Determination of the Ground Characterization in Canakkale within the Scope of Liquefact Project

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ABSTRACT

The main objective of this study is the determination of the soil properties of Canakkale test site depending on the EU H2020 LIQUEFACT project titled "Liquefact: Assessment and mitigation of liquefaction potential across Europe: a holistic approach to protect structures/ infrastructures for improved resilience to earthquake-induced liquefaction disasters". The concept of the study includes pre-existing investigations and complementary (in-situ and laboratory) tests. As part of complementary tests, 6 investigation areas had been chosen in Canakkale site and in-situ tests had been performed. In-situ tests can be considered as Standard Penetration Test (SPT), Cone Penetration Test (CPT (CPTU and SCPT)), Marchetti Dilatometer Test (DMT) and geophysical measurements. In the investigation areas, boreholes had been opened to perform Standard Penetration Test. In addition to SPT, CPT and DMT had been carried out. Geophysical measurements that applied during research were downhole seismic, PS-logging, seismic refraction, 2D-Remi, MASW, microtremor (H/V Nakamura method) and 2D resistivity profiling. Seismic refraction, MASW, and microtremor measurements had already been performed in pre-existing studies although the dynamic soil properties had not been measured. Therefore, these properties had been measured by using resonant column and cyclic direct shear test. The general idea is to compare results of the geophysical and other measurements, to identify ground characterization of the site.

DESCRIPTION OF THE SITE AND GEOLOGICAL SETTING

Canakkale takes place in Marmara Region in Turkey. The region is the most important one in terms of industry and population. Except these socio-economical aspects, Marmara is one of the seismologically active regions from geophysical point of view. Map of the region, past earthquakes, study area and the active faults are represented in Figure 1.

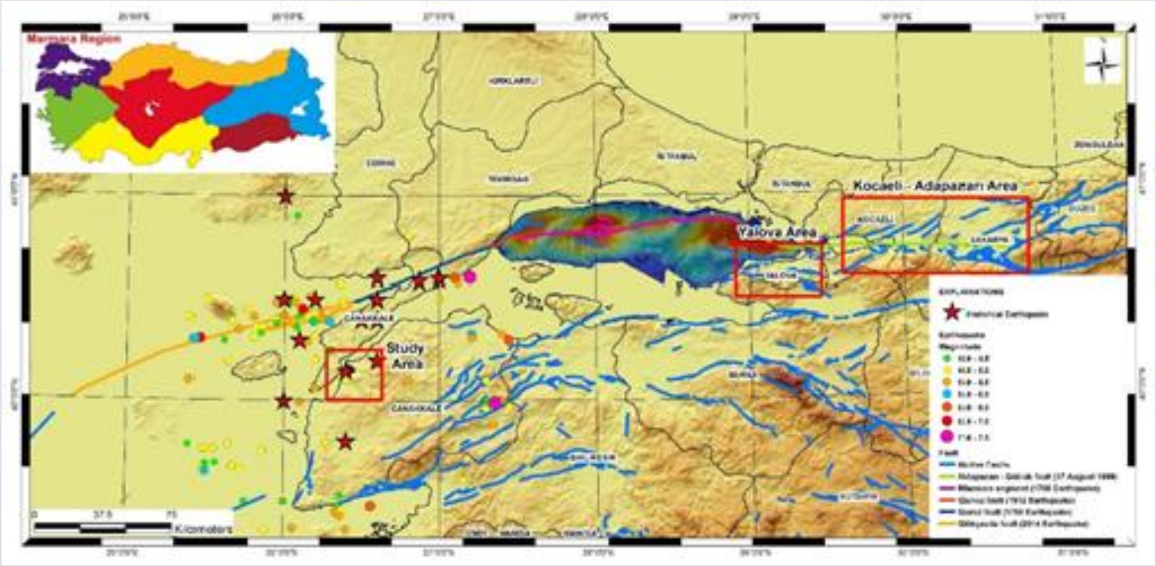

Figure 1 : Marmara Region, past earthquakes, study area and the active faults in the region

3D engineering geological subsoil model was prepared to be used for the identification and characterization of potentially liquefiable soils and is given in Figure 2. The model reveals that the test site includes liquefaction prone areas due to river meander points, estuarine deposits, alluvial ridges and reclamation fills.

Gazhanedere formation (Tmg), Alçıtepe formation (Tmal), Alluvium (Qal) and Artificial fills (Qd) are encountered in the area. The Gazhanedere Formation, as designated by Saltık (1974) at Mürefte city, is widely distributed on the Gelibolu Peninsula, the northern part of the Gulf of Saros and the Strait of Çanakkale (Dardanelles). In the study area, the formation consists of coarse clastics of meandering-river origin containing some coal seams and lacustrine clay deposits. The Alçıtepe formation (described by Önem, 1974), represents shallow marine and lacustrine depositional environments (Yaltırak et al., 1998 and references therein). On the Gelibolu Peninsula, the Alçıtepe formation is made up by sandy limestone, oolitic limestone, sandstone and Mactra-bearing limestone intercalations. In the field area, most commonly involves alluvium formed by stapled sediments. The dispersion as well as formation of these alluvium was realized under the influence of Sarıçay stream. Sarıçay stream primarily accumulated in lowlands having plain nature by carrying the sediments from high levels throughout its previous stream bed as well as its recent bed.

There is an artificial fill area (Qd) with approximately 25 m band width throughout the coast line which is formed under control by Canakkale Municipality. General topography of the field area has low slope land structure (0-10%).

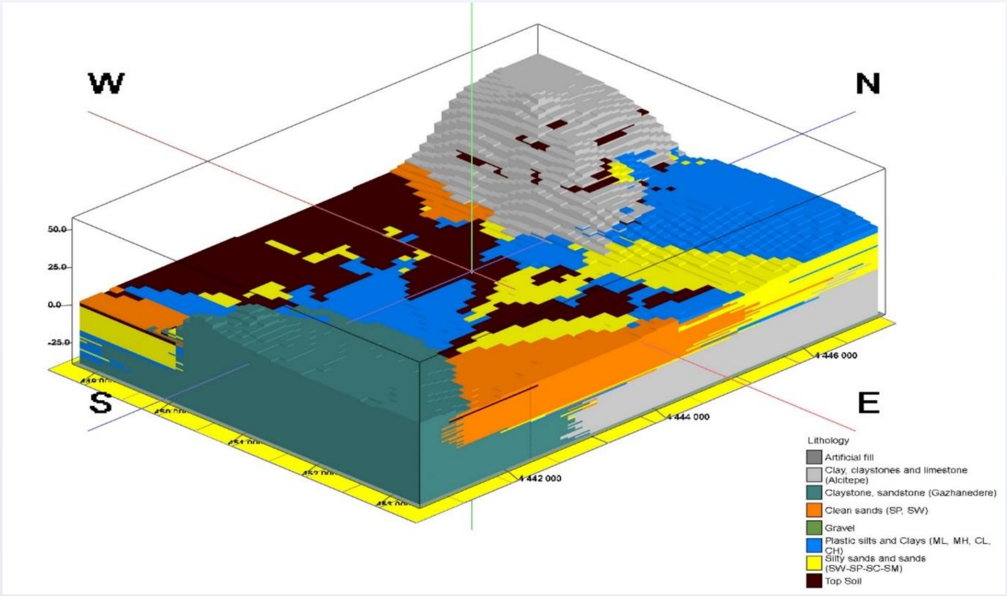

Figure 2: 3D engineering geological subsoil model. Geographical Information System (GIS) was developed and used throughout the project. Site geomorphology was assessed through existing geomorphological maps, digital terrain models and detailed topographic maps. An important source for information was Canakkale Municipality Report (2013) and Buyuksarac et al. (2013).

SEISMIC HAZARD ANALYSIS

City is surrounded by a number of active faults it is only about 50 km away from these major fault systems (Figure 3). These major fault zone have produced many earthquakes greater than magnitude 6.0 in past. Periodicity of these big earthquake may be estimated to be 110 year. Earthquake with a magnitude between 5 and 6 appear to have occurred in 20-30 year interval. Any earthquake greater than 5 in and around this zone is assumed to have caused severe damage in Troia area (Yilmaz, 2003).

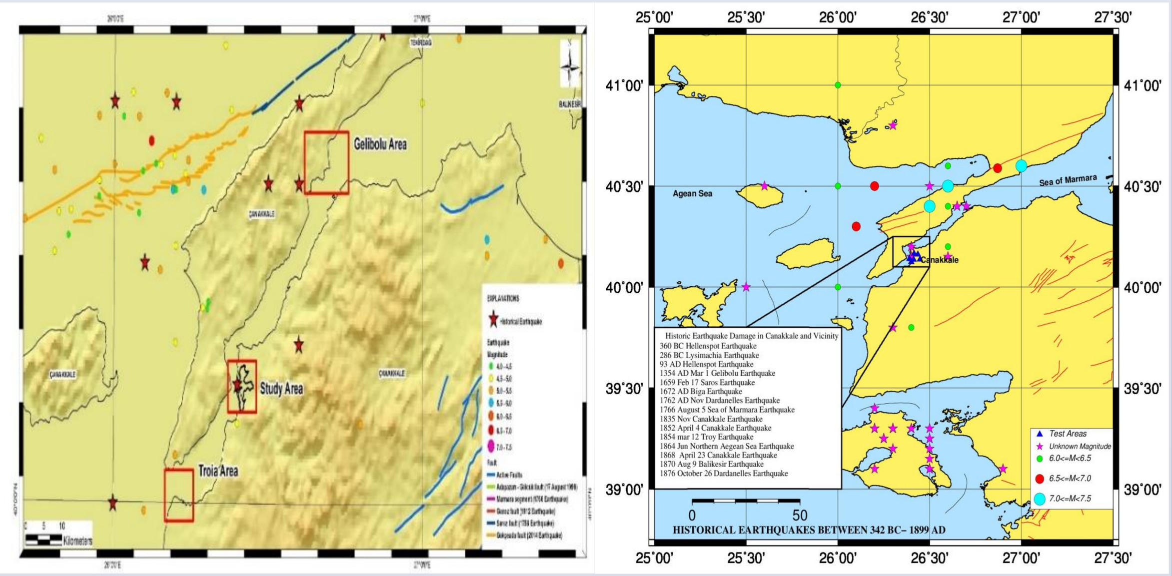

Figure 3: Left map shows study area and other important locations, faults, earthquake magnitudes. Right map represents historical earthquakes, active faults and test areas with blue triangles.

In order to determine the expected accelerations, a probabilistic seismic hazard analysis was carried out for the test site in this study. Figure 4 shows ground motion map for 50 years and exceedance rates of 2 with return periods of 2475 years for the project site. Based on the seismic hazard analyses performed for the region, the ground accelerations for exceedance rates (2%, 5% and 10% with return periods of 2475, 975 and 475 years) for project site were estimated as 0.17g, 0.39g, 0.51g and 0.78g.

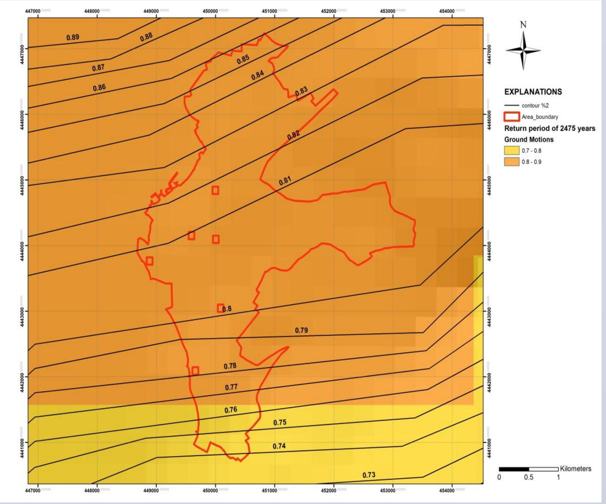

Figure 4: Ground motion map for 50 years and exceedance rates of 2% with return periods of 2475 years in Project Site

GROUND CHARACTERIZATION

The data from pre-existing soil investigation studies was gathered in the first stage. Pre-existing data showed that there are lithological units of Quaternary (Holocene) soil deposits. As part of complementary tests, six investigation areas had been chosen in Canakkale site and in-situ tests had been performed. In-situ tests can be considered as Standard Penetration Test (SPT), Cone Penetration Test (CPT (CPTU and SCPT)), Marchetti Dilatometer Test (DMT) and geophysical measurements. All performed tests and corresponding areas represented in Table 1.

Table 1: Field tests carried out in the areas

Areas \ Tests	SPT	SCPT	CPTu	Downhole Seismic	PS - Logging Seismic	2D Resistivity	Seismic Refraction	MASW	DMT	2D Re-Mi	Microtremor	H/V Nakamura	Laboratory Tests*	RAP**
Area - 1	√	√		√	√	√	√	√	√	√	√	√	√	√
Area - 2	√	√		√	√	√	√	√	√	√	√	√	√	√
Area - 3	√	√		√	√	√	√	√	√	√	√	√	√	√
Area - 4	√		√					√					√	√
Area - 5	√	√						√					√	√
Area - 6	√		√					√					√	√
City Center						√								

* RAP: Resonance Acousting Profiling, a new method which is not mentioned in this poster.

** Laboratory Tests: Sieve analysis, hydrometer, consistency limits, resonant column test (RCT), torsional shear test (TST), dynamic simple shear (DSS) tests

Ground characterization through laboratory testing focused on coarse-grained soils including clean sands, silty-sands and non-plastic sandy-silts deposits in view of the susceptibility of these geomaterials to liquefaction. Several sieve analyses and Atterberg Limits tests which were documented in the pre-existing studies were evaluated. In the complementary study, additional sieve analyses and Atterberg Limit tests were carried out. Tests revealed that majority of the samples contained less than 25% fine content. This means that the behaviour is governed by the coarse particles in the matrix. Liquid Limits were measured to be between 20%-56% and some samples did not show plastic behaviour. Majority of the soils are sandy soils, with varying amounts of silts. , it was determined that at relative densities of 35% and 65%, shear wave velocities measured in the field could be measured in the laboratory. Relative densities obtained from field tests were also found to vary in this range. Tests were carried out on twelve (12) clean sand and silty sand samples. The relative densities were adjusted between 35% and 65% under 100 kPa and 200 kPa confining pressures. Clean sands do not contain any fines, since the soil was washed to be cleaned out of fines and silty sands contained 15% fines. In DSS tests, two different type of soils were tested. These soils can be grouped as "Clean sands" which do not contain any fines, since the soil was washed to be cleaned out of fines and "Silty sands" which contained 15% fines. 14 DSS tests on silty sand samples were carried out as saturated, while 16 DSS tests on sand samples were carried out as dry in this complementary laboratory study. 6 clean sand samples were also tested as saturated so that comparisons between dry and saturated testing can be made. The details of the tests are presented in the original report.. The results of DSS tests revealed that; under tested CSR values, both soils were highly liquefiable.

RESULTS

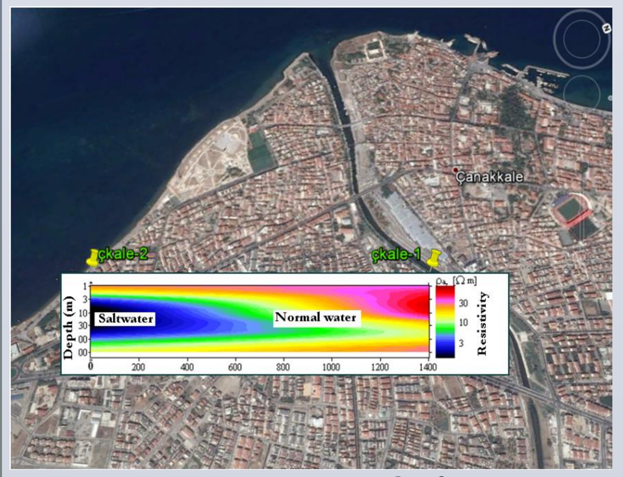

Figure 5: 2D Resistivity result of city center

Table 2: Interpretation of Figure 5.

Thickness (m)	Resistivity (Ωm)	Layer Info
0.6	25.1	Top Soil
4.95	84.3	Man-made Fill
18.8	15.1	Clayey Soil Layer
26.8	6.02	Saturated Aquifer
56.1	188	Impermeable Zone

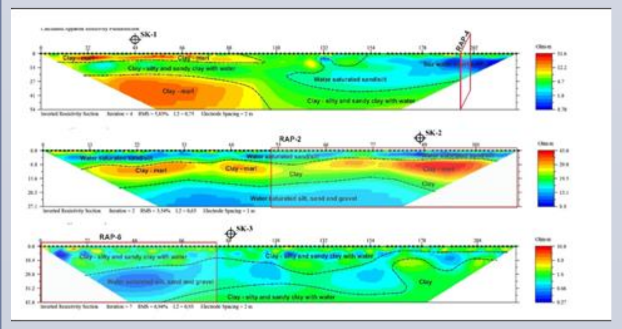

Figure 6: 2D Resistivity results of study areas from 1 to 3

Resistivity models in Figure 6 indicates the occurance of the groundwater in the gravel layers which underlies the clayey layers (at about 20-25 m depth) and causes artesian pressures. There were hints about this artesian pressure during borehole opening and SPT and CPT tests.

Figure 7: Measured shear wave velocity values together with soil profile

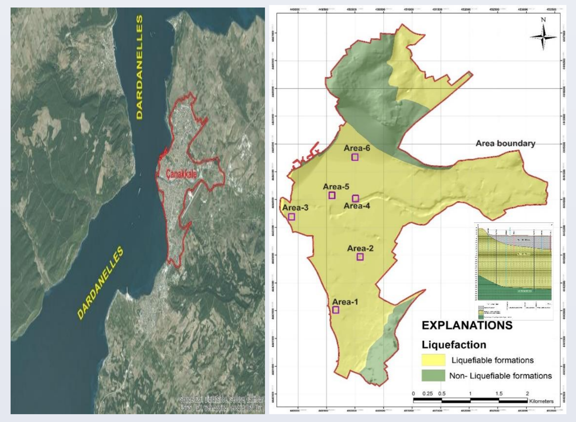

Figure 8: Liquefiable area in the test site

A summary of the results obtained from all tests for the six areas are given in Figure 7. To summarize the profiles, it can be stated that; in the first 30 m, the corrected SPT values ($N_{1,60}$) are very low ranging from 2 and 27. Shear wave velocities are between 130 m/s to 340 m/s. Soil types are sands, gravels, silts, silty sands, clays, silty clays, fills and sand-silt-clay mixtures. Fine contents values range from 2% to 54 % in average. Most of the time, low fine contents are dominating in the area. Soil classes can be listed as SP-SM, SP, SM, ML, SW, SW-SM, SC. It should be recalled that these soil classes are highly liquefiable. Based on all these solid and reliable information taken from the six study areas in Canakkale test site, it is clear that the study areas are highly susceptible to liquefaction. Liquefiable area of the test site was plotted according to represented in Figure 8.

CONCLUSION

Both geophysical and geotechnical test results show that Canakkale region includes liquefaction prone areas due to river meander points, estuarine deposits, alluvial ridges and reclamation fills. The Troia area and the Çanakkale, in northwest Anatolia, are located between two most active fault zones. These active fault systems have caused several severe earthquakes which damaged the Troia area. Based on seismic hazard analyses performed for the region, the ground accelerations for exceedance rates (2%, 5% and 10% with return periods of 2475, 975 and 475 years) for project site have been estimated as 0.17g, 0.39g, 0.51g and 0.78g. At about 20 m depths, plastic silts and clays are encountered in most of the boreholes. A gravel layer lies beneath this layer. Results of field tests showed that tests for all the areas, the shear wave velocities were low. In the first 30 m, the corrected SPT values ($N_{1,60}$) are very low ranging from 2 and 27. Soil types are sands, gravels, silts, silty sands, clays, silty clays, fills and sand-silt-clay mixtures. Fine contents values range from 2% to 54% in average. Most of the time, low fine contents are dominating in the area. Soil classes can be listed as SP-SM, SP, SM, ML, SW, SW-SM, SC. It should be recalled that these soil classes are highly liquefiable.

REFERENCES

Akıl, B. and Bekler, T. (2013): "Analysis of Earthquake Hazard and Perceptibility Study in Çanakkale, NW Turkey, Nat Hazards", **DOI:10.1007/s11069-013-0659-1**

Ambraseys, N. (2009): *Earthquakes in the Mediterranean and Middle East: a multidisciplinary study of seismicity up to 1900*. Cambridge University Press.

Code, Turkish Earthquake (2007): Specification for buildings to be built in seismic zones. *Ministry of Public Works and Settlement, Government of Republic of Turkey* (2007).

Buyuksarac, A., Tunusluoglu, M.C., Bekler, T, Yalciner, C.C., Karaca, O., Ekinci, Y., Demirci, A., Dinc, O. S. (2013): "Geological and geotechnical investigation project of Canakkale", Canakkale Municipality Report**.**

Canakkale Municipality Report (2013), "Geological and geotechnical investigation project of Canakkale", (prepared for Buyuksarac et al (2013) for the municipality.)

Geosan (2008): Forum Canakkale geotechnical investigation report, Istanbul.

Gundogdu, O., Altinok, Y., Akkargan, S., Sayin, N., Hisarli, M., Ozcep, F., Ozcep, T., and Ozer, N. (2002): "An Investigation on 17 ¨ August 1999 Golcuk Earthquake, in Turkish", Report, Istanbul Univeristy Reasearch Fund, Project Number: 1383/081299, Istanbul.

Herece, E. (1990): "The fault trace of the 1953 Yenice-Gonen earthquake and the westernmost known extension of the NAF system in the Biga peninsula". Min Res Expl Bull Turkey, **111**, 31-42.

Ketin, I. (1969): "About the strike-slip movement of North Anatolia (in German)", Bull. Miner. Res. Explor. Inst. Turk., **72**, 1– 28.

Kramer, Steven L. (1996): Geotechnical earthquake engineering. Pearson Education India.

Monkul, M.M., Gültekin, C., Gülver, M., Akın, Ö., and Eseller-Bayat, E. (2015): "Estimation of liquefaction potential from dry and saturated sandy soils under drained constant volume cyclic simple shear loading". Soil Dynamics and Earthquake Engineering, **75**, 27-36.

Monkul, M.M., and Yamamuro, J.A. (2011): "Influence of silt size and content on liquefaction behavior of sands". Canadian Geotechnical Journal, **48(6)**, 931-942.

Ohta, Y, and N Goto (1978): "Empirical shear wave velocity equations in terms of characteristic soil indexes", *Earthq.Eng. Struct. Dyn.*, 6:167–187.

Onem, Y. (1974): "Gelibolu Yarımadası ve Çanakkale dolaylarının jeolojisi". TPAO Rap, **877,** 30.

Ozçep F., Karabulut S., Özel A.O., Özçep T., İmre N. and Zarif İ.H. (2014): "Liquefaction-Induced Settlement, Site Effects And Damage In The Vicinity Of Yalova City During The 1999 Izmit Earthquake, Turkey", Journal Of Earth System Science, **vol.123**, pp.73-89, 2014

Ozcep, F. (2010): "SoilEngineering: A Microsoft Excel® spreadsheet© program for geotechnical and geophysical analysis of soils". Computers & Geosciences,**36(10),** 1355-1361.

Sayin, N., Gundogdu, O., Ozcep, F., and Hisarlı, M. (2002): "Earthquake hazard in Istanbul", *Proceedings, International Conference on Earth Sciences and Electronics*, Istanbul University, Faculty of Engineering, Istanbul, 87–93.

Taymaz T., Tan O. and Yolsal S. (2004): "Active tectonics of Turkey and surroundings: seismic risk in the Marmara sea region". In: Fujii N, Kasahara J, Higashihara H, Ogawa K. (eds) *The proceedings of 1st international workshop on active monitoring in the solid earth geophysics* (IWAM04), extended abstract book pp:110–115.

Yaltırak, C., Alpar, B. and Yüce, H. (1998): "Tectonic elements controlling the evolution of the Gulf of Saros (northeastern Aegean Sea, Turkey)".Tectonophysics, **300(1)**, 227-248.

Yilmaz, Y. (2003): "Seismotectonics and Geology of Troia And Surrounding Areas, Northwest Anatolia", İn: Wagner, G. A., Pernicka, E., & Uerpmann, H:P. (Eds.). (2013). Troia And The Troad: Scientific Approaches. Springer Science & Business Media.

Zuykov, I., unpublished, "The Resonance Acoustic Profiling (RAP) method and its use for various tasks", Power Point presentation. (http://www.alterra.geoacoustic.com/)

http://www.canakkale.bel.tr/kent-rehberiturkce-ingilizce-363

http://www.visitcanakkale.com/EN/canakkale/S/1855.

http://www.hurriyetdailynews.com/Default.aspx?pageID=238&srch=earthquake&nID=105381.

http://www.hurriyetdailynews.com/traces-of-tsunami-discovered-in-gokceada-.aspx?pageID=238&nID=67286&NewsCatID=375

http://www.canakkale.bel.tr/kent-rehberiturkce-ingilizce-363

http://www.alterra.geoacoustic.com/