GROUND MOTION IN THE EPICENTRAL REGION OF THE MAY 6, 1976 FRIULI EARTHQUAKE IN NORTH ITALY

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SUMMARY

A uniform set of small distribution transformers of the electricity supply lifeline responded to the mainshock by sliding on their concrete bases. The slip vectors were mapped in the field and are correlated to the nearest strong motion record. The correlation suggests that overall motion in the epicentral region was three times more intense than the strongest recorded motion, indicating peak horizontal accelerations over 1.0g. The slip vectors combined with the north-south thrust fault plane solution from teleseismic data suggest that the strongly shaken area was also affected by the stopping phase of a buried earthquake fault.

INTRODUCTION

Although many strong motion instruments recorded the May 6 Friuli earthquake, none of them was close enough to sample ground motion in the heavily damaged epicentral area. After the mainshock strong motion instruments were moved into the epicentral area and recorded an impressive number of accelerograms from the aftershock activity (Basili et al., 1976).

The nearest record of the mainshock was obtained at Diga de l'Ambiesta (see Fig.1) on a hill by the abutment of the Verzegnis Dam. During a field mission, four weeks after the earthquake, strong motion in the epicentral area was studied on the basis of the base motion of small distribution transformers of the power supply network. (See picture on Fig. 1.) The field measurements were performed within a zone around 10km wide crossing the epicentral region in a north-west direction; the north west end of the zone comprised transformers around the strong motion instrument at Diga de l'Ambiesta.

The field measurements and a preliminary analysis have been presented in detail elsewhere (Papastamatiou 1976, 1977). In this contribution we summarise the previous work and present a calibration of the field data on the basis of the strong motion record at Diga de l'Ambiesta. This research has two incentives: first to elucidate ground motion in the epicentral region and second to evaluate the nearest strong motion record with respect to the heavily damaged area of the Friuli earthquake.

FIELD MEASUREMENTS

The small distribution transformers have uniform dimensions and are housed in uniform cabins, as shown on the picture on Fig. 1.The picture shows the cabin at Gemona Piovega; in this case the transformer (follow arrow on the picture) was taken out of the cabin to be replaced. There

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were probably as many as 1000 such transformers in the epicentral region. Only 22 were visited during the fourth week after the May 6, 1976 shock. In a few cases the transformer had already been removed for repair whereas in other cases no motion of the transformer could be detected. In many cases the transformer had moved leaving a clear trace on the concrete pad. The location of the transformers visited during the mission is shown on Fig. 1 as well as the location of the strong motion instrument at Diga de l'Ambiesta. Also shown on the same figure is a broad classification of foundation conditions in hard calcareous rock, soft flysh and recent alluvium along the Tagliamento river. The base motion of the transformers is shown on Fig. 2; transformers around the strong motion instrument did not show any detectable base motion. In the calibration of field measurements on the basis of the record at Diga de l'Ambiesta it is assumed that the detection threshold for the base motion was 2cm.

The slip vectors on Fig. 2 suggest patterns inside the strongly shaken area: around Diga de l'Ambiesta the predominant direction is east-west whereas inside the epicentral region the predominant direction becomes north-south. In the area between Gemona and the Tagliamento river motion is particularly intense in both north-south and east-west directions. The orientation of the slip vectors is not consistent. However, the field measurements suggest a weak pattern of convergence towards an almost east-west line Osoppo-Artegna. This pattern is reinforced by the slip vectors of larger transformers (Papastamatiou, 1976) and indicates that ground motion diverged away from the Osoppo-Artegna line in a north-south direction. This sense of motion is opposite to the one expected from the focal mechanism of the Friuli earthquake, i.e. thrust in a north-south direction (Van Bemmelen, 1977) and is thought to reflect the stopping phase of a buried thrust.

CALIBRATION OF FIELD DATA

As a first approximation the transformers were modelled as blocks which are free to slide in any direction on a horizontal surface. Assuming a constant resistance to sliding, the block moves relative to the ground whenever this resistance is exceeded by the inertia forces according to the following equation of motion:

$$m\ddot{u} = m\ddot{y} - S \qquad \text{(Eq. 1)}$$

where
m = mass of the block
s = the resistance to sliding
$\ddot{y}$ = ground acceleration
$\ddot{u}$ = relative acceleration of the block w.r.t. the ground

Normalising (Eq. 1) w.r.t. the mass of the block gives:

$$\ddot{u} = \ddot{y} - r \qquad \text{(Eq. 2)}$$

where $r = s/m$ = resistance coefficient.

For a frictional resistance, for example, the resistance coefficient equals tan ϕ, where ϕ is the coefficient of friction. The actual value of r was obtained on the assumption that the block subjected to the strong motion record at Diga de l'Ambiesta (CNEN/ENEL, 1976) moved by 2 centimetres relative to the ground. Only the first 20 seconds of the 34 seconds long horizontal components were analysed because this part of the record contains all the strong part of ground shaking without being heavily contaminated by long period processing errors. The two horizontal acceleration components were subjected to a parabolic base line correction and then plugged into Eq. 2. This equation was numerically solved for a range of values $0.05 < r < 0.25$. For each value of r, the resulting north-south and east-west components of the relative block displacement were combined on a "field seismoscope" trace and the maximum slip was recorded. This procedure indicated a value of $r = 0.15$ for a threshold base motion of 2 centimetres.

In a second cycle of computations the resistance coefficient was fixed to $r = 0.15$ and the strong motion record was scaled up in order to cover the range of relative displacements observed in the field. Scaling was applied on the amplitude of the accelerograms alone. The "seismoscope" traces for the scaled up motion by factors of 1, 2 and 4 are shown on Fig. 3. On the same figure are shown field displacements from Fig. 2 that present similarities with the computed motions:

i. For Factor=1 (actual ground motion) the computed motion is compared to the field displacements at Tolmezzo, on alluvium, near the strong motion instrument. The similarity of the two records reinforces the impression from the field data that predominant motion recorded at Diga de l'Ambiesta has a different space distribution from the motion in the heavily damaged area.

ii For Factor=2 the computed motion is compared to the field record at Gemona Sottostazione, on rock. The two traces present similarities although the field vector is predominantly north-south.

iii For Factor=4 the computed motion is compared to the field displacement at Gemona Taboga, on alluvium. Again the similarity is interesting although it is difficult to account for the strong east-west component on the basis of the seismic source mechanism alone. It is possible that ground motion in this area is influenced by the recent alluvial deposits from the Tagliamento River.

Also shown on Fig. 3 is the seismoscope for the recorded ground motion amplified by a factor of 3; this level of motion corresponds to the overall intensity of field measurements in the epicentral area. The trace is composed of an early body wave phase in a general north-west direction and a later surface wave phase in a north-south direction. It is thought that the transformers responded primarily to the body wave phase and that for this phase the north south component clearly dominates ground motion in the epicentral area.

The importance of the vertical component in the epicentral region cannot be evaluated on the basis of the horizontal field displacements; field measurements, however, demonstrate the change in the two horizontal components as one approaches the epicentre and suggest that a similar change is probable on the vertical component as well.

Figure 4 illustrates the estimated overall ground motion and block displacements in the epicentral region. The estimate is based on an average block displacement of about 14 centimetres (Papastamatiou, 1976) leading to a scaling factor of 3. Two sets of plots are presented for the two different components of motion. Both components show peak accelerations around 1.0g and indicate that the block responded primarily to the strong S-wave pulse.

CONCLUSIONS

Analysis of field data in conjunction with the strong motion recordings of the May 6, 1976 Friuli earthquake gives an insight into ground motion in the strongly shaken epicentral area. The electric power transformers in this area responded primarily to body wave ground motion and indicated variations in the distribution of different components of ground motion. The variation is clear in the horizontal components, namely a rotation towards the north-south direction as one approaches the macroseismic epicentre. The field measurements do not give any information on vertical motion apart from the impression that this component of motion was quite strong in the epicentral region. Field data is insufficient to map the predominant orientation of ground motion around the epicentre; it does, however, suggest superposition of the stopping phase of a buried thrust. As far as the intensity of ground motion is concerned, field measurements suggest an overall scaling factor of three from the nearest strong motion instrument to the epicentral area, indicating that the peak ground acceleration in the heavily damaged area exceeded 1.0g.

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REFERENCES

BASILI, M et al. (1976), Strong motion records relative to the Friuli Earthquake, Bolletino di Geofisica, 72(1):335-348.

CNEN/ENEL, (1976), Vol. I. Uncorrected accelerograms, part 1, accelerograms 028 through 064, Rome, Italy.

PAPASTAMATIOU, D. (1977), The May 6, 1976 Friuli Earthquake : Field Measurements I, Publ. Inst. Geophys. Polish Academy of Sciences, A-6 (117).

PAPASTAMATIOU, D. (1976), The May 6, 1976 Friuli Earthquake : Field Measurements II, Bolletino di Geofisica, 72(1): 851-859.

VAN BEMMELEN, R.W. (1977), Note on the seismicity of north-eastern Italy, Tectonophysics 39(4):T13-T19.

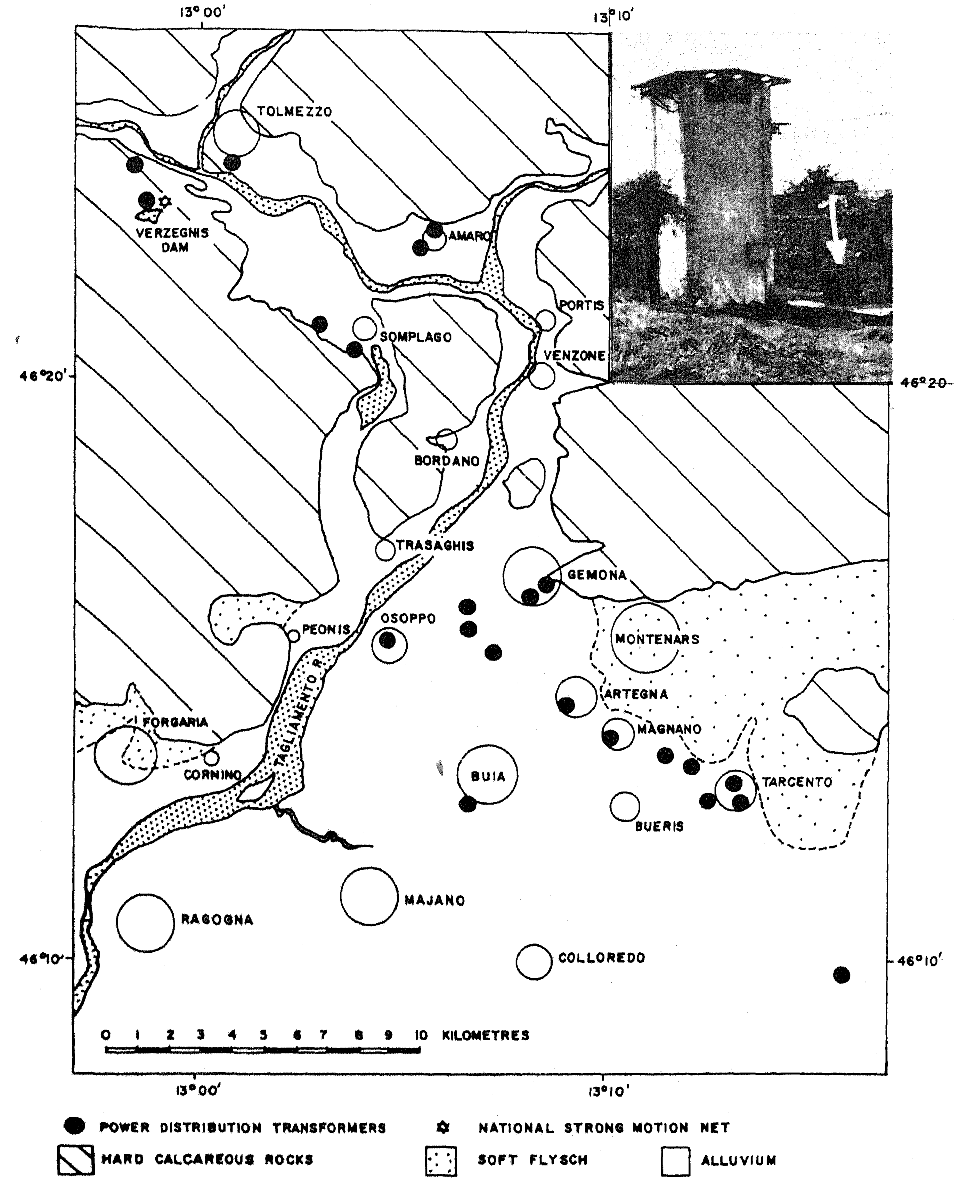
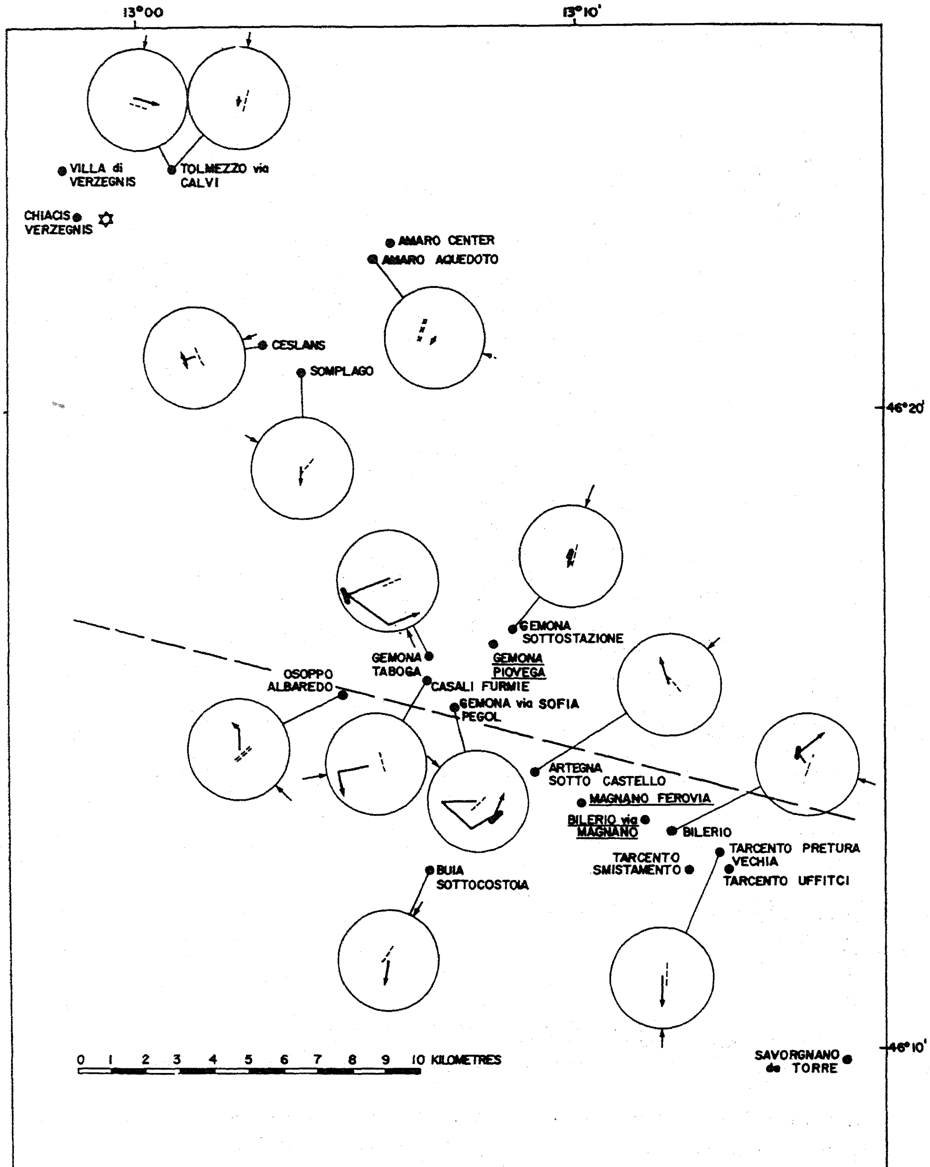


FIG. 1 LOCATION OF TRANSFORMERS VISITED AFTER THE MAY 6, 1976 EARTHQUAKE



SCALE FOR BASE MOTION : 20cm

BASE MOTION RESTRICTED :

ORIENTATION OF ROLLERS : ---

ORIENTATION OF SKATES : ===

STRONG MOTION INSTRUMENT : ✡

NOTE :- IF BASE MOTION IS NOT SHOWN, THE TRANSFORMER DID NOT MOVE OR WAS REMOVED. REMOVED TRANSFORMERS ARE UNDERLINED.

FIG. 2 BASE MOTION OF DISTRIBUTION TRANSFORMERS

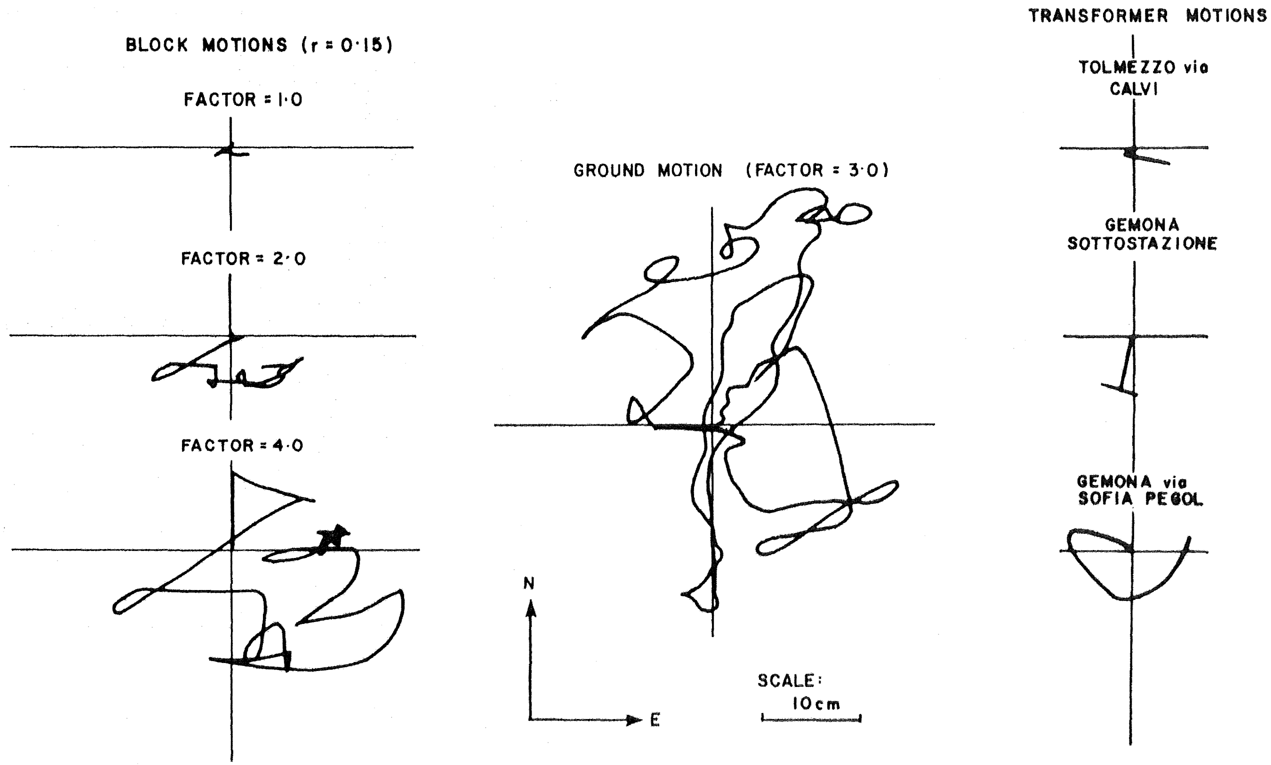


FIG 3 COMPARISON OF COMPUTED MOTIONS WITH FIELD MEASUREMENTS

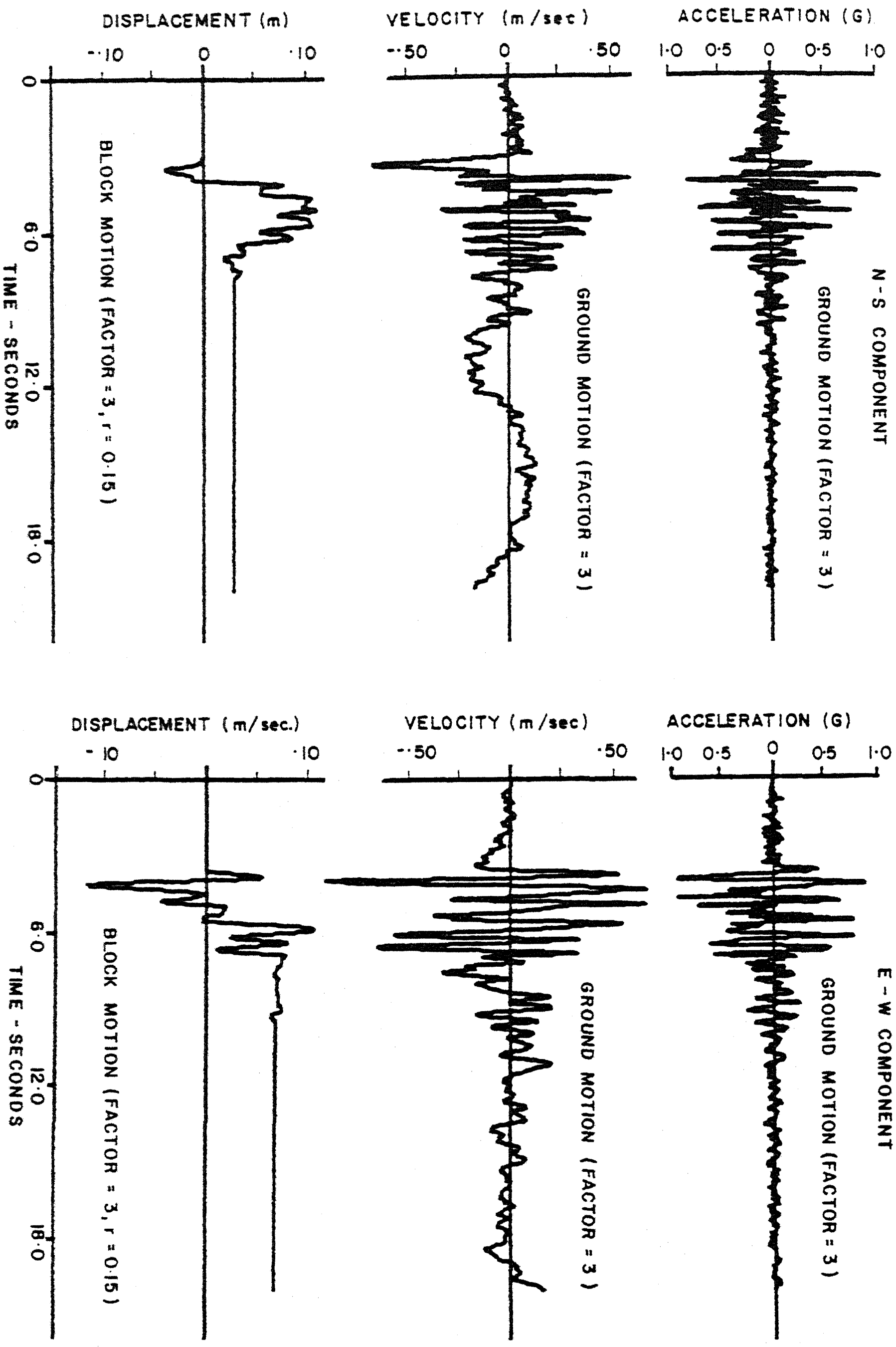


FIG. 4 ESTIMATED OVERALL MOTION AND BLOCK DISPLACEMENT IN THE EPICENTRAL REGION