

**C-4) - THE PREDICTION OF THE INTERFLOW ZONES IN IGNEOUS ROCKS
UNDER THE HOLY PLACE, MAKKAH BY GEOELECTRICAL
SOUNDINGS,KUTSAL MEKKE ŞEHRİNDE KABE YAKININDA ELEKTRİKİ
SONDAJ ÖLÇÜMLERİYLE VOLKANİK KAYA İÇİNDEKİ YERALTI SUYUNUN**

ÖZET :

Genellikle volkanik ve püskürük kayaların içerisinde yer altı suyu, tabakalanma sınırları boyunca ayrıca çatlak ve kırıklar istikametinde gelişim göstermektedir. Bundan böyle bozuşmuş kayalar yüksek porozite ve permeabilite değerleri vermektedir. Eğer bozuşma zonları derinlere kadar uzanırsa yeraltı suları için ideal bir su kaynakları oluştururlar. Fakat püskürük kütlelerin masif olması halinde yer altı suyu içermedikleri bilinmektedir. Bu çalışmalar daha önceki Zigana Tüneli boyunca yapılan araştırmalara benzer tarzda rezistivite eğrileri üzerinde anormal bükülmelerin görülmesi üzerine derinlerde muhtemel fay zonları boyunca yer altı suyu hareketlerinin mevcudiyeti düşünülmüştür. Kabe'nin hemen yakınında alınmış olan 3 adet ölçü Şekil ?? 'de görülmektedir. R-06 ve R-12 'de 25 ve 60. metrelerde suyla doymuş bir zonun mevcudiyeti görülmektedir. R-09 eğrisi üzerinde ise 60 metreden başlayan ezilme zonu 100 metreden daha derinlere kadar etkili olduğu görülmektedir. Görünür rezistivitedeki ani düşüşler muhtemel bir fay zonunun mevcudiyetini göstermektedir. R-06 noktasındaki ezilme zonu R-03 noktasına göre daha sığdır. Yapılmış olan Gül diyagram mevcut hakim durumdaki eklem ve fay zonlarının durumlarını yansıtmaktadır. Bu zonlar volkanik kayalar içinde bozuşma ve kırıklık gösteren doğrultular boyunca yer altı suyunun hareketli olduğuna işaret etmektedir. Bu son durum zemzem suyunun temel kaya içerisinde çok derinlerden geldiğini göstermekte ve ana kırıklar boyunca alüvyon içine sızmaktadır. Açılacak iki mekanik sondajın R-12 ve R-03 noktalarında 120 metreye kadar inilmesi halinde verimli miktarda su temin edileceği düşünülmektedir. Bu şekilde yağmur suyu tünellerinin zemzem suyuna olan olumsuz etkinliği ortadan kaldırmış,buna ilave olarak Kabe etrafında yoğun bina stoklarının zeminde oluşturdukları kirlilik elemine edilerek, belkide temel kaya suyunun daha verimli olmasına fırsat verecektir. Yazarın resmi görevi nedeniyle Türkiyeye dönmesi ,yukarda izah edilen ZemZem suyunun derinlerdeki ezilme zonuyla olan ilişkisinin sonuçlandırılmamış bir proje olarak kalmasına neden olmuştur.Yeni nesil jeofizikçilerin araştırma yapabilecekleri bu önemli konu, kutsal topraklarda hala araştırılmayı beklemektedir.

**DETECTION OF THE SHEAR AND WEATHERED ZONE IN IGNEOUS ROCKS BY
USING ELECTRICAL SOUNDINGS:**

It is generally accepted that in volcanic and igneous rocks, the movement of water is restricted to joints, bedding planes and fissures. Consequently, the decomposed rocks has a high porosity and permeability; and if the weathering extends to depth, it forms an ideal reservoir for underground water. But, however, the solid igneous rocks contain no water.

1.1. A new technique for Determination of shear-zones from sounding curves.

A significant relationship between electrical resistivity and rock mechanics techniques has been found during in-situ field and laboratory studies. A procedure then has been developed and used for the prediction of weathered and fault zones in bedrock. (Ref.1). The detection of fault zones has also practical importance in mining areas since the most mineralized zones generally occur along the fault or weathered zones.

In order to detect the fault zones using the Wenner configuration, in-situ geophysical and geological parameters were investigated. These are : water-pressure tests, drilling time records of the bore holes, core recovery data, apparent and true resistivity values, and P-wave velocity (see Figs.3,4,5,6,7,8,9, and 11 – Ref-1).

Figs. 5 and 6 provide interesting data when field results of the Wenner electrical sounding and the average drilling time curve are present together. It is common knowledge that any increase in the degree of compaction and cementation of the foundation rocks requires longer drilling time. It is interesting to note that the apparent resistivity versus electrode separation curves are parallel to the average drilling time versus depth curves. (See fig 5 and 6). As the average drilling time of the bore hole decrease, the apparent resistivity also decreases. It may , therefore, be concluded that the apparent resistivity depends very much on the degree of cementation and compaction of the foundation rocks.

Significant resemblance was also found between laboratory (or field) geophysical and rock mechanics studies. See figs. 2c and 2d.

i) When a rock specimen is strained within or beyond its elastic limit, it gives $\sigma - \epsilon$ curve as shown in fig 2a. Any changes in the specimen length changed the length of the strain gauge strips, finally the relationship between the resistivity change and strain parameters can be expressed in the following form:

$$K \cdot \Delta L/L = \Delta R/R \cdot (1/K) = \epsilon$$

Where ΔR is the decrease in resistance of the gauge of initial resistance R , $\Delta L/L$ is the strain causing ΔR . Since K and R are declared by the manufacturer it is only necessary to determine ΔR in order to evaluate $\Delta L/L$.

It is clear from above expression that the strain indicator is actually measuring the resistivity change under different stress range, since the strain gauge is being inserted as one of the arms of a Wheatstone bridge.

The fundamental characteristics of the engineering stress strain curve is that as the slope of the stress-strain curve increases, the modulus of elasticity and compressive strength increase, Ref(4). Above the linear range (AB), of fig 2a the strain increased more rapidly for equal-stress increments until failure occurred (fig 2a- stage III- see also fig 7).

ii) Similarly, the main aim of the resistivity survey is to measure resistivity change under different depth (or stress strain) conditions (see fig 2d). Resistivity equipment also operates on a Wheatstone bridge circuit principle. As the slope of the ρ_{α} - a curve decreases, the foundation rocks show heavily broken shear zones (see fig 4). But when the slope of the ρ_{α} - a versus depth curve increases, the lithological description of the bore hole indicates massive or compact rock layers (see figs 7 and 8). Ref.1.

It is extremely important and useful to remember the resemblance between the stress-strain curve shown in figures 7 and 8. These properties of the stress-strain curve an apparent resistivity depth curves will be extremely useful in the detection of fault zones. Comprehensive geophysical and geological investigations were carried out in order to determine fault zones and dynamic modulus of elasticity of the rocks along the Zigana Highway tunnel in the design stage. It was found that the low resistivity layer (indicated by the black column) is associated with fault zones which dip at various angles (see fig 1). Ref.1.

Large amount of groundwater was discovered during excavation period of tunnel, from the dasitic rock where there are shrinkage cracks or other joints and interflow zones as indicated in Fig 1.

RESULT OF THE PRESENT STUDY :

It can be noticed from the interpretation of the three (3) curves of Profile VI, VII and X Figs (I-1, I-2, I-3) that the weathered and shear zone (the saturated zone) starts at 60 meters from surface and continues more than 100 meters. It can also be noticed that the depth of the saturated zone in stations R-06 and R-12 are about 25 and 60 meters, respectively. Sharp decrease in the apparent (or true) resistivity is clear indication of the existence of a probable fault zone. The depth to the shear zone in station R-06 is very shallow as compared to the station R-03 . This may be due to the dominant dip of joints and faults in the bedrock as indicated by Rose diagram.

Reinterpretation of the resistivity soundings by using a new technique described above indicates a deep weathering zone which will create an interflow zones in igneous rocks. This

result also indicate clearly that the Zamzam water comes from deeper part of the crustal material and finally infiltrates into the alluvium by means of major cracks as shown in Rose diagram.

I propose that two (2) deep boreholes (up to 120 meters) should be performed in stations R-12 and R-03. Water pressure and pumping tests should then be carried out between 70 and 120 meters. Long term groundwater sampling from wells should be performed in determining the content of dissolved matter in stored groundwater within the shear zone.

If there are plenty of water available from deep drilling in zones of intensive jointing or fracturing, the adverse effects of the storm water tunnels on Zamzam water will also be minimized.

As described in Report III the value of the groundwater conductivity (C) in the interflow zones (between 60-100 meters) was found about 1303 $\mu\text{mhos/cm}$.

But it is interesting to note that C value for the station R-06 was found about 518 $\mu\text{mhos/cm}$.