THE ELASTIC PROPERTIES DETERMINATION OF VOLCANIC ROCKS BY USING ULTRASONIC METHOD

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In this study, elastic properties of volcanic rocks, which were obtained from the Afyonkarahisar region, have been examined by using ultrasonic methods. Ultrasonic elastic properties of rocks have been compared with compressive strength data. Evaluated ultrasonic velocities, both transverse and longitudinal, have been used to calculate the elasticity modulus of these volcanic rocks. The results indicate that the ultrasonic elastic properties of the rocks show a linear relation depending on the classification of the rocks.

Keywords: Elasticity, Ultrasonic Velocity, Volcanic Rocks.

1. Introduction

Volcanic rocks are usually fine-grained or aphanitic to glassy in texture. They often contain clasts of other rocks and phenocrysts. Volcanic rocks are named according to both their chemical composition and texture. Volcanic rocks are composed of minute, strong, tough mineral crystals, generally arranged in an extremely dense, interlocking manner. This structure results in negligible porosity, ~~and~~ great strength and durability within the lifetime of the engineering structures [1]. Basalt is a very common volcanic rock with low silica content. Rhyolite is a volcanic rock with high silica content. Alteration of rocks and minerals in the geothermal regions has been studied by many investigators in various localities since last century. Rhyolitic, andesitic, trachyandesitic and basaltic volcanic rock products are widespread in Afyonkarahisar, in western Turkey (Fig. 1) and its surrounding areas where you can find many natural stone quarries [2-4]. Weathering and subsequent alteration processes affect rocks by changing their physical, chemical, mineralogical, petrographical and mechanical properties. Although these changes provide important inputs for project designs, especially in engineering geology and civil engineering, their complex nature in rocks makes evaluation difficult for non-specialists [5]. The corresponding elastic constants of a rock and the velocity anisotropy are determined not only by the bulk composition of the rock itself but also by how these constituent minerals are organized within the rock [6]. In this study, we used an ultrasonic technique such as the pulse-echo method to characterize the elastic constants of Köprülü volcanic rocks by measuring the ultrasonic wave velocities. The effective elastic constants of volcanic rocks are calculated from the ultrasonic wave velocities.

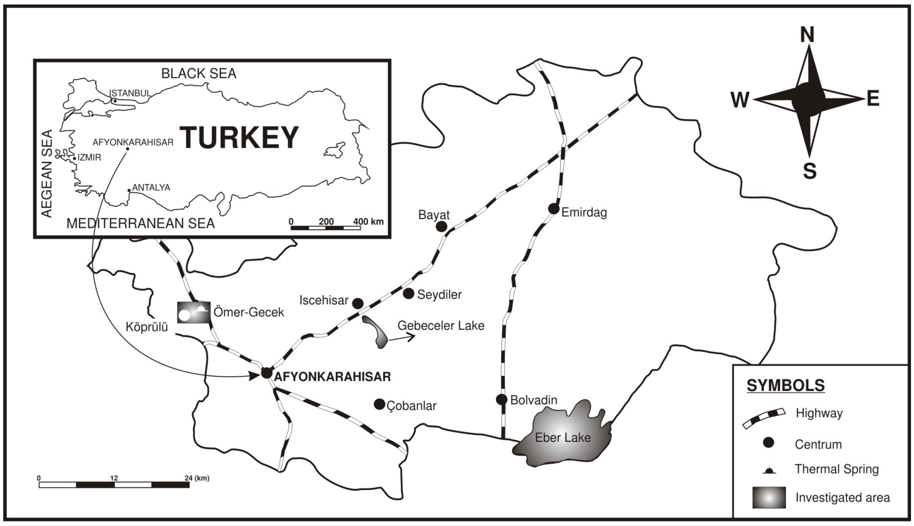

Figure 1. Location map of Afyonkarahisar

2. Materials and Methods

Geological properties of various alteration zones are distinguished in the Köprülü (Fig. 2) volcanic rocks based on differences in the texture and color of the original rock. The volcanic rocks were investigated according to formation and the following volcanic rocks were selected and classified into three groups:

i. The unaltered/fresh zone (UZ)
ii. The altered zone (AZ)
iii. The ferrous zone (FZ)

2.1. The Unaltered/Fresh Zone (UZ)

This zone is generally grey in color; the darker material being harder than the lighter bands. The hornblende and pyroxene crystals show only a low degree of alteration while the flow structure is visible.

2.2. The Altered Zone (AZ)

The altered zone characterizes the initial phase of alteration and is lighter in colour. The hornblende and pyroxene etc show a more distinct alteration rim and have frequently a bright yellow color.

2.3. The Ferrous Zone (FZ)

Ferrous solutions have intensely penetrated into the rock through~~out~~ the fractures and pores and the matrix of the rock is altered, particularly along the bands which contain the pores. The size of the pores is increased and the color of the rock is pink and yellowish red where the ferrous solutions have penetrated into the pores. In the final stages of alteration, a siliceous solution has also entered the pores and deposited a light brown opal [7].

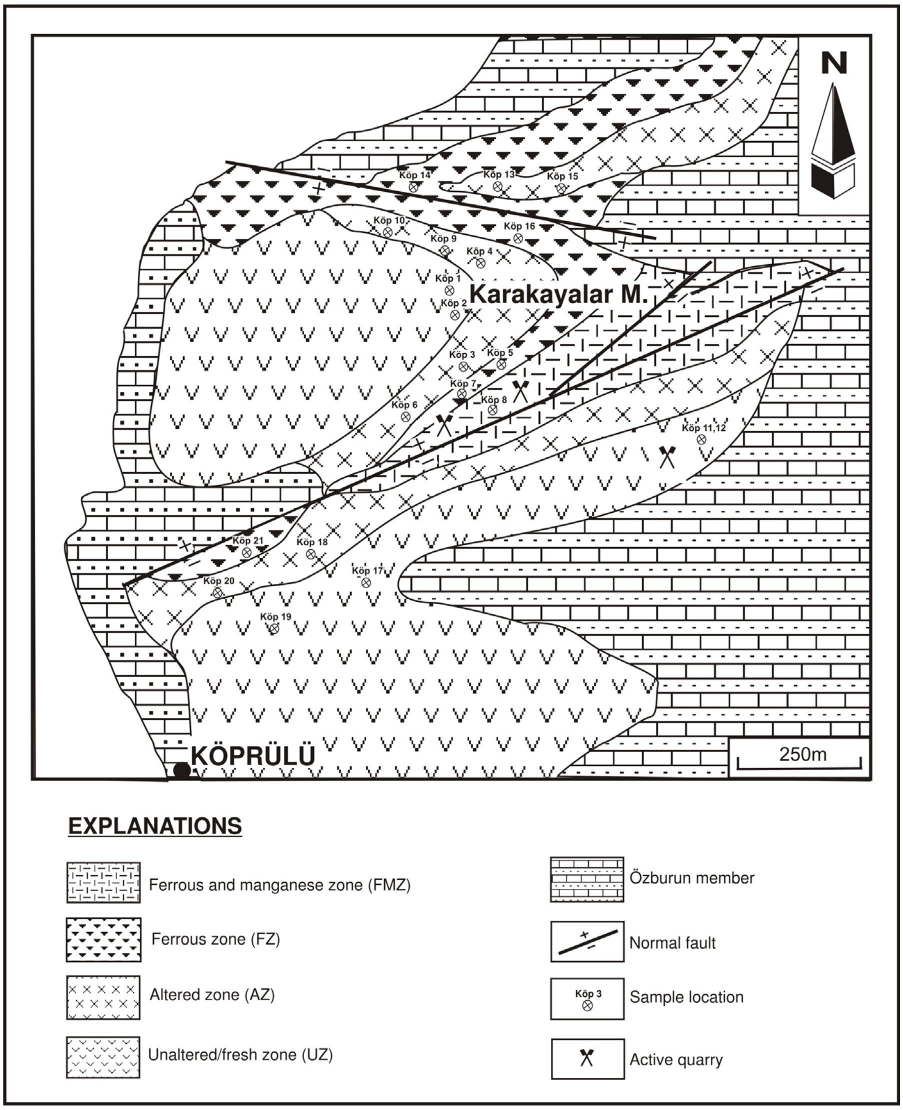

Figure 2. Alteration map of study area.

Fourteen samples were obtained from three different alteration zones in the Köprülü volcanic rocks and all the samples are listed in table 1. Usually ultrasonic testing methods are used to detect cracks and other discontinuities in solids as a non-destructive testing [8-10]. Mechanical properties such as elasticity modulus (E), shear modulus (G) and Poisson ratio (ν)

can also be found. By determining the longitudinal velocity (V_L) and the transverse velocity (V_T) of ultrasonic waves, elastic properties can be estimated by the following relations [8-10]:

$$E = \rho V_T^2 \frac{3V_L^2 - 4V_T^2}{V_L^2 - V_T^2} \tag{1}$$

$$G = \rho V_T^2 \tag{2}$$

$$\nu = \frac{\left(V_L/V_T\right)^2 - 2}{2\left[\left(V_L/V_T\right)^2 - 1\right]} \tag{3}$$

where ρ is the density of the volcanic rocks.

Table 1. The samples from the different alteration zones.

Alteration Zone	Samples
Unaltered/fresh zone (UZ)	Kop-1, Kop-11, Kop-12, Kop-17, Kop-19
Altered zone (AZ)	Kop-6, Kop-9, Kop-13, Kop-15, Kop-18, Kop-20
Ferrous zone (FZ)	Kop-14, Kop-16, Kop-21

Longitudinal and transverse ultrasonic velocity measurements have been conducted at TUBITAK, Marmara Research Center, by using a Krautkramer, USN 52L type ultrasonic flaw detector and 4 MHz ultrasonic normal beam probes (MB4Y and MB4F).

2.4. The Compressive Strength (CS)

The compressive strength of the material corresponds to the stress at the red point shown on the curve in fig 3. Even in a compression test, there is a linear region where the material follows Hooke's Law. Hence for this region $\boldsymbol{\sigma = E\varepsilon}$ where this time E refers to the Young's Modulus for compression.

This linear region ends at what is known as the yield point. Above this point the material behaves plastically and will not return to its original length once the load is removed.

There is a difference between the engineering stress and the true stress. Arslan et al. [11] gave a correlation between compressive strength and young modulus.

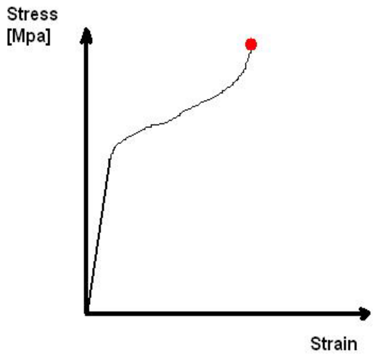

Figure 3. Engineering stress-strain curve for a typical specimen.

3. Results

By using a pulse-echo technique, ultrasonic longitudinal velocity, ultrasonic transverse velocity, Young Modulus (E) and uniaxial compressive strength (UCS) have been determined and are given in table 2. Uniaxial compressive strength values were measured by Yıldız et al [7].

Table 2. The calculated Young's modulus, densities, ultrasonic velocity and compressive strength of volcanic rock samples.

Alteration Zone	**Samples**	**ρ (gr/cm^3)**	V_L **(m/s)**	V_T **(m/s)**	***E* (kg/ms^2) *x*10^{10}**	**Uniaxial compressive strength (*MPa*)**
			(4 MHz)			
Unaltered/ fresh zone (UZ)	**1**	2,81	4710	2250	3,847	52,62
	11	2,97	3860	2323	3,898	57,08
	12	2,60	3260	2080	2,6023	33,32
	17	2,96	3500	2155	3,285	51,85
	19	2,66	4465	2275	3,647	47,33
Altered zone (AZ)	**6**	2,63	4100	2040	2,923	20,89
	9	2,72	3640	2003	2,799	36,76
	13	2,88	3700	2126	3,264	37,37
	15	2,80	3400	1722	2,2044	24,08
	18	2,76	3600	1900	2,604	16,66
	20	2,68	4600	2650	4,711	31,78
Ferrous zone (FZ)	**14**	2,75	4030	1890	2,67	13,23
	16	2,72	3320	1580	1,838	22,32
	21	2,37	3380	2280	3,0198	40

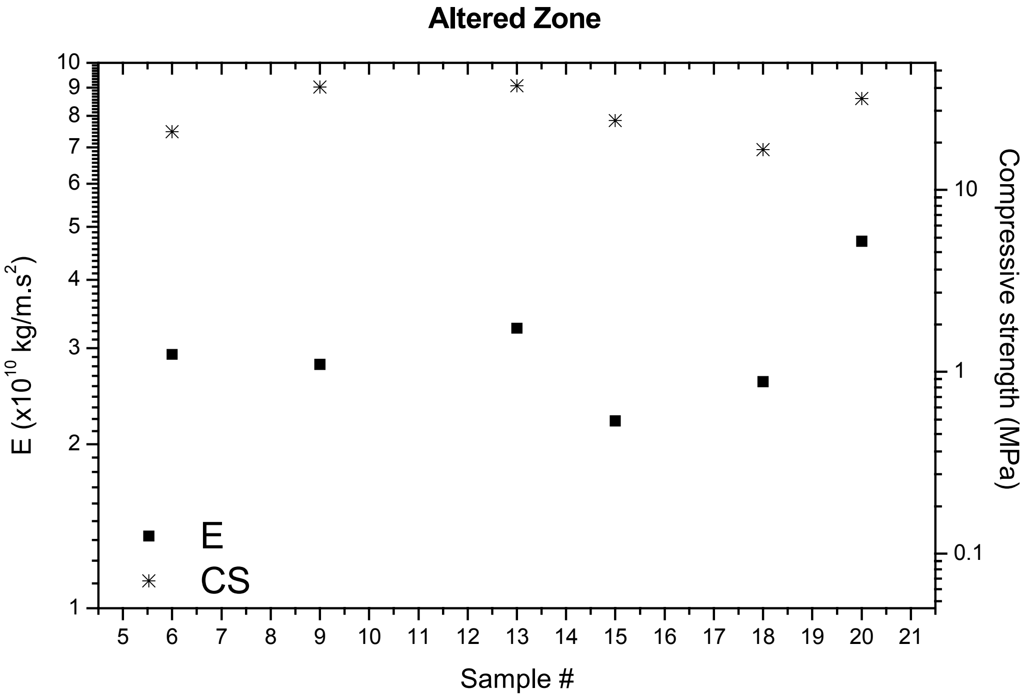

Figure 4. Young's Modulus and compressive strength values of altered zone samples.

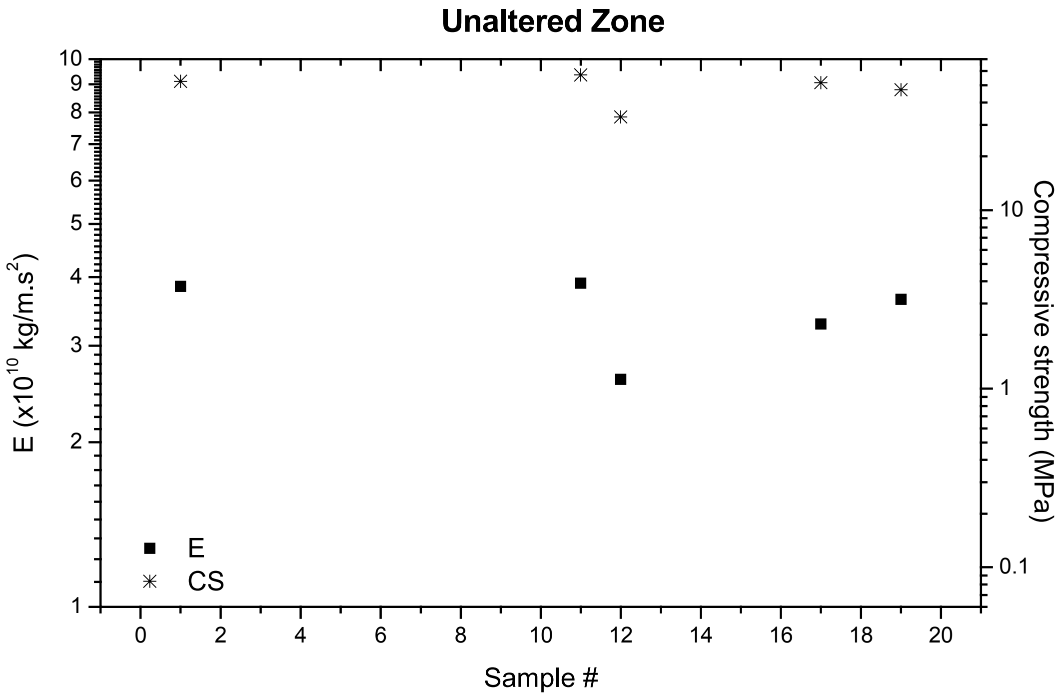

Figure 5. Young's Modulus and compressive strength values of unaltered zone samples.

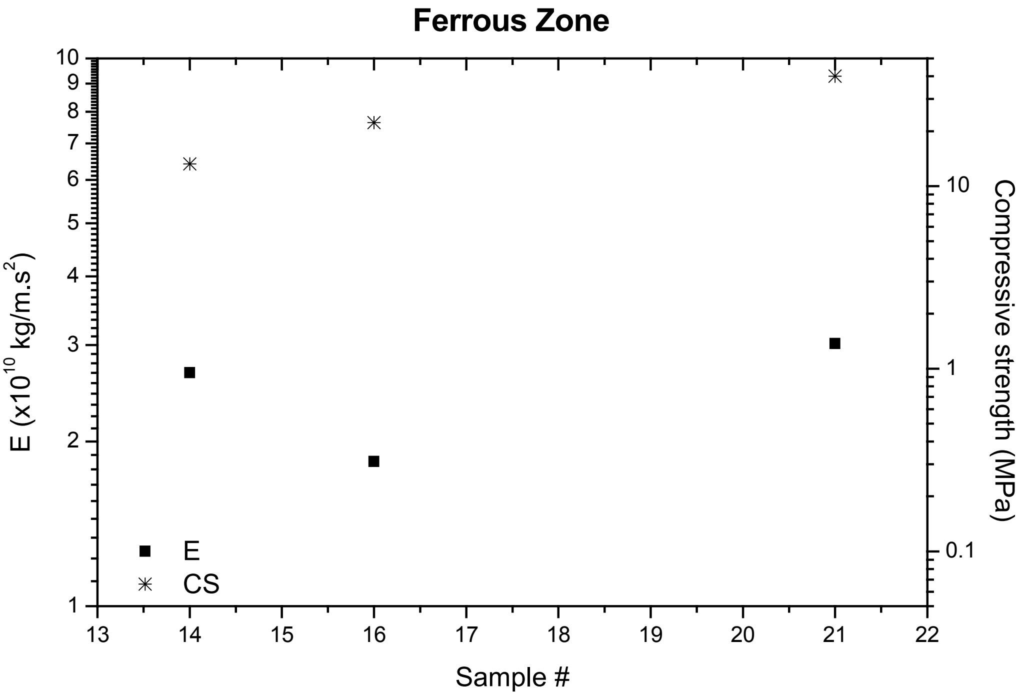

Figure 6. Young's Modulus and compressive strength values of ferrous zone samples.

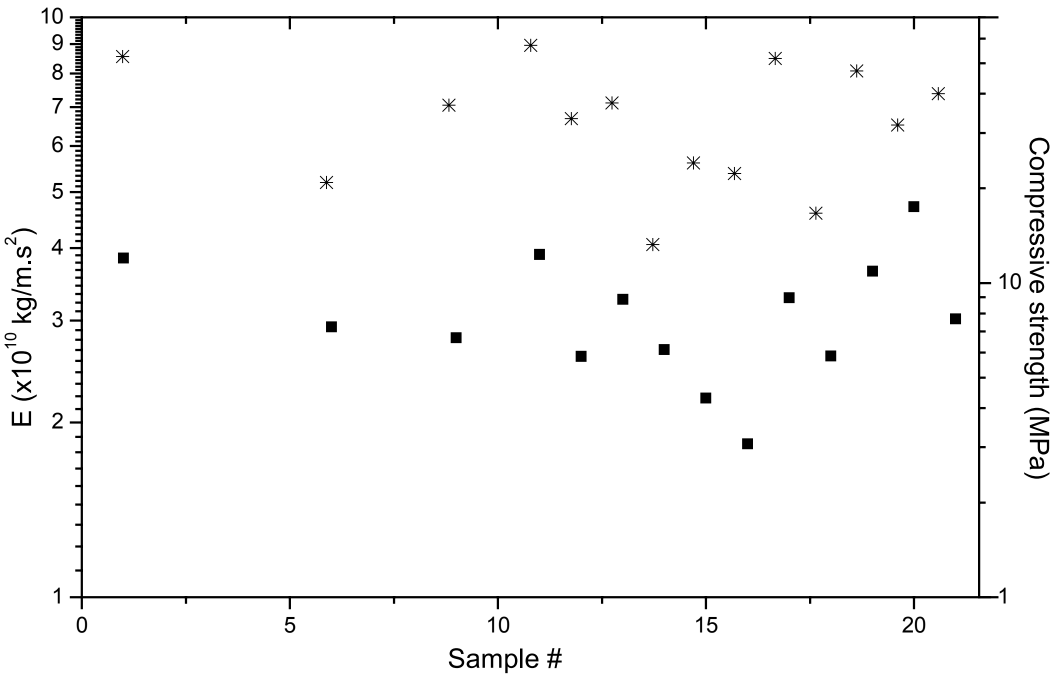

Figure 7. Young's Modulus and compressive strength values of all samples.

In fig. 4, the young moduli of altered zone samples show similarity with compressive strength values. It is valid for unaltered and ferrous zone samples which are shown in fig.5 and fig. 6, respectively. Correlation between compressive strength and Young moduli for all samples are shown in fig 7.

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