

## STRONG MOTION DATA CENTRE: BUREAU OF MINERAL RESOURCES, CANADA

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### Abstract

A Strong Motion Data Centre, for the collection, storage, distribution and preliminary analysis of accelerograms from the Australian and New Guinean regions, has recently been established at Canberra by the Australian Bureau of Mineral Resources.

The work undertaken at the Centre is described and examples of the processing facilities available are given. Extensive use is made of computers in the analysis of the accelerograms and the plotting of the results.

By December 1970 thirteen accelerographs had been obtained, by several institutions, for installation in the Australian and New Guinea regions and 24 accelerograms had been received at the Centre for analysis. The instruments located on unconsolidated material at Lae, Yonki and Panguna are currently producing about 5 accelerograms per year and the maximum ground acceleration recorded so far, of 0.12 g, was obtained at Panguna, where the accelerograph is located on recent unconsolidated volcanic ash.

### 1. Introduction

This paper describes the work which has recently been carried out at the Bureau of Mineral Resources in Canberra to establish a strong motion data centre for the Australian and New Guinean regions. Considerable emphasis has been placed by many workers in the field of earthquake engineering on the paucity of good large amplitude records of ground motion obtained from epicentral areas of damaging earthquakes. In recent years, there has been some improvement in the situation due mainly to the increased effort, on a world wide basis, that has been put into the installation of more accelerographs. However, it is still very difficult to obtain good data because of the low probability of a large earthquake occurring close to an operational accelerograph. Furthermore, the accelerograms that are available may not be appropriate to many design problems because of differences in earthquake source mechanisms, and because of the differences in ground response from site to site due to the large variations in near-surface geological conditions.

Our aim in Canberra is to collect, in digitised form, a library of accelerograms that have been obtained from the Australian and New Guinean regions. These will be available to all institutions participating in the

scheme and any other organisations that may acquire strong motion data. It is hoped that from these results it will be possible to predict the dynamic behaviour of the ground during a large earthquake, and to determine more accurately the structural engineers' requirements as far as earthquake risk is concerned.

### 2. Regional Seismicity

#### New Guinea Area

Although the high level of earthquake activity in the New Guinea region has been known for many years (Sieberg, 1910), it is only recently, with the installation of several regional seismographs and improved computing facilities, that the distribution of earthquakes in the New Guinea region has become fairly well known (Denham, 1969). It appears that most of the earthquakes result from the interaction of the northern boundary of the northward moving Indian-Australia (I-A) block and the westward moving west Pacific block.

The predominant influence in the region is the northward moving I-A block. This produces the high seismicity associated with the Solomon Sea trench complex and the north New Guinea mainland. The east-west influence of the Pacific block is almost entirely eliminated except at the extreme north and north west edges of the New Guinea region, because of the "shadow zone" effect resulting from the vigorous underthrusting of the Pacific block, which is believed to be taking place in the Tonga-Kermadec region (Isacks, Sykes and Oliver, 1969).

The parameters of shallow earthquakes are of the greatest importance in studies relating to earthquake risk. Figure 1 shows all known earthquakes, having a body wave magnitude (mb) of 5 or greater, that have occurred in the region from 1958 through 1969, at depths of 40 km or less. These data were obtained from the earthquake data file kept in Port Moresby (Denham and Byrne 1970). The most vulnerable areas are along the south coast of New Britain and the north coast of the New Guinea mainland, with zones of very high risk near Wewak and in east New Britain south of Rabaul. There is also a zone in the south eastern corner of Papua which experiences several shallow earthquakes, but the level of activity there is somewhat lower than in the main New Britain-New Guinea seismic belt. Fortunately the shocks associated with the Bismarck Sea seismic lineation are mostly sub-marine and are not likely to cause any direct structural damage to land based structures except where the zone is located close to the coast.

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At the same time as the detailed seismicity

picture was being revealed, the earthquake risk in the region was becoming a more important factor in the economic development of the country. Before the 1960s, the capital invested in civil engineering works was very small, but during the last few years, with the increased development of the region (due to mining and agricultural projects, tourism and the growth of urban areas) the number of buildings and facilities which can be damaged by earthquakes has increased considerably. As these developments continue the potential danger from earthquakes will increase correspondingly. A brief examination of the damage caused by four recent series of earthquakes emphasises the importance of earthquake risk in New Guinea.

These four earthquake series all occurred in the main earthquake zone and Figure 1 indicates the locations of the epicentres. None of these events were located in unusual or unexpected locations and they can be regarded as typical events for the north New Guinea-New Britain seismic zone.

The first earthquake series took place in August 1967 when two major earthquakes shook the Kokopo and Kabaleo areas of the Gazelle Peninsula, east New Britain. They caused damage estimated at about \$172,000 (Heming, 1969). These were followed in September 1968 by the west New Britain earthquake which caused damage worth over \$150,000 to the SEACOM cable where it crossed the ocean trench (Denham, 1970, and Krause, White, Piper and Heegen, 1970). The Wewak earthquakes occurred during September and October 1968 and they caused damage worth about \$200,000 to buildings facilities in the Wewak district (Denham, 1970).

The following year, 1969, was a quiet year seismically in New Guinea, with no reported earthquake damage, but in 1970 a large earthquake took place near Madang. This caused at least 15 deaths and damage provisionally estimated at about \$1 million. These figures put the current financial loss in New Guinea resulting from earthquake damage at a rate of approximately \$400,000 per year.

An important point to notice is that most of the damage that occurred as a result of these four series of earthquakes would not have taken place had the earthquakes occurred ten years earlier because very few of the buildings or facilities damaged by these events were in existence then. This fact emphasises how the potential earthquake risk in any region is a direct function of its economic development.

### Australian Continent

The level of seismicity of the Australian continent is lower than any other continental area except Antarctica. Figure 2 shows all known earthquakes having a unified magnitude (m) of 5 or greater that have occurred from 1897 until the end of November 1970. These data have been taken from the paper by Doyle, Everingham and Sutton (1968), on the seismicity of the Australian Continent; the Mundaring Geophysical Observatory Annual Reports for 1967-1969 (Everingham and Gregson, 1969); and the paper by Sutton (1969) presented at the Melbourne Earthquake Engineering Symposium.

Most of the seismic activity is probably due to stresses within the lithospheric plate

as it moves northwards and may be associated with changes in spreading rates (Cleary and Simpson, personal communication).

However, the activity is so low that only in a few areas has it been possible to locate any definite trends and obtain frequency of occurrence relationships. Two such areas are in the Adelaide region of South Australia, and the Meckering region of Western Australia. Both these areas have suffered large damaging earthquakes within the last 20 years and earthquake risk must definitely be considered in these regions. The last major damaging earthquake to occur in the South Australian seismic zone took place in 1954.

After this event, which caused damage in excess of \$1 million (Kerr Grant, 1956), some earthquake resistant design factors were incorporated in all new school buildings in the state.

The seismic zone in south-western Australia has been referred to as the Yandanooka-Cape Riche Lineament (Everingham, 1968). Activity in this zone has been high in recent years and both the Meckering (1968) and Calingiri (1970) earthquakes originated from this feature. In this region the seismic activity is high enough for the earthquake risk to be quantitatively estimated.

For the remainder of the continent the seismicity patterns are fragmentary and the earthquake risk uncertain. There are small areas, such as that near the Northern Territory-South Australia border, and that in eastern New South Wales near Gunning, which have experienced higher than normal seismic activity. However, it is not yet certain whether these regions are part of definite trends or merely isolated features. The observational time scale is too short and the level of seismicity too low for the complete picture to be revealed so far.

Nevertheless, the recent industrial growth throughout Australia due to mining ventures in remote areas, and the intensive urbanisation around the capital cities, has given rise to an awareness of the potential earthquake risk. In 1969 a symposium was convened in Melbourne to discuss earthquake engineering in Australia and a National Committee was formed during the conference.

### 3. Instrumentation

At the time of writing, there are ten accelerographs operating in the Australian and New Guinean regions. These are all situated in New Guinea. In addition two accelerographs have recently been obtained for use in the Adelaide region (D. Sutton, personal communication) but these have not yet been permanently installed. Figure 3 shows the locations of the accelerographs, and also the seismograph stations, in operation during 1970. The locations of the two South Australian instruments are shown schematically. The accelerograph shown near TLS is presently undergoing repair and not in operation. Table 1 lists the co-ordinates of the instruments and gives details about the foundations on which they are located.

Skinner's visit to Papua-New Guinea in

1967 (Skinner, 1968) resulted in the installation of the first accelerographs in the region. They were acquired by different institutions for a variety of reasons. On Bougainville the instruments were installed to assist Conzinc Riotinto of Australia (CRA) in determining the slope of the open cut mine at Panguna. Clearly, in an earthquake region slope stability of the mine workings is highly dependent on the potential effect of earthquakes and could affect directly the economic operation of the prospect.

At Cape Hoskins on the north coast of New Britain an accelerograph was installed to provide information for the design considerations at the processing plant for a large Palm Oil project operated by Harrison and Crossfield Pty. Ltd.

The instruments at the Upper Ramu were obtained by the Australian Commonwealth Department of Works (CDW) to record ground motion records in the vicinity of the hydro-electric scheme due to be commenced in the near future. Two accelerographs have been installed; one at Yonki near the site of the dam, on recent unconsolidated lake sediments which are at least 50 metres thick, and one at the intake site on fresh siltstone and greywacke of Miocene age. The soft rock accelerograph was installed in 1967 and has been triggered 15 times since then. The instrument located on the hard rock site has not been triggered since it was installed in July 1969.

The Rabaul and Wewak accelerographs were also obtained by CDW and installed as a first step in setting up a regional network of accelerographs to provide ground motion at typical urban sites in zones of high earthquake risk.

At Lae the instruments are operated by the Civil Engineering Department of the Papua and New Guinea Institute of Technology. One is situated on the top of a 30 m water tower and the other is located at the base of the tower. The objects of the experiment are to observe the ground and tower motions during earthquakes and ascertain whether the calculated response due to the actual ground motion will be the same as that observed from the accelerograph located at the top of the tower.

#### 4. Analysis of Accelerograms and Preliminary Results

At the time of writing at least 30 accelerograms have been obtained in the New Guinea region and 24 of these have now been received at the Strong Motion Data Centre. Table 2 lists the details of the accelerograms received so far, and indicates the progress that has been made in the reduction and analysis programme. All the records received have been obtained from the Skinner-Duflou M02 accelerographs.

The original accelerograms, which are recorded on 35 mm film, are copied, and photographically enlarged by a factor of about 5.0. Figure 4 shows a record enlarged for digitization. It was obtained in March 1970 from Panguna. This accelerogram contains the highest acceleration yet recorded in the New Guinea region. Unfortunately, the baseline trace was missing and the edge of the film had to be used as a baseline.

The accelerograms are digitized at 0.02 second intervals on a scaling table. Digitized ordinates are obtained from a shaft position encoding disc fitted to the Y drive of the scaler. The output from the scaler is coupled to a paper tape punch. The 4096 position encoder allows a resolution of about one thirteenth of a millimetre, and the overall accuracy of the system is about  $\pm 0.1$  mm. This corresponds to a sensitivity of about 0.001 g on a typical M02 horizontal trace; however, the accuracy is usually limited by trace thicknesses, which can amount to at least 0.5 mm when the original film has been enlarged by a factor of 5.0.

The complete methods of analysis are still under development but the block diagrams of the scheme currently operating are shown in Figures 5a, b and c and give an indication of the operations carried out. The paper tapes produced from the scaling machine are reduced to punched cards as indicated in figure 5a, and the scheme outlined in 5b is then applied. The filter, and response spectra parts of the system have not been completely developed. The filter system will be a flexible high-pass filter to eliminate the very low frequency variations in the record due to errors in scaling and baseline correction procedures. The response spectra part of the operation is being designed to plot the output for acceleration, velocity and displacement. This part of the system and the baseline corrections are based on the methods developed by Nigam and Jennings (1969). At a later date the modifications proposed by Boyce (1970) will probably be incorporated as an optional method of obtaining baseline corrections.

A typical computer plot for the corrected acceleration, velocity, and displacement is shown in figure 6 for the Yonki north-south component recorded on 14th November 1967. Starting with the three corrected components of acceleration, velocity, and displacement, the maximum of each of these vector quantities can be determined, and the Fourier analyses and power spectra can be computed as indicated in figure 5c. A computer plot of the power spectra is shown in figure 7. Plots of this type are available for all accelerograms that have been reduced.

The Yonki accelerograph has so far been triggered 15 times since it was installed. Using these results an attempt was made to estimate the constants  $b_1$ ,  $b_2$  and  $b_3$  in the equation

$$Y = b_1 e^{b_2 M} b_3 R \quad \dots (1)$$

which relates the magnitude, M, and the slant distance R to the peak ground motion Y (Cornell, 1968). In this equation Y can represent acceleration, velocity or displacement. At the time of writing only eight reliable sets of values for R, M and Y were available. However, a least squares solution for equation (1) was attempted and this resulted in the following equation.

$$\log_{10} Y = -0.2 + 0.2 M - 1.1 \log_{10} R \quad \dots (2)$$

where M is the Richter magnitude, R the distance in kilometres and Y the maximum acceleration in

terms of  $g$ . Although the values of  $b_1$ ,  $b_2$  and  $b_3$  seem to be reasonable the standard errors of the estimates are very high ( $+0.3$ ,  $+0.5$  and  $+1.5$  respectively), and more points will be required to obtain reliable values - assuming of course that equation (1) applies at Yonki.

## 5. Discussion and Conclusions

The first steps in the establishment of a strong motion data centre for the Australian and New Guinean regions have been described. We are perhaps fortunate in having a region of high seismicity like New Guinea readily available for the installation of accelerographs and in a few years we may be able to obtain enough accelerograms to record some very large ground motions. The instruments located at Lae Base, Yonki, and at the Panguna soft rock site are currently producing about five accelerograms per year. At this rate it should be possible to obtain, within a few years, meaningful quantitative estimates for the expected ground motion at these locations.

In the near future it is hoped that accelerographs will be installed on the south coast of New Britain, and also on the New Guinea mainland, so that all areas likely to be developed economically will be covered by strong motion instruments. In the meantime, the accelerographs at Rabaul and Wewak should provide one or two records every year if the current seismic activity is maintained.

Data on the differences in ground movement due to different local geological conditions can also be expected. At each of the Upper Ramu and Panguna sites one accelerograph was installed on hard competent rock and another on recent unconsolidated material. This was in an effort to obtain amplification factors between the soft and hard rock localities. Unfortunately, neither of the instruments located on the hard rock have yet been triggered, despite maximum accelerations of  $.04 g$  at Yonki and  $.12 g$  at Panguna having occurred on the soft rock sites while both instruments were operational.

Since the accelerographs are triggered from a vertical sensing device it is difficult to estimate the magnification factors involved without direct comparison records between the hard and soft rock sites. Nevertheless, the results obtained so far indicate that the magnifications at Panguna and Yonki could be as high as those obtained in the San Francisco bay area by Borchardt (1970), in which horizontal ground velocities were as much as ten times greater on recent muds than on nearby bedrock.

Although the seismicity of the New Guinea region ensures the occurrence of many earthquakes producing comparatively large accelerations this is somewhat offset by some of the problems encountered in operating accelerographs in isolated tropical locations. The high temperature and humidities experienced in the region cause rapid deterioration to the film, and corrosion to the battery terminals. As a result record loss was fairly high during 1968. However, in recent months, due to more frequent maintenance visits and a better appreciation of the difficulties involved, the situation has improved considerably.

One other problem which has occurred is that of identifying the earthquakes recorded

on the accelerographs. The Lae base, Panguna and Wewak instruments have each been triggered by earthquakes whose hypocentres are not known and considerable difficulty was encountered in identifying the early Yonki events because of the high level of earthquake activity in the region in the few months following its installation. This problem will continue to occur where the accelerographs are operated in remote regions of high seismic activity.

In the Australian region the level of seismicity is at least an order of magnitude less than that experienced in New Guinea and the problems of assessing quantitative risk factors are much greater because of the paucity of data. The accelerographs to be located in the Adelaide area may provide valuable information in that region and it is planned to install accelerographs in the vicinity of Meckering where the level of seismic activity is still high.

Apart from the seismic risk in the Meckering and Adelaide regions, the Hydro-electric Commission of Tasmania and the Public Works Department of Western Australia are both well aware of the possibility of earthquakes being triggered from the additional crustal loading experienced when a large dam is filled. Accelerographs may be installed at the Ord River dam in northern Western Australia and at the Gordon River development scheme in Tasmania, to provide data in case any earthquakes are caused (due to this reason).

Nevertheless, although several accelerographs are likely to be installed on the Australian continent the New Guinea region will continue to be the main source of strong motion data.

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## References

- Borchardt, R. D. (1970) - Effects of Local Geology on Ground Motion near San Francisco Bay, Bull. Seism. Soc. Am. Vol. 60 pp. 29-61.
- Boyce, W. H. (1970) - Integration of Accelerograms, Bull. Seism. Soc. Am. Vol. 60, No. 1, p. 261.
- Cornell, C. A. (1968) - Engineering Seismic Risk Analysis, Bull. Seism. Soc. Amer., Vol. 58, pp. 1583-1606.
- Denham, D. (1969) - Distribution of Earthquakes in the New Guinea Solomon Islands Region, J. Geophys. Res., Vol. 73, pp. 5855-5899.
- Denham, D. (1970) - Recent Damaging Earthquakes in New Guinea. Proceedings of the Earthquake Engineering Symposium, Melbourne, October, 1969.
- Denham, D. and Byrne, W.M.J. (1970) - A storage and retrieval system of Seismic data

- for the New Guinea and Solomon Islands Region. Proceedings of the Earthquake Engineering Symposium, Melbourne, October, 1969.
- Doyle, H. A., Everingham, I. B., and Sutton, D. J. (1968) - Seismicity of the Australian Continent. J. Geol. Soc. Aust., Vol. 15 pp. 295-312.
- Everingham, I. B., (1968) - Seismicity of Western Australia, Bur. Min. Resour. Aust. Report No. 132
- Everingham, I. B., and Gregson P. J. (1969) - Mundaring Geophysical Observatory Annual Report 1967, Bur. Min. Resour. Aust. Rec. 1969/96 (unpubl.) Reports for 1968 and 1969 in press by same authors.
- Heming, R. F. (1969) - The Kokopo (New Britain) Earthquakes of the 14th August 1967. Bur. Min. Resour. Aust. Rec. 1969/24 (unpubl.)
- Isacks, B., Sykes, L. R. and Oliver, J., (1969) - Focal Mechanisms of Deep and Shallow Earthquakes in the Tonga-Kermadec Region and the Tectonics of Island Arcs. Geol. Soc. of America Bull., Vol. 80, pp. 1443-1470.
- Kerr Grant, C., (1956) - The Adelaide Earthquake of 1st March 1954. Trans. R. Soc. S. Aust., Vol. 79, pp. 177-185.
- Krause, D. C., White, W. C., Piper, D.J.W. and Heezen, B. C., (1970) - Turbidity Currents and Cable Breaks in the Western New Britain Trench. Geol. Soc. of America Bull., Vol. 81, pp. 2153-2160.
- Nigam, N. C. and Jennings, P. C. - Calculation of Response Spectra from Strong-Motion Earthquake Records. Bull. Seism. Soc. Am., Vol. 59, No. 2, pp. 909-922.
- Sieberg, A. (1910) - Die Erdbebentätigkeit in Deutsch-Neuguinea (Kaiser-Wilhelmland und Bismarck-archipel). Petermanns Geographische Mitt., II, Heft 2/3.
- Skinner, R. I. (1968) - Report on Earthquake Engineering Problems in the Territory of Papua and New Guinea, Including Strong-Motion Recording. Bur. Min. Resour. Aust. Record 1968/140 (unpubl.).
- Sutton, D. J. (1970) - Accelerations, Magnitude and Frequency Variations of South Australian Earthquakes. Proceedings of the Earthquake Engineering Symposium, Melbourne, October 1969.

TABLE 1

## DETAILS OF ACCELEROGRAPHS INSTALLED IN NEW GUINEA

Location	Co-ordinates	Foundation	Instrument and block number	Date Installed	Operator
Panguna Bougainville	06° 19.5' S 155° 29.1' E elevation 640 m	unconsolidated volcanic ash and weathered bedrock	M02 25/39	Installed in Kieta August 1967, moved to Panguna, 1968	Bougainville Copper Pty. Ltd. (C.R.A.)
Panguna Bougainville	not known	hard rock site lithology not known	M02 29/43	Installed in Kieta August 1967, moved to Panguna, 1968	Bougainville Copper Pty. Ltd. (C.R.A.)
Kobuan Bougainville	06° 13.4' S 155° 37.1' E elevation 65 m	weathered andesitic lava	RMT 280	not known	Bougainville Copper Pty. Ltd. (C.R.A.)
Panguna Bougainville	not known	not known	RMT 280	not known	Bougainville Copper Pty. Ltd. (C.R.A.)
Rabaul	04° 13.2' S 152° 11.6' E elevation 9 m	volcanic ash	M02/165	April 1968	Operated by B.M.R. for Commonwealth Department of Works (C.D.W.)
Wewak	03° 35.4' S 143° 41.2' E elevation 10m	Weathered coral	M02	October 1968	Operated by B.M.R. for C.D.W.
Cape Hoskins	05° 28.2' S 150° 22.8' E elevation 100 m	volcanic ash	M02	November 1968	Harrison and Crossfield
Upper Ramu Intake	06° 14.2' S 145° 57.9' E elevation 1190 m	Miocene siltstone and greywacke	M02	November 1967	B.M.R. for C.D.W.
Upper Ramu Yonki	06° 14.7' S 145° 58.7' E elevation 1250 m	Recent lake sediments	M02/44	July 1969	B.M.R. for C.D.W.
Lae Base	06° 42.8' S 146° 59.4' E elevation 31 m	Recent alluvium	M02	Late 1968	Papua and New Guinea Institute of Technology
Lae Tower	06° 42.8' S 146° 59.4' E elevation 60 m	Top of water tower	M02	Late 1968	Papua and New Guinea Institute of Technology

TABLE 2  
ACCELEROGRAMS RECEIVED AT DATA CENTRE

Location	Date Triggered	Maximum acceleration cm/sec <sup>2</sup>	Remarks
Yonki	14.11.67	54.1	power spectra and digitized outputs available
Yonki	28. 4.68	27.2	power spectra and digitized outputs available
Yonki	11. 5.68	>15	fogging obscures most of record
Yonki	3. 6.68	~37	reductions and analysis not completed
Yonki	17. 6.68	~41	reductions and analysis not completed
Yonki	16. 9.68	~ 8	reductions and analysis not completed
Wewak	29.10.68	not known	film jammed, record unusable
Yonki	7. 1.69	~13	reductions and analysis not completed
Lae Base	7. 1.69	33.8	power spectra and digitized outputs available
Yonki	10. 3.69	~45	reductions and analysis not completed
Lae Base	10. 3.69	not known	reductions and analysis not completed
Yonki	8. 5.69	not known	record mostly fogged
Yonki	14. 6.69	~26	reductions and analysis not completed
Yonki	24. 6.69	~57	reductions and analysis not completed
Lae Base	24. 6.69	not known	reductions and analysis not completed
Lae Base	2. 8.69	not known	reductions and analysis not completed
Lae Base	2. 8.69	not known	reductions and analysis not completed earthquake hypocentre uncertain
Rabaul	3. 8.69	not known	reductions and analysis not completed
Lae Base	23. 8.69	not known	reductions and analysis not completed
Panguna (soft rock)	7. 9.69	not known	reductions and analysis not completed
Panguna (soft rock)	16.11.69	not known	reductions and analysis not completed
Panguna (soft rock)	16.11.69 to 30.12.69	not known	earthquake hypocentre not known, reductions and analysis not completed
Panguna	28. 3.70	121.9	power spectra and digitized outputs available
Yonki	13. 5.70	~ 41	reductions and analysis not completed

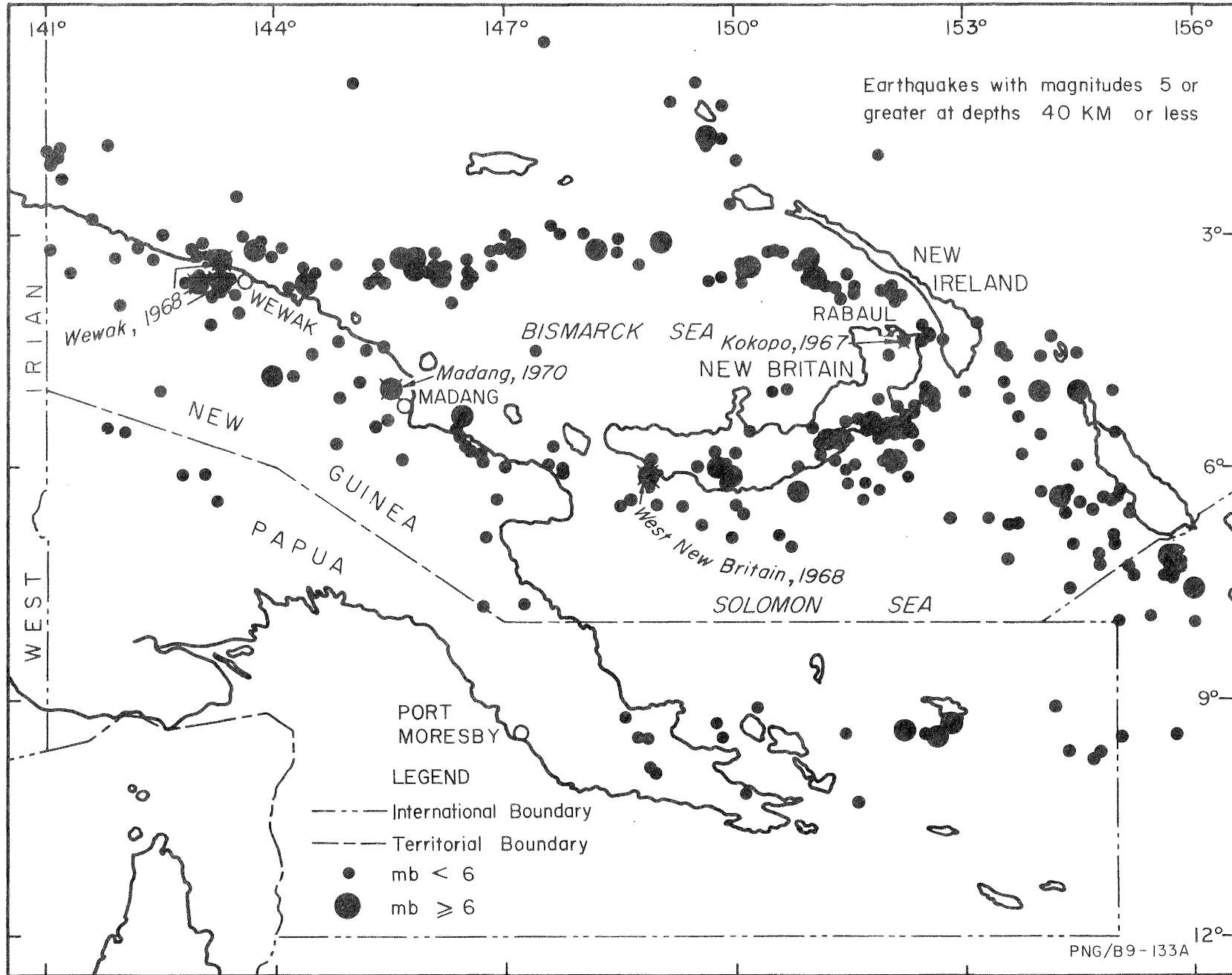


FIG 1 Shallow Earthquakes for the period 1958 through 1969

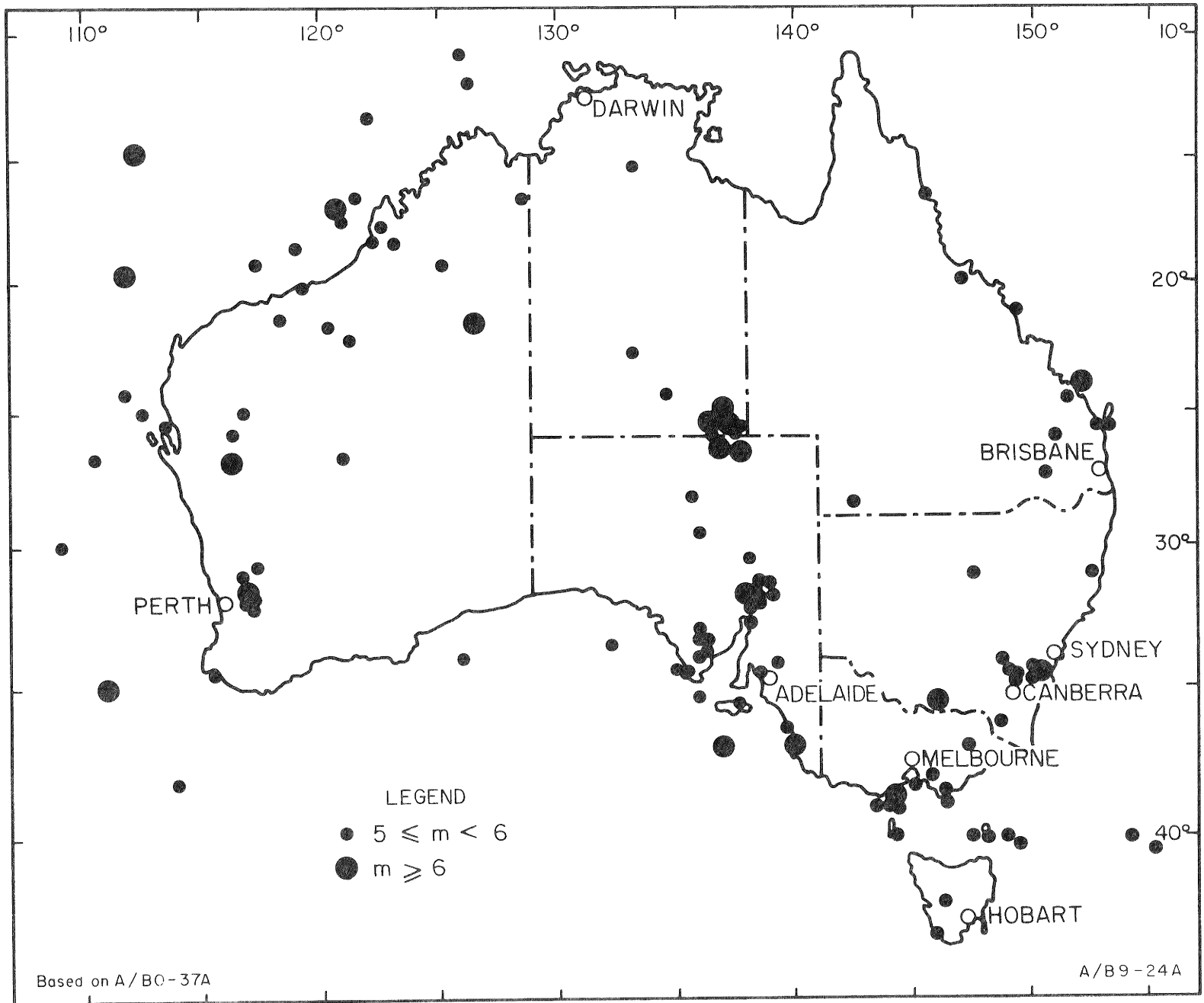


FIG 2 Earthquakes with magnitude(m) 5 or greater, 1900 - 1970

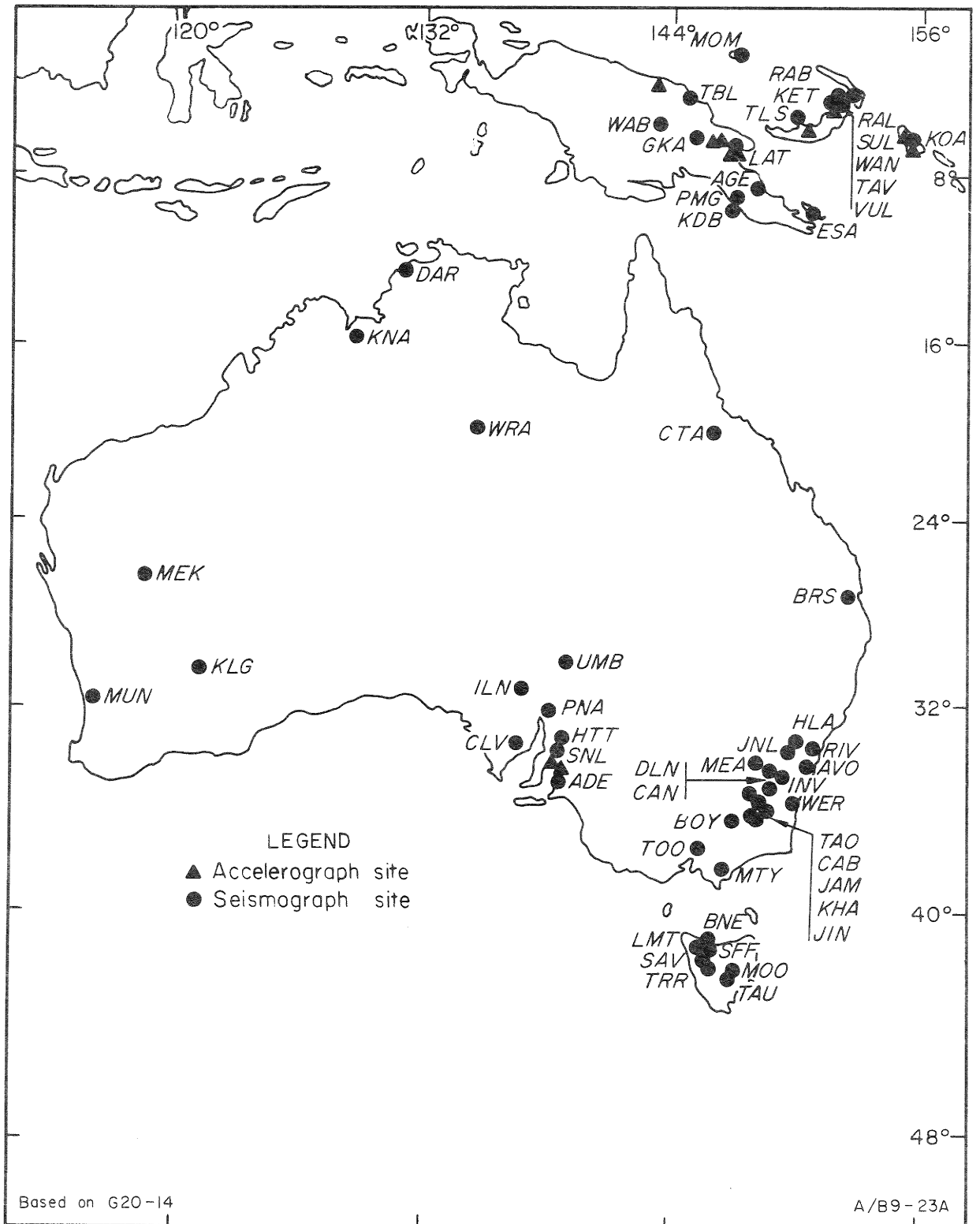


FIG 3 Locations of accelerographs and seismographs  
 Australia and New Guinea 1970

PANGUNA BOUGAINVILLE  
28 MARCH 1970  
(Magnification x5.0)

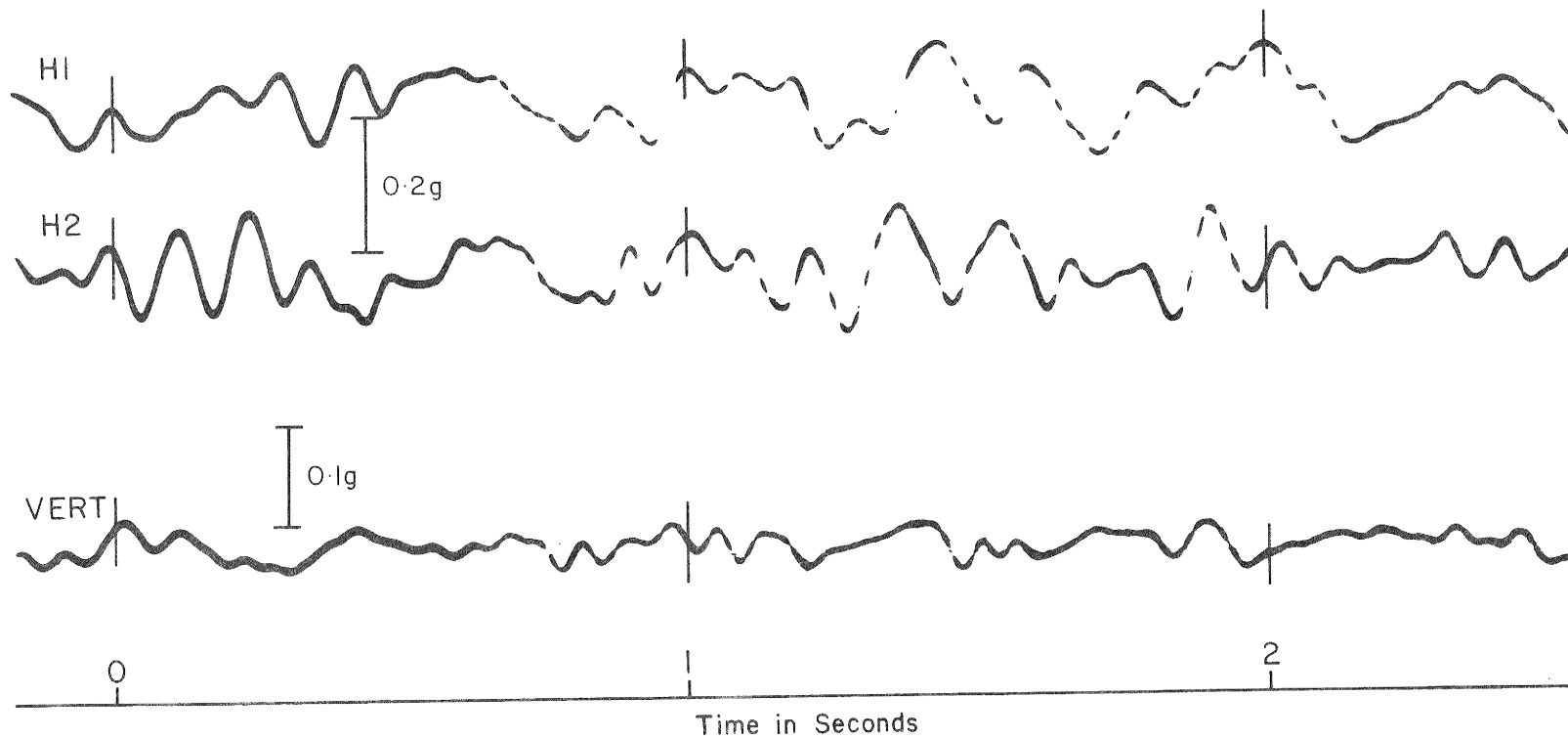


FIG 4

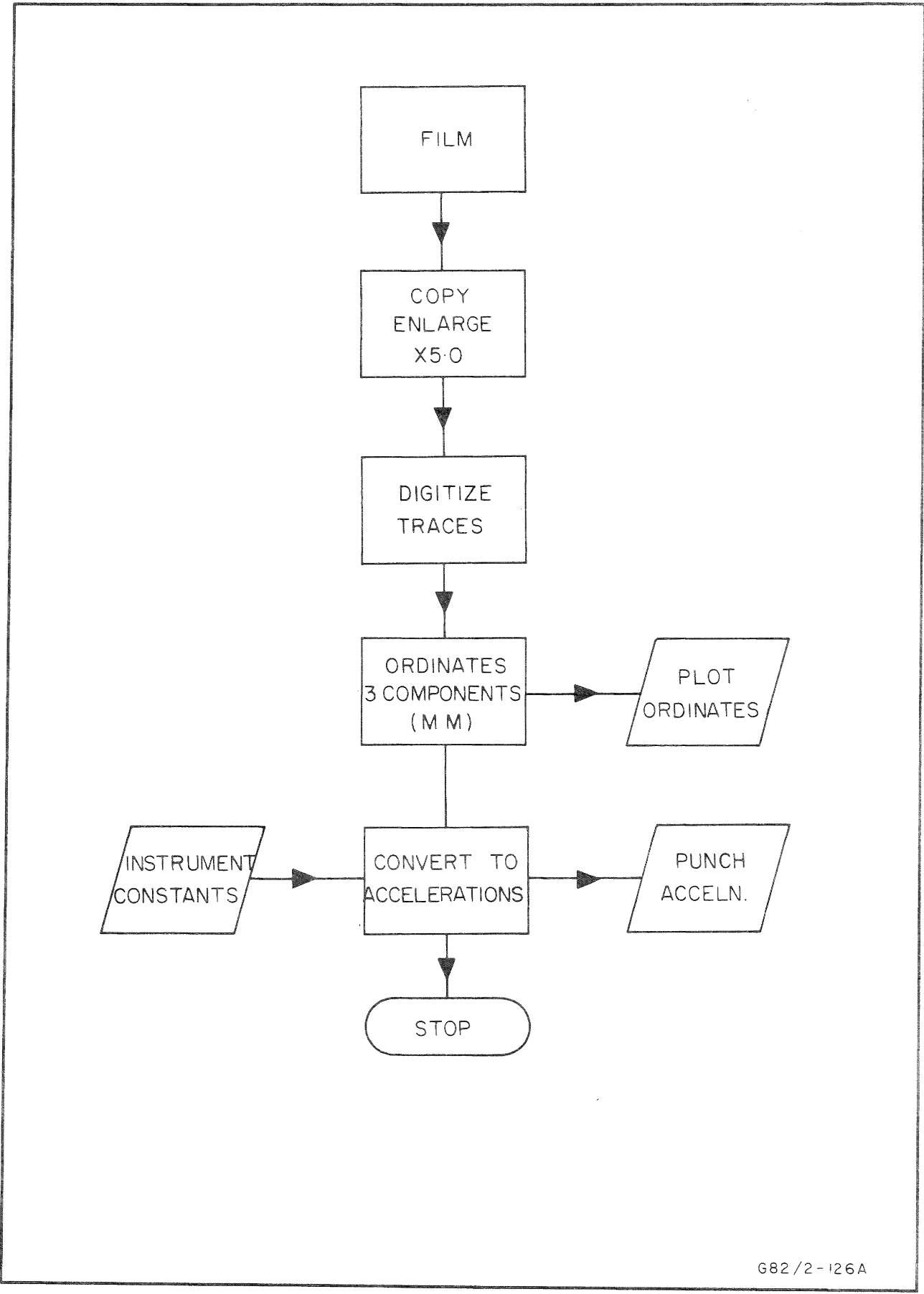


FIG 5a

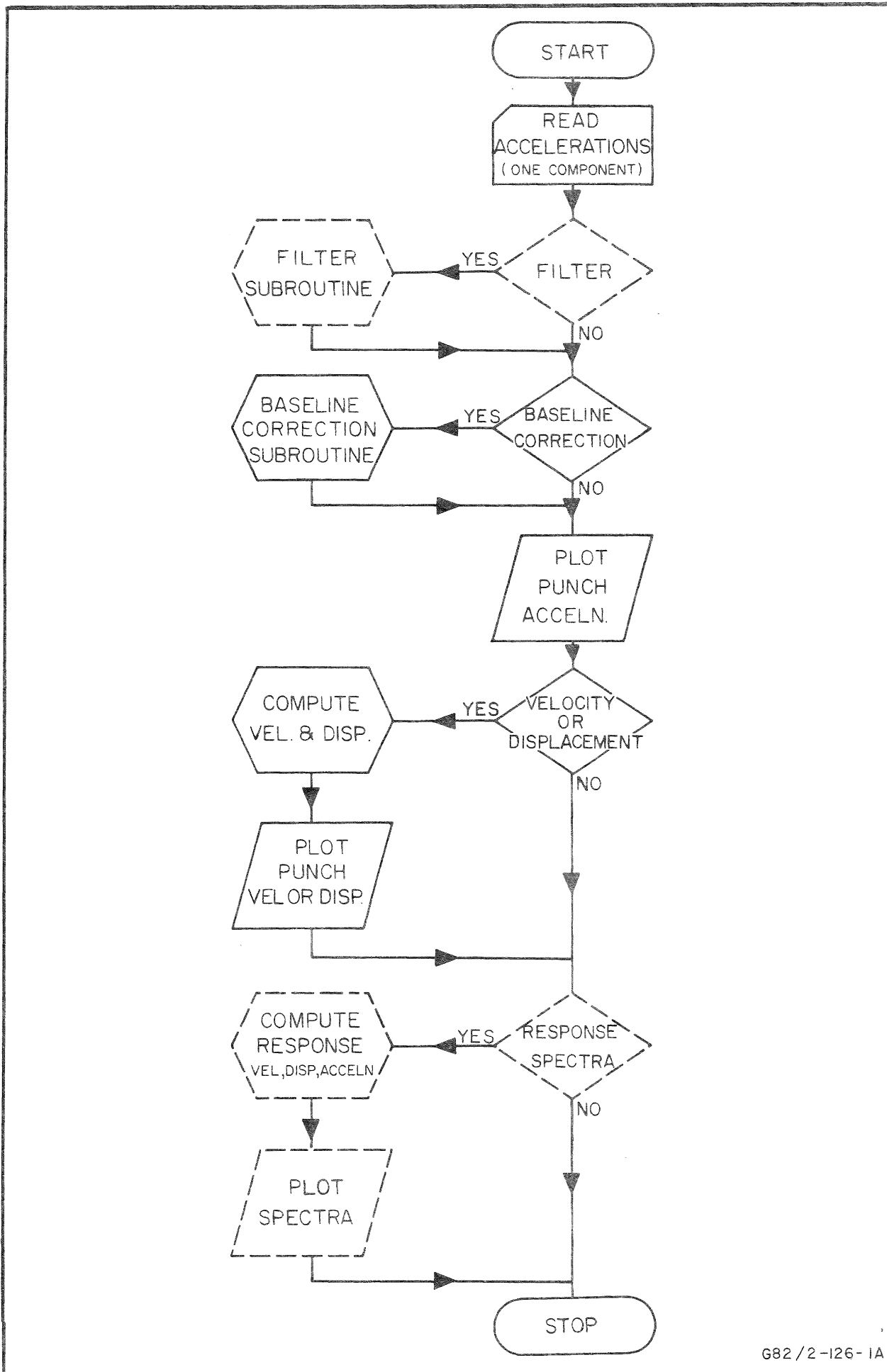


FIG 5b

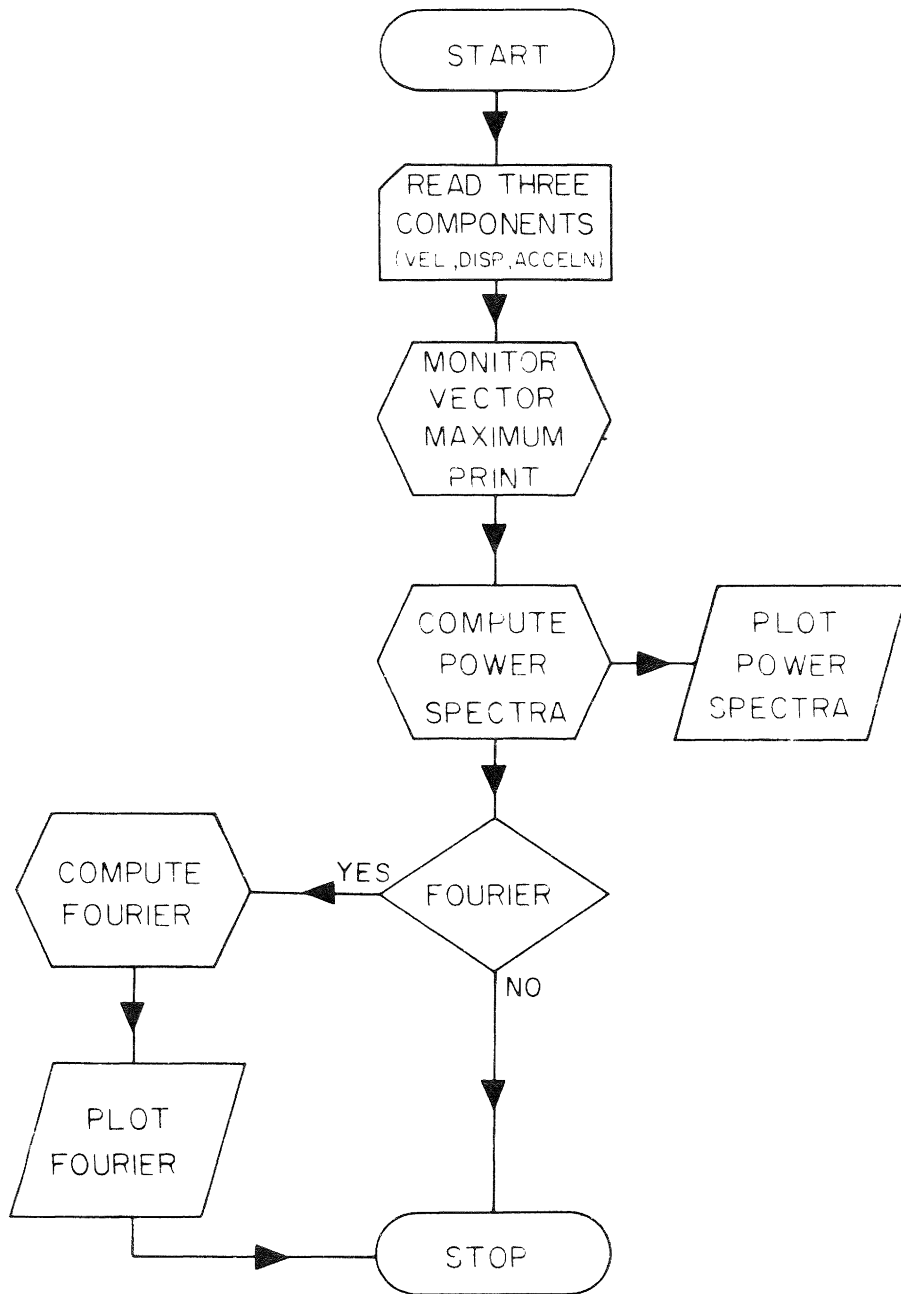


FIG 5c

# ANALYSIS OF YONKI ACCELEROGRAPH RECORD FOR 14th NOVEMBER 1967

## A. NORTH-SOUTH HORIZONTAL COMPONENT

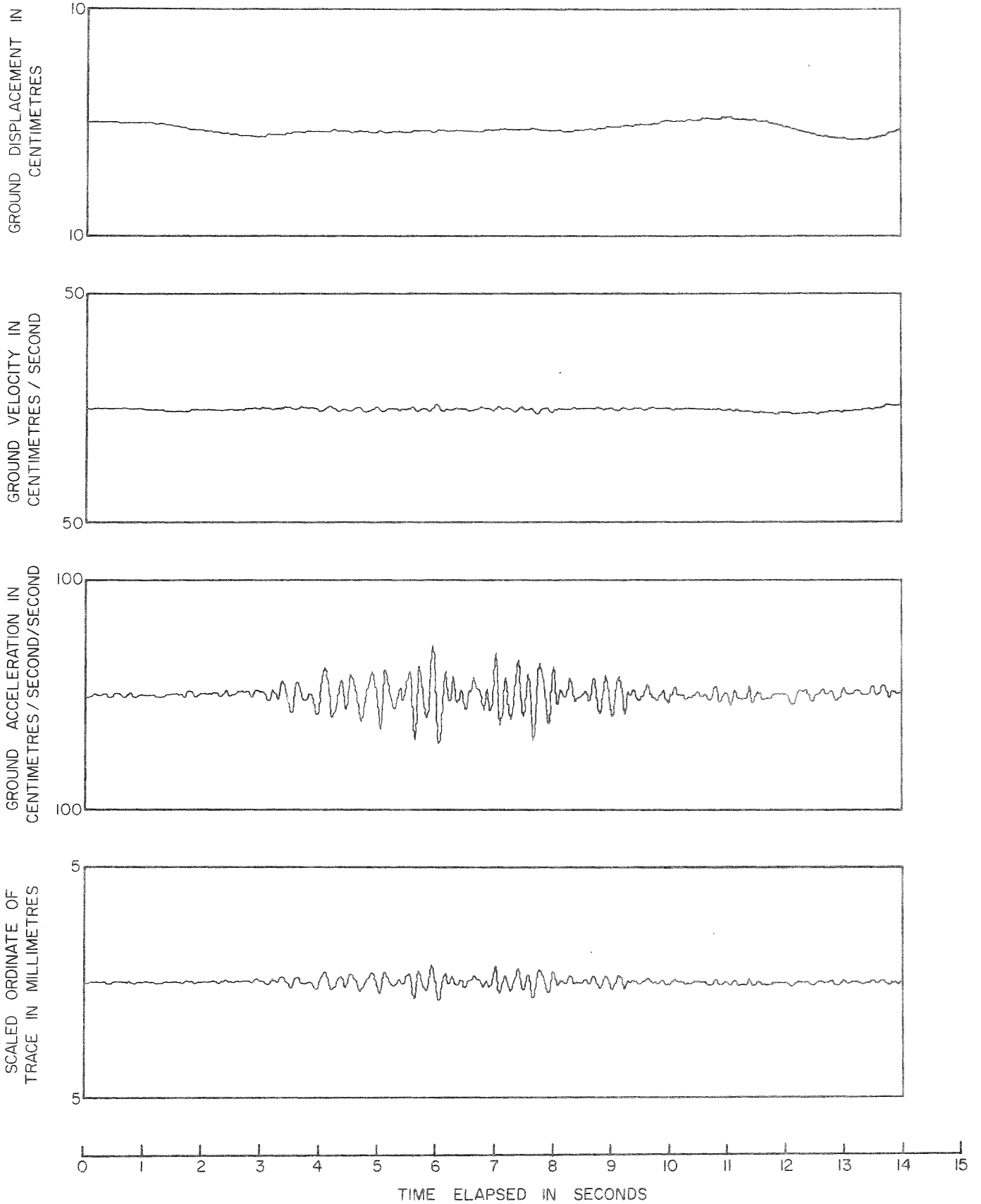


FIG 6

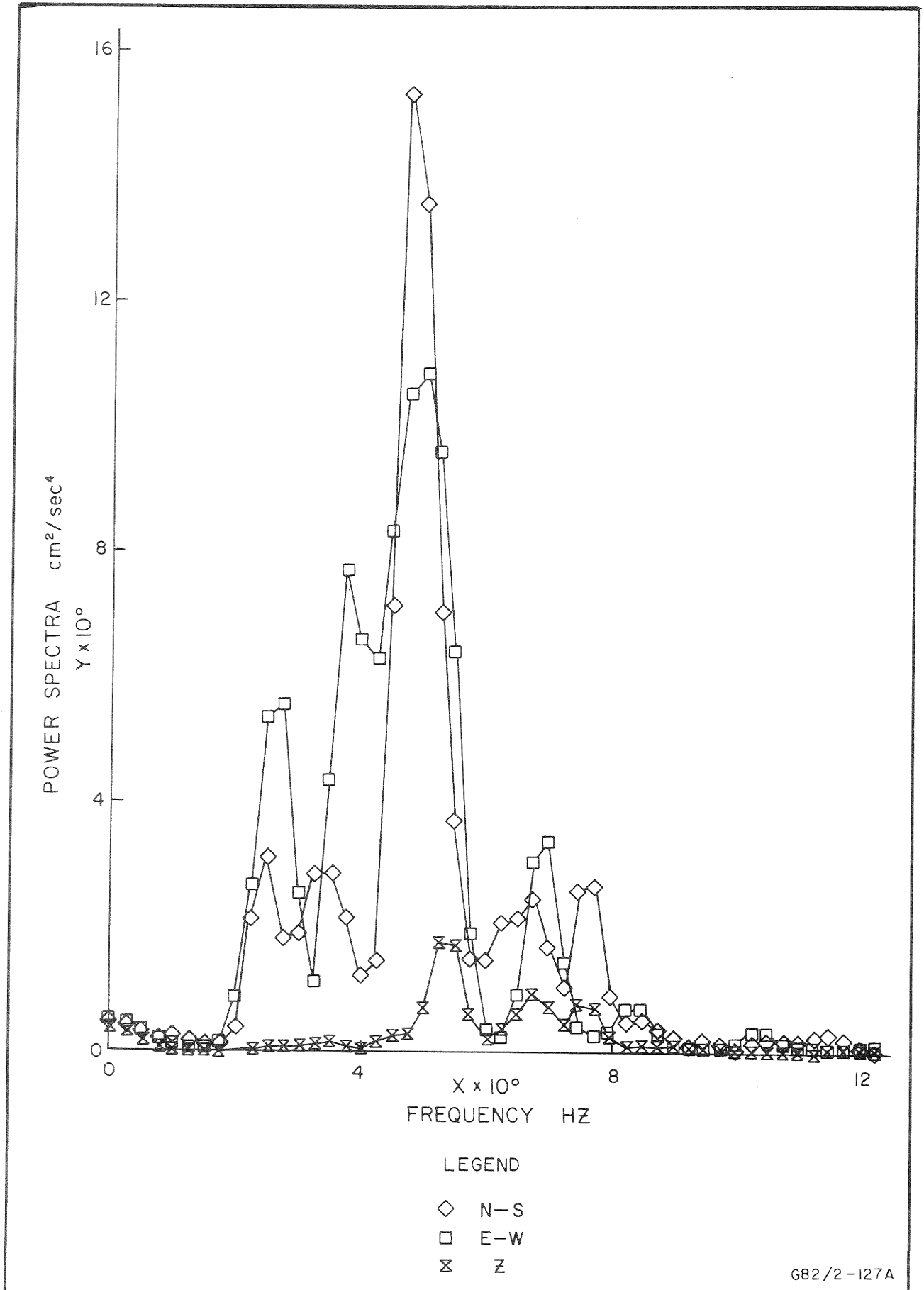


FIG 7 Power Spectra for Yonki 14 November 1967