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ANOMALOUS EVENTS, SURFACE WAVE PROPAGATION, AND TECTONICS OF CENTRAL ASIA

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August 1977

Semi-Annual Report No. 1

1 October 1976 - 31 March 1977

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Sponsored by:

Defense Advanced Research Projects Agency
ARPA Order No. 3291

Monitored by:

AFOSR under Contract No. F49620-77-C-0008

Name of Contractor: Columbia University

Effective Date of Contract: 1 October 1976

Contract Expiration Date: 30 September 1977

Amount of Contract: $95,000

Contract No. F49620-77-C-0008

Principal Investigator & Program Director: Lynn R. Sykes
914-359-2900

Abstract

During the first six months of this contract, research was carried out in the following areas of interest to the contract.

1. A portion of a study of intra-plate seismicity, alkaline magmatism and other tectonism post-dating continental separation related to the tectonics of the French test site in Algeria. This study shows that the test site is not in the middle of a shield area. The tectonic setting is significant in some studies of the estimation of yield from seismic amplitude.

2. A study is underway to determine how well the source parameters of an earthquake can be prescribed by a limited number of seismic stations. Both WWSSN and VLP stations are being used, but emphasis is being placed on the VLP data. Earthquakes from a Mid-Atlantic Ridge swarm are being used as the basic data set.

3. A study of the velocity structure under the Tibetan Plateau using normal and higher mode surface waves recorded by nearby WWSSN stations.

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1.) Sykes has completed the draft of a long paper on "Intra-plate seismicity, alkaline magmatism, and other tectonism post-dating continental separation". One item of his study that concerns the nuclear test detection program is his analysis of intra-plate earthquakes and magmatism that has occurred during the last fifty million years in Africa. That study has relevance to the tectonics of the French test site in Algeria, which has been used for some studies of estimations of yield from seismic amplitudes. Contrary to much prior thought about the tectonic setting of the French test site, it is in fact not located in the middle of a shield area. A number of papers on the geology of west Africa indicate that magmatism has occurred in the Ahaggar area near the French test site within the last 25 million years. In that sense the volcanism is much like the Nevada test site. Burke and Dewey conclude that the Ahaggar region of west Africa is a region of elevated topography and is one of several hot spots in Africa today.

During the last few years considerable progress has been made in developing a plate-tectonic framework for Africa. Three large cratonic areas in which the rocks are older than two thousand million years are found in Africa. These older shield areas are surrounded by rocks of Pan-African age, about 700 to 450 million years old. Evidence is now accumulating that several of the zones of Pan-African deformation represent suturing of new continental material on the sides of the older cratons. One of these three cratons, the west African craton, occupies a large area of the bulge of west Africa to the south of an old plate boundary along the South Atlas fault. Rocks of the younger Pan-African age are found along the east side of the west African craton in a belt stretching from the Ahaggar region to the Gulf of Guinea near Accra-Ghana. This belt of Pan-African age is the youngest belt of rocks in Africa that predates the continental separation of Africa from South America. As Africa and South America started to fragment, rift valleys were formed along the west side of the west African craton and along its eastern side. The western set of rifts developed into the present South Atlantic Ocean while a series of rifts extending from Nigeria to Chad experienced rifting and magmatism but did not develop into a full ocean. It is exactly along that trend that magmas less than 25 million years are found in west Africa. They are not found within the older craton of the west African shield. Sykes finds that continents tend to be broken apart along previous zones of deformation such as to minimize new fracture being developed within the older cratonic areas. Many of these reactivated faults tend to be active for long periods of time after the initial separation of continents. This phenomenon can be seen in east Africa today where the rift valleys are multi-branched and tend to follow old zones of weakness near the edge of cratons. Presumably at some time in the future a new ocean will develop along the East African rift valleys and some of the zones of multi-branch rifting will be stranded on one or the other plate. These stranded rift valleys may be sources of earthquakes and of magmatism for several tens of millions of years. It is believed that this process went on along the east side of the west African craton during the Cretaceous and Cenozoic eras.

Thus, the French test site is not located in a cratonic area but instead is in a region that was reactivated during the separation of Africa from the Americas. It also experienced volcanism in the last 25 million years. Hence, seismic signals leaving that region may be attenuated more like those leaving the Nevada test site than those from test sites in shield areas or platforms that have not been the sites of igneous for hundreds of millions of years.

2.) The following study is relevant to the nuclear explosive detection program because the participants are attempting to develop a technique to determine the source parameters of earthquakes using a limited number of seismographic stations. If this can be done effectively for the swarm test set discussed below, it might be possible to discriminate against underground nuclear explosions using a "source parameter" technique using a limited number of VLP- or SRO-type stations.

In this study a number of earthquakes from a swarm sequence are being analyzed to determine how well source parameters can be determined by a very limited number of stations and to study the source parameters of swarm events in detail. The source parameters of earthquakes in swarm sequences have not been thoroughly investigated to date. This is due, in part, to the scarcity of records of sufficient amplitude and quality to justify detailed analysis. In particular, there have been few individual events in earthquake swarms from areas, such as the Mid-Atlantic Ridge, which have exceeded a detection threshold of about m_b = 5.0 for WWSSN stations in Europe and North America.

This study is making use of both WWSSN and VLP data to help alleviate the data problem. Thirty-four events of an earthquake swarm, clustered around 27.35°N and 44.30°W in the time period 15 to 25 May 1974 are under study. The observations made to date include:

In Figure 1 the tidal acceleration for May 15 is plotted versus time. The origin time of 24 of the events from the swarm are plotted on the same time scale. It seems apparent that the onset of the swarm coincides with increase in tidal acceleration.

In Figure 2 the observed amplitudes of 32.7 sec Rayleigh waves of one of the first events in the swarm are plotted as a function of azimuth. The approximation of the curve to a two-lobed radiation pattern indicates normal or reverse motion on a high-angle fault trending about N20°W. The observed Rayleigh wave radiation patterns (Figures 3 and 4) for two events that occurred about eight hours later showed the four-lobed patterns associated with strike-slip focal mechanisms.

Twenty-one Rayleigh wave amplitude spectra have been calculated using data from the VLP seismograph station, Ogdensburg. Two of these spectra are shown in Figure 5. There is an evident increase in the amplitude density between periods of 30 to 50 seconds for event 2 compared to event 33. This implies either a variation in focal depth during the period of the swarm or different focal mechanisms for the two events.

3.) A working knowledge of the velocity and attenuation structure beneath the Tibetan Plateau is significant to the discrimination problem for explosions denotated in the Sinkiang Province. The study described in the following paragraphs bears directly on the problem of determining these structures.

Despite the important advance made in the past decade and the wide acceptance of the theory of plate tectonics, a great deal still remains unknown to us. In fact, the theory does not explain and cannot uniquely interpret many important features of the earth, especially in regions of active tectonism. To Chun, the theory is still in an early stage of development and its application needs to be extremely cautious.

The Tibetan Plateau is one such place that some of the important unsolved problems can be directly tackled and hopefully resolved. These include an estimate of the relative importance of the plate driving forces; elastic and inelastic behavior of the subducted lithosphere; anisotropy of the upper mantle; mode of magma generation and volcanism; attenuation coefficients for the crust and upper mantle.

Chun and Yoshii (1977) conclude that the crustal velocities under the Tibetan Plateau is generally low. They further suggest the possible existence of a low velocity zone of intermediate depth within the crust. Chun (in preparation), based on extensive pure-path studies of short-period Rayleigh waves, concludes that the Tibetan Plateau is devoid of thick and low velocity sediments suggested by Chen and Molnar (1975). While the above studies shed some light on the structure of the Tibetan Plateau and provides certain constraints on future tectonic models, we still have no hint about the nature of the upper mantle structure.

As a very preliminary step to gain insight into some of the problems, Chun has carefully selected and processed a large amount of surface wave data relevant to the crustal and upper mantle structures of the Tibetan Plateau and its adjacent regions. The data include the fundamental mode Rayleigh and Love waves (5-155 sec), higher mode surface waves (3-25 sec), and fundamental and higher leaky modes (10-100 sec). Approximately 75 propagation paths are being analyzed in an effort to resolve the upper mantle anisotropy in the Tibetan region and the regional differences in terms of their seismic structures and attenuation properties.

The finding of the present project is expected to yield first-hand information on the physical characteristics of the upper mantle under the Tibetan Plateau which are until now very poorly known.

References

Chen, W.P. and P. Molnar (1975). Short period Rayleigh-wave dispersion across the Tibetan Plateau. Bull. Seism. Soc. Am., 65, 1051-1057.

Chun K.Y. and T. Yoshii (1977). Crustal structure of the Tibetan Plateau: A surface wave study by a moving window analysis. Bull. Seism. Soc. Am., 67, 735-750.

TABLE 1

List of the Earthquake Swarm from North Atlantic Mid-Oceanic Ridge
May 15, 1974 to May 25, 1974

Events	Date	O.T.	Lat.	Long.	Magnitude
No. 1	May 15, 1974	4h37m39.4s	27.43N	44.41W	4.5
No. 2		5h36m13.6s	27.40N	44.20W	4.5
No. 3		6h56m15.5s	27.47N	44.31W	3.9
No. 4		7h22m49.9s	27.48N	44.39W	4.5
No. 5		7h25m08.8s	27.30N	44.80W	4.3
No. 6		7h30m16.5s	27.47N	44.30W	4.3
No. 7		7h55m05.1s	27.40N	44.40W	4.4
No. 8		8h00m36.0s	27.30N	44.60W	4.1
No. 9		8h16m52.5s	27.15N	44.27W	4.1
No. 10		8h54m54.6s	27.45N	44.33W	4.4
No. 11		9h02m54.0s	28.30N	44.60W	3.9
No. 12		9h27m34.6s	27.34N	44.23W	4.1
No. 13		10h01m32.0s	27.40N	44.26W	4.1
No. 14		10h05m46.5s	27.43N	44.54W	4.6
No. 15		10h20m07.1s	27.30N	44.30W	4.4
No. 16		10h33m20.3s	27.43N	44.33W	4.3
No. 17		10h33m58.0s	27.38N	44.27W	5.1
No. 18		10h47m51.0s	29.30N	44.90W	Poorly Determined
No. 19	May 19, 1974	11h08m07.3s	27.34N	44.43W	4.6
No. 20		11h49m12.0s	26.00N	44.30W	Poorly Determined
No. 21		12h13m09.1s	34.13N	55.62W	4.8
No. 22		12h52m42.0s	27.50N	44.42W	4.2
No. 23		13h37m13.0s	27.44N	44.30W	4.9
No. 24		13h44m10.6s	27.39N	44.37W	4.5
No. 25		13h59m15.7s	27.37N	44.46W	4.7
No. 26		14h52m03.9s	27.28N	44.14W	4.5
No. 27		16h50m35.0s	24.00N	44.20W	4.3
No. 28		17h13m36.3s	24.47N	44.23W	4.3
No. 29		19h29m32.2s	27.38N	44.39W	5.2
No. 30		22h21m41.0s	27.35N	44.28W	4.7
No. 31	May 16, 1974	21h23m47.9s	27.43N	44.31W	4.5
No. 32	May 23, 1974	9h23m00.1s	27.32N	44.46W	4.7
No. 33		11h08m29.0s	27.33N	44.43W	5.1
No. 34		15h46m01.1s	27.46N	44.44W	4.5

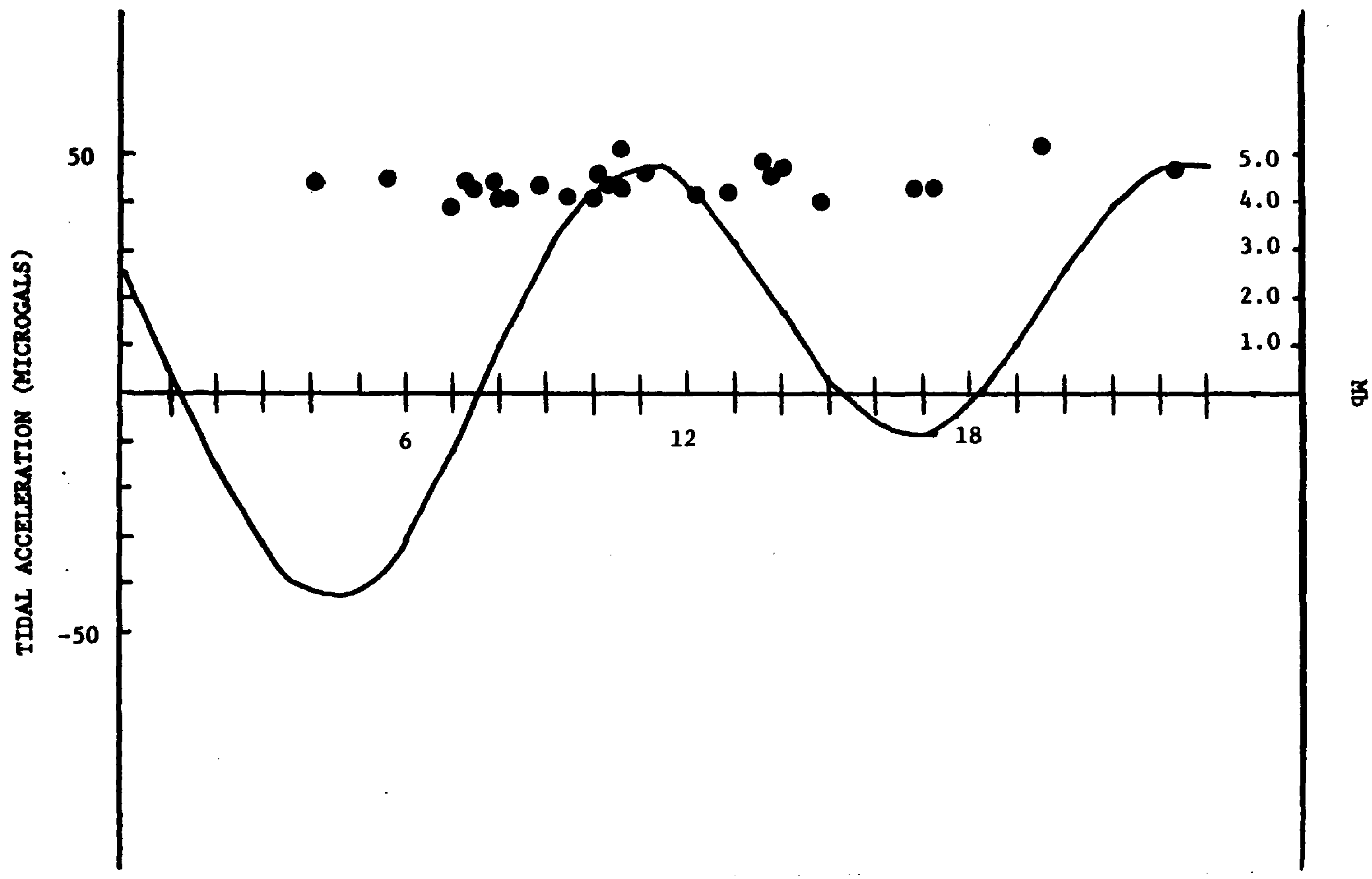

Figure 1: Both tidal acceleration and the magnitude of events are plotted on G.C.T. time axis of May 15, 1974. The earthquakes of the swarm occurred this day, and started at the exact time when the semi-diurnal component of the tide was to be rising.

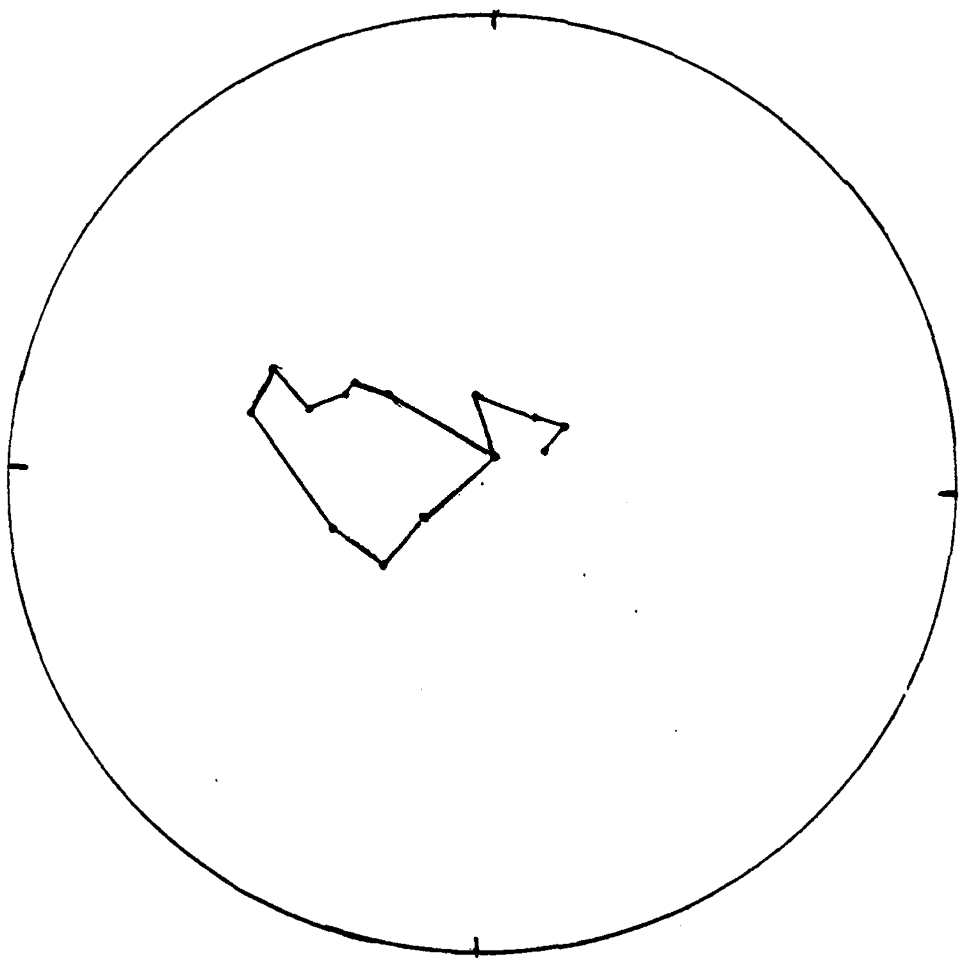

Figure 2: The Fourier analysed Rayleigh wave amplitudes of events No. 2, No. 23 and No. 25 are plotted as azimuth. These amplitudes of 32.7 second period are corrected by geometrical spreading and attenuation factors.

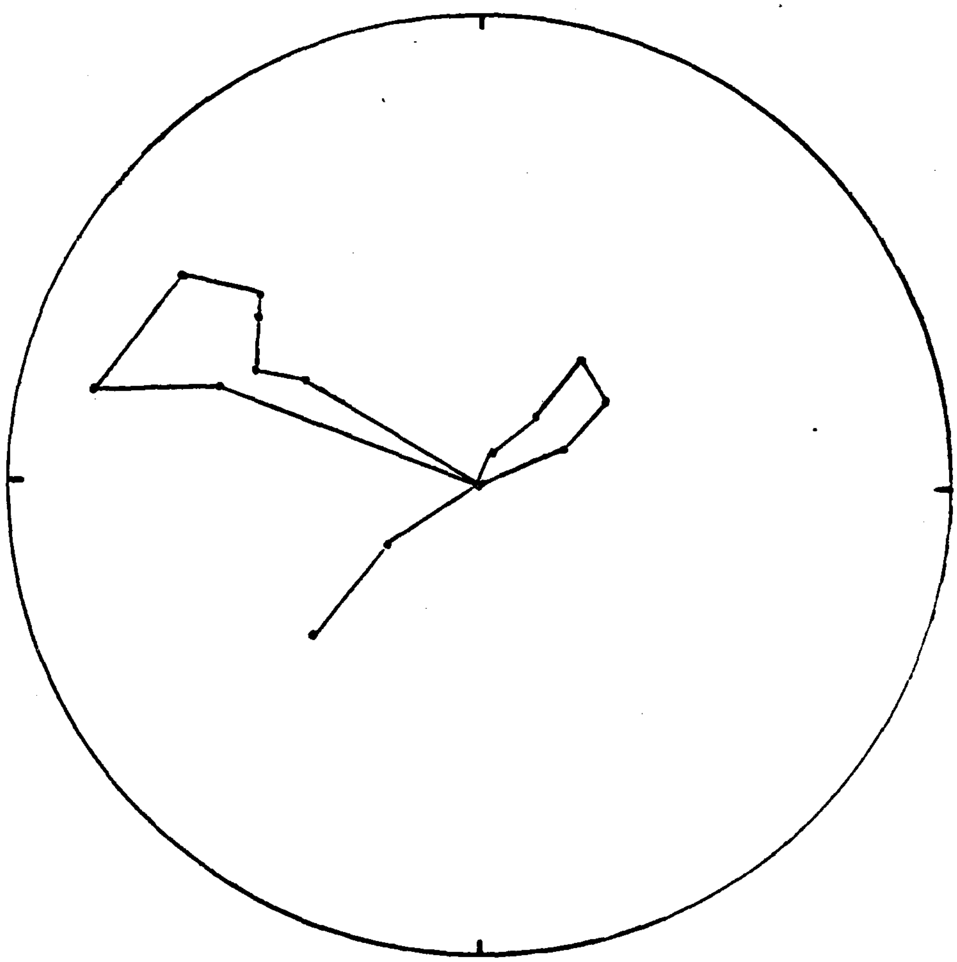

Figure 3: The Fourier analysed Rayleigh wave amplitudes of events No. 2, No. 23 and No. 25 are plotted as azimuth. These amplitudes of 32.7 second period are corrected by geometrical spreading and attenuation factors.

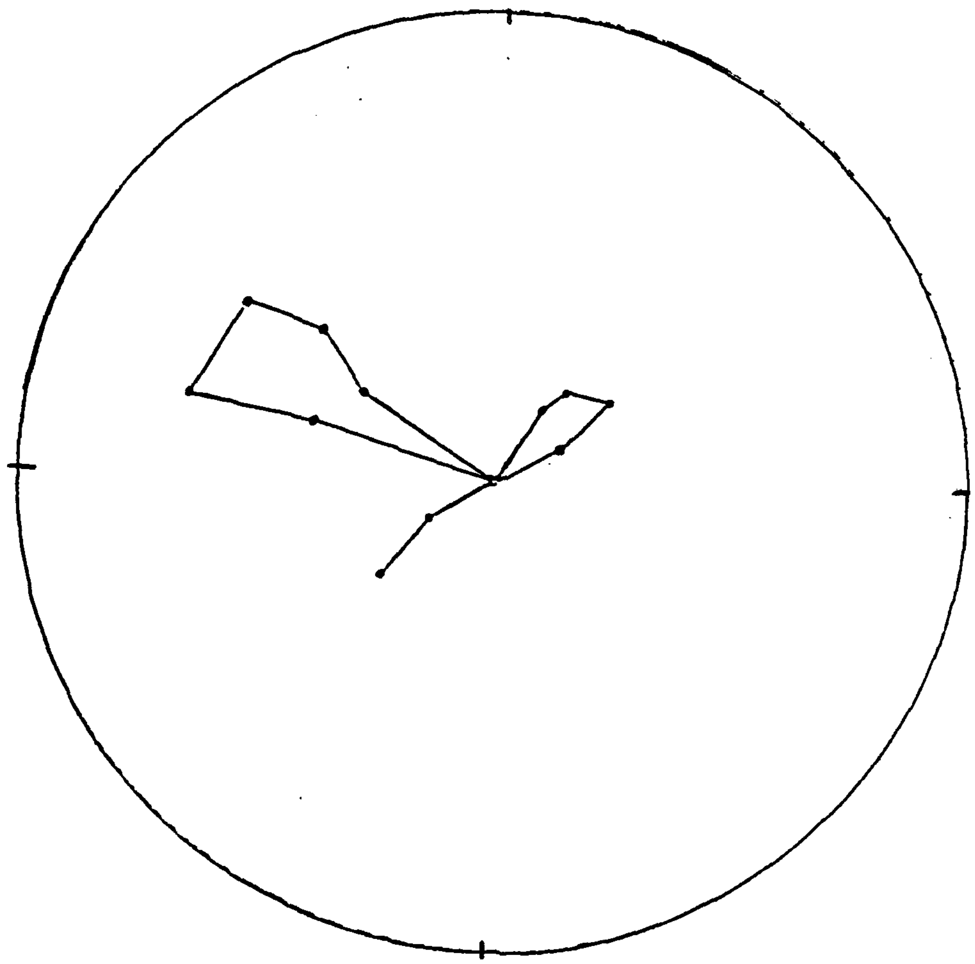

Figure 4: The Fourier analysed Rayleigh wave amplitudes of events No. 2, No. 23 and No. 25 are plotted as azimuth. These amplitudes of 32.7 second period are corrected by geometrical spreading and attenuation factors.

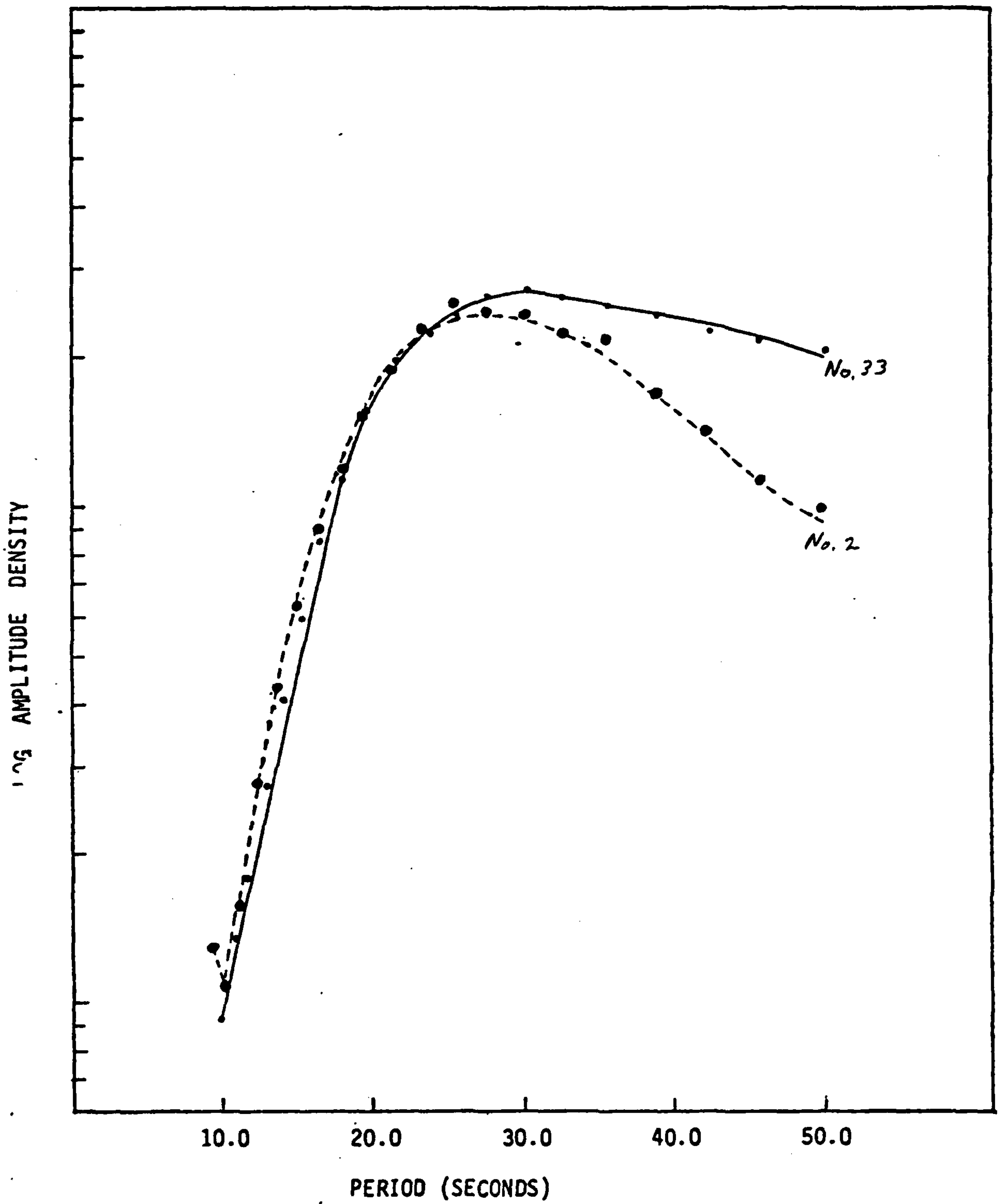

Figure 5: Rayleigh wave amplitude spectra of No. 2 and No. 33 events are shown from periods 10 second to 50 second. These Rayleigh waves are recorded on the vertical components of VLP high gain station at Ogdensburg, New Jersey.