Turkish Studies
International Periodical for the Languages, Literature and History of Turkish or Turkic
Volume 11/2 Winter 2016, p. 665-684
DOI Number: http://dx.doi.org/10.7827/TurkishStudies.9052
ISSN: 1308-2140, ANKARA-TURKEY

Article Info/Makale Bilgisi
Received/Geliş: 18.12.2016 **Accepted/Kabul:** 20.01.2016
Referees/Hakemler: Doç. Dr. Ahmet ATASOY – Doç. Dr. Bayram ÇETİN

This article was checked by iThenticate.

PHYSICO-CHEMICAL FEATURES OF MINERAL WATERS FOUND IN HATAY OPHIOLITES AND THEIR RELATIONSHIPS WITH FAULT CHARACTERISTICS

Atilla KARATAŞ[*] - Şana SUNGUR[**] - Vedat YILMAZ[***]

ABSTRACT

We discuss the systems and kinematic structures of many faults via different viewpoints around Hatay, which is an active and complex transition zone among the African, Arabian and Anatolian plates. The studies on the complex multi-component structures provides more comprehensive interpretation interferences through the findings from a variety of relevent disciplines. It is therefore of critical importance to collect and analyze a broady variety of data and methods for accuurate identifications of the fault characteristics around Hatay. A physico-chemical analysis of mineral water spring was conducted to provide additional data on the geotectonic structures. The results were then evaluated in terms of the structural properties of faults, which generated relevant sources. Mineral consumption and it's seasonal changings of those mineral waters are observed by correlating for disclosure the relation between aquifers and springs. Throughout this study, the faults generating both spring groups were found to be similar in terms of the physical and kinematic properties. It was also evidenced that the faults creating both "Kisecik I and II springs" and "Tahtaköprü and Suluca springs" have the same mechanisms regardless of the system they belong to. Therefore, it was found to be necessary to further address the fault lines, where the mineral water springs are connected, within the same tectonic structures.

STRUCTURED ABSTRACT

We discuss the systems and kinematic structures of many faults via different viewpoints around Hatay, which is an active and complex transition zone among the African, Arabian and Anatolian plates. Complicated tectonic activities in Hatay resulted in a complex geologic

[*] Yrd. Doç. Dr. Marmara Üniversitesi Fen Edebiyat Fakültesi, Coğrafya Bölümü, El-mek: karatasatilla@hotmail.com
[**] Prof. Dr. Mustafa Kemal Üniversitesi/Fen-Edebiyat Fakültesi/Kimya Bölümü/Analitik Kimya Anabilim Dalı
[***] Mustafa Kemal Üniversitesi Araştırma ve Uygulama Hastanesi, Biyokimya Laboratuvarı.

structure. It is possible to observe geological structures with varying ages and lithologies from the Precambrian period to the current date. Ophiolites that belong to Upper Cretaceous are of particular importance since they harbor the mineral water springs, the subject of the current study. This unit, located in the south of Belen Strait of Amanos Mountains and is the main element of the section called South Amanos Mountains, is called Kızıldağ Ophiolite in the literature and displays a horst character connected to normal faults that border the northwest and southeast of the anticlinal whose core is also formed by it. Existence of a multitude of faults that were placed vertically or diagonally to the main lines in the northeast-southwest direction shaped the fault mosaic and independent block tectonism in the area. As a result, complete ocean floor volcanic sequence composed of base to top tectonite-peridotite, cumulate-gabbro, diabase-dyke complex and pillow lava outcropped in the form of concentric circles from inside out and from old to young due to higher level of abrasion in mid-section where elevation is the highest. Outcrops that belong to Kızıldağ Ophiolites with a total surface area of 810.86 km^2 are divided in the following manner: 67% tectonite-peridotite, 18.1% cumulate-gabbro, 13.2% diabase-dyke complex and 1.7% pillow lava.

The studies on the complex multi-component structures provides more comprehensive interpretation interferences through the findings from a variety of relevent disciplines. It is therefore of critical importance to collect and analyze a broady variety of data and methods for accuurate identifications of the fault characteristics around Hatay. It is known that water sets the ground for changes in rock structure both in physical and chemical terms and is one of the most effective factors in weathering processes. While some substances such as salt and carbonate varieties are washed away as a result of these processes, new minerals and compounds are generated. Water which is the element that undertakes the abovementioned operations related to washing and transportation receives new minerals and compounds in its structure based on this process and undergoes a type of contamination. This phenomenon takes place in the framework of hydraulic, hydrologic and hydrothermal alterations due to water's corrosion and corrosion effects. Therefore, the mineral content of water changes according to both the rock types with which it is in contact with and under the control of weathering processes that affect these rocks. Mineral structure of the water is closely related to the features of the geologic units through which it travels and the interaction process with these units. Weathering processes and the equilibrium of mineral water are two different parameters that provide information about one another. A physico-chemical analysis of mineral water spring was conducted to provide additional data on the geotectonic structures. The results were then evaluated in terms of the structural properties of faults, which generated relevant sources. Mineral consumption and it's seasonal changings of those mineral waters are observed by correlating for disclosure the relation between aquifers and springs.

The first significant findings obtained as a result of the analyses conducted during the framework of the study is the extremely similar temperatures among the springs. As we know, waters with temperatures between 20-30 °C are called epithermal waters. Although the temperature of Kisecik I spring which is right under the limits puts this spring among cold mineral waters, other springs are categorized as epithermal waters. General view is that temperatures included in a narrow belt such as 6.90 °C between 19.45 and 26.35 ° point to the fact that these springs are composed of waters coming from similar depths. Also the fact that the springs are classified as acrothermal waters due to their total mineral concentrations with low mineral loads points to small spring aquifer depth and a basin composed of waters that has not been underground for long periods of time. Increased in loads due to oxidation of especially the iron minerals in rock structures with high metallic mineral content such as ophiolites is directly proportional to the speed of chemical reactions and the time elapsed. The fact that high concentrations were not reached in this manner show that springs are in low temperatures, have alkaline characters and the interaction between spring waters and rocks are limited.

Another issue observed by the analyses is the extensive harmony in all springs both in terms of average mineral distribution and also in terms of the seasonal changes in this distribution. Therefore, it is possible to report the influence of highly similar conditions both between two springs on the same line and between spring groups located in two different lines in terms of mixture from surface waters, geological environment and reservoir depth. Seasonal changes in water temperatures were observed in all of the springs studied in the framework of the study and it was found that they were not independent of the effects of surface conditions. However, this effect was similar for all springs and it was related to the mixture of mineral waters to surface waters as can be observed from the changes in seasonal pH values. The pH values that increase during summer and winter months decrease in spring and autumn when comparatively more precipitation is observed. Abnormal increases in the parameters such as ammonium, sodium, sulphate and potassium in especially spring and partially in summer months indicate that minerals that were carried from the surface as a result of washing off by sheet flow and irrigation flow into mineral waters.

Results show that the faults that transmit Kisecik I and Kisecik II mineral water springs and Tahtaköprü and Suluca mineral water springs to the surface were generated in similar environmental conditions and that they have very similar properties. Whether these faults are the ones that compensate the relative motion of Anatolian plate in the west-southwest direction or are the ones shaped by the pull of African plate that subducted under Anatolia or generated by the tension impact of rifting in the east, they are the product of the same mechanism under all conditions and the same tectonic regime is dominant in both regions. Therefore, it would be fitting to assess these two sections of Amanos Mountains in the same tectonic unit during geotectonic based studies that will be conducted in the region.

Throughout this study, the faults generating both spring groups were found to be similar in terms of the physical and kinematic properties. It was also evidenced that the faults creating both "Kisecik I and II springs" and "Tahtaköprü and Suluca springs" have the same mechanisms regardless of the system they belong to. Therefore, it was found to be necessary to further address the fault lines, where the

mineral water springs are connected, within the same tectonic structures.

Keywords: Hatay, tectonics, physicochemistry of mineral waters, fault structure, Amanos Mountains, fault springs, Kisecik, Tahtaköprü.

HATAY'DA OFİYOLİTLER İÇERİSİNDEN ÇIKAN MİNERALLİ SULARIN FİZİKO-KİMYASAL ÖZELLİKLERİ VE FAY KARAKTERİSTİKLERİ İLE İLİŞKİLERİ

ÖZET

Afrika, Arabistan ve Anadolu levhaları arasındaki jeotektonik açıdan çok hareketli ve karmaşık bir geçiş zonuna karşılık gelen Hatay çevresinde, birçok fayın ait olduğu sistem ve kinematik yapısına dair tartışmalar farklı fikirler üzerinden sürmektedir. Söz konusu çok bileşenli ve karmaşık yapının tam anlamıyla çözülebilmesi amacıyla yapılan çalışmalarda, değişik disiplinlere ait bulgular kullanılmak suretiyle daha kapsamlı çıkarımlarda bulunulmaktadır. Dolayısıyla Hatay çevresindeki fayların karakteristik özelliklerinin doğru bir şekilde belirlenebilmesi için çok sayıda veri ve yöntemin birlikte değerlendirilmesi büyük öneme sahiptir. Bu çalışma kapsamında jeotektonik yapıya dair veri kaynaklarına bir yenisini eklemek için bölgedeki mineralli su kaynaklarının fiziko-kimyasal analizi yapılmış ve sonuçlar ilgili kaynakların ortaya çıkmasına vesile olan fayların yapısal özellikleri perspektifinden değerlendirilmiştir. Kaynak noktalarından alınan su numunelerinde mineral içeriği ve bu içerikte meydana gelen dönemsel değişiklikler korele edilerek akiferler ile kaynak noktaları arasındaki süreç benzerlikleri araştırılmıştır. Çalışma sonunda elde edilen bulgular her iki kaynak grubunu ortaya çıkaran fayların fiziksel ve kinematik özellikleri açısından benzerlik arz ettikleri yönündedir. Neticede hangi sisteme ait olurlarsa olsunlar, hem Kisecik I ve II kaynaklarını hem de Tahtaköprü ve Suluca kaynaklarını meydana getiren fayların aynı mekanizmanın parçaları olduğuna dair güçlü bir delile ulaşılmıştır. Dolayısıyla çalışmaya konu olan mineralli su kaynaklarının bağlı bulunduğu fay hatlarının aynı tektonik yapı içerisinde değerlendirilmesi gerekmektedir.

Çalışma alanındaki mineralli su kaynakları Kızıldağ ofiyoliti bünyesindeki tektonit-peridotitler içerisinden çıkmaktadır. Bu sebeple ofiyolitik istifin en altında yer alan tektonit-peridotit grubundaki kayaçların çözülme süreçleri ve bu süreçler sonunda ortaya çıkan ürünler mineralli suların içeriği ile de doğrudan ilgilidir. Bununla birlikte mineralli suların izledikleri yol olan fay hatlarının, faylanma sırasında metamorfize olarak çözünmeye daha elverişli hale gelen enkaza, yani milonit zonlarına yataklık ettiği; dolayısıyla da yeni oluşan kayaç yapılarının özelliklerine bağlı olarak suların mineral yapılarıyla ilişkide oldukları gerçeği gözardı edilmemelidir.

Tektonit-peridotit grubu harzburgit, dünit, verlit ve lerzolit litolojisinde olup, bu kayaç yapılarının tamamı oluşum safhasında hidrotermal alterasyona maruz kalmışlardır. Olivin içeriklerinin yüksek oluşuna bağlı olarak (örneğin dunitte bu oran %90'dan fazladır) yoğun bir serpantinizasyon ve talklaşma sergileyen birim elemanlarının olivin ve hematit gibi ferromagnezyen bileşenleri, sürecin sonunda serpantin

ve talk gibi kayaçların kaynağını oluşturmuşlardır. Kayaçların bileşiminde yer alan olivin, klinopiroksen ve ortopirokseni meydana getiren demir mineralleri ise oksidasyon sonucu limonite dönüşmüşlerdir. Yine klinopiroksenler segregasyon ve uralitizasyon neticesinde uralit, smaragdit ve klorit gibi yeni amfibol ve kil türleri meydana getirmişlerdir. Aynı şekilde kromitin de peridotit grubunun segregasyonu ile oluştuğu bilinmektedir. Sonuçta tektonit-peridotit grubunun konsolide kayaçları ya daha düşük dirence sahip kayaçlara ya da kil türevlerine dönüşmüşlerdir. Talklaşma ve serpantinizasyon hidrotermal alterasyon ve dinamo metamorfizma olaylarının bir sonucu iken, segregasyon soğuma sürecinin, uralitizasyon ise kayaçların bünyesindeki piroksenlerin yeşil renkli amfibole dönüşmesinin neticesinde ortaya çıkmaktadır. Yerin derinliklerindeki parajenez ve paramorfizma olaylarıyla ilişkili olan bütün bu süreçler, yeraltı suları tarafından daha kolay ayrıştırılarak mineralize edilen unsurların ortaya çıkmasına ve oksidasyon, hidratasyon ve hidroliz gibi kimyasal reaksiyonlar sonucu suların mineral yapılarının değişmesine ortam hazırlamaktadırlar. Dolayısıyla yeraltı sularının yüzeye ulaşmak için izledikleri yollara karşılık gelen fayların, yeraltı sularının söz konusu birimlerle ilişki kurabilecekleri şekilde bir güzergâh takip etmeleri gerekmektedir. Şüphesiz izlenen bu yolun yapısı ile mineralli suların fiziko-kimyasal özellikleri tam bir uyum içerisindedir.

Çalışma alanındaki mineralli sularda yapılan analizler, suların özellikle mineral yapılarının ortaya konması noktasında önemli katkılar sağlamıştır. Böylelikle her dört kaynağa ait parametrelerin aynı şartlar altında analiz edilerek bir bütünün parçaları şeklinde değerlendirilmesi imkânı doğmuştur. Bu ise laboratuvar koşullarından kaynaklanacak sapmaları ortadan kaldırmıştır. Öte yandan çalışma kapsamında elde edilen bulguların tek tek yorumlanması yerine, bazı dikkat çekici noktalara vurgu yapılarak suların mineral dengeleri arasındaki toplu bir uyum veya uyumsuzluk durumunun araştırılması yolu benimsenmiştir.

Çalışmaya konu olan kaynakların tamamında su sıcaklıklarının belirgin bir mevsimsel değişim sergilediği, dolayısıyla kaynakların yüzey koşullarının etkisinden bağımsız olmadıkları izlenmiştir. Ancak bu etki kaynakların tamamı için benzer olup, mevsimsel pH değerlerindeki değişimden de anlaşılacağı üzere, mineralli sulara yüzey sularından olan karışıma bağlıdır. Zira yaz ve kış aylarında yükselen pH değerleri nispeten daha fazla yağışın düştüğü ilkbahar ve sonbahar döneminde düşmektedir. Özellikle ilkbaharda ve kısmen de yaz döneminde amonyum, sodyum, sülfat ve potasyum gibi paremetrelerde görülen anormal artış, seyelan veya sulama sularıyla yüzeyden yıkanarak taşınan minerallerin mineralli sulara karıştığının bir göstergesidir.

Bilindiği gibi sulardaki kimyasal oksijen ihtiyacının (KOİ) biyolojik oksijen ihtiyacından (BOİ) büyüklüğü oranında kimyasal reaksiyon veya aktivitenin biyolojik reaksiyon veya aktiviteden baskın olduğu sonucuna ulaşılır. Bu durum her dört kaynakta da net olarak görülebilmektedir. Öte yandan sulardaki kalsiyum ve karbonat türevlerinin yoğunluğu ile bu yoğunluğun bir göstergesi olan sertlik derecesinin, ofiyolitlerin altında yer alan Arap plakasına ait karbonatlardan kaynaklandığı anlaşılmaktadır. Yüzey koşullarında ofiyolitik seri elemanlarından başka herhangi bir litolojik birimle teması olmayan suların kalsiyum ve karbonat türevlerini çözündürerek bünyelerine alabilecekleri yegâne birimin söz konusu karbonatlı kayaçlar olması böyle bir kanaate varılmasının temel dayanağıdır.

Mineralli sular içerisindeki metaller arasında, tektonit-peridotit grubu üyelerinde bolca bulunan demir ve magnezyum gibi minerallerin ağırlığı net bir şekilde hissedilmektedir. Aynı şekilde yüksek arsenik konsantrasyonu da söz konusu litolojik birimlerin etkisinde gelişen bir durumdur. Çünkü sulardaki arsenik yoğunluğuna en büyük katkıyı sağlayan sülfür mineralleri ile demir ve bakır içeren kayaçların yanı sıra demir oksitlerin de ofiyolitik seri elemanları içerisinde çok yüksek oranda bulunduğu bilinmektedir.

Yapılan analizler neticesinde elde edilen bulgular arasında ilk dikkat çekenlerden biri kaynakların oldukça yakın seyreden sıcaklıklarıdır. Bilindiği gibi sıcaklığı 20 ila 30 °C arasındaki sulara epitermal sular denilmektedir. Kisecik I kaynağının sınırın hemen altındaki sıcaklığı (19,45 °C) bu kaynağı soğuk mineralli sular arasına sokmakla birlikte diğer kaynaklar epitermal sular sınıfında yer almaktadırlar. Genel görünüm ise 19,45 ile 26,35 °C arasındaki 6,90 °C gibi dar bir bantta yer alan sıcaklıkların, bu kaynakların benzer derinliklerden gelen suları içerdikleri yönündedir. Ayrıca kaynakların toplam mineral konsantrasyonları bakımından akrotermal sular sınıfında yer alıp düşük mineral yüküne sahip olmaları da, kaynak akifer derinliğinin az ve buradaki haznenin de çok uzun bir süre yeraltında kalmayan sulardan ibaret olduğuna işaret etmektedir. Çünkü ofiyolitler gibi metalik mineral içeriği yüksek olan kayaç yapıları içerisinde özellikle demir minerallerinin oksitlenmesine bağlı yükün artması, kimyasal reaksiyonların hızı ve geçen süre ile doğru orantılıdır. Bu şekilde yüksek konsantrasyonlara ulaşılmamış olması kaynakların düşük sıcaklıkta ve alkali karakterde olmasının yanı sıra, kaynak suları ile kayaçlar arasındaki etkileşimin kısıtlı olduğunu da göstermektedir.

Anliz sonuçlarında göze çarpan bir diğer husus ise bütün kaynaklarda gerek ortalama mineral dağılımının gerekse bu dağılımda mevsimsel bazda görülen değişikliklerin büyük bir uyum göstermesidir. Dolayısıyla aynı hat üzerindeki iki kaynak arasında olduğu gibi, iki farklı hat üzerinde bulunan kaynak grupları arasında da, yüzey sularından karışım, bulunulan jeolojik ortam ve kaynak hazne derinliği gibi özellikler açısından çok benzer koşulların etkili olduğundan söz etmek mümkündür.

Sonuç itibariyle, Kisecik I ve Kisecik II mineralli su kaynakları ile Tahtaköprü ve Suluca mineralli su kaynaklarını yeryüzeyine ulaştıran fayların, benzer ortam koşullarında ortaya çıktığı ve birbirine çok yakın özelliklere sahip faylar olduğu anlaşılmaktadır. Bu faylar ister Anadolu levhasının batı-güneybatı yönündeki göreceli hareketini telafi eden faylar olsun, ister Anadolu'nun altına dalan Afrika levhasının çekmesiyle şekillensin, isterse doğusundaki riftleşmenin tansiyon etkisiyle ortaya çıksın, her durumda aynı mekanizmanın ürünü olup iki bölgede de aynı tektonik rejimin hüküm sürdüğünü göstermektedirler. Dolayısıyla bölgede yapılacak jeotektonik temelli çalışmalarda Amanoslar'ın bu iki bölümünün aynı tektonik birim içerisinde değerlendirilmesi yerinde olacaktır.

Anahtar Kelimeler: Hatay, tektonik, mineralli suların fiziko-kimyası, fay strüktürü, Amanos Dağları, fay kaynakları, Kisecik, Tahtaköprü.

1. Introduction

Hatay, located where African, Arabian and Anatolian plates converge, corresponds to a tectonically active area as a result (Figure 1). Especially compensation of the Arabian plate's relatively faster motion at the northern bound, compared to African plate, by Dead Sea Fault Zone (Quennell, 1956; Freund, 1965; Garfunkel, 1981; Garfunkel et al., 1981; Courtillot et al., 1987; Joffe and Garfunkel, 1987; Brink et al., 1999) prepared the conditions for the existence of a tectonic gulley that cuts through the province in the north-south direction. On the other hand, continuing neo-tectonic activities in the region (Günay, 1984; Selçuk, 1985; Perinçek and Eren, 1990; Över et al., 2001; Rojay et al., 2001; Över et al., 2004a; Karabacak et al., 2010; Tarı et al., 2014, Avcı and Günok, 2015; Pektezel, 2015), activity in the subduction zone connected to Hellenic and Cyprus Arcs in the southwest (Över et al., 2002) and collective elevation in Amanos Mountains where horst activities are ongoing (Şengör and Yılmaz, 1983; Toprak et al., 2002; Boulton and Robertson, 2007; Boulton and Robertson, 2008) caused the formation of many faults with highly different structures. When the views such as East Anatolian Fault's continuance up to Amik Plain (Allen, 1969; Arpat and Şaroğlu, 1975; Kelling et al., 1987; Kiratzi, 1993; Rotstein, 1984; Şengör et al., 1985; Över et al., 2004a; Herece, 2008) and the existence of Cyprus-Antioch Transform Fault (Över et al., 2004b) are included in this complex situation, discussions about the structures and properties of the faults in the region are increasing day by day.

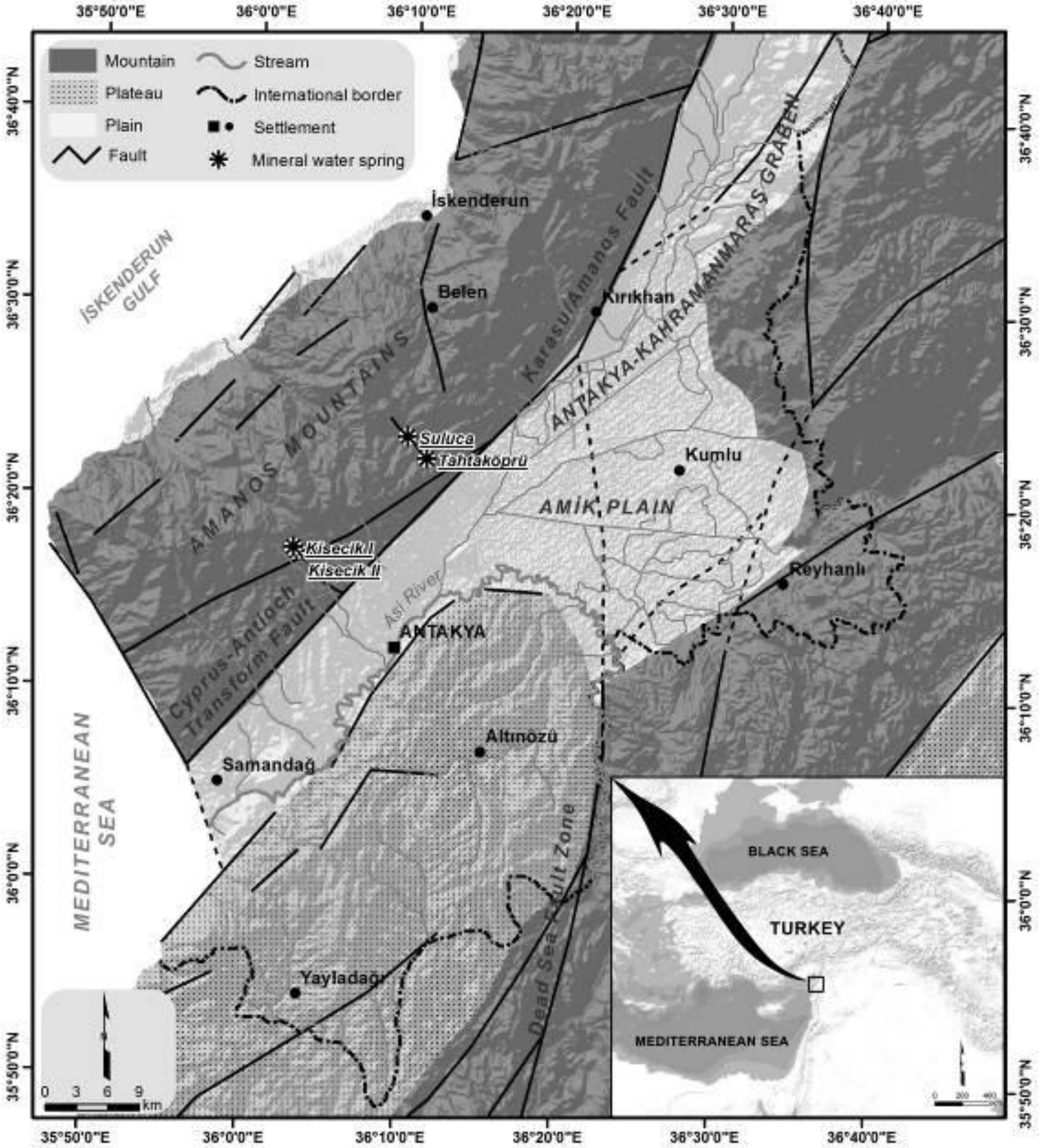

Figure 1. Location map of the study area and its immediate vicinity and main tectonic lines in the region.

Complicated tectonic activities in Hatay resulted in a complex geologic structure. It is possible to observe geological structures with varying ages and lithologies from the Precambrian period to the current date. Ophiolites that belong to Upper Cretaceous are of particular importance since they harbor the mineral water springs, the subject of the current study (Karataş and Korkmaz, 2012). This unit, located in the south of Belen Strait of Amanos Mountains and is the main element of the section called South Amanos Mountains, is called Kızıldağ Ophiolite in the literature (Dilek et al., 1991; Bağcı et al,, 2005; Dilek and Thy, 2009) and displays a horst character connected to normal faults that border the northwest and southeast of the anticlinal whose core is also formed by it (Yılmaz, 1984). Existence of a multitude of faults that were placed vertically or diagonally to the main lines in the northeast-southwest direction shaped the fault mosaic and independent block tectonism in the area. As a result, complete ocean floor volcanic sequence composed of base to top tectonite-peridotite, cumulate-gabbro, diabase-dyke complex and pillow lava outcropped in the form of concentric circles from inside out and from old to young due to higher level of abrasion in mid-section where elevation is the highest (Figure 2). Outcrops that belong to Kızıldağ Ophiolites with a total surface area of 810.86 km² are divided in the following manner: 67% tectonite-peridotite, 18.1% cumulate-gabbro, 13.2% diabase-dyke complex and 1.7% pillow lava.

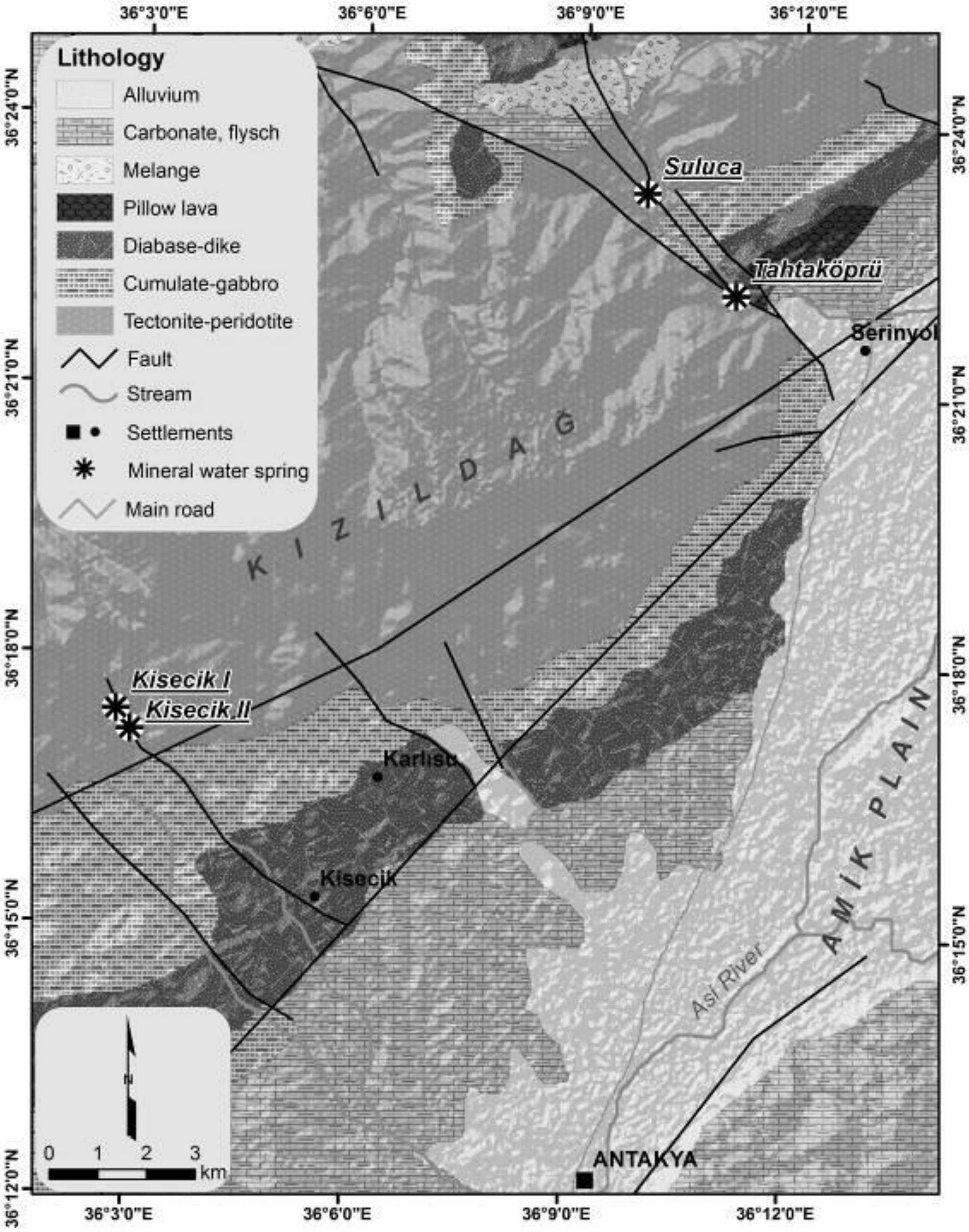

Figure 2. Geo-tectonic strucute of the study area.

It is known that water sets the ground for changes in rock structure both in physical and chemical terms and is one of the most effective factors in weathering processes. While some substances such as salt and carbonate varieties are washed away as a result of these processes, new minerals and compounds are generated (Atalay, 2011). Water which is the element that undertakes the abovementioned operations related to washing and transportation receives new minerals and compounds in its structure based on this process and undergoes a type of contamination. This phenomenon takes place in the framework of hydraulic, hydrologic and hydrothermal alterations due to water's corrosion and corrosion effects. Therefore, the mineral content of water changes according to both the rock types with which it is in contact with and under the control of weathering processes that affect these rocks. Mineral structure of the water is closely related to the features of the geologic units through which it travels and the interaction process with these units. Weathering processes and the equilibrium of mineral water are two different parameters that provide information about one another.

2. Material and Methods

The digital terrain model used in the study was generated with the help of ArcMap 10 package program (ESRI) and ASTER GDEM 15 m resolution Digital Elevation Model (DEM) (METI and NASA). Faults and geologic structure were organized based on Yalçın (1980), Yılmaz (1984), Lyberis et al. (1992), Yürür, and Chorowicz (1998), Rojay et al. (2001), MRE (2002), Yurtmen et al. (2002), Över et al. (2004b), Albora et al. (2006), Herece (2008), Karabacak et al. (2010, 2012), Emre et al. (2012a, b), Duman et al. (2012) and Yönlü et el. (2013) and our field findings. Related sheets of 1/25000 and 1/100000 scale topography maps of General Command of Mapping (GCM) of Turkey are utilized whenever necessary. Chemical structures of rocks in tectonite-peridotite group and the stages they undergo during the weathering processes were identified according to findings obtained in the field as well as based on Yalçınlar (1968), Harker (1970), Pınar Erdem (1976), Geological Society of Turkey and TMMOB JMO (1982), Sür (1994), Dilek et al. (1997), İlbeyli (2004) and Dilek and Furnes (2009).

Water samples obtained in the framework of physical and chemical analyses of mineral waters were placed in colorless and chemically cleaned glass bottles. Bottles that will be used to collect samples for heavy metal analysis were first rinsed with HNO_3 and pure water. For cation analysis, concentrated and high-purity HNO_3 was added to the bottles as pH < 2. Colored bottles sterilized for an hour in 180 ºC dry heat were utilized for bacteriological analyses. Samples for taken in 3-month periods and were analyzed without delay. Water temperature was measured with a mercury thermometer with 1 °C calibration and pH levels were measured digital pH meter with 0.01 sensitivity. Total dissolved solid substance amount was obtained by first separating suspended solids via filtration and then weighing the remaining solid substances after vaporizing the filtered water at 103 °C for an hour (Şengül and Türkman, 1998). Dissolved oxygen was designated with the help of Winkler method (Winkler, 1888). Water samples were placed in special BOD bottles to which 2-3 drops of nutrient solution were added. 2-3 NaOH tablets were placed in the semi-stoppers in bottle caps. BOD bottles were closed with manometers set at zero and placed in the mixer. BOD values were read and recorded at the same time every day and after reading the BOD value at the end of day five, it was multiplied by the multiplier to obtain the results (Şengül and Türkman, 1998). Specific amount of $K_2Cr_2O_7$ was added to the water sample at a specific volume to determine the bio-chemical oxygen demand and out into reaction by boiling it for two hours in H_2SO_4 environment with the help of condenser. Excess $K_2Cr_2O_7$ was subjected to backward titration with $FeSO_4$ solution. O_2 equivalent to the used $K_2Cr_2O_7$ provided the COD values in the sample (Şengül and Türkman, 1998). Nitrogen was determined with Kjeldahl method (Kjeldahl, 1883). For phosphate assignment, the sample was boiled with HNO_3 and ammonium molybdate was added after cooling. Yellow ammonium phosphomolybdate was formed and it was agreed that the generated color should be directly proportional to the phosphate concentrate. Spectrophotometric method was used. Spectroquant readymade bulks were used in assigning free chlorine and readings were taken at 550m wave length in spectrophotometer. Solution obtained by dissolving 4 ml measure 1 g resorcinol and 1.1 g zirconil chloride octahydrate in 2 ml water sample and diluting it to 500 ml by adding 7.5 ml HCl and solution obtained by dissolving 4 ml measure 1 g sodium sulphate and 1.5 g sodium acetate trihydrate in 500 ml water were added to 2 ml water sample to assign nitrite. After mixing well, readings were taken at 347 nm wave length in spectrophotometer (Şengül and Türkman, 1998). Spectroquant readymade bulks were used in assigning nitrite and readings were taken at 340 nm wave length and fluorine amount is determined by using photoflex (Şengül and Türkman, 1998). Sulphate was assigned by adding barium chloride in HCl environment as precipitating it as barium sulfate, and the precipitated material was filtered and washed with pure water until it contained no chloride. Later it was burned and weighed in the form of $BaSO_4$ (Şengül and Türkman, 1998). While assigning carbonate and bicarbonate, 1 drop of phenolphthalein indicator was added t the sample and it was titrated with H_2SO_4 until it turned to colorless from pink. Later, 2 drops of methylorange indicator was added on the colorless solution and was titrated with H_2SO_4 until its color turned from yellow to onion skin red (Peker, 2007). All heavy metals and metals such as sodium, potassium, calcium, magnesium and aluminum were determined through ICP. Water sample was filtered with the help sterile filter paper in order to examine the microbiological properties of water and filter paper was spread in the petri dish and enough agar was added to cover it. Following average 24-48 hours incubation, black and bright spots formed on agar were counted to determine the number of coliform in the water (Şengül and Türkman, 1998).

Relationship between physico-chemical analysis results and weathering processes of the rocks in the peridotite group among ophiolites was examined by reviewing them together. Later mineral concentrations of all springs were undertaken comparatively and findings obtained about the faults that direct mineral waters to the ground, and the position and situation of aquifers through which mineral waters flow and ground surface.

3. Results

Mineral spring waters in the study area originate from tectonite-peridotites under Kızıldağ ophiolite. Therefore, weathering processes in tectonite-peridotite group located at the bottom of ophiolitic sequence and the products of these processes are directly related to the content of mineral waters (Table 1). However, it should be remembered that fault lines, i.e. the tracks followed by mineral waters, act as beds for the debris which is more suitable to be dissolved by metamorphism during faulting (mylonite zones) (Karataş, 2011); and therefore they are in relation with the mineral structures of water based on newly formed rock properties.

Table 1. Rock structure and weathering features of tectonite-peridotites*

Dominant rocks	Rock forming minerals	Element compound	Weathering processes	Weathering products
Harzburgite	Olivine, Orthopyroxene	$(MgFe)_2\ SiO_4$ (Mg, Fe, Ca) (Mg, Fe, Al) (Si, Al)$_2$ O_6	Serpentinization Segregation Oxidation Talc production	Serpentine, Chromite, Limonite, Talc
Dunite	Olivine	$(MgFe)_2\ SiO_4$	Serpentinization Segregation Oxidation Talc production	Serpentine, Chromite, Limonite, Talc
Wehrlite	Olivine, Clinopyroxene	$(MgFe)_2\ SiO_4$ (Ca, Mg, Fe, Al)$_2$ (Si, Al)$_2$ O_6	Serpentinization Uralitization Segregation Oxidation Talc production	Serpentine, Uralite, Smaragdite, Chlorite, Chromite, Limonite, Talc
Lherzolite	Olivine, Clinopyroxene, Orthopyroxene	$(MgFe)_2\ SiO_4$ (Ca, Mg, Fe, Al)$_2$ (Si, Al)$_2$ O_6 (Mg, Fe, Ca) (Mg, Fe, Al) (Si, Al)$_2$ O_6	Serpentinization Uralitization Segregation Oxidation Talc production	Serpentine, Uralite, Smaragdite, Chlorite, Chromite, Limonite, Talc

*Information in the table based on our field studies and Yalçınlar (1968), Harker (1970), Pınar Erdem (1976), Geological Socieity of Turkey and TMMOB JMO (1982), Sür (1994) Dilek et al. (1997), İlbeyli (2004) and Dilek and Furnes (2009).

Tectonite-peridotite group is included in harzburgite, dunite, wehrlite and lherzolite lithology and all of these rock structures were exposed to hydrothermal alteration during the formation period. Based on high olivine content (e.g. dunite more than 90%), ferromagnesian components of unit elements that present extensive serpentinization and high talc content such as olivine and hematite generated the source for rocks like serpentine and talc at the end of the process (Harker, 1970; Pınar Erdem, 1976). Iron minerals that generate olivine, clinopyroxene and orthopyroxene in rock compounds transformed into limonite as a result of oxidation. Clinopyroxenes created new amphibole and clay types such as uralite, smaragdite and chlorite as a result of segregation and uralitization. It is also known that chromite was generated with the segregation of the peridotite group (Pınar Erdem, 1976). In the end, they were transformed into consolidated rocks of tectonite-peridotite group or rocks or clay derivatives with low resistance. High talc content and serpentinization are results of hydrothermal alteration and dynamo metamorphism events while segregation occurs as a result of cooling process and uralitization is the result of rock bound pyroxenes transformation into green amphiboles. All these processes which are closely related to underground paragenesis and paramorphism caused the emergence of mineralized elements easily resolved by underground waters and prepared the change in mineral structures of the water as a result of chemical reactions such as oxidation, hydratation and hydrolysis. Therefore, faults that correspond to the tracks followed by underground water to reach the surface need to follow a route through which underground waters can to relate to above mentioned units (Başkaya, 2015). Of course, properties of the tracks that is followed and the physico-chemical properties of mineral waters are in complete compatibility.

Analyses conducted on mineral waters in the study area made significant contributions regarding the presentation of water properties especially the properties of mineral waters (Table 2). The study enabled the analysis of parameters that belonged to four springs under the same conditions and assessment of the results as parts of whole. This opportunity removed all deviations that would have been caused by lab conditions. On the other hand, some significant points were emphasized to investigate a collective harmony or disharmony between mineral equilibrium of waters instead of interpreting the study findings one by one.

Table 2. Main mineral concentration of mineral water springs.

	Kisecik I	Kisecik II	Tahtaköprü	Suluca
Temperature (°C)	19.45 ± 0.5	25.40 ± 0.6	26.35 ± 0.6	23.02 ± 0.6
pH	10.24 ± 0.3	10.66 ± 0.4	11.06 ± 0.4	11.03 ± 0.4
BOD	12.50 ± 0.2	5.00 ± 0.1	5.00 ± 0.1	5.00 ± 0.1
COD (mg/l)	80.50 ± 1.5	71.75 ± 1.5	74.00 ± 1.4	83.50 ± 1.5
Dis. Oxygen (mg/l)	6.58 ± 0.2	6.38 ± 0.2	1.28 ± 0.2	1.90 ± 0.2
Amonium (mg/l)	0.04 ± 0.002	0.02 ± 0.002	0.33 ± 0.008	0.02 ± 0.002
Nitrite (mg/l)	0.06 ± 0.002	0.04 ± 0.002	0.05 ± 0.002	0.04 ± 0.002
Nirtate (mg/l)	3.86 ± 0.02	3.21 ± 0.02	14.26 ± 0.02	4.51 ± 0.02
Phosphate (mg/l)	0.13 ± 0.002	0.19 ± 0.002	0.19 ± 0.002	0.11 ± 0.002
Sulfate (mg/l)	1.51 ± 0.02	3.51 ± 0.02	1.50 ± 0.02	1.50 ± 0.02
Sulfite (mg/l)	0.68 ± 0.02	0.88 ± 0.02	2.95 ± 0.02	0.98 ± 0.02
F. Chlorine (mg/l)	0.04 ± 0.002	0.05 ± 0.002	0.05 ± 0.002	0.05 ± 0.002
Fluorure (µg/l)	104.25 ± 2	104.25 ± 2	104.25 ± 2	41.75 ± 0.7
TDS ($CaCO_3$/l)	152.50 ± 2	142.50 ± 1.8	125.00 ± 1.6	82.50 ± 1.5
Carbonate (mg/l)	18.25 ± 0.4	16.00 ± 0.4	15.08 ± 0.3	12.58 ± 0.3
Bicarbonate (mg/l)	12.98 ± 0.4	17.22 ± 0.4	19.22 ± 0.4	8.59 ± 0.2
Sodium (mg/l)	19.45 ± 0.5	20.58 ± 0.5	25.74 ± 0.7	40.71 ± 0.9
Potassium (mg/l)	0.97 ± 0.02	0.95 ± 0.02	1.00 ± 0.02	2.00 ± 0.02
Calcium (mg/l)	8.65 ± 0.2	15.74 ± 0.4	14.49 ± 0.4	13.02 ± 0.4
Magnesium (mg/l)	0.22 ± 0.04	0.41 ± 0.07	0.21 ± 0.07	0.33 ± 0.07
Aluminum (mg/l)	0.06 ± 0.002	0.08 ± 0.003	0.13 ± 0.003	0.09 ± 0.003
Ferrum (µg/l)	1.19 ± 0.02	1.15 ± 0.02	1.26 ± 0.02	1.55 ± 0.02
Mangane (µg/l)	0.005 ± 0.0002	0.005 ± 0.0002	0.005 ± 0.0002	0.007 ± 0.0002
Copper (µg/l)	0.005 ± 0.0002	0.005 ± 0.0002	0.007 ± 0.0002	0.007 ± 0.0002
Zinc (µg/l)	0.015 ± 0.0002	0.013 ± 0.0002	0.015 ± 0.0002	0.015 ± 0.0002
Barium (µg/l)	0.009 ± 0.0002	0.009 ± 0.0002	0.008 ± 0.0002	0.010 ± 0.0002
Arsenic (µg/l)	0.028 ± 0.0002	0.028 ± 0.0002	0.019 ± 0.0002	0.016 ± 0.0002
Cadmium (µg/l)	0.011 ± 0.0002	0.011 ± 0.0002	0.010 ± 0.0002	0.010 ± 0.0002
Chromium (µg/l)	0.008 ± 0.0002	0.008 ± 0.0002	0.008 ± 0.0002	0.008 ± 0.0002
Nickel (µg/l)	0.011 ± 0.0002	0.011 ± 0.0002	0.010 ± 0.0002	0.012 ± 0.0002
Lead (µg/l)	0.007 ± 0.0002	0.007 ± 0.0002	0.006 ± 0.0002	0.005 ± 0.0002
Antimoine (µg/l)	0.014 ± 0.0001	0.016 ± 0.0002	0.017 ± 0.0001	0.028 ± 0.0001
Cobalt (µg/l)	0.009 ± 0.0002	0.009 ± 0.0002	0.009 ± 0.0002	0.009 ± 0.0002

Seasonal changes in water temperatures were observed in all of the springs studied in the framework of the study and it was found that they were not independent of the effects of surface conditions. However, this effect was similar for all springs and it was related to the mixture of mineral waters to surface waters as can be observed from the changes in seasonal pH values. The pH values that increase during summer and winter months decrease in spring and autumn when comparatively more precipitation is observed. Abnormal increases in the parameters such as ammonium, sodium, sulphate and potassium in especially spring and partially in summer months indicate that minerals that were carried from the surface as a result of washing off by sheet flow and irrigation flow into mineral waters.

As it is known, the finding that chemical reaction or activity is more dominant than the biological reaction or activity can be obtained proportional to the ratio of magnitude of chemical oxygen demand (COD) in waters compared to biological oxygen demand (BOD). This was clearly observed in all four springs. On the other hand, density of calcium and carbonate derivatives in waters and degree of hardness which is an indicator of this density were found to be related to carbonates that belong to the Arabian plate located under the ophiolites. The fact that the only unit is the carbonate rocks to incorporate calcium and carbonate derivatives for waters which do not have any contact with lithologic units other than ophiolitic series elements in surface conditions is the basic foundation for this conviction.

Among the metals in mineral waters, dominance of minerals such as iron and magnesium, usually found profusely in tectonite-peridotite group members, can be clearly observed. Similarly, high arsenic concentration is also a situation that develops with the influence of lithologic units because it is known that in addition to sulphur minerals and rocks with iron and copper content that provide the biggest contribution to arsenic density in waters (Matschullat, 2000; Bissen and Frimmel, 2003; Bilici Başkan and Pala, 2009) iron oxides are also (Jain et al., 1999; Sadiq et al., 2002) found in high densities among ophiolitic series elements.

4. Discussion

One of the first significant findings obtained as a result of the analyses conducted during the framework of the study is the extremely similar temperatures among the springs. As we know, waters with temperatures between 20-30 °C are called epithermal waters. Although the temperature of Kisecik I spring which is right under the limits (19.45 °C) puts this spring among cold mineral waters, other springs are categorized as epithermal waters. General view is that temperatures included in a narrow belt such as 6.90 °C between 19.45 and 26.35 ° point to the fact that these springs are composed of waters coming from similar depths. Also the fact that the springs are classified as acrothermal waters due to their total mineral concentrations with low mineral loads points to small spring aquifer depth and a basin composed of waters that has not been underground for long periods of time. Increased in loads due to oxidation of especially the iron minerals in rock structures with high metallic mineral content such as ophiolites is directly proportional to the speed of chemical reactions and the time elapsed. The fact that high concentrations were not reached in this manner show that springs are in low temperatures, have alkaline characters and the interaction between spring waters and rocks are limited.

Another issue observed by the analyses is the extensive harmony in all springs both in terms of average mineral distribution and also in terms of the seasonal changes in this distribution (Figure 3). Therefore, it is possible to report the influence of highly similar conditions both between two springs on the same line and between spring groups located in two different lines in terms of mixture from surface waters, geological environment and reservoir depth.

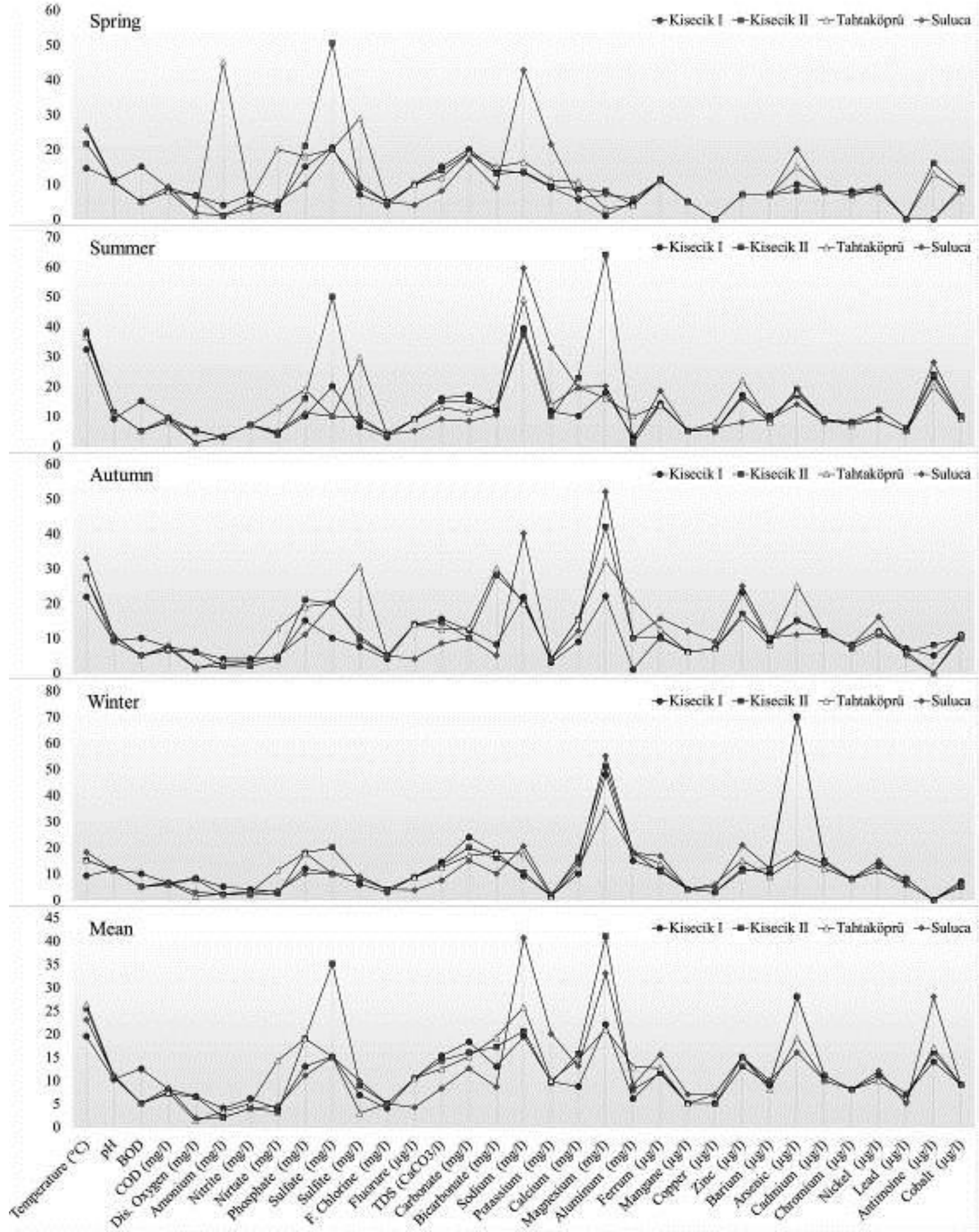

Figure 3. Mineral equilibrium of springs and seasonal changes in the amount of minerals.

Results show that the faults that transmit Kisecik I and Kisecik II mineral water springs and Tahtaköprü and Suluca mineral water springs to the surface were generated in similar environmental conditions and that they have very similar properties. Whether these faults are the ones that compensate the relative motion of Anatolian plate in the west-southwest direction or are the ones shaped by the pull of African plate that subducted under Anatolia or generated by the tension impact of rifting in the east, they are the product of the same mechanism under all conditions and the same tectonic regime is dominant in both regions. Therefore, it would be fitting to assess these two sections of Amanos Mountains in the same tectonic unit during geotectonic based studies that will be conducted in the region.

Acknowledgments

This work has been supported by Mustafa Kemal University Scientific Reseach Projects Coordination Units (Project Nu.: 9621). Maps throughout this study were created using ArcGIS® software by Esri. Digital Elevation Model (DEM), which used in this study, ASTER GDEM is a product of METI and NASA.

REFERENCES

Albora, A.M., Sayın, N., and Uçan, O.M. (2006). Evaluation of tectonic structure of İskenderun basin (Turkey) using steerable filters. Marine Geophysical Researches, 27, 225–239.

Allen, C.R. (1969). Active Faulting in Northern Turkey. Contribution 1577. Division of Geological Sciences, California Institute of Technology, California, 32 p.

Arpat, E., and Şaroğlu, F. (1975). Some recent tectonic events in Turkey. Bulletin on Turkey Geological Socieity, 18, 91–101.

Atalay, İ. (2011). Toprak Oluşumu, Sınıflandırılması ve Coğrafyası. Meta Basım Matbaacılık Hizmetleri, İzmir, 512 p. (in Turkish with English Abstract)

Avcı, V. And Günek, H. (2015). Karlıova havzası ve çevresinin (Bingöl) heyelan duyarlılık haritasının oluşturulması. Turkish Studies International Periodical For The Languages, Literature and History of Turkish or Turkic, Volume 10/2 Winter 2015, p. 49-68.

Bağcı, U., Parlak, O., and Höck, V. (2005). Whole rock and mineral chemistry of cumulates from the Kızıldağ (Hatay) ophiolite (Turkey): Clues for multiple magma generation during crustal accretion in the Southern Neotethyan Ocean. Mineralogical Magazine, 69, 53–76.

Başkaya, Z. (2015). Coğrafi etmenler ve termal turizm potansiyeli açısından çermik (Diyarbakır) kaplıcalarının değerlendirilmesi. Turkish Studies International Periodical For The Languages, Literature and History of Turkish or Turkic, Volume 10/6 Spring 2015, p. 307-340.

Bilici Başkan, M., and Pala, A. (2009). İçme sularında arsenik kirliliği: Ülkemiz açısından bir değerlendirme. Pamukkale University Engineering Faculty Journal of Engineering Sciences, 15, 69–79 (in Turkish with English Abstract)

Bissen, M., and Frimmel, F.H. (2003). Arsenic–a review part I: Occurrence, toxicity, speciation, mobility. Acta Hydrochemistry et Hydrobiology, 1, 9–18.

Boulton, S.J., and Robertson, A.H.F. (2008). The Neogene-Recent Hatay Graben, South Central Turkey: graben formation in a setting of oblique extension (transtension) related to post-collisional tectonic escape. Geological Magazine, 145, 800–821.

Boulton, S.J., and Robertson, A.H.F. (2007). The Miocene of the Hatay area, S Turkey: Transition from the Arabian passive margin to an underfilled foreland basin related to closure of the Southern Neotethys Ocean. Sedimentary Geology, 198, 93–124.

Brink, U.S., Rybakov, M., Al-Zoubi, A.S., Hassouneh, M., Frieslander, U., Batayneh, A.T., Goldschmidt, V., Daoud, M.N., Rotstein, Y., and Hall, J.K. (1999). Anatomy of the Dead Sea transform: Does it reflect continuous changes in plate motion?. Geology, 27, 887–890.

Courtillot, V., Armijo, R., and Tapponnier, P. (1987). The sinai triple junction revisited. Tectonophysics, 141, 181–190.

Dilek, Y., and Furnes, H. (2009). Structure and geochemistry of Tethyan ophiolites and their petrogenesis in subduction rollback systems. Lithos, 113, 1–20.

Dilek, Y., and Thy, P. (2009). Island arc tholeiite to boninitic melt evolution of the cretaceous Kizildag (Turkey) ophiolite: model for multi-stage early arc–forearc magmatism in Tethyan subduction factories. Lithos, 113, 68–87.

Dilek, Y., Coulton, A., and Hurst, S.D. (1997). Serpentinization and hydrothermal veining in peridotites at site 920 in the mark area. In: Karson JA, Cannat M, Miller DJ, Elthon D (ed.). Proceedings of the Ocean Drilling Program, Scientific Results, Vol. 153. College Station, TX (Ocean Drilling Program), p. 35–59.

Dilek, Y., Eldridge, M.M., Delaloye, M., and Karson, J.A. (1991). A magmatic extension and tectonic denudation in the Kizildağ ophiolite, southern Turkey: ımplication fort he evolution of neotethyan oceanic crust. In: Peters, T. and Nicholas, A. (eds.). Ophiolite Genesis and Evolution of the Oceanic Lithosphere, Ministry of Petroleum and Minerals, Sultanate of Oman. Springer, p. 485–500.

Duman, T.Y., Emre, Ö., Özalp, S., Olgun, Ş., and Elmacı, H. (2012). 1/250.000 scale active fault maps series of Turkey, Şanlıurfa (NJ 37-10) and Suruç (NJ 37-14) Quadrangles. Serial Number: 43. General Directorate of Mineral Research and Exploration, Ankara-Turkey.

Emre, Ö., Duman, T.Y., and Olgun, Ş. (2012a). 1/250.000 scale active fault maps series of Turkey, Antakya (NJ 37-13) Quadrangle. Serial Number: 39. General Directorate of Mineral Research and Exploration, Ankara-Turkey.

Emre, Ö., Duman, T.Y., Olgun, Ş., Elmacı, H., and Özalp, S. (2012b). 1/250.000 scale active fault maps series of Turkey, Gaziantep (NJ 37-9) Quadrangle. Serial Number: 38. General Directorate of Mineral Research and Exploration, Ankara-Turkey.

Freund, R. (1965). A model of the structural development of Israel and adjacent areas since Upper Cretaceous times. Geological Magazine, 102, 189–205.

Garfunkel, Z. (1981). Internal structure of the Dead Sea leaky transform (rift) in relation to plate kinematics. Tectonophysics, 80, 81–108.

Garfunkel, Z., Zak, I., and Freund, R. (1981). Active faulting in the Dead Rift. Tectonophysics, 80, 1–26.

Geological Societiy of Turkey (1982). Jeoloji El Kitabı. Ayyıldız Matbaası, Ankara, 65 p. (in Turkish with English Abstract)

Günay, Y. (1984). Amanos Dağları'nın Jeolojisi ve Karasu - Hatay Grabeninin Petrol Olanakları. TPAŞ arama Grubu Başkanlığı Hakkâri-Şaryaj Projesi. Türkiye Petrolleri Anonim Ortaklığı Rapor No:1954, Ankara, 98 p. (in Turkish with English Abstract)

Harker, A. (1970). Öğrenciler İçin Petrografi. Translation: Bürküt Y, Teknik Üniversite Matbaası, İstanbul, 286 p. (in Turkish with English Abstract)

Herece, E. (2008). Doğu Anadolu Fayı (DAF) Atlası. Maden Tetkik ve Arama Genel Müdürlüğü, Özel Yayın Serisi 13, Ankara, 177 p. (in Turkish with English Abstract)

İlbeyli, N. (2004). Yer Biliminin (Jeoloji) Esasları Ders Notları. Palme Yayıncılık, Ankara, 267 p. (in Turkish with English Abstract).

Jain, A., Raven, K.P., and Loeppert, R.H. (1999). Arsenite and arsenate adsorption on ferrihydrite: Surface charge reduction and net oh-release stoichiometry. Environmental Sciences & Technologies, 33, 1179–1184.

Joffe, S., and Garfunkel, Z. (1987). Plate kinematics of the circum Red Sea- a re-evaluation. Tectonophysics, 141, 5–22.

Karabacak, V., Akyüz, H.S., Kıyak, N.G., Altunel, E., Meghraoui, M., and Yönlü, Ö. (2012). Doğu Anadolu Fay Zonu'nun Gölbaşı (Adıyaman) ile Karataş (Adana) arasındaki kesiminin geç Kuvaterner aktivitesi. The Scientific and Technological Research Center of Turkey, Proje No: 109Y04, Ankara, 418 p. (in Turkish with English Abstract)

Karabacak, V., Altunel, E., Meghraoui, M., and Akyüz, H.S. (2010). Field evidences from northern Dead Sea Fault Zone (South Turkey): New findings for the ınitiation age and slip rate. Tectonophysics, 480, 172–182.

Karataş, A. (2011). Fayların doğal kaynak sularının oluşum ve gelişimine etkileri. In: Ekinci, D. (ed.), Fiziki Coğrafya Araştırmaları; Sistematik ve Bölgesel. Türk Coğrafya Kurumu Yayınları No: 6, İstanbul, p. 659–670. (in Turkish with English Abstract)

Karataş, A., and Korkmaz, H. (2012). Hatay İli'nin Su Potansiyeli ve Sürdürülebilir Yönetimi. I. Baskı, Color Ofset. Mustafa Kemal Üniversitesi, Yayın No: 40, Hatay, 169 p. (in Turkish with English Abstract)

Kelling, G., Gökçen, S.L., Floyd, P.A., and Gökçen, N. (1987). Neogene tectonics and plate convergence in the Eastern Mediterranean: new data from southern Turkey. Geology, 15, 425–429.

Kiratzi, A. (1993). A study on the active crustal deformation of the North and East Anatolian Fault Zones. Tectonophysics, 225, 191–203.

Kjeldahl, J.Z. (1883). A new method for the determination of nitrogen in organic bodies. Analytical Chemistry, 22, 366–382.

Lyberis, N., Yürür, T., Chorowicz, J., Kasapoğlu, E., and Gündoğdu, N. (1992). The East Anatolian Fault: An oblique collisional belt. Tectonophysics, 204, 1–15.

Matschullat, J. (2000). Arsenic in the geosphere — a review. Science of The Total Environment, 249, 297–312.

MTA. (2002). 1/500.000 Ölçekli Türkiye Jeoloji Haritası, Hatay Paftası.

Över, S., Özden, S., and Yılmaz, H. (2004a). Late Cenozoic stress evolution along the Karasu Valley, SE Turkey, Tectonophysics, 380, 43–68.

Över, S., Özden, S., Ünlügenç, U.C., and Yılmaz, H. (2004b). A synthesis: Late Cenozoic stress field distribution at northeastern corner of the Eastern Mediterranean, SE Turkey. Comptes Rendus Geoscience, 336, 93–103.

Över, S., Ünlügenç, U.C., and Özden, S. (2001). Hatay bölgesinde etkin gerilme durumları. Yerbilimleri, 23, 1–14 (in Turkish with English Abstract)

Över, S., Ünlügenç, U.C., and Bellier, O. (2002). Quaternary stress regime change in the Hatay region (SE Turkey). Geophysical Journal International, 148, 1–14.

Peker, İ. (2007). Çevre Mühendisliği Kimyası, Birsen Yayınevi, İstanbul, 239 p. (in Turkish with English Abstract)

Pektezel, H. (2015). Gençali fayı'nın (Bursa) tektonik jeomorfoloji özellikleri. Turkish Studies International Periodical For The Languages, Literature and History of Turkish or Turkic, Volume 10/2 Winter 2015, p. 773-798.

Perinçek, D., and Eren, A.G. (1990). Doğrultu atımlı Doğu Anadolu ve Ölüdeniz fay zonları etki alanında gelişen Amik Havzasının kökeni. Türkiye 8. Petrol Kongresi Bildiri Kitabı, 180–192, Ankara (in Turkish with English Abstract)

Pınar Erdem, N. (1976). Mühendislik Jeolojisi, İstanbul Devlet Mühendislik ve Mimarlık Akademisi Yayınları Sayı: 156. Kurtulmuş Matbaası, İstanbul, 412 p. (in Turkish with English Abstract)

Quennell, A.M. (1956). Tectonics of the Dead Sea rift. Congreso Geologico Internacional, 20th sesion, Asociacion de Servicios Geologicos Africanos: Mexico City, p. 385–405.

Rojay, B., Heiman, A., and Toprak, V. (2001). Neotectonic and volcanic characteristics of the Karasu Fault Zone (Anatolia, Turkey): The transition zone between the Dead Sea Transform and The East Anatolian Fault Zone. Geodinamica Acta, 14, 1–17.

Rotstein, Y. (1984). Counterclockwise rotation of the Anatolian block. Tectonophysics, 108, 71–91.

Sadiq, M., Locke, A., Spiers, G., and Pearson, D.A.B. (2002). Geochemical behavior of arsenic in Kelly Lake, Ontario. Water Air and Soil Pollution, 141, 299–312.

Selçuk, H. (1985). Kızıldağ-Keldağ-Hatay Dolayının Jeolojisi ve Jeodinamik Evrimi. Maden Tetkik ve Arama Genel Müdürlüğü Jeoloji Etütleri Dairesi Başkanlığı, Ankara, 115 p. (in Turkish with English Abstract)

Sür, Ö. (1994). Strüktüral Jeomorfoloji. Ankara Üniversitesi Dil ve Tarih-Coğrafya Fakültesi Yayın No: 373. Ankara Üniversitesi Basımevi, Ankara, 127 p. (in Turkish with English Abstract)

Şengör, A.M.C., and Yılmaz, Y. (1983). Türkiye'de Tetis'in evrimi: Levha tektoniği açısından bir yaklaşım. Türkiye Jeoloji Kurumu, Yerbilimlkeri Özel Dizisi No: 1. Ankara, 75 p. (in Turkish with English Abstract)

Şengör, A.M.C., Görür, N., and Şaroğlu, F. (1985). Strike-slip faulting and related basin formation in zone of tectonic escape: Turkey as a case study. In: Biddle, K.T. and Christie-Blick, N. (eds.), Strike-slip Deformation, Basin Deformation and Sedimantation. Social and Economical Paleontology and Mineralogy Special Publication, 37, 227–264.

Şengül, F., and Türkman, A. (1998). Su ve Atıksu Analizleri. Türkiye Mimarlar ve Mühendisler Odası Birliği Çevre Mühendisleri Odası, İzmir, 151 p. (in Turkish with English Abstract)

Tarı, U., Tüysüz, O., Genç, Ş.C., İmren, C., Blackwell, B.A.B., Lom, N., Tekeşin, Ö., Üsküplü, S., Erel, L., Altıok, S., and Beyhan, M. (2014). The geology and morphology of the Antakya Graben between the Amik Triple Junction and the Cyprus Arc. Geodinamica Acta, 26, 1–29.

Toprak, V., Rojay, B., and Heimann, A. (2002). Hatay Grabeninin neotektonik evrimi ve Ölüdeniz fay kuşağı ile ilişkisi. Proje No: YDABAG-391, Ankara, 57 p. (in Turkish with English Abstract)

Winkler, L.W. (1888). Die Bestimmung des in wasser gelösten sauerstoffen. Berichte der Deutschen Chemischen Gesellschaft, 21, 2843–2855.

Yalçın, N. (1980). Lithological characteristics of the Amanos mountain range and its significance on the tectonic evolution of the Southeast Turkey. Bulletin of the Geological Society of Turkey, 23, 21–30.

Yalçınlar, İ. (1968). Strüktüral Morfoloji I. Genişletilmiş İkinci Baskı, İstanbul Üniversitesi Yayın No: 800, Edebiyat Fakültesi Yayın No: 24. Taş Matbaası, İstanbul, 496 p. (in Turkish with English Abstract)

Yılmaz, Y. (1984). Amanos Dağları'nın Jeolojisi (Cilt: 1-4). Türkiye Petrolleri Anonim Ortaklığı Rapor No:1920 (Yayımlanmamış). Ankara, 532 p. (in Turkish with English Abstract)

Yönlü, Ö., Altunel, E., Karabacak, V., and Akyüz, H.S. (2013). Evolution of the Gölbaşı basin and its implications for the long-term offset on the East Anatolian Fault Zone, Turkey. Journal of Geodynamics, 65, 272–281.

Yurtmen, S., Guillou, H., Westaway, R., Rowbotham, G., and Tatar, O. (2002). Rate of strike-slip motion on the Amanos Fault Karasu Valley, southern Turkey constrained by K-Ar dating and geochemical analysis of Quaternary basalts. Tectonophysics, 344, 207–246

Yürür, M.T., and Chorowicz, J. (1998). Recent volcanism, tectonics and plate kinematics near the junction of the African, Arabian and Anatolian plates in the Eastern Mediterranean. Journal of Volcanology and Geothermal Research, 85, 1–15.

Citation Information/Kaynakça Bilgisi

Karataş, A. – Sungur, Ş. & Yılmaz, V. (2016). "Physico-Chemical Features of Mineral Waters Found in Hatay Ophiolites and Their Relationships with Fault Characteristics / Hatay'da Ofiyolitler İçerisinden Çıkan Mineralli Suların Fiziko-Kimyasal Özellikleri ve Fay Karakteristikleri İle İlişkileri", *TURKISH STUDIES -International Periodical for the Languages, Literature and History of Turkish or Turkic-, ISSN: 1308-2140, (Prof. Dr. Hayati Akyol Armağanı),* Volume 11/2 Winter 2016, ANKARA/TURKEY, www.turkishstudies.net, DOI Number: http://dx.doi.org/10.7827/TurkishStudies.9052, p. 665-684.