and separated by furrows that are not deeply indented. All segments radiate from dorsal mound which is slightly anterior (?) of center. Lappets are not distinct. Periderm seems to be preserved as carbonaceous film at least 0.5 mm in thickness.

Holotype: Sp. No. 68:5:3, Rutgers Museum Collection; length 4.7 cm; width, 4.1 cm. Named for Kittatinny Mountain at Delaware Water Gap.

Horizon and locality: Lower Shawangunk (Tuscarora) formation (Early Silurian), Delaware Water Gap, Pennsylvania.

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5 June 1968

Atmospheric Aerosols: Increased Concentrations during the Last Decade

Abstract. *Atmospheric turbidity values calculated each month from solar radiation observations at Mauna Loa Observatory, Hawaii, show an increase of aerosols from 1958 through the present. These data indicate that either the effects of the Mount Agung eruption are still being observed or a longer-term trend of increasing turbidity is in evidence.*

The possibility of climate modification resulting from increased concentrations of atmospheric aerosols has been a popular topic of discussion in meteorology. McCormick and Ludwig (*1*) explored this idea from the viewpoint that man-made pollutants are the source of increasing numbers of aerosols. By contrast, violent volcanic eruptions which inject large quantities of aerosols into the atmosphere have also been suggested as a mechanism for large-scale climate change (*2*). We report here on variations in the solar radiation data from Mauna Loa Observatory, Hawaii (which has been in operation for 10 years) by considering the influence of both these aerosol sources on the radiation measurements.

A measure of the concentration of atmospheric aerosols is provided by surface observations of the total amount of direct solar radiation, which are made on a routine basis at several United States localities, including the Mauna Loa Observatory. This station is particularly well suited for such measurements and for their application to estimates of aerosol densities on a global scale. At an elevation of 3398 m, the observatory is above much of the atmospheric water vapor. Most of the days each year are clear or partly cloudy, and it is remote from local sources of pollution (*3*). Four observations of direct solar radiation are made at Mauna Loa, in the morning and in the afternoon, providing that the sky is cloud-free near the sun, at prespecified times so that the solar angle is the same for corresponding observations on each day. These measurements began in November 1957, and, except for June 1958 and March 1964, the data have been published monthly through December 1967 (*4*). However, these observations (on which our report is based) are tentative and subject to future correction.

For our study, monthly averages of the Linke turbidity factor were computed according to the method outlined by Fritz (*5*) for each of the eight observation times. These were averaged to yield a single turbidity value for each month. Linke turbidity, T, is defined by

$$T = (\ln I_0 - \ln I)/(\ln I_0 - \ln I') \quad (1)$$

where I_0 is the solar constant, I is the observed direct solar radiation, and I' is the amount of direct radiation which would be transmitted through a clear, dustfree atmosphere with 1 cm of precipitable water vapor. Thus, each unit on the Linke scale corresponds to the depletion of the direct solar beam which would result from passing vertically through one such atmosphere. Particulate attenuation and water vapor absorption are the primary factors affecting variations of the Linke turbidity. If the water vapor concentration is assumed to be relatively constant from year to year, then large, longer-term changes of turbidity will be the result of variations of particulates.

Since the observed monthly values of turbidity had an annual variation, the average monthly turbidities were expressed as departures from the normal values for each individual month, the normal values being calculated from the data on the entire period through 1967. The results were subjected to three-point binominal smoothing (Fig. 1). The aver-

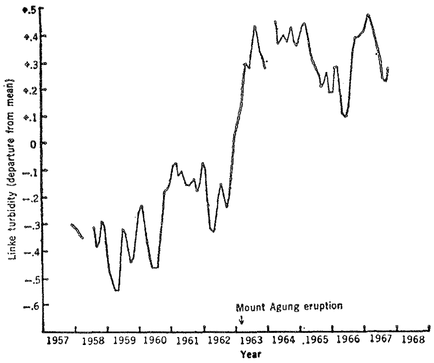

Fig. 1. Trend of monthly anomalies of Linke turbidity factor calculated from published normal incidence radiation data for Mauna Loa, Hawaii. Three-point binomial smoothing has been used.

age turbidity for the entire 10-year period is 2.98.

The rapid increase in turbidity during mid-1963 (Fig. 1) was detected in many other parts of the world. This increase was the result of the eruption of Mount Agung in the East Indies in March 1963 (*6*). By considering this event as the major factor influencing large-scale changes of turbidity during the last decade, Fig. 1 can simply be interpreted as representing pre-eruption and post-eruption levels of turbidity.

If the Mauna Loa data are seen from this viewpoint, their unusual aspect is that by the end of 1967 (nearly 5 years after the eruption) the turbidity had not decreased to pre-eruption levels. Such a long period of reduced radiation after such an event has not previously been reported. For example, even after the very violent eruption of Krakatoa in 1883 the direct solar radiation returned to normal within 3 years, and for other, less intense eruptions the period of decreased radiation was even shorter (*7*).

We support an alternate interpretation of these data—that the Mount Agung effect is superimposed on a longer-term trend, a trend of increasing turbidity, which could have man-made pollution as its origin. Bryson (*8*) discussed various climatic aspects of such a contemporary turbidity trend. Examined from this viewpoint, Fig. 1 shows generally increasing turbidity during the decade despite the considerable scatter of the data, such as the positive departures during 1961 and from mid-1966 through mid-1967. Thus, the effect of the eruption can be seen as gradually diminishing during most of 1965 and the first half of 1966. By mid-1966, however, the long-term trend, which was also evident during the pre-eruption period, began to dominate the turbidity values while there was continued attrition of the Mount Agung aerosols. This explanation is supported by similar radiation data from the South Pole station (*6*) which show decreasing turbidity from late 1964 through early 1966.

To estimate the magnitude of such a long-term trend two linear regression lines were fitted to the unsmoothed monthly averages. The first incorporated all data through February 1963 (the pre-eruption period), and the second included the entire data sample, except for the 3-year interval from March 1963 through February 1966 inclusive (the period arbitrarily selected as that influenced by the eruption). The regression yielded Linke turbidity changes of $0.61 \pm .19$ and $0.83 \pm .08$ per decade, respectively, where the listed accuracies are twice the computed standard error. Thus, the addition of the 1966 and 1967 data to the pre-eruption sample increases the earlier turbidity trend, suggesting either that the aerosol content was increasing more rapidly during the past several years or that a small residue from Mount Agung was still present during this time.

Our interpretation, that the observations indicate a long-term turbidity increase, is supported by additional independent data whereas none exists to support the concept of radiational effects from a volcanic eruption lasting 5 years. McCormick and Ludwig (*1*) presented data from Davos, Switzerland, and Washington, D.C., which showed turbidity increases of approximately 20 and 10 percent per decade, respectively, for the general period of 1910 to 1960. In addition, measurements by Schaefer (*9*) at both rural and urban United States locations indicate that atmospheric particulate concentrations have increased by at least an order of magnitude during the past 10 years, and Davitaya (*10*) has shown that the dustfall in the high Caucasus increased nearly 20-fold between the 1930's and the 1960's.

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24 June 1968

Guatemela: Preliminary Zircon Ages from Central Cordillera

Abstract. *Concordia resolution of uranium-lead analyses of zircons from rocks of the Guatemalan Cordillera indicates a period of plutonism, and perhaps metamorphism, in late Paleozoic times (345 ± 20 million years). Gneisses of the Chuacús Series yield an age of 1075 ± 25 million years which may be either the age of a source terrain for the original sediments, or the age of principal metamorphism. Zircons from a Paleozoic granite intruding the gneisses appear to contain inherited or contaminating material acquired during the process of magma generation or emplacement, or both.*

Interest in the geology of Central America has increased during the past several years, not least because knowledge of this region can be expected to yield information pertinent to theories of crustal structure, crustal evolution, and continental drift. In parts of Central America, Late Paleozoic or younger formations (or both) are underlain by gneisses and schists of problematical age; thus the antiquity of the Central American crust remains unknown until these rocks are dated.

The oldest rocks of the Guatemalan Cordillera are garnet-mica schists, granitic gneisses, and associated marbles and amphibolites of the Chuacús Series (*1*). Intruding the Chuacús Series are weakly foliated to massive granites of the Rabinal and Matanzas bodies. These crystalline rocks are overlain by the Pennsylvanian or early Permian Santa Rosa Formation, which consists of coarse clastics containing fragments of schist, gneiss, and granite in the lower part of the section, and shales and thin limestones in the upper part.

The Chuacús Series grades upward through a zone of sheared mica schists and chloritic cataclasites into a sequence of meta-arkoses, feldspathic phyllites, and marbles. McBirney (*1*) suggested that these more weakly metamorphosed sediments may be correlative with the Santa Rosa Formation, thereby indicating the possibility of a Late Paleozoic period of metamorphism in Guatemala.

We analyzed zircons from a sample of Rabinal granite collected about 5 km north of the town of Rabinal, and from two samples of the Chuacús Series; sample 1 is a biotite-albite-quartz granite gneiss collected from a road about 109 km on Route 5 south of Rabinal and sample 2 is a biotite-albite-epidote gneiss from the crest of the Sierra de Chuacús south of Salama. Standard procedures were used, with the addition of hydrofluoric acid washes of the zircon concentrates to remove undesirable mineral impurities.

Zircons from the gneisses are white to pale brown, almost opaque, and commonly show rounded terminations or rounded to euhedral cores surrounded by overgrowth material. In contrast, zircons from the granite are deep purple, transparent, and prominently zoned. However, 1 or 2 percent of this concentrate consisted of grayish white, cloudy-opaque grains similar in appearance to the gneiss zircons.

Analytical results are shown in Table 1 and Fig. 1. A linear chord fits all the data points on the concordia diagram within analytical error (estimated to be approximately 1.5 percent in the radiogenic isotope ratios). This pattern indicates that the isotopic characteristics of the zircons are explicable in terms of two essentially episodic events which occurred at times given by the upper and lower intercepts of the chord

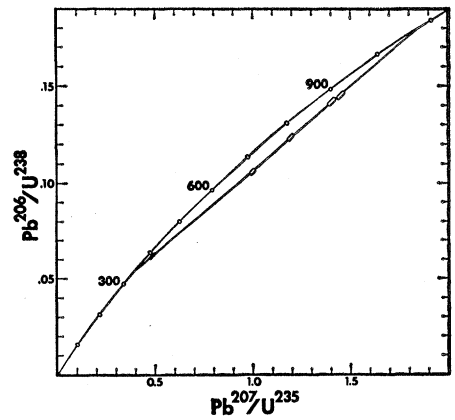

Fig. 1. Concordia representation of analytical data from Table 1.