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Evaluation and factors that control the intensity of the Umbria earthquake (Central Italy, 26 September 1997

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ABSTRACT: The earthquake of Umbria, with a magnitude of Ms=5.9 which took place on the 26th of September 1997, caused many deaths and large damages in the broader area Folio-Nocera Umbria-Camerino-Spoleto of Central Italy. In the epicentral area, where some big and numerous small settlements occur, it was carried out an evaluation of the damages in the EMS-1992. During the recording phase it was noticed an important differentiation in the intensity values from one settlement unit to the other, according to the geographical position. After the detailed recording of the damages and evaluation of the intensities it was found out that the most important factor for the occurrence of the damages was the geological conditions that prevailed in each locatuib and particularly the occurrence of specific formations over the rocky bedrock. Furthermore an equally important role in controlling the intensities was played by the fault zones, mainly in the narrow epicentral area.

RÉSUMÉ: Le tremblement de terre d' Umbria, qui avait un amplitude de Ms=5.9, et qui a eu lieu le 26/9/1997 a provoqué un grand nombre de victimes et catastrophes aux regions de Foligno – Nocera Umbria – Camerino – Spoleto (Italie centrale). A la région d' épicentre, où se trouve un grand nombre de petits villages et peu de grandes villes, une évaluation detaillée des catastrophes à eu lieu. Au cours de cette évaluation, il est devenu evident que le facteur le plus important pour les catastrophes sont les conditions géologiques de chaque location, et en particulier les formations differents qui se trouvent sur le sub-stratum rocheux. En plus, les zones de failles ont joue un rôle aussi important sur le contrôle des intesités, en particulier dans la région épicentrale.

1 INTRODUCTION

On Friday the 26th of September 1997 at 9:40 GMT a strong earthquake of Ms=5.9 intensity hit the area of Umbria in central Italy. The epicenter of the quake has coordinates 43.00N and 12.80E, the focus is 10 km deep, and is situated in the broad area of Cesi village which suffered significant damage and which is 50 km to the east of the town of Perugia (Central Italy). Additionally the build up areas that were more severely hit are Cesi, Verchiano, Colfiorito, Voltellina, Annifo, Valtopina, Costa, San Martino, Collecurti, Fraia, Nocera Umbria, etc.

Prior to the main seismic event the seismic activity that took place gave the earthquake of the 26th of September 1997 at 0:11 GMT which was the most typical earthquake of this period, with a magnitude of Ms=5.4, while the preseismic sequence begun on the 4th of September 1997 with an earthquake of Ms=4.4. After the seismic the main shock occurred many other earthquakes of significant magnitude which were felt by the inhabitants, and which deteriorated the existing damages.

According to the official reports 11 people were killed, 150 were injured, about 10.000 people became homeless and 100.000 temporarily homeless. Overall the number of build up areas that suffered significant damages exceeds 100, which are spread in a mountainous land of roughly 1.000 square kilometers.

Finally, it is noteworthy that there were severe damages on historical monuments, for instance the Basilika of San Franzesco and the medieval monuments of the town of Assisi, the historical center of Nocera Umbria, Santa Maria of Spoleto, Santa Aikaterini and Santa Maria of Camerino, the historical center of Foligno, etc.

Finally after presenting some data about the geological framework of the area, there will be shown the recorded data and an evaluation of the intensities. Lastly it will follow a discussion on the

factors that acted on the differentiation of the intensities.

2 GEOTECTONIC FRAMEWORK-CONDITIONS OF FOUNDING

The struck by the earthquake area-epicentral area occupies part of the mountainous land of the Apennines which constitutes the axial mountain range of central Italy.

From a geological point of view (Centamore et al. 1979, Boccaletti et al. 1985, Calamita et al. 1986, Barberri et al. 1993), the epicentral as well as the broader area consists of thin bedded, folded and thrusted limestones, cherty limestones, marly limestones, marly clays and marls which belong to the Umbria-Marche Unit (Fig. 1). The above formations appear in successive, elongated occurrences due to repeated thrusts along the main direction N-S to NW-SE, they are of Upper Triassic-Lower, Middle Miocene age and form the basement rock.

Furthermore in the area (Fig. 1) occur formations of Upper Miocene age, mainly in the eastern part of the map and in the area of Camerino. They consist of sandstones, gypsum, toffites, etc. These formations either cover uncomfortably the above formations (Umbria-Marche Unit, as shown in the area of Camerino, or underlie the frontal part of the thrust of the basement formations. Additionally in the area outcrop formations of Middle Pliocene -Lower Pleistocene age, which are made of sandstones, conglomerates and pelites that cover comformably the above formations.

In places the above Plio-Peistocene are uncomformably overlaid with recent formations which are represented by continental deposits and especially red clays, silicic red beds, talus scree, etc. They are of Upper Pleistocene-Holocene age, usually occupy the morphological lows of the mountain range and have restricted thickness. They

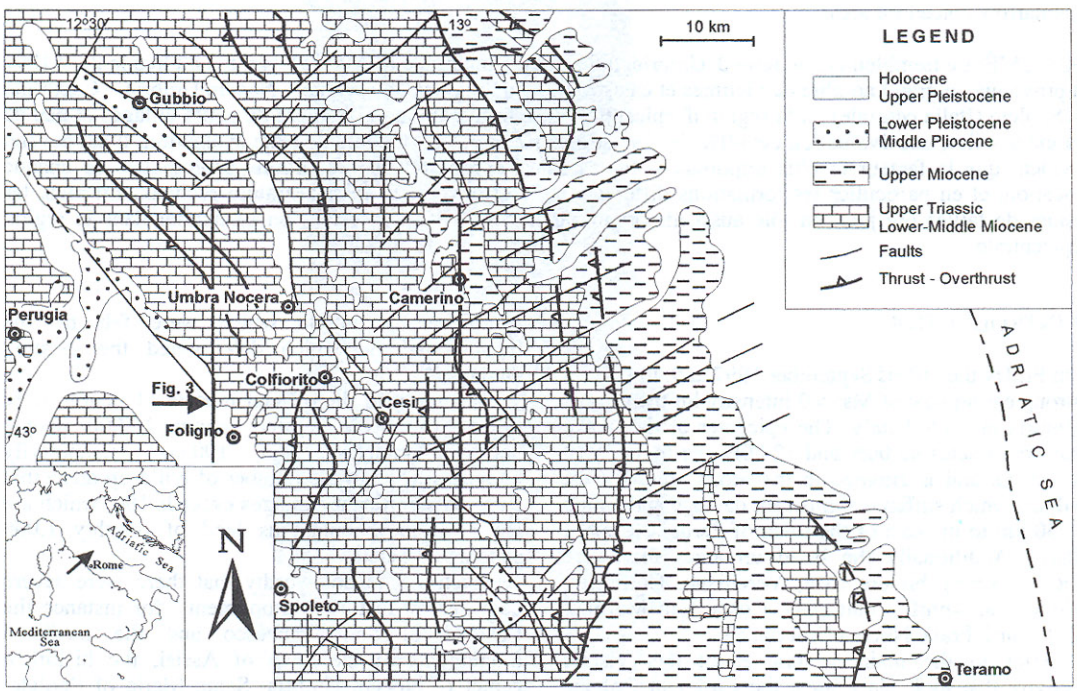

Figure 1. Geological sketch map of the broad region which was struck by the 26th of September 1997 earthquake.

also occur in the Foligno and Teramo plains, etc. (Fig. 2).

In the broad epicentral area the formations are cut by a number of faults of a general orientation NW-SE parallel to the main arrangement of the formations, most of which are normal.

Additionally, a second system of faults occurs with a transversal orientation, NE-SW and a significant horizontal component of displacement. According to the available data and especially the focal mechanism and the field observations, the first system of normal faults with a general strike NW-SE has a close relation with the particular seismic activity. The earthquake is caused by tectonic stretching of general direction NE-SW, in accordance with the geometrical and dynamic characteristics of the fault plane, of NW-SE direction and the interpretation of the mechanism of earthquake plain solution (Cello et al. 1997).

Figure 2. View of recent, Holocene age formations made of continental deposits which form the low relief and carbonatic formations of the Umbria-Marche Unit which form a relatively high relief.

The built-up units, which were struck by the earthquake of the 26th of September 1997, were founded on a variety of geological formations. Overall they can be distinguished in the following groups:

- Those based on recent formations, made of continental deposits, of Upper Pleistocene-Holocene age, such as Collecurti, Verchiano, Voltelina , San Martino, Cassete, Colfiorito, etc. Additionally, the basement rocks were superficially but intensively weathered in most places, had restricted thickness and overlaid the rocky formations of Triassic-Miocene age.
- Those founded on rocky, usually carbonatic, formations of Triassic-Miocene age, like Serravalle di Chienti, Serfo, Corneto, Piaggia, Sellano, Rasenna, etc.
- Finally, those built on a variety of geological formations and especially on loose recent formations (Upper Pleistocene-Holocene) and rocky formations (Triassic-Miocene), like for instance Cesi, Costa, Anifo, Forcella, etc. In the above cases, the contact between those two formations intersects the residential areas, while rarely the contact coincided with the fault zone in which there were indications for fault reactivation (i.e. Costa).

3 DATA RECORDINGS-ESTIMATION OF INTESITIES

Recordings of damages on the constructions after the shock of September 26th, 1997 was conducted according to the European Macroseismic Scale 1992 (E.M.S-1992). The E.M.S.-1992 solves some important problems that the use of the M.S.K and its variations created (Grunthal ed. 1993).

The main advantages of the use of E.M.S.-1992, especially when dealing with damages in urban complexes, are the following:

- Easier recognition of the type of structure. New types of buildings, not existing in the previous scales, are included.
- Easier and objective recognition of the vulnerability class of the structure. New types of buildings after antiseismic design are included.
- Precise evaluation of the grade of damage.

Estimation of the intensity per urban unit is made through a clear quantification while effects on objects and on nature are taken into account.

Based on the comprehensive presentation and the guidelines included in the final form of the E.M.S.-1992, we conducted a complete recording of the types of buildings , their vulnerability class and the grade of damage on construction, just after the earthquake (Lekkas 1996, Lekkas et al. 1996). We also collected data on the effects of the shock on humans, objects and nature. For the facilitation of the procedure, the recording was conducted per village and the data were plotted on detailed maps (Fig. 3).

Especially, according to the recordings, the maximum epicentral intensity was IX+ of the EMS-1992 scale and was evidenced in the villages of Cesi, Annifo, Collecurti. In those particular areas many buildings of vulnerability class C suffer damage of

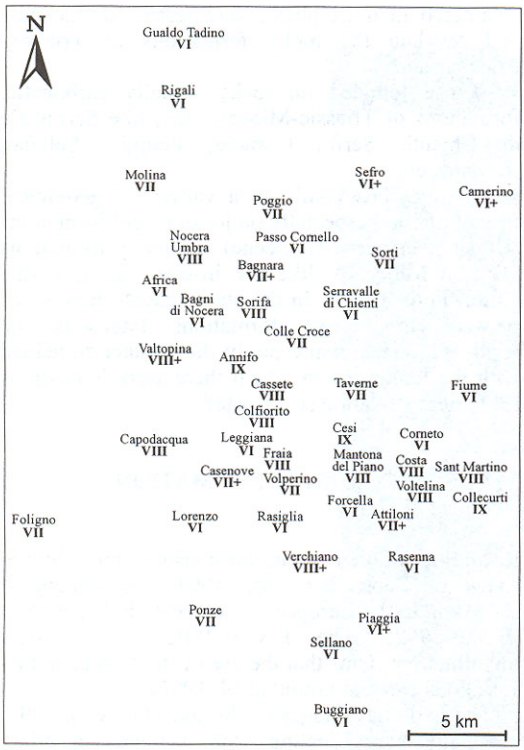

Figure 3. Evaluation of intensities according to the EMS-1992 scale.

grade 3. Many buildings of class B and a few of class C suffer damage of grade 4. Many buildings of class A and a few of class B suffer damage of grade 5.

Moreover, intensities VIII grade of the E.M.S-1992 scale were manifested in many residential units, such as Colfiorito, Verchiano, Sorifa, Nocera Umbria, Cassete, Aquapagana, Costa, San Martino, Capodacqua, Voltellina, Voltopina, Fraia, etc. In these particular areas many buildings of vulnerability class B and a few C suffer damage of grade 2. Many buildings of class A and a few of a class B suffer damage grade 3, few buildings of class A suffer damage of grade 4 (Fig. 4).

Damage of VII intensity of the EMS-1992 scale was recorded in many residential units, like Gualdo Tadino, Rigali, Sefro, Serravalle di Chianti, Africa, Leggiana, Fiume, Buggiano, Lorenzo, Cammerino, etc. In these areas damages of grade 2 (Fig. 5).

Notably, residential units with intensities of grade VI of the EMS-1992 scale but also smaller intensities were recorded from a broad region around the epicentral area.

Figure 4. View of class B building and grade of damage 5, to the north of Nocera Umbria.

Figure 5. View of class B building and grade of damage 4, in the area of Casenova.

As far as the geographical distribution of damages is concerned, it is found out that around the narrow epicentral area, which is situated between the

villages of Cesi and Annifo, there were recorded intensities of IX grade of the EMS-1992, only in some places.

The prevalent intensities within this narrow geographical space was of VIII grade, while rarely emerge intensities of grade VI of the EMS-1992. In the broad region of Nocera Umbria, Lorenzo, Pasenna, Serravalle di Chianti it is found out a mixing of intensities of grade VIII to VI of the EMS-1992 (Fig. 6, 7). Similar mixing is also noticed in the broader area, mainly with intensities of grade VI, VII, and occasionally VIII, like for instance in the case of Valtopina.

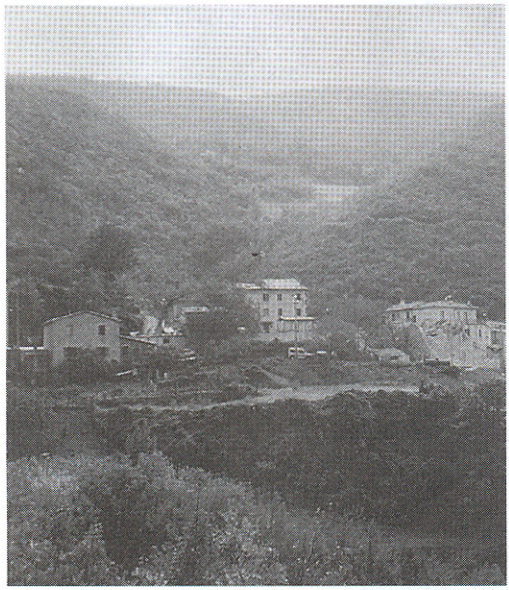

Figure 6. View of a built-up unit in the broad region of Nocera Umbria-Baghara, which suffered significant damages and was based on talus scree.

4 DATA CORRELATION-CONCLUSIONS

From the concise description of the geotectonic conditions-founding conditions of the built up areas, on the one hand, and the recording and evaluation of the intensities on the other hand, it is possible to draw some conclusions related to the magnitude and the distribution of damages from the earthquake of Umbria (Central Italy) on the 26th of September 1997.

Critical role in the occurrence of the high intensities in the built up areas of the epicentral region played not only the short distance from the focus of the earthquake but also the founding ground. Especially the built up areas such as Collecurti, in which the intensity reached IX grade of the EMS-1992 was founded on recent formations of Upper Pleistocene-Holocene age which consists of siliceous red beds, red clays, talus scree etc. These formations overlay the rocky basement, have restricted thickness, around 40 m and in places are superficially but intensively weathered.

Additionally, intensities of VIII grade of the EMS-1992 scale were observed in the whole region, like the town Colfiorito, Verchiano, Voltelina, Cassete, Valtopina, etc. These residential units were based on the whole or mostly on the above formations. On the contrary, built-up units based on rocky formations mainly carbonatic showed significantly lower intensities, even if they were close to the epicenter. Such units were Rasiglia, Leggiano, Passo, Sefro, Rasenna, etc.

It is noteworthy that often built-up areas which are in short distance, which are founded on different geological formations showed alternately low and high intensities, independently from the distance and the direction from the epicenter and the morphology.

This is more evident along the road Nocera Umbria, Annifo, Colfiorito, Cesi, Rasenna, where successively appear built-up units with small and big damage according to the founding formation.

Finally, special mention has to be done on the particular built-up areas, such as Costa and Cesi, in which the differentiation of intensities in relation to

Figure 7. View of a built-up unit in the broad region of Colfiorito with small damages < VI, which was founded on rocky formations of the Umbria-Marche Unit.

the founding rock is shown more clearly from one square to the next. Especially, in the first case which is adjacent to a fault zone, which separates different geological units and bears additional traces of reactivation, the picture is exceptionally representative.

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