mately 12 cm deep and 20 cm wide. This was clearly a penetration pit crater, which indicates a very low terminal velocity for the meteorite. There were no reports of craters that might be explosion craters. The reports of the trajectory from local observers were contradictory, and establishing the approximate path of the bolide will probably have to wait until a large number of observers can be interviewed.

In hand specimens, the meteorite appears homogeneous from piece to piece, dark grey, with many obvious chondrules averaging approximately 2 mm in diameter but ranging to as much as 13 mm. Most specimens are hard and not readily friable except where badly fractured by impact or subsequent handling. On fractured surfaces, approximately 60 percent of the chondrules are broken through, but the remainder have nicely preserved hemispherical surfaces. The general appearance is similar to Mokoia or Vigarano, but the color is slightly lighter grey. The bulk density measured by air-comparison pycnometry is 3.67 g/cm^3.

Petrographic thin and polished sections show less than 1 percent metal and an estimated overall average of 60 percent chondrules and 40 percent matrix. In standard thickness sections, much of the matrix is opaque (Fig. 1, a–c) with some transparent microcrystalline matrix. However, in sections 0.01 mm thick (Fig. 1d) a much greater proportion of the matrix can be seen to be microcrystalline. X-ray diffraction patterns from bulk samples and nonmagnetic fractions have well-defined narrow olivine peaks, indicating relatively homogeneous olivine composition. Clinopyroxene is abundant, and there is a small amount of turbid glass. Chondrules are mostly well-defined to sharply defined. Pueblito de Allende would seem to best fit petrologic type 4 but seems to have many affinities for type 3 also (*1*). Detailed petrographic and mineralogic description is now in progress, and will be the subject of a later paper which should resolve this question.

Preliminary analytical information (Table 1) is sufficient to establish that Pueblito de Allende is a C group chondrite (*1*) based on the possible values of the ratio of metallic iron to total iron and of total iron to silica. The petrographic and chemical data now available indicate that the specimen should be classified as a C4 or C3.

Table. 1. Chemical analyses of the Pueblito de Allende meteorite.

Oxide or element	Optical emission spectrograph * (wt %)	Atomic absorption † (wt %)	Spectrophotometric ‡ (wt %)
SiO_2	31.0		33.35
MgO	21.3	20.7	
FeO (total Fe)	31.9		28.9
Al_2O_3	2.9		3.75§
CaO	2.8	2.35	
Na_2O	0.60		
K_2O	0.01	0.093	
TiO_2	0.17		
MnO	0.14		
Ni	1.40		
Cr	0.32		
C	0.27¶		
N	0.007¶ 0.0055¶		
Co	0.79		
Zr	0.0036		
B	0.010‖		
Cu	0.008		

* Monitored with W-1 and a synthetic dunite standard; analyst: R. Martin. † Analysts: J. Allen and P. Johnson. ‡ Analysts: D. Bennett and P. Johnson. § Probably high due to iron interference. ¶ By combustion and chromatographic detection; analyst: C. Moore. ‖ Sample was prepared by grinding in a boron nitride mortar, but standards did not show contamination.

One of the prime objectives of obtaining portions of this fall was to return suitable specimens to the Lunar Receiving Laboratory Radiation Counting Facility for total gamma and gamma-gamma coincidence spectrometry as quickly as possible in order to make analyses for isotopes with short half-lives (*2*). The 4180-g specimen was introduced into the gamma counter, and data was taken at 6:16 a.m. on 12 February, an elapsed time from fall to counter of approximately 101 hours. The other two large specimens (1259 and 782 g) are also being counted.

We believe that we have identified the following isotopes: U (Bi^{214}), Th (Tl^{208}), K^{40}, Al^{26}, Co^{60}, Na^{22}, Mn^{54}, and Na^{24} (half life = 15.0 hours). In addition, the following isotopes are tentatively identified: Be^{7}, Mn^{52} (half life = 5.7 days), Co^{56}, and Cr^{51}. Several peaks appear in the spectra that have not yet been identified. Data collection and evaluation is continuing in order to confirm the identification of the above isotopes and to obtain less complex spectra after the decay of the short-lived isotopes. A detailed evaluation of the gamma spectra from this meteorite is the subject of continuing work and will be reported later.

The counting of samples of short terrestrial age such as Pueblito de Allende is an excellent rehearsal for the Lunar Receiving Laboratory Radiation Counting Facility, because it is probable that many of the same isotopes will be present in the samples to be returned from the moon by the Apollo project.

The size of the total fall around Pueblito de Allende is an interesting subject for speculation. All of the specimens recovered prior to 11 February came from obvious places, such as small towns, roads, and very close to houses, and these specimens collectively weighed approximately 27 kg. Based on the geographic distribution of finds, it is estimated that the area of the fall covered at least 150 km^2, and it is reasonable to expect that many more specimens will be recovered from surrounding desert areas.

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1. W. R. Van Schmus and J. A. Wood, *Geochim. Cosmochim. Acta* **31**, 747 (1967).
2. Rapid recovery of specimens and data would not have been possible without excellent cooperation from local authorities and individuals. Ruben Rocha Chavez, editor of *Correo del Parral*, was very helpful in locating the sites of falls and persons who had fragments. The Municipal President of Hidalgo del Parral, Carlos Franco, extended every official courtesy and gave considerable support to efforts to obtain new specimens. Ing. Manuel Gomez deserves special thanks for his hospitality and help in guiding, interpreting, and helping in the acquisition of specimens. Dr. Carleton Moore's rapid response in providing analyses for carbon and nitrogen is very much appreciated.

18 February 1969

Evaporation Retarded by Monolayers

Abstract. *The reduction in the steady-state rate of evaporation of water by hexadecanol monolayers depends only on the air velocity above the surface and is independent of the absolute rate of evaporation up to air velocities of 40 centimeters per second. This indicates that the monolayer does not affect the vaporization step but increases the size of the diffusion boundary layer. The mechanism (the creation of a surface pressure gradient in the monolayer which reduces the net stress on the surface by the air) is discussed.*

The reduction in the rate of evaporation of liquids by monolayers is of theoretical as well as practical interest (*1*). In discussion of the role of the monolayer, it is useful to consider the sequence of steps in the evaporation process as follows:

$$\mathrm{A} \overset{\text{adsorption}}{\rightleftarrows} \mathrm{B} \overset{\text{vaporization}}{\rightleftarrows} \mathrm{C} \overset{\text{diffusion}}{\rightarrow} \mathrm{D} \overset{\text{convection}}{\rightarrow} \mathrm{E}$$

Here, $A \rightleftarrows B$ represents the equilibrium between liquid molecules in the bulk and in the surface. The establishment of this equilibrium would be expected to be very rapid. It is considered not to be influenced by the presence of a monolayer, since this would lead to changes in the surface tension, which have not been observed. The expression $D \rightarrow E$ stands for the transport of vapor molecules by convection at the edge of the boundary layer; $C \rightarrow D$ is the molecular diffusion of vapor through a diffusion boundary layer. Generally, the evaporation rate (v) is equal to the rate of this diffusion step and may be described by the equation

$$v = \frac{D\,(C_0 - C)}{\delta} \qquad (1)$$

where D is diffusion coefficient, δ is the effective thickness of diffusion layer, and C_0 and C are concentrations at the two surfaces of the diffusion layer. From measurements of the temperature gradient near an evaporating surface it has been inferred (*2*) that monolayers of hexadecanol influence the magnitude of δ. However, in view of the difficulty in measuring temperature gradients precisely and of the fact that the diffusion and thermal boundary layers need not always be identical, it cannot be concluded with certainty that this is the only role of the monolayer in evaporation reduction.

Many favor the idea that monolayers influence evaporation by means of an interfacial barrier; that is, by retarding the vaporization step $B \rightarrow C$ in the equilibrium $B \rightleftarrows C$ established between water molecules in the surface and an adjacent layer of vapor molecules. However, experiments have demonstrated (*3*) that multimolecular films (~1 μ thick) are required to provide a significant barrier for diffusion of molecules from the liquid to the vapor. If a monolayer were to retard step $B \rightarrow C$, then the rate of evaporation in the steady state could still be described by Eq. 1, except that C_0 would now have a value below the equilibrium vapor concentration. The retarding effect of the monolayer in this hypothetical case would then depend on the rate of step $C \rightarrow D$ and would vary according to the conditions, becoming zero when step $C \rightarrow D$ is made sufficiently slow (*4*).

Table 1. Retardation of evaporation by hexadecanol as a function of air velocity and relative humidity.

U_0 (cm/sec)	Conditions	Relative humidity (%)	v (g cm^{-2} sec^{-1})	Reduction by monolayer (%)
0	No monolayer	20	1.49×10^{-6}	
		80	3.67×10^{-7}	
	Hexadecanol	20	1.06×10^{-6}	28.8
		80	2.62×10^{-7}	28.6
75	No monolayer	25	7.15×10^{-6}	
		89	1.03×10^{-6}	
	Hexadecanol	25	3.70×10^{-6}	48.2
		89	5.34×10^{-7}	48.2
240	No monolayer	25	1.71×10^{-5}	
		90	2.23×10^{-6}	
	Hexadecanol	25	6.02×10^{-6}	64.8
		90	8.08×10^{-7}	63.8
390	No monolayer	25	2.55×10^{-5}	
		89	3.66×10^{-6}	
	Hexadecanol	25	8.21×10^{-6}	67.8
		89	1.19×10^{-6}	67.5
480	No monolayer	24	4.04×10^{-5}	
	Hexadecanol	24	1.28×10^{-5}	68.3

A simple test may be carried out to determine which step a monolayer is affecting when it retards the evaporation rate. If water is the liquid, the amount of retardation caused by the monolayer is measured under several different conditions of forced convection at one value of the ambient relative humidity, and the series of experiments is repeated at another value of the relative humidity, sufficiently different to appreciably alter the absolute rates. If the monolayer alters the evaporation rate by affecting the vaporization step only, then the percentage of retardation should depend on the absolute rate of evaporation and not on the conditions, whereas if it affects the diffusion layer, the retardation should depend on the hydrodynamic conditions and be independent of the absolute rate. If both mechanisms operate, an intermediate result would be expected.

An oven with temperature controlled at 20° ± 0.2°C and equipped with an electric fan whose speed was regulated by means of a Variac was used. The air velocity (U_0) about 3 cm above the sample surface was measured with a flowmeter (Lambrecht No. 640), inserted through a hole in the top of the oven. The lower relative humidity (~ 25 percent) was maintained with large trays of calcium chloride placed in the oven; the higher relative humidity (~ 89 percent) by use of trays of approximately 3 *M* potassium chloride solution (surface area, ~ 900 cm^2). The relative humidity inside the oven was measured with a Lambrecht direct-reading hair hygrometer viewed through a perspex window in the top of the oven. Evaporation rates were measured in aluminum trays (9.0 cm square) whose edges were rounded for streamlining; the top edges and outside of the tray were thinly coated with paraffin wax to prevent spillage. For each measurement, the tray was filled with water to within about 1 mm of the top, placed in posi-

Table 2. Effect of hexadecanol monolayers on boundary layer properties.

U_0 (cm/sec)	Conditions	δ (cm)	δ_0 (cm)	τ (dyne cm^{-2})
75	No monolayer	0.46	0.41	3.3×10^{-2}
	Hexadecanol	0.89	.79	1.7×10^{-2}
240	No monolayer	0.19	.23	1.9×10^{-1}
	Hexadecanol	0.54	.65	6.8×10^{-2}
390	No monolayer	0.13	.18	4.0×10^{-1}
	Hexadecanol	0.40	.55	1.3×10^{-1}
480	No monolayer	0.08	.16	5.5×10^{-1}
	Hexadecanol	0.26	.52	1.7×10^{-1}

tion on a copper block in the path of the air current, and allowed to stand for 30 minutes in order to attain steady-state conditions. It was then taken out and quickly weighed in an analytical balance weighing to 0.0001 g (*5*). Weighings were repeated at intervals of approximately 60 minutes. Monolayers of hexadecanol were spread at their equilibrium spreading pressure by addition of a small excess of crystals to the surface.

The retardation of evaporation by the hexadecanol monolayer is the same under comparable conditions of convection and is independent of the absolute rate of evaporation (Table 1). Thus, for these experiments, the hexadecanol monolayer produces no barrier to the vaporization step and exerts its effect by altering the hydrodynamic boundary conditions.

When air is passed over a liquid surface, there is always some movement of the surface as a result of the net stress due to the air. If a sufficiently incompressible monolayer is placed on the surface, the stress (τ) due to the moving air compresses the monolayer, producing a surface-pressure gradient ($d\pi/dx$) which opposes the stress. The back stress of the monolayer reduces the net stress on the surface (*6*) and therefore consequently increases the size of the boundary layer.

The highest air velocity (U_0) in these experiments was 480 cm/sec so that, at a value of 0.15 for the kinematic viscosity (ν) of air at 20°C, the highest value of the Reynolds Number ($\mathrm{Re} = U_0 \cdot x/\nu$) calculated at the far end of the tray ($x = 9.0$ cm) is 29×10^4. Laminar flow may therefore be assumed in all the experiments.

Values of δ were calculated from Eq. 1 (Table 2). For the experiments without monolayers, the average thickness of the hydrodynamic boundary layer δ_0 which occurs at about $x = 3.8$ cm, was calculated from (*7*)

$$\delta_o = 4.64\ \mathrm{Re}_x^{-1/2}\ x \qquad (2)$$

Corresponding values of δ_0 for the experiments with monolayer covered surfaces were calculated by assuming δ to be proportional to δ_0 at a given air velocity (*8*). Finally, the net stress on the surface (*9*) was calculated from

$$\tau = \eta\ (U_o/\delta_o) \qquad (3)$$

where η is the viscosity of air (1.83×10^{-4} poise at 20°C).

If no net flow of the monolayer occurs under steady-state conditions, $\tau = d\pi/dx$. Thus, from the data in Table 2; it is seen that remarkably small surface pressure gradients can cause significant changes in boundary layer properties and consequently evaporation rates. The condition of no net flow is probably approached more closely by highly incompressible monolayers, thus explaining the effectiveness of these in reducing evaporation (*10*). More measurements of surface pressure gradients and flow patterns of monolayers in wind tunnel experiments would help considerably in the understanding of the effectiveness of different monolayers in reducing evaporation.

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2. F. MacRitchie, *Nature* **218**, 669 (1968).
3. R. W. Powell, *Trans. Faraday Soc.* **39**, 311 (1943).
4. Thus, the "specific evaporation resistance" which has often been calculated for monolayers is not a material property as, for example, the specific electrical resistance of a metal. In fact, where a reaction sequence involves one or more equilibrium steps, as occurs in mass transport across interfaces and through membranes, the analogy with a simple electrical circuit breaks down and the calculation of resistances for different steps from kinetic data becomes of dubious validity.
5. This method of measuring evaporation rates is considered superior to that originally introduced by Langmuir and Schaefer [I. Langmuir and V. J. Schaefer, *J. Franklin Inst.* **235**, 119 (1943)]. It is easier to treat theoretically since it is essentially evaporation into a semi-infinite reservoir from an accurately known surface area. The conditions can also be varied more easily. The Langmuir-Schaefer method is complicated by the geometry of the system and by the introduction of additional diffusion and temperature gradients due to the presence of the absorbent. Steady-state conditions are therefore more difficult to attain.
6. J. T. Davies and E. K. Rideal, *Interfacial Phenomena* (Academic Press, London, 1961), p. 268.
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8. V. G. Levich, *Physicochemical Hydrodynamics*, Scripta Technica, Inc., Trans. (Prentice-Hall, Englewood Cliffs, N.J., 1963), p. 59.
9. The assumption of a linear velocity gradient is an approximation and will give only rough values for the shear stress.
10. For certain surfactant films, it has been shown [L. F. Mockros and R. B. Krone, *Science* **161**, 361 (1968)] that a balance between the net stress on the surface and the back stress due to the film cannot necessarily be assumed owing to flow of the film.

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Synaptic Activation of an Electrogenic Sodium Pump

Abstract. *An identified molluscan interneuron mediates different cholinergic synaptic actions by increasing the conductance of its follower cells to different ions. We have now found that this interneuron also mediates a new class of synaptic actions which does not involve a conductance change but the activation of an electrogenic sodium pump. This synaptic action results in a prolonged inhibitory synaptic potential which is dependent on metabolism and is selectively blocked by cooling and ouabain. In cells which have this synaptic potential, part of the resting membrane potential is also maintained by an electrogenic sodium pump. The same transmitter, acetylcholine, can independently stimulate both a chloride ion conductance and a sodium pump mechanism in the same follower cell by acting on two different postsynaptic receptors.*

The established mechanisms of chemical synaptic transmission involve an increase in the conductance of the postsynaptic membrane to one or more ion species which then move down their concentration gradients without requiring metabolic energy (for review, see *1*). Nishi and Koketsu (*2*) have recently suggested the existence of a new class of chemical synaptic transmission which is metabolically dependent and involves the activation of an electrogenic Na^+ pump. Their conclusions were based on studies of the slow inhibitory postsynaptic potential in the frog sympathetic ganglion using a sucrose gap technique for recording the activity of populations of nerve cells. However, the conclusions of Nishi and Koketsu have recently been challenged by the more direct studies of Kobayashi and Libet (*3*) using intracellular recordings. We now present independent evidence for the synaptic activation of an electrogenic Na^+ pump based on intracellular recordings from individual identified cells in the abdominal ganglion of the marine mollusc, *Aplysia*. Furthermore, our data indicate that the same transmitter, acetylcholine, can independently stimulate both the conductance and the Na^+ pump mechanisms for synaptic transmission.

An identified interneuron (cell L10) in the abdominal ganglion of *Aplysia californica* mediates three different synaptic actions—excitation, inhibition, and conjoint excitation-inhibition—via dif-