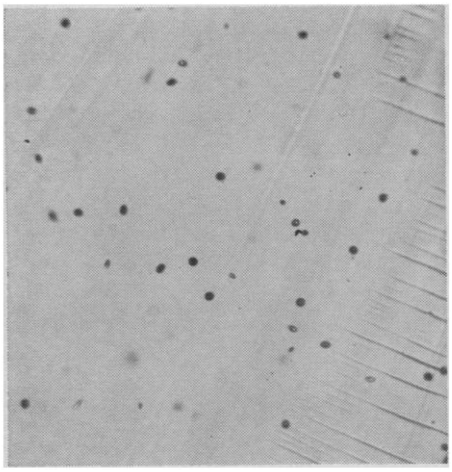

Fig. 1. Fission-track pits in a 4th to 2nd century B.C. glass from the Achemaenid Palace at Persepolis. Irradiated with 1.3 $\times 10^{15}$ thermal neutrons per square centimeter; etched in hydrogen fluoride.

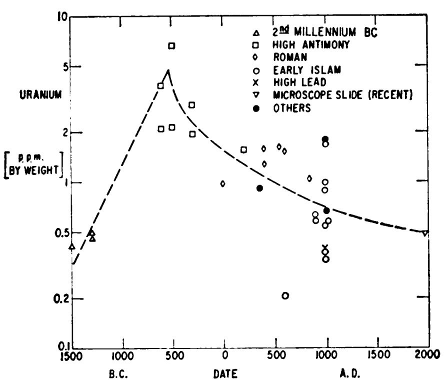

Fig. 2. Uranium contents of glasses as a function of the probable dates of origin.

both of which precluded track counting. As the figure shows, there appears to be a historical trend from initially low (2nd millennium B.C.) to high (group with high antimony content), then to progressively lower but more widely scattered values of uranium concentration. There is only one result for a lead glass, since it was found that the others contained crystalline phases. It might, at first thought, be suggested that this variation with time is associated with a similar variation of one of the major glass constituents. However, comparison of the uranium content with those of Sb, Mn, Mg, Pb, and K revealed no such correlation.

The results in Fig. 2 show that knowledge of the uranium content of glasses aids in distinguishing between some of the groups recognized by Sayre and Smith. For example, the 2nd millennium B.C. group is distinct from the high antimony group, which in turn is distinct (except for one sample) from the other more recent groups. Whether uranium can be used to subdivide the major groups is unclear from this work. Unfortunately, the number of samples in any one group is too small to allow a statistically meaningful trend to be detected. A second difficulty arises from the fact that the true age of many of the samples is only known within ± 200 years, so that trends within groups are likely to be obscured.

In part, this study was undertaken so that we might learn whether ancient glasses commonly contain enough uranium to allow dating by counting the tracks caused by spontaneous fission (*6*), a procedure that has made possible the dating of natural glasses (*4, 7*) and certain man-made glasses to which uranium has been intentionally added (*8*). On the basis of the present measurements we conclude that only the group of glasses rich in antimony can be dated with a reasonable amount of work, and then rather imprecisely. For a typical such glass (3 parts per million of uranium and 2000 years old) it would be necessary to survey nearly 10 cm^2 of surface to count 16 tracks caused by spontaneous fission. Since the likely error on such a count is ± 25 percent, it should be apparent that this procedure may be a proper method of authenticating the great age of a glass but that it is not a convenient method of establishing a precise age. There are, however, exceptional glasses with a high uranium content, such as that analyzed from the 1st century villa at Cape Posilipo near Naples (*9*). Such material could be readily dated by the fission track method.

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23 March 1964

Radar Observations of Jupiter

The recent opposition of Jupiter has provided an opportunity for a group of engineers and scientists at the Jet Propulsion Laboratory to study that planet by radar. Experiments were conducted almost nightly from 17 October to 23 November 1963, at the Goldstone Tracking Station, located in the Mojave desert of California (*1*).

The parameters of the radar system were as follows: antenna gain (two-way, including losses), 108.5 db; continuous transmitter power, 100 kw; wavelength, 12.5 cm; total system noise temperature, 28°K. A continuous wave signal was transmitted to Jupiter for intervals of 1 hour and 6 minutes (the time taken by a radar signal to get to Jupiter and back). At the end of each transmission, the antenna was switched to the receiver. After another similar interval, the transmitter was again switched on. There were, during the course of the experiments, 100 such runs.

Two signal processing devices were used simultaneously: (i) total echo power through a bandpass filter was measured, with the receiver in the configuration of a Dicke radiometer, and (ii) the signal spectrum was measured by the digital equivalent of a bank of 44 contiguous bandpass filters of adjustable bandwidth.

A wave of high spectral purity was transmitted to Jupiter, but the echo was both shifted and broadened in frequency by the Doppler effect. The shift was caused by the relative orbital velocity between Jupiter and the radar station, and was accounted for by the use of an ephemeris-tuned receiver (*2*); while the broadening was caused by the rotation of Jupiter, which imparts differing velocities along the line of sight to different parts of the surface. The spectrum analyzer was designed to measure this broadening.

Jupiter rotates at such a rapid rate that a broadening of up to 398 kcy/sec might be observed. However, if the surface were very smooth, echoes would not be returned from the limbs, and the observed Doppler broadening would be less. If Jupiter had the same reflecting properties as Mars (*3*), the echo bandwidth would be 24 kcy/sec. The bandwidth would be greater if Jupiter were similar to Venus (*4*).

Theory suggests that optimum detection of a weak signal which is masked by strong background noise requires filtering which matches the bandwidth of the signal, hence a search had to be made for the appropriate bandwidth. Since the narrower the bandwidth the more easily detected is the echo, and since there was no a priori knowledge available, observations were begun at the narrower bandwidths.

During the day, the known characteristics of Venus were used for calibrating the entire radar system. For example, on 8 November, the distance between Earth and Venus was 150 million miles, and successful contact was made with only 2.3×10^{-22} watt of received power. This required 2.7 hours of signal integration time.

All the results with the narrow bandwidths indicated negligible echo power, and served to set the following upper limits: (i) for a bandwidth of 25 cy/sec, a probable error of 1.4×10^{-23} watt; (ii) for 50 cy/sec, a probable error of 2.9×10^{-23} watt; (iii) for 400 cy/sec, a probable error of 9.2×10^{-23} watt. The range from 50 to 400 cy/sec was investigated by the spectrum analyzer. Thus no narrow band echo, within the aforementioned probable errors, was observed.

More than 68 hours of signal integration were then obtained with the spectrum analyzer set to the wide bandwidth of 33 kcy/sec. Most of the individual runs showed no evidence of an echo. Occasionally, however, a run would indicate the presence of a significant return.

It was noticed that the time intervals between "significant" runs were most often a multiple of the rotation period of Jupiter (System I, 9.841 hours; there was negligible correlation with Systems II and III). This suggested that a single localized area on Jupiter was both a good and a smooth reflector. To investigate this possibility, Jupiter was divided into eight "time zones" and all of the runs which illuminated a given time zone were averaged together. Eight zones were chosen because Jupiter rotates about ⅛ revolution during one run. Sixty-six runs were taken in this way, and they give good coverage of all of the zones. The eight resulting spectrograms are shown in Fig. 1.

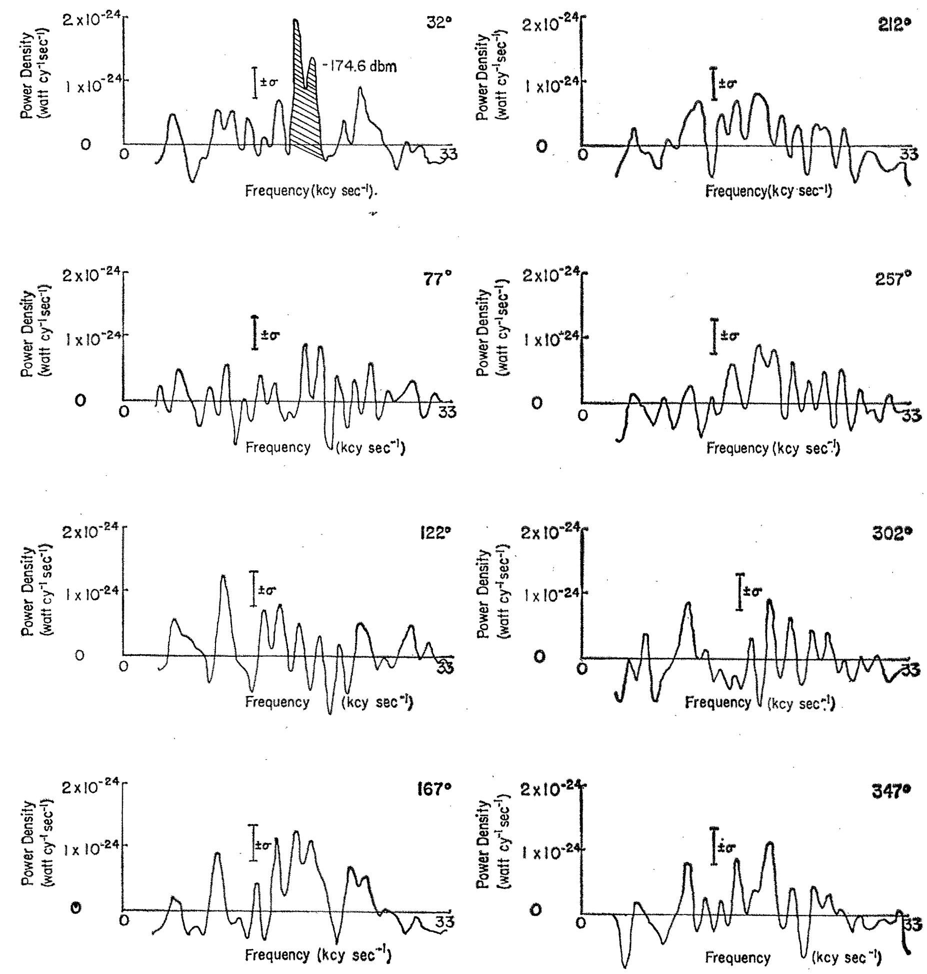

Fig. 1. Spectrograms from eight "time zones" of Jupiter.

The zone centered about the Jovian longitude of 32 degrees gave a response which is statistically significant. Although this detection cannot be considered absolutely conclusive, the echo peak is almost 8 times the standard deviation. This zone is not correlated with the celebrated red spot of Jupiter. The other zones show little, if any, echo; and the average of all runs shows negligible return.

The echo power, integrated from the spectrogram of the 32-degree zone, is 3.4×10^{-21} watt. This corresponds to a radar cross-section for this area of Jupiter of 60 percent of its geometric cross-section, that is, the echo power was 60 percent of that expected from a spherical conductor of the same curvature and distance.

The echo bandwidth, from the 32-degree spectrogram, is approximately 3.3 kcy/sec. This corresponds to reflections from a disk on Jupiter, centered about the sub-Earth point, of 730 miles in diameter. The actual reflecting area may be much larger than this, but because of the smoothness, echoes originating outside of this disk would not be directed back toward the Earth.

The spectrogram presents the echo approximately 2 kcy/sec higher in frequency than predicted from the Earth and Jupiter ephemerides. This is far too large to be accounted for by an error in the velocity of Jupiter. The echo from Venus was always within a few cycles per second of the predicted frequency. The discrepancy may have been caused by a slight slope of the reflecting surface. A slope of only 1.0 percent would account for the frequency shift which was observed.

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