Geological report at the seismic station IV.MODE – Modena (MO)

Working Group: **Sara LOVATI** **Claudia MASCANDOLA** **Marco MASSA**	Date: December 2018
Subject: **Final report illustrating the geological setting for station IV.MODE**	

Convenzione DPC-INGV 2018, Allegato B2: Obiettivo 1 - TASK B: "Caratterizzazione siti accelerometrici" (Coord. G. Cultrera, F. Pacor)

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1. INTRODUCTION

The geological description is related to the site of studied seismic station. The coordinates are reported in Table 1.

Table 1

CODE	NAME	LATITUDE	LONGITUDE	QUOTA (a.s.l.)
IV.MODE	Modena	44.6297	10.9491	41
ADDRESS	Via P. Vivarelli, 10, 41125 Modena (MO), Italy			

2. TOPOGRAPHIC AND GEOLOGICAL INFORMATION

Topographic information related to the site are reported in Table 2. Table 3 summarizes all available geological maps from literature for geological analyses.

Table 2

Topograpy	Description	Class
	Flat surfaces, isolated slope and reliefs with slope i<=15°	T1

Table 3

Geological map	Source	Scale
IV.MODE	Geological map of Italy sheets *086* (Modena) and *087* (Bologna)	1:100.000
IV.MODE	Geological map of Italy sheet *201* (Modena)	1:50.000
IV.MODE	Geological map of Emilia Romagna Region	1:10.000
IV.MODE	Geological and technical maps – Seismic Microzonation *level 3*	1:5.000

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In Table 4 Geological, Lithological and Lithotechnical Units (according to Seismic Microzonation classification; Technical Commission MS, 2015) are described and are concerned to maps of following chapters. The term "original" means the result comes from a preexisting cartography (Table 3); the term "deduced" means the result comes from an interpretation of a preexisting cartography according to the nomenclature of corresponding cartography.

Table 4

GEOLOGICAL UNITS (10k Regione Emilia Romagna) *original*		LITHOLOGICAL UNITS (Amanti et al., 2008) *deduced*		LITHOTECHNICAL UNIT (MZS) *original*	
code	description	code	description	code	description
AES8a	silt	B1	Fine granulometry	CL	Organic clays of medium-high plasticity, organic silt

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3. GEOLOGICAL MAP

In Figure 1 Geological Map is reported in a 1kmx1Km square around the station.

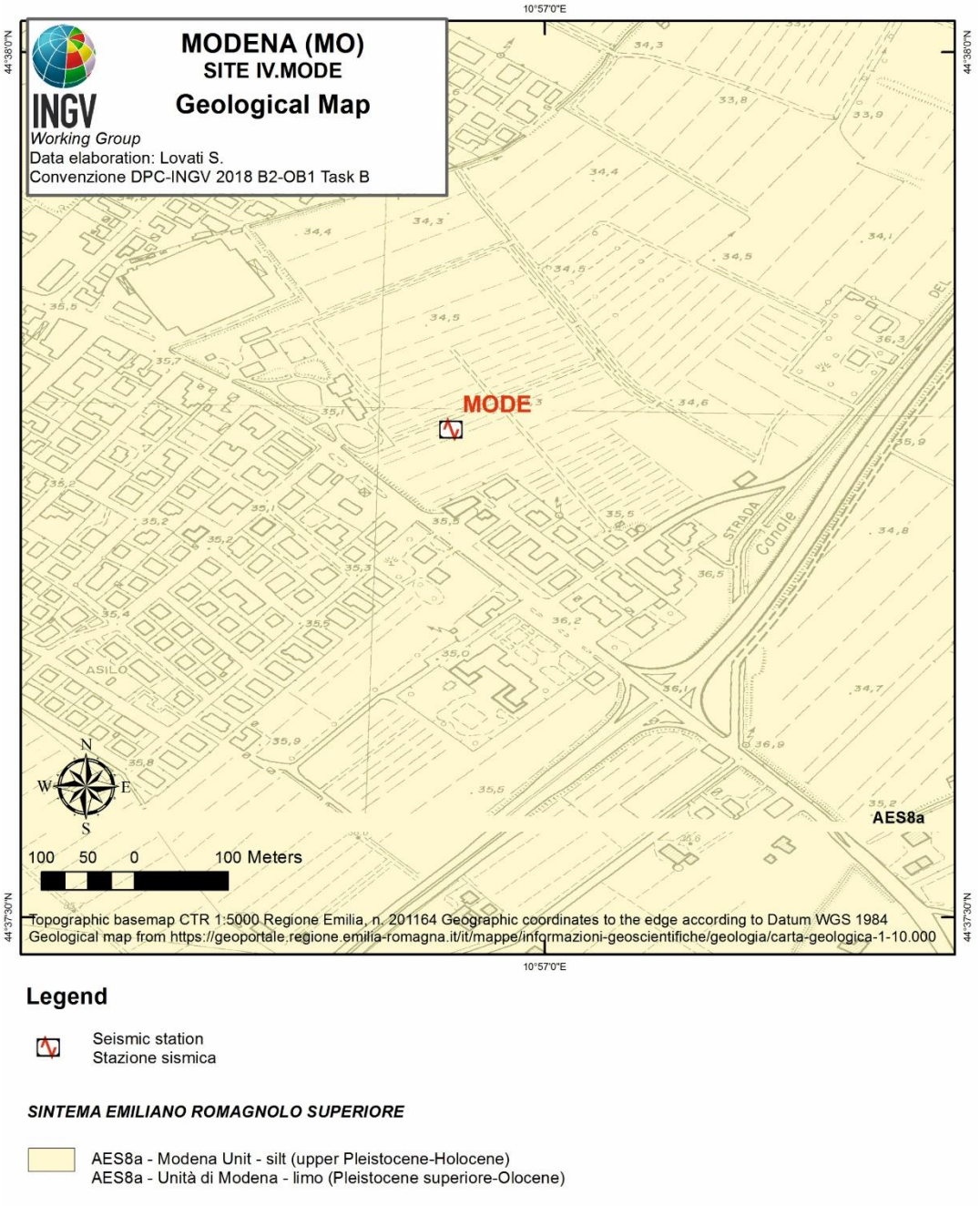

Figure 1. Geological map of seismic station IV.MODE. Scale 1:5.000. Geological units are established according to the nomenclature of geological map 1:10.000 of Emilia Romagna Region.

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4. LITHOLOGICAL MAP

In Figure 2 Lithological Map is reported in a 1kmx1Km square around the station.

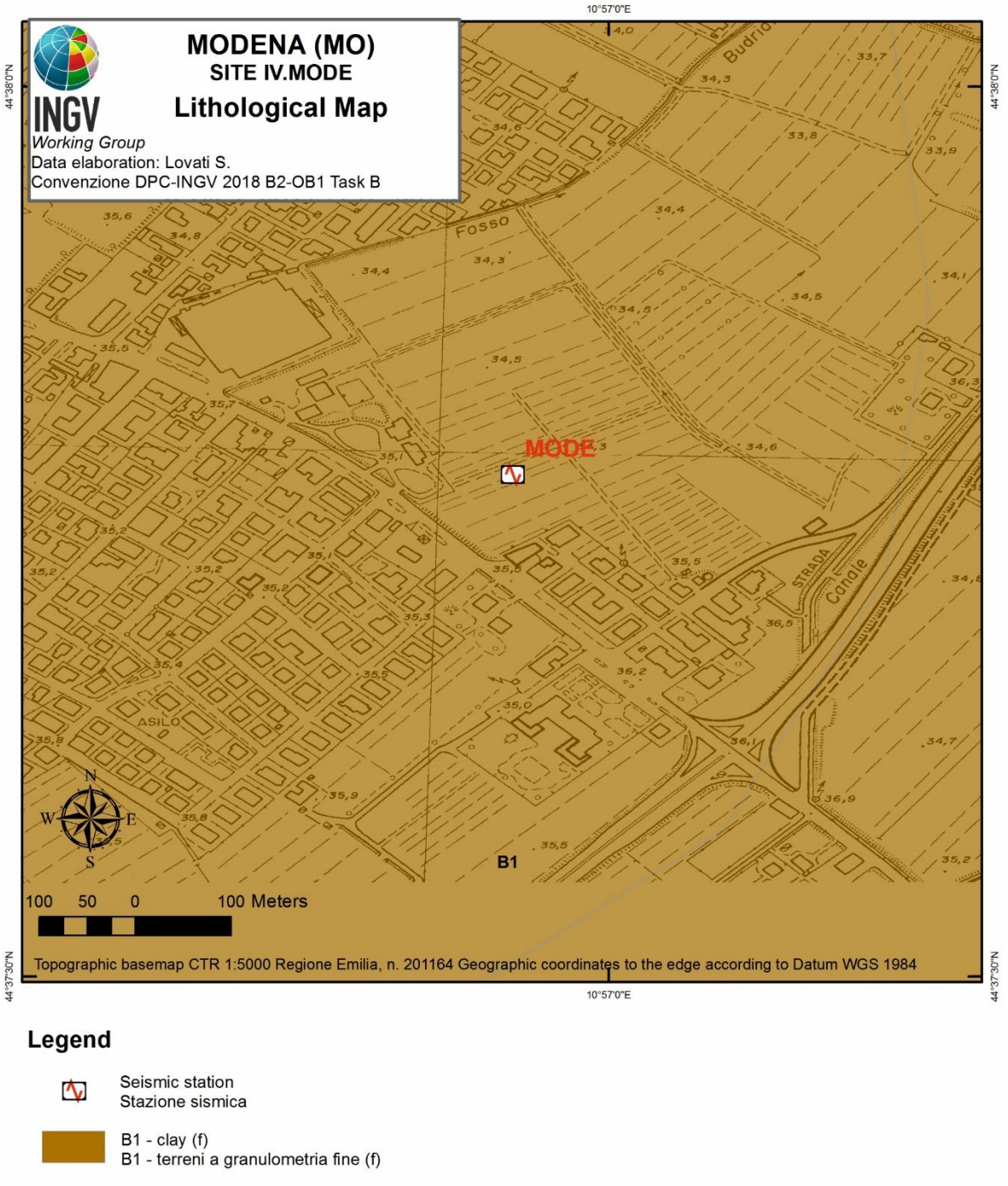

Figure 2: Lithological map of station IV.MODE. Scale 1:5.000. The codes of the lithological units are assigned according to the nomenclature of the Lithological map ISPRA 1: 100.000 (Amanti et al. 2008).

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5. LITHOTECHNICAL MAP

In Figure 3 Lithotechnical Map is reported in a 1kmx1Km square around the station.

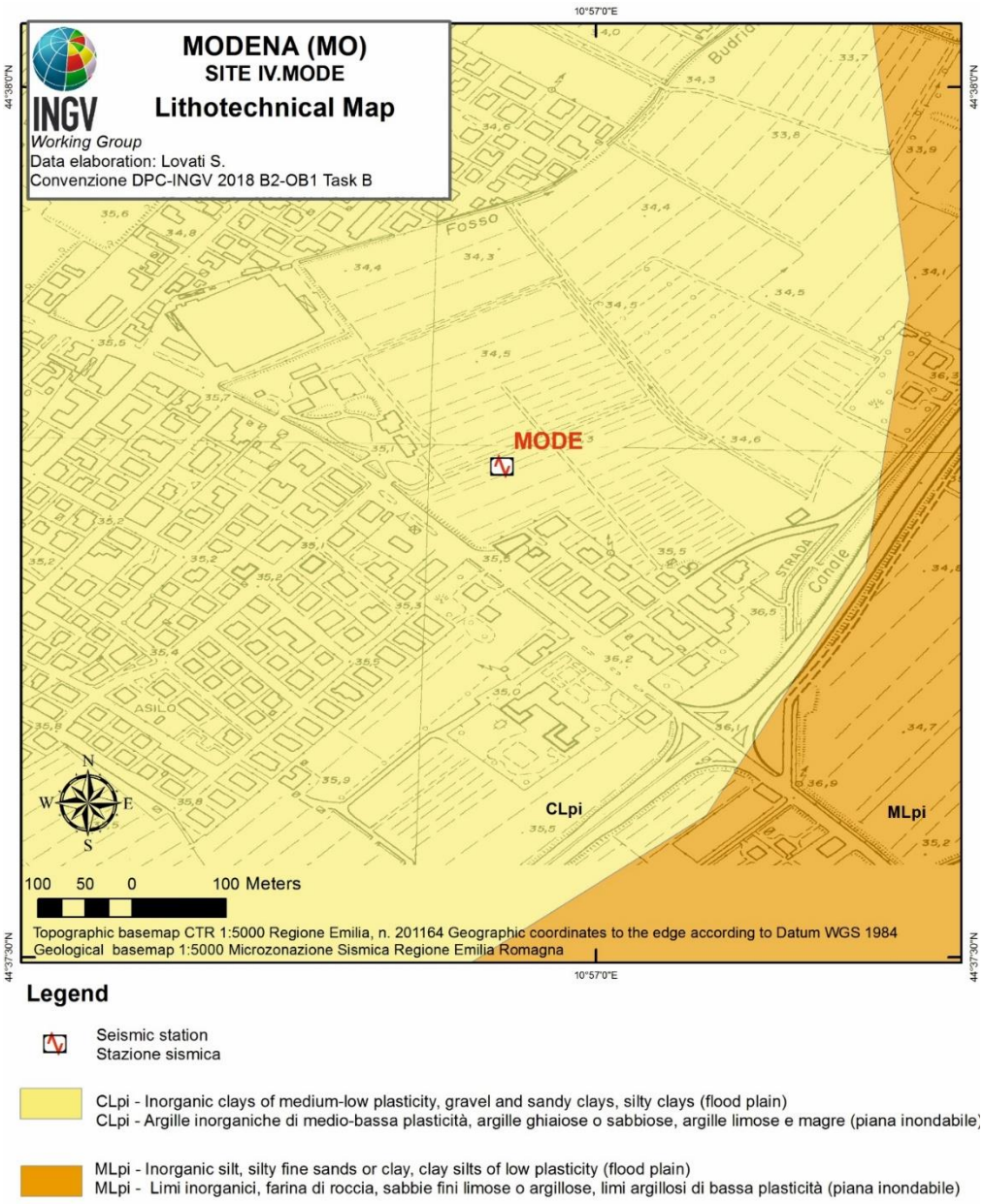

Figure 3: Lithotechnical map of the seismic station IV.MODE. Scale 1:5.000. The lithotechnical units are assigned according to the nomenclature of Seismic Microzonation (Technical Commission MS, 2015).

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6. SURVEY MAP

Figure 4 shows the survey Map reported both previous investigations and geophysics surveys conducted by INGV Working Group.

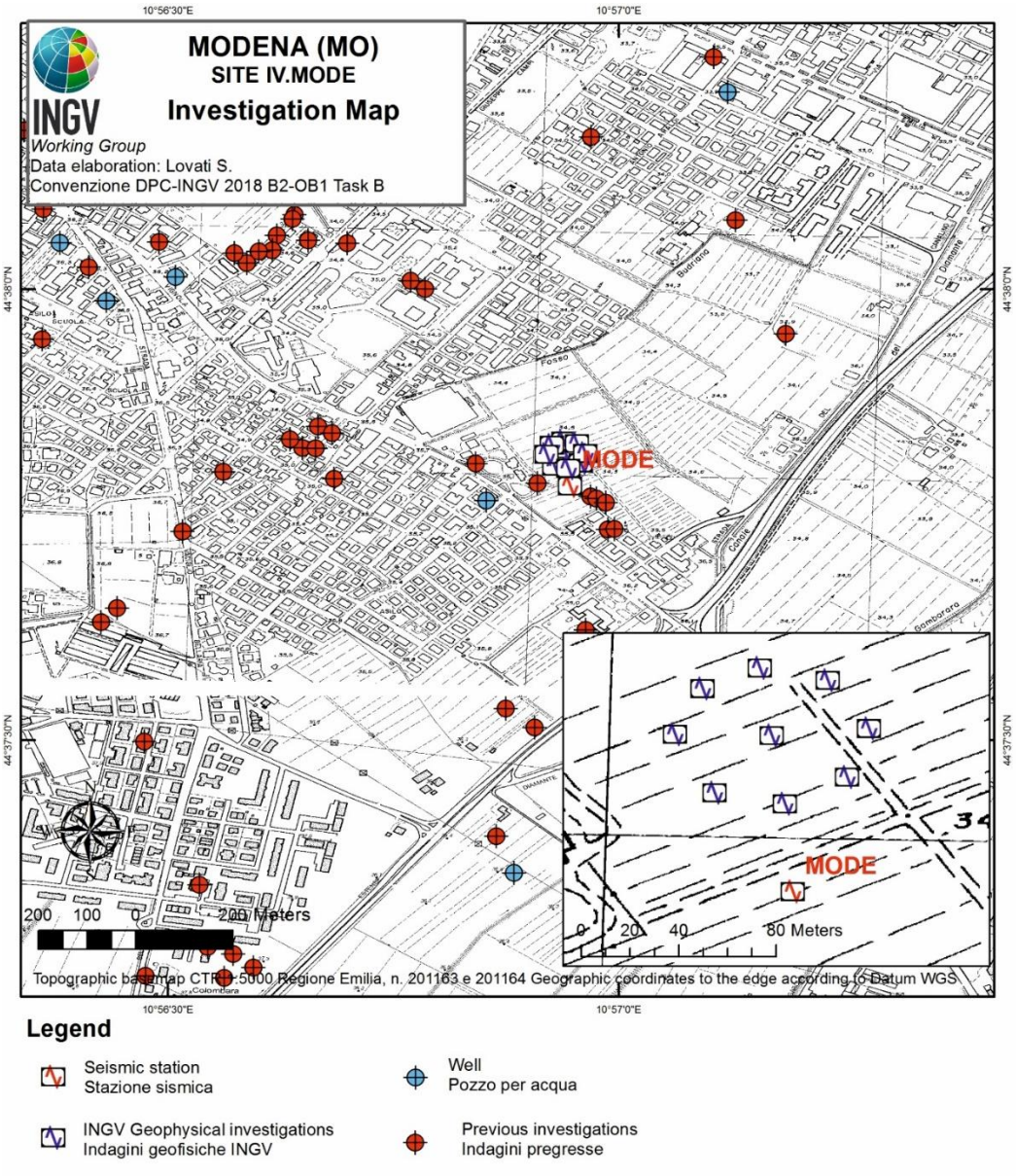

Figure 4: Map of the surveys in the surroundings of the station IV.MODE. Scala 1: 10.000. The box at the bottom right contains a zoom of the area with the detail of the geophysical 9-stations array conducted by INGV Working Group for the seismic characterization of the site (Agreement DPC-INGV 2018, Allegato B2: Obiettivo 1 - TASK B, Velocity profile report IV.MODE)

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7. GEOLOGICAL MODEL

7.1 General description

The studied area is located in the South-East area of Modena Municipality in the court of Engineering Department "Enzo Ferrari". It belongs to the sedimentary basin of the Po Plain sedimentary basin, arises, since the Late Cretaceous, as a consequence of the thrusting of Alps and the Apennines chains that loaded and flexed the continental crust originating a foredeep basins with a thick syn-orogenic clastic sequence (Doglioni, 1993) and a complex buried tectonic structure that is characterized by the south verging thrust system of the Alps and the north-verging thrust system of the Apennines.

The Po Valley basin is strongly involved in the Apennine tectonic with the formation of thrust systems (*Arco delle pieghe emiliane*, *Dorsale ferrarese*, Castellarin et al., 1985), separated by similar synform structures over which they partially overlap, involving the sediments of the lower Pliocene - upper middle Pliocene (Figure 5). The Po Valley structures derive from an embryonic tectonics overlapping a low-angle surfaces (20-30°), whose inclination increases going to the south. Since Miocene the advance of the Apennine front caused flexural collapses in the front of the Po plain area and the formation of a subsiding basin. Since Pleistocene, a sedimentary cycle began (Marine Quaternary "Qm" in Ricci Lucchi et al. 1982) leading to the filling of the Po plain that closes with sandy –pebbly deposits called "Yellow Sands" (Figure 5). Above the Qm the continental quaternary deposits developped, constituting The Supersintema Emiliano Romagnolo. This last one is divided in Sintema Emiliano-Romagnolo Inferiore (AEI, middle Pleistocene), and Sintema Emiliano-Romagnolo Superiore (AES, middle Pleistocene-Holocene) separated by a discontinuity detectable in the marginal areas of the plain and connected to a tectonic raising phase of Appennine structures. The Sintema Emiliano-Romagnolo Inferiore and the Sintema Emiliano-Romagnolo Superiore are characterized by depositional cycles (subsyntemes). AEI synthem is a stratigraphic unit deposited in sedimentary environments of coastal plain, interfluvial basin and distal cone. It consists mainly of silty and clayey silt deposits, typically bluish-gray in color, in which gravel levels are interleaved and becomes locally predominant in correspondence with the main fluvial flows.

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AES synthem is an alluvial unit with proximal fan deposits and terraced deposits. It consists of gravels in correspondence with the main fluvial systems passing to silt granulometry with rare intercalations of sand and gravel in the area of inter-conoid. The discontinuities that divide the subsyntemes are represented in the high plain areas by well-developed paleosoils associated to periods of interruption of the sedimentation which allowed the pedogenesis of the top part of the sandy-gravel deposits.

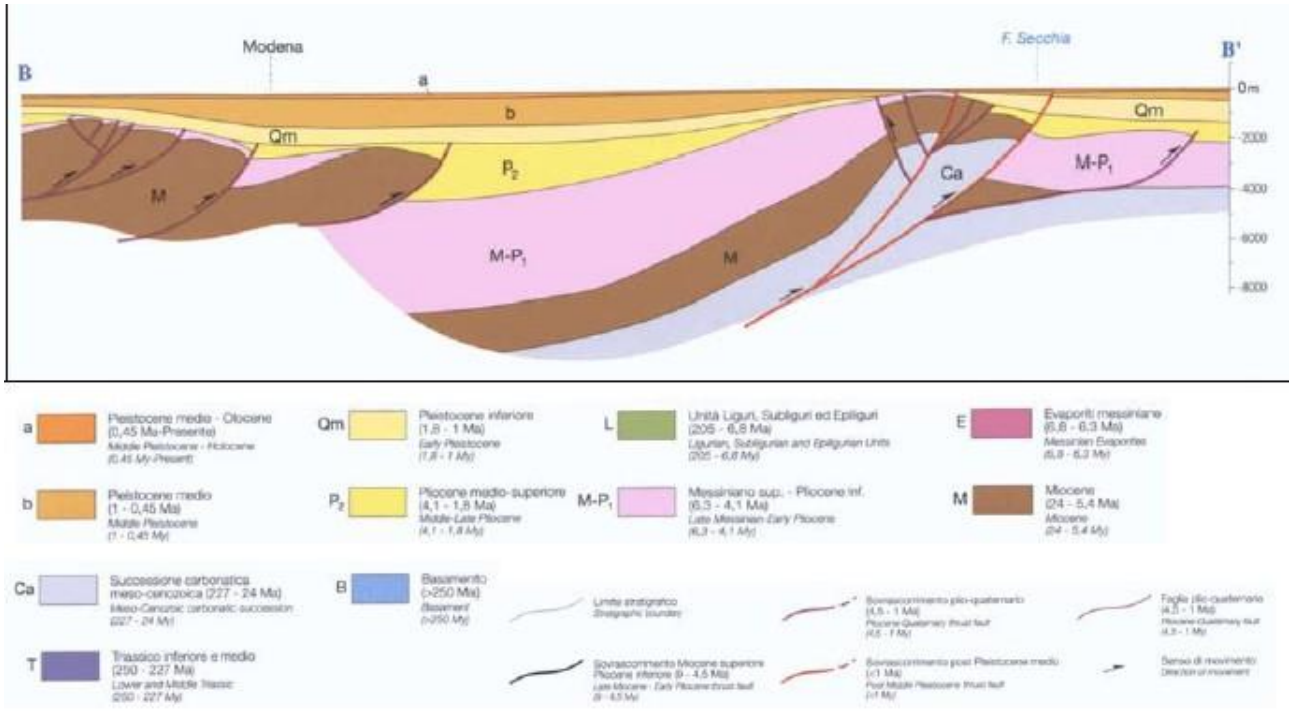

Figure 5: Deep geological section of Modena plain (Pieri & Groppi, 1981). Legend: Q:Quaternary, Plms: middle-upper Pliocene, Pli: early Pliocene, Ms: upper Miocene, Mn: middle Miocene, Mi: early Miocene, PG: Paleogene, Mz: Paleozoico, L: Liguridi.

7.2 Geological Section

Data related to the stratigraphies of wells for hydrogeological purposes allowed the acquisition of stratigraphic information up to 80 m of depth, beyond which there are no direct investigations available (Figure 6 bottom left and right).

The stratigraphy shows the presence of yellow clayey sediments alternating with blue clays and thin sand lenses in the most superficial layers with yellow gravels and fine yellow sands up to

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a depth of about 20 m. From 20 to about 50 m depth yellow and blue gravels alternate with sand lenses and intervals of blue clay with pebbles. From 50-60 m the clay component with gravel lenses and yellow sand is predominant. Starting from 80 m the proposed model has a high degree of uncertainty due to the lack of direct investigations. According to Sheet 201 "Modena" (Geological Map of Italy scale 1: 50.000- ISPRA - Geological Service of Italy, 2014b) the deeper unit is AES6 (Subsintema of Bazzano, middle-upper Pleistocene) characterized by a general coarsening-upward trend, with alluvial flooding clay sand and silt (main available source from Videpi, http://unmig.sviluppoeconomico.gov.it/videpi/videpi.asp).

In the geological model of the studied area the basis of the *Sintema Emiliano-Romagnolo Superiore* (AES) is set at depths varying from about 160 to 220 m (Technical Commission MS, 2015). Moving upward the next unit is represented by the depositional cycles of the Subsintema of Villa Verrucchio (AES7, upper Pleistocene) characterized by prevalent silt with subordinate gravels and sands in the lower portion and mainly gravelly-sandy deposits of conoid of the river Secchia. It is divided into two sub-unit, the Vignola Unit (AES7b, upper Pleistocene), made by coarse-grained granulometry with sedimentation characteristic of the last glacial phase and the Niviano Unit (AES7a, upper Pleistocene), that represents the lower fine-grained granulometry of the penultimate interglacial.

The outcropping deposits belong to the Modena Unit AES8a (Upper Pleistocene-Holocene) consisting of silty clay, clay and silt deposited in an alluvial environment. In the study area the thickness is around 7 -8 m The AES8a belongs to the Subsintema of Ravenna (AES8 - Upper Pleistocene-Holocene), mainly consisting of clay and silt at the base of which A0 acquifer is set (Figure 6 bottom left and right).

7.3 Subsoil model

A subsoil model is built up to a depth of 200 m for the area around the IV.MODE station (Figure 6 right), based on geological information from literature, oil drilling, and public databases. According to MZ Modena Municipality (2015), the seismic bedrock is at the base of the AES6 unit, in correspondence of a significant seismic impedance contrast, characterized by Vs around 600-650 m/s. According to a recent regional study performed in the Po Plain (Mascandola et al., 2018), the seismic bedrock can be found around 160 m depth. Considering the uncertainty at these depths, we can assume the seismic bedrock at depths ranging from 140-160 m.

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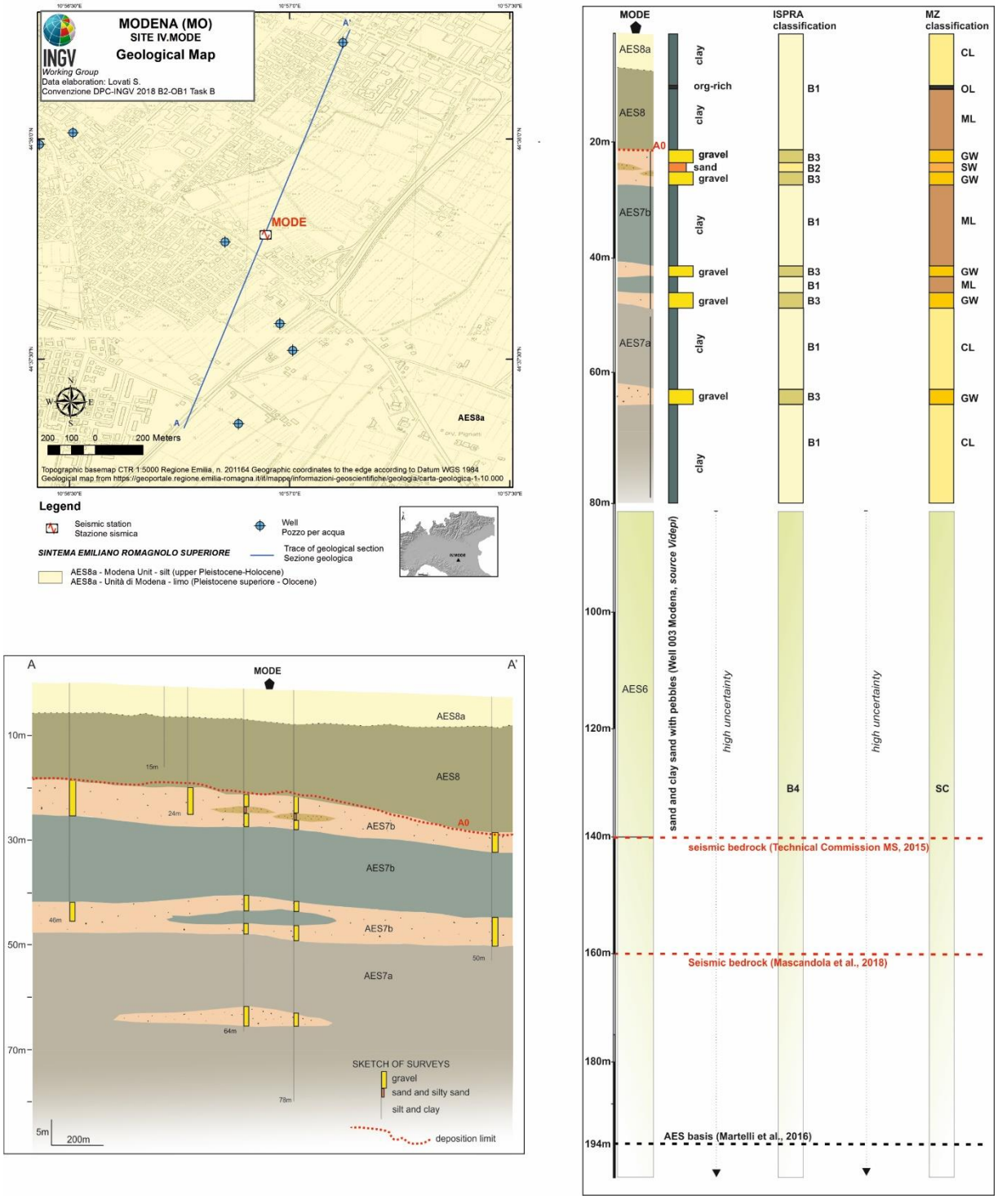

Figure 6: Bottom left: Geological section A-A' crossing seismic station IV.MODE. Right: Subsoil model under the IV.MODE seismic station and classification according to ISPRA: B1: clay, B2: sand, B3: gravel; according to MZ: CL: inorganic clay, silty and sandy clay, OL: organic silt and silty clay, ML: silt, silty-clay sand, clay silt, GW: gravel, mixed gravel-sand, SW: sand and gravel-sand, SC: clay sands, mixture of sand and clay. From 80 m the proposed stratigraphy has a high degree of uncertainty due to lack of direct information.

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8. REFERENCES

Amanti M., Battaglini L., Campo V., Cipolloni C., Congi M.P., Conte G., Delogu D., Ventura R., Zonetti C. (2008). The Lithological map of Italy at 1:100.000 scale: An example of re-use of an existing paper geological map. 33rd International Geological Conference, IEI02310L – 6-14th August, Oslo (Norway).

Castellarin A., Eva C., Giglia G., Vai G.B. (1985). Analisi strutturale del Fronte Appenninico Padano, G. Geol., 47, 47-76.

Commissione tecnica per la microzonazione sismica (2015). Microzonazione sismica. Standard di rappresentazione e archiviazione informatica, Versione 4.0b (Commissione tecnica inter-istituzionale per la MS nominata con DPCM 21 aprile 2011).

Doglioni, C. (1993). Some remarks on the origin of foredeeps, Tectonophysics, 228(1-2), 1-20.

ISPRA - Geological Survey of Italy - Lithological map of Italy 1:100.000 - Geological Survey Portal http://sgi.isprambiente.it/geoportal/ Sheets *086* (Modena) and *087* (Bologna).

ISPRA (2014b) - Geological Survey of Italy - Geological Map of Italy 1: 50.000. Sheet *201* (Modena).

Martelli, L., M. Bonini, L. Calabrese, G. Corti, G. Ercolessi, F. C. Molinari, L. Piccardi, S. Pondrelli, F. Sani, and P. Severi (2017). Carta sismotettonica della Regione Emilia-Romagna e aree limitrofe, scala 1:250.000 (edizione 2016). Con note illustrative, Regione Emilia-Romagna, SGSS; CNR, IGG sez. FI; Università degli Studi di Firenze, DST; INGV sez. BO. D.R.E.AM. Italia (in Italian).

Martelli L. and Romani M. (2013). Microzonazione Sismica e analisi della condizione limite per l'emergenza delle aree epicentrali dei terremoti della pianura emiliana di maggio giugno 2012, relazione illustrativa, Servizio geologico, sismico e dei suoli Regione 751 Emilia Romagna.

Cite as: Working group INGV "Agreement DPC-INGV 2018, Allegato B2, Obiettivo 1 - TASK B", (2018). Geological report at the seismic station IV. MODE- MODENA. doi: 10.5281/zenodo.2359019

Mascandola C., Massa M., Barani S., Albarello D., Lovati S., Martelli L., Poggi V. (2018). Mapping the seismic bedrock of the Po Plain (Italy) through ambient-vibration monitoring, Bulletin of Seismological Society of America.

Pieri, M., and G. Groppi (1981). Subsurface geological structure of the Po Plain, Italy, in Progetto Finalizzato Geodinamica/Sottoprogetto "Modello Strutturale", edited by C.N.R., Publ. N° 414.

REGIONE Emilia-Romagna, ENI-AGIP (1998). Riserve idriche sotterranee della Regione Emilia-Romagna. A cura di G. Di Dio. S.EL.CA. (Firenze), 120 pp.

Regione Emilia Romagna – Geoportale - https://geoportale.regione.emilia-romagna.it/it.

Videpi, http://unmig.sviluppoeconomico.gov.it/videpi/videpi.asp.

Working group INGV "Agreement DPC-INGV 2018, Allegato B2, Obiettivo 1 - TASK B", (2018). Velocity profile report at the seismic station IV.MODE-MODENA. doi: 10.5281/zenodo.2222319

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