ping observed by Bridgman in the silicates may have been a reflection of the same high-pressure instability that we have observed. Unfortunately, the two results cannot be quantitatively compared because of the difficulty in estimating the actual pressure in Bridgman's shearing experiments.

The observation that many silicates which deform stably at low pressures become unstable at high pressure raises a number of questions. It is not yet clear how faulting in this upper brittle region differs physically from that near atmospheric pressure; if the two are the same, then the intervening field of stability must be studied in even greater detail. The presence of weak alteration minerals or high porosity, or both, seems to be important but the detailed significance of these characteristics is far from clear.

The sudden instability at high pressure might, in the natural situation, produce earthquakes, although there are at least two major uncertainties in this extrapolation to the earth. The matter of scale needs further study; the samples we have studied are many orders of magnitude smaller than the natural counterpart. How should one scale stress drop, for example? Does a natural earthquake correspond to an audible stress drop in our experiments, or to one of the subaudible microfracturing events as described by Mogi (*15*), Scholz (*16*), and others? A second area of uncertainty is that of the effect on instabilities, at any scale, of the elasticity or stiffness of the surroundings. Although we found that an order of magnitude of variation in stiffness of the loading device had no effect on amplitude of stick-slip during frictional sliding (*8*), it is not known how variation in stiffness affects the stability of deformation in porous or altered silicates. And, even if we understood this variation in laboratory experiments, how may one characterize stiffness in natural rock?

If one is willing to overlook these difficulties and to apply our findings directly to the earth, then one is tempted to suggest that earthquakes of intermediate and even deep focus may be a result of high-pressure instability of silicate rocks. Before we can say whether this is true or not, we must determine the embrittlement boundary for silicates as a function of temperature as well as pressure. Griggs *et al.* (*17*) demonstrated that rocks like granite and diabase may deform stably at temperatures in excess of 500°C at 5 kb. But it is not known whether, at these temperatures, sudden instability reappears at still higher pressures as in our room-temperature experiments.

One result which may be important in earthquake studies is that the choice of geological materials in which earthquakes might be produced is broadened to include deeply buried sedimentary rocks and porous volcanic rocks and perhaps even unconsolidated granular materials as well.

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2. Not all fractures in compression release energy suddenly. In so-called ductile faulting, for example, a fault is produced without a sudden stress drop. Different types of faulting are reviewed by J. Handin, in *Handbook of Physical Constants*, S. P. Clark, Ed. (Geological Society of America Memoir No. 97, New York, 1966), p. 228.
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18. We are grateful to Dr. N. Carter of Yale University, who deformed two samples of Spruce Pine dunite in his solid-medium piston-cylinder apparatus. We have benefited from discussions with a number of persons, who should not be held in any way responsible for the views and interpretations presented here. J. B. Walsh, M. S. Paterson, H. Heard, and G. Robertson offered helpful criticism of early versions of this paper. Supported by NSF grant GA-613.

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Wind Measurements in Noctilucent Clouds

Abstract. *The results of eight soundings conducted from sites at high latitude during the summers of 1963 through 1965 suggest that a relation exists between the winds at the mesopause and the occurrence of noctilucent clouds. These measurements indicate that situations in which noctilucent clouds are present are associated with lower wind speeds than is the case where there are no clouds.*

For many years noctilucent clouds have been observed to occur exclusively at high latitudes during the summer, a pattern recently confirmed by Fogle and Haurwitz (*1*). Once it was established that the light from noctilucent clouds is scattered sunlight, the solar depression angles required to illuminate the clouds were determined, and it became apparent that these solar depression angles occur daily at most other latitudes and seasons (*1*, p. 286). This suggested that the extremely cold mesopause which we had observed to be unique to the high latitudes in summer might be related to the occurrence of noctilucent clouds.

In order to examine the possible relation between the temperature of the mesopause and the occurrence of noctilucent clouds, we conducted a total of eight rocket soundings during the sum-

Table 1. Observed mesopause winds in the presence and absence of noctilucent clouds.

Sounding	Site	Date	Local standard time	Wind Direction (deg)	Wind Speed (m sec⁻¹)	Noctilucent cloud condition
1	Kronogard	30 July 1963	0128	101	31	Moderate display
2	Kronogard	7 August 1964	0216	328	36	Moderate to strong display
3	Kronogard	16 August 1964	0313	089	84	Weak display
4	Kronogard	17 August 1964	0249	352	24	Moderate display
5	Barrow	7 August 1965	0113	267	29	Strong display
6	Kronogard	2 August 1963	0127	053	96	No clouds
7	Kronogard	8 August 1963	0029	032	165	No clouds
8	Barrow	9 August 1965	0010	072	54	No clouds

mers of 1963 through 1965 in order to measure the temperature structure of the mesosphere both during cloud displays and in the confirmed absence of these clouds.

We used the acoustic grenade technique to obtain profiles of temperature and wind to heights of 90 to 95 km (*2*). Six of the soundings were launched from Kronogard, Sweden (66°N) in cooperation with the Swedish Space Committee, and the other two were launched from Barrow, Alaska (71°N). The times and dates of the soundings are given in Table 1.

Theon *et al.* have discussed the effect of the temperature structure on the production of noctilucent clouds (*3*). We present here the wind profiles which were measured simultaneously as part of those same grenade soundings.

Fogle and Haurwitz reported that the mean wind at noctilucent cloud height, as determined from 97 ground-based measurements of cloud drift, was 40 m sec^{-1} from the northeast direction (*1*, p. 303). Included in this average value were wind speeds as high as 200 m sec^{-1}. The wind speeds we observed at the mesopause ranged from 24 to 84 m sec^{-1} during noctilucent cloud displays (Table 1). The complete wind profiles (Fig. 1) correspond to the values in Table 1; thus profiles 1 through 5 were obtained during noctilucent cloud displays and profiles 6 through 8 were obtained under cloudless conditions. The wind at the mesopause in each profile corresponds to the value given in Table 1. In every case, there was a strong wind shear at the mesopause which resulted either from a shift in wind direction, a change in wind speed, or both. These wind shears at the mesopause are not believed to be related to the occurrence of noctilucent clouds because similar shears have often been observed at other latitudes and seasons (*4*).

We believe, however, that the lower wind speeds at the mesopause, which accompanied the noctilucent cloud displays, are significant. The wind speeds in the presence of noctilucent clouds (Table 1) were light to moderate with the exception of profile number 3, which exhibited a weak display of noctilucent clouds. In cases where the clouds were absent, the wind speed at the mesopause was moderate to strong. The mean wind speed in the five cases with noctilucent clouds present was 41 m sec^{-1}; in the three cases with the clouds absent the mean wind speed was 105 m sec^{-1}.

With this sample, the hypothesis that the distribution of wind speed at times when noctilucent clouds occurred is identical to that when no clouds occurred was tested by means of the *U* test (a statistical test for checking one hypothesis against another for a limited sample of data) (*5*) against the alternate hypothesis that the wind population during the occurrence of noctilucent clouds is situated in a lower-speed region than the wind population in the absence of clouds. The results of these calculations affirm to a .95 confidence level that displays of noctilucent clouds are associated with lower wind speeds than is the case in the absence of clouds.

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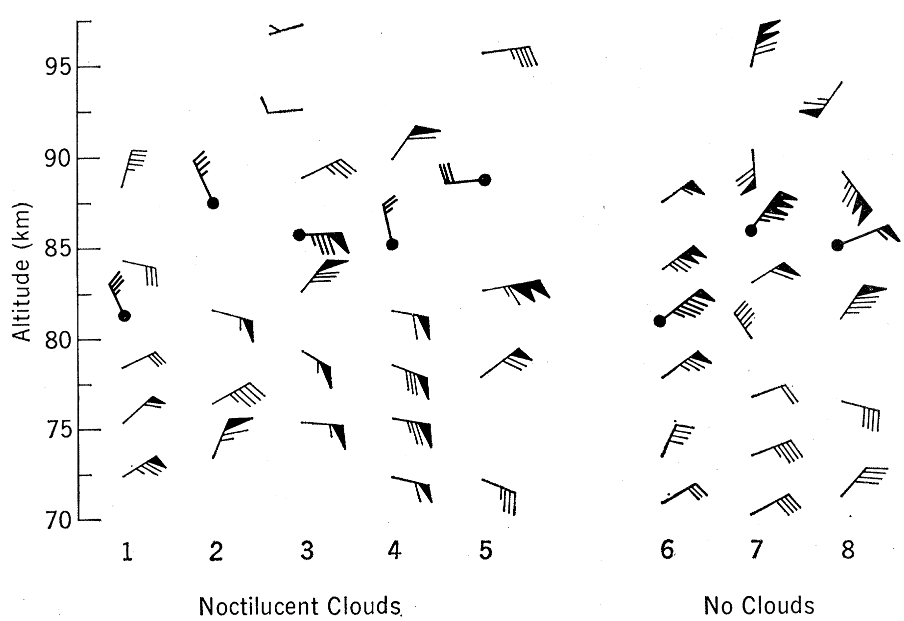

Fig. 1. Horizontal wind profiles measured in the presence and absence of noctilucent clouds (see Table 1). The wind at the mesopause is denoted by a dot on the shaft of wind symbol. Wind direction is indicated by alignment of shaft on a standard compass rose with north (360°) at the top of the figure. Wind speeds are given by the sum of the barbs and triangles, where each short barb denotes 5 m sec^{-1}, each long barb 10 m sec^{-1}, and each triangle 50 m sec^{-1}.

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