream, and this fact has been submitted as evidence that groundwater and surface water are not connected (*1*). Once established as a fact in court, a decision can be obtained in some states that action taken upon the groundwater body cannot possibly have any effect on the surface water body. Such a stand may be taken by a groundwater user to prove that pumping cannot deplete surface water. A groundwater user could similarly argue that he cannot contaminate surface water by discharging waste into his well. Results derived from a hydraulic model, analogous to the geologic setting commonly found near an effluent stream, show that such arguments in many cases may be spurious. Only by adequate definition of both the geology and hydraulics near the stream can the courts render sound judgment on such matters (*2*).

The model (Fig. 1) consists of a watertight plexiglass case containing a porous consolidated mixture of sand and epoxy resin (*3*). It is 30 inches long, 1 inch thick, and 12 inches high at each end and slopes down to a small channel near the center. The channel represents the cross section of the effluent stream. Ink was discharged into the model through a perforated brass tube buried in each end. The ink entering the sand progresses through it and marks the path of flow, or flow line, from each perforation. Water was recharged into both ends and discharged only from the simulated stream. The water table nearly coincided with the rock surface on either side of the stream. Figure 1 indicates the general direction of flow at several times after the flow of ink was started.

The flow lines turn up near the center and appear to defy gravity. Although the water is definitely flowing upward topographically, it is flowing downward hydraulically in accordance with physical principles. Groundwater always moves from regions of high hydraulic head to regions of low hydraulic head.

The effluent stream may be compared with a horizontal well. In a man-made well, an area of low head is produced by pumping and the groundwater thus flows from the surrounding areas of high hydraulic head to the region of lower head near the well. The effluent stream is also an area of low head, but the head distribution about the stream is a function of the topography and rainfall which have caused a high water table to form; a region of high hydraulic head surrounding the topographically low-stream channel is thus furnished. Consequently, water moves from the adjacent highland into the stream.

Figure 2 shows the flow diagram of