

# Investigation of travertine properties using geophysical methods

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**ABSTRACT:** Recently, the seismic and resistivity methods are used for determination of physical properties of rocks with depth since the methods are economical and practical in comparison with other field-testing methods. The study area has different travertine, which has different litho-type, in terms of their color and mechanical properties. The purpose of this study is to investigate the physical properties of the travertine in the field by using geophysical methods including resistivity and seismic. In order to achieve the goal, resistivity and seismic measurement were performed along the profile, which is chosen according the representative site in the area where is Kaklık district in Denizli. After geophysical measurement in the field, samples were collected and physical properties of the travertine was also tested in the laboratory. As a result of study, it is concluded that seismic and resistivity methods could be used for investigating the quality and physical properties of the travertine and in comparison with other field testing, these two methods are more practical and economical for engineered projects.

## 1 INTRODUCTION

Travertine is one of the main export products for the Denizli city as well as the country. In order to make right and valuable investment on travertine, operation of travertine quarries needs enough technological knowledge as well as engineering practices and human performance. Achieve the goal of that, from the beginning of the early stage of quarry operation, geophysical methods and technological evaluation should be performed on the quarry area. Kaklık district, having the main travertine quarries in the city, was chosen to evaluate geophysical properties of travertine. In the district, Kömürcüoğlu travertine quarry was chosen and evaluated as plot quarry to conduct geophysical and engineering measurement. The study area, Kömürcüoğlu travertine field and its surroundings, occupy in Kaklık-Kocabaş district where is north of Denizli city with 35 km away. In the past and recent, geological investigation has been conducted with different researchers and engineers to evaluate travertine prosperities and qualities in the area. Sun (1990) studied geological properties of the Denizli basin and he performed geological map of the basin. Altunel (1996) studied on morphological classification of travertine and relationship between travertine and active tectonic-seismicity of the Pamukkale region and its surroundings. Özpınar et al. (2001) studied geological and petrologic properties of travertine in Kaklık-Kocabaş district. They

stated that travertine mostly composed of CaO and also includes SiO<sub>2</sub>, MgO and K<sub>2</sub>O as trace.

## 2 GEOLOGY

Kömürcüoğlu travertine field takes place in the eastern site of the Kaklık district. Geological map of the travertine field and surrounding are given in Figure 1. In the field, host rock has Miocene-Pleistocene ages and named as Kızılburun formation, composed of siltstone, marl, and limestone and above this formation, travertine and alluvial deposits occupies with discordance. Stratigraphy section of the area is given in Figure 2. In the area there are some local faults that are parallel to each other and their direction is NE-SW and NE-SW, which those have significant affect on creation of the basin after deposition of travertine (Özpınar, et al. 2001). Most of the faults in the study area, directed NE-SW with 60-80 degrees (Figure 3). In the study area, travertine is mostly white color, and has compact texture but there is also brownish, yellowish color, porous travertine could be seen as local site in the quarry.

## 3 GEOPHYSICAL AND GEOMECHANICAL INVESTIGATIONS ON TRAVERTINE

In order to investigate continuity of the compact travertine with depth in the area, there have been borehole opening, geophysical methods and geomechanical laboratory investigation was conducted.

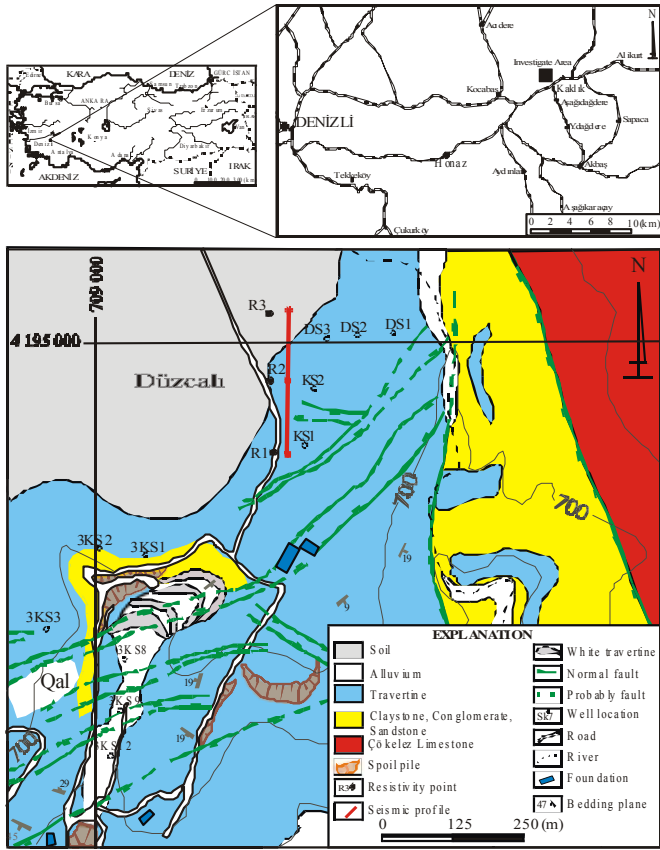


Figure 1. Geological Map of the study area a geophysical methods points (Modified Özpınar 2002).

Age	Thickness	Litology	Explanation
UPPER MIOCENE-LOWER PIOCENE	10-15 m	[Pattern]	Brown travertine
	10-16 m	[Pattern]	White travertine
		[Pattern]	Brown travertine
	3-5 m	[Pattern]	Clay, marl, gravel
	5-10 m	[Pattern]	Clay, marl, gravel
	5-10 m	[Pattern]	White travertine
	3-5 m	[Pattern]	Clay, marl, gravel
	10 m	[Pattern]	Brown travertine
3-6 m	[Pattern]	White travertine	

Figure 2. Stratigraphic section of the study area

Geological observation was conducted and geological formation was observed and recorded along the boreholes as borehole opening. In the area, where boreholes were drilled, geophysical methods that are seismic and resistivity measurement was performed and physico-mechanical properties of travertine was investigated with testing in the laboratory.



Figure 3. Local parallel faults influencing the block dimension in the Travertine Quarry

In this paper, geophysical methods were performed on the North edge of the quarry and the opened boreholes and geophysical measurement and laboratory tests results were correlated each other since quarry is operated towards this direction. Correlation and relationship between 3 boreholes opened on the North of the quarry and geophysical measurement at the same place is given in Figure 4.

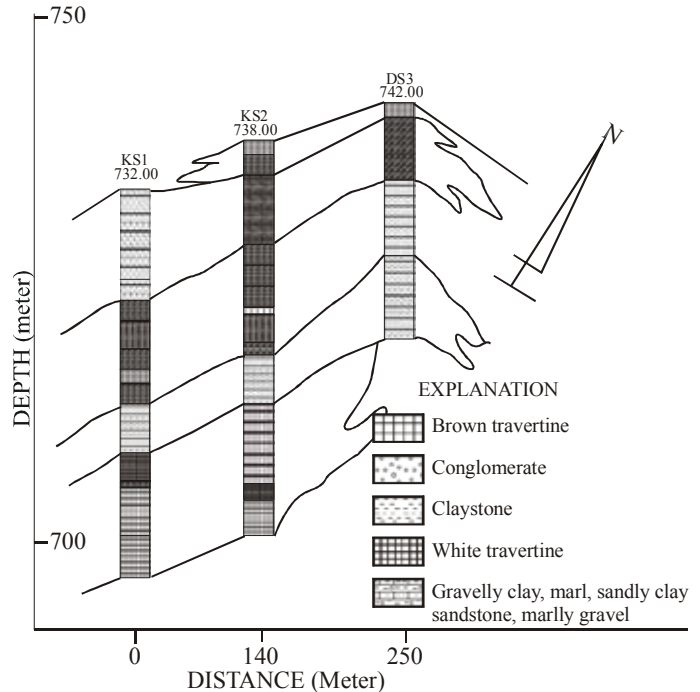


Figure 4. Correlation of the boreholes and geological formation related to geophysical profiles

Seismic refraction and Schlumberger electric surveys methods were performed to investigate fracture zones with depth and to determine the boundaries between good and bad quality of travertine in terms of commercial usage. Tests profile was taken along the N-W direction with 300 meter. Along the test profile, at 5 profiles, P-wave velocity was measured. To transform the seismic energy to the depth, seismic resources (special blasters) was buried in one-meter depth of the surface. Along the seismic profile distance between geophones was taken 12.5 meter and ABEM-Terraloc MK6 12 channel digital seismograph was used for recording velocities. After measurement of velocities, using SeisOpt@2D software performed data interpretation was made.

Along the testing profile, time-distance graphics (black square point) and inversion curves (blue rectangle point) investigated by SeisOpt@2D software is given in Figure 5. In the Figure 5, using time-distance curves, velocity distribution mapping was conducted and given in Figure 6.

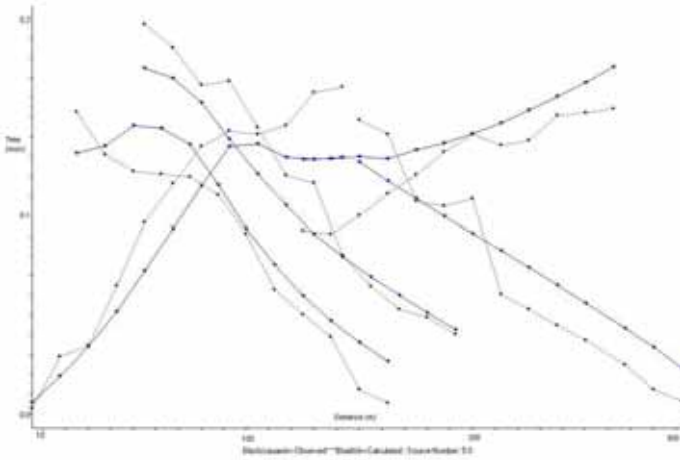


Figure 5. Along the testing profile, time-distance graphics (black square point) and inversion curves (blue rectangle point) investigated by SeisOpt@2D software

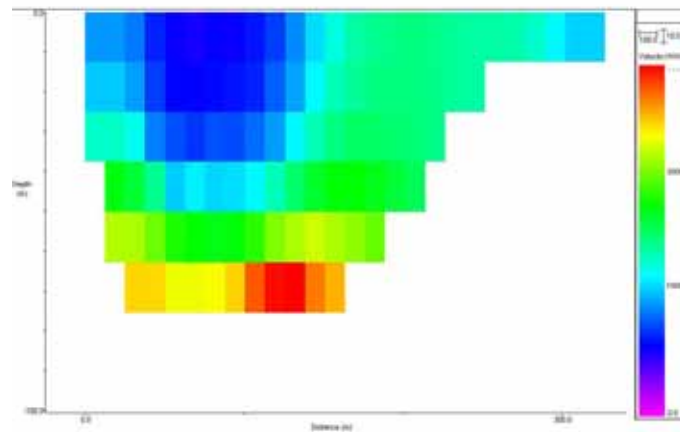


Figure 6. Velocity cross-section belongs to seismic profiles using SeisOpt@2D software

Comparing seismic refraction data acquired in K m r o lu travertine with resistivity data, seismic modeling, wells and actual geological sections give effectively representation of the quality of rocks; where the high-velocity values correspond to rock of good quality and the low values correspond to a poor quality rock. With the electric resistivity method, it is possible to obtain a schlumberger electric sounding with 150 m aperture to characterize the geoelectric stratigraphy of the fracture zones in the travertine.

The data were acquired with resistivimeter, and allowing a theoretical investigation of up to 80 m in depth. For comparative purposes, the origin of that

profile corresponds to the 5 m position in the seismic refraction profile. A smoothing modeling technique based on the Ipi2win software (Moscow State University) was used for interpretation.

As a result of the resistivity measurement achieved data was evaluated using Ipi2win software and thickness of the formations was found. In the software, performing the 2D modeling of the schlumberger survey methods, pseudo-section of apparent electric resistivity, and the interpreted geoelectric model was achieved as given in Figure 7.

In the field travertine is divided in 3 categories according to their physical properties. Light green level has crack and porous travertine with brown color and resistivity of the level is about 300-100 ohmmeters. Pink color demonstrates the filling material with resistivity of 10000-30000 ohmmeter and blue level shows white travertine level with 10-30 ohmmeters resistivity.

The high resistivity was found around the 50-m depth agree with the top of the white travertine. In this figure, there is a conductive anomaly area can be observed between 0 and 75 m on the profile. The anomaly coincides with the high attenuation anomalies observed in the seismic refraction profile.

The test in the laboratory was conducted according to TS 699 (Turkish Standard Institute). As a result of the geomechanical-testing program and geophysical investigation achieved result is given in Table 1.

#### 4 CONCLUSIONS

As a result of the borehole observation and carrot recovery, and geophysical investigation in the field, it is concluded that thickness of travertine mass decreases towards NE of the field and west of the field has brownish color travertine.

Travertine on the west of the field can be operated since it is still economic as observed from carrot recovery gathered from boreholes. Quality of the travertine operated in the quarry is good and acceptable according to Turkish Standard Institute- Natural Stone Testing Methods and Investigation.

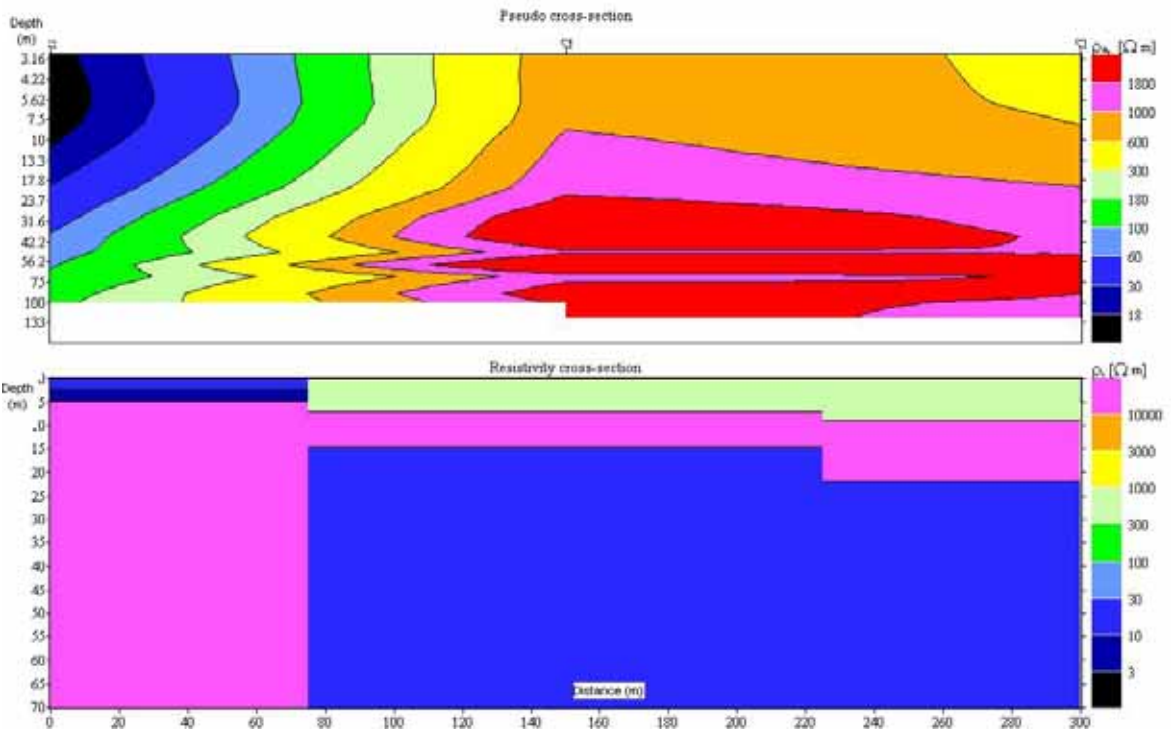


Figure 5. 2D modeling of the schlumberger electric survey with distance of 150 m

Method	Uniaxial Compressive Strength (Mpa)			Porosity (%)	Water Absorption by Weight (%)	Water Absorption by Volume (%)	Specific Gravity	Seismic Velocity (m/sn)			Resistivity (ohm-m)		
	Min.	Max.	Average					Min.	Max.	Average	Min.	Max.	Average
Filling Material	-	-	-		-	-	-	300	700	550	10000	30000	15000
Brown Travertine	49.0	64.0	58.0	3.2	2.6	4.2	2.48	700	1750	1300	300	1000	700
White Travertine	55.0	67.0	62.0	2.3	1.6	2.9	2.53	1750	2900	2400	10	30	20

Table 1. Correlation between geomechanical and geophysical investigation of travertine

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