APPLICATION OF THE LARGE AREA SEISMIC MICROZONING RESULTS TO THE RECONSTRUCTION PLANNING AND CODES IN THE MARCHE REGION.

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SUMMARY

The present paper is closely related to that presented by Pergalani *et al.* [1], which describes, from a scientific point of view, the method and results of a seismic microzoning of the area affected by the Umbro-Marchean earthquake. Here, it is reported how the results have been extended from the methodological sample of those Authors to a far greater number of sites (502 built-up areas, with surface and semi-deep technical data, in a territory amounting to as much as 20% of the Marches Region) surveyed during the delicate phase of defining the codes and regulations needed for planning and reconstruction.

After large-area surveying, the criteria for assessing the local amplification coefficient were acquired and applied to the whole set of maps (mostly at a scale of 1:5000, but some at 1:2000). Maps of the sites processed (containing information about local amplification coefficients to use in planning, and about landslides which had been surveyed), were then handed back to the local administrations (Communes) to enable their technicians and planners to have the information they needed for planning and calculating in accordance with the codes that the Regions had meanwhile issued.

These codes and instructions extended the national ones currently in force, considering the effective local data instead of merely what the law proposed on the basis of a hypothetical model.

Therefore, for the first time in Italy, the reconstruction will also have access to local amplification information, although with the insufficient detail that short-term coding entails.

From the administrative point of view, the whole process showed how a good degree of integration between technical-scientific researchers and public bodies is obtainable.

INTRODUCTION

The seismic sequence that interested the Umbria-Marche Apennine, started on september 3th 1997 (22.07 GMT) with a local magnitude 4.%. The next shocks on september 26th 1997 at h.0.33 GMT (local magnitude 5.6) and on h.9.40 GMT (local magnitude 5.9), evidenced that this part of the Apenninic range was caracterized by an extensional seismic deformation with SW-NE direction [2].

Due to this sequence several investigations have been started to evaluate damaging and local effets on site.

Specifically, these investigations allowed to underline the strict relationship between the geological and morphologica characteristics of the site and the level of damaging of buildings [3] [4] [5].

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APPLYING THE RESULTS OF THE URGENT SEISMIC MICROZONING SURVEY WHILE FOLLOWING THE MARCHES REGIONAL GUIDELINES

1. Geological aspects: one of the innovative features of the reconstruction in Umbria and the Marches after the 1997-98 earthquake.

Law No. 61/98 [6] dealing with the reconstruction in Umbria and the Marches after the 1997-98 earthquake states that any technical guidelines issued for planning should contain “specific technical regulations for the reconstruction, after duly assessing the possibility, and having obtained an affirmative answer, that the seismic risk is aggravated by local on site conditions” (Art. 2, paragraph 3, lett.d).

In order to assess the on site effects, the Marches Region carried out urgent seismic microzoning surveys in those communes and villages (the so-called Zone A) which were declared by the government to be heavily damaged by the September 1997 seismic crisis. This investigation was carried out in 502 built-up areas in those communes declared to be heavily damaged (shaded in red), which amount to 20% of the territory of the Region (Fig.1).

After due agreement with the Marchean branch of the Geology Professional Order, 85 geologists, , applied the “surveying regulations” laid down by the two Regions of Umbria and the Marches in collaboration with the National Research Council (CNR) and the National Seismic Office (SSN), and which are outlined in [7].

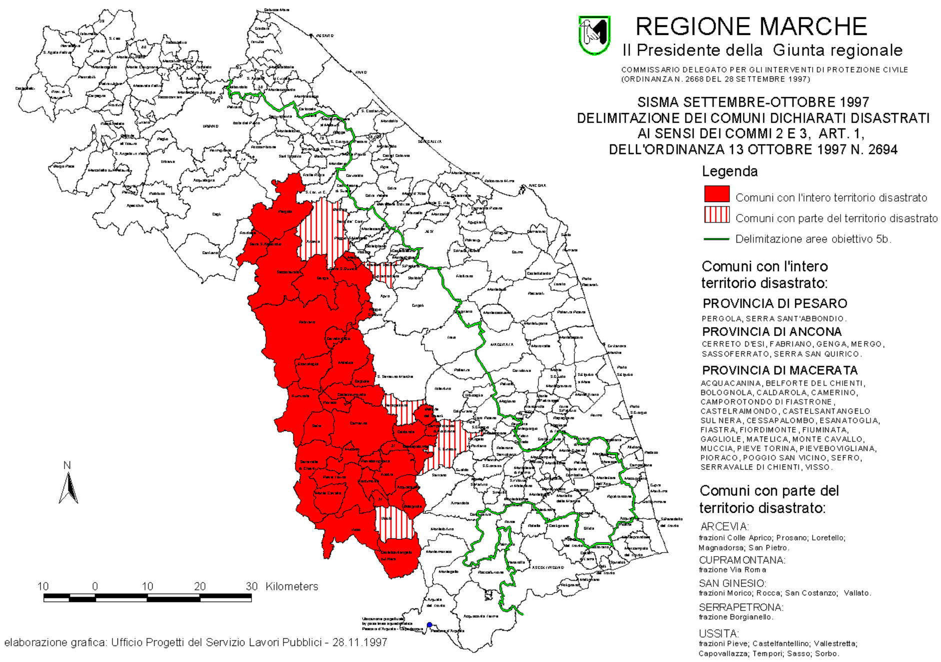


Fig.1 – Location map of the Marche region. In red the area, mentioned “Fasca A”, interested by microzoning.

The results of the survey conducted by each worker for each site were illustrated by a series of maps (scale 1:2000 or 1:5000) as follows:

- analytical maps:
  - geological maps;
  - morphological maps;
  - lithotechnical maps;
- synthetic map:
  - maps of those zones liable to amplification or local instability dynamics.

One or more geological section, one illustrated relation that explained the geological framework of the area investigated, was prepared.
The synthetic map was made by a codified superposition of the thematic elements mapped in the three analytical maps (geological, morphological, and lithotechnical) and defines a zoning of situations with homogeneous behavior, as reported in Table I [1].

Tab. 1 - Table of the amplification coefficients for the geologic and geomorphologic situations

Local effect situations	*Lithologic units*	**Thickness**	**Fa**
E-5 Cliff with height ≥ 10 m	Debris	< 10m 10-20m 20-30m	1.2 1.4 1.6
	Travertine	< 10m 10-20m 20-30m	1.1 1.3 1.4
E-7 Valley filled by alluvial deposits	Clayey fluvial-lacustrine deposits and silty-clayey alluvial deposits; colluvium	< 10m 10-20m 20-30m	1.2 1.5 1.7
	Sandy-gravel fluvial-lacustrine deposits and sandy-gravel alluvial deposits	< 10m 10-20m 20-30m	1.1 1.2 1.4
E-8 Slope toe, slope debris and alluvial fan		< 10m 10-20m 20-30m	1.2 1.5 1.7
	Ratio height/width		**Fa**
E-6 Ridge area	< 0.1 0.1-0.2 0.2-0.3		1.0 1.2 1.4
E-1; E-2; E-3 Unstable area and potentially unstable area	Investigations to evaluate the instability and to define the feasibility of interventions of stabilization		
E-4 Soft soil (low density fills, saturated soils with abundant fine fraction)	Investigations to evaluate the feasibility of interventions of consolidation		
E-9 Stratigraphic-tectonic contact between two lithologic units with different geotechnic characteristics	Investigations to evaluate the differential sinking under seismic conditions and the consequent interventions on foundations		

Once the zones having homogeneous behavior had been circumscribed, the Marches Region then attributed to each of the zones identified a relative “Fa” reference value by applying the matrix model [8] shown in the Table. The maps thus obtained were then sent to all the communes making up the sample to be used by their planners.

In view of the power entrusted to the regions to promulgate technical guidelines for the reconstruction, the practical application of the “Fa” value obtained was defined by a decree of the regional authorities [8], in which they established that seismic planning actions should be expressed in terms of “Fa” (varying from 1 to 1.8 in the sites surveyed) instead of by the coefficient “ε” (with a national standard of 1 or 1.3 according to the thickness of cover and depth of bedrock) [9].
The reference value “Fa” wasn’t attributed to situations E1, E2, and E3 (hydrogeological instability of various degrees) typified by criticalness independently of the local response, and also to E4 (bad-quality terrains) and E9 (contact zones between terrains with different behavioral patterns). The reason for this was that for these zones no absolutely valid code could be justified with regard to the type behavior in the individual areas of building foundations and of the structural characteristics of the buildings themselves. As indicated in the Table above, the SSN and IRRS [1] prescribe ad hoc surveying for such situations (supplementary geological surveys).

On the basis of the survey results, homogeneous zoning could be performed of all the sites sampled, although two different sets of regulations were formulated corresponding to the two different types of data obtained:

a) seismic planning actions to be incorporated in structural calculations for repair work with seismic improvements [10]:

- the regional guidelines consider the “Fa” coefficient values within the framework of the “Technical Guidelines” for planning as reported in Appendix B to decree No. 2153/98 [10] issued by the Regional Government;
- the application of the “Fa” values allows for the lithological, lithotechnical, and geomorphological factors and has the same conceptual significance as does the coefficient ε in the prevailing seismic norms for ordinary building (Ministerial decree of 16 Jan. 1996) [11], although the latter coefficient allows only for the lithologic factor;
- the “Fa” coefficient values, resulting from urgent surveys, are therefore found between 1 and 1.8, whereas the coefficient ε for seismic norms is either 1 or 1.3 [11]

Using the “Fa” project seismic planning actions instead of the coefficient ε generally determines an increase in repair costs compared with those foreseen under the ordinary laws. In fact, as said previously, while ε has a maximum value of 1.3, that for “Fa” is between 1.8 and 2.0.
To compensate for the higher cost of intervention, which aims to afford greater safety for the buildings, the regional guidelines [10] foresee a particular rise expressed as a percent increase in the sum of money allocated for the works, a distinction being made between repair works with seismic improvement and total reconstruction:

D7	Increase in structural costs due to local effects: **D7.1 -** for repair work with seismic improvement: linear increase (§) up to	20%
	D7.2 - for reconstruction: linear increase (#) up to	15%

§ = (Fa – 1) x 20 # = (Fa – 1) x 15

With the aim of offering conditions of homogeneity to all citizens requesting financial support, the Region has decided that all interventions to be carried out in the regional territory, including those outside Zone A, should enjoy the same degree of protection by using the “Fa” value when planning the works. With appropriate administrative measures [9], it has thus been established that:

- the methodology reported in [1] shall be used at all sites and for every building, with the necessary studies to verify the thickness of cover from which to derive the correct “Fa” value from Table I;
- the increase to be applied to determine the amount of contribution for private persons will take into account the “Fa” value utilized during the structural calculations;

checks will be made for any error in using the correct “Fa” value (in order to afford homogeneous seismic protection).

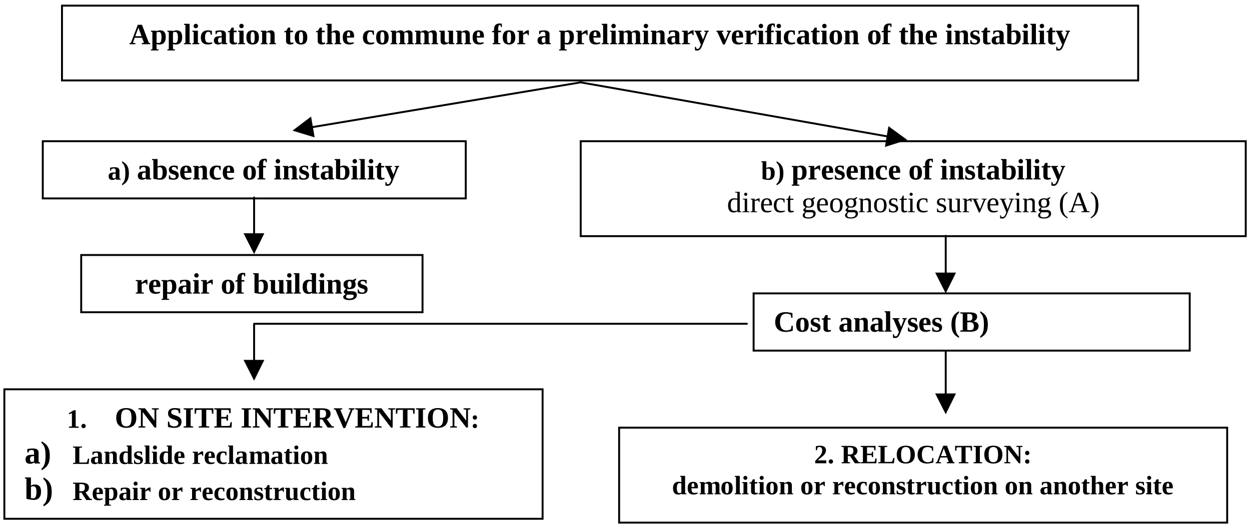
b) Hydrogeological instability:

- in the surveyed area, zones characterized by quiescent landslides (“E2”) have been identified [7] as well as those having landslide potential or being exposed to risk of landslide (“E3”);
- the fact that buildings are sited in areas characterized by active (E1) or potential (E3) instability represents a limitation on the procedure for granting the public funding for their repair or reconstruction; in fact, any intervention can be carried out only after due verification [12];
- conversely, for interventions that are to be funded under Art. 4 of Law No. 61/98 (private buildings) [6], the presence of quiescent instability (“E2”) is not considered a limiting factor for granting the support since, by definition, it is not held to be a relevant element in inducing danger. In fact, these are individual buildings subject to direct intervention and are totally unrelated with any modifications in local morphological conditions;
- this norm is valid for the whole regional territory, independently of whether the area is one in which urgent investigations have been made.

The problem of hydrogeological instability has been faced considering that particularly serious situations, not only those in Zone A but in the whole regional territory, could lead to:

- the relocating of the building when it is in a particularly dangerous condition;
- the reclamation and consolidation of the land if such an intervention were to be “convenient”;
- consequently, a procedure for verifying the real conditions of risk for buildings or built-up areas sited in, or upslope or downslope of, zones of instability.

The Region has decided on a verification procedure in several steps, as outlined below:



A - FEASIBILITY STUDY

a) The feasibility study should contain at least the following elements:

b) a technical report on the building which is the subject of preliminary verification, specifying the funding requested under Art. 4 of Law No. 61/98 and subsequent modifications to it;

c) a synthetic technical report on the hydrogeological instability together with the results of the geognostic survey;

d) a detailed description of the factors which taken together define the value of the building: i.e., environmental, historic, architectonic, cultural and functional;

e) the development of alternative solutions expressed in terms of cost analysis, as illustrated below under point G.3, also taking into account the benefit to be gained and their landscape-environmental compatibility;

f) an analysis of the congruency of the alternative solutions with the current urban and landscape-environmental norms and planning;

g) an analysis of the congruency between the environmental, historic, architectonic, cultural and functional value of the site and of the property that are subject to relocation, on the one hand, and the corresponding values of the site proposed for relocation, also in view of the use to which the buildings to be relocated will be put;

h) should the instability affect several buildings, the reports, analyses and evaluations, as described above, must be extended to all the buildings concerned and to the respective foundation areas.

B - COST ANALYSIS

a) P1: cost of reclaiming unstable land;

b) P2: cost of repairing the buildings and relative infrastructure. In the case of buildings of historic interest, allowance will be made for the greater expense connected with the intervention;

c) P3: cost of reconstructing elsewhere, including any urbanization expenses and those for purchasing the land, as well as any costs due to loss of productivity as a result of reconstructing on another site.

Whenever:

a) the sum of P1 and P2 is less than or equal to the cost of P3, it will be possible to reclaim the unstable land and repair the building and relative infrastructure;

b) the sum of P1 and P2 is greater than the cost of P3, the feasibility study shall be subject to examination by the Technical-Scientific Committee who will make cost-benefit analyses based on comparing the sum of P1 and P2 with the cost of P3, while taking into account the following evaluation criteria: the historic and artistic value of the property; the landscape value of the sites involved; the economic value of the activities connected with the existent building.

2 – The case of Collecurti in the Commune of Serravalle del Chienti (Province of Macerata)

The Commune of Serravalle del Chienti, one of the hundred centers most hard hit by the 1997 earthquake, has requested that for ten of the built-up areas in its territory the reconstruction should be developed in an integrated form (i.e., buildings plus infrastructure).

Among these built-up areas is that of Collecurti, situated in the lacustrine valley-bed plain overlooking a limestone relief which is characterized by particularly complex geological and geomorphological situation. Already in the IRRS study of the sampled centers, that of Collecurti appeared problematic. As the SSN/IRRS "Conclusive Report" states:

> "*for the built-up area of Collecurti (see the Table), the stratigraphy led to analyses of the local seismic response which was in contrast with the state of damage ascertained in the buildings. In order to study in greater depth the reason for this discrepancy, it is suggested that specific investigations should be carried out for the exact stratigraphic reconstruction and above all for the geotechnic properties of the landforms making up the hill on which the village is sited. As a rough guide, the amplification coefficient resulting from the table of amplification is given; this coefficient, formed by the two "Fa" coefficients regarding the ridge effect (1.2) and the presence of loose cover terrains (1.4), yields an "Fa" value of 1.7*"

Table of "Fa" values assigned to the studied locality (Collecurti)*)*

LOCALITY	COMUNE	PREVALENT TYPE SITUATION	Fa
COLLECURTI	**Serravalle d. Chienti**	*ridge (E8) cover terrain*	*1.2 x 1.4*

The same was stated by the Marches Region Technical-Scientific Committee who, in support of the Commune's request for direct investigations, found it opportune to produce reliable results both with regard to the degree of safety to attribute to the buildings subsequent to reconstruction works (thus avoiding the hypothesis of relocating the center) and to the level of efficacy of the method utilized for the urgent survey.

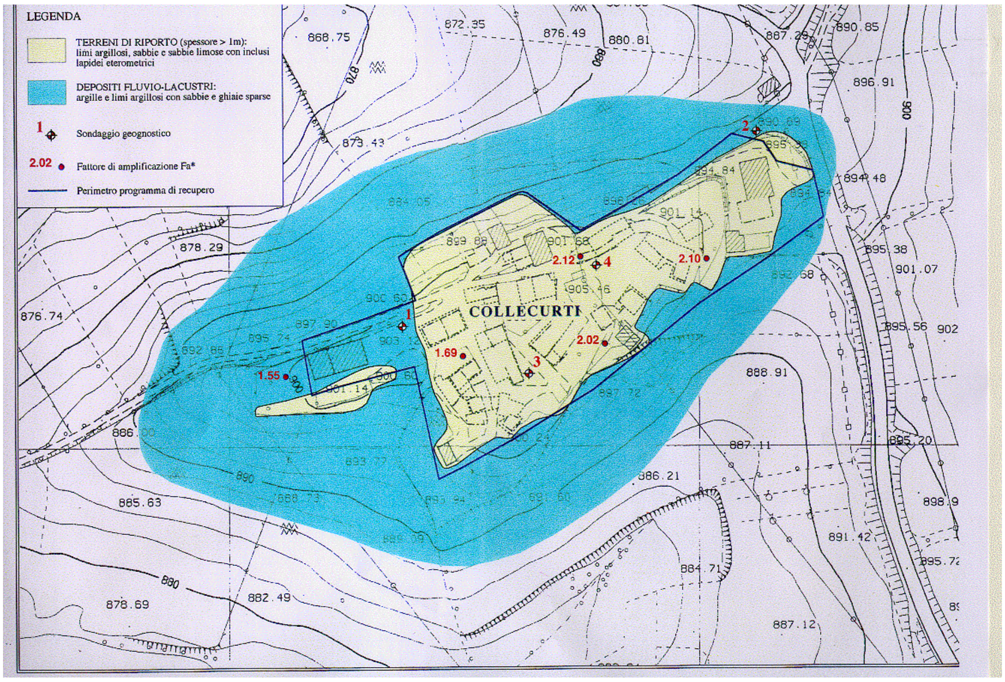


Fig.2 – Geological scheme of the Colecurti area.

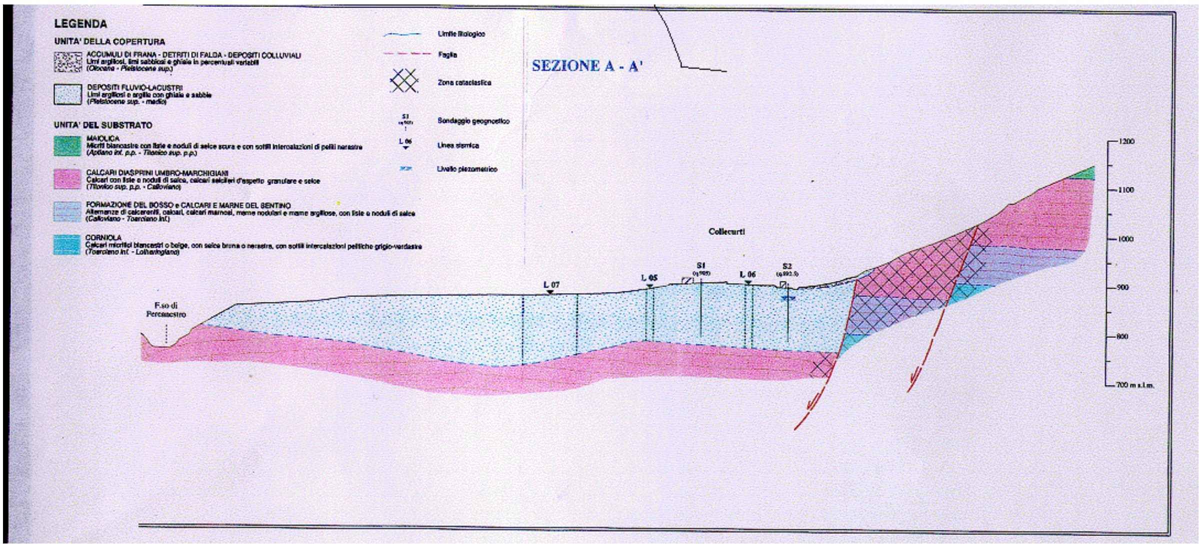


Fig.3 – Geological cross-section througt the Collecurti area.

The study, carried out using experimental methods in conjunction with the Geophysics Laboratory of the University of Camerino and in agreement with the IRRS/CNR in Milan, yielded significant results from the technical standpoint, as is shown in the synthetic mapping (Fig.2 and 3) contained in the study [13].
In particular, the local seismic response was determined by an integrated evaluation of the data obtained on site (structural survey, experimental geophysical measurements, direct geognostic surveying, continuous core analysis, and laboratory tests).
The evaluation was accomplished by means of the theoretical model used for attributing an "Fa" value equal to 1.7, but utilizing numerical data (for which modified "Fa" values, given as "Fa*" were obtained); in a short time, this allowed an excellent degree of approximation to be achieved and technical executive measures to be elaborated. These could be taken as binding elements for carrying out the Recovery Program.

In order to have a detailed assessment of the Collecurti investigation, it might be useful to give some aspects of the results together with the guidelines recommended in [13].

"......... The study of the effects on site .... allowed us to calculate a modified "Fa*" Amplification factor, by taking the average value between the methods of Nakamura and Kanai-Tanaka; this had the same physical significance as that derived from the IRRS/CNR seismic microzoning campaign.

“This average modified “Fa*” Amplification factor calculated for Collecurti was equal to 1.89, a value which tends to increase, proceeding WSW away from the center along the ridge, until it reaches a maximum value of 3.8 at Station C4. At Station A6 to the north in the valley bed, in the direction of Voltellina, at lower altitude (870 m a.s.l.) with respect to the built-up area (903 m a.s.l.), the modified “Fa*” Amplification factor returns to low values (1.1) which indicates a possible ridge effect as a contributory cause of the amplification phenomena encountered in the Collecurti built-up area.....”

“....In drawing up the operative urban plan, particular attention should be paid to the planimetric and altimetric planning of the foundation areas of the new buildings and infrastructures so as allow for the removal of any transported material which might be present. In the phase of planning the buildings, in view of the elastic amplification spectra measured which show maximum peaks at frequencies of between 1.0 and 3.0 Hz (equal to 1.0 and 3.0 sec), it is advisable to remain above these frequencies in order to avoid any soil-buildings double resonance effects”.

CONCLUSIONS

Reconstruction in Umbria and the Marches is still in progress, and it is foreseen that a large amount of the total number of buildings will have been completed by 2001 (i.e., 3-4 years after the main event, while the fastest large-area reconstruction in Italy - Friuli 1976 - was 90% completed in 10 years). The choice of *low retrofitting*, for the large-scale reduction of vulnerability now available with *low-cost* and *low-impact* interventions, especially on masonry buildings, seems to be a good choice also on which to base a program of seismic risk reduction in an area, like Italy, which suffers victims and damage from earthquakes, *not because of high hazard*, but of *high vulnerability*.

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