NORSAR

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FINAL REPORT
NORSAR PHASE 3

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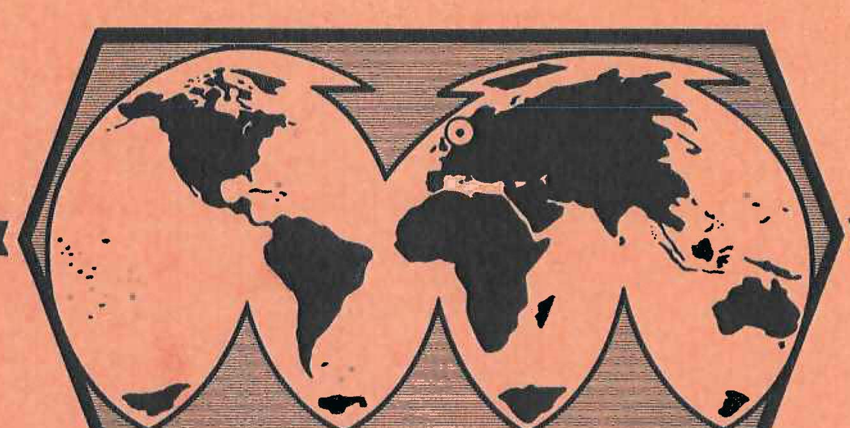

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VII. SUMMARY OF SPECIAL TECHNICAL REPORTS/PAPERS PREPARED

VII.1 Seismic Velocity Variations and Solid Earth Tides

We have previously (Final Technical Report, 1 July 1974-30 June 1975; Semiannual Technical Report 1 July - 31 December 1975) reported on this project, in which 2.778 Hz monochromatic waves from a hydroelectric power plant have been used for precise monitoring of seismic velocities. It has been found that precisions of the order of 10^{-3} are obtained when 2 hours of data are stacked, and 10^{-4} with 7 days of data. The average group velocity is around 3.5 km/s.

In order to determine the wave type that we are observing, a three-component set of short period seismometers was installed in site 14C02, 4.7 km away from the source. The particle motion was then derived by application of Fourier analysis and stacking, where relative amplitudes and phase delays were used in the actual contructions of the plot, as shown in Fig. VII.1.1. It is seen there that the radial to transverse amplitude ratio is so small that only S-waves can satisfactorily explain the observations. This solution is also consistent with the velocity observations around 3.5 km/s.

A systematic search for periodicities in the data has revealed the presence of velocity variations with a cycle time of 12 hours. This is shown in Fig. VII.1.2, where the two full cycles in the 24 hours plot demonstrate that we are not observing a hidden diurnal component (such as a non-symmetric temperature effect). We have searched the data for a number of other periods too, and find a response for periods in the range of 11-13 hours. This of course should be expected when only 7 days of data have been analyzed, but it is noteworthy here that the measured phase delays for the different periods in the 11-13 hours range are found from simulation analysis not to be consistent with leakage from a single spectral component.

The closest place to look for a source of these velocity variations is in the earth tidal field, which has been calculated theoretically through the harmonic expansion of the tide-generating potential of second order. In this way, the horizontal components of the strain tensor have been calculated for the time periods in question, but no correlation has been found with the observed velocity variations, with the important exception that the periods coincide. This lack of correlation so far as initial phase is concerned does not, however, exclude the possibility of a tidal source. This is because there are factors such as ocean loading and atmospheric pressure variations which have not been taken into consideration in the theoretical calculations. More important, however is the doubt that we have as to the assumption of a direct relationship between velocity and strain, this is partly because the (unknown) distribution in direction and size of the cracks in the material also enters this relationship.

The velocity variations displayed in Fig. VII.1.2 are of the order of 10^{-3}. The predictions here, based on extrapolation of laboratory values, give values of the order of 10^{-5}. If the velocity variations that we observe are actually caused by earth tides, this therefore means that there is a very high velocity sensitivity to stress variations in the uppermost layer of the earth.

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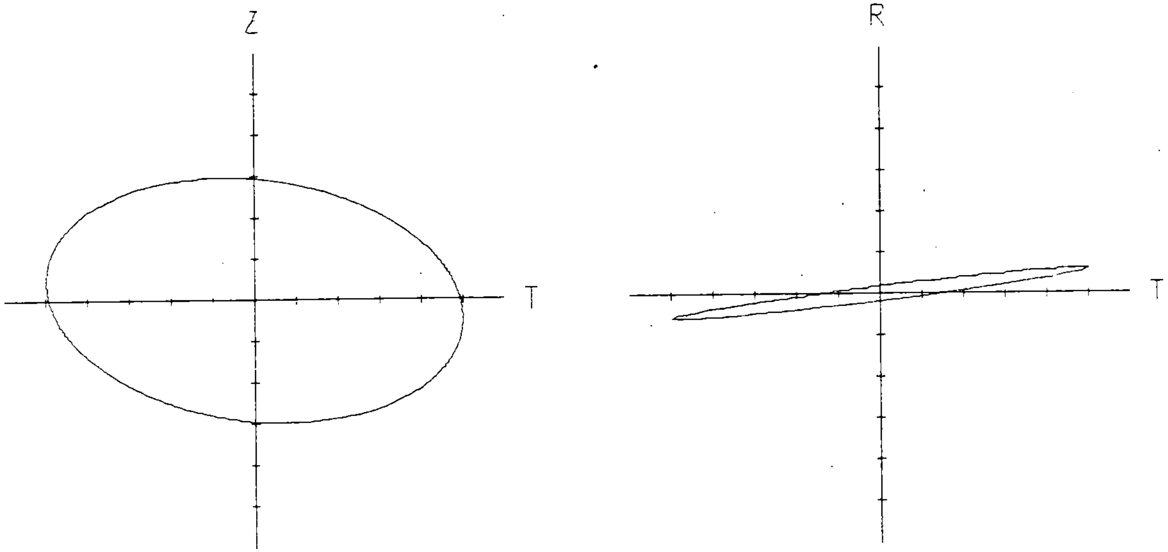

Fig. VII.1.1 Particle motion plot of the 2.778 Hz monochromatic waves as recorded 4.7 km away from the source. The solution is based on about 10 hours of data.

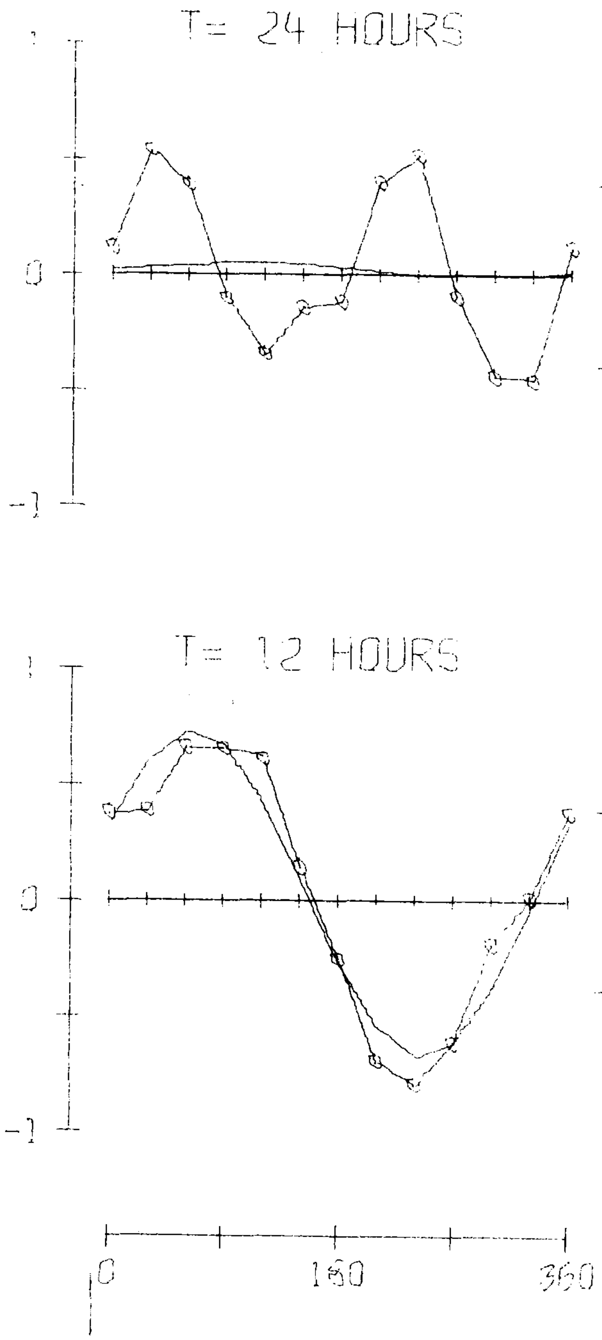

Fig. VII.1.2 Propagational phase angle differences when measured with a sliding window procedure in such a way that the presence of the searched-for periodicity should show up in the form of a one cycle sine wave. This is the case for T=12 hours, while it is the 12 hours periodicity which shows up as two cycles on the plot for T=24 hours.