The contribution of integrated geologic survey and geophysical investigations for seismic microzonation of Arischia (AQ)

Domenico Berti,* Claudio Cesi,** Rinalda Di Stefano,* Valeria Eulilli,* Luca Maria Puzzilli,* Mauro Roma*

Summary

After the April 6th, 2009 L'Aquila earthquake (Mw 6.3) and the following emergency activity, the National Department of Civil Protection (DPC) planned an extensive seismic microzonation study, involving ISPRA in coordinating and executing geological, geophysical and geotechnical surveys into ten municipalities surrounding the earthquake epicenter, interested by severe damages, to provide local administrations with an effective tool for reconstruction plans and management of provisional structure location. The study, coordinated by the National Department of Civil Protection and by the Abruzzo Region, was extended to the towns affected by macroseismic intensity equal or greater than VII MCS, grouped into 12 "Macro-areas" [WORKING GROUP SM L'AQUILA, 2010]. About 150 researchers and technicians of ten Italian universities where involved, together with eight research institutes (including ISPRA), the Order of Abruzzo Geologists, four regional offices (Abruzzo, Emilia-Romagna, Lazio and Tuscany) and the Autonomous Province of Trento. In this framework ISPRA was responsible for coordinating the technical and scientific activities and for the execution of geological, geophysical and geotechnical surveys in the 10 municipalities of the Macro-areas 6 and 7, including Arischia (Macroarea 7). As other towns, Arischia suffered significant damages not only in its historical centre but also along an area of recent expansion, corresponding to Via Macindole, where the degree of damage showed an apparently erratic distribution, suggesting that the effort in re-defining geological (depth of bedrock, geometry of the sedimentary bodies, etc.) and geotechnical features of this area was highly recommended. The paper describes how the application of prospecting and surveying techniques (geological surveys, resistivity sections, drilling, down-hole) allowed a decisive improvement in the geological knowledge of the area, contributing to define the subsoil model for the purposes of seismic microzonation. The adopted procedures for field activities, as geological surveys and geoelectrical investigations, are described in detail; the interpretation of geophysical and geotechnical data and their correlation with the geological units are explained; finally the microzonation map in seismic perspective is presented.

Location of the town of Arischia and damage caused by L'Aquila earthquake

Arischia is the northernmost town to be severely damaged during the earthquake of April 6th, 2009: it is included in the province of L'Aquila and located approx. 14 km north of the latter, along the junction between the Aterno River plain and the Gran Sasso Mounts Group. The central part of the town located at 800-900 m a.s.l. is elongated northwest – south eastward (San Vincenzo Hill and the Old Town). Two recent expansion zones are "Boccanello" to NW and "Macindole" to SE, closer to the SS 80 - L'Aquila Teramo. After the seismic sequence most of the buildings in the old town suffered severe structural damages (Fig. 1), or even collapsed, because of the macroseismic intensity of 7-8 degrees on MCS scale [GALLI *et al.*, 2009]. In this part of Arischia five people lost their lives.

* ISPRA- Dipartimento Difesa del Suolo- Servizio Geologico d'Italia

** Presidenza del Consiglio dei Ministri

The San Vincenzo Hill sector (which was built on stable rock, as seen later) and the "Boccanello" area suffered a minor damage, mainly for some groups or for individual buildings, whereas in the "Macindole" area many buildings edified even close together (with the same constructive technique) suffered a quite different degree of damage, as depicted in figure 2.

This singularity suggested a mandatory effort in re-defining the subsoil model for this area, throughout the following field activities:

- recognize and map all outcropping pre-quaternary formations in order to define the presence and location, in depth, of the seismic bedrock under the more recent covers;
- recognize and differentiate all outcropping quaternary formations distinguishing their facies in order to genetically classify them (i.e. landslide body, alluvial fans, detrital cover etc.);
- recognize and map eventual anthropogenic deposits, define their thickness and lateral extension;
- characterize all lithological units in terms of mechanical behaviour under seismic conditions.

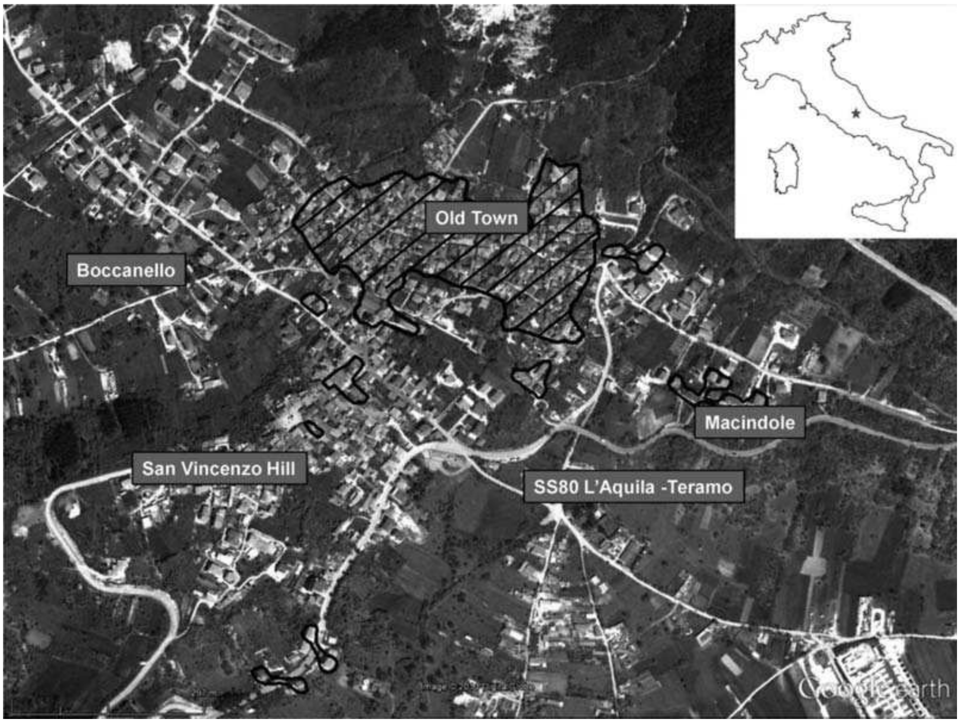

Fig. 1 – Village of Arischia (AQ): the black lines bound areas with severely damaged buildings, the hatched area indicates the part of the old town with restricted access after mainshock (base map from Google Earth).
Fig. 1 – Paese di Arischia (AQ): le linee nere delimitano aree con edifici gravemente danneggiati, l'area in tratteggio indica la parte del centro storico ad accesso interdetto dopo la scossa principale (mappa da Google Earth).

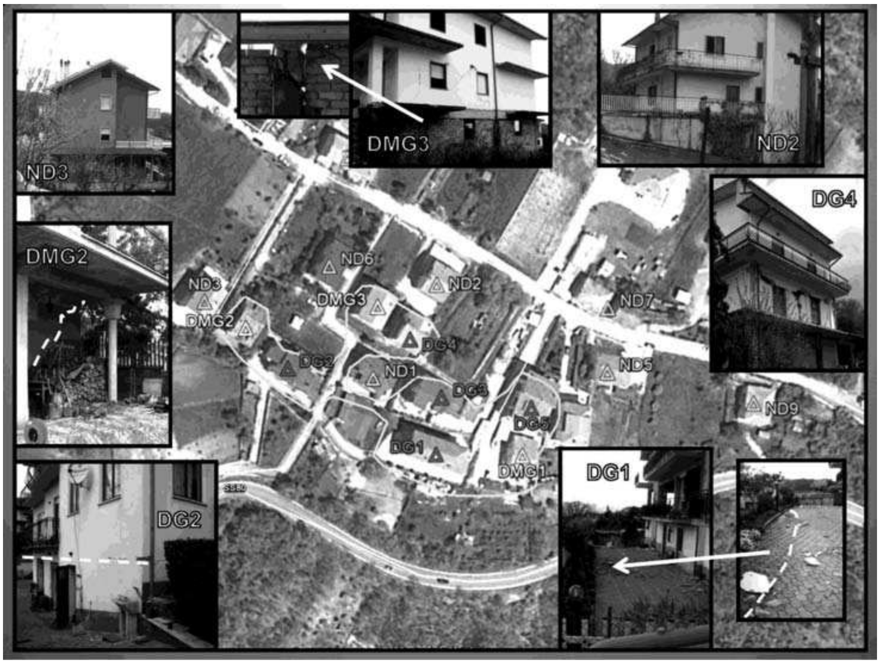

Fig. 2 – Distribution of structural damages in the area of Macindole (light gray). Legend: DG – buildings with severe damages; DMG – buildings with middle-severe damages; ND-buildings without damages (or with slight damage to single architectural elements).
Fig. 2 – Distribuzione dei danni strutturali nell'area di Macindole (in grigio). Legenda : DG – edifici con danni gravissimi; DMG – edifici con danni medio-gravi; ND-edifici senza danni (o con lievi danni a singoli elementi architettonici).

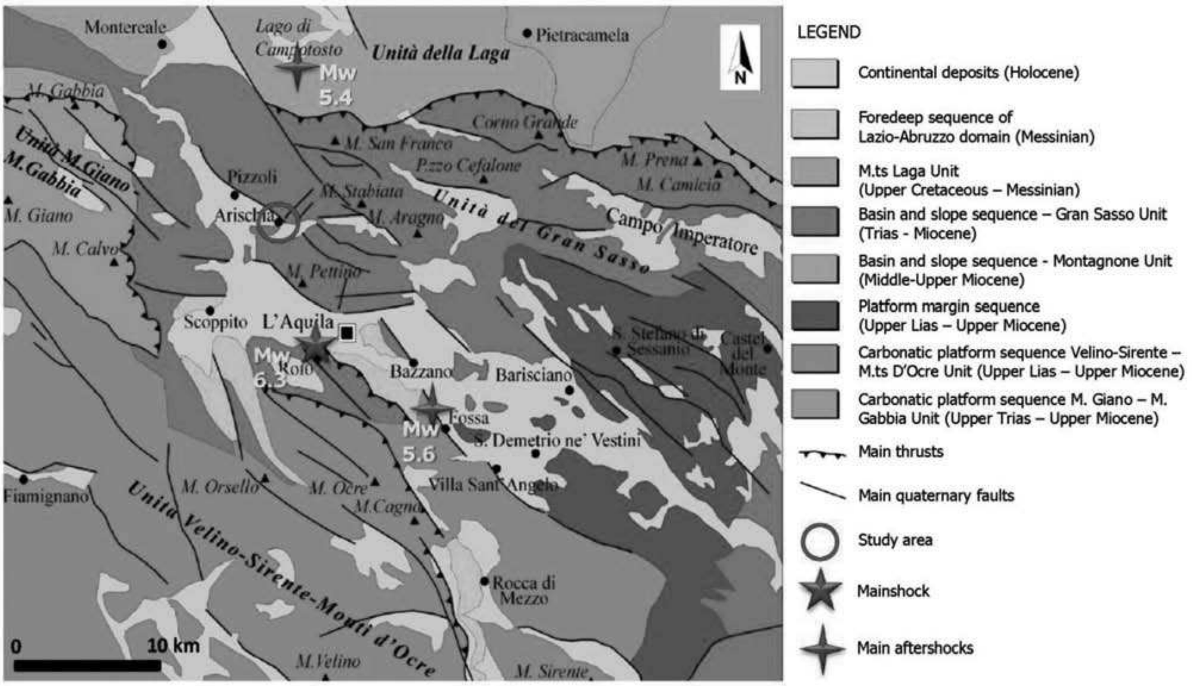

Fig. 3 – Structural - geologic sketch map of the area between M.ts Laga chain and Avezzano town (modified from BLUMETTI *et al.*, 2002).
Fig. 3 – Carta geologico-strutturale schematica dell'area compresa tra i Monti della Laga ed Avezzano (modificata da BLUMETTI et al.*, 2002).*

Geological features

From a tectonic-sedimentary point of view, Arischia is located in a sector characterized by different geological paleo-environments: the Lazio-Abruzzo platform southwards and its transition to the Umbro-Marche basin (north and northwest), the slope of the Gran Sasso to east and the foreland basin of Laga M.ts further northwards [SALVUCCI, 1995; PIANA, 1995; BLUMETTI *et al.*, 2002] (Fig. 3). The events that structured the orogen during the compressive tectonic phase took place from the upper Miocene to middle Pliocene. The Apennine chain was later affected by a distensive tectonics that displaced all the structures previously put in place, giving rise to the quaternary faults system which led to the formation and evolution of some inter-mountain basins (Fig. 3).

This faults system shows recent activity along some segments like those of Paganica, L'Aquila (Mt. Pettino fault) and Pizzoli-Arischia ([BLUMETTI, 1995; BLUMETTI *et al.*, 2002; MORETTI *et al.,* 2012]. Arischia is located in the southwest portion of the 1:50.000 italian geological sheet 349 "Gran Sasso" (Fig.4): the village is built along the SW foothill slope of "Mt. Omo–Mt. La Pacima" at the hangingwall of the Arischia-Pizzoli fault [BLUMETTI, 1995; BLUMETTI *et al.*, 2002]. This main tectonic element puts in contact, in the western and northern part of the village, the dolomitic and cataclastic limestones of "Calcare Massiccio" (footwall) with the "Marne con Cerrogna" formation (hangingwall) whereas in the easternmost part of the area, along the same tectonic line, the "Marne a Fucoidi" outcrops at footwall and the "Marne con Cerrogna" was supposed at hangingwall (Fig. 4).

From the preliminary analysis of damages distribution into the entire village, it was clear that the previous geological information from existent cartography was not sufficiently detailed to explain the extent of the damage and especially its distribution. Focusing to the Macindole area, the urbanized sector lies on a wide cover of holocenic continental deposits that rectified the ancient slope of pleistocenic units toward a uniform angle of about 10° (Fig. 4). The pre-quaternary formations outcropping along the foothill would suggest the presence, in depth, of a relatively simple geological setting: a indistinct holocenic detrital cover, with variable thickness, laying on the "Marne con Cerrogna".

Methodology

The Seismic Microzonation (hereafter cited as SM) is a cognitive tool aiming at the mitigation of seismic risk of an area. It should be conducted on

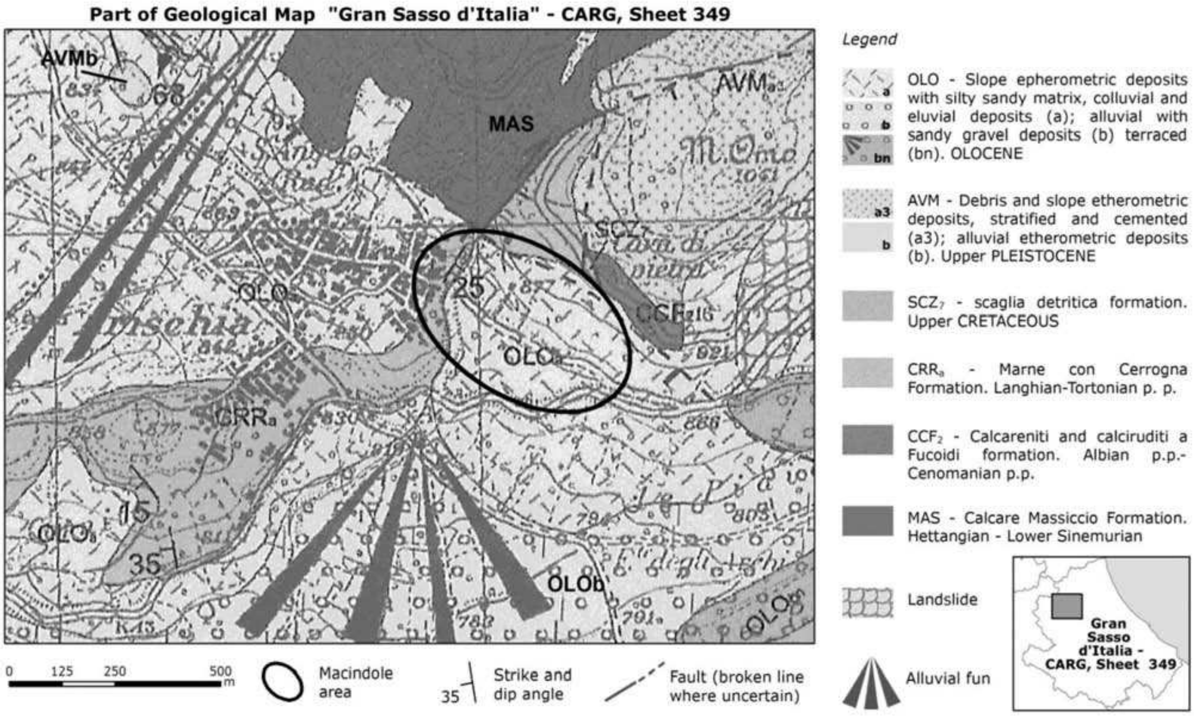

Fig. 4 – Geologic map at 1:50.000 scale of the Arischia town and (in black) the via Macindole area (modified from n.349 "Gran Sasso" geological sheet at scale 1:50.000).

Fig. 4 – Carta geologica 1:50.000 relativa all'abitato di Arischia e ubicazione (in nero) dell'area di Via Macindole (modificato dal Foglio Geologico n.349 "Gran Sasso" in scala 1:50.000).

the basis of the "Guidelines for seismic microzonation" [PRESIDENZA DEL CONSIGLIO DEI MINISTRI - DPC, 2008] that define three levels of detail and the corresponding improvements of knowledge that should be carried out to achieve each ones, depending also on the local hazard and on the available resources:

– Level 1 is an introductory level, consisting of a collection of existing data processed to define the subsoil model and a SM map in which the territory is qualitatively classified into homogeneous microzones;
– Level 2 introduces the quantitative elements associated with the homogeneous zones, using additional investigations, if necessary, and a new SM map is produced;
– Level 3 contains insights on topics and/or on particular areas.

Level 1 should provide useful geological, geomorphological and geotechnical information, identifying areas potentially affected by amplification of ground motions and therefore addressing subsequent detailed investigations.

For the definition of the subsoil model of Arischia with respect to Level 1 of SM, in particular for the Macindole area, detailed geological surveys (1:5000) and geophysical prospecting (ERT) were performed to achieve a preliminary geological setting and to reconstruct the stratigraphic succession. After this step, the Authors established the location of a borehole in the centre of the "Macindole" area: it was drilled up to 25 m from ground level and borehole tests were also performed (SPT and Down Hole) for the seismic characterization of the terrains. All data were integrated to define the Homogeneous Units [Guidelines for MS studies by PRES. DEL CONS.

Fig. 5 – Poorly cemented heterometric pebbles and rare boulders, in a silty-clay pinkish matrix.

Fig. 5 – Detriti eterometrici con grandi blocchi, poco o mediamente cementati, matrice fine rosata di entità variabile.

DEI MIN.- DPC, 2008] to realize the map of seismic zonation of Level 1 described in the following.

Geological surveys

The geological survey started from upstream of Via Macindole where the slope gradually became steeper because of the disruption due to the Pizzoli-Arischia tectonic line: here the outcrops of pre-quaternary units were mapped in detail, the tectonic setting was re-defined and two NS faults were recognized. The new and most important result of this survey is that one of the two tectonic lines continues towards the foothill area, as clearly confirmed by the contact between "Marne con Cerrogna" with "scaglia detritica – Scaglia Cinerea" downstream the SS 80. Due to the activity along these faults and due to the bedrock lithological characteristics, rocks were mechanically and chemically weathered and in many outcrops they completely lost their structure. Prolonged tectonic activity has contributed to the pro-

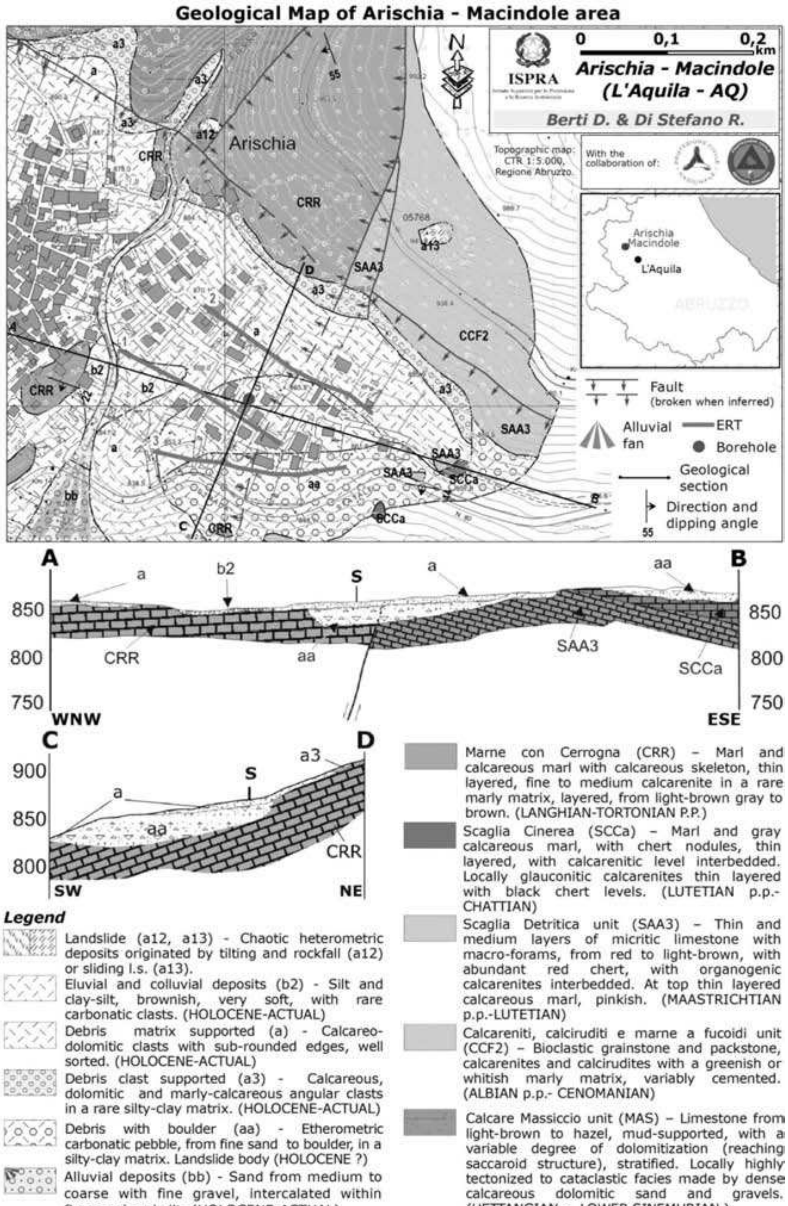

Fig. 6 – Detailed geological map 1:5.000 for Via Macindole area, geological sections (A-B, C-D), geoelectrical profiles and borehole location (modified from "Carta Geologica" WORKING GROUP SM AQ, 2010).

Fig. 6 – Dettaglio della carta geologica 1:5.000 per l'area di Via Macindole, sezioni geologiche (A-B, C-D), ubicazione dei profili geoelettrici e del sondaggio (modificato dalla "Carta Geologica" edita in WORKING GROUP SM AQ, 2010).

Tab. I – Geometrical features and arrays used for electrode deployments along three profiles.
Tab. I – Caratteristiche geometriche e dispositivi usati per la distribuzione degli elettrodi lungo i tre profili.

Code	a spacing (m)	Length (m)	Arrays
ERT1	2.5	237.5	Wenner, Pole-Dipole
ERT 2	2.5	237.5	Wenner, Dipole-Dipole
ERT 3	2.5	237.5	Wenner - Pole-Dipole

duction and accumulation of very thick debris, the formation and evolution of multiple generations of fans and, where the slope has more energy, the development of gravitational phenomena with different evolution, nature and extent. This was evident downstream the SS 80, where debris outcrops with heterometric clasts, some of those too big (boulder), and with sedimentary structure too chaotic to be compatible with a just detrital origin (Fig. 5).

The presence of this deposits, considering the steep slope upstream of Via Macindole, where some landslides are currently active, suggested that this area could be occupied, in depth, by an "old landslide" body hidden by recent holocenic debris.

Geological Map of Arischia

Despite the difficulties encountered in surveying such a restricted and highly damaged area, in which the thick layer of holocenic deposits has levelled the surface and the recent urbanization has further masked the geological and geomorphological features, the final geological map succeeded in to reconstructing the stratigrafic sequence from substrate bedrock to quaternary deposits (Fig. 6). Furthermore the 1:5.000 map describes, in a more appropriate way, the lithological characteristics of the continental covers, defines their thickness and allows to reconstruct a new and unexpected geological settlement for Via Macindole. As depicted in the geological section A-B of figure 6, the final geological model inside the urbanized sector is characterized by a monocline with a gentle deepening direction toward SW with frequent weak undulations at outcropping scale inside the ductile formations of "Marne con Cerrogna" and "Scaglia Cinerea". Note that, under the most damaged area of Macindole, the "old landslide" body and the shape of contact with the overlaying bedrock were depicted along the geological section, thanks to the interpretation of geoelectrical data.

Geoelectrical prospecting

Electrical surveys in Arischia were conducted in the Macindole area starting from May 2009: n. 3 electrical resistivity tomographies (ERT) with 96 electrodes spaced 2.5 m were carried out, using different arrays as shown in table I.

After a preliminary quality control and checking of measurements made directly on the field, the inverse 2D model of resistivity distribution along each profile was obtained by means of RES2DINV software (Geotomo Software) that uses an inversion routine based on the smoothness-constrained least-squares method proposed by de Groot-Hedlin and Constable [De Groot-Hedlin and Constable,1990] with further improvement by Loke and Barker [Loke and Barker, 1996] to reduce the computational time. The profile ERT1 was performed transversely to slope, downstream from Macindole street, with approximate direction NW-SE. The result obtained inverting the Wenner dataset was considered as the most representative of geological features in depth. In the first part of the section, between the 45 and 60 m at surface, a shallow conductive body with curved shape, interpreted as a paleochannel filled by fine deposits, can be easily identified: toward the middle of ERT the thickness of this conductive layer decrease to a constant value of about 3-4 meters, suggesting a horizontal stratigraphic setting parallel to the topographic surface. In the middle of the array a lateral variation of resistivity exists within the 25-30 m depth, between a more resistive body on the left side (200 Ω m) and a more conductive one on the right (Fig. 7a). The latter is limited, in depth, by higher values of resistivity starting from 130 m at surface, south-eastward. The lateral change in resistivity represents the most important feature of subsoil highlighted by this tomography, suggesting different geological settings in a restricted area. In figures 7b and 7c the results of the Wenner and pole-dipole robust inversions are shown: even using different constraints, the electrical models are congruent for the same array and also comparing different arrays. Profile ERT 2 has been developed upstream of Macindole street, taking advantage from the local absence of buildings along the profile trace. This sector presumably was not affected by excavation and/or backfilling works as occurred for the urbanized area instead, so that useful information has been obtained about the apparent resistivity of natural soils. Furthermore, deploying profile in this way, it has been possible to investigate the pres-

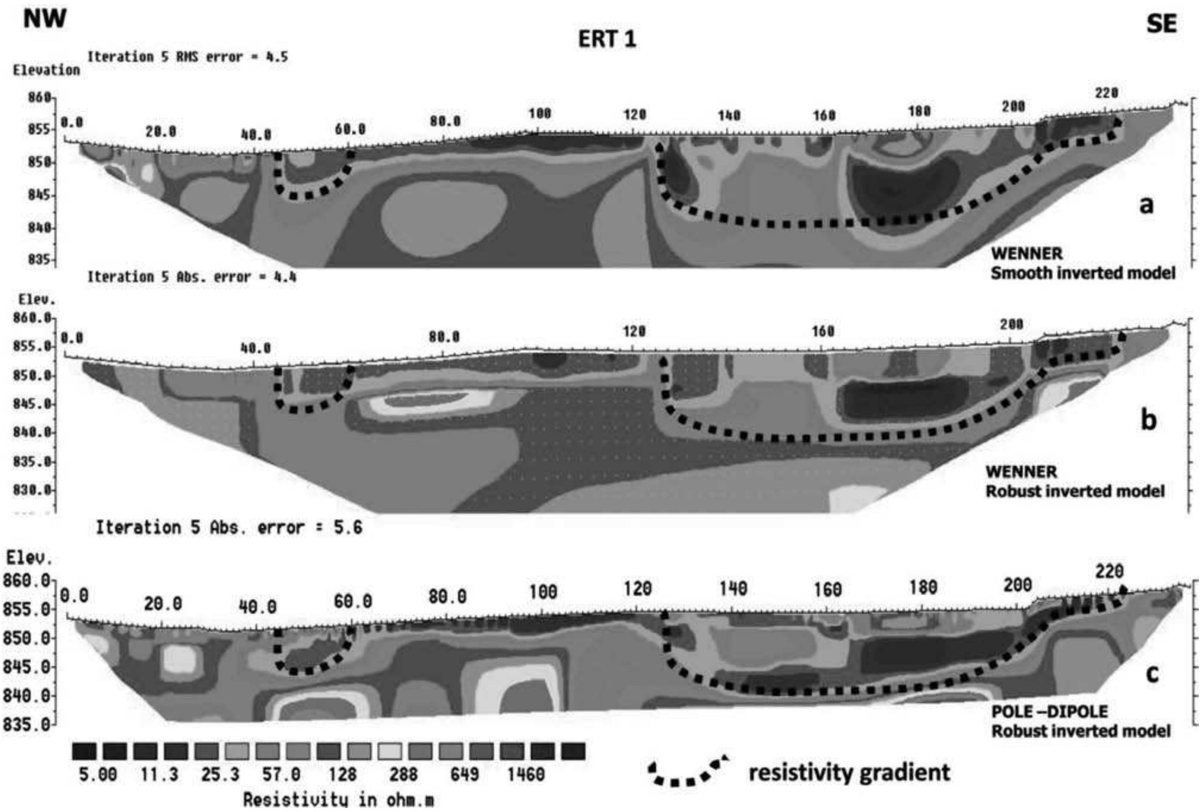

Fig. 7 – Comparison of geoelectrical models derived from smooth a) and robust inversion b) of Wenner and Pole-Dipole c) data along ERT 1 profile.

Fig. 7 – Confronto tra i modelli geolettrici derivati dalla inversione smooth e robusta dei dati Wenner e Polo-Dipolo lungo il profilo ERT 1.

ence of a normal fault dipping north-westward (see geological map in Fig. 5).

Along this profile the distribution of apparent resistivity values is depicted in figure 8 derived by robust inversion of the Wenner dataset. Starting from soil surface, it can be observed a conductive body with rather homogeneous distribution of rho between 5 and 30 Ωm, continuous throughout the entire section and limited by resistivity values of 60 Ωm at the bottom. Near the middle of the section a lateral variation is clearly defined between a moderately resistive body and a more resistive one in the lower right portion of image, characterized by ρ values greater than 1400 Ωm.

Profile ERT 3 was performed immediately upstream of the roadway SS 80 "L'Aquila Teramo", along a section topographically uneven: the location planned for this ERT was suggested by the presence of

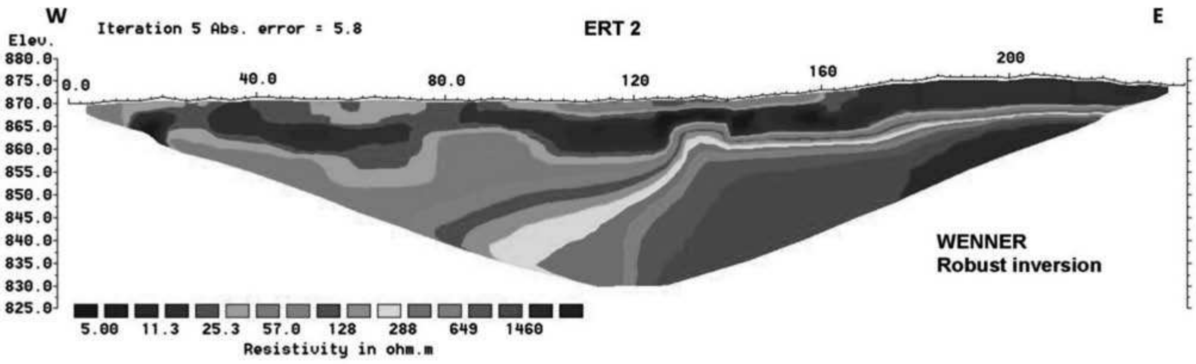

Fig. 8 – Electrical tomography ERT 2 carried out upstream of Via Macindole.

Fig. 8 – Tomografia elettrica ERT 2 nel settore a monte della sede stradale di Via Macindole.

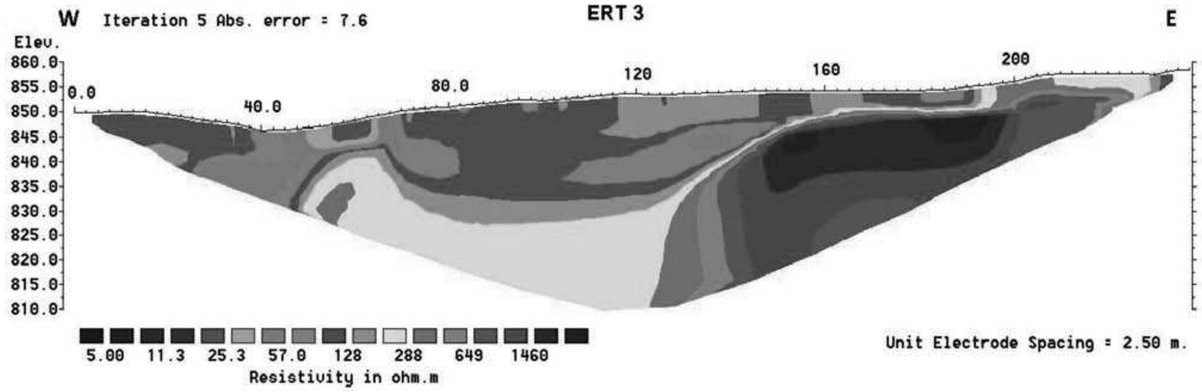

Fig. 9 – Electrical tomography ERT3 in the area immediately upstream of SS 80 "L'Aquila-Teramo".
Fig. 9 – Tomografia elettrica ERT3 nel settore subito a monte della SS 80 L'Aquila-Teramo.

two buildings, nearly destroyed by the earthquake (DG1 and DG2 in Fig. 3), and by some fractures visible on surface. The tomography that better describes the distribution of resistivity on the subsurface was the one obtained inverting Wenner data with robust constrain (Fig. 9).

Starting from W, a homogeneous body of about 120 Ωm is identified, it passes laterally to a small and well defined conductive surficial body (15-30 Ωm) bounded by layers with intermediate to high resistivity (max 250 Ωm at bottom). From 80 m at surface eastward, the tomography suggested the presence of three bodies characterized by distinct resistivity ranges and with articulated shapes: a superficial body with intermediate resistivity lies along a curved surface on a more resistive body with values a little less than 290 Ωm. The contact between these layers tapers smoothly to East where the surficial resistivity grows till a little more than 300 Ωm. A clear lateral resistivity contrast between 140 and 150 m at surface is worth of attention: in this portion of tomography the resistivity values pass from about 650 to 1400 Ωm. Before the realization of a borehole (described in the following), the association of the geophysical data with surface geology made possible a correlation between the resistivity distributions and geological units. In particular, along the tomographies n. 2 and 3, it could be distinguished the lithoid unit of the "scaglia detritica", which have been associated with the highest values of resistivity, from the "Marne con Cerrogna" consisting of alternating calcarenites, marls and calcareous marls, which have been associated with resistivity values ranging between 120 W m (predominant marly fraction) and 500 W m (predominant calcarenitic fraction). Along profile ERT 2 the tectonic contact between these units is

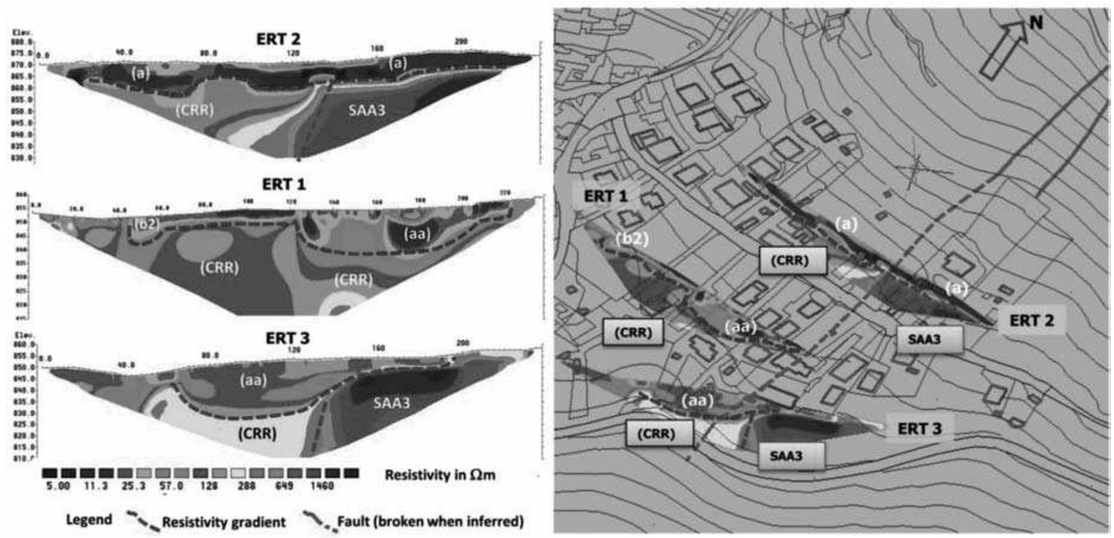

Fig. 10 – Resistivity 3D image and its correlation with the geological units.
Fig. 10 – Correlazione con le unità geologiche indicate nella carta geologica e visualizzazione pseudo - 3D dei modelli geoelettrici.

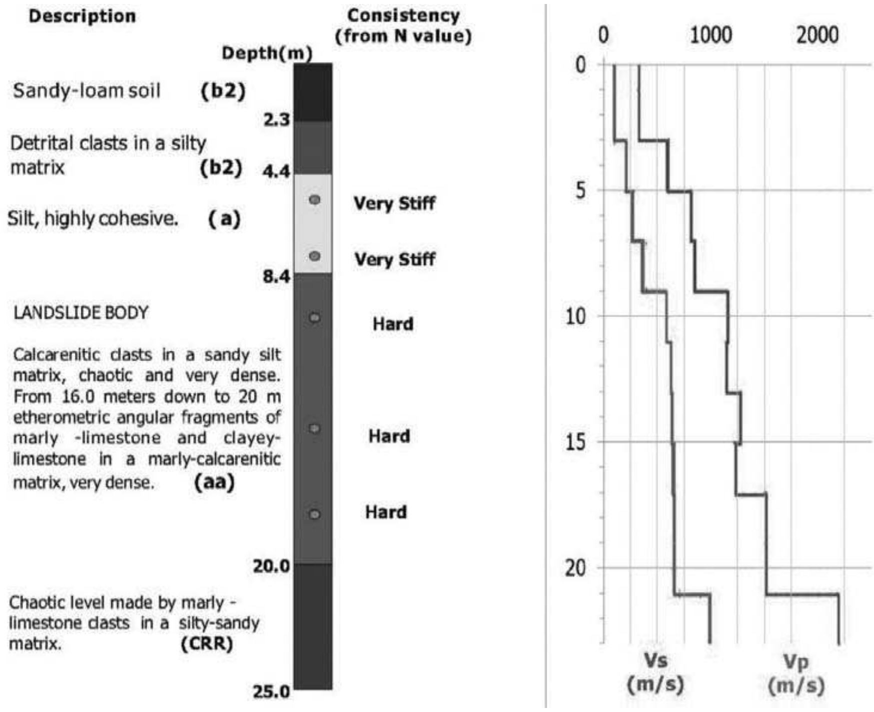

Fig. 11 – Synthetic stratigraphy and geotechnical data in terms of consistency and Vp-Vs profiles (modified from Working Group MS-AQ, 2010).

Fig. 11 – Stratigrafia sintetica e dati geotecnici in termini di consistenza e profili di velocità Vp-Vs (modificato da Working Group MS-AQ, 2010).

confirmed by the sharp gradient of resistivity near the middle of the section; furthermore it confirms that the fault is dipping toward W with a high angle. The same tectonic line continues downstream intercepted also by ERT 3: here the resistivity contrast is less sharp but enough defined. Along ERT 1 we couldn't identify a so clear resistivity change in depth, but this was not unexpected because the information derived from geological surveys suggested that the tomography was probably carried out, almost entirely, in the area occupied in depth from the "Marne con Cerrogna". The gradual increase of the resistivity along the eastern edge of the same tomography was in total agreement with the surface data: it could be related to the buried presence of the "scaglia detritica" that rises more eastward in contact with "Marne con Cerrogna" along the NNE-SSW tectonic element mentioned above. In the pseudo 3D reconstruction these correlations become evident as depicted in figure 10.

Borehole stratigraphy

On the basis of integrated information derived by geologic survey and electrical prospecting, the location for the borehole was established in the Macindole area very close to ERT 1 profile (Fig. 6); the first two meters consist of a brown sandy-loam soil, matrix-supported, with anthropogenic angular pebbles, from moderately dense to lose. It was referred to the geological unit named **b2**). In depth it is followed by a brownish level with detrital clasts < 1 cm in a silty matrix: from 4.4 meters there is a brownish silt, cohesive and slightly moist, with rare millimetric carbonate concretions more frequent near the bottom of layer at 8.4 meters (unit **a**). The following about twelve meters of drilling (8.4 – 20.0 m) involved a complex geological body, chaotic and very dense, consisting by calcarenitic clasts in a sandy-silty matrix, reddish to brown until 13,8 meters of depth (unit **aa**). This deposit becomes matrix supported in depth and from 16.0 meters down to bottom of layer there is a clear change in constitution of skeleton and matrix: heterometric angular fragments of marly-limestone and clayey-limestone in a marly-calcarenitic matrix, very dense (**CRR** formation). All the above features confirm that this was the old landslide geological body on the basis of geological survey and geoelectrical investigations. Borehole ends with 5 meters of a chaotic level made by marly-limestone clasts in a silty-sandy matrix that decrease in granulometry to the bottom of borehole. Figure 11 summarizes

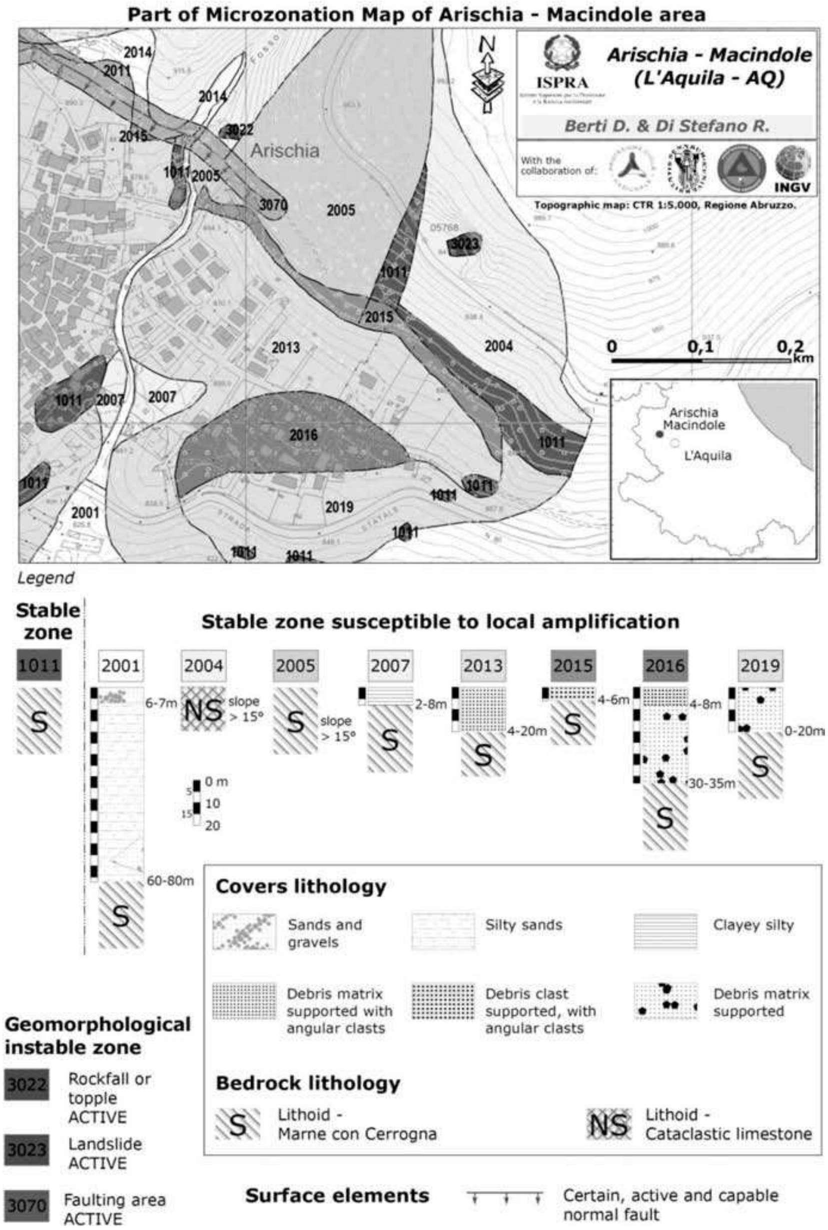

Fig. 12 – Map of homogeneous microzones in seismic perspective for Macindole area (modified from "Carta delle Microzone omogenee in prospettiva sismica" in WORKING GROUP SM AQ, 2010).

Fig. 12 – Carta delle microzone omogenee in prospettiva sismica per l'area di Macindole (modificato da "Carta delle Microzone omogenee in prospettiva sismica" in WORKING GROUP SM AQ, 2010).

the stratigraphic and geotechnical informations described below.

Borehole tests

-SPT test

Along the borehole n. 5 Standard Penetration Tests were performed in order to give an immediate estimate of consistency of soils: the stiffness of layers were always high, as the values of N was generally up to 30 and all the tests conducted in the depth range between 8-18 m were interrupted after 100 blows.

-Down Hole test

From the DH test executed in Macindole area a very good agreement between changes in Vs values and stratigraphic profile was found, furthermore it was observed a progressive increase in soil stiffness below the first soft sandy-loam layer (anthropic), considering the velocity profiles and the N values. Two jumps in Vs value seemed to be well correlated with the top and bottom surface of the "old landslide body": the velocity of S-waves increases of more than 280 m/s and of about 380 m/s, respectively at 9 m and at 21 meter of depth. At the latter depth the highest values of Vs allowed individuating the local seismic bedrock for this area, furthermore at depth of 21 m also the Vp value increases of about 600 m/s reaching more than 2100 m/s.

Seismic Microzonation of the Macindole area

All the considerations discussed above where integrated in a map of homogeneous microzones in seismic perspective in which some micro-areas were identified as homogeneous sectors on the basis of main parameters as:

- type and thickness of debris differentiated on the basis of lithological and lithotecnical characteristics, considered stable but susceptible to local amplification;
- type and depth of bedrock, stratified ("S") or not stratified ("NS");
- geomorphological features of outcropping bedrock, stable with slope angle less than 15°, unstable for more than 15° and/or in the presence of landslide;
- structural setting, considering the bedrock unstable near the active fault (30 meters across the fault line).

As depicted in figure 12, the integration of geological, geophysical and geotechnical data allowed to distinguish in this sector a great microzone named 2013 and six microzones (1011, 2004, 2005, 2007, 2016, 2015, 2019) just inside and downstream the most damaged area, characterized as stable zones but susceptible of local seismic amplification. In the same figure were distinguished three instable microzones 3022, 3023 and 3070, due to the presence of active landslide and active faulting area. In the southeastern Arischia urbanized sector a predominantly cohesive soil outcrops, 5 – 15 m thick, consisting of matrix supported debris of medium - high consistency, resting on a bedrock of "Marne con Cerrogna" or "Scaglia Cinerea" (microzone 2013). In the microzone 1011 the bedrock outcrops without a strong mechanical deformation and the slope angle is less than 15°; the area is considered stable. In the sector located at north of Via Macindole, near the SS 80, outcrop "Marne con Cerrogna" ("S"), "calcareniti e calciruditi a fucoidi" and "Calcare Massiccio" (both "NS") that have poor mechanical properties due to the strong structural deformation and a slope angle greater than 15°(microzones 2004, 2005). At the foot of the slope the substrate is locally covered by a detrital clasts-supported unit (microzone 2015). The southern area of Via Macindole is characterized, below 4-8 m of debris (Vs= 235 m/s), by the presence of a chaotic body (Vs=650 m/s) with polygenic heterometric elements (microzone 2016). This sedimentary body (Fig. 5), outcropping in the southernmost area of "Via Macindole" near the SS 80, was intercepted by the borehole "S" and its lateral extension was determined throughout interpretation of the ERT 2 and ERT 3 (microzone 2019). It was interpreted as an "old landslide" body from 20 to 35 meters thick, that could have led the occurrence of local seismic amplification phenomena in the Macindole area. Between Via Macindole and M.te Omo Valley the stratified bedrock lies under a colluvial silty-clay deposit of 2-8 meters thickness (microzone 2007). Finally, the southwest area of Via Macindole is characterized by the presence of an alluvial-fan deposit, thick 60-80 meters, consisting of silty sand alternating with gravel in lenses, lying on a stratified bedrock (microzone 2001). It's worth noting that, due to the very complex litho-stratigraphic setting, the Level 3 of SM for Macindole could be defined, according with DPCM, only using a 2D analysis of seismic response [WORKING GROUP SM–AQ, 2010].

Conclusions

The April 6th, 2009 L'Aquila earthquake hit many towns surrounding L'Aquila and it's province, severely damaging historical centers but also areas of recent urban sprawl: among the latter, the example of Via Macindole in Arischia (AQ) represents an interesting case in which the urbanized area was developed without any urbanization plan and the seismic design of buildings was not supported by appropriate geological and geotechnical knowledge. The note shows a successful example of integration between geological surveying and geophysical investigations that allowed the definition of an appropriate subsoil model for this area. The Microzonation Map proposed for Macindole by the authors reflects the evidence of a complex geological setting defined only after a very detailed survey and using geophysical prospecting as DH and ERT. This latter helps in the definition of the microzones and to estimate variation of the buried morphology over local bedrock, determined in an efficient way without the extensive use of drillings. The damage distribution observed in the Macindole area was linked to the presence, under a detrital cover, of an old landslide body which could have led the occurrence of local seismic amplification phenomena. This study demonstrate, further, the importance of defining a subsoil model for those urbanized areas whose geomorphological evolution is strongly influenced by recent tectonic activity. As for the Macinodole area, the geological setting could be characterized by the presence of extremely heterogeneous sedimentary bodies, with complex morphology, whose seismic response can be extremely variable even in a very restricted area.

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Il contributo integrato del rilevamento geologico e delle indagini geofisiche nello studio di microzonazione sismica di Arischia (AQ)

Sommario

A seguito del sisma del 6 aprile 2009 - che ha interessato la conca de L'Aquila (Mw 6.3) - e delle successive attività emergenziali, il DPC (Dipartimento della Protezione Civile) ha pianificato estesi studi di microzonazione sismica (MS) per la ricostruzione dei comuni più danneggiati dell'area colpita dal terremoto. Lo studio, promosso e coordinato dal Dipartimento Nazionale della Protezione Civile con la Regione Abruzzo, ha riguardato i centri abitati che hanno risentito di un'intensità macrosismica pari o superiore al VII grado MCS, raggruppati in 12 "Macroaree" [WORKING GROUP SM L'AQUILA, 2010]. Lo studio ha coinvolto circa 150 ricercatori e tecnici di dieci università italiane, otto istituti di ricerca tra i quali l'ISPRA, l'Ordine dei Geologi dell'Abruzzo, quattro regioni (Abruzzo, Emilia-Romagna, Lazio e Toscana) e la Provincia Autonoma di Trento. In tale quadro è stato affidato all'ISPRA il coordinamento delle attività tecnico-scientifiche e l'esecuzione di rilievi ed indagini di tipo geologico, geofisico, geognostico e geotecnico nei 10 territori comunali ricadenti nelle Macroaree 6 e 7, tra i quali anche Arischia (Macroarea 7). Come in altre municipalità, il centro storico di Arischia ha subito ingenti danni, ma quelli più severi sono stati registrati in un'area di recente espansione urbanistica, dove è stata rilevata una considerevole variabilità degli effetti macrosismici. La presente nota rappresenta un estratto del più ampio studio effettuato da ISPRA in questo comune e riguarda il settore dell'abitato di Via Macindole, dove la prima analisi effettuata sull'entità e sulla distribuzione dei danni non era sembrata coerente con le precedenti conoscenze geologiche locali. L'esecuzione di rilievi geologici e geofisici di dettaglio in tale località ha portato a un decisivo progresso delle conoscenze contribuendo, assieme alla caratterizzazione geotecnica dei terreni, alla definizione del modello di sottosuolo di riferimento richiesto dalle Linee guida per la MS [PRES. DEL CONS. DEI MIN.-DPC, 2008].