ADVANTAGES OF INTEGRATING PHOTO-GEOLGY AND FIELD-BASED GEOLOGICAL MAPPING. AN EXAMPLE FROM POST-SEISMIC ACTIVITIES IN AMATRICE (CENTRAL ITALY)

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Introduction. On 24 August 2016, central Italy was struck by a M_w 6.0 earthquake, which damaged many villages in the Lazio, Marche, Abruzzo, and Umbria regions. Immediately following the early rescue activities, it was necessary to develop a seismic microzonation within the area showing the higher level of damage. In this paper, we show an integrated approach, at wide area scale, of photogeological mapping and field-based geological survey, which was developed and adopted for the 140 km² wide Amatrice depression, a relatively homogeneous physiographic area situated along the Central Apennines ridge (between the Gorzano Mt ridge to the east, and the Sibillini Mts thrust front, to the west). The aim of this approach is to detect and detail those morphological, stratigraphic and structural features (terraces edges, alluvial fans, flat surfaces, escarpments, landslides, fault lines, bedding) critical for defining subsoil models for seismic microzonation.

Method. Photo-geological information was obtained by the visual interpretation of one set of black and white stereoscopic aerial photographs flown in 1954, at 1:33,000 scale. Aerial photographs were interpreted by two researchers, using a Galileo SFG 3/B discussion stereoscope, with 1.25× and 4× zoom capability. Interpretation was then validated using an improved Galileo Siscam Falcon ZII discussion stereoscope, with a 1.5× to 13.5× continuous zoom, which allows for more detailed analyses.

The main benefits of using 1954 black and white aerial photographs consists in the less extent and density of the forest coverage, and in a less developed urbanization and human modification of the landscape compared to the present day. These characteristics facilitate the identification and recognition of features related to bedding, fault lines and landslides.

The photo-geological information was originally drawn on a transparent plastic sheet placed over the aerial photographs, and then transferred on a 1:10,000 scale topographic base map using a semi-automatic rigorous orthorectification procedure (GRASS development team, 2016) designed to reduce mapping errors and make the overall mapping procedure more efficient (Santangelo et al., 2015a); a photo-geological map was thus produced (Fig. 1). Since the activity of microzonation is a work still in progress, the map presented in this paper is in a draft version.

Interpretation of the aerial photographs was also aided by field-based geological surveys and the review of bibliographical data including geological maps (Koopman, 1983; Cacciuni et al., 1991; Festa, 2005). Field data were collected at 1:5,000 scale and were used to validate and integrate the photo-geological map.

Aerial photographs interpretation. The photo-geological map of the study area (Fig. 1) incorporates five thematic layers including:

i) bedding information of the bedrock and continental deposits;

ii) structural features (e.g. fault traces and associated triangular facets);

iii) lithological features (e.g., substratum and Quaternary continental deposits);

The overall time needed for completing the interpretation of four stereograms at 1:33,000 scale (140 km²) and the orthorectification of the aerial photographs was of 12 working days of two researchers, which means a ratio of 1.5 km² per hour by two researchers.

Bedding information. A Bedding trace (BT) is the linear intersection between a rock layer and the topographic surface (Santangelo et al., 2015b). Visual evidence of a BT on remote imagery depends on multiple factors, including: (i) the type, mechanical and hydrological characteristics...
of the rocks, ii) the contrast in resistance to erosion of the different rock layers (morphoselection), iii) the attitude of the bedding planes, iv) the topography and v) the presence of vegetation that may emphasize (or hide) individual beddings (Marchesini et al., 2013).

The bedding traces were used to derive information on the attitude of the bedding plane, by the intersection of the bedding traces with the local topography, visible in the stereoscopic images. The attitude of the bedding planes were grouped in 5 classes (sub-horizontal, gentle dipping, moderate, elevate, upside down). In the photo-geological map (Fig. 1), the BTs are represented by green lines, which path shows the lateral continuity of the morphological evidences of the rock layers having different competence. These evidences are widely represented in the map, particularly along the slopes where heterogeneous multi-layered sequences crop out. On the other hand, where massive and homogeneous arenaceous units crop out, or where the slopes are covered by dense tree canopies, the photointerpretation is more complex, which results in a lower density of BTs.

Fig. 1 – Draft version of the photo-geological map of the Amatrice depression. (A) Amatrice, (B) Ritrosi, (C) Torrita-Scai.
Structural features. Since the signature of structural features on a landscape is essentially morphological, they can be detected exploiting the 3D capability of stereoscopic aerial photographs. Elements such as (i) alignments of escarpments and counter-escarpments systems, (ii) sudden variations in the bedding attitude, (iii) alignment of slope changes along ridges or along slopes are commonly used in the aerial photo-interpretation. In the study area, normal faults generally follow a linear trend, are associated with triangular facets, and can delimitate intramontane basins, whereas thrust systems are more curvilinear, are associated with fold systems and in places with upside-down bedding.

Lithological features. The map in Fig. 1 shows two main lithological groups, one referring to the terrigenous and pelagic sediments (i.e. the local geological substratum, composed of sandstone and siltstone of the Laga Formation and minor limestone and marls), and one referring to the Quaternary continental deposits. In the map, the substratum is not colored, and shows a diffuse presence of bedding traces. On the contrary, the continental deposits are classified in the map as follows: recent alluvial deposits (cyan), alluvial fans (light blue), terraced alluvial deposits (green), and landslides (yellow). Recent alluvial deposits appear as flat areas situated in the present-day river plains. Terraced alluvial deposits appear as nearly flat areas (in places slightly concave or showing a slope of less than 2-3°) suspended at different elevations compared to the present-day river plains. In the area, villages such as Amatrice and Retroi were built up on most of the top of the highest terraced deposits. In this paper, we use the term “landslide” to encompass only slides and slide-flows, and not flows, falls and topples. In the map, deep-seated landslides are represented with the crown area separate from the deposit area, as opposed to shallow landslides.

Integration of field geology and photo-geology interpretation. In order to integrate and validate the photo-geological interpretation, field recognitions were addressed to selected areas characterized by interferences of geomorphological-structural features revealed by the photo-geological interpretation. For these areas, we focused on relationships between geometry and extent of cover deposits, bedding of the substratum, and areal arrangement and distribution of the main fault systems. Some examples are presented below.

In Amatrice bedding planes of the substratum, moderate to elevate dipping toward SW and NE, are cut by N-S trending high angle normal faults. The latter have a clear morphological expression featured by fault plane scarps and triangular facets, which are critical elements for evaluating morpho-structurally induced amplification effects. Comparison of these elements with the information provided by the photo-geological map, revealed a disagreement between the two data sets. In particular, a set of evident linear elements showing N-S trending were interpreted as bedding traces, whereas the field recognition verified that such elements belong to a family of N-S trending high angle normal faults.

In the Retroi village, south east of Amatrice, the integrated approach allows, at local scale, to distinguish the inner edge and conglomerates of a fluvial terrace (the Retroi Unit), onlapping the substratum, from the outer edge and conglomerates of a SW-prograding alluvial fan (the Sommati-Amatrice Unit), downlapping the substratum. The reconstructed morpho-stratigraphic setting would be likely used for defining different seismically homogeneous microzones (SM working group, 2015). Large scale geological field recognition activities confirmed all the main morpho-structural elements shown in the photo-geological map.

In the small Torrita-Scai basin, west of Amatrice, Pleistocene alluvial-lacustrine sand and silt cover with disconformity the substratum with average thickness of 30 m, and form a relatively flat area bounded by hilly relieves. Local morphological irregularities detected by photo- and field geology may suggest thickening, corresponding to small alluvial fans, or thinning, at the base of terraces escarpments, of the covering sediments. The irregular geometry of the Pleistocene cover can be reflected into areas with different expected amplification effects (basin effects): the higher the amplification, the thinner the cover. For the Retroi village, a large scale geological field recognition have confirmed the photo-geological interpretation. Moreover, a
field check was carried out by one of the two researchers who performed the interpretation on a 8 km² area close to the Torrita and Scai villages. Field evidences were found in good agreement with BTs and structural elements identified through the photo-geological analysis.

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**References**


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