ACCELEROGRAPH RECORDINGS OF THE MUSA EARTHQUAKE

16 SEPTEMBER, 1972

B.Gaull*

SUMMARY

On 16 September, 1972 at 04 15 09.8 UT an earthquake of magnitude ML 5.0 occurred in southeast Papua within about 20 km of a proposed dam site on the Musa River. The earthquake triggered two accelerographs, Musa A and Musa B, one at the crest and one at the base of the dam site. The peak ground accelerations recorded by the accelerographs were 1.85 m/s^2 and 0.39 m/s^2 respectively; the peak ground velocities were 87 mm/s and 2.0 mm/s; and the corresponding mean periods of the ground motion were about 0.23 and 0.04 s.

The difference in the nature of the accelerograms is attributed to the difference in the geological and topographical settings of the accelerograph sites. The upper site has an elevation of 406 m and consists of about 60 m of weathered sediments overlying fresh ultramafics. The lower site has an elevation of 112 m and consists of an outcrop of the ultramafic complex.

1. INTRODUCTION

In June, 1972 the Bureau of Mineral Resources, Geology and Geophysics (BMR), installed 2 accelerographs (hereafter called "Musa A" and "Musa B"), 600 m apart, one on weathered sediments on the crest of one of the abutments and one on hard ultramafic rock at the base, of a proposed dam site on the Musa River in southeast Papua (Fig. 1).

At about 04 15 10 UT on 16 September, 1972 an earthquake of magnitude ML 5.0 occurred within 20 km of the dam site and triggered the accelerographs. Despite the closeness of the accelerographs, the accelerograms differ in both acceleration amplitude and period (Figs. 2 and 3).

The triggerings were significant insofar as this was the first time in Papua New Guinea that two strong-motion instruments recorded simultaneously on nearby hard and soft rock sites.

2. GROUND MOTION AT THE ACCELEROGRAPH SITES

Table 1 lists the maximum ground acceleration and velocities in the vertical, north-south, and east-west directions; and the periods of ground motion at the times of maximum acceleration. Fig. 2 shows the three components of both accelerograms and Fig. 3 is a digitized representation of both ground acceleration and velocity at the Musa A site.

Accelerations greater than 0.3 m/s^2 (0.03 g where g is the acceleration owing to gravity) were recorded for about 11 seconds by the Musa A accelerograph.

Accelerations greater than about 0.15 m/s^2 were recorded for a duration of

* Department of Minerals and Energy, Port Moresby Geophysics Observatory, Papua New Guinea.

about 5.5 seconds at the Musa B site.

3. ACCELEROGRAPH SITES

Figure 4 shows both accelerograph-site profiles down to bedrock and includes seismic shear wave velocity, density and thickness of each layer. This data was acquired from seismic work (Bishop et al, in prep.) and drilling (Macias, 1971) in the vicinity of the accelerograph sites. The bedrock which outcrops at the Musa B site is an ultramafic complex (seismic shear wave velocity near surface of about 2500 m/s and density 2.8 x 10^3 kg/m^3 and is also found 60 m beneath a deeply weathered sedimentary pile at the Musa A site.

The 2.5 sec S-P time on both accelerograms suggests that the earthquake hypocentre was about 19 km from the dam site which is much greater than the distance separating the two accelerographs (0.6km). Therefore the propagation path to the top of the ultramafics at both sites could be considered to be identical and consequently the differences between recorded ground motion at the two sites is attributed to near surface features of the sites alone.

4. THEORETICAL MODEL TO ACCOUNT FOR ACCELERATION AMPLIFICATION IN LAYERED SYSTEMS

Madera (1970) outlined a theoretical method to predict the fundamental period of the seismic waves and the amplification of seismic acceleration in soil profiles above bedrock. He obtained good agreement between computed and measured values. The principle is that resonance of seismic waves is set up in the layered system above bedrock, which amplifies the incoming signal. Because it is a resonance effect, the dominating period recorded on the accelerogram should be related to the fundamental period of the layered model.

On application of Madera's (1970) method to the profile with parameters shown in Fig.

4, a fundamental period of about 0.26 s was computed for the Musa A site. This value compares reasonably well with the measured mean Musa A accelerogram period of 0.23 s at the time of peak acceleration (Table 1).

Because the propagation paths through the ultramafics are considered to be identical, it is reasonable to assume that the input signal at the top of the ultra-mafics beneath Musa A is the same as that registered at Musa B. Therefore Madera's (1970) model could be used to estimate the peak acceleration amplification at Musa A directly with respect to Musa B. When this was carried out an amplification ratio of 2 was obtained. When extreme estimates of layer density and internal damping were substituted, the maximum possible amplific-ation ratio attainable was 2.7, which is still significantly less than the measured acceleration ratio of 4.5. Hence Madera's (1970) model does not fully account for the amplification of acceleration which took place at the Musa A site.

5. TOPOGRAPHICAL FACTOR

Davis & West (1973) have observed the effects of topography on ground motion at station sites carefully selected so that the only difference between them was topo-graphy. Their results indicate that the amount of amplification and the periods at which it occurs vary with the size of the mountain, and are probably a function of the relation between the wavelengths of the incoming seismic signal and the dimensions of the mountain. The suggested causative mechanism for this amplification is resonance of the mountain set up by shear waves when the wavelength of these waves are of the same order as the dimensions of the mountain.

Musa A and B sites are located respect-ively near the crest and base of a 400 m high mountain. Assuming a shear wave velocity of 3.5 km/s and using a period of 0.25 s (corresponding roughly to the period at peak acceleration) a wavelength of about 900 m is obtained, which is about half the width of the mountain. Using the results obtained by Davis & West (1973) for a mount-ain of similar size (Mt. Butler, Nevada), it was found that the average amplification ratio of ground motion at the crest relative to the base was about 2.5.

Hence the total amplification ratio of the ground motion at Musa A relative to Musa B when the combined effect of lithological and topographical factors are taken into account has been theoretically estimated at about 5, which is in reasonable agreement with the measured ratio of about 4.5.

6. YONKI DAMSITE ACCELEROGRAMS

On 20 September, 1974 in the eastern highlands of Papua New Guinea, an amplifica-tion factor of maximum ground acceleration amplitude of about 8 was registered between a weathered sedimentary accelerograph site (Yonki) and a hard rock site (Intake) about 1 km apart. Preliminary maximum recorded acceleration and period at the Yonki site were 2.3 m sec^{-2} and 0.17 secs respectively, and at the Intake site were 0.28 m sec^{-2} and 0.09 secs respectively. Records have

not yet been analysed but it is anticipated that this amplification is again due to the combination of the weathered sedimentary pile and the topography at the Yonki site.

7. CONCLUSIONS

1. An earthquake of magnitude ML 5.0 triggered the two accelerographs at the Musa River dam site on 16 September, 1972. The maximum acceleration recorded by the Musa A accelerograph at the crest of the dam was 1.85 m/s^2 at a period of 0.23 s. An acceleration in excess of 0.3 m/s^2 was sustained at the site for about 11 s. The maximum acceleration recorded by the Musa B accelerograph at the base of the dam site was 0.39 m/s^2 at a period of 0.04 s. An acceleration in excess of 0.3 m/s^2 was sustained for about 2 seconds.

2. The 2.5 s S-P time interval on the accelerograms indicates that the separation between the earthquake hypocentre and the dam site was about 19 km.

3. It is suggested that the 4.5:1 ratio of amplitude of ground acceleration which occurred at the Musa A site relative to that of the Musa B site can be explained by the combined effect of the lithology and topography.

8. REFERENCES

Bishop, I. D., Pollock, E. J. and Pettifer, G. R. (in prep.), "Musa River hydro-electric-scheme seismic survey, P.N.G., 1970", Bur. Miner. Resour. Aust. Rec. (unpubl.).

Davis, L. L., and West, L. R. (1973), "Observed effects of topography on ground motion", Bull. seism. Soc. Amer. 63, 283-98.

Macias, L. F. (1971), "Geology of the Musa Gorge dam site area, Eastern Papua", Geological Survey of Papua New Guinea Note on Investigation, 71-008.

Madera, G. A. (1970), "Fundamental period and amplification of peak acceleration in layered systems", Dept. Civ. Eng., Massachusetts Inst. of Tech. Rpt. No. R69-15, Soils Publ. No. 260.

TABLE 1.

SUMMARY OF GROUND MOTION AT MUSA GORGE 16 SEPTEMBER, 1972

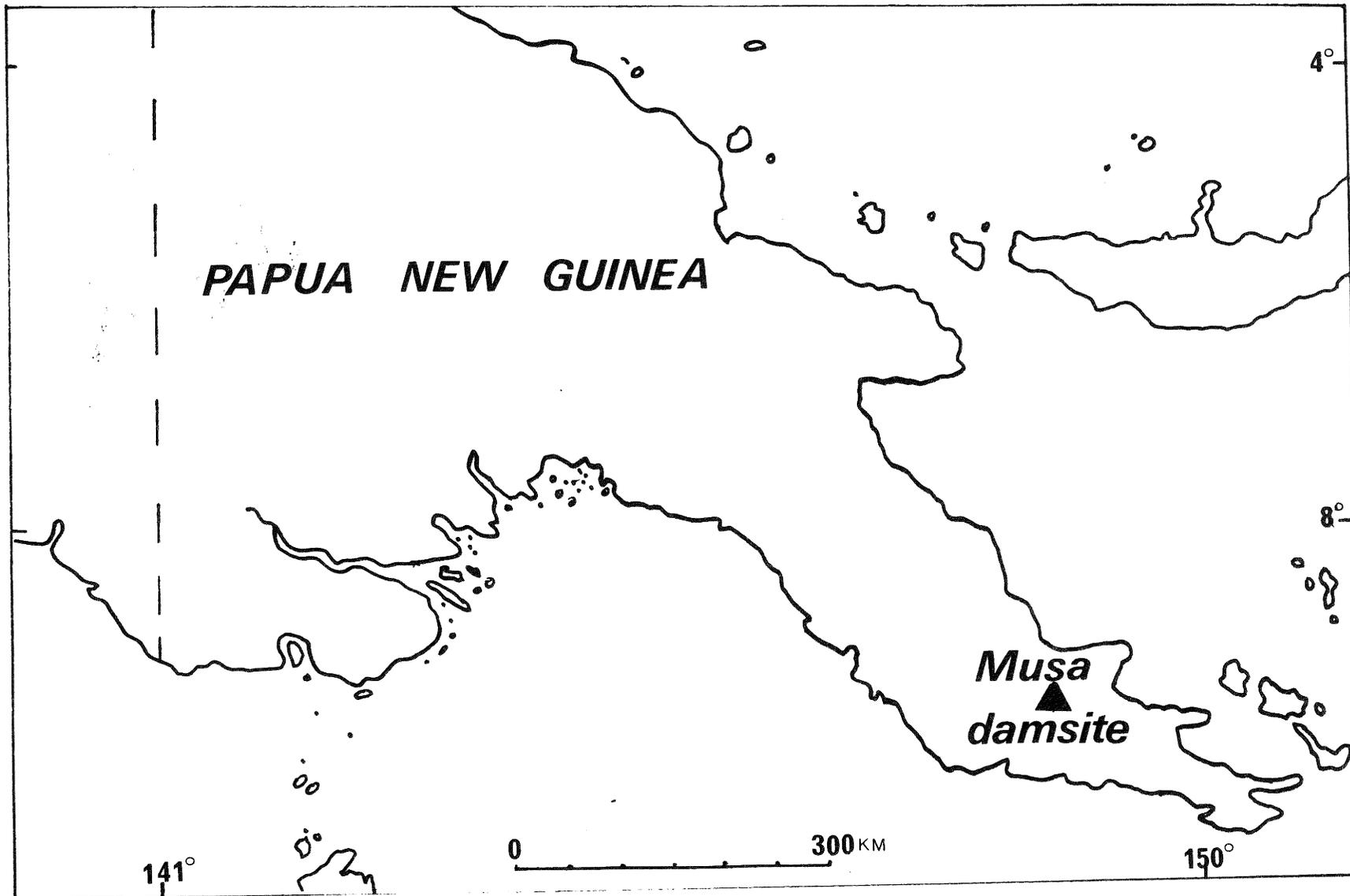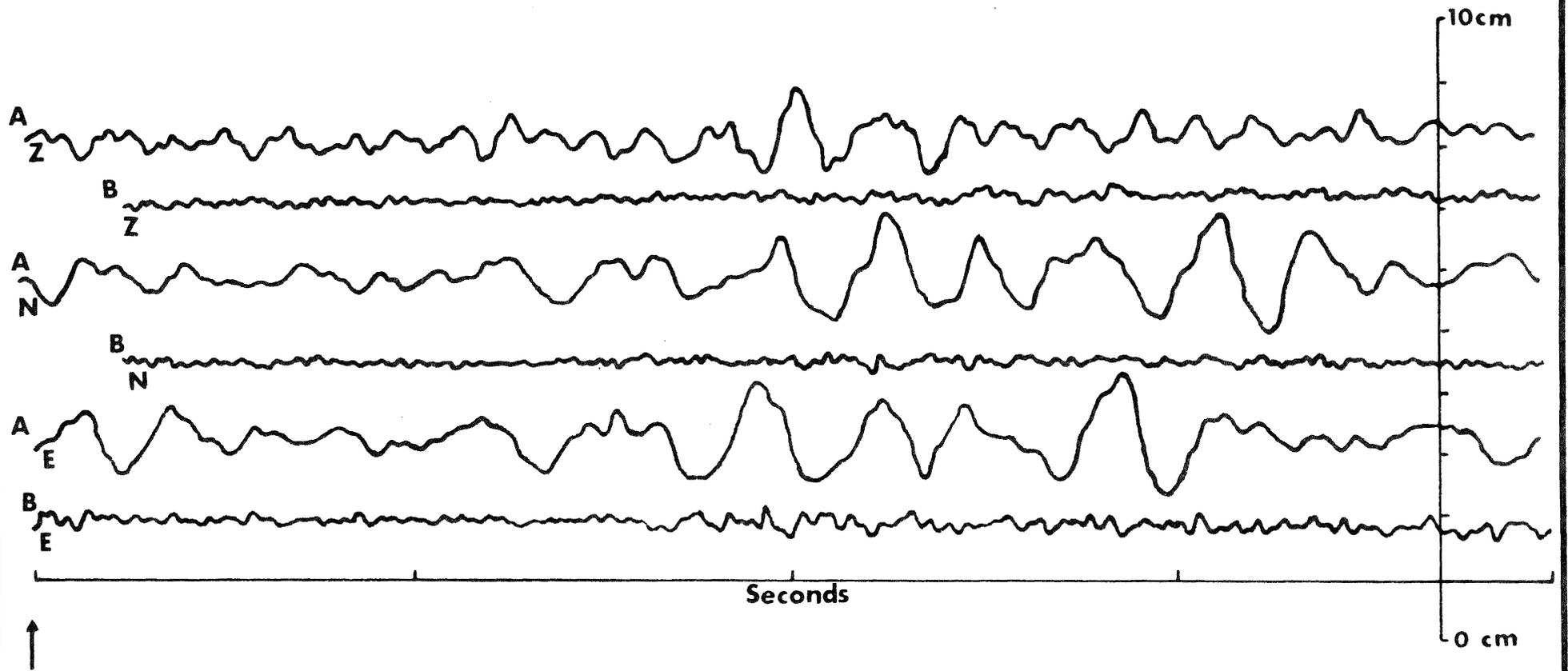| Component	Max. accel. m/s^2	Max. velocity mm/s	Period (s) P wave	S wave
MUSA A				
Z	0.28	7	0.11	0.14
NS	0.78	46	0.09	0.22
EW	1.66	74	0.09	0.25
Vector Resultant	1.85	87	Mean	0.23
MUSA B				
Z	0.01	1.3	0.03	0.04
NS	0.39	1.4	0.03	0.04
EW	0.03	0.6	0.03	0.05
Vector Resultant	0.39	2.0	Mean	0.04

FIGURE 1 : LOCALITY OF MUSA RIVER

VERTICAL SCALE (approx)

HORIZONTAL COMPONENTS: $1cm \equiv 1.7ms^{-2}$

VERTICAL COMPONENTS: $1cm \equiv 1.1ms^{-2}$
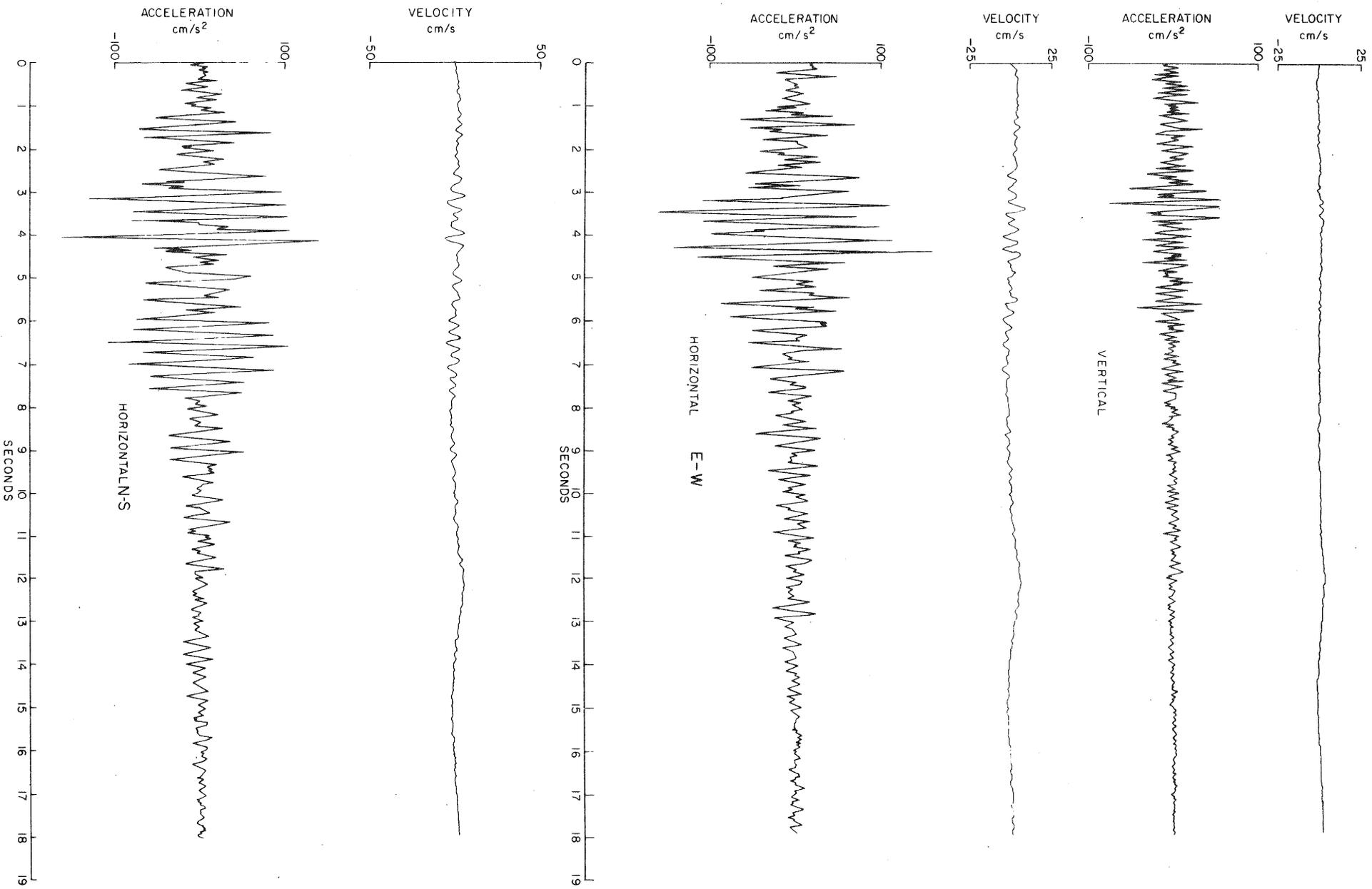
FIGURE 2 : COPIES OF MUSA RIVER ACCELEROGRAMS

FIGURE 3: GROUND MOTIONS FROM MUSA A ACCELEROGRAPH

FIGURE 4:

THE MUSA PROFILES

Depth (m)	MUSA A	MUSA B

0

$Cs = 171$ m/s

$\gamma = 2.2 \times 10^3$ kg/m^3

1

$Cs = 285$ m/s

$\gamma = 2.5 \times 10^3$ kg/m^3

6

$Cs = 456$ m/s

$\gamma = 2.25 \times 10^3$ kg/m^3

24

$Cs = 1311$ m/s

$\gamma = 2.35 \times 10^3$ kg/m^3

61

$Cs = 2565$ m/s

$\gamma = 2.8 \times 10^3$ kg/m^3

$Cs = 2280$ m/s

$\gamma = 2.8 \times 10^3$ kg/m^3

(Left margin label: Highly weathered sediments)

(Label between profiles: Ultramafics)

Notation

Cs = seismic shear wave velocity

γ = density

Note (1) Density values are estimates supplied by Macias (pers. comm.) who examined the drill cores.

(2) The Musa A accelerograph site is 300 m above the Musa B site.