PRELIMINARY RESULTS OF THE ALBANIAN GEOTECHNICAL MAP AT THE SCALE 1:200 000: A CASE STUDY

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ABSTRACT

A study about the “Albanian geotechnical map at the scale 1:200 000" was carried out in 2012 in Albania for civil engineering purposes and the results about Sazani, PeriAdriatic Depression and Ionian geotectonic zones are here reported. The study was based on the physical-mechanical properties of soils and rocks, lithological and hydrogeological characteristics and geodynamics phenomena (landslides and sand liquefaction zones). Consequently, the whole territory has been classified into several geotechnical areas providing sufficient and accurate data for the urban planners and civil designers and some recommendations for the stakeholders.
Keywords: *Geotechnical zone, physical mechanical properties, soils, rocks, landslide, sand liquefaction*

1. INTRODUCTION

In the present paper the compilation process of the geotechnical map at scale 1:200000 is reported. The study about the map was carried out in Sazani, PeriAdriatic Depression and Ionian geotectonic zones from 2012 to 2018 for regional planning purposes. After the 1990s several geotechnical mappings have been carried out at the scale from 5000 to 1:10 000 and 1:25 000 for the main towns and touristic areas in Albania and used for various purposes concerning urban planning and infrastructure development (Muceku and Zeqo 2002; Muceku and Lamaj 2005; 2009; Muceku *et al*., 2009; Muceku 2010; Muceku and Dushi 2011; Muceku 2012; Muceku *et al*., 2013; Muceku *et al*., 2014). As such a map for the whole country has not been compiled yet, geotechnical mapping at the scale 1: 200 000 has been carried out in Albania for regional planning purposes during 2012.

Various data and methods were used for map compilation. The outcropping rocks and soils were evaluated basing on soils and geo-mechanical classifications (Brown 1981; ASTM 2011) as a means to address the geotechnical map compilation. In addition, scientific data and methods reported in (UNESCO 1976; Dahms 1981; Rohde *et al*., 1981; Zuquette 2003; Rozos *et al*., 2004; Mesina 2006; Grana *et al*., 2013) were of great help. Moreover, detail desk study, many field works, and laboratory tests were carried out. The present paper aims to provide accurate geotechnical data about the Albanian territory for regional planning purposes and to serve as a guideline for geotechnical map compilation in a near future.

2. METHODS AND MATERIALS

Several geotechnical investigations have been carried out from 2012 to 2018 in south and west Albania (Fig. 1). Sazani, PeriAdriatic depression and Ionian geotectonic zones were included. The method applied for the map compilation is in the forthcoming paragraph described. The criteria applied based on (UNESCO 1976; Dahms 1981; Zuquette 2003; Rozos *et al*., 2004; Muceku and Lamaj 2005; Mesina 2006., Muceku *et al*., 2009; Muceku and Lamaj 2009; Muceku 2010; Muceku and Dushi 2011; Muceku 2012; Grana *et al*., 2013; Muceku *et al*., 2013; Muceku *et al*., 2014) included: i) lithological characteristics, e.g. soils and rock types, soils thickness, etc; ii) hydrogeological characteristics, e.g. depth of ground water table and aggressive waters; iii) geodynamics phenomena like landslides and sand liquefaction and, iv) physical and mechanical properties of rocks and soils.

The process of map compilation comprised several phases (Dahms 1981; IAEG 1981; Mesina 2006; Muceku and Lamaj 2009; Muceku and Dushi

2011; Muceku 2012; Grana *et al*., 2013) and was based on the aforementioned criteria: i) data collection and literature review, ii) field mapping and geotechnical investigation, iii) laboratory analysis, iv) interpretation and correlation of the date obtained from field-laboratory works and, iv) preparation and publication of the geotechnical map together with text.

In the first phase, published and unpublished data about the lithological and hydrogeological characteristics, geodynamics phenomena and physical and mechanical properties of rocks and soils (Shehu and Dhima 1983; Zeqo *et al*., 1995; Guri *et al*., 1999; Xhomo *et al*., 1999 Muceku and Zeqo 2002; Xhomo *et al*., 2002; Muceku *et al*., 2008; Aliaj 2010; Eftimi 2010; Pambuku 2015) were collected, studied and reviewed. The second phase concerned the field mapping and geotechnical investigations. This phase was carried out at the determined site and at the scale 1:25 000 to 1:50 000 (Muceku *et al*., 2018) to evaluate soil and rock types, soils thickness, weathering crust of rocks, faulting zones and discontinuities, hydrogeological characteristics (ground water table and aggressive water), fluvial and coastal changes and mass movements of the outcropping rocks and soils. Moreover, during this phase many explorations works (pits 3.0-5.0m and boreholes10.0-30.0m deep) were completed and soils and rock samples were collected for laboratory analysis to determine the physical and mechanical properties such as the particle size analysis, bulk density, Atterberg's limits, moisture content, specific density and uniaxial compressive strength test. The data were processed and analyzed in terms of geotechnical map compilation and publication of map's text. Furthermore, based on the physical and mechanical properties and geotechnical classifications (Brown 1981; ASTM 2011) of soils and rocks, the Albanian territory was classified into seven geotechnical zones: i) zone of strong rocks, ii) zone of moderately hard rocks, iii) zone of weak rocks, iv) zone of very weak rocks, v) zone of cohesionless soil, vi) zone of cohesive soils and, vii) zone of organic soils etc. In addition, the geotechnical map illustates soils thickness, ground water table level, aggressive water, river and hill erosion, earth flow, earth slides, rock falls, debris slides, subsidence, liquefaction and tectonic zones, the river system, lakes, road network and the residential areas (village, town).

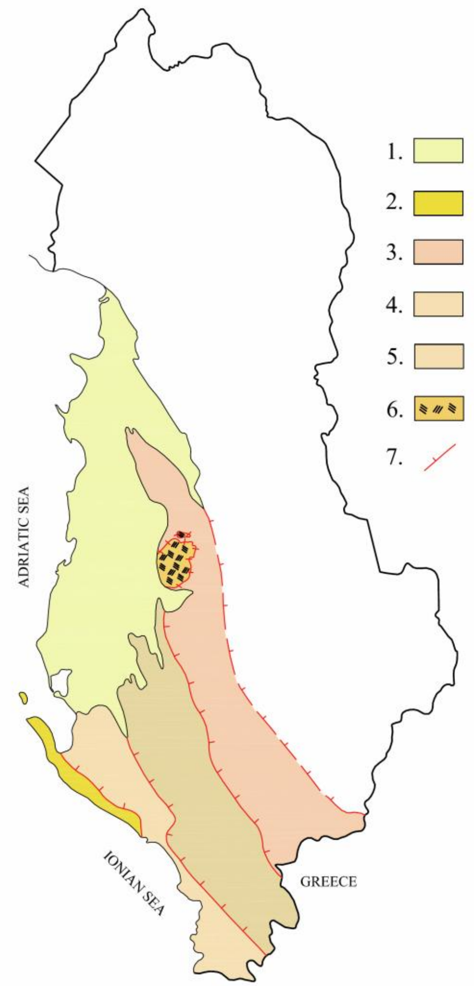

Fig.1: Geotectonic units of southwestern part of Albania and the studied area (Xhomo *et al*., 1999)**1-**PeriAdriatic depression, **2**- Sazani, **3**- Ionian geotectonic unit, **3-5**-Ionian geotectonic unit (Berat, Kurveleshi and Çika belt), **6**-Evaporites of Dumre**, 7**- Thrust fault.

3. RESULTS AND DISCUSSIONS

The results obtained from the previous studies, field and laboratory works for the Sazani, PeriAdriatic Depression and Ionian geotectonic units are in this section reported and discussed. They are a means to address the compilation of the geotechnical map at scale 1:200 000 based on the aforementioned criteria as they make up the key geo-factors related to foundation problems. A brief review of these geo-factors is here made:

3.1. Lithology

Figure 2 depicts the investigated region lithologically consisting of gravels, sands, silts and clay soils, flysch, molasses, limestones and gypsum rocks. Soil deposits were found in the delta of the river and valleys (alluvium deposits) of Drini (Lezha area), Mati, Ishmi, Erzeni, Shkumbini, Semani, Vjosa and Bistrica and in the Adriatic and Ionian coast (beach, lagoon and swamp deposits) and in the hill and mountain slopes (diluvium deposits). Mountain and hill chains with a northwest – southeast extension and elevation range from 100.0-500.0m (west) to 1500.0-2189.0m (M. Nemerçkës, south) consist of rock formations.

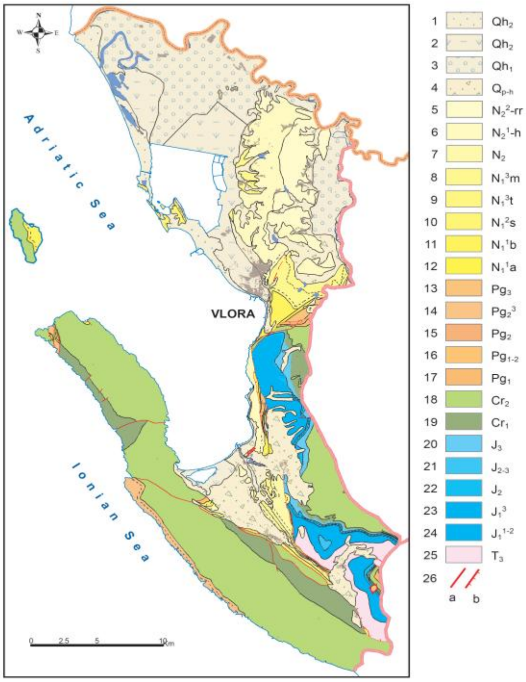

Fig. 2: A part of Albanian geological map (Vlore region), scale 1:200 000. (Xhomo *et al.*,2002). **1**. Holocene-Qh_2-beach sand; **2**. Holocene-Qh_2-lagoon and swamp deposits, clay, silt and organic matter; **3**. Holocene-Qh_1-alluvial and proluvial deposits, gravel, sand, clay, silt; **4**. Pleistocene-Holocene-Qp-h-deluvial deposits, silt-sand-gravel mixture; **5**. Middle Pliocene-N_2^2rr (Rrogozhina unit), conglomerate and sandstone; **6**. Lower Pliocene-N_2^1h (Helmasi unit), claystone and siltstone; **7**. Pliocene-N_2, claystone, siltstone and sandstone; **8**. Messinian-N_1^3m, massive sandstone, gyps, claystone and siltstone; **9**. Tortonian-N_1^3t, claystone, siltstone and sandstone; **10**. Serravallian-N_1^2s, claystone, siltstone and sandstone; **11**. Burdigalian-N_1^1b, marl claystone, marl, siltstone and sandstone; **12**. Aquitanian-N_1^1a, flysch, claystone-siltstone-sandstone intercalation; **13**. Oligocene-Pg_3, flysch claystone-siltstone-sandstone intercalation; **14-17**. Paleocene-Upper Eocene-Pg_1-Pg_2^3, bedded limestone; **18**. Upper Cretaceous-Cr_2, dolomitic limestone, dolomite; **19**. Lower Cretaceous-Cr_1, limestone; **20-24**. Lower-Upper Jurassic-J_1-J_3, limestone and dolomite; **25**. Upper Triassic-T_3; **26**. (a) fault, (b) thrust fault.

3.2. Hydrogeology

The region consists of several hydrogeological complexes (Muceku and Zeqo 2002; Muceku and Lamaj 2005; Muceku *et al*., 2009; Muceku and Lamaj 2009; Eftimi 2010; Muceku 2011; Muceku and Dushi 2011; Muceku 2012; Pambuku 2015; Muceku *et al*., 2018) like gravels, sands, molasses, flysch, gypsum and limestone complexes. The ground water in the studied area is mainly related to the gravels, sands, multiple and mixed hydrogeological complexes (intercalation of gravels layers with sand layers) which could be met in the rivers delta and valleys of Drini (Lezha), Mati, Ishmi, Erzeni, Shkumbini, Semani, Vjosa and Bistrica and in the Adriatic and Ionian coast and form locally important aquifers (water wells) for the family and regionally important aquifers from which are supplying several residential centers with water of very good quality. The ground water table in the coast area is from 0.5-0.8 to 2.5-3.0m deep and towards east is from 3.5-5.0 to 7.5-10.0m deep. Chemical elements concentration in the shallow ground waters were measured in the dug well, 4.5-5.5m deep, and ground waters measured in the boreholes from 20.0-30.0m to 100.0-150.0m deep, differ from one geotechnical zone to other. The geotechnical zone of the cohesionless soil consists of the gravel-sand-silt mixtures and sands of good quality. The mean chemical composition of ground waters of Durrës-Kavajë alluvial plain (Lalzi Bay to the delta of the Shkumbini River) is here reported: Na^+ = 8.26-60.04 mg/liter, K^+ = 0.51-2.12 mg/liter, Ca^{2+}= 3.14-8.99 mg/liter, Mg^{2+} = 8.55-30.52 mg/liter, HCO_3^-= 6.55-6.79 mg/liter, CO_3 = 1.20 mg/liter, NO_3 = 1.75-6.3 mg/liter, NH_4 = 1.12-3.75 mg/liter, SO_4 = 1.41-18.12 mg/liter, Cl = 2.2-100.9 mg/liter, Ph = 7.1-7.2 and electrical conductivity ECw = 1.5-10.3 (Muceku and Lamaj 2009; Muceku *et al*., 2018). The ground waters of alluvial plain between the Shkumbini River and Semani River have the mean chemical content: Na^+ + K^+=427.82 mg/l, Ca^{2+}= 97.19mg/l, Mg $^{2+}$ = 185.32mg/l, Fe $^{2+3+}$ = 0.04mg/l, NH_4^+ = 0.07mg/l, HCO_3^- = 994.3mg/l, Cl^- = 388.73mg/l, SO_4^{2-} =385.58mg/l, NO_3^-=176.0mg/l, NO_2^-=0.2mg/l, H_2SiO_3=4.54mg/l, general mineralization= 2665.07mg/l and hardness=56.25 (German grade) (Muceku 2012; Muceku *et al*., 2018). The ground water in the geotechnical zone of organic soils (organic silts and clays highly organic soils-peat) has the following the chemical parameters: Na^+ + K^+ =23381.14mg/l, Ca^{2+}= 876.75mg/l, Mg^{2+} = 2793.76mg/l, Fe $^{2+3+}$ =1.51mg/l, NH_4^+ = 1.4mg/l, HCO_3^- = 566.08mg/l, Cl^- = 41091.25mg/l, SO_4^{2-}=5150.75mg/l, NO_3=0.2mg/l, NO_2^- =0.2mg/l, H_2SiO_3=5.19mg/l, general mineralization= 73863.04mg/l and hardness =765.94 (German grade), (Muceku 2012; Muceku *et al*., 2018).

The elements concentration in the ground water of the geotechnical zone with cohesionless soils found in the alluvial plain of the Bistrica River is as following: Na^+ + K^+ = 12.19, Ca^{2+}= 110.22 mg/l, Mg $^{2+}$ = 18.24 mg/l, Fe $^{2+3+}$

= 0.08 mg/l, NH_4^+ = 0.0mg/l, HCO_3^- = 280.6mg/l, CO_3^{2-} = 0.0 mg/l, Cl^- = 21.3mg/l, SO_4^{2-} = 111.93mg/l, NO_3^-= trace, NO_2^-= 0.0mg/l, PH = 7.18 (Muceku and Dushi 2011). The mean value of the chemical content in the ground water in geotechnical zone of weak rocks (flysch rocks) is: $Na^+ + K^+$ = 63.83mg/l, Ca^{2+}= 119.23mg/l, Mg^{2+} = 44.99mg/l, Fe^{2+3+} = 0.02mg/l, $NH^+{}_4$= 0.0mg/l, $HCO^-{}_3$= 469.70mg/l, CO_3^{2-}=0.0mg/l, Cl^- = 72.78mg/l, SO_4^{2-} = 120.98mg/l, $NO^-{}_3$ = 7.2mg/l, $NO^-{}_2$=0.04 mg/l, PH =7.39 (Muceku *et al.*, 2018). Regarding the ground water in the geotechnical zone of hard rocks samples were collected from the karst springs (Pambuku 2015): i) Blue Eye (Saranda), where mean chemical content value is Na = 5.29-5.52mg/liter, K = 0.84-1.06mg/liter, Ca = 73.15-105.21mg/liter, Mg = 29.18-12.77 mg/liter, Fe^{2+3+}= 0.02-0.12mg/l, HCO_3 = 198.25-210.45 mg/liter, CO_3 = 0.0 mg/liter, NO_3 = 0.74-1.42 mg/liter, NO_2 = 0.0-0.01 mg/liter, SO_4 = 125.51-130.86mg/liter, Cl = 14.2-15.98mg/liter, Ph = 7.68-7.74 H_2SiO_3=1.04-1.3mg/l, general mineralization= 447.96-482.62mg/l and Hardness=16.94-17.64 (German grade), ii) Borshi (Himara), where the mean chemical content value (Pambuku 2015) is as following: Na = 1.61-24.84 mg/liter, K = 0.37-0.39 mg/liter, Ca = 42.08-53.11 mg/liter, Mg = 6.69-8.51 mg/liter, Fe^{2+3+}= 0.04-0.06 mg/l, NH_4 = 0.05 mg/liter, HCO_3 = 164.70-168.36 mg/liter, CO_3 = 0.0 mg/liter, NO_3 = 0.60-1.06 mg/liter, NO_2 = 0.0 mg/liter, SO_4 = 9.47-10.29mg/liter, Cl = 7.10-21.30 mg/liter, Ph = 7.96-8.12, H_2SiO_3=1.56-1.78 mg/l, general mineralization= 447.96-482.62 mg/l and hardness=7.84-8.96 (German grade), iii) Uji i Ftohtë (Vlora) the mean chemical content value (Pambuku 2015): Na = 7.59-11.04 mg/liter, K = 0.8-0.82 mg/liter, Ca = 49.1-54.11 mg/liter, Mg = 10.94-15.2 mg/liter, Fe^{2+3+}= 0.04-0.07 mg/l, NH_4 = 0.01mg/liter, HCO_3 = 167.75-204.35 mg/liter, CO_3 = 0.01-12.0 mg/liter, NO_3 = 1.51-2.05 mg/liter, NO_2 = 0.0-0.01mg/liter, SO_4 = 19.34-19.75 mg/liter, Cl = 15.98-12.43 mg/liter, Ph = 7.83-7.94, H_2SiO_3=1.04-1.04 mg/l, general mineralization=317.95-286.92mg/l and Hardness=10.36-10.08 (German grade).

The data showed that the chemical elements are not aggressive to concrete iron, except for the chemical elements met in the geotechnical zone with organic soils (organic silts and clays highly organic soil-peat), where the ground waters are aggressive to concrete iron due to the Mg^{2+} and SO_4^{2-} values overpassing the limit (Rohde and Becker 1998). Moreover, some aquifers (sands and gravels) located close to Adriatic seaside have low to high amounts of saline waters. The ground water in the molasses and flysch complexes relate to the sandstone and conglomerate layers, which represent the locally important aquifers for the public water wells. Geotechnical mapping for these rocks reported that the water flow of the springs ranges from 0.05 lit/sec to 0.2 lit/sec. The level groundwater level of these complexes is less than 15.0m (Muceku *et al.*, 2018).

The groundwater in the limestone and gypsum hydrogeological complexes relates to karstified and fissured bedrocks. Eftimi (2010) reported that the karst phenomenon is well developed in the carbonate's massif extending along the Ionian coast, from Vlora to Saranda and carbonates massif of Mali i Gjerë. This complex generates several water springs with discharge ranging from 2.5-4.0m^3/sec to 12.0-20.0m^3/sec. Water discharge from the karst springs in the Ionian Sea is 20 m^3/s water. The water is of good quality (Eftimi 2010). Here we can mention Uji Ftohtë which mean discharge is 2.5m^3/s and Syri i Kaltër, largest karst spring in Albania, which mean discharge is 18.4 m^3/s (Eftimi 2010). Field exploration (Muceku and Zeqo 2002; Muceku *et. al*., 2008; Muceku *et. al*., 2018) reported that the ground water in these complexes could be met very deep, e.g. the ground waters in the carbonic formations which are the effluents of the Ionian Sea. Many springs flow out of these formations. They are in contact with the flysch formations. The latter are located in south of the investigated area and discharged in the sea. Caves and sinkholes have been created in the Dumreja gypsum rocks by the karst's development. Eighty-five karst lakes have been created from water surface ranging from 0.005- 0.375 km^2 (lake of Çartallozi-Degë from 8.75 to 9.7 km^2) and 14.2 km^2 (lake of Seferani and Çestinja). Springs flow out of this formation with a discharge from 0.028-0.166 lit/sec up to 0.194-0.416 lit/sec. The ground water along this complex relates to sinkholes, caverns and fissures. It could also be met very deep.

3.3. Geodynamics phenomena

Neotectonics and seismicity: The investigated area comprises the Sazani and Ionian geotectonic zones which are part of the external tectonic zones and the PeriAdriatic Depresion (Aliaj *et al*., 2010). The Sazani and Ionian zones consist of carbonate formations dating Cretaceous-Paleogene and carbonate formations dating Mesozoic-Eocene and flysch dating Oligocene-Lower Miocene, respectively. The PeriAdriatic Depresion, which extends in the west of the external tectonic zone, from the Vlora-Tepelena transversal fault (south) to the Shkodra- Peja fault (north), comprises the flat areas and hills of the Albanian lowlands and molasses formations that are deposited in the Middle Miocene-Pliocene and is intensely influenced by post-Pliocene compressional movements and Pliocene-Quaternary Foreland in Adriatic and Ionian off-shore (Aliaj *et al*., 2010). This area is strongly affected by active thrust and back-thrust faults, reverse fault, normal fault, strike-slip, flexure and diapir evaporite dome types (Aliaj *et al*., 2010). Aliaj *et al*., (2010) said that one longitudinal and two transversal active fault zones could be met: i) the Ionian-Adriatic thrust fault zone, NW to almost NNW tendency, ii) the Shkodra-Tropoja normal fault zone with NE tendency and, iii) the Elbasani-Dibra normal fault zone, NE tendency (Aliaj *et al*., 2010). As earthquake events from moderate (M= 5.5-5.9) to large magnitude (M> 6.5) have been recorded, it could be concluded that it is characterized by high seismic activity (Aliaj *et al*., 2010).

Landslides: The present zone is highly affected by mass movements. The types, distribution and their consequences are here briefly described. The present results are obtained from a detailed engineering geological mapping carried out in this area at the scale 1:25000 (Muceku *et al*., 2008). Most of the area represents a hilly terrain with angles varying between 11^o-25^o to 35^o-55^o and consists of rocks with low geotechnical parameters (very weak and weak rocks) and soils— the source for mass movement phenomena. Mass movement occurrences in this zone and their location show that their activity is closely related to the geomorphology, lithological formations, geotechnical properties of bedrocks and soils, seismic and neotectonic activity, precipitation and anthropogenic activities. The mapped landslides on studied area are classified based on earth flow, earth slides, rocks fall and debris slides (Cruden *et al.,* 1996). Earth slides and earth flow occurred on the hill slope areas consisting of molasses and flysch rocks. They are 15.0-35.0m to 80.0 m long, 15.0-40.0 m to 110.0 m wide, and 1.7 - 4.0m to 7.0 - 8.5m thick. The earth slide body consists of inorganic silts and clays with sands and gravels. The earth flows are 20.0-50.0 m to 60.0 m long, 8.0-25.0 m up to 40.0 m wide, and from 1.0 - 3.0m to 4.5 - 5.5m thick. The rocks fall and debris slides could be met in the southwest and south of the studied area. They occurred on the limestone rocks with an extension from Vlora-Tepelena to Konispol-Përmeti zone. The rockfalls and debris slides materials consist respectively of broken limestones rocks (cobbles, blocks) and gravels-sands mixtures with little fines. These phenomena mostly occurred on hill slopes with angle exceeding 45^o. The debris slides are 10.0-25.0m to 40.0 m long, 5.0-15.0 m to 60.0 m wide, and 0.7 - 1.5m to 2.5 - 3.5m thick. Earth slides occurred in hill slopes that consist of molasses and flysch rocks prevail. Field work data recorded 1270 landslides events. These landslides lead to major disasters (1-2 stores households destroyed and damaged, affected road infrastructure and agriculture) hampered the development of the area.

Subsidence: Many sinkholes and caves in the Dumrea region were created due to dissolution of gypsum depositions. It is an ongoing well-known and phenomenon. Eighty-five lakes have been formed due to this phenomenon. Four sinkholes were formed in 1982, 1998 and 1999 (Fierza village). A sinkhole with a diameter of 30.0 m and 100.0 m deep was formed in 2009 in the village of Shala (Muceku *et al*., 2018). Consequently, this region represents a real risk to local population.

Liquefaction: The studied area is subject of the sand liquefaction phenomenon. Aliaj (2010) said that in last century occasionally have been occurred the sands liquefaction in Albania, which we are briefly discussed here. The earthquake of June 01, 1905 with magnitude M=6.6 triggered sands liquefaction along Drini and Buna River. As a result, subsidence ground fissures were created. The earthquake of December 27, 1926, with magnitude M=6.0 caused sand liquefaction (sand-boils type) in the Shijaku and Durrësi region. Subsidence and ground fissures were caused in the following events: the earthquake of August 17, 1948, with magnitude M=5.5 created sand liquefaction (sand-boils type) in Trush village, Shkodër, where some subsidence were created; the earthquake of March 18, 1962, in Fieri, with magnitude M=6.0.Sand liquefaction was triggered on river's bank of Gjanica (Rërës village, Fieri) and Vjosa (Novosele and Mifolvillages) and Semani delta area. The earthquake of September 1, 1959, in the Kuçi village, Lushnje region, with magnitude M=6.2 caused sand liquefaction in Ngurëz e Vogël and Arapaj village (Lushnje region); Kurjan dam, Struma and Çuka village, (Fieri region); Kozara village (Kuçove region); Çiflik-Poshnje and Pashalli village (Berat region). The earthquake of April 15, 1979, with the magnitude M=6.9 and epicenter in the Montenegrin coast, hit the Shkoda region. It triggered sands liquefaction in the riverbanks of Drini and Buna and Velipoja region (Dibra, 1983; Shehu and Dhima, 1983). The field investigations involved the geotechnical mapping, boreholes, SPT tests, seismic observations and laboratory analysis carried out from 2000 to 2018 (Muceku and Zeqo 2002; Muceku *et al*., 2008; Muceku *et al*., 2018) to identify potential liquefaction areas. Several potential liquefaction areas along the Drini River extending from Bahçallëk Square to Shirq-Trush-Dajç-Reç village were identified in addition to those in Adriatic coastal area (Velipoja village); the area between Shëngjini and Tale villages; from Hamallaj to Bishti i Pallës (Lalzi Bay-Adriatic Coast); in Durrësi urban area; in area between the delta of Shkumbini River to Karavasta Lagoon; several areas in first terrace and delta of Semani and Vjosa River and along the seaside from Vlora to Zvërneci Village.

3.4. Physical and mechanical properties

Many soil and rock samples were collected during the field works (Muceku *et al*., 2018). Once collected, laboratory investigation was carried out and data about the physical and mechanical properties (Shehu and Dhima 1983; Zeqo *et al*., 1995; Guri *et al*., 1999; Muceku and Zeqo 2002; Muceku *et al*., 2008) were used for the compilation of the Albanian geotechnical map at the scale 1:200 000. The results of the physical and mechanical properties of soils and outcrop rocks, including the particle size analysis, bulk density, Atterberg’s limits, moisture content, specific density and uniaxial compressive strength are in the Table 1-4 reported.

Table 1. Type of soils

Geotechnics zone	Gravel	Sand	Silt	Clay	
	%	%	%	%	USCS
Cohesionless Soils (RT)	57.7 63.3	20.6 26.3	12.1 24.8	1.9 3.5	GM-GP
(RB)	47.8 53.3	24.7 29.5	16.4 26.3	2.2 4.1	SC, GP
Cohesionless Soils-BSa		80.4 84.4	8.3 12.1	6.8 7.1	SM, SW
Cohesive Soils (Pro, Del)		36.2 42.2	48.7 68.5	9.10 25.3	ML, CL
	0.0 7.5	20.2 31.4	54.8 58.6	11.3 19.2	ML, CL
Organic Soils	1.2	10.6 19.7	55.5 61.2	32.7	OH, OL

RT-river terrace soils; RB-river bed soils; Bsa-beach sands; Pro & Del-proluvial and deluvial soils;

Table 2. Physical properties of soils

Geotechnics zone	L_L	P_L	W_n	γ	γ_o	USCS
	%	%	%	kN/m^3	kN/m^3	
Cohesionless Soils (RT)	-	-	0.0 35.7	19.9- 21.6	24.0 26.3	GM-GP
(RB)	-	-	18.8 25.7	19.2 19.6	26.42 26.50	SC, GP
Cohesionless Soils-BSa	-	-	25.2 33.8	17.0 17.5	26.1 26.5	SM, SW
Cohesive Soils (Pro, Del)	29.8 33.8	20.7 21.5	24.9 29.4	18.8 19.1	26.6 27.1	ML, CL
	37.4 40.5	21.2 22.8	22.7 26.4	19.0 19.5	26.7 26.9	ML, CL
Organic Soils	45.5 54.5	32.5 35.8	44.8 48.3	16.0 16.9	27.0 27.1	OH, OL
	107.0 113.0	74.0 85.0	121.0 130.0	10.08 10.59	13.43 15.50	Pt

P_L-Plastic limit; L_L-liquid limit; W_n- natural water content; γ-bulk density; γ_o-specific density;

Table 3. Physical properties of rocks

Nr	Geotechnics Zone	Physical properties		
		W_n	γ	γ_o
		%	kN/m^3	kN/m^3
1	Hard rock	0.11-0.14	26.7-27.4	27.2-27.9
		0.01-0.04	2.72-2.77	28.0-28.4
2	Moderately hard rock	0.27-0.31	25.76-26.94	27.94-28.97
		-	22.4-25.8	24.7-27.3
3	Weak rock	2.5-3.4	25.21-25.40	25.94-26.01
		4.7-1.9	24.76-25.22	27.62-28.10
4	Very weak rock	4.5-7.3	22.20-23.20	24.60-27.90
		2.7-3.9	24.76-25.22	25.35-25.81

W_n- Natural water content; γ-bulk density; γ_o-specific density;

Table 4. Mechanical properties of rocks

Nr	Geotechnics Zone	Mechanical properties	
		τ_c MPa	Rock type
1	Hard rock	89.1-99.4	L_M
		580-632	L_{ThB}
2	Moderately hard rock	25.84-47.66	S_{ast},C_{ong}
		26.1-31.6	G_{yp}
3	Weak rock	6.8-17.7	F_L-S_{ast}-C_{last}
		5.47-8.13	Mo-Cong
4	Very weak rock	2.04-2.43	M_o-C_{ong}
		3.3-3.6	F_L-C_{last}-S_{ast}

τ_c - uniaxial compression strength; L_M-massive limestones; L_{ThB}-thin bedded limestones; S_{ast}-sandstone; C_{ong}-conglomerates, G_{yp}-Gypsum; F_L-flysch: S_{ast}-C_{last}-sandstones & claystones; M_o-molasses: C_{ong}-conglomerates; M_o-molasses: C_{last}-claystones; F_L-flysch: C_{last}-S_{ast}-claystones &sandstones; Claystones & sandstone.

3.5. Geotechnical map

The geotechnical map at the scale 1:200 000 for the Sazani, PeriAdriatic Depression and Ionian geotectonic zones was compiled based on many studies, field and laboratory works and the application of the geotechnical classifications (Brown 1981; ASTM 2011). Geotechnical zones and sites were classified based on lithology and physical-mechanical properties of rocks and soils (Fig. 3). However, hydrogeology and geodynamics phenomena were of greater importance. Seven geotechnical zones were defined based on these characteristics: i) zone of strong rock, ii) zone of medium rocks; iii) zone of weak rocks, iv) zone of very weak rocks, v) zone of cohesionless soils, vi) zone of cohesive soils and, vii) zone of organic soils.

i) Geotechnical zone of hard rock-L.

This zone consists of limestones with thin-medium strata ranging from 0.2-0.3m to 1.0-1.5m, light gray in color. It is located in the south and southwest of the area.

ii) Geotechnical zone of medium strong rocks-M_{co}.

It consists of medium strength rocks-molasses, which are the conglomerate formations. This zone is found between of the geological unit of Rrogozhina and lie from Durrësi-Kavaja up to Lushnja-Vlora.

iii) Geotechnical zone of weak rock-*Fl_{Sa}, M_{sa}, M_{co},*

This geotechnical zone consists of flysch, molasses and gypsum rocks. The flysch consists of combination of clay stones and siltstones layers, whereas the molasses are represented by sandstones and conglomerates.

iv) Geotechnical zone of very weak rock-M_{si}, M_{cl},Fl_{cs}.

It is represented by molasses and flysch rocks. It is a combination of clay stones and siltstones layers.

v) Geotechnical zone of cohesionless *soils:*

There are two geotechnical sites: v.1) the gravel-sand-silts mixtures-GM and, v.2) sands (SW, SP) and sands with fines (SM, SC).

v.1) The gravel-sand-silts mixtures-GM: consists of soils rich in gravel-sand-silts mixtures, saturated and medium to dense state. This zone extends along the rivers delta and river’s valleys of Drini

(Lezha), Mati, Ishmi, Erzeni, Shkumbini, Semani, Vjosa and Drinosi Bistrica. Here, the soils are 70.0-80.0 m (River basin of Ishmi) to 230.0-250.0 m thick (Divjaka area).

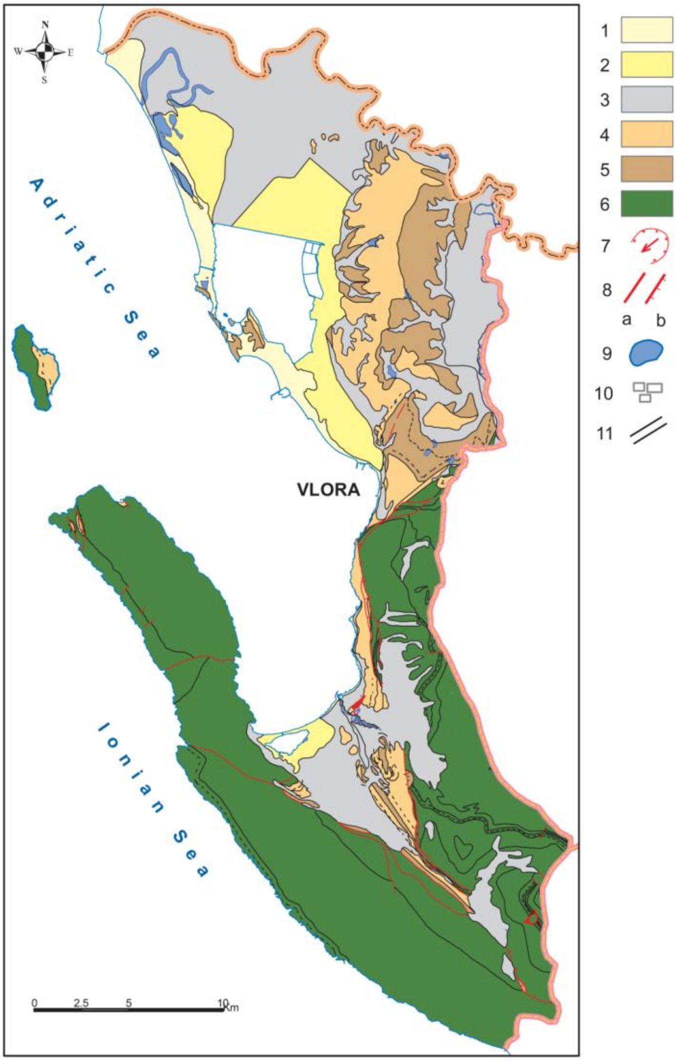

Fig. 3: A part of Albanian geotechnical map (Vlore region), at the scale 1:200 000. **1.** Geotechnical zone of cohesionless soils-sands (SW, SP, SM, SC); **2.**Geotechnical zone of organic clays, silts and peat (OL, OH, Pt); **3.**Geotechnical zone of cohesive soils, inorganic silts and clays (ML, CL); **4.**Geotechnical zone of very weak rock, claystones-siltstones-sandstones intercalation (Fl_a, M_a, M_o); **5**. geotechnical zone of weak rock, sandstone, conglomerate, marl (S_{ast}, C_{ong}, M_{ar}); **6.**geotechnical zone of hard rock, limestone, dolomite(L_M, L_{ThB}, D_{ol}); 7. landslide; **8. (a)**fault, **(b)** thrust fault; **9.** Lake; **10.** Residential center; **11.** Traffic road.

v.2) The sands (SW, SP) and sands with fines (SM, SC).

They lie along Adriatic and Ionian coast, creating the sandy beach. These soils are represented by clean (SW, SP), sands, sand-clay (SC) and sand-silts mixtures SM. Here, the soils are 2.0 5.0 to 12.0-30.0 m thick.

vi) Geotechnical zone of cohesive soils

They are represented by the inorganic silts (ML) and clay (CL) with very fine sands soils type, low plasticity and moderate to stiff consistency. These soils could be met in most of the area, creating the flat areas and hill slopes. Generally, they are 2.5-5.0m to 12.0-15.0m thick.

vii) Geotechnical zone of organic soils-OL, OH, PT.

These soils consist of organic silts and organic silty clays of low plasticity (OL), organic clays of medium to high plasticity (OH) and highly organic soil-Peat (PT). They could be met along the western lowlands, from Shëngjini Village (north) to Vlora town (south) in east of sandy beach belt.

These soils are from 5.0-6.0 m to 10.0-15.0 m thick. In addition, the geotechnical map at scale 1:200 000 shows these geodynamic phenomena occurred: erosion, earth flow, earth slides, rocks fall and debris slides, subsidence, liquefaction areas and tectonic zones, which are represented by the red colored symbols as explained in the legend (Fig.3). Moreover, river system, lakes, road network and the residential areas (villages, town) are also given. Consequently, the geotechnical map represents a very important database for civil engineering.

4. CONCLUSIONS

The Geotechnical map of Albania at the scale 1:200 000 was compiled based on geofactors like the lithology, physical-mechanical properties of rocks and soils, hydrogeology and geodynamic phenomena. In addition, field and laboratory works and the application of the geotechnical classifications were carried out for the geotechnical map at the scale 1:200 000 for the Sazani, PeriAdriatic Depression and Ionian geotectonic zones classified into seven geotechnical zones: i) zone of strong rocks, ii) zone of moderately hard rocks, iii) zone of weak rocks, iv) zone of very weak rocks, v) zone of cohesionless soil, vi) zone of cohesive soils and, vii) zone of organic soils etc.

The area is highly affected by mass movements, neotectonics and seismicity, subsidence (sinkholes and caves in the Dumre area) and sand liquefaction phenomenon (Adriatic coast and Lowland). The mapped landslides on studied area are classified into earth flow, earth slides, rocks fall and debris slides. Earth slides prevail. They occurred on hill slopes that consist of molasses and flysch rocks. Field work reported that about 1270 landslides were mapped in this area. These landslides lead to major disasters (1-2 stores households destroyed and damaged, affected road infrastructure and agriculture) hampered the development of the area.

Geotechnical mapping reported that the geotechnical zone of organic soils (OL, OH, PT) consists of organic silts and organic silty clays of low plasticity (OL), organic clays of medium to high plasticity (OH) and highly organic soil-peat (PT) making civil engineering activities very difficult.

Chemical analysis of the ground waters reported that most of chemical elements are not aggressive to concrete iron, except forthegeotechnical zone of organic soils (organic silts and clays highly organic soils-peat), where the ground waters are aggressive to concrete iron due to the Mg^{2+} and SO_4^{2-} values overpassing the limit.

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