THE LITHOLOGICAL INFORMATION OF RAMNICU VALCEA SEISMIC SITE BASED ON DRILL CUTTINGS AND IMPLICATIONS IN SEISMOLOGY

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ABSTRACT

Shear wave velocity variance at the shallower parts of the soil profile can be caused by the presence of the groundwater, grain size distribution, density, consolidation, and degree of cementation. According to TSC 2007, the local site classes are named from Z1 to Z4 denoting hard/very stiff formations to weak/very loose formations, respectively. The Quaternary sediments of Ramnicu Valcea city were penetrated recently by a 12” drill hole at depth of 40 m. During the drilling process, the drill cuttings were sampled, labeled, and packed up. Drill cuttings were caught as composite samples that reflect the various lithologies drilled over a 3 m interval. In the last 4 m the sample rate increase to 1 sample per meter. The main objective of this paper is to build up a lithological profile based mass concentration of drill cuttings sample. To do this, the grain size analysis was performed in order to obtain the mass concentrations for gravel, sand, mud for each sample. The lithology of the borehole profile is represented as a mass percentage of different textural classes. The result of the grain size analysis shows that the upper and bottom part of the bottom predominate the gravel and the middle part is mostly muddy. The sand content doesn’t look to follow a pattern, but the highest peaks in sand content are noticed after the gravel decreases and before the gravel increases. The lithological profile of a seismic site helps us to understand the geological properties that may influence the propagation of seismic waves. Lithological information associated to every seismic site helps us to better understand the local site effects that play an important role in modifying the intensity of ground shaking. In that way, the abnormal variation of PGA (peak ground acceleration) could be explained.

Keywords: lithological information, drill cuttings, grain size analysis, lithological profile.

INTRODUCTION

The propagation of seismic waves through different rock layers from focus to the surface is strongly influenced by the local geology and affect the ground motion characteristics. The rock layers have a significant effect on the level of ground motion (Eker et al., 2012; Drennov et al., 2013). The Turkish Seismic Code (TSC 2007), classify the soils into four main groups relating to their soil properties. The combination of different lithologies and the thickness of the top layers give the local site class. According to TSC 2007, the local site classes are named from Z1 to Z4 denoting hard/very stiff formations to weak/very loose formations, respectively.
M. Kuruoglu and T. Eskisar (2015) performing a dynamic site-response analysis, and show that for alluvial location of the study area, the limits of spectrum defined in Turkish Seismic Code (TSC 2007) is accessed or exceeded. The type formations in the studied area are represented by clays/silts of high/low plasticity and clayey sand/clayey gravel layers. The analyses along Izmir Fault for an earthquake with Mw=6.5 shows PGAs between 0.40g and 0.62g. The lowest PGA is calculated where the depth to bedrock is shallower (10-30m), and high PGA would be achieved where the loose alluvial sediment with a shallow groundwater table is present. The IBC 2009(International Code Council, ICC2009) site classification describes the site classes depend on average shear wave velocities to 30 m. The site classes are represented in table 1.

Table 1 IBC site class definitions using the average shear wave velocity to 30m.

Site class	Soil profile name	Average properties in top 30 m Soil shear wave velocity, Vs (30), (m/s)
A	Hard rock	V_s (30) > 1500
B	Rock	760<V_s (30) ≤ 1500
C	Very dense soil and soft rock	360<V_s (30) ≤ 760
D	Stiff soil profile	180 ≤ V_s (30) ≤ 360
E	Soft soil profile	V_s (30) <180

Additionally, the TBC classification (Turkish Building Code 1998) site classes are based on an evaluation of the lithology of the surface stratum along with the shear wave velocity. This classification describes four soil groups (A, B, C, D) with shear wave velocities bigger than 1000ms for massive volcanic/metamorphic rocks (A) and shear velocities smaller than 200ms for deep alluvial layers with a high water table, loose sand, soft clay, silty clay.
Shear wave velocity variance, especially at the shallower parts of the soil profile can be caused by the presence of the groundwater and the fluctuations of its level. More than that, grain size distribution, density, consolidation, and degree of cementation can affect shear wave velocity results (Inazaki, 2006 and Eker et al. 2012)
The main purpose of the paper is to get lithological information from drill cuttings sample. Because the drilling process involves mechanical deformation of the samples and mixing of the different lithology layers, it was used the grain size analysis in order to get the most reliable lithological information of these mixed interval samples.

GEOLOGY OF THE STUDY AREA

The Quaternary sediments of Ramnicu Valcea city were penetrated recently by a 12” drill hole at depth of 40 m. These sediments were located in Getic Depresion, the most internal and deformed part of the South Carpathians foreland. The Getic Depression is known as hilly area that links the Moesian platform with the South Carpathians. The Getic Depression is located between the Dambovita River to the east and the Danube Valley in the west. To the south, the Getic Depression is bounded by the Pericarpathian fault. Although it’s latest Cretaceous to Late Miocene sediments are buried beneath the post-tectonic cover of the Dacian basin, subsurface data show that these were thrust over the Moesian platform (Schmid et al., 2008). The basement of Getic Depression is Moesian type (Wallachian sector) and is bended nearby Southern Carpathians (Săndulescu, 1984).

Starting from Upper Campanian (Late Cretaceous), the Getic Depression acts like a sedimentary basin till the end of Miocene (Late Sarmatian) (Sandulescu, 1984). The deposition of the Getic Depression sedimentary sequence was determined by large-scale tectonics of South Carpathians evolution and regional eustatic changes that have created five sedimentary cycles by third order, from Upper Cretaceous to Middle Miocene. The Upper Campanian–Upper Miocene sediments of the Getic Depression are mostly siliciclastic with small intercalations of tuffs, salt and limestones. These formations are less than 5 km thick and were deposited in a basin which is less than 100km wide (Răbăgia et al., 2011a, Krézsek et al 2013).

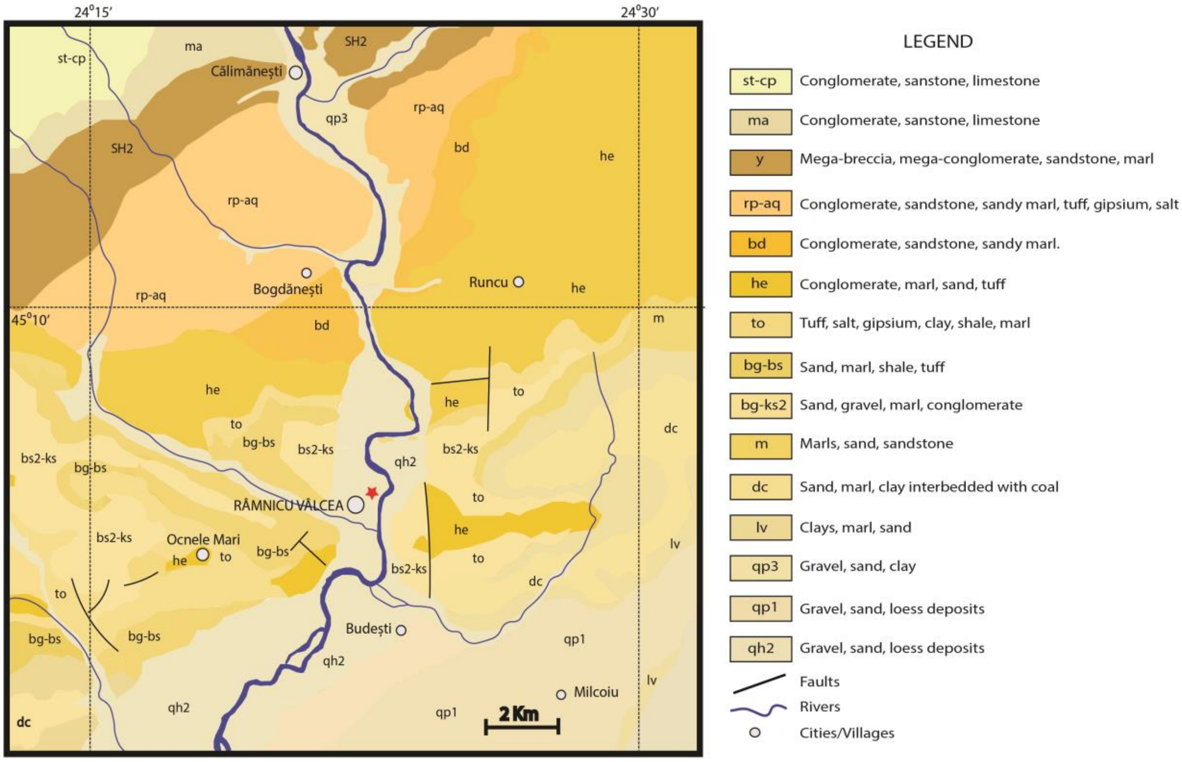

Figure 1 - *Geological map of studied area (From 1:200000 Geological map L-34-XXV of the Geological Institute, 1968), and the location of borehole (red star)*

The Cretaceous-Middle Miocene deformed sediments of Getic Depression are covered by an Upper Miocene-Quaternary post-tectonic cover which extend southwards overlying the Moesian foreland. These formations are manly composed by: claystones, sands, coals, gravels, marls and loess deposits (Figure 1).

METHODS

The analysed samples come from drill cuttings which were sampled labelled and packed up. Drill cuttings were caught as composite samples that reflect the various lithologies drilled over a 3 m interval, but in the last 4 m, the sample rate increase to 1 sample per meter. So, from the surface to the bottom of the borehole (40m) were sampled a total of 16 samples. Cuttings are the small pieces of rock that are chipped away by the bit while a well is being drilled. Recently detached rock fragments are transported and mixed by the drill-mud from the bit to the surface where they can be caught and analysed. Drill cuttings are often the only physical lithological data that is recovered from a well and the data obtained from these cuttings are used as supportive information in reservoir and lithological description, geological correlation and formation identification, special, geophysical, geological, or engineering analyses. This borehole has been drilled to install a downhole seismometer in order to minimize the seismic noise.
Grain size is the most fundamental physical property of sediments and geologists and sedimentologists used the grains size information to study the dynamic condition of transportation and deposition; engineers use the grain size to study sample permeability and stability under the load; geochemists use grain size to study kinetic reactions and the affinities of fine-grained particles and contaminants etc.
The analyzed samples weight more than 1 kg and it is known that the larger the analyzed sample the more accurate the grain size analysis. Not the whole sample was used, the original sample was very well mixed and then a random bulk sample was taken (~100g). The bulk samples were labelled with the depth interval and were dried over 24 hours in the oven at around 70C in order to remove the water. The Gross wet-sample weight minus the weight dry samples give us the water concentration.
After the samples have been dried and weighed, the wet sieve procedure was performed. A 62-micron sieve was used to separate the sand from clay and silt and a 2 mm sieve to separate the sand from gravel. Further, from one sample resulted two wet samples per interval. One sample is represented by the gravel that remains in the 2 mm sieve, and another sample is represented by the sand that remains in the 62-micron sieve. Arenitic fraction and ruditic fraction goes again to the oven at around 70 C^{o} to be dried. After approximately 24 hours, the weighting procedure was repeated for the arenitic fraction and ruditic fraction. So, the data has been centralized in a table with the first column represented by depth interval, the second column represented by the mass of the entire dry sample(lutitic, arenitic, ruditic fraction), the third column is represented by the mass of the dry arenitic fraction the next column is represented by the mass of the dry ruditic fraction. The mass of fine fraction presented in all samples was represented by soft, hydratable, and washable clays/silt that was calculated mathematically from dry sample minus the sum of dry arenitic and ruditic fractions. Using wet sieving and the method of drying and weighing twice led to the finding of the fine fraction represented by clay. The drilling process that mixed very well different granulometric classes create very poorly sorted samples. Using the wet sieve procedure to separate the gravel, sand, and

clay/silt represent a trade-off between efficiency and quality results. The last step in the granulometric analysis was to convert the mass of all three granulometric classes in percentage. Also, every sample was selected from the 2 mm sieve the biggest clast. Using a digital micrometer was calculated the maximum grain size founded in each sample. The maximum grain size gives us information about the hydrodynamic conditions existing at the time of deposition and the source of sedimentary rocks.

RESULTS

Raw grain-size data are typically in the form of weight percentages of sediment in various size classes. Grain size analysis, therefore, provides important clues to the sediment provenance, transport history, and depositional conditions (Folk and Ward, 1957). This method was the most reliable method to get lithological information from the cohesionless quaternary sediments which were highly mixed during the drilling process. Because of that, it was impossible to get the real percentage of lithology types using only the microscope, and therefore the granulometric analysis was a very useful tool to obtain a lithological profile of the quaternary sediments.

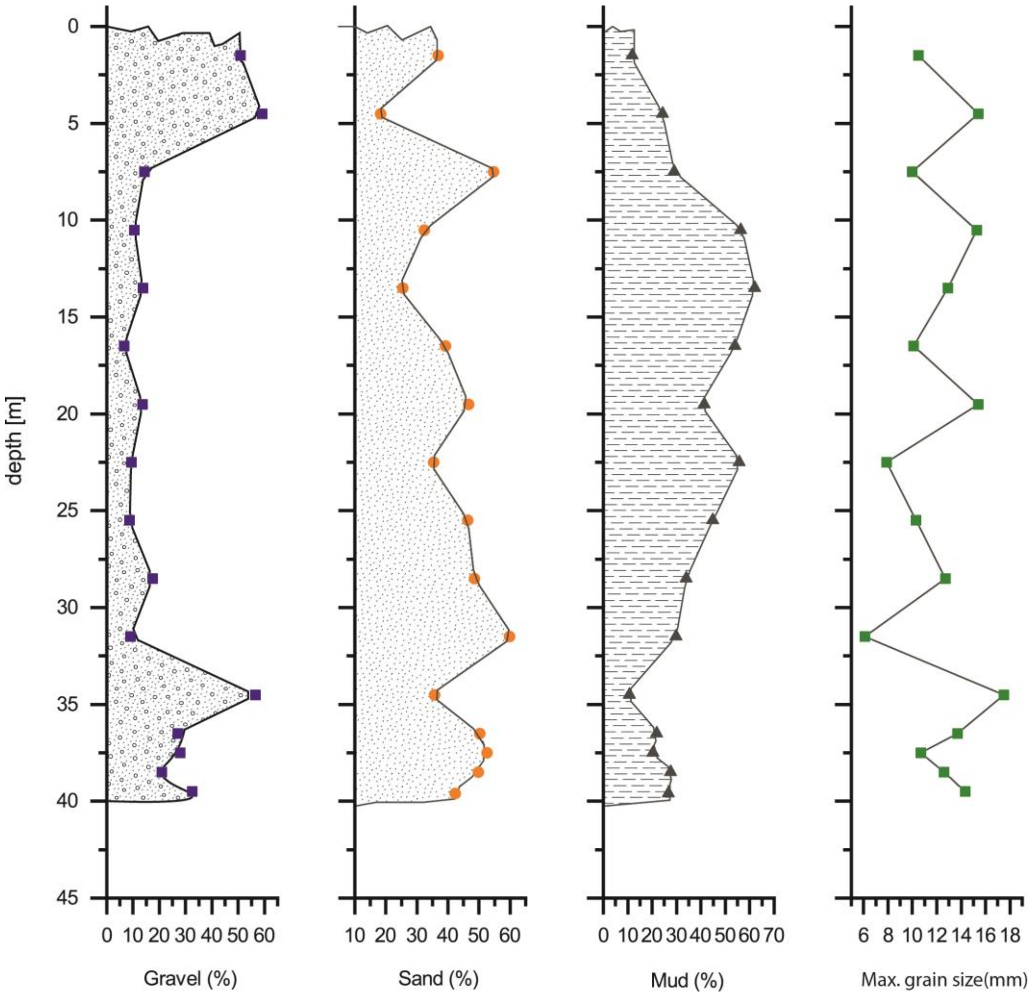

Figure 2 Mass percentage of gravel, sand, mud and the maximum grain size.

In figure 2 are represented the mass concentrations for gravel, sand, mud from 0 m to 40 m depth. In the upper part of the section, the total gravel content is between 50 and 59%. Between 6 m and 33 m, the gravel content decreases to 7-17%. In the lower part of the lithological profile the gravel content increase again. The maximum grain size seems to match with gravel content when the percentage of gravel increases also the grain size increase. This particularity is more visible in the bottom part of the lithological profile. The grain size depends on the type of depositional environment. The high content of gravel is settled in fluvial processes that include the motion of sediment and erosion or deposition on the river bed. Ruditic fraction needs high energy to be transported and should be well correlated with the maximum grain size

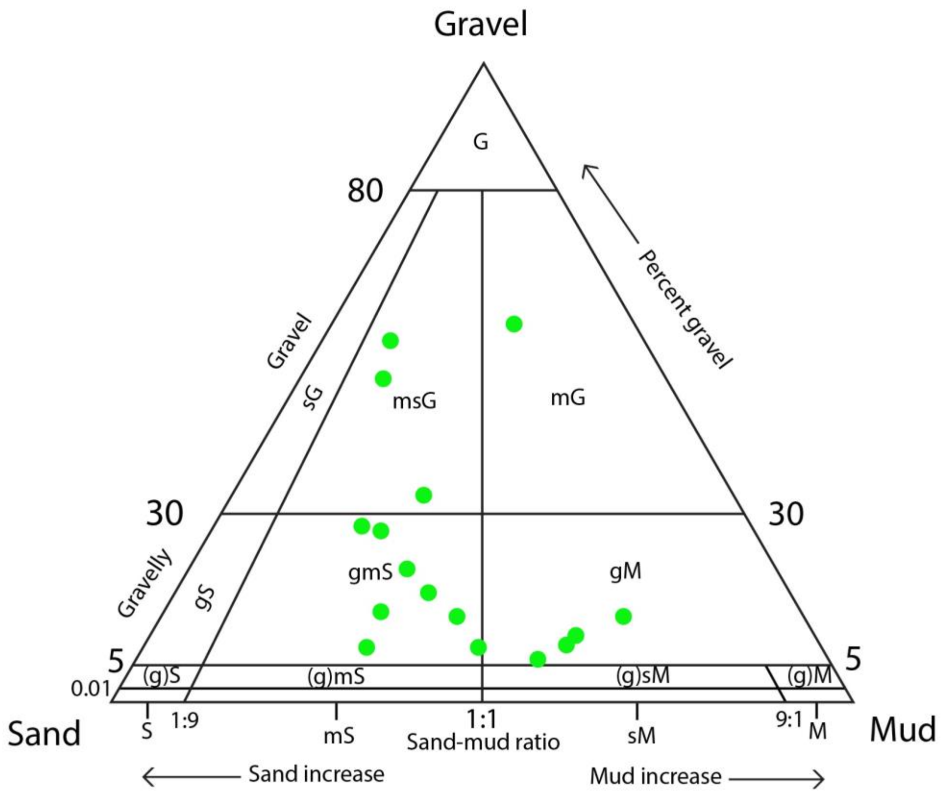

Figure 3. Triangular diagram showing grain-size composition of 15 naturally occurring sediments (textural classes of Folk, 1954, 1980) based on weight percent of their aggregates (mud, sand, and gravel) content as determined by grain-size analysis. The threshold for the recognition of gravel is greater than or equal to 0.01 weight percent. The gravel axis is shown to scale except for the 0.01 value. The sediment classes: M, mud; m, muddy; S, sand; s, sandy; G, gravel; g, gravelly; (g), slightly gravelly

The sand content variate from 61 to 16% and doesn't look to follow a pattern. The highest peaks in sand content is noticed after the gravel decreases and before the gravel increases. That indicates the transition from muddy-sandy gravel (msG) to gravelly mud (gM) sediments and the transition from gravelly mud to muddy-sandy gravel sediments

(Fig.3). The mud content along the lithological profile is inversely proportional to gravel content. The highest mud content is located in the middle part of the lithological profile (6-33m).
In figure 3 is represented the Folk's classification of naturally occurring sediment that contains 15 sediment classes which have been defined by the weight percent of the aggregates. Folk combines silt and clay into mud aggregate and this triangular diagram is designed to reveal the effects of transport on sediment grains. And because of that, the most important criterion is the gravel content. The highest number of the samples are located in gmS (gravelly-muddy sand) class and are fallowed by gM (gravelly mud) class. According to IBC class, the Ramnicu Valcea lithological profile shows loose and soft formations which can be included in E class (soft soil profile).

CONCLUSION

The main propose of this study was to obtain lithological information of Ramnicu Valcea seismic site by analysing the drill cuttings. The grain size analysis was chosen method because it was the most reliable method to get lithological information from the soft quaternary sediments high mixed by the drilling process. The results show the mass concentration of gravel, sand, and mud of all sampled intervals from 0 to 40m depth. To see the predominant lithology of analysed samples, the results were plotted in a Folk triangular diagram.
Lithological information associated with every seismic site helps us to better understand the local site effects that can play an important role in modifying the intensity of ground shaking. Depends on lithologies and the thickness of upper strata, the seismic sites are belongings to different site classes. The analysed samples of Ramnicul Valcea borehole contain soft and loose formations with the highest number of samples located in gmS (gravelly-muddy sand) class and gM (gravelly mud) class. According to IBC class the Ramnicu Valcea lithological profile can be included in class E (soft soil profile). This study represents the first step in dynamic properties of quaternary sedimentary rocks of Ramnicu Valcea seismic site. The lithological information obtained in this study will be correlated with the future seismic measurements to define a better dynamic and elastic properties of the Quaternary sedimentary strata.

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