Nat. Hazards Earth Syst. Sci. Discuss.,
doi:10.5194/nhess-2016-313-AC4, 2017

Natural Hazards and Earth System Sciences
Open Access
Discussions

Interactive comment on "Shallow subsurface geology and seismic microzonation in a deep continental basin. The Avezzano Town, Fucino basin (central Italy)" *by* Paolo Boncio et al.

Paolo Boncio et al.

pboncio@unich.it

Received and published: 1 February 2017

Author reply to referee #4 comments on "Shallow subsurface geology and seismic microzonation in a deep continental basin. The Avezzano town, Fucino basin (central Italy)" by Paolo Boncio et al.

REFEREE:

GENERAL COMMENTS:

This paper concerns the results of a basic microzonation study which was carried out in central Italy, in the area of Avezzano. This town was completely destroyed by the 1915 earthquake. According to the Authors, the local geological conditions, due to the

location of the town along the marginal areas of an intramontane continental basin, have remarkably contributed to the amplification of the damages.

The study of the geological, morphological and structural control-factors on the local seismic site response can thus potentially represent a significant contribution of broad interest, considering that several old villages and towns of central and southern Italy are located in comparable geological and morphological settings. In its present form the manuscript, representing a very good and detailed technical report of the microzonation studies, has a local relevance and leaves almost unresolved some fundamental issues. Nevertheless, if framed in a more detailed and exhaustive geological model, the robust dataset that includes geological and geophysical data could be a valid base of knowledge to turn the paper in a scientific paper of broad interest. The Authors correctly emphasize the crucial importance of a solid geological model in interpreting the seismic site characterization. Paradoxically, the interpretation of the geological data seems to be too poorly detailed, if compared with the large amount of available information. The individuation of the causes of the local site effects of the 1915 event and the evaluation of future seismic responses on the new town should require a more detailed geological model, beyond the objectives of the basic microzonation analysis, taking into account all the possible aspects (geometry of the thrust system, location and arrangement of the Quaternary normal faults, location of the active and capable faults, lithological lateral variations within the cover units) that may contribute to the amplification of the ground motion. The peculiar complexity of the geological setting of the site imposes the application of 2D or 3D simulation model of the seismic response that requires analyses more advanced than those planned for the basic (first level) seismic microzonation. A possible target of the paper should be to propose a geological model responding to the requirements for a more advanced (third level) seismic microzonation study. The presented data are largely sufficient to achieve this target. In the next specific comments I suggest to the Authors some issues to be solved in the revision of the paper.

RESPONSE: We would like to thank the reviewer for the useful comments. We are going to comply all the general comments. We hope to clear all the requests through our responses below and by revising the text in the manuscript.

The queries about the specific comments have been answered below.

SPECIFIC COMMENTS:

REFEREE:

âĂć In the geological setting and in the following sections are almost obscure on both the significance and the role of the SSE-dipping Tre Monti Fault System, during the evolution of the intramontane basin. The Fucino Basin is, in fact, described as an half-graben connected to the motion, since the Late Pleistocene, along the SW-dipping Fucino master fault system. It is unclear the origin of the Lower Pleistocene depocenter (pull-apart? thrust-top?) bordered by the Tre Monti system. This issue is relevant in term of geometry of the faults along the northern border of the basin that should represent the most impressive tectonic feature buried in the subsurface of Avezzano.

âĂć The Author should also explain the present-day kinematics of the active segments of the northern border, associated to the normal faulting along the Fucino master normal fault.

RESPONSE: We accept the comments and we decided to improve the "Geological setting" section. Also following the comments of Referee #1, we are going to better describe the structural geology of the Fucino basin. We will also clarify some aspects regarding the geometry and kinematics of the Tre-Monti fault system. However, it is worth to note that we mainly refer to available literature, as the present paper deals more specifically with the surface and shallow subsurface geology of the area, not the deep geometry of the fault systems.

REFEREE:

âĂć I would also point out the discrepancies in Fig. 1 where the active faults reported

in the map are absent in the geological profile. I suggest to draw an original transect, illustrating the geometry of the active faults and their relation with the previous features of the thrust system. Would be also useful provide a regional scale cross section across the northern border of the basin to help the full understanding of the tectonic setting of the Avezzano area by readers not familiar with the area.

RESPONSE: We agree with this comment. We will draw an original geological transect that takes into account the geometry of the active faults reported in Figure 1b. It is based on our original data for that regarding the western sector, and on the data published by Cavinato et al. (2002) for the central and eastern sectors.

The relation of the normal fault systems with the thrust system would be an intriguing aspect but it implies the analysis and interpretation of deep geophysical data. In our opinion, this aspect is beyond the focus of this paper.

REFEREE:

âĂć The adopted methodology is inspired to the application of the National Civil Protection guidelines for the first level microzonation studies that are necessary, but clearly insufficient to represent the complexity of the examined geological context. The Authors are thus invited to point out how their approach has significantly improved the guidelines, with specific regards to the implementation of the geological field analyses to employ as tool for deciphering analogous geological setting.

RESPONSE: We accept the comments and we are going to modify the "Introduction", "Methodology" and "Discussion and Conclusion" sections in order to better explain the geological field analysis phase. In particular, we will focus on the structure of the Geological-Technical Map. The structure of the Geological-Technical Map (G-T Map) proposed in this paper represents a new methodological approach compared to that required by the Italian SM guidelines. In fact, the Italian SM guidelines, published in 2008 (see SM Working Group, 2015 * for the English edition), do not provide technical specifications for the G-T Map. Some implementations have been published more recently (e.g., Martini et al., 2011**; “Standard di rappresentazione e archiviazione informatica. Microzonazione sismica. Versione 4.0b, 2015” available online at http://www.protezionecivile.gov.it/resources/cms/documents/StandardMS_4_0b.pdf). These implementations provide some guidelines for the G-T Map that favour the mapping of textural features for cover soils (gravel, sand, silt, etc.) and geo-mechanical features for the geological bedrock (lapideous vs pelitic vs interlayering, stratification, fracturing, etc.). A number of basic geologic data, necessary for the 3D reconstruction of geological bodies, are lost (chronostratigraphic relations, sedimentary environments, etc.). In any case, specific instructions for building the G-T Map are not provided. The aim of this work is not to modify the Italian guidelines, but we propose an original methodological procedure for building a G-T Map for SM which might be of interest for scientists and professionals working in the field of SM, in Italy or elsewhere. This procedure was adopted for basic (Level 1) SM of the Abruzzo Region. The proposed methodology and the resulting G-T Map preserve basic geological data, and implement them with additional lithological-technical features useful for SM.

REFEREE:

âĂć The new structure of the Geological-Technical Map proposed in the paper represent a very good proposal aiming at preserve and better exploit the original geological data on which the entire microzonation process is based. Coherently with this appreciable purpose, I invite the Authors to consider the structural features as part of the base geological map, as they actually are, rather than part of the geomorphological and hydrological map. This would help for a better reconstruction of the 3D subsurface geometry that also include the sharp vertical offsets of the bedrock-covers contact across the main fault planes.

RESPONSE:âĂÍ This is a good suggestion. Actually, the structural features are part of a base geological map but, in this context, we prefer to preserve the current layout of the Geological-Technical Map. In fact, layers 1 and 2 are made exclusively of polygon features. Even though not specifically stated in the manuscript, this choice has direct

implications of GIS-aided data process.âĂÍ

REFEREE:

âĂć The three types of margin adopted as model do not consider any role, control or indirect interference between the site response and the primary geometry of the Neogene thrust belt of Apennines.

RESPONSE: The seismic site response is mainly controlled by the presence of high impedance contrast interfaces. In the Fucino basin, it is represented by the contact between the continental basin infill and the bedrock, here represented by carbonate and/or flysch units. For this reason, even if the reconstruction of the primary geometry of the Neogene thrust would be an intriguing aspect, the site response is not significantly influenced by it. This point will be better described during the revision.

REFEREE:

Some evidences along the transect G-G', almost parallel to the transect from Cavinato et al., 2002 of Fig. 1, would suggest the possibility of a different interpretation of the geometry of the margin, consisting of the NE dipping carbonate monocline of Mt. Salvino. The authors extend the monocline beneath the flysch sequences, flooring the Upper Pliocene-Lower Pleistocene alluvial and lacustrine deposits of the basin. They attribute to the flysch strata the same attitude of the carbonates. This implies a sharp strata truncation of the flysch levels along the unconformity at the base of the lacustrine deposits and an exaggerated thickness of the flysch monocline concealed beneath the basin. I invite the Authors to discuss and eventually refuse the geometry of the margin proposed in Cavinato et al. (2002) that interpreted the carbonate monocline as the forelimb of a ramp anticline overthrusting the flysch sequence lying almost parallel to the base of the alluvial and lacustrine deposits.

RESPONSE: Actually, our reconstruction and that proposed by Cavinato et al. (2002) are not so different. Section G-G' is only a small portion of the section proposed by

Cavinato et al. (westernmost portion of the section). In any case, in the revised version we will discuss the similarities/differences with existing literature.

REFEREE:

âĂć The geometry of the normal faults buried along the northern border of the basin is too poorly defined if compared with that of the segments exposed at the eastern edge of the same margin. The Authors are invited to better reconstruct the continuity of the buried structures tectonically controlling the margin.

âĂć The Authors should try to solve the uncertainties about the lithofacies of Lac 1 and Lac 2 along the marginal areas beneath the town of Avezzano.

RESPONSE: We accept the comments. We will add a further geological section (H-H', see Figure 7 for the location) in which we provide more details on the geometry of the normal faults and on the contact between Lac1 and Lac2.

REFEREE:

âĂć They are also invited to synthesize the different columns related to the 1D subsurface models referred to the single microzones in a 2D model emphasizing the lateral discontinuities and their possible role in determining the seismic site response.

RESPONSE: It is a good suggestion. We would like to produce a new figure in which we provide a 2-D synthesis of the 3 types of margin, using the MOPS simplified stratigraphic logs.

REFEREE:

âĂć Finally, the conclusions are too generic. I expect that Authors make some further efforts to define the different causes that were directly responsible for the amplification of the damages in the Avezzano area and consequently delineate the good practices to employ in the geological analyses for the seismic microzonation of similar complex settings.

RESPONSE: Following also the suggestions by Referee #1, in the revised version of the manuscript we will modify the "Introduction", "Methodology" and "Discussion and Conclusion" sections in order to highlight the main results, in terms of both methodology (Geological-Technical Map) and implications for geological factors controlling site response in the Avezzano town.

REFEREE:

I hope the Authors can find the above listed comments constructive and useful for the improvement of their paper.

RESPONSE: We thank the Referee, who made really constructive comments.

CITED REFERENCES * SM Working Group (2015) – Guidelines for Seismic Microzonation. Civil Protection Department and Conference of Regions and Autonomous Provinces of Italy. 1 Vol. English edition of: Gruppo di lavoro MS, Indirizzi e criteri per la microzonazione sismica, Conferenza delle Regioni e delle Province autonome – Dipartimento della protezione civile, Roma, 2008, 3 vol. e Dvd. Available online at http://www.protezionecivile.gov.it/httpdocs/cms/attach_extra/GuidelinesForSeismicMicrozona
** Martini et al. (2011) in Ingegneria Sismica XXVIII,2, 2011, available online at http://www.protezionecivile.gov.it/resources/cms/documents/aggiornamento_indirizzi_microz

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2016-313, 2016.