To test this prediction, we used the avoidance response because it is the easiest of the three nonlight responses to measure. Because it is necessary to obtain a net increase in growth to test a substrate-limitation model, a simple bending response is not adequate. This arises from the fact that a decrease in growth on one side would also cause an increase in bending with no increase in net growth. A way around this dilemma is to place a double barrier around the sporangiophore and observe the growth response when both sides of the sporangiophore are trying to grow away from their respective barriers. A transient growth response (referred to as an avoidance growth response) occurs when a steadily growing sporangiophore is either inserted into a capillary or between glass cover slips 2 mm apart (*5*). This growth response is very similar to the light growth response except that the initiation of the response often occurs in less than 1 minute. This is quite unlike the light growth response which never begins before 2.5 minutes and often as late as 3 minutes after the stimulus.

We were first interested in whether a series of double-barrier stimuli would give a series of avoidance growth responses (Fig. 1). The apparatus for observing the change in growth rate was an optical comparator (*6*). A double barrier consisting of two glass cover slips 2 mm apart was placed around the sporangiophore by a trolley-like device, and changes in growth rate were recorded with the comparator. The placement of the barrier was from the side and normal to the direction of observation. There is a transient growth response with essentially no significant latent period. Removal and reinsertion of the double barrier causes a second similar response as does the third removal and insertion.

We were then interested in whether the avoidance growth response occurred during a period when a light stimulus gave no light growth response (Fig. 2). The stage IV sporangiophore was given a large increment (step-up) from 0 to 82 mw/cm$^2$ by means of an argon laser (488 nm). After 10 minutes the light was shut off for 2 minutes and then a second stimulus of 30 seconds was given. There was no response. None was expected since the sporangiophore was still light-adapted, and, at these very high intensities, the light-receiving mechanism was fully saturated (*7*). If the second stimulus was an avoidance stimulus resulting from a double barrier, there was an avoidance growth response (Fig. 2).

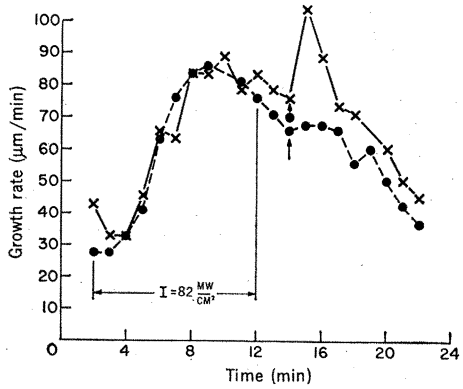

Fig. 2. The dotted line represents the control with a 10-minute stimulus given at an intensity of 82 mw/cm$^2$ followed by 2 minutes in the dark and then by a 30-second light stimulus at the same intensity indicated by the upward arrow ↑. The solid line represents results of the same experiment except that after 2 minutes in the dark a double barrier is inserted around the sporangiophore.

Thus, even after a light stimulus, saturating in intensity, the organism still has the ability to grow faster. Additionally, the avoidance stimulus acts either at some point between the light-receiving mechanism and the final response or on an independent parallel branch.

The technique of saturating one sensory pathway of an organism to a point where it no longer responds to that stimulus but does respond to another type of stimulus is a classic test for habituation. Accordingly, a saturating light stimulus habituates *Phycomyces* to a light stimulus but not to an avoidance stimulus.

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5. These findings are based on the work of various student groups participating in the summer courses and workshops at the Cold Spring Harbor Laboratory of Quantitative Biology.
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8. We thank F. Barnes for fruitful discussions and for the use of his laser. We thank the Mechanical Engineering Department for lending us their optical comparator and L. Massie for help in calibrating the laser.

19 January 1970; revised 6 April 1970

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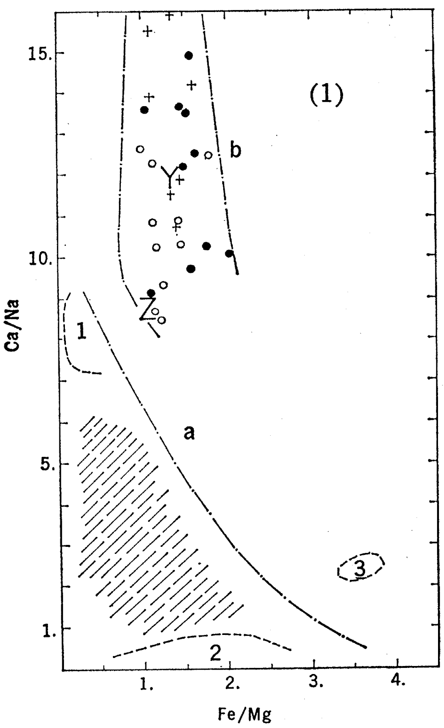
# Chemical Individuality of Lunar, Meteoritic, and Terrestrial Silicate Rocks

Turner and Ulbrich (*1*) recently suggested a basis for the chemical comparison of nonterrestrial with terrestrial rocks. Particular emphasis was placed upon atomic ratios such as Ca/Na, (Ca + K)/Na, Fe/Mg, and Al/Ti, which in terrestrial igneous rocks conform to sharply limited general patterns reflecting genesis and fractional crystallization of magmas under conditions prevailing in the outer mantle and crust of the earth (*2*).

In this note I illustrate the potentiality of this same suggestion by presenting some composition fields plotted respectively for appropriate igneous rocks, eucrite meteorites, and surface lunar materials sampled by Surveyor 5 and 6 (*3*) and the Apollo 11 mission (table 1 in *4*; *5*, *6*). Analyses of 140 igneous rocks were selected at random from the recent literature to cover the $SiO_2$ range from 39 to 55 percent [excluding analyses of monomineralic rocks such as anorthosites and analyses in which the individual value for any of the three oxides CaO, MgO, or (FeO + $Fe_2O_3$) falls below 2 percent]. The selected data include extreme and rare as well as common rock types (such as basalt). Individual points are not plotted in the accompanying diagrams, since their clustering might convey an impression of statistical significance in no way warranted by and quite outside the scope of this study.

In Fig. 1 terrestrial and extraterrestrial rocks are seen to fall in two mu-



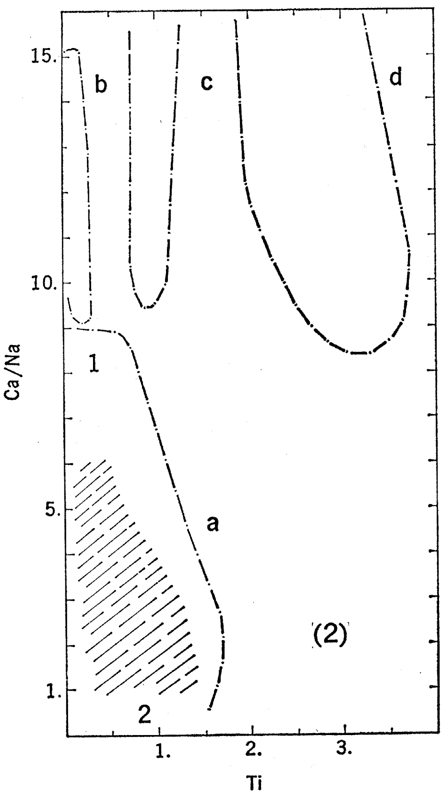


Fig. 1 (left). Atomic ratios (Ca/Na plotted against Fe/Mg). (a) Terrestrial igneous common rocks (basalts, andesites, and most basic and ultramafic rocks) fall in hatched area. Some special types (eclogite blocks, madupites, ankaratrites) cluster around area 1; feldspathoidal rocks cluster around area 2; and certain iron-rich tholeiitic differentiates (mainly pegmatoid) cluster around area 3. (b) Lunar samples (Apollo 11): (open circles) data from (*4*); (crosses) data from (*5, 6*). (Filled circles) Selected eucrite meteorites. Lunar samples from Apollo 12, not shown individually, are spread throughout the same field (*7*). *Y*, alpha-scatter data from Surveyor 5, Mare Tranquillitatis (*3*); *Z*, alpha-scatter data from Surveyor 6, Sinus Medii (*3*). Fig. 2 (right). Atomic ratio, Ca/Na plotted against Ti (atomic percentage), for same rocks as in Fig. 1. (a) Values for most terrestrial igneous rocks fall in the hatched area. (b) Eucrites; (c) Apollo 12 samples; and (d) Apollo 11 samples. Compositions 1 and 2 have the same significance as in Fig. 1.

tually distinct areas. In the field of terrestrial rocks high values of Ca/Na are invariably associated with low values of Fe/Mg. In the field of lunar rocks and eucrites both ratios are consistently high. Plots of other chemical parameters, for example, Ca/Na against Ti (Fig. 2), likewise reveal consistent chemical differences between terrestrial and nonterrestrial rocks (and also between lunar rocks sampled to this date and eucrite meteorites). The strong vertical dispersion of points for high Ca/Na values of nonterrestrial rocks merely reflects variation in uniformly low Na values, either real or perhaps within the range of analytical precision. This dispersion, which has no fundamental significance, would vanish on a semilogarithmic plot.

Collectively, the chemical data plotted in Figs. 1 and 2 preclude identification of lunar and meteoritic rocks with familiar terrestrial rock types such as basalt and gabbro which they may, however, resemble texturally and to some degree mineralogically. Indeed, although some contributors to recent literature on lunar rocks persist in employing the standard nomenclature of petrology, some have stressed, on other chemical grounds than those stated above, the fundamental difference that appears to mark the separate identities of terrestrial and extraterrestrial rocks (*6*). Perhaps it is already time for those working in the field to consider setting up a suitable nomenclature for lunar rocks.

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7. Since this note was submitted for publication, preliminary analyses of lunar samples from Apollo 12 have become available [table 2 in Lunar Sample Preliminary Examination Team, *Science* **167**, 1325 (1970)]. These data are shown in Figs. 1 and 2.
8. Supported by NSF grant GA 10636. I thank Professor F. J. Turner for valuable suggestions and for reading the manuscript.

24 February 1970; revised 16 April 1970

## Heavy Carbon

The statement that "the $\delta^{13}C$ data [+13 to +18.5 per mil relative to the PDB isotope standard] demonstrate that the carbon measured in these two [lunar surface] samples is definitely nonterrestrial since such positive values have never been found on earth" (*1*) is incorrect. The heaviest naturally occurring terrestrial carbon known occurs in ultramafic igneous rocks and has a $\delta^{13}C$ value as high as +24.8 per mil with respect to the PDB standard $CO_2$ (*2*).

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11 February 1970

In condensing the original manuscript (*1*) the meaning of the sentence was unfortunately changed. We apologize and thank Dr. Weber for his indication. In our expanded paper (*2*) the sentence has been clarified and mention is made that such positive values have only been found on earth in some types of carbonates. The point is that the measured values are not the result of terrestrial contamination.

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24 April 1970