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Using 1-D and 2-D modelling of ground motion for seismic zonation criteria: results for the city of Rome

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Abstract
The geological information collected in the last years by the Istituto Nazionale di Geofisica for the city of Rome is used to construct 1- and 2-D models of the nearsurface structure. These models are the basis for the numerical generation of synthetic accelerograms which can simulate the horizontal ground motion (SH waves) produced in the different areas of the city by a large ($M \approx 7$) potential earthquake 100 km away in Central Apennines. The proposed methodology yields earthquake engineering parameters (peak ground acceleration and velocity, Arias intensity, energy flux, response spectra) whose spatial variations are consistent with the damage distribution caused by the strongest earthquakes felt in Rome during its long history. Based on the macroseismic information and the results of the numerical simulations, general criteria for seismic zonation of the city of Rome are proposed.

Key words *Rome – strong ground motions – 1-D modelling – 2-D modelling – seismic microzoning*

1. Introduction

Even in case of a weak seismic input at the bedrock, the presence of surficial unconsolidated sediments can produce unexpected damage at the surface. This is the case of Rome, which during its long history suffered damage up to intensity VII-VIII of the Mercalli-Cancani-Sieberg scale due to the largest earthquakes in the Apennines (see Molin and Guidoboni, 1989). In the city, the occurrence of the strongest damage episodes seems to be restricted to the Holocene alluvial areas (Ambrosini *et al.*, 1987; Salvi *et al.*, 1991), with a significant concentration close to the edges of the Tiber river valley (see fig. 9 of the paper by Tertulliani and Riguzzi, 1995, this volume).

In absence of instrumental data, the development of techniques able to infer the spatial variability of ground motion during earthquakes is particularly important for a city like Rome as it is rich in ancient monuments and historical buildings, which are likely to be less resistant to the seismic action even in case of a moderate level of excitation. In full awareness that the computation of potential strong ground motions in the different zones of the city is a fundamental tool to mitigate seismic risk and organize the public and private intervent priorities, Rovelli *et al.* (1994, 1995) proposed a hybrid technique able to generate a suite of synthetic accelerograms (SH waves) along 2-D profiles, whose amplitudes were modelled as a function of moment-magnitude (*M*), distance from the source (*R*), and local geology. Comparing the results of their modelling with predictions based on empirical observations in Italy (Sabetta and Pugliese, 1987; Pugliese and Sabetta, 1989) and Western North America (Boore *et al.*, 1993), Rovelli *et al.* (1994) found a satisfactory agreement for seismological pa-

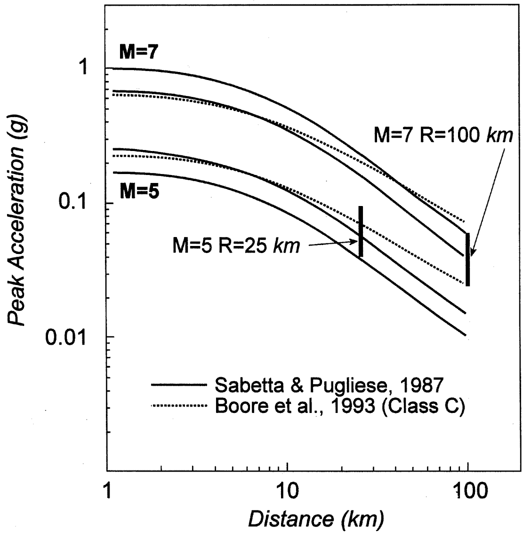

Fig. 1. Range of variability (vertical bar) of *pga* as predicted for the city of Rome in the case of both a ***M*** 7 earthquake in the Apennines and a ***M*** 5 earthquake in the Alban Hills, compared with the regressions by Sabetta and Pugliese (1987) (soil, upper curve, stiff, lower curve) and Boore *et al.* (1993) (Site Class C).

rameters such as peak ground acceleration and velocity as well as response spectra, which are mostly representative for earthquake engineering applications. For sake of example, fig. 1 shows this comparison for peak ground accelerations (*pga*) as estimated by Rovelli *et al.* (1995) for the maximum expected local (Alban Hills, $M=5$, at a distance $R=25$ km from the centre of Rome) and regional (Central Apennines, $M=7$, $R=100$ km) earthquakes. In spite of the low values found in their numerical modelling for firm sites ($pga \approx 30$-40 gals), the amplitude of horizontal ground accelerations resulted to be significantly larger (by more than a factor of 2) for soft sites especially near the edges of the Tiber river valley or within sharp bedrock incisions filled by unconsolidated sediments (see fig. 8 in Rovelli *et al.*, 1994, and fig. 3 in Rovelli *et al.*, 1995). The results derived from this kind of numerical modelling are consistent with the macroseismic observations, which also stress the magnification of damage for those geological situations.

In the approach proposed by Rovelli *et al.* (1994, 1995), the effects of the nearsurface geology on the transverse component of ground motion are modelled through a 2-D finite-difference algorithm. Although less sophisticated than other methods (see Fäh *et al.*, 1993), this methodology still requires the availability of powerful computers and long computation times. On the other hand, apart from advanced research studies, fast and low-cost procedures (possibly on PC's) are attractive mainly for routine applications. In this sense, a 1-D approach could be often preferred. It is noteworthy that 1-D modelling has been proved to lead to a satisfactory fit of observations during the international experiments of Turkey Flat (California) and Ashigara Valley (Japan). Although 2-D modelling can be performed for the city of Rome thanks to the availability of more than 3000 drillings providing stratigraphies and geological logs, so rich a data bank frequently is not available and buried geometries cannot be every reconstructed in detail. When sparse data are available, only a 1-D approach can be adopted. Of course, using 1-D models implies simplified physical processes without the interference effects due to the curved interfaces, and users have to be aware of the errors that are to be expected as a consequence of this simplification. So far few papers faced the problem of quantifying the difference between 1- and 2-D results in terms of ground motion parameters for real geological profiles, but this can be useful for future engineering applications.

To this purpose, two 2-D geological profiles crossing downtown Rome are used to compare the results of 1-D and 2-D modelling of nearsurface SH-wave propagation.

2. Estimating potential strong ground motions for microzoning criteria

Variations of the local geology in urban areas control the damage distribution during earthquakes (Singh *et al.*, 1988; Borcherdt *et al.*, 1989; Cranswick *et al.*, 1990). When instrumental data are lacking, numerical methods can be very useful in providing synthetic accelerograms for the different geological units, on condition that the nearsurface structures are sufficiently well known. The different synthetic outputs at the surface are usually obtained from a bedrock input which is propagated through laterally varying upper-layers. Therefore, the final results derive from a two-step process (A and B): step A is devoted to the estimation of the input incident at the bedrock; step B computes the very local propagation. While there are small differences in the literature between the techniques to be used in step B (finite-element or finite-differences), a large variability does exist relatively to step A (see Zahradník and Moczo, 1995).

As far as the city of Rome is concerned, Rovelli *et al.* (1994) stressed the limit of a deterministic modelling of regional propagation of seismic waves coming from Central Apennines to Rome, due to the inadequacy of a simplified horizontally-layered lithosphere structure for an area that is characterized by one of the largest 3-D crustal heterogeneities observed in Italy (Nicolich, 1990). In this case, a stochastic approach is particularly well suited to step A (Rovelli *et al.*, 1994). Figure 2 represents a sketch showing the main features of the method that we propose to compute synthetic time histories of ground motion at the surface as a function of nearsurface structure within a urban area. The «bedrock accelerograms» are computed (step A) through the generation of a

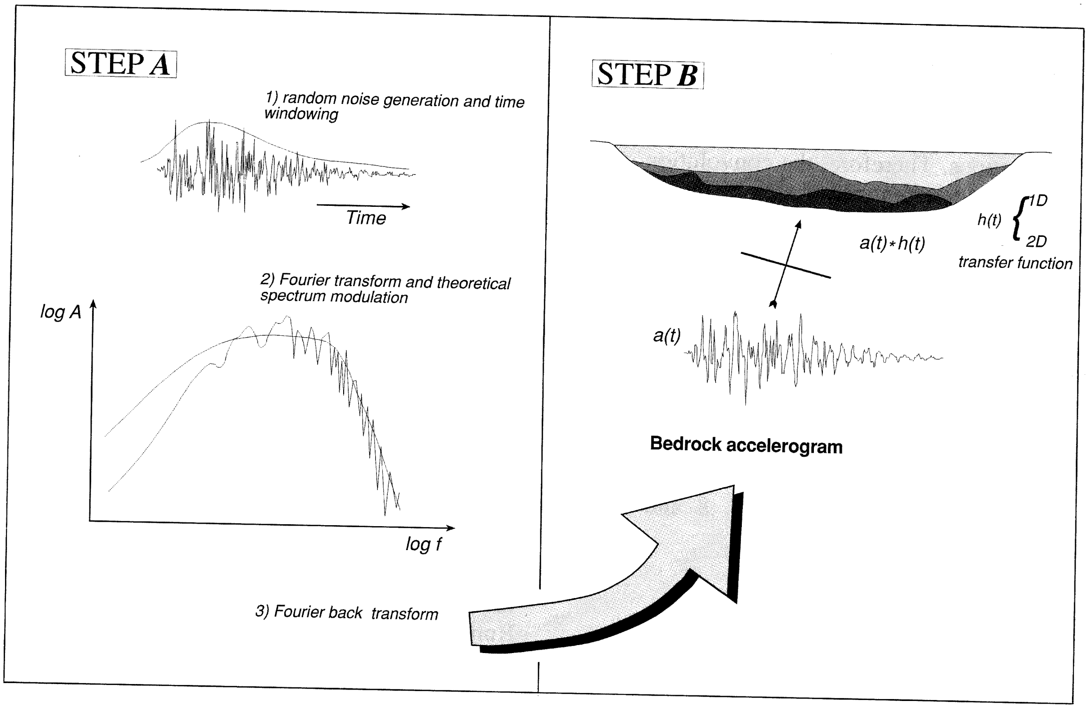

Fig. 2. Schematic representation of our modelling methodology. In the first step (A) the input incident at the bedrock is modelled through a stochastic procedure (Boore, 1983), including source and entire path propagation. In the second step (B) the effects of very local geology are simulated through 1-D or 2-D transfer functions, using a Haskell-Thompson algorithm or a finite-difference technique, respectively. The bedrock accelerograms are then convolved by the nearsurface-structure transfer functions. This convolution yields the final surface accelerograms.

time-windowed random series whose flat spectrum is modulated by a frequency-domain scaling model based on observations (it is the technique proposed by Boore, 1983, basically). In our approach, the source contribution is given by the omega-square spectral model of shear-waves, and the whole-path propagation is modelled in the frequency domain by the combination of a low-pass filter (the effect of anelastic dissipation, see Anderson and Hough, 1984) and a high-pass filter (the effect of decreasing seismic impedance in the upper crust, see Joyner and Fumal, 1984). The procedure details are presented in Rovelli *et al.* (1994); in that paper, the advantages of using a stochastic approach compared to deterministic ones are also discussed. In the sketch of fig. 2, the local upper-layer propagation (step B) can be simulated by 1-D or 2-D models, using a Haskell-Thompson approach (Haskell, 1953, 1960) or a finite-difference technique (see Caserta, 1995), respectively. The outputs at the surface, obtained from a delta-like input obliquely incident as a plane SH wave, are used as site transfer functions. Therefore, the convolution of the bedrock accelerograms of step A by these site transfer functions yields the transverse component expected at the surface for the horizontal ground motion, in a 1-D or 2-D approximation. The spatial variation of parameters of engineering significance can be consequently estimated as a function of the local geology: peak ground velocity and acceleration, Arias intensity, duration, flux of seismic energy, response spectra are then simply computed from the surface synthetic accelerograms of the different geological units (*e.g.*, see figs. 8 and 10 in Rovelli *et al.*, 1994).

3. Comparing results from 1-D and 2-D modelling

In engineering practice, the simplest – and therefore the most largely used – procedure to model the effects of the impedance contrast in the upper earth is by using 1-D transfer functions. Even though it is well known *a priori* that this approach is a simplification of reality, the method is fast and can be routinely used without sophisticated modelling, even with low-cost computers. The U.S. standards recommend this approach: computer codes have nowadays undergone a long testing period to be validated and implemented, and guarantee satisfactory results. One of the conclusions emerging from international experiments in California and Japan is that 1-D predictions did fit observations satisfactorily, and 2-D and 3-D models were not successful in providing a more accurate fit (Bard, 1995). One physical explanation could be the low Q value of the surficial layers both at Turkey Flat and Ashigara Valley: as demonstrated by Zahradník *et al.* (1992) the higher the attenuation the closer the similarity between 2-D and 1-D response. However, even when geometries of buried structures are really well-known, uncertainties in measured velocity values can seriously affect the results of sophisticated modelling. As suggested by Field and Jacobs (1993), difficulties in constructing the correct models represent nowadays the major limit of the theoretical approach, discouraging often the use of 2- or even 3-D codes outside a research environment.

Here, we want to estimate the difference between 1-D and 2-D predictions in the case of two geological profiles crossing the historical centre of Rome. For this area, the availability of a data bank collecting stratigraphies and geological information from more than 3000 well logs allows us to reconstruct the hidden geometries satisfactorily, at least up to a depth of ≈ 100 m. At this depth, the drilling data find the seismic bedrock of the Roman area. It is composed of strongly overconsolidated Pliocene clays, which are more than 700 m thick as evidenced by a deep borehole in Rome's historical centre (Signorini, 1939).

Using the methodology described in the previous section, Rovelli *et al.* (1994) reconstructed the 2-D profile and computed the seismic response along two geological configurations typical of Rome (for their location see fig. 2 of Rovelli *et al.*, 1994). Horizontal ground accelerations (SH waves) were estimated for a potential magnitude 7 earthquake, occurring 100 km far from Rome. The first profile crosses the Tiber river valley, which is the main geological element of the city: a large, quite regular NS structure incised down to the Pliocene bedrock and filled up by a 60 m thick layer of unconsolidated, water saturated sandy clays. These Holocene sediments form a wide, flat alluvial plain including the most part of the historical centre. The second profile was relative to the Palatino area which is characterized by the presence of close smaller-size incisions filled with unconsolidated sediments (Holocene alluvium and poorly consolidated artificial coverages) that create a single element of surface continuity through an extended soft-sediment body with variable thickness. Figure 3 shows these 2-D profiles and the transient response to a delta-like seismic input vertically incident to the bedrock. The results shown in fig. 3 were performed using a finite-difference technique (Caserta, 1995); the input was given as a vertically incident plane SH wave. Elastic and anelastic model parameters are listed in table I.

The transient-response wavelets at the surface were used by Rovelli *et al.* (1994) as 2-D transfer functions, and convolved by the «bedrock accelerograms» generated in step A. In practice, the «bedrock accelerograms» were

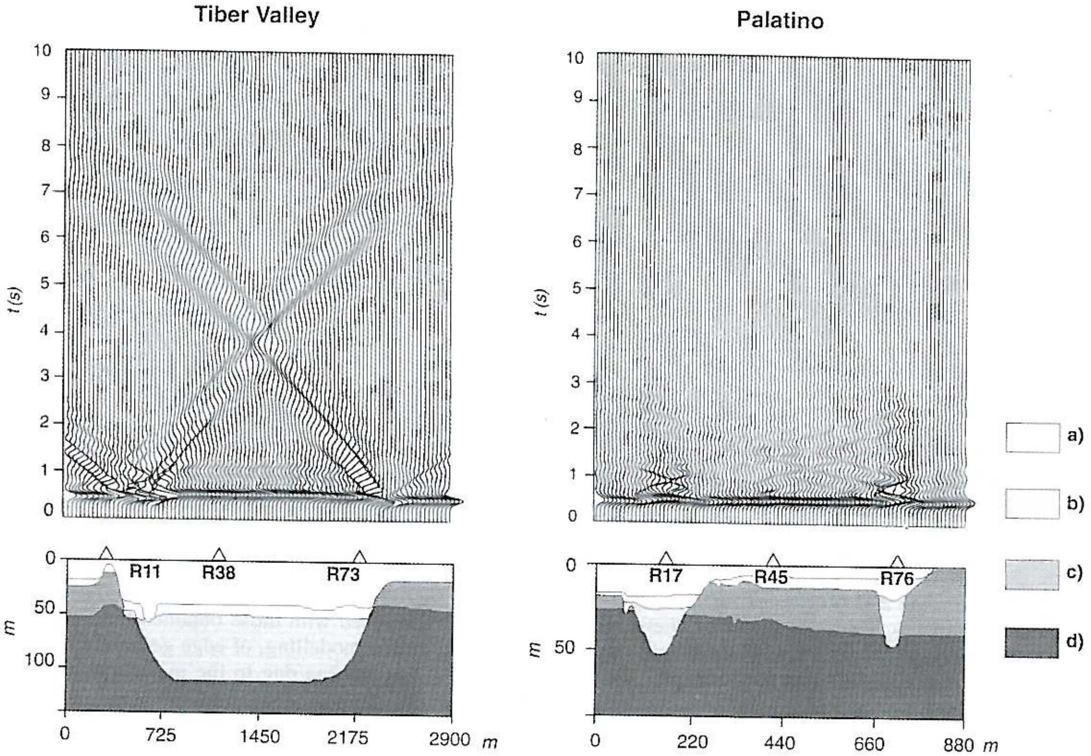

Fig. 3. Based on a 2-D model including topographic variations as well as heterogeneities of elastic and anelastic parameters, the transient response along two profiles representative of the city of Rome is numerically computed using a finite-difference technique; synthetic seismograms are the pseudoimpulse responses to a vertically incident plane SH-wave (from Rovelli *et al.*, 1994). Symbols a), b), c) and d) are the same used in table I to characterize the subsurface materials.

Table I. Elastic and anelastic parameters used for the near-surface propagation modelling.

	Geological unit	Density (g/cm^3)	Shear-velocity (m/s)	Quality factor
a	Fill deposits	1.95	150	5
b	Holocene alluvium	1.95	300	10
c	Volcanic deposits and Pleistocene sediments	2.0	400	20
d	Pliocene clays	2.1	600	50

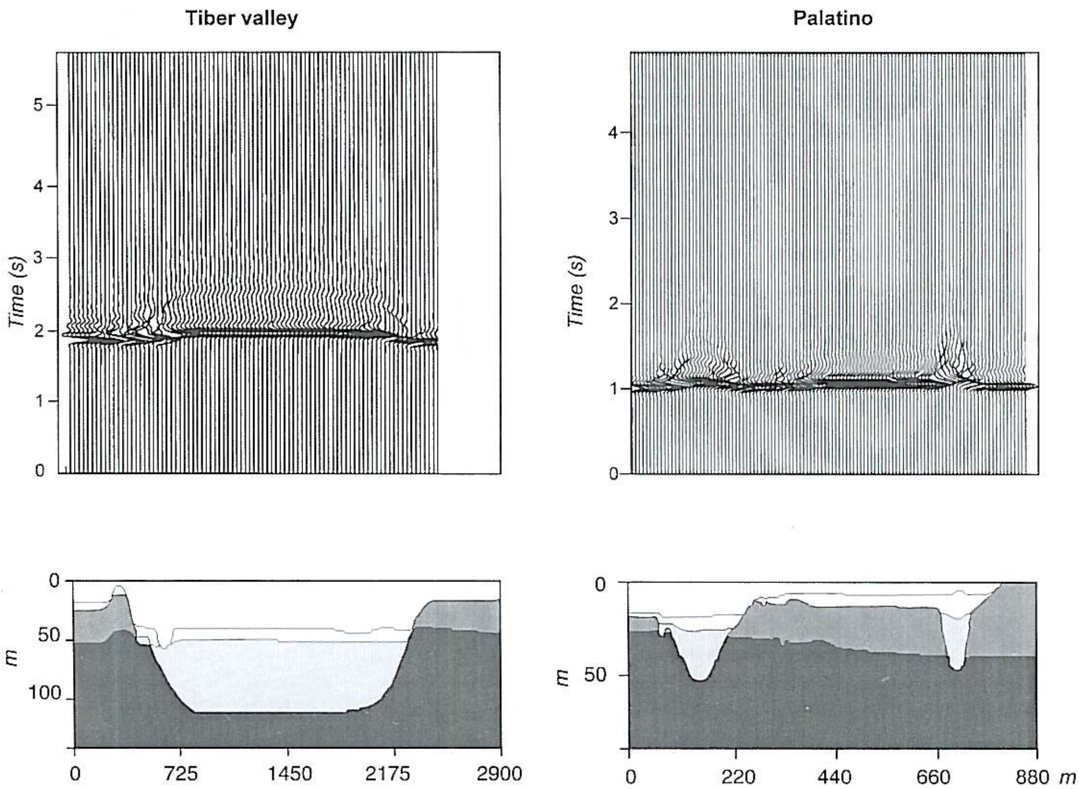

Fig. 4. From the 2-D profiles of fig. 3, a suite of adjacent 1-D models is constructed, and the application of a propagator-matrix technique yields synthetic seismograms to be compared with those obtained from the 2-D computation in the previous figure: differences are due to the lack, in this modelling, of edge generated surface waves, focusing and defocusing effects, and the other interference phenomena due to the model curve interfaces.

constrained to fit the spectral scaling estimated from strong-motion accelerograms recorded at rock sites in the region (Rovelli *et al.*, 1988); the acceleration spectrum expected for a magnitude 7 earthquake at an epicentral distance of 100 km was used. After the convolution of the 2-D transfer functions by the «bedrock accelerograms», Rovelli *et al.* (1994) averaged the results over an ensemble of 25 simulations, and drew the mean values of peak ground motions, Arias intensity and energy flux at the surface along the two profiles of fig. 3; 5% damped pseudovelocity response spectra were computed as well (see figs. 8 and 10 of the paper by Rovelli *et al.*, 1994). It is noteworthy that the average values found in this way are consistent with the results of Rome's hazard estimates by Sabetta and Paciello (1995) for a return period of 500 years, which is realistic for magnitude 7 earthquakes in the Apennines.

We now employ the same set of «bedrock accelerograms» to estimate peak ground motions and other parameters, in the case of a 1-D modelling of the seismic response for SH waves along the two profiles. The procedure is that developed by Rovelli *et al.* (1994) for the 2-D case. Figure 4 shows the suite of 1-D pseudo-impulse responses computed from a series of adjacent, independent stacks of horizontal layers obtained, one for each receiver, by vertically cutting the 2-D profile at each site. Comparing fig. 4 with fig. 3 we see a much more regular pattern in the 1-D modelling for both the two profiles, because only the vertical reverberations are reproduced in the 1-D modelling without the contributions from curve interfaces and related interference phenomena.

Interestingly, significant variations of peak ground motion between 1- and 2-D modelling appear to be restricted to a small percentage of the two profiles (see fig. 5). Also in this case the low Q of the upper layers could play an

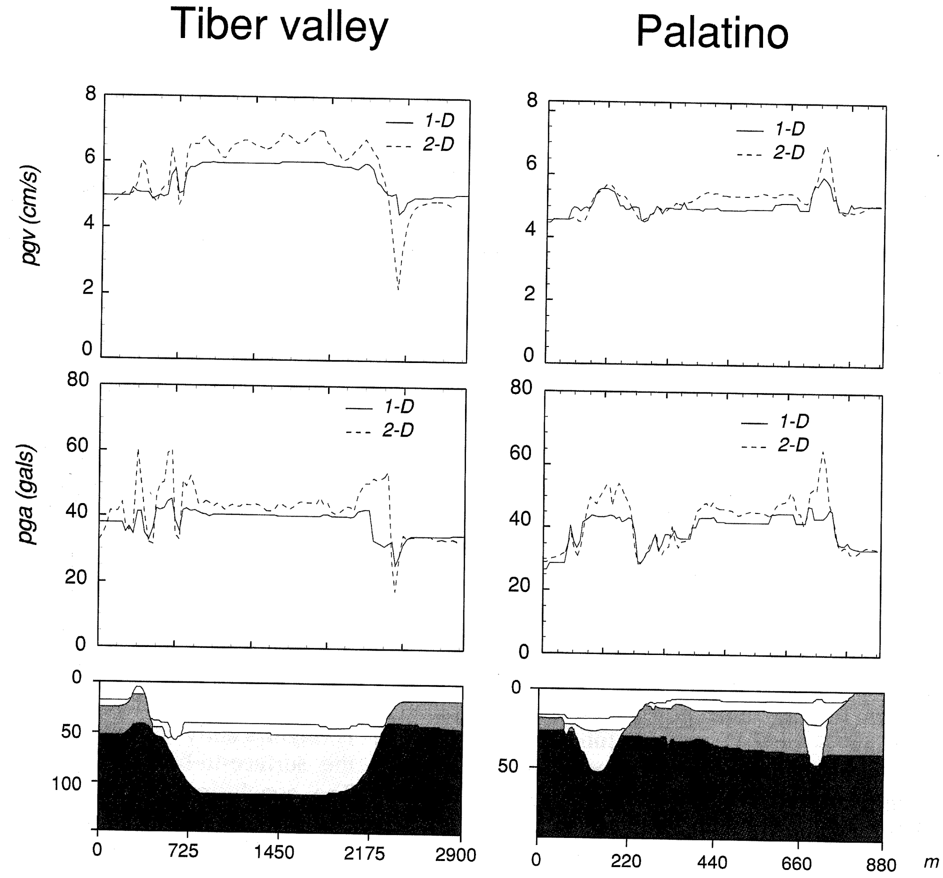

Fig. 5. Behaviour of *pga* and *pgv* resulting from 1-D and 2-D numerical modelling.

important role in the similarity between 1-D and 2-D results. However, in spite of the similar trend for each profile, large differences are found for ground acceleration (by more than 40%, in terms of *pga*) in correspondence to narrow critical zones such as valley edges as well as sharp alluvium-filled incisions as long as they are deep enough to penetrate into the seismic bedrock. Actually, for these geological situations the concentration of the highest level damage during earthquakes is consistent with the largest amplifications found in the 2-D modelling. Of course, these ground-motion amplifications are due to strong lateral heterogeneities and consequently cannot be predicted in a 1-D approach. For ground velocity, the maximum difference between 1- and 2-D models seems to be lower, even though in one of the two profiles (Tiber valley) is not concentrated over limited segments as *pga* does (see fig. 5). In particular, in the edge zones *pga* results in 60-70 gals for 2-D models against 45-55 for 1-D models, whereas *pgv* values as large as 6-7 cm/s characterize the whole Tiber basin and the sharpest bedrock incisions in the 2-D modelling, with slightly lower values (by less than 20%) in the 1-D modelling. But the most impressive feature of fig. 5 is that changes of local geology produce variations of ground motion whose pattern is well identified in both 1- and 2-D models. For ground acceleration, over more than 80% of the two profiles 1-D predictions match very closely the 2-D ones.

As far as pseudovelocity response spectra are concerned, fig. 6 shows a comparison between colour amplitude scales for 1- and 2-D modelling. Of course, the choice of the amplitude scale is arbitrary, and colour pattern can change slightly when different scales are adopted. Here, we have used the same colour scale as in Rovelli *et al.* (1994). However, in all cases «a colour zonation» shows a very similar pattern for the same profile, independently of using 1- or 2-D transfer functions. Looking at the individual response spectra, we see that significant differences between 1- and 2-D models are mostly concentrated at the same critical zones found for *pga* and *pgv*.

In order to test the reliability of our methodology in predicting how much the horizontal ground motion is amplified on soft sediments in Rome, we have compared the soft-to-firm site ratio for *pga* and *pgv* along the two profiles with the soil amplification factor of the empirical relationships by Sabetta and Pugliese (1987). Figure 7 depicts peak ground motion amplifications as deduced from fig. 5, dividing the surface values by the bedrock prediction as estimated by Rovelli *et al.*, 1994 (26 gals for *pga*, and 4.6 cm/s for *pgv*). The horizontal straight lines in fig. 7 allow to compare the soil amplification resulting from numerical modelling with the average soft-to-firm factor computed by Sabetta and Pugliese (1987). These authors estimated a difference by factor of 1.48 for *pga* for shallow soils, and 1.36 for *pgv* for deep soils: for this reason, the comparison is mostly significant with the Palatino profile for *pga*, and with the Tiber valley profile for *pgv*. The empirical factor by Sabetta and Pugliese (1987) matches satisfactorily the 1-D results for soft sites; compared to the 2-D modelling, we see that the difference is significant only when edge complications occur.

The surface amplification against the bedrock has been estimated also for 5% damped pseudovelocity response spectra, through the spectral ratios between surface and bedrock synthetics. The result of this ratio is shown in fig. 8. Two main features emerge from this figure. First, it confirms that the largest amplifications (yellow) can be predicted only by adopting 2-D models, whereas the predominant pattern characterizing each profile (transition green-to-pink) is well identified independently of using 1- or 2-D transfer functions. Second, it demonstrates that not necessarily all the amplified frequency bands have to be taken into account in assessing seismic hazard, but their importance is determined, band by band, by the spectral amplitude of the bedrock input. In fact, the colour pattern resulting from the computation of absolute values of response spectra (fig. 6) is significantly different from that showing the surface-to-bedrock spectral ratio (fig. 8). The conclusion is that microzoning criteria based only on estimates of the relative spectral amplifications against the bedrock can be misleading in precisely attributing the right importance to the different physical effects.

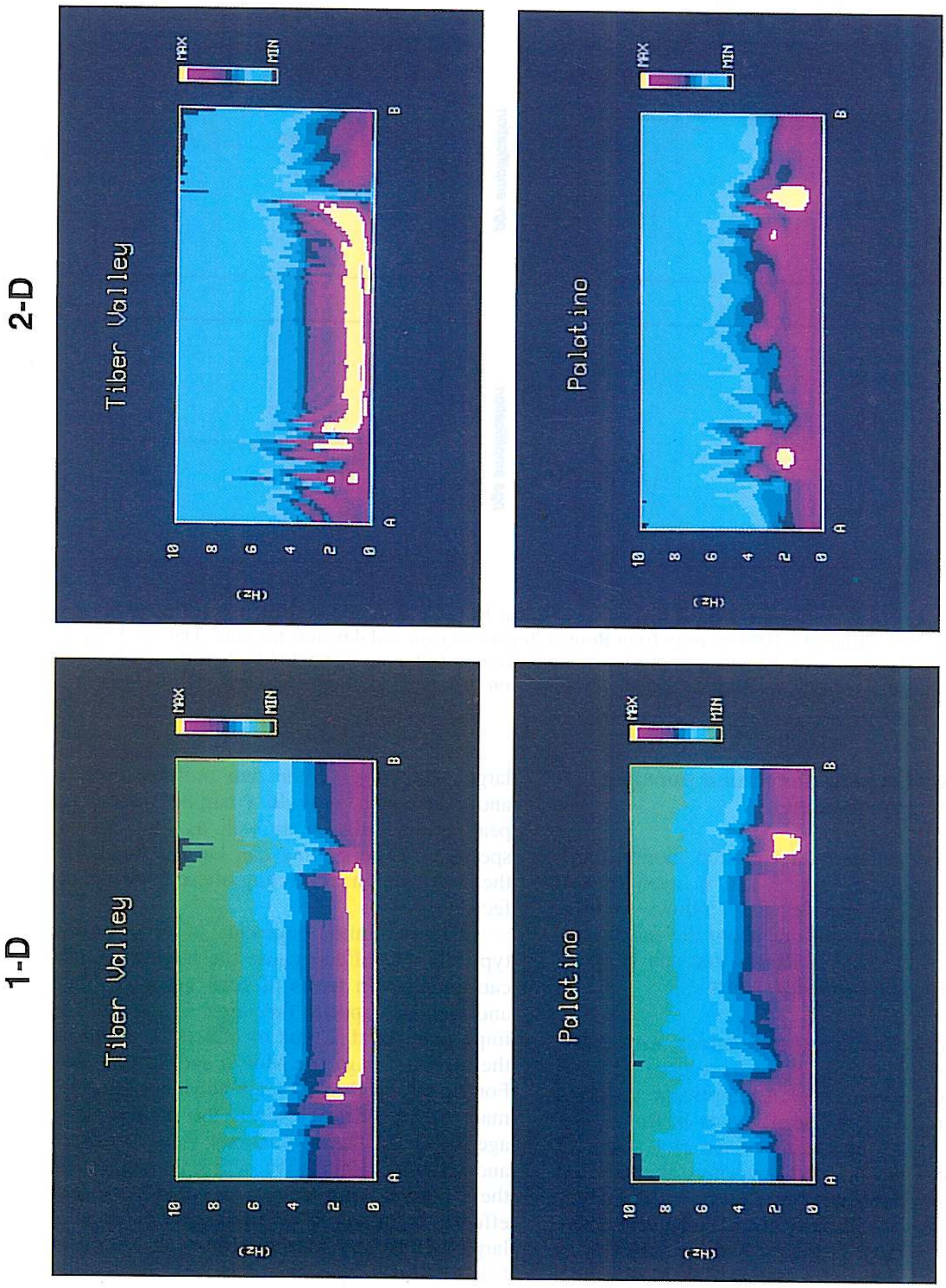

Fig. 6. Behaviour of the average 5% damped pseudovelocity response spectra as a function of frequency and spatial location along the Tiber river valley and the Palatino profiles. A and B are the extreme sites of the two profiles. The colour scale visualizes the amplitude variations of response spectra: yellow means spectral values higher than 10 cm/s, pink values ranging from 7.5 to 10 cm/s, roughly.

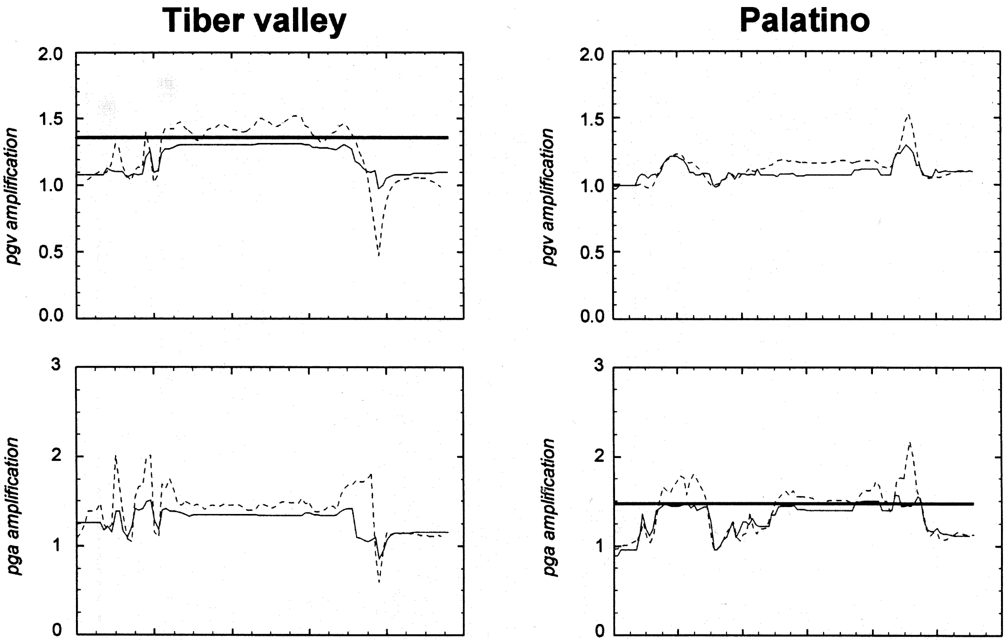

Fig. 7. Amplification of peak ground motion against the bedrock as deduced from the surface-to-bedrock ratio for a ***M*** 7 earthquake 100 km away from Rome (26 gals for *pga*, and 4.6 cm/s for *pgv*). The two horizontal straight lines represent the average soft-to-firm amplification factors as computed by Sabetta and Pugliese (1987) through a regression using the Italian strong-motion data bank (1.48 for *pga*, and 1.36 for *pgv*).

4. General criteria for seismic zonation of the city of Rome

The behaviour of the ground motion parameters shown in figs. 5 and 6, even though limited to two profiles only, allows to infer more general conclusions about the seismic response in the city of Rome, that can be summarized in the following items.

i) In our numerical simulations, earthquake engineering parameters such as *pga*, *pgv* and response spectra show a significant variation between «firm» and «soft» sites in Rome. Because of the long history of the city, traces of this effect can be read nowadays as stored on ancient monuments (see Boschi *et al.*, 1995). Hereinafter we generically call the amplification on the large Holocene bodies in the city as a «basin» effect. It is noteworthy that, over a large percentage of the two profiles, both 1- and 2-D results provide a similar pattern for peak ground motion as well as for response spectra: 1-D modelling can be as efficient as the 2-D one in predicting these «basin» effects.

ii) Over limited segments of our profiles, typically 2-D effects cause the largest amplifications, both in terms of peak ground motion and response spectra (see figs. 7 and 8). The importance of this type of effects is known in the literature (*e.g.*, see Moczo and Bard, 1993). For the city of Rome, an abundant collection of macroseismic data confirms the highest damage level for these situations (see Tertulliani and Riguzzi, 1995). We will call generically these highest amplification episodes as «edge» effects, including both the sharp borders of large basins and narrow, irregular sediment-filled bedrock incisions. The most representa-

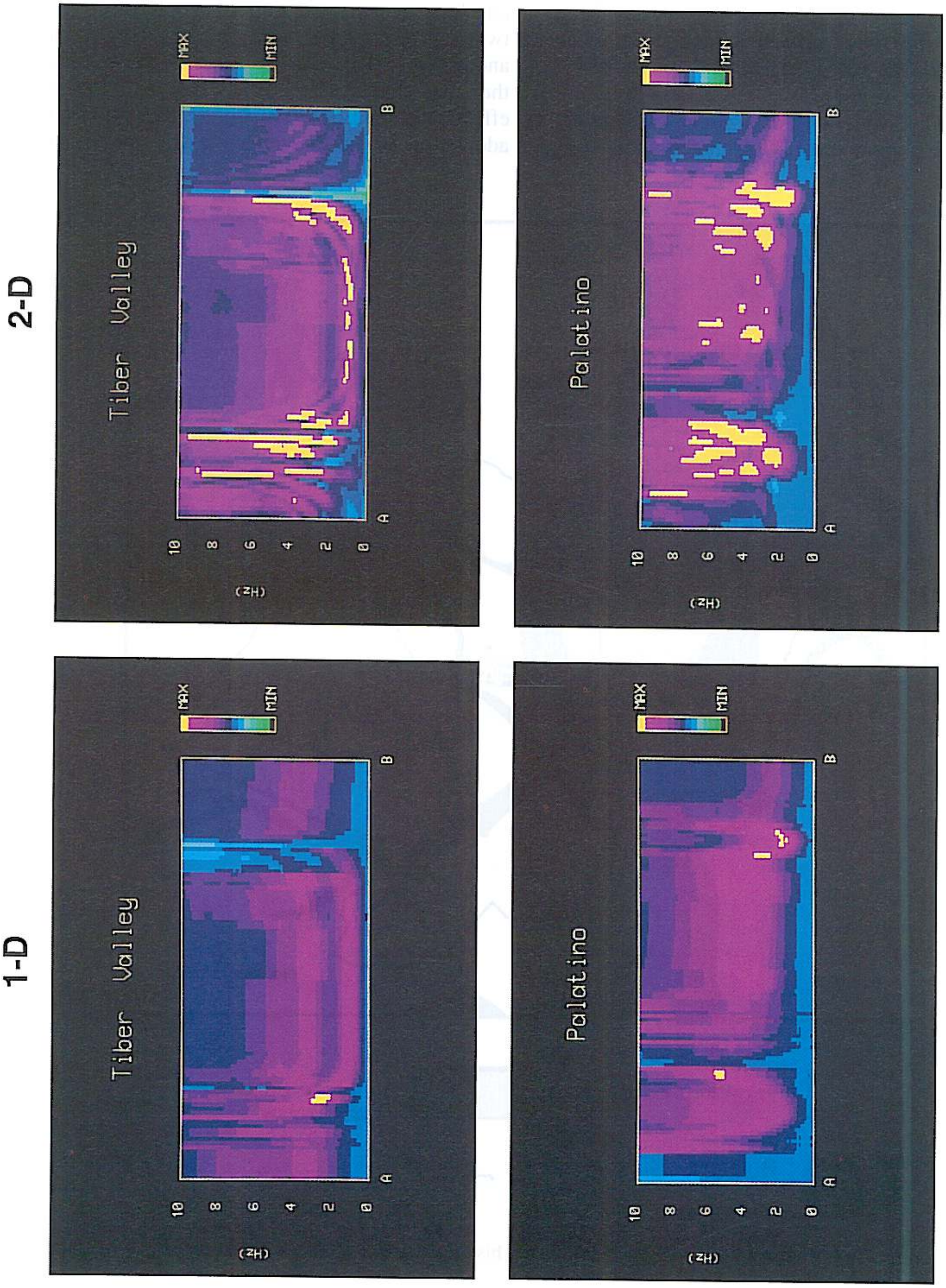

Fig. 8. Amplification of 5% damped pseudovelocity response spectra against the bedrock input. The colour scale visualizes the variation of response spectra amplifications as a function of frequency and spatial location along the two profiles: yellow means amplifications larger than 2.2, pink values ranging from 1.7 to 2.2 cm/s, roughly.

tive monument of Rome seems to have been affected by these effects in historical times (Funiciello *et al.*, 1995; Moczo *et al.*, 1995; both in this volume).

iii) The availability of a numerical data set concerning more than 3000 stratigraphic logs allows to reconstruct the buried interfaces between different units with a high detail (Marra and Rosa, 1995). On the basis of these data, the areas characterized by «basin» and «edge» effects are identified (see fig. 9). The criterion adopted to bound the «edge» zones consists in

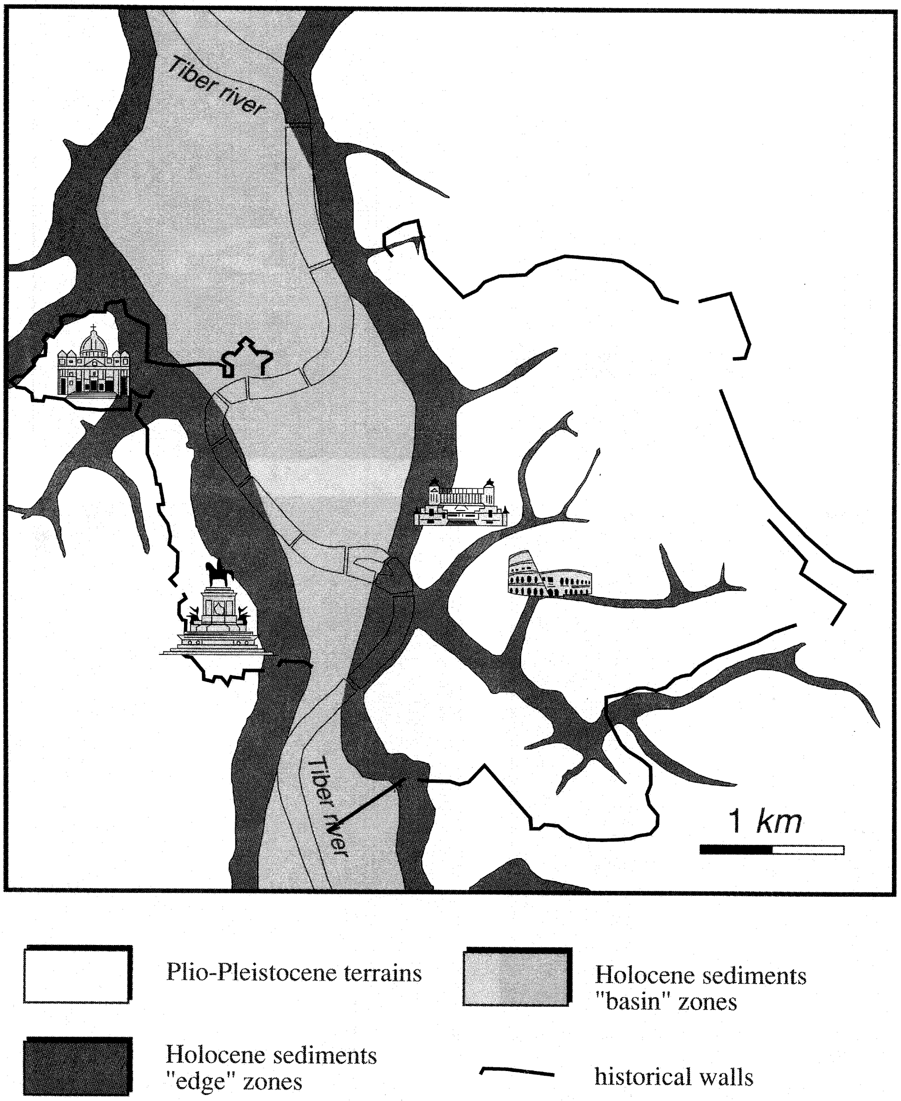

Fig. 9. Contouring of «basin» and «edge» zones in the historical centre of Rome based on results from numerical modelling and according to macroseimic data.

contouring the −40 m isobath which roungly matches the 60 m isopach, representing the transition between the steep and the flat part of the alluvium-bedrock interface.

This is still a preliminary approach to the seismic microzoning of the city. It takes into account the most peculiar aspects of both macroseismic data and results of the numerical simulations for large Apennine earthquakes, but does not consider the low-level seismicity within the urbanized area (Tertulliani and Riguzzi, 1995) and an important category of site effects: the amplification due to sharp topography variations. Even though the weight of topographic effects cannot be precisely defined in terms of damage because of a poor statistics, results of 2-D numerical modelling suggest that topography amplification could be significant for engineering applications (see Rovelli *et al.*, 1994). However, due to the Rome's structure, they are typically 3-D effects and an adequate study never was performed to quantify topography amplifications in the city.

Other more complex zonation criteria were proposed in the literature for Rome (Fäh *et al.*, 1993). Our opinion is that often a too high level of detail is not justified by the real information available about the nearsurface geometry and mechanical properties. The correct geological interpretation is a very delicate step: only geologists expert of the study area can guarantee the correct recognition of the stratigraphical and lithological characters which are the basis for a proper choice of elastic and anelastic parameters to be used in the numerical modelling. For sake of example, Fäh *et al.* (1993) attribute a strong impedance contrast to the interface between the volcanic coverage and an underlying Pleistocene sedimentary body. In their modelling, this produces effects whose weight is determinant for microzoning purposes. In reality, no experimental evidence exists for such a strong impedance constrast, and therefore this interface could have no practical importance in terms of microzoning implications. In our opinion, the mechanical properties attributed by Fäh *et al.* (1993) to the volcanics seem to be not appropriate to their lithology: volcanics in that area («tufi antichi» Auct.) are mostly composed of incoherent pozzolanaceous to cinerithic deposits (Ventriglia, 1971), often bearing a clayey alteration matrix, which have globally the same mechanical behaviour of Pleistocene deposits (gravel, sands and clays). Simultaneously, Fäh *et al.* (1993) attribute to the Pleistocene deposits (Sicilian Auct.) the same shear-velocity value used in their model for the Holocene alluvium. In spite of the similar lithology, these latter are much younger sediments (only ≈ 10 ky against ≈ 600 ky of the Pleistocene ones), significantly less consolidated and with a much highler water content (see Bozzano *et al.*, 1995). All these considerations weaken the hypothesis of a strong impedance contrast between Pleistocene sediments and surface volcanic deposits: in this case, many relevant effects emphasized by Fäh *et al.* (1993) in terms of microzoning criteria for Rome lose their importance.

Our opinion is that seismologists have to be cautious in proposing microzoning criteria which are derived from model assumptions not well constrained by observations. In particular, results which can significantly change when a different choice of parameters is adopted should not be proposed for microzoning purposes, until experimental evidence allows better constraints on the model.

In full awareness that *in situ* measurements are still inadequate to performe a definitive picture of elastic and anelastic parameters in Rome, we propose microzoning criteria whose results would not change significantly as a function of these parameters, even though the final ground-motion amplitudes could differ slightly from those presented in this study. The good agreement with the seismic response of the city in terms of macroseismic observations seems to confirm the reliability of the preliminary microzoning criteria that we propose.

5. Conclusions

A methodology is proposed which allows to compute ground motion parameters of engineering interest for an urban area, when data on the nearsurface geology are available. A comparison between 1- and 2-D modelling has been accomplished for important, monumental and strategical areas of the city of Rome. Two different geological profiles were investigated, one of them was across the Tiber river valley whereas the second spanned a representative section across the Palatino hill. The geological cross-sections were obtained from an abundant data set of drillings collected in the last years by the Istituto Nazionale di Geofisica within the urban area of Rome. From general, 3-D images of the buried structures within the historical centre, 2-D cross-sections were drawn and used for finite-difference modelling of SH-wave propagation within laterally heterogeneous near-surface structures. From the 2-D profiles, a suite of adjacent 1-D models were obtained, and a propagator-matrix technique was used to obtain synthetic seismograms to be compared with those obtained from 2-D computations.

Looking at the comparison between 1- and 2-D results, the overall impression is that 1-D predictions can be extremely useful for engineering applications and microzoning purposes. «Basin» microzones can be identified using a 1-D approach as precisely as using 2-D models. Over more than 80% of the two profiles the 1-D predictions of ground acceleration match very closely the 2-D ones. However, it has to be stressed that the narrow segments where 1-D predictions fail coincide with critical zones, where the maximum ground motions are expected as due to «edge» effects. These effects cannot be predicted in a 1-D approach. Users of routine 1-D codes have to be aware of this limitation in assessing seismic hazard.

Based on the spatial variations estimated for earthquake engineering parameters, some general criteria for the seismic microzoning of Rome have been inferred. A map drawn on the basis of these criteria is consistent with the distribution of damage observed during the strongest earthquakes felt in the historical centre of Rome.

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