A COMPARISON OF LAVA FLOW RHEOLOGY CALCULATIONS FOR HIGH-RESOLUTION DATA SETS FROM HAWAII AND MARS; J.H. Fink, (Geology Dept., Arizona State Univ., Tempe, AZ 85287) and J.R. Zimbelman (LPI, Houston, Texas 77058)

Attempts to remotely determine the composition of martian lava flows have been based on a few simple models that relate rheology to morphology. These models involve many broad assumptions about the rheology of lava and the dynamics of flow. Several investigators (ourselves included) have pointed out the many limitations of these models and have proposed more elaborate ones that take into account such factors as time-dependent effusion rates, power-law rheology, and temperature variations. However, owing to inherent limitations of the Viking data sets, these more elaborate models will probably never be directly applicable to martian flows. In contrast, our approach in the present study has been to evaluate the simple models by applying them to very well-documented flows in Hawaii and to see how well they can predict known properties.

We report on measurements of six flows that erupted along the East Rift of Kilauea Volcano in 1983 and 1984 and flowed down its steep southern flank. For many of the flows, temporal and temperature data are available, as well as morphologic and topographic information. In a previous study (1) we showed that yield strengths calculated from flow margin heights provide more accurate results than those based on levee dimensions or channel widths. We also showed that viscosities computed from actual measurements of flow velocities were more reliable than those based on estimated or average velocity values. Here we plot longitudinal variations of yield strength as a function of both distance and time and show that they are best fit by exponential curves. Next we artificially "degrade" the Hawaiian data to Viking resolution to see if the same patterns can be found. Finally we calculate the same variables for some flows observed on high resolution images of Ascraeus Mons to see if exponential variations can be detected.

Laboratory data confirm that both yield strength and viscosity of basaltic magma vary exponentially with the inverse of temperature. Thus we would expect that a steadily cooling flow advancing with constant velocity should exhibit an exponential increase in both properties. To test this idea, we combined flow margin heights measured in the field by the USGS with slopes taken from a 20-foot contour interval topographic map and an assumed constant density value of 2.5 g/cc to get yield strengths. From flow front positions measured at known times we were able to extrapolate approximate times of formation for the measured flow margins, and with velocities derived from these times we used the Jeffrey's equation to calculate viscosities. We also checked the validity of the constant velocity assumption by plotting distance versus time.

Figure 1 shows the exponential regression of strength on dimensionless distance for the 7.6 km long Phase 2 Royal Gardens flow. Distance was scaled by the separation between the first and last observation points along the flow, which were within 200 meters of the vent and toe of the flow, respectively. The r-squared coefficient is 0.81. Figure 2 shows the regression of strength on dimensionless time, which is scaled by the time interval between the formation of the first and last points along the profile. Again the r-square value is high (0.86).

Similar calculations and plots were made for Phases 3 (2 flows), 4, 5 (2 flows), 17, 18, 30, and 31, and all showed exponential increases in strength with distance and time. These flows ranged in length from 5.3 to 8.4 km. The overall variation in strength between flows is small, and all values are consistent with lab data for basalts. Nonetheless a significant exponential longitudinal increase is apparent in all flows. The magnitude of the strength increase is consistent with temperature data (2) that show a drop of up to 15 degrees C from the vent to the distal region of several of the flows.

Would this pattern of strength increase be detectable if our Hawaiian measurements had a resolution comparable to that of Viking data for martian volcanoes? In order to address this question we took our thickness and slope data for several of the Hawaiian flows and degraded them using 5, 10, and 15 meter filters. Figure 3 shows the result for the Phase 2 flow with a 5 m filter. The exponential trend can still be observed although the slope is less. For the 15 m filter (not shown), the pattern is no longer statistically significant. These results indicate that longitudinal variations in yield strength should be detectable in Viking data sets where topographic slope can be resolved to within 10 degrees and vertical distances within 5 m.

In Figure 4 we plot a strength profile calculated for a well-exposed 11-km long flow on Ascraeus Mons (3). Again the exponential trend is apparent, and the values are typical of basalt yield strengths, but the slope is considerably less than for the Kilauea flows. Our work suggests that this may be the result of the low resolution of the data, it may indicate that the portion of the flow measured was near the distal end, or it may reflect a composition more silicic than that of the Kilauea basalts. Further studies of this type may allow strength profiles to become a new tool for remote identification of lava composition.

Ref: (1) Fink, J.H. and Zimbelman, J.R., 1986, Bull. Volcanol., v. 48, p. 87-96.
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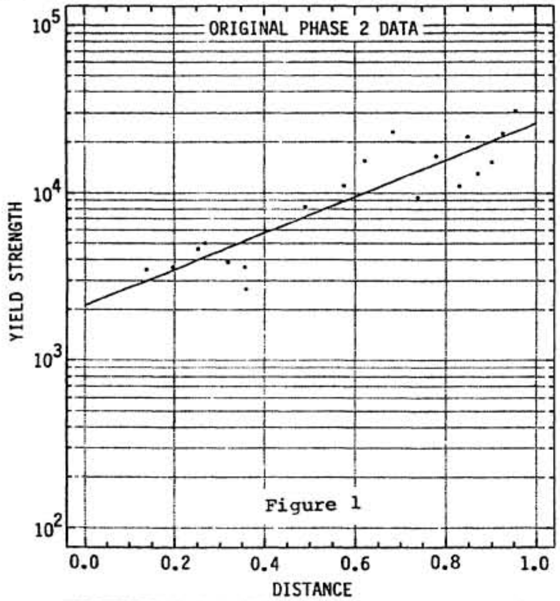

Figure 1

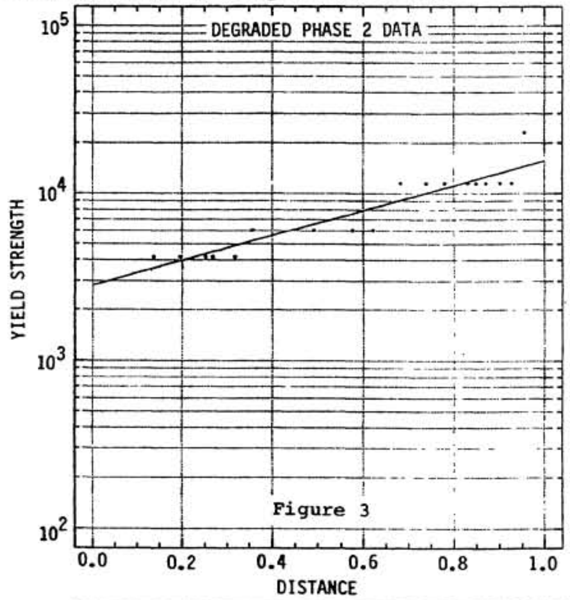

Figure 3

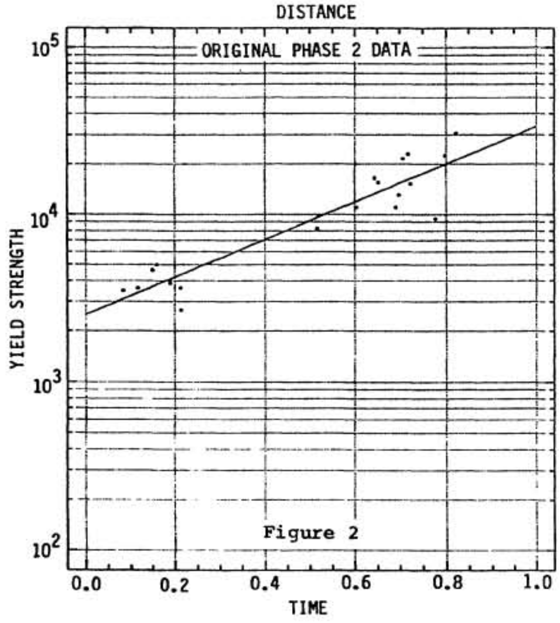

Figure 2

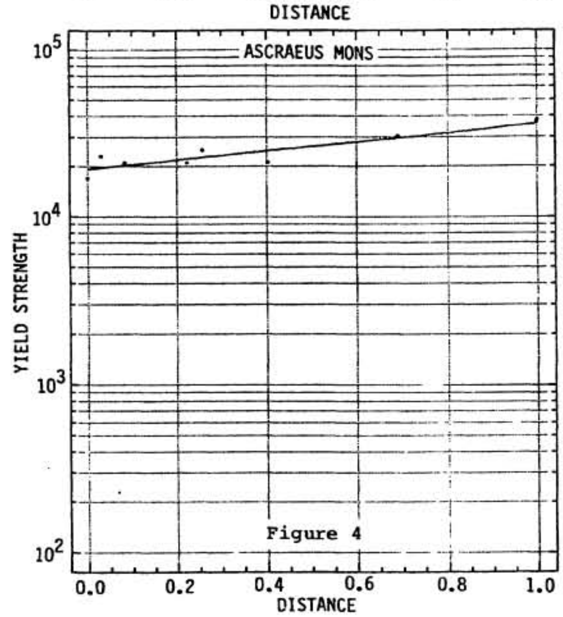

Figure 4

HIGH RESOLUTION SPECTRAL ANALYSIS OF IRISH OAK RADIOCARBON RECORD

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The origin of the long period variations in the radiocarbon production rate is not known. To establish precise periods and probabilities of the spectral line features, a high resolution Bayesian spectral decomposition was performed on the Belfast Irish Oak radiocarbon record (1). This new statistical algorithm (2) replaces more traditional Fourier techniques. Although it is model dependent, this method does not require evenly spaced data, and is capable of orders of magnitude improvements in resolution accuracy.

In our calculations, the model is composed of multiple periodic functions combined with a third order detrend. To the extent that the data represent a superposition of periodic processes, their time scales and relative amplitudes can be determined. In this preliminary report we have restricted the model to periods longer than 150 years and an optimum solution is reached with sixteen frequencies as shown in figure 1. These spectral features are plotted in the frequency domain as Gaussians with the height of each peak determined by the power of the spectral feature and the width set to the one sigma confidence in the frequency value. Reconstruction of the data from these periods is also possible because phase information is retained in the calculations. The reconstructed and original time series are shown in figure 2.

The existence of sixteen spectral lines need not imply sixteen independent processes. First, any non-sinusoidal but periodic process will create harmonic overtones. Moreover, the non-linear interaction of two periods is observed as sum and difference frequencies. To examine this possibility, a computer code was written to find the minimum number of frequencies (linearly independent) which span the set using integer coefficients. These permutations showed that the long period spectrum could be explained as the combination of four fundamental frequencies. The features in the 200 year region, reported previously from the La Jolla record (3), appear very prominently in this spectrum. Indeed the line at 0.0048 years-1 (208 years) is one of the strongest features indicated by the calculation. The DFT of the La Jolla radiocarbon sequence is shown in figure 3. The La Jolla data is currently being examined using the Bayesian algorithm. Preliminary results suggest close correspondence with the Belfast results reported here. Variability in the amplitudes of spectral features reported earlier is a possible source of the interdependent features via amplitude modulation.

The more complex problem of detecting aperiodic behavior is presently being investigated via the Grassberger-Procaccia dimensionality algorithm (4). We hope to distinguish between a simple limit cycle model and a strange attractor model for the underlying dynamical system which forces the radiocarbon spectrum. This approach is still restricted by data noise and requires further investigation.

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Conclusions: A long period spectrum characterizes the Belfast radiocarbon variations; preliminary comparisons indicate this correlates with the earlier La Jolla sequence. Most lines of the Belfast record appear linearly related via sum and difference frequencies between, at most, four underlying periods. This raises the possibility of non-linear mixing between the four basic periods. The Belfast spectrum appears to match the earlier spectrum reported for the La Jolla sequence including the 200 year line. Current candidates for the forcing are (a) variations in the intensity of the geomagnetic field, (b) modulation of the cosmic ray source by long period variations of the interplanetary magnetic field, (c) an atmosphere-ocean resonance, (d) or some combination of these.

References: (1) Pearson G. W. et al., (1986) *Radiocarbon*, **28**, 2B, 911. (2) Bretthorst G. L., (1987) Ph.D. Thesis, Washington Univ. (3) Sonett, C.P. (1984) *Rev. Geophys. Spa. Phys.*, **22**, 239. (4) Grassberger, P. and I. Procaccia, (1983) *Physica* **9D**, 189.

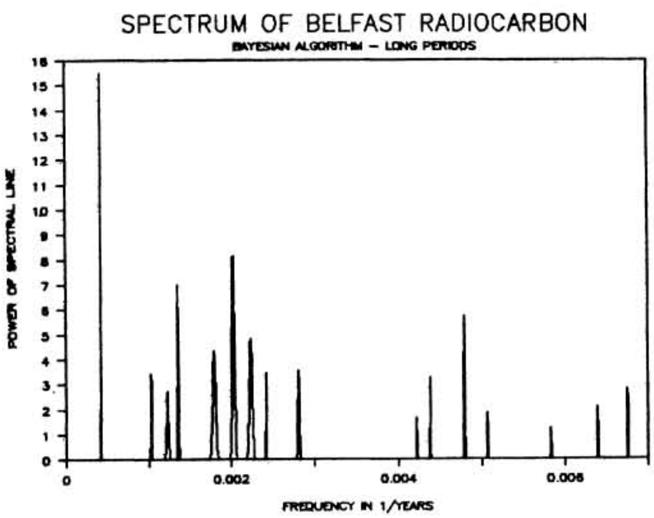

Figure 1

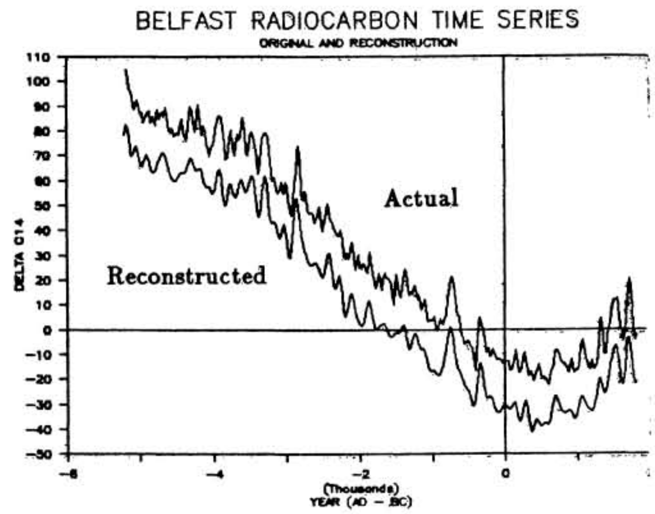

Figure 2

For reconstructed time series subtract 20 from y scale

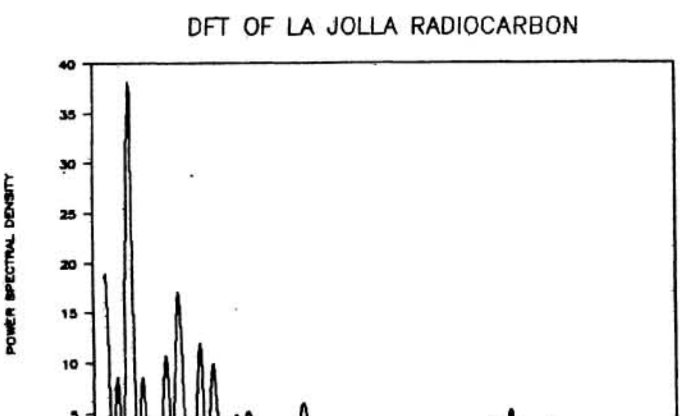

Figure 3

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