Table 1. Number of earthquakes at 8-hour intervals after explosion. The expected number in the total area in columns 2 and 3 is 35.26, in the area from 430 to 860 km from the test site in column 4 is 20.01.

	Number of earthquakes		
	In total area		In area
Inter- val (hours)	In inter- vals from 104 hours before deto- nation	In inter- vals from 2160 hours after deto- nation	430 to 860 km from test site in intervals from det- onation
0-8	48	39	33
8-16	28	32	32
16-24	33	61	30
24-32	22	31	41
32-40	29	29	23
40-48	31	42	17
48-56	24	45	27
56-64	33	29	20
64-72	35	45	15
72-80	58	37	12
80-88	45	16	27
88-96	27	26	17
96–104	35	37	25

pected number for this area is 20.01 in each interval. The first four numbers are all two standard deviations above the expected number, strongly suggesting that seismic activity was indeed stimulated in this region.

The numbers of earthquakes in the 8-hour intervals immediately preceding the explosions are reported in column 2 (Table 1), the last number in this column being the number of earthquakes falling in the interval 0 to 8 hours immediately preceding the explosions. As may be seen, there is no pattern whatsoever in the numbers. We also added 2160 hours (90 days) to the times of the explosions and counted the numbers of earthquakes in the 8-hour intervals following these new times (Table 1, column 3). Again, there is no recognizable pattern.

Neither our original data nor the new ones presented in Table 1 can be interpreted as a "rediscovery" of the dubious 24-hour period, as suggested by Anderson et al. For, in our original data, this should have been manifested in high values not only for the first and fourth numbers, but also for the seventh, tenth, and thirteenth numbers. The seventh, tenth, and thirteenth numbers in our original table (1) add up to 106 earthquakes, compared to an expected number of 105.78 earthquakes. Columns 2 and 3 of Table 1 also show the absence of the 24-hour period. Of the 26 numbers in these columns, nine are in the appropriate time intervals. Their sum is 324, compared to an expected number of 317.34.

The data in columns 2 and 3 of Table 1 show that the model suggested by Ryall and Boucher is incorrect. According to these authors, our analytical procedure should produce a linear decrease of numbers of earthquakes with increasing time, on which are superimposed five or six peaks representing intensive activity during the first few hours of aftershock sequences. Column 2 of Table 1 actually shows a small increase with time, but the correlation coefficient (0.2903) is not significant. Column 3 shows a small decrease with time but, again, the correlation coefficient (-0.3151) is not significant.

Allen and Bailey miss entirely the main point of our thesis. Underground nuclear tests conducted so far have been presumably made at locations and depths chosen so as to avoid the release of large amounts of seismic energy. Our contention is that underground nuclear tests conducted at suitable locations and depths could trig-

Bentonite Landslides

The essential conditions cited by Anderson et al. (1) for development of bentonite debris flows in Northern Alaska include "easily hydrated interbedded bentonite deposits . . . slopes of 5 to 20 degrees . . . and water in moderate quantities for at least several weeks duration." Anderson et al. consider these landforms and this geomorphic process to be unique to the arctic environment. This conclusion is contradictory to other published reports and evidence presented here. Yatsu discusses the widespread occurrence of landslides of the flow type associated with the hydration of swelling clay minerals, such as montmorillonite. Using examples of landslide materials from Japan, Scandinavia, and Canada, Yatsu concludes, "if bedrock contains some components of swelling clay minerals it swells with pressure when afforded with water and is apt to become unconsolidated clayey debris. Such detritus is easily affected by mass-movement of slip or flow types" (2).

Similarly, in a discussion of the chemical stabilization of an active landslide in Des Moines, Iowa, Handy and Williams report that "x-ray and grainsize analyses of the sliding soil indicated that it contains 25 to 30 percent calcium-saturated montmorillonite clay" (3).

Our work confirms the presence of

ger the release of large amounts of seismic energy. The very meaning of the word *trigger* signifies an energy output greater than the input. Clearly, only if this were the case could underground nuclear explosions be conceivably used to control earthquakes (2).

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- The first suggestion in print to use underground nuclear explosions for earthquake control is not in (I) above, as we thought, but in a paper by Brune and Pomeroy [J. Geophys. Res. 68, 5020 (1963)], a contribution that escaped our attention when we wrote our paper.
- 3. Supported by NSF grants GA-4302 and GA-10082; computer work supported by the University of Miami. Contribution No. 1148 from the School of Marine and Atmospheric Sciences, University of Miami.

26 December 1969

other bentonite landslides in widely differing climatic areas. Mudflows with very similar morphological characteristics to those in Alaska have been described in Northern Ireland, $54^{\circ}50'N$, $05^{\circ}50'W$. These have three distinct parts, a source area, a flow track zone through which debris is transported, and a depositional toe zone. X-ray



Fig. 1. X-ray diffractometer traces of landslide materials from Northern Ireland, St. Lucia, B.W.I., and Barbados, B.W.I. (CuK α radiation).

diffraction analysis of the mudflow clays (derived from Liassic shales) shows the presence of large amounts of montmorillonite clay together with illite and kaolinite (Fig. 1A). The mean ratio of montmorillonite plus illite to kaolinite is 9.5:1. The mudflow is seasonal in character and related to the hydration of clays in the shales by rainfall, which averages 105 cm per vear.

On St. Lucia island, British West Indies, 13°44'N, 60°57'W, a series of coastal landslides are also associated with almost pure, swelling montmorillonite clay (Fig. 1B), derived from weathering volcanic bedrock. These landslides appear to move erratically and are related to water saturation of the clays during periods of heavy rainfall. Rainfall rates of up to 9.7 cm per day have been recorded in an area which locally averages 125 cm per year.

In the Scotland district of Barbados, 13°00'N, 59°30'W, Tertiary shales rich in montmorillonite, kaolinite, and illite (Fig. 1C) are exposed by erosion of a coral cap. These clay minerals contribute to widespread landslide activity, which is now being studied by the Soil Conservation Service of Barbados. This slope instability occurs within an area that receives 125 to 200 cm of rainfall annually.

The close association between landslide activity and the presence of montmorillonite-rich clays in Northern Ireland, St. Lucia, and Barbados is not coincidental. Bentonite clays are susceptible to changes in physical properties, such as plasticity, when subjected to wetting and drying. These changes are further enhanced in the presence of highly hydrated sodium and magnesium exchangeable ions (5). Sodium ions are associated with the clays in both St. Lucia (up to 0.59 percent) and Northern Ireland (up to 0.17 percent).

Climatic conditions which allow alternate hydration and dehydration of such clays can be found almost everywhere except in truly arid areas. Certainly, the periodicity of movement in bentonite landslides can be influenced by climatic factors. In arctic areas, hydration may be restricted to periods of thaw, thus imparting a seasonality to the landslide activity. Alternatively, in temperate and tropical areas effective precipitation can be reduced by evapotranspiration factors (4). However, there is a limit to the relevance of climatic criteria since groundwater supply of moisture may

exceed the importance of direct precipitation. Thus, the primary factor in the location of many flow-type landslides is not a simple climatic one, but it is rather the presence of bentonite clay minerals in the slope materials. The distribution of bentonite landslides is thus largely geologically controlled.

The landslides described by Anderson et al. provide additional evidence of the relationship between slope instability and the mineralogy and the geochemistry of slope materials. But, it is readily apparent that there is no justification for associating these landslides with a particular climatic environment.

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14 October 1969

It was not our intent to convey the impression that all bentonite-rich mud flows are unique to the Arctic. We recognize that mud and debris flows in clay soil occur on a worldwide basis. What we do believe may be unique about the bentonite flows near Umiat has to do with channel morphology, the relation between slope angle and the flow regime, the frequency of flow activity, and the density of the flow channel distribution on permafrostunderlain terrain. Climatic factors play a significant role in governing mudand debris-flow regimes; however, we would not maintain that these factors are dominant over geologic aspects.

We do not maintain that bentonite debris flows are restricted to Arctic regions: we believe, however, that the frequency and morphology presented by the bentonite debris flows when they occur over permafrost are sufficiently distinctive that, on aerial photographs, bentonite debris flows may be differentiated from other types of flows with considerable reliability. The examples of mud or debris flows described by Prior and Ho do not appear to have a morphology like that of the Umiat bentonite flows. No confirmed examples of similar flows have been brought to our attention since our earlier communication, although one of us (Brown) has learned on a recent trip to Siberia that somewhat similar flows do occur there.

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5 December 1969

α_1 -Antitrypsin Deficiency

The unusually high incidence of heterozygous α_1 -antitrypsin deficiency reported by Kueppers et al. (1) in both normal and emphysematous populations requires careful and critical examination of the method employed for detecting such heterozygosity. Kueppers et al. report that their antigenantibody crossed-electrophoresis procedure distinguishes between normal α_1 antitrypsin and an electrophoretically distinct but antigenically identical species of α_1 -antitrypsin in the heterozygote. This assertion is based upon the observation that all obligatory heterozygotes (offspring of known homozygotes) have a distinctive antitrypsin pattern on crossed electrophoresis. However, Kueppers et al. present no evidence to confirm the heterozygosity of those subjects with a heterozygous pattern in their healthy control population, as could be done through family studies. In addition, they say that a mixture of equal parts of serum from normal and deficient homozygotes yields the same pattern as that of a heterozygote. Kueppers and Bearn (2) earlier stated that serums from individuals homozygous for the deficient gene show a virtual absence of α_1 -antitrypsin bands. Thus, one wonders why mere dilution of normal serum antitrypsin by another serum specimen lacking antitrypsin should result in a pattern resembling that seen in heterozygous deficiency. Kueppers et al. apparently did not determine the type of antitrypsin pattern that results when normal serum is mixed with another serum deprived of its α_1 -globulin by