

JEM 454

HİDROJEOKİMYA

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Uygulamalı Jeoloji Uzmanı
(Hidrojeolog)

su hayattır...

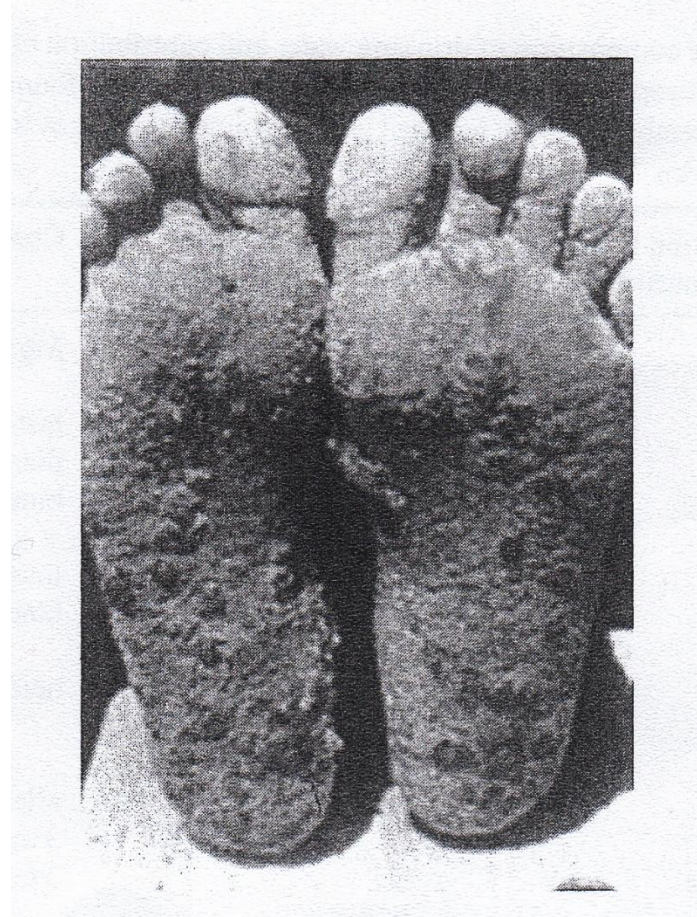
Haftalık Ders Programı

1. Hidrojeokimyaya giriş, suyun önemi, standartlar
2. Çözünmüş maddelerin konsantrasyon dönüşümleri
3. Yeraltı Suyu Örnekleme ve korunması
4. Su Dünyasında kullanılan yaygın parametrelerin açıklaması
5. Aktivite katsayıları
6. Sudaki elementlerin kökeni
7. Kimyasal verilerin analizi-grafiksel değerlendirme
8. Schoeller, Piper, Bar, Stiff, Dairesel diyagramların yorumları
9. Hidrokimyasal verilerin örnek çalışmalarla değerlendirilmesi
10. Bilgisayar laboratuvarında hidrokimyasal analiz yöntemlerinin kullanılması
11. Kompozisyon diyagramları ve karışım hesabı
12. Laboratuvarında Multi Analizer cihazının kullanımı ve pH, EC, T parametrelerinin ölçümü
13. Yüzeysel-yeraltı suyu ilişkisinin hidrokimyasal yöntemle incelenmesi-örnek çalışma
14. Duraylı izotopların hidrolojide kullanımı

İçme suyunun besin olarak katkısı ve içme suyu bileşenleri için standartlar. Avrupa Birliği İçme Suyu limitleri «www.europa.eu.int» adresinden bulunabilir. Dünya Sağlık Örgütü (WHO) için www.who.int/entity/dwq/en, USA için «www.epa.gov/safewater/» adresine bakabilirsiniz.

Constituent	Contribution to mineral nutrition (%)	Maximal admissible concentration (mg/L)	Comment
Mg ²⁺	3–10	50	Mg/SO ₄ diarrhea
Na ⁺	1–4	200	
Cl ⁻	2–15	250	taste; safe < 600 mg/L
SO ₄ ²⁻		250	diarrhea
NO ₃ ⁻		50	blue baby disease
NO ₂ ⁻		0.5	
F ⁻	10–50	1.5	lower at high water consumption
As	≈30	0.01	black-foot disease, skin cancer
Se		0.01	
Al	..	0.2	acidification/Al-flocculation
Mn		0.05	
Fe		0.2	
Ni		0.02	allergy
Cu	6–10	2	3 mg/L in new piping systems
Zn	negligible	0.1	5 mg/L in new piping systems
Cd	..	0.005	
Pb	..	0.01	
Cr	20–30	0.05	
Hg		0.001	

Deri lezyonları (siyah ayak hastalığı)
Yüksek konsantrasyonlu arsenik içeren içme sularından
kaynaklanmaktadır.



Appelo ve Postma (2005)

Birimlerin geçirimsizlik değerleri

Material	Hydraulic conductivity (m/sec)
SEDIMENTARY	
Gravel	$3 \times 10^{-4} - 3 \times 10^{-2}$
Coarse sand	$9 \times 10^{-7} - 6 \times 10^{-3}$
Medium sand	$9 \times 10^{-7} - 5 \times 10^{-4}$
Fine sand	$2 \times 10^{-7} - 2 \times 10^{-4}$
Silt, loess	$1 \times 10^{-9} - 2 \times 10^{-5}$
Till	$1 \times 10^{-12} - 2 \times 10^{-6}$
Clay	$1 \times 10^{-11} - 4.7 \times 10^{-9}$
Unweathered marine clay	$8 \times 10^{-13} - 2 \times 10^{-9}$
SEDIMENTARY ROCKS	
Karst and reef limestone	$1 \times 10^{-6} - 2 \times 10^{-2}$
Limestone, dolomite	$1 \times 10^{-9} - 6 \times 10^{-6}$
Sandstone	$3 \times 10^{-10} - 6 \times 10^{-6}$
Siltstone	$1 \times 10^{-11} - 1.4 \times 10^{-8}$
Salt	$1 \times 10^{-12} - 1 \times 10^{-10}$
Anhydrite	$4 \times 10^{-13} - 2 \times 10^{-8}$
Shale	$1 \times 10^{-13} - 2 \times 10^{-9}$
CRYSTALLINE ROCKS	
Permeable basalt	$4 \times 10^{-7} - 2 \times 10^{-2}$
Fractured igneous and metamorphic rock	$8 \times 10^{-9} - 3 \times 10^{-4}$
Weathered granite	$3.3 \times 10^{-6} - 5.2 \times 10^{-5}$
Weathered gabbro	$5.5 \times 10^{-7} - 3.8 \times 10^{-6}$
Basalt	$2 \times 10^{-11} - 4.2 \times 10^{-7}$
Unfractured igneous and metamorphic rocks	$3 \times 10^{-14} - 2 \times 10^{-10}$
To convert meters per second to	Multiply by
cm/sec	10^2
(gal/day)/ft ²	2.12×10^6
ft/sec	3.28
ft/yr	1×10^8
darcy	1.04×10^5
ft ²	1.1×10^{-6}
cm ²	1×10^{-3}
To convert any of the above to meters per second	Divide by the appropriate number above

Domenico and Schwartz (1990)

Çözünmüş maddeler için konsantrasyon birimleri

mg/L	milligrams per liter sample
µg/L	micrograms per liter sample
ppm	parts per million by weight of sample
ppb	parts per billion by weight of sample
mmol/L	millimoles per liter sample
µmol/L	micromoles per liter sample
meq/L	milliequivalents per liter of sample
mmol _c /L	milliequivalents per liter of sample
epm	equivalents per million, by weight of sample
M	molality, moles per kg of H ₂ O
mM	millimoles per kg of H ₂ O
N	normality, equivalents per liter

$$\text{mmol/L} = \text{mg/L} / (\text{gram formula weight})$$

$$\text{mmol/L} = \text{ppm} \cdot (\text{density of sample}) / (\text{gram formula weight})$$

$$\text{mmol/L} = \text{meq/L} / (\text{charge of ion})$$

$$\text{mmol/L} = \text{molality} \times \text{density} \times \frac{(\text{weight solution} - \text{weight solutes})}{(\text{weight solution})} \times 1000$$

- Analiz birimleri:
- mg/l (miligramperliter) bir litre çözeltildeki bileşen konsantrasyonu
- Ppm (partspermillion) bileşenin kütlesinin çözeltili kütlesine oranı (massfraction). Konsantrasyonla karıştırılmamalı
- ppb (partsperbillion)
- mmol/l bir litre çözeltildeki herhangi bir bileşenin milimol cinsinden konsantrasyonu (molarkonsantrasyon)
- meq/l (miliequivalentperliter) molar konsantrasyonun elektriksel eşdeğeri
- epm (equivalentspermillion) çözeltildeki bir bileşenin çözeltilinin tamamının elektriksel eşdeğerine oranı
- M (molality) çözeltildeki bir bileşenin çözücü (H₂O) nun kütlesine oranı
- EC (electricalconductivity) elektriksel iletkenlik
- pH - log[H⁺]

Appelo ve Postma (2005)

Konsantrasyon birimlerinin yeniden hesaplanması-Dönüştürmeler (mg/l, meq/l, mmol/l)

EXAMPLE 1.1. *Recalculation of concentration units*

1. Gram formula weights are calculated from the periodic system as reproduced in Table 1.4 from the *Handbook of chemistry and physics*.
The mass of 1 mol Ca is 40.08 grams.
1 mol SO_4^{2-} weighs: 32.06 grams from sulfur + 4×15.9994 grams from oxygen, in total: 96.06 grams.
2. Conversion of mg/L to mmol/L is obtained by dividing by the weight of the element or molecule.
Thus, a river water contains 1.2 mg Na^+ /L;
This corresponds to $1.2 / 22.99 = 0.052$ mmol Na^+ /L;
The sample also contains 0.6 mg SO_4^{2-} /L;
This equals $0.6 / 96.06 = 0.006$ mmol SO_4^{2-} /L.
3. The term mmol/L indicates the number of ions or molecules in the water when multiplied by Avogadro's number. For Na^+ in the river water sample it amounts to $0.052 \times 10^{-3} \times 6.022 \times 10^{23} = 3.1 \times 10^{19}$ ions of Na^+ in 1 liter of water. (Quite a lot really!)
4. Ions are electrically charged, and the sums of positive and negative charges in a given water sample must balance. This condition is termed the electroneutrality or electrical balance of the solution. Since mmol/L represents the number of molecules, it should be multiplied by the charge of the ions to yield their total charge in meq/L. Thus:
 0.052 mmol Na^+ /L $\times 1 = 0.052$ meq/L;
 1.8 mmol Ca^{2+} /L $\times 2 = 3.6$ meq/L;
 0.41 mmol SO_4^{2-} /L $\times -2 = -0.82$ meq/L.

İyonların Atom Ağırlığı ve ekivalen değerleri

İyonlar	Ca	Mg	Na	K	Cl	SO ₄	HCO ₃	CO ₃
Atom veya formül ağırlığı	40	24	23	39	35,5	96	61	60
Değerlik	2	2	1	1	1	2	1	2
Ekivalen değeri (eşdeğer ağırlığı)	20	12	23	39	35,5	48	61	30

¹/₁
NO₃⁻
62
1
62

Örnek Problem çözümü

Ca : 367,53

Mg : 65,94

Na : 49,71

K : 18,10

Cl : 5,30

SO₄ : 530,42

HCO₃ : 860,10

CO₃ : -

$$r_{Ca} = \frac{367,53}{20} = 18,3 \text{ mek/l} \quad r_{Cl} = \frac{5,30}{35,5} = 0,15 \text{ mek/l}$$

$$r_{Mg} = \frac{65,94}{12} = 5,52 \text{ mek/l} \quad r_{SO_4} = \frac{530,42}{48} = 11,04 \text{ mek/l}$$

$$r_{Na} = \frac{49,71}{23} = 2,16 \text{ mek/l} \quad r_{HCO_3} = \frac{860,10}{61} = 14,10 \text{ mek/l}$$

$$r_{K} = \frac{18,10}{39} = 0,46 \text{ mek/l} \quad \text{olarak hesaplanır.}$$

Katyonlar toplamı: 26,48 mek/l , Anyonlar toplamı: 25,29 mek/l dir.

Canik (1998)

$$\% r \text{ Ca} = \frac{18,34.100}{26.48} = 69,25$$

$$\% r \text{ Mg} = \frac{5.52.10}{26.48} = 20,85$$

$$\% r \text{ Na} = \frac{2,16.100}{26.48} = 8,15$$

$$\% r \text{ K} = \frac{0,46.100}{26.48} = 1,75$$

Toplam: % 100.00

$$\% r \text{ Cl} = \frac{0,15.100}{25,29} = 0,59$$

$$\% r \text{ SO}_4 = \frac{11,04.100}{25,29} = 43,65$$

$$\% r \text{ HCO}_3 = \frac{14,10.100}{25,29} = 55,76$$

hesaplanmıştır.

Toplam: % 100.00

Canik (1998)

^{hidrojen}
2- Suyun pH' ı: Saf su çok az OH⁻ ve H⁺ iyonları içerir. 25 °C ta $\langle \text{OH}^- \rangle \langle \text{H}^+ \rangle = 1,008 \cdot 10^{-14}$ olup, OH⁻ ve H⁺ konsantrasyonları eşittir. $\langle \text{OH}^- \rangle = \langle \text{H}^+ \rangle = \sqrt{1,008 \cdot 10^{-14}} = 1,004 \cdot 10^{-7}$ olur. O halde, 10 milyon su molekülü yanında, 1 molekül su OH⁻ ve H⁺ iyonlarına ayrılmıştır. H⁺ konsantrasyonunun kologaritması pH değerini verir.

$$\text{pH} = \log \frac{1}{H} \quad \text{olup, } \text{pH} = \log 1 - \log H \text{ buradan:}$$

$$\text{pH} = \text{kolog } H \quad \text{elde edilir.}$$

3- Gazlar: Sıcak ve mineralli sularda en çok CO₂, H₂S, O₂, N₂, CH₄, radon vb bulunur. Gazlar atmosferik kökenli olduğu gibi, biyokimyasal, volkanik, termometamorfik veya mağmatik iç kökenli de olabilirler. Suda çözülmüş CO₂ mg/l olarak şu formülle hesaplanır:

$$\text{CO}_2 = 1,6 \cdot 10^{6 - \text{pH}} \cdot \text{HCO}_3 \quad \text{olup, formülde:}$$

pH : Suda ölçülen pH değeri,
HCO₃ : Suda belirlenen değer, mg/l dir.

Canik (1998)

SUDAKİ İYONLARIN BOLLUKLARI VE ÖRNEKLEME

**TABLE 7.1 Relative Abundance of Dissolved Solids in Potable Water
(after Davis and DeWiest¹⁴)**

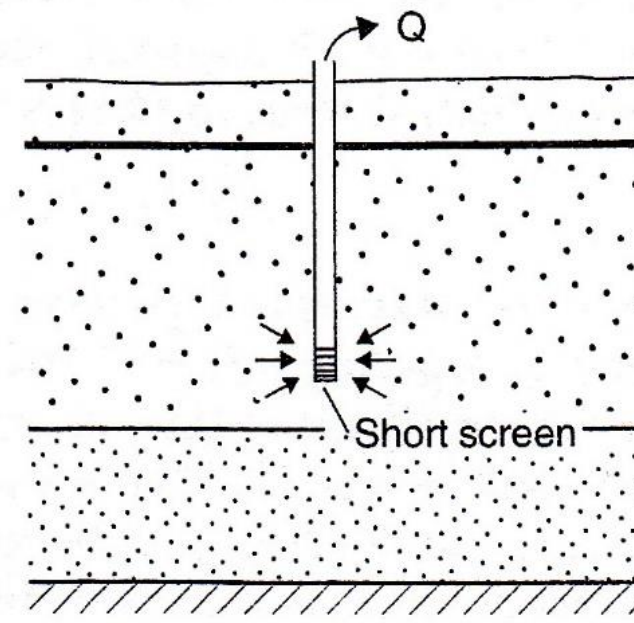
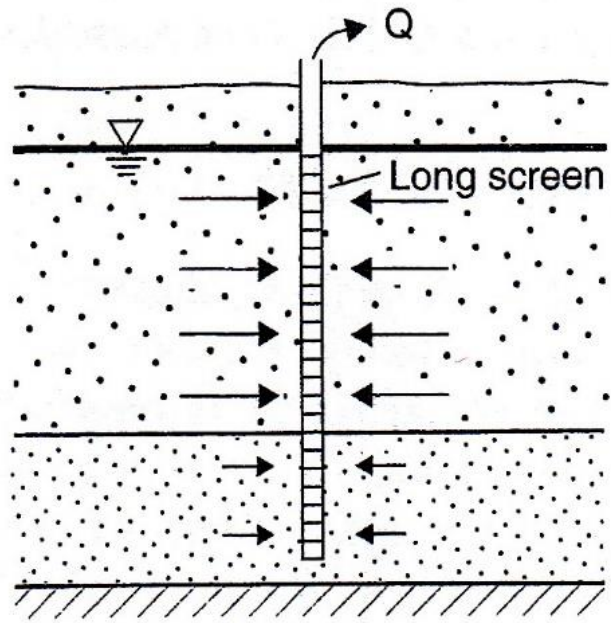
Major Constituents (1.0 to 1000 mg/l)	Secondary Constituents (0.01 to 10.0 mg/l)	Minor Constituents (0.0001 to 0.1 mg/l)	Trace Constituents (generally less than 0.001 mg/l)
Sodium	Iron	Antimony ^a	Beryllium
Calcium	Strontium	Aluminum	Bismuth
Magnesium	Potassium	Arsenic	Cerium ^a
Bicarbonate	Carbonate	Barium	Cesium
Sulfate	Nitrate	Bromide	Gallium
Chloride	Fluoride	Cadmium ^a	Gold
Silica	Boron	Chromium ^a	Indium
		Cobalt	Lanthanum
		Copper	Niobium ^a
		Germanium ^a	Platinum
		Iodide	Radium
		Lead	Ruthenium ^a
		Lithium	Scandium ^a
		Manganese	Silver
		Molybdenum	Thallium ^a
		Nickel	Thorium ^a
		Phosphate	Tin
		Rubidium ^a	Tungsten ^a
		Selenium	Ytterbium
		Titanium ^a	Yttrium ^a
		Uranium	Zirconium ^a
		Vanadium	
		Zinc	

^aThese elements occupy an uncertain position in the list.

Yeraltı Suyu Örneklemesi

- Yeraltı suyunun örneklenmesi ve kimyasal analizi pahalı bir işlem olduğu gibi yeni sondaj kuyularının açılması daha da pahalıdır.
- Gerçek yeraltı suyu kompozisyonunu elde edebilmek için örneklerin temsil edici olması gerekmektedir.

- **Bütünleşik derinlik veya özel örnekleme derinliği**
-
- Yeraltı suyu örnekleme için iki farklı yaklaşım Şekil 7.1'de verilmiştir.
- Birinci kuyuda tüm akifer ince ve iri kumlu seviyelerde tamamen filtrelenmiştir.
- İkinci kuyuda ise sadece kaba kumlu seviye filtrelenmiştir.
- Kaba kumlu ve ince kumlu seviyelerin geçirimsizliği farklıdır. Kaba kum daha fazla geçirimsizliğe sahiptir. Bu, örneklemede soldaki 1. kuyudan alınan örnekte problem oluşturmaktadır.

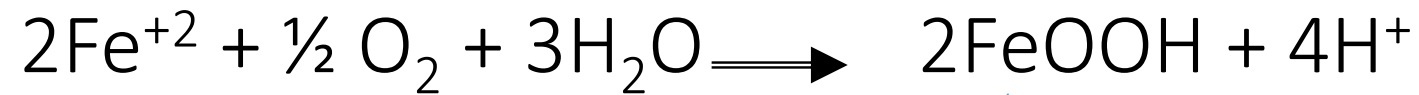


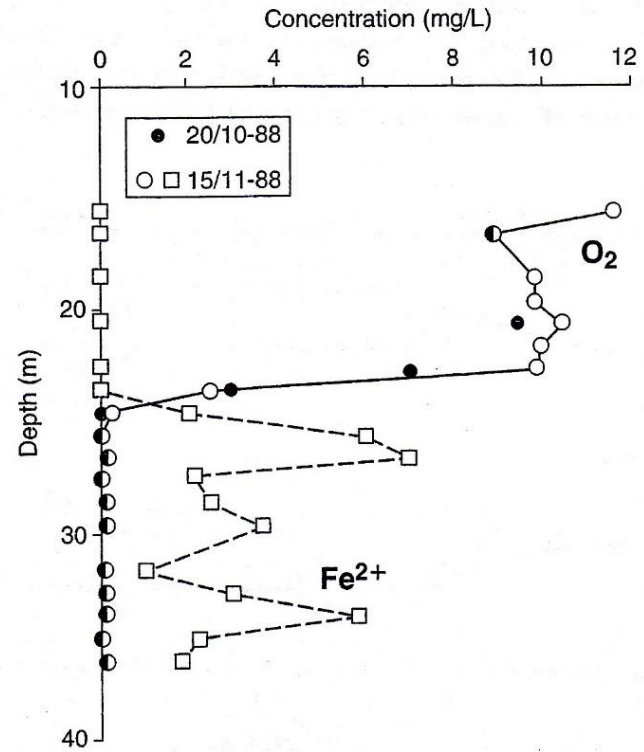
Appello ve Postma (2005)

SU ÖRNEKLEMESİNDE DİKKAT EDİLECEK HUSUSLAR

- Yeraltı suyu kompozisyonu küçük mesafelerde bile büyük farklılıklar göstermektedir.
- Tamamen filtrelenen kuyulardan alınan sular karışım suyudur. Belli seviyeleri temsil etmemektedir.
- Şekil 1.8'de yeraltı suyu kimyası profili görülmektedir. Kumlu akiferde özel-spesifik açılan kuyuda anoksik (Fe^{+2} 'li) zonun üzerinde oksik (O_2) bir zon olduğu tespit edilmiştir.

Anoksik ve oksik zonu içeren bir filtreleme yapılarak alınan örneklerde her iki zonun suları karıştığından aşağıdaki reaksiyonla demiroksit (götit) oluşmakta ve asit açığa çıkmaktadır.





Appello ve Postma (2005)

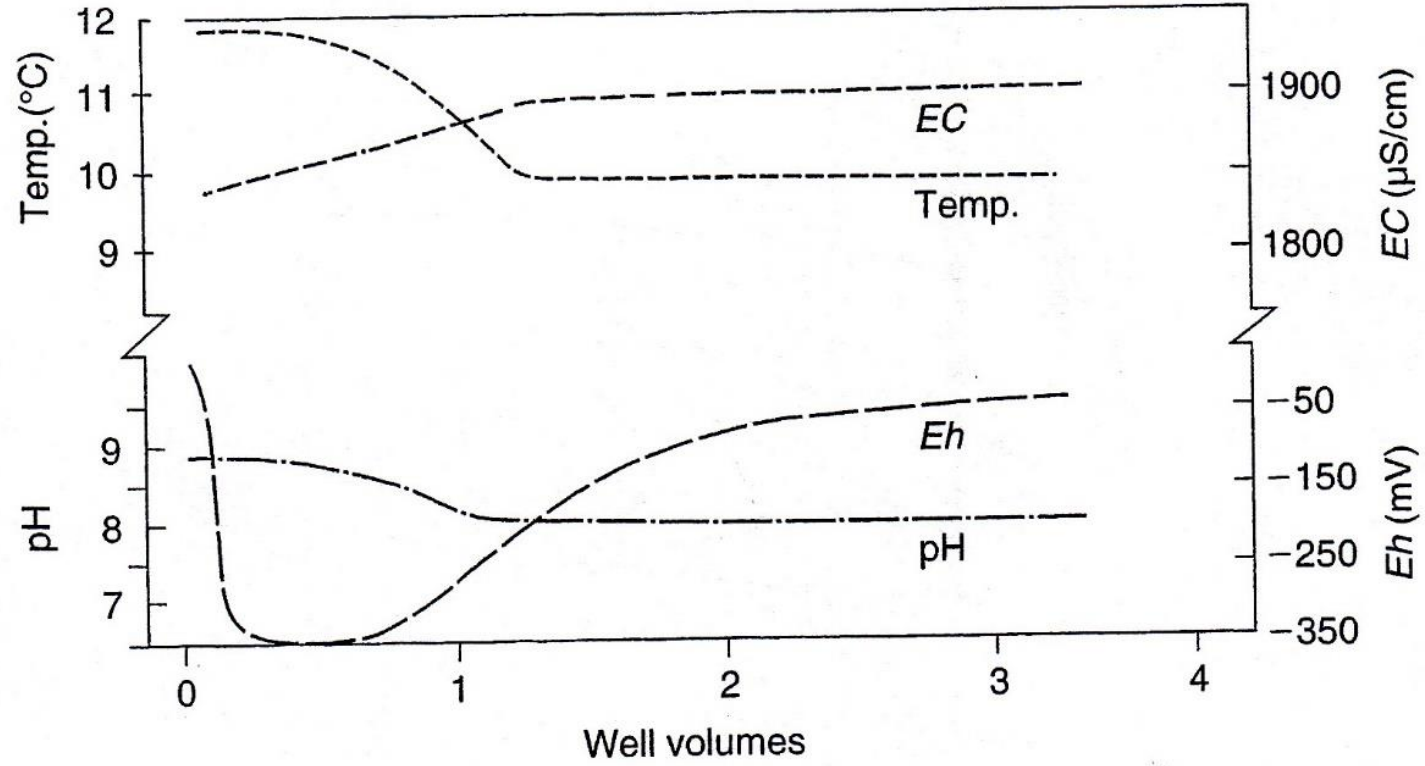
- Bu şartlarda alınan örneğin kompozisyonu karışım ve reaksiyonun büyüklüğüne bağlı olarak değişmektedir.
- Benzer reaksiyonlar sığ kuyularda, hava ile temasta olan seviyelerde, geniş çaplı açık kuyularda oluşabilir.

Yeraltı suyu örneklemesinde prosedürler ve sorunlar

- **1.** Kuyudan belirli hacimde su çekiminden sonra örnekleme yapılması
- (Şekil 1.9); EC, pH, T ve Eh'in sabitlenmesi,
- **2.** Filtrenin uzun olması ile basıncı farklı olan iki farklı seviyeden su karışımı olabilir (şekil 1.10A),
- **3.** Kille tecrit edilen zonlardan aşağıya-örnekleme kuşağına su sızması (Şekil 1.10B),
- **4.** Kuyunun anülüs kısmından yüzeydeki kirletici kimyasallar akifer sisteme süzülebilir ve kirletebilir (Şekil 1.10C),
- **5.** Sondaj borusundaki hasarlar sonucunda borudaki yırtılma ve delinmeler sonucu kuyuya su gelişleri ve su gidişleri olabilir (Şekil 1.10D).

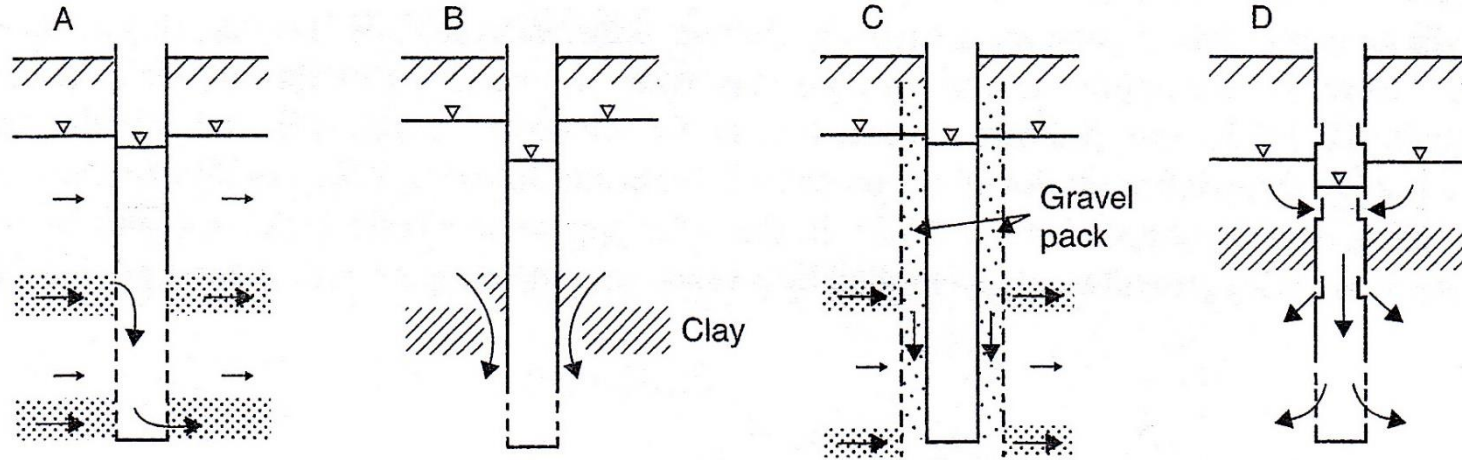
Appello ve Postma (2005)

Örnekleme öncesinde kuyulardan dışarı atılması öngörülen su hacmi



Appello ve Postma (2005)

Su Örneklemesinde Sondaja Bağlı Hatalar



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Hidrolik ilişkiler-Su seviye gradyanı

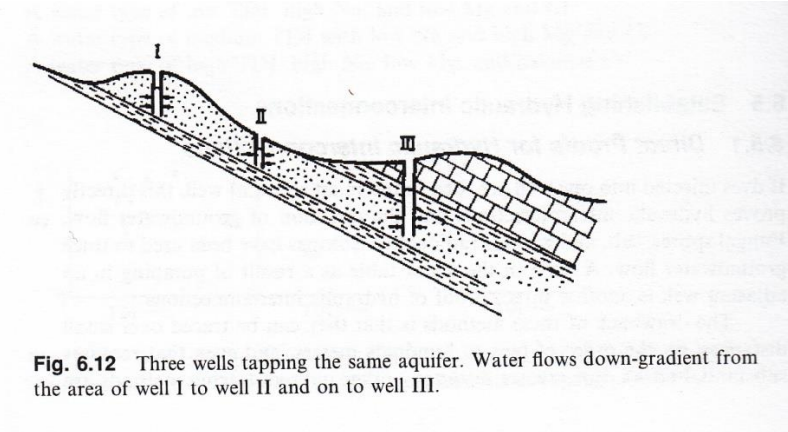


Fig. 6.12 Three wells tapping the same aquifer. Water flows down-gradient from the area of well I to well II and on to well III.

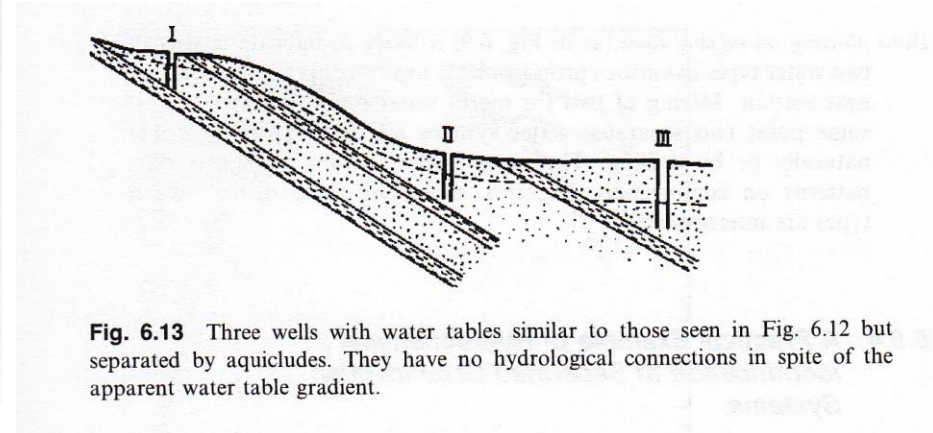


Fig. 6.13 Three wells with water tables similar to those seen in Fig. 6.12 but separated by aquicludes. They have no hydrological connections in spite of the apparent water table gradient.

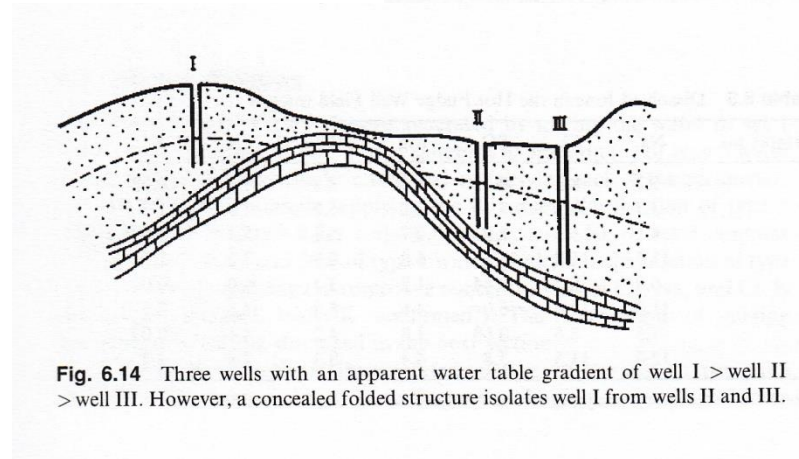
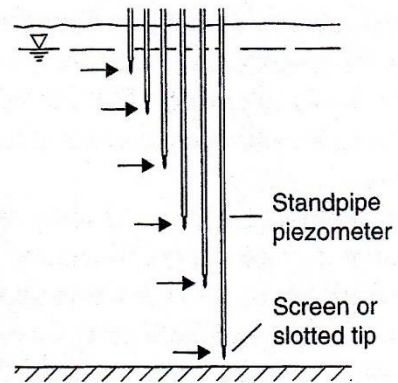


Fig. 6.14 Three wells with an apparent water table gradient of well I > well II > well III. However, a concealed folded structure isolates well I from wells II and III.

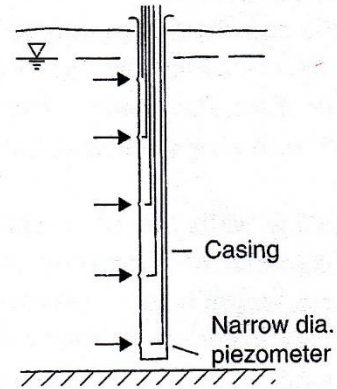
Özel Örnekleme Derinliği için Yaklaşımlar

- **1.** Konvansiyonel piyezometreler
- (Şekil 1.11 A),
- **2.** Tek borulu-çok piyezometreli sistemler (Şekil 1.11A),
- **3.** Oyük Gövdeli Delgi sistemi
- (Şekil 1.11C).

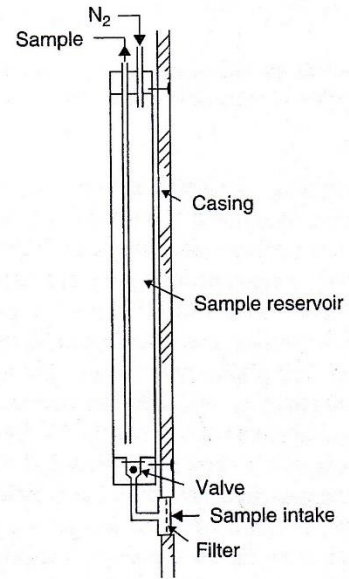
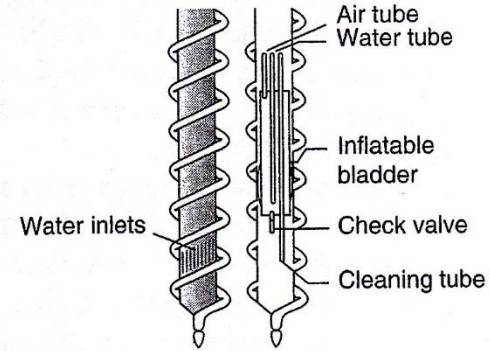
Conventional piezometers



Multiple piezometers in a single casing



Hollow stem auger



Appello ve Postma (2005)

Su dnyasnda kullanılan yaygın parametreler

Sertlik	EC	TIC
Sertlik derecesi	pH	TOC
Geçici sertlik	Eh	COD
Kalıcı sertlik	pe	BOD
Renk	Alkalinite	
	Asidite	

Yaygın parametrelerin açıklaması

Hardness	Sum of the ions which can precipitate as “hard particles” from water. Sum of Ca^{2+} and Mg^{2+} , and sometimes Fe^{2+} . Expressed in meq/L or mg CaCO_3/L or in hardness degrees. $100 \text{ mg CaCO}_3/\text{L} \cong 1 \text{ mmol CaCO}_3/\text{L} \cong 2 \text{ meq Ca}^{2+}/\text{L}$
Hardness degrees	1 german degree = 17.8 mg CaCO_3/L 1 french degree = 10 mg CaCO_3/L
Temporary hardness	Part of Ca^{2+} and Mg^{2+} concentrations which are balanced by HCO_3^- (all expressed in meq/L) and can thus precipitate as carbonate
Permanent hardness	Part of Ca^{2+} and Mg^{2+} in excess of HCO_3^- (all expressed in meq/L)
Color	Measured by comparison with a solution of cobalt and platinum
EC	Electrical Conductivity, in $\mu\text{S}/\text{cm}$ ($= \mu\text{mho}/\text{cm}$), $EC \approx 100 \times \text{meq (anions or cations)}/\text{L}$
pH	$-\log[\text{H}^+]$, the log of H^+ activity (dimensionless).
Eh	Redox potential, expressed in Volt. measured with platinum/reference electrode
pe	Redox potential expressed as $-\log[e^-]$. $[e^-]$ is “activity” of electrons. $pe = Eh/0.059$ at 25°C .
Alkalinity (<i>Alk</i>)	Acid neutralizing capacity. Determined by titrating with acid down to a pH of about 4.5. Equal to the concentrations of $m_{\text{HCO}_3^-} + 2m_{\text{CO}_3^{2-}}$ (mmol/L) in most samples.
Acidity	Base neutralising capacity. Determined by titrating up to a pH of about 8.3. Equal to H_2CO_3 concentration in most samples except when Al^{3+} or Fe^{3+} are present
TIC	Total inorganic carbon
TOC	Total organic carbon
COD	Chemical oxygen demand. Measured as chemical reduction of permanganate or dichromate solution, and expressed in oxygen equivalents
BOD	Biological oxygen demand.

Analiz için alınan su örneklerinin kimyasal parametrelerinin korunması

Parameter	Conservation/field analysis
Na ⁺ , K ⁺ , Mg ²⁺ , Ca ²⁺ NH ₄ ⁺ , Si, PO ₄ ³⁻ Heavy metals SO ₄ ²⁻ , Cl ⁻ NO ₃ ⁻ , NO ₂ ⁻	Acidify to pH <2 in polyethylene container (preferably HNO ₃ for AAS or ICP-analysis). Acidify to pH <2 in glass or acid rinsed polypropylene container. Cool to 4°C. Store cool at 4°C and analyze within 24 hours or add bactericide like thymol. (Note that NO ₃ ⁻ may form from NH ₄ ⁺ in reduced samples. NO ₂ ⁻ may self-decompose even when a bactericide is added.)
H ₂ S	To avoid degassing, collect sample in a Zn-acetate solution, precipitating ZnS. Spectrophotometry in the field or later in the laboratory.
<i>TIC</i>	Dilute sample to <i>TIC</i> < 0.4 mmol/L. (This effectively reduces CO ₂ pressure, and prevents the escape of CO ₂).
Alkalinity Fe ²⁺	Field titration with the GRAN method (Stumm and Morgan, 1996) Spectrophotometry in the field. Alternatively determined as Fe-total in an acidified sample.
pH, Temp., <i>EC</i> , O ₂ CH ₄	Field measurement in a flow cell. Unfiltered sample collected avoiding degassing, then acidified.

Suda Çözünen Elementlerin Kökeni

Element	Köken	Azalması
Ca ⁺²	Karbonatların çözünmesi Jipsler, piroksen, amfibol, feldspat, dolomit, kil mineralleri	İyon değişimi Karbonat minerallerinin çökmesi
Mg ⁺²	Karbonat minerallerinin çözünmesi Olivin, piroksen, amfibol, magnezit, kil mineralleri	İyon değişimi
Na ⁺	Killer, feldspat (albit), evaporit (halit), endüstriyel atıklar, mirabilit (Na ₂ SO ₄ .10H ₂ O)	İyon değişimi
K ⁺	Feldspat, k-evaporitler, gübreler, feldspatoid, bazı mikalar, kil mineralleri, silikatların çözünmesi	İyon değişimi
SiO ₂	Silikatların hidrolizi, Amorf silika (çört, opal), feldspat, ferromagnezyum, kil mineralleri	
Fe	Sülfitlerin oksidasyonu Hematit ve pirit, demir boruların korozyonu, derinlik kayaları: amfibol, ferromagnezyumlu mikalar, demirli sülfid, demirli sülfid veya demirli pirit, magnetit, Kumtaşı: oksitler, karbonatlar, Sülfidler veya demirli kil mineralleri	
Cl ⁻	Deniz suyu, gübre, yağış, doğal acı sular, yol tuzlaması, rüzgarlar tarafından taşınan malzeme, evaporit çökelleri, kirlilik, derinlik kayalarından minör miktarda	İnert-konzervatif
SO ₄ ⁻²	Sülfid yataklarının oksidasyonu, jips, anhidrit, deniz suyu, rüzgarla taşınan maddeler, piritin oksidasyonu, bakteriyel indirgenme, gübreler	Çok indirgen şartlar haricinde konservatif
HCO ₃ ⁻ CO ₃ ⁻²	Kireçtaşı, dolomit çözünmesi, zemin ve atmosferik CO ₂	Karbonat minerallerinin çökmesi
NO ₃ ⁻	Sentetik ve organik gübre, gübre kaynaklı NH ₄ nitrifikasyonu, rüzgarla taşınan maddeler, amonyumun oksidasyonu, kirlilik oluşumu, baklagiller ve bitki artıkları, hayvan dışkısı	Anaerobik şartlarda denitrifikasyon (nitratın amonyuma dönüşmesi)

Sudaki Elementlerin Kökeni

Table 11.3 Sources of ions in water

	Source
<i>Major ions (>1 mg l⁻¹)</i>	
Calcium Ca ²⁺	Carbonates, gypsum
Magnesium Mg ²⁺	Olivine, pyroxene, amphiboles
Sodium Na ⁺	Clays, feldspars, evaporites, industrial waste
Potassium K ⁺	Feldspar, fertilizers, K-evaporites
Bicarbonate HCO ³⁻	Soil and atmospheric CO ₂ , carbonates
Chloride Cl ⁻	Windborne, rain water, sea water and natural brines, evaporite deposits; pollution
Sulphate SO ₄ ²⁻	Gypsum and anhydrite, sea water, windborne, oxidation of pyrite
Nitrate NO ³⁻	Windborne, oxidation of ammonia or organic nitrogen, contamination
Silica SiO ₂	Hydrolysis of silicates
<i>Minor ions (1–0.1 mg l⁻¹)</i>	
Iron Fe ²⁺	Oxides and sulphides, e.g. hematite and pyrite; corrosion of iron pipes
Manganese Mn ²⁺	Oxides and hydroxides
Boron B	Tourmaline, evaporites, sewage, sea water
Fluoride F ⁻	Fluorine-bearing minerals, viz. fluorite, biotite
<i>Trace elements (<0.1 mg l⁻¹)</i>	
As	Arsenic minerals, e.g. arsenopyrite, arsenic insecticides
I	Marine vegetation, evaporites
Zn	Sphalerite, industrial waste
Heavy metals (Hg, Pb, Cd, Cr)	Industrial waste and igneous rock weathering, under mild reducing conditions
Radioactive elements e.g. U, Ra, etc.	Uraniferous minerals, nuclear tests and nuclear power plants

Table 3.1 Lithological Imprints on Groundwater Composition

Rock	Groundwater composition
Sandstone	Low salinity (300–500 mg/l); HCO_3^- major anion, Na^+ , Ca^{2+} , Mg^{2+} in similar amounts; good taste.
Limestone	Low salinity (500–800 mg/l); HCO_3^- major anion, Ca^{2+} dominant cation; good taste.
Dolomite	Low salinity (500–800 mg/l); HCO_3^- major anion, Mg^{2+} equals Ca^{2+} ; good taste.
Granite	Very low salinity (300 mg/l); HCO_3^- major anion, Ca^{2+} and Na^+ major cations; very good taste.
Basalt	Low salinity (400 mg/l); HCO_3^- major anion; Na^+ , Ca^{2+} , Mg^{2+} equally important; good taste.
Schist	Low salinity (300 mg/l); HCO_3^- major anion; Ca^{2+} and Na^+ major cations; good taste.
Marl	Medium salinity (1200 mg/l); HCO_3^- and Cl^- major anions, Na^+ and Ca^{2+} major cations; poor taste but potable.
Clay and shale	Often containing rock salt and gypsum. High salinity (900–2000 mg/l); Cl^- dominant anion, followed by SO_4^{2-} ; Na^+ major cation; poor taste, occasionally nonpotable.
Gypsum	High salinity (2000–4000 mg/l); SO_4^{2-} dominant anion; Ca^{2+} dominant cation, followed by Mg^{2+} or Na^+ ; bitter, nonpotable.

Table 6.1. Factors controlling various hydrochemical parameters.

	Parameter	Source	Sink
Soil-related parameters	CO ₂	Root respiration and degradation of organic matter	Dissolution of carbonate minerals, Degassing in conduits
	²²² Rn	Radioactive decay of ²²⁶ Ra	Radioactive decay with half-life of 3.8 days
	Dissolved organic carbon (DOC)	Decomposition of litter and humus	Sorption to clay minerals, biodegradation
	NO ₃ ⁻ ⁽¹⁾	Synthetic and organic fertilizer, nitrification of NH ₄ ⁺ from fertilizer	Denitrification under anaerobic conditions
	NH ₄ ⁺ ⁽¹⁾	Synthetic and organic fertilizer, decomposition of soil organic matter	Nitrification, Ion exchange
	PO ₄ ³⁻ ⁽¹⁾	Synthetic and organic fertilizer	Sorption on Fe-hydroxides, precipitation with Ca ²⁺
	Cl ⁻ ⁽¹⁾	Fertilizer, Rain, road salts	Conservative
	SO ₄ ²⁻ ⁽¹⁾	Fertilizer	Conservative except under very reducing conditions
Carbonate-rock related parameters	K ⁺ ⁽¹⁾	Fertilizer, Dissolution of silicates	Ion-exchange
	Turbidity	Particles from soil zone, also from sediments in conduits	Filtration
	Ca ²⁺	Dissolution of carbonate minerals	Ion-exchange, precipitation of carbonate minerals
	Mg ²⁺ HCO ₃ ⁻	Dissolution of carbonate minerals Dissolution of carbonate minerals	Ion-exchange Precipitation of carbonate minerals
Parameters related to other rock types	δ ¹³ C of DIC	Dissolution of soil gas CO ₂ , carbonate minerals	
	SO ₄ ²⁻	Dissolution of gypsum and anhydrite in evaporates	Conservative except under very reducing conditions
	Sr ²⁺ Various trace metals	Dissolution of celestite Dissolution of evaporites (see text)	Ion-exchange
Anthropogenic compounds	Metals	Fertilizers, road runoff, air pollution	Adsorption, Precipitation
	Pesticides Volatile organic compounds	Agriculture Industrial sites, landfills, traffic	Adsorption, Transformation Volatilisation, Sorption, Biodegradation

⁽¹⁾ partly of anthropogenic origin.

KİMYASAL VERİLERİN SUNUMU

Tabloların Oluşturulması

Table 6.1

Sample no.	K	Cl	Mg	Na	SO ₄	Ca	HCO ₃	Temp. (° C)
71	0.60	9.11	1.78	8.10	1.09	2.72	3.00	21.4
72	1.03	15.5	2.76	11.5	1.36	3.84	4.22	26.1
73	0.02	0.53	0.47	0.91	0.73	1.22	1.36	15.2
74	0.16	2.67	0.80	2.71	0.82	1.60	1.76	16.8
75	0.31	4.82	1.13	4.51	0.91	1.97	2.17	18.3
76	0.75	11.3	2.10	9.90	1.18	3.10	3.41	23.0
77	1.18	17.7	3.08	15.3	1.45	4.21	4.62	27.6
78	0.89	13.3	2.43	11.7	1.27	3.47	3.81	24.5
79	0.46	6.97	1.46	6.30	1.00	2.35	2.59	19.9

Table 6.2 Chemical Composition of the Green Mice Springs Complex (meq/l)

Sample no.	Spring	Temp. (° C)	K	Na	Ca	Mg	Cl	HCO ₃	SO ₄	TDI
73	A	15.2	0.02	0.91	1.22	0.47	0.53	1.36	0.73	5.24
74	C	16.8	0.16	2.71	1.60	0.80	2.67	1.76	0.82	10.5
75	E	18.3	0.31	4.51	1.97	1.13	4.82	2.17	0.91	15.8
79	B	19.9	0.46	6.30	2.35	1.46	6.97	2.59	1.00	21.1
71	D	21.4	0.60	8.10	2.72	1.78	9.11	3.00	1.09	26.4
76	I	23.0	0.75	9.90	3.10	2.10	11.3	3.41	1.18	31.7
78	F	24.5	0.89	11.7	3.47	2.43	13.4	3.81	1.27	37.0
72	G	26.1	1.03	13.5	3.84	2.76	15.5	4.22	1.36	38.8
77	H	27.6	1.18	15.3	4.21	3.08	17.7	4.62	1.45	47.5

Big Chemistry Laboratory, Dataland. Temperature measurement error: $\pm 0.2^\circ\text{C}$; analytical errors are $\pm 2\%$ for Na, Ca, Cl, and HCO₃ and $\pm 5\%$ for K, Mg, and SO₄.

Mazor (2004)

Tabloların Oluşturulması

Table 6.3 Rearranged Chemical Composition Data of the Green Mice Springs Complex (meq/l)

Sample no.	Spring	Temp. (° C)	K	Mg	Ca	Na	SO ₄	HCO ₃	Cl	TDI
73	A	15.2	0.02	0.47	1.22	0.91	0.73	1.36	0.53	5.24
74	C	16.8	0.16	0.80	1.60	2.71	0.82	1.76	2.67	10.5
75	E	18.3	0.31	1.13	1.97	4.51	0.91	2.17	4.82	15.8
79	B	19.9	0.46	1.46	2.35	6.30	1.00	2.59	6.97	21.1
71	D	21.4	0.60	1.78	2.72	8.10	1.09	3.00	9.11	26.4
76	I	23.0	0.75	2.10	3.10	9.90	1.18	3.41	11.3	31.7
78	F	24.5	0.89	2.43	3.47	11.7	1.27	3.81	13.4	37.0
72	G	26.1	1.03	2.76	3.84	13.5	1.36	4.22	15.5	38.8
77	H	27.6	1.18	3.08	4.21	13.3	1.45	4.62	17.7	47.5

Big Chemistry Laboratory, Dataland. Temperature measurement error: $\pm 0.2^\circ \text{C}$; analytical errors are $\pm 2\%$ for Na, Ca, Cl, and HCO₃ and $\pm 5\%$ for K, Mg, and SO₄.

Grafiksel Deęerlendirmeler

- ❖ Üçgen Diyagram,
- ❖ Schoeller diyagramı,
- ❖ Piper Diyagramı,
- ❖ Bar Diyagramı,
- ❖ Dairesel Diyagram,
- ❖ Stif Diyagramı

Su Hayattır...

Logaritmik – Milimetrik konsantrasyon eksenleri

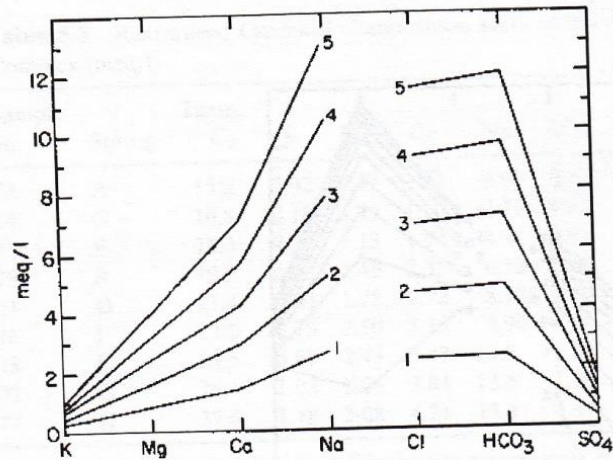


Fig. 6.2 A linear fingerprint diagram of samples that resulted from different degrees of dilution of a saline water (Table 6.4). The data reveal compositional lines of different patterns, although their relative ion abundance is the same.

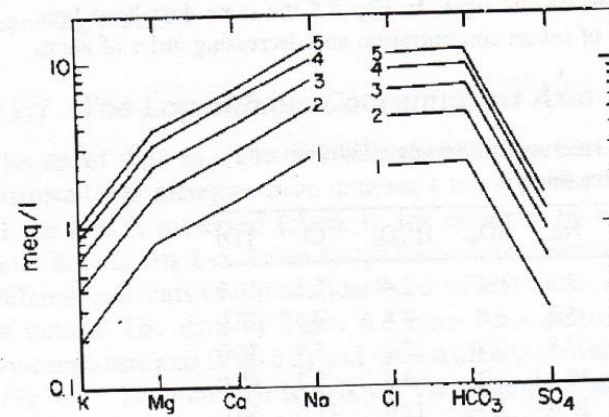


Fig. 6.3 The data of Fig. 6.2 (Table 6.4) replotted on a semilogarithmic axis. Parallel lines of the same pattern are obtained, well reflecting different degrees of dilution of the same saline water.

Yarı Logaritmik Kağıtlar

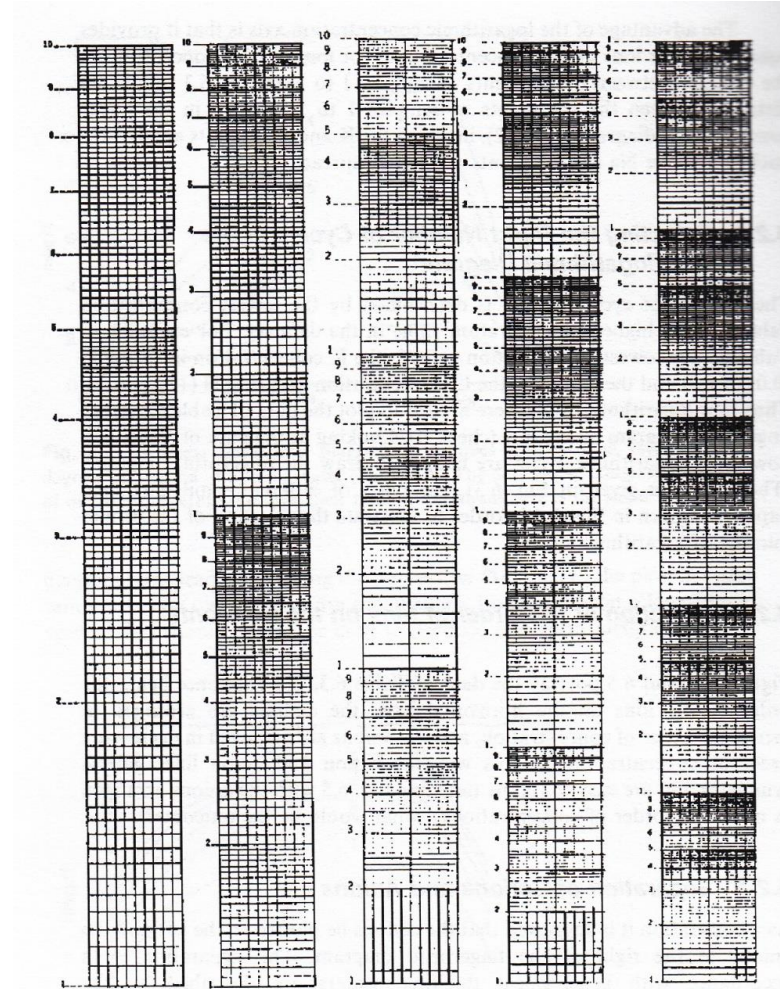


Fig. 6.4 Semilogarithmic papers with 1, 2, 3, 4, and 5 cycles. The 5-cycle is most convenient for the majority of hydrochemical data processing tasks.

Mazor (2004)

Parmak izi diyagramı (Şekil 6.1'in aynı verileri)

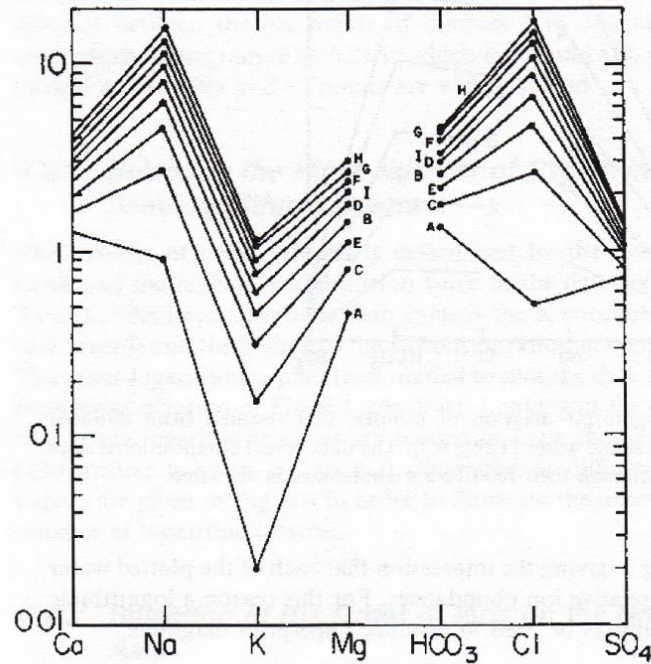


Fig. 6.1 A fingerprint diagram of the data of Table 6.3. Cations are by convention plotted on the left and anions on the right. In Fig. 6.5 the same data have been replotted in increasing order of cation concentration and decreasing order of anion concentration.

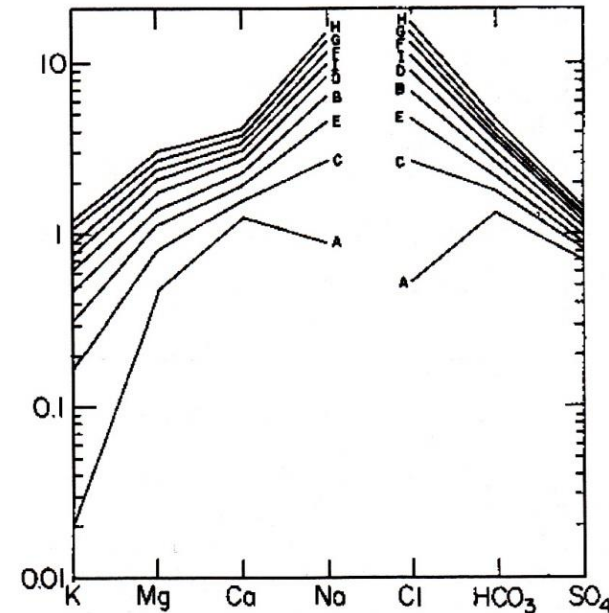
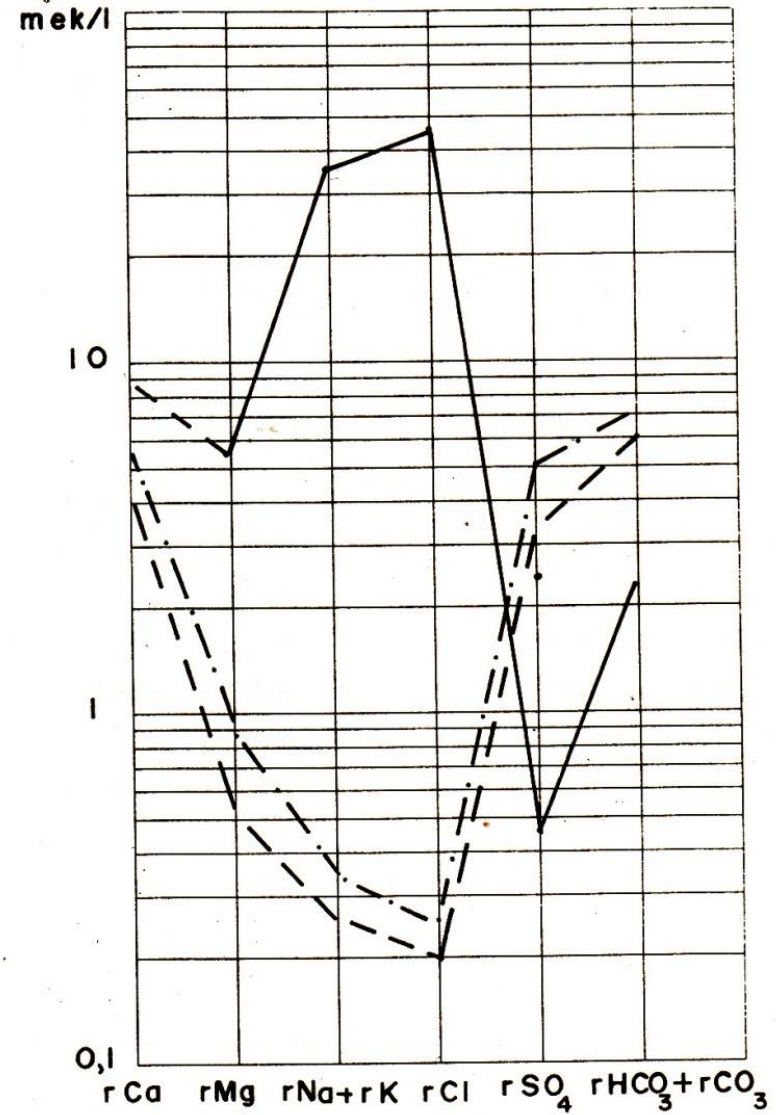
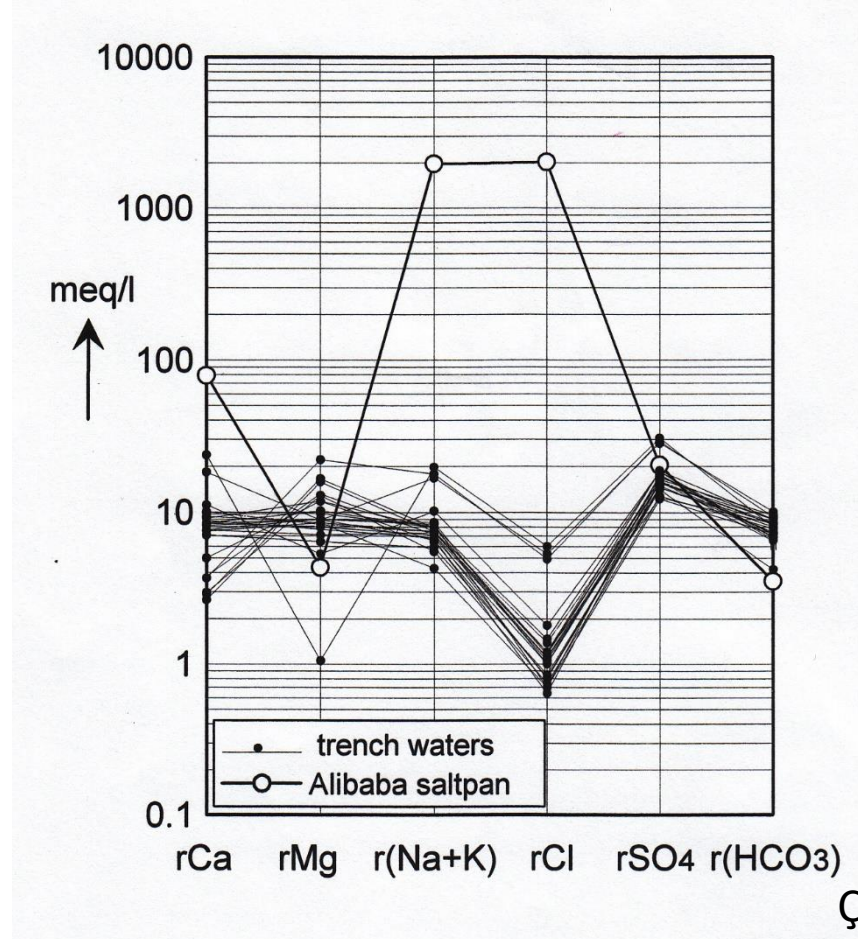


Fig. 6.5 Fingerprint diagram of the same data as in Fig. 6.1 (Table 6.3), but cations are arranged in an increasing order of concentration, and anions are arranged in a decreasing order of concentration, resulting in simple lines that can readily be compared.

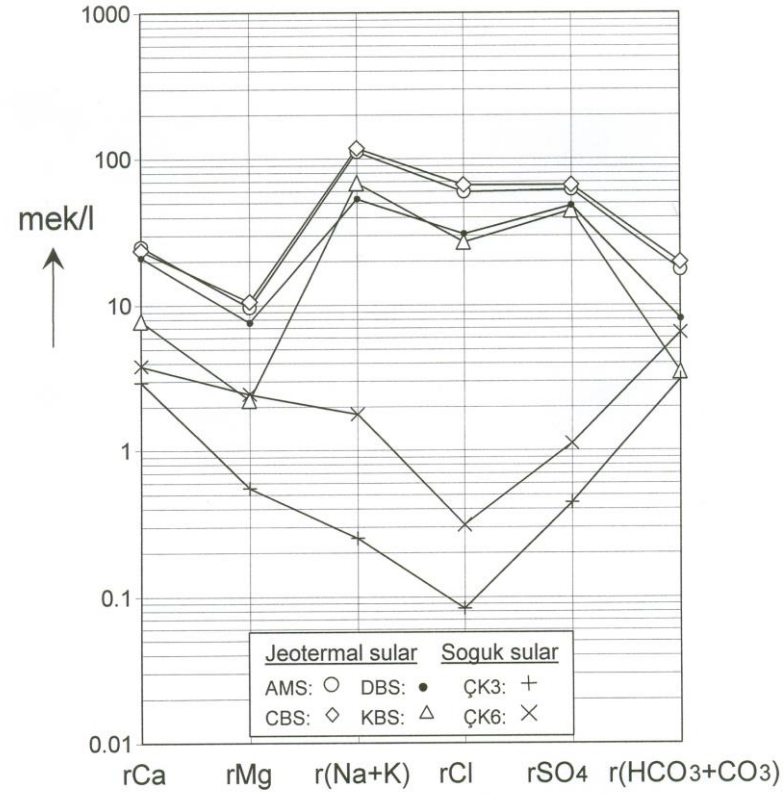
Schoeller Yarı Logaritmik Diyagramı (örnek uygulama)



Ali Baba Tuzlası Kaynağı ve diğer yeraltı suyu örneklerinin
(Sungurlu, Çorum)
Schoeller Diyagramı ile değerlendirilmesi



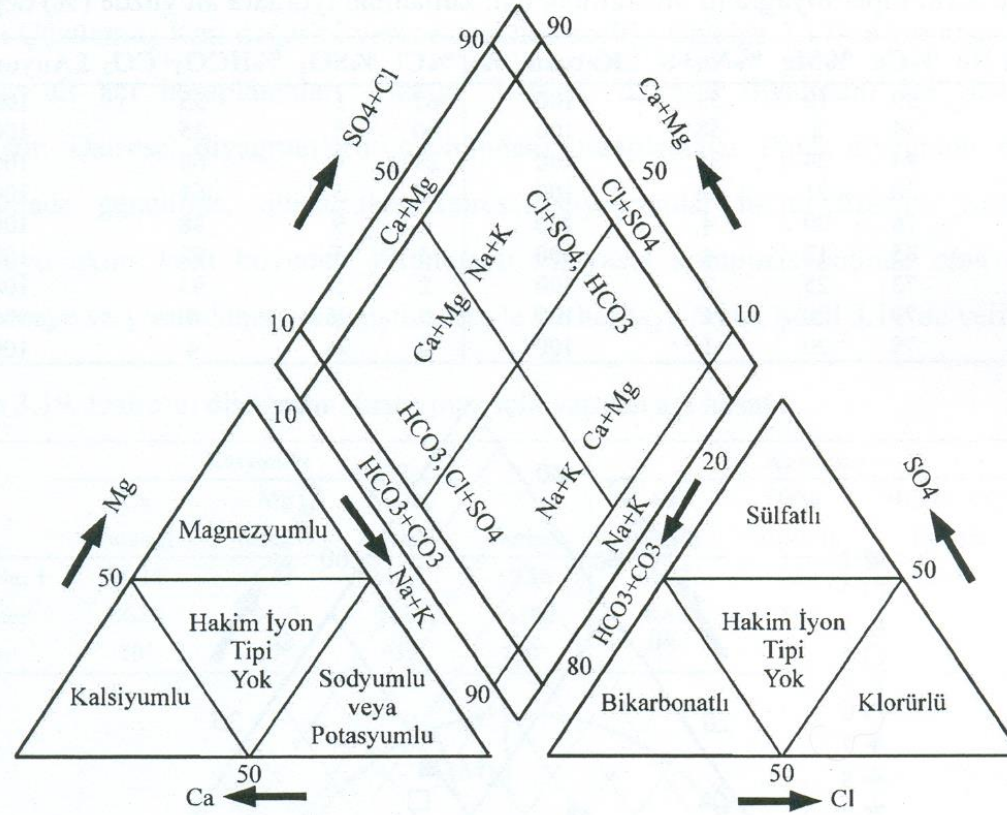
Ayaş-Beypazarı Jeotermal Sahası



Çelmen and Çelik (2009)

PIPER DIYAGRAMI

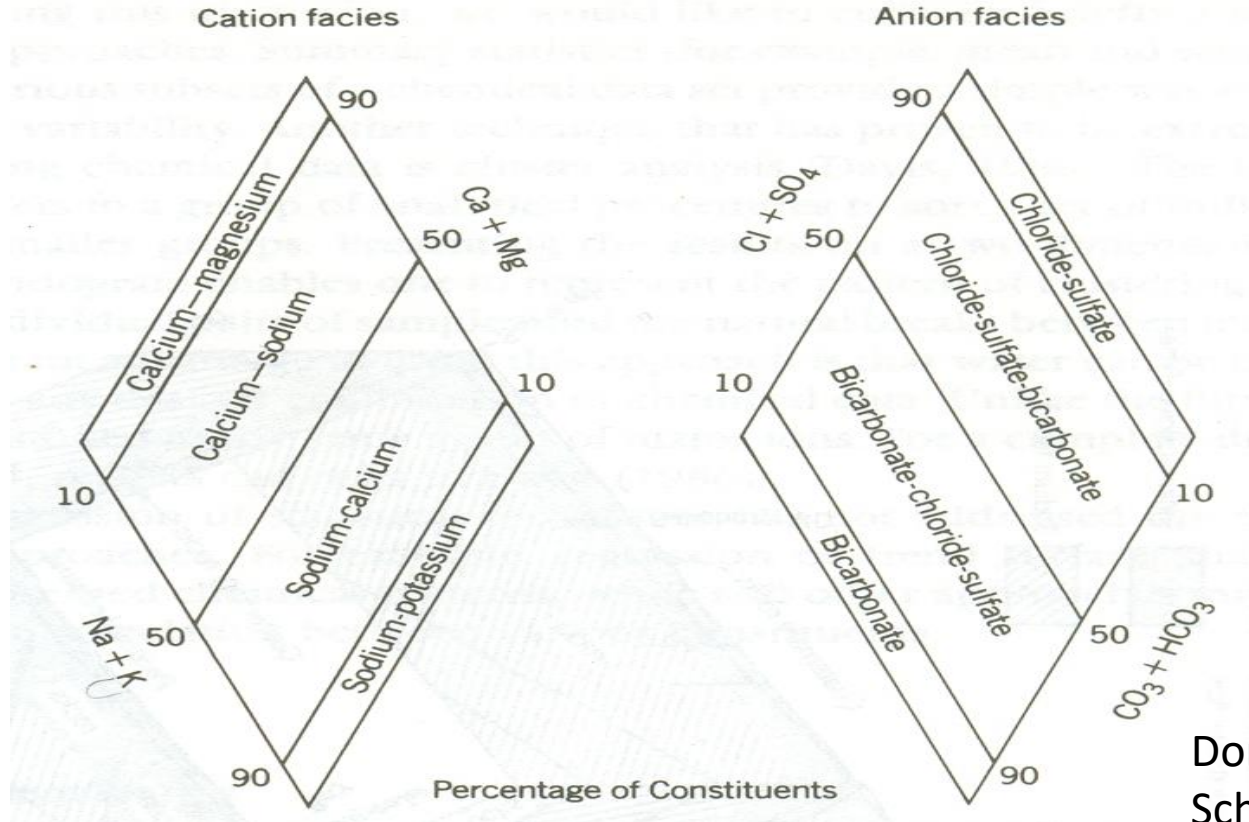
Piper Diyagramı



Domenico and
Schwartz (1990)

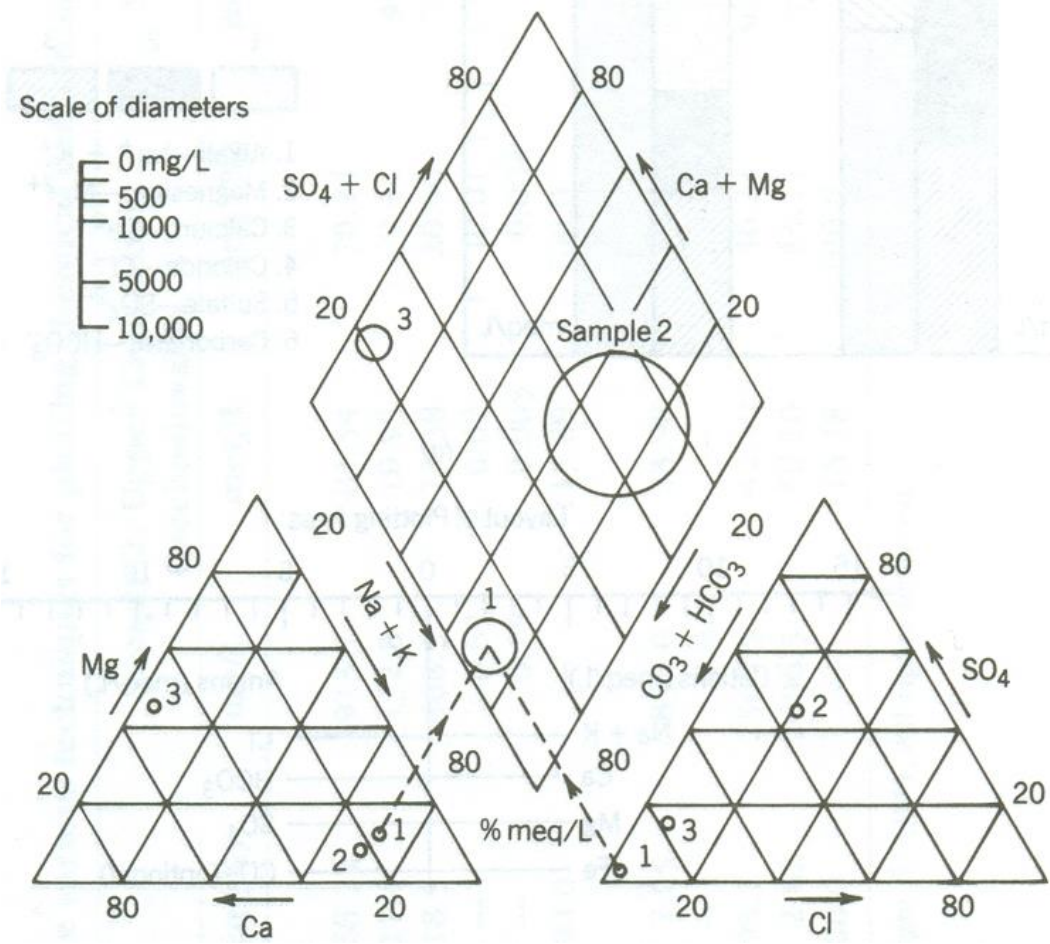
Su Hayattır...

Piper Diyagramının Analizi



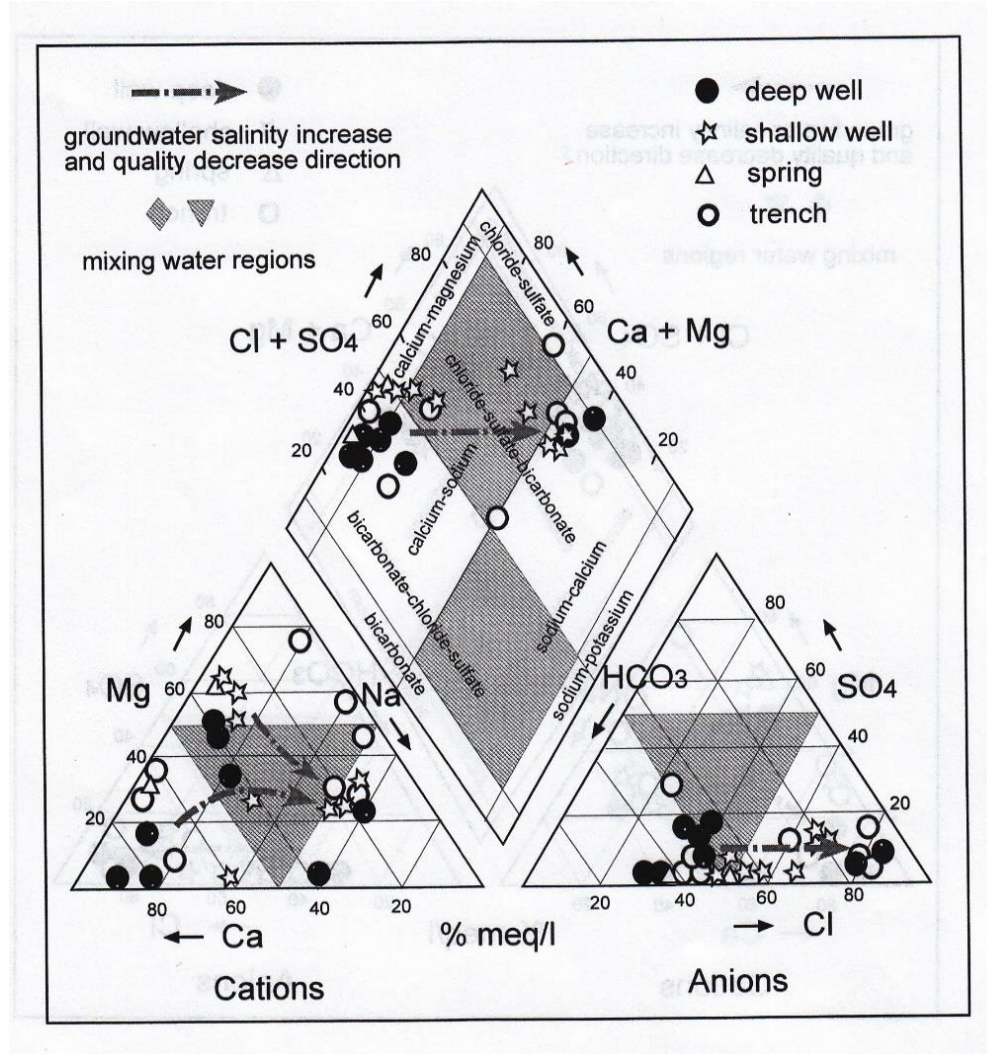
Domenico and Schwartz (1990)

Piper Diyagramına Su Noktalarının Yerleştirilmesi



Hem (1985)

Seyfe Gölü çevresinde (Kırşehir) Piper Diyagramı uygulaması



Çelik ve diğ. (2008)

BAR, DAİRESEL VE STIFF DİYAGRAMLARI

Bar Diyagramı

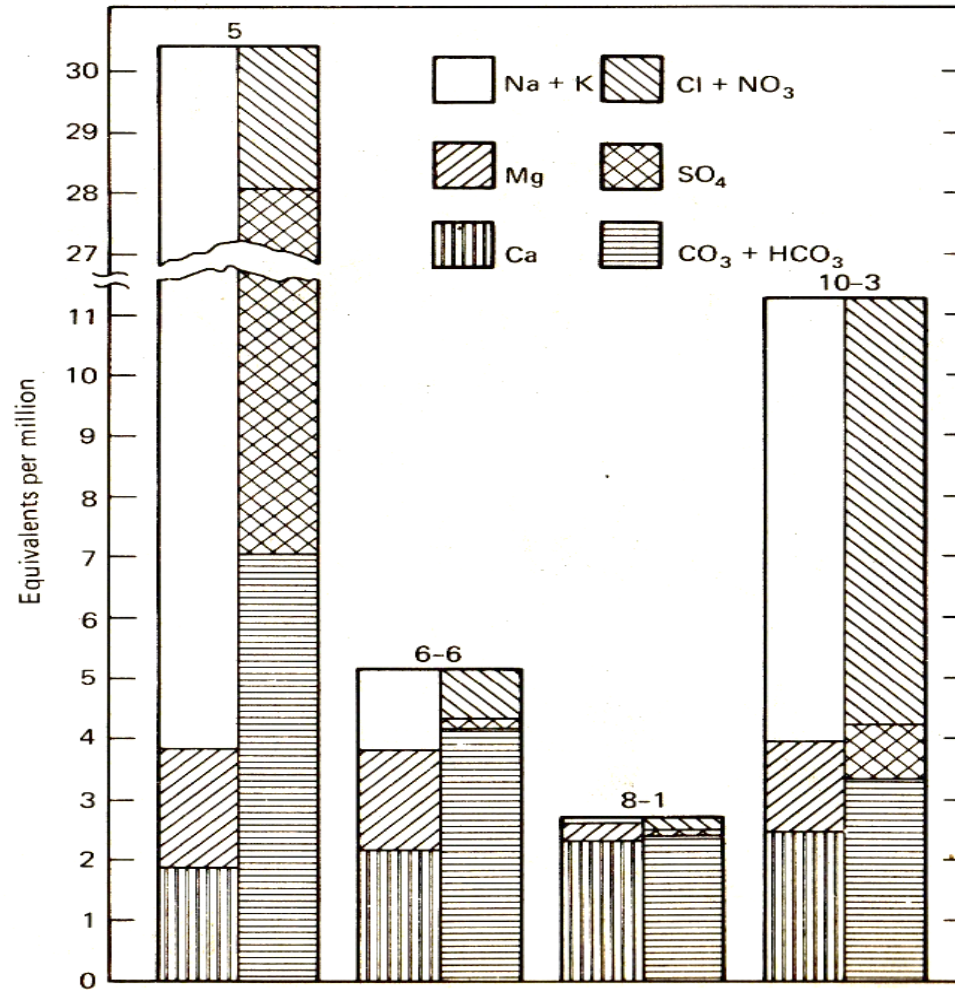


Fig. 7.3 Vertical bar graphs for representing analyses of groundwater quality (after Hem²³).

Dairesel Diyagramlar

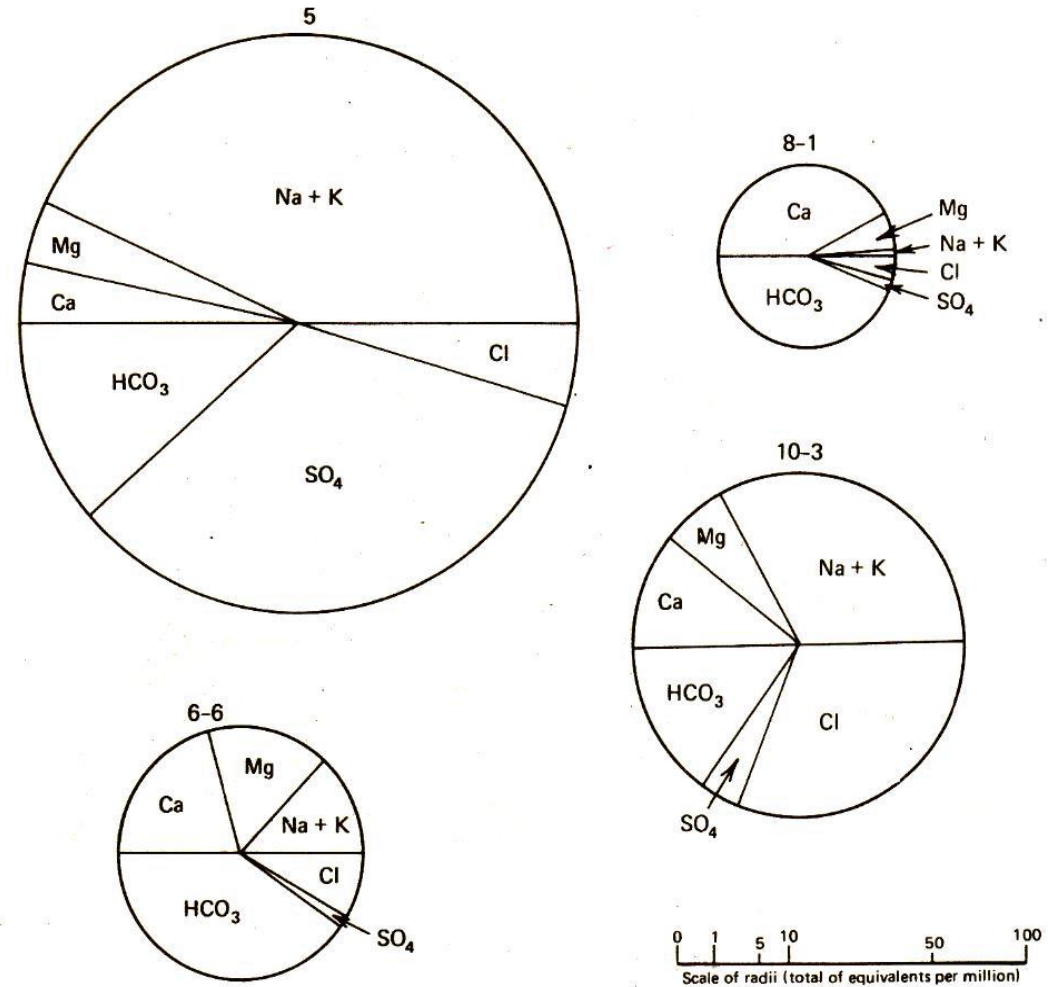
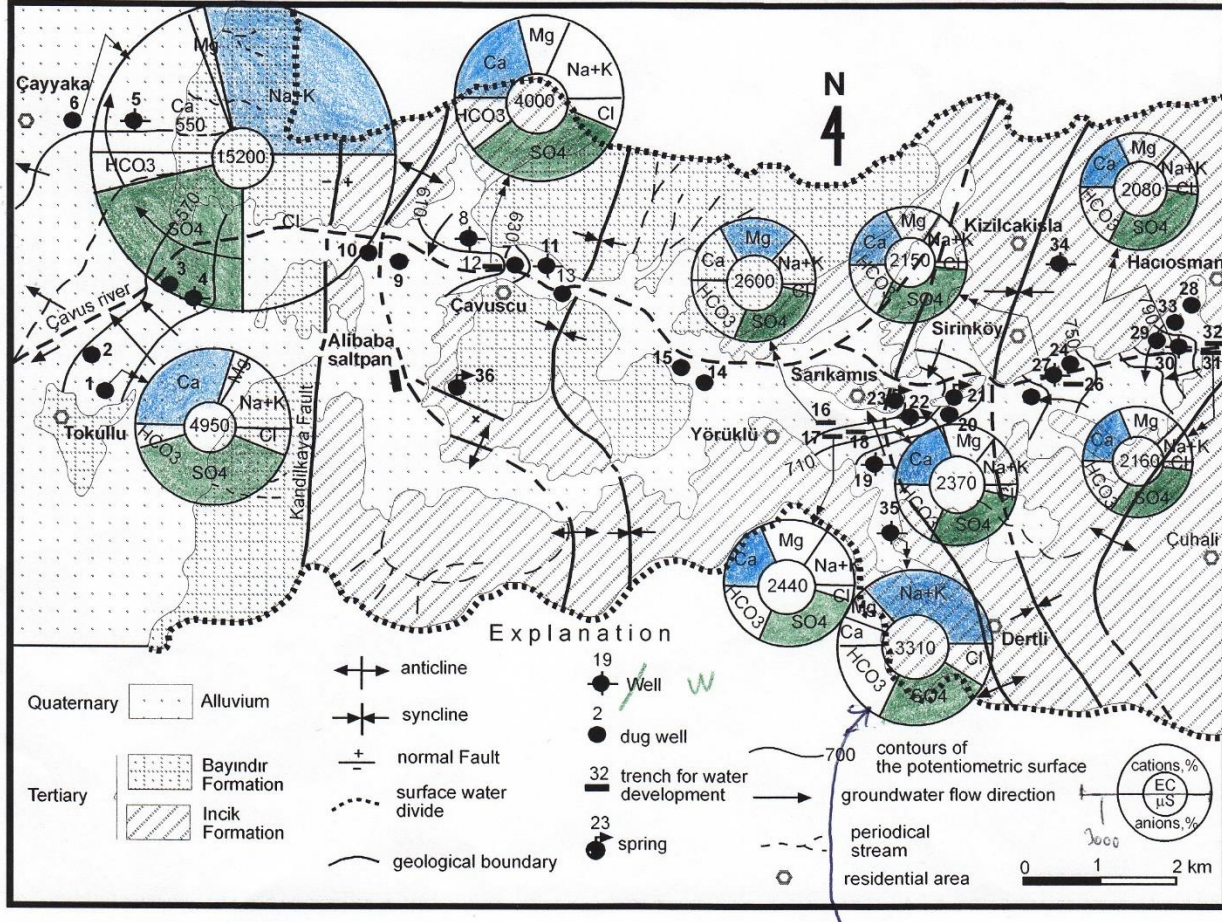


Fig. 7.6 Circular diagrams for representing analyses of groundwater quality (after Hem²³).

Hem (1985)

Çavuş Çayı havzasında dairesel diyagram uygulaması (Ali Baba Tuzlası ve dolayı, Sungurlu, Çorum)

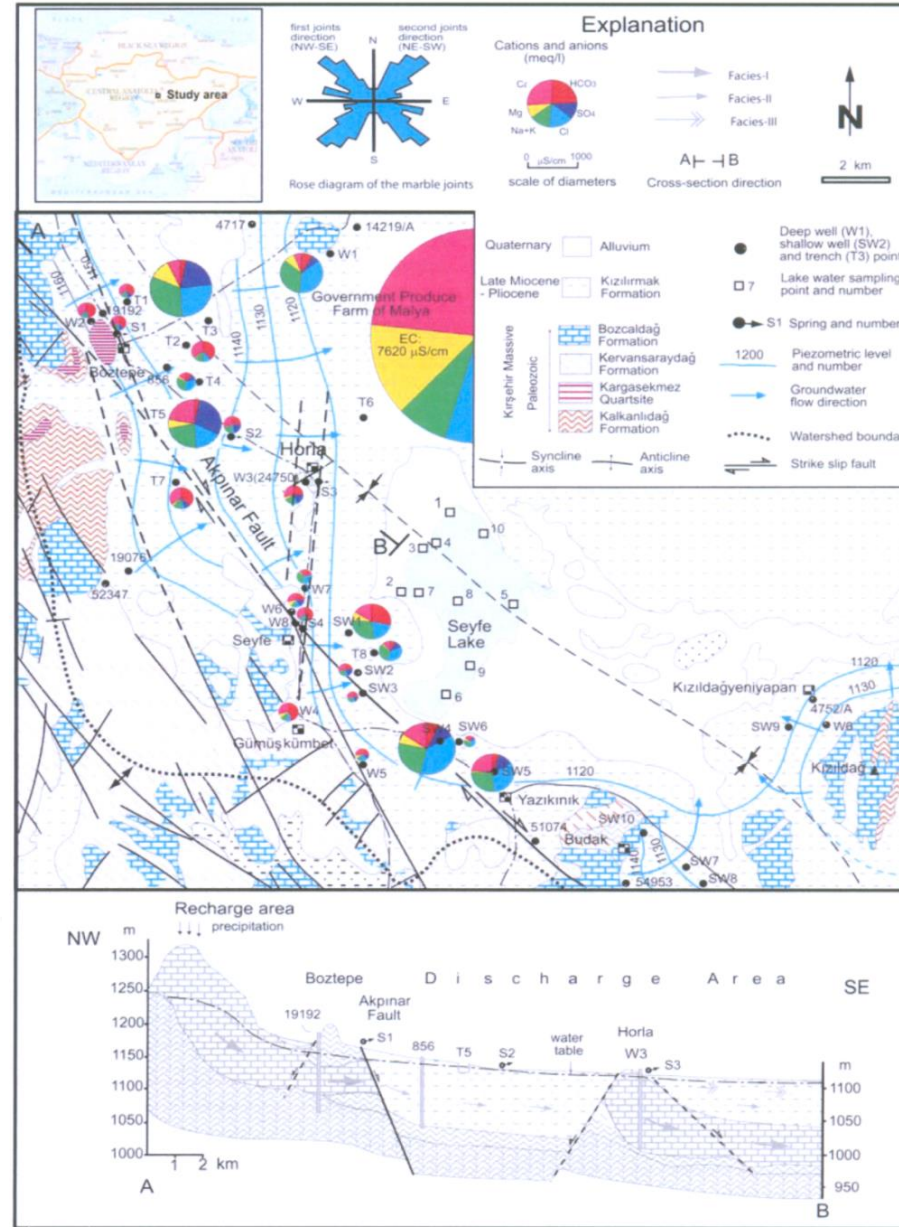


Çelik and Yıldırım (2006)

Su Hayattır...

Seyfe Gölü ve çevresinde Yeraltı suyu kalitesi değişimi (Dairesel Diyagram)

Fig. 1 Location, hydrogeological map and cross-sections of the study area

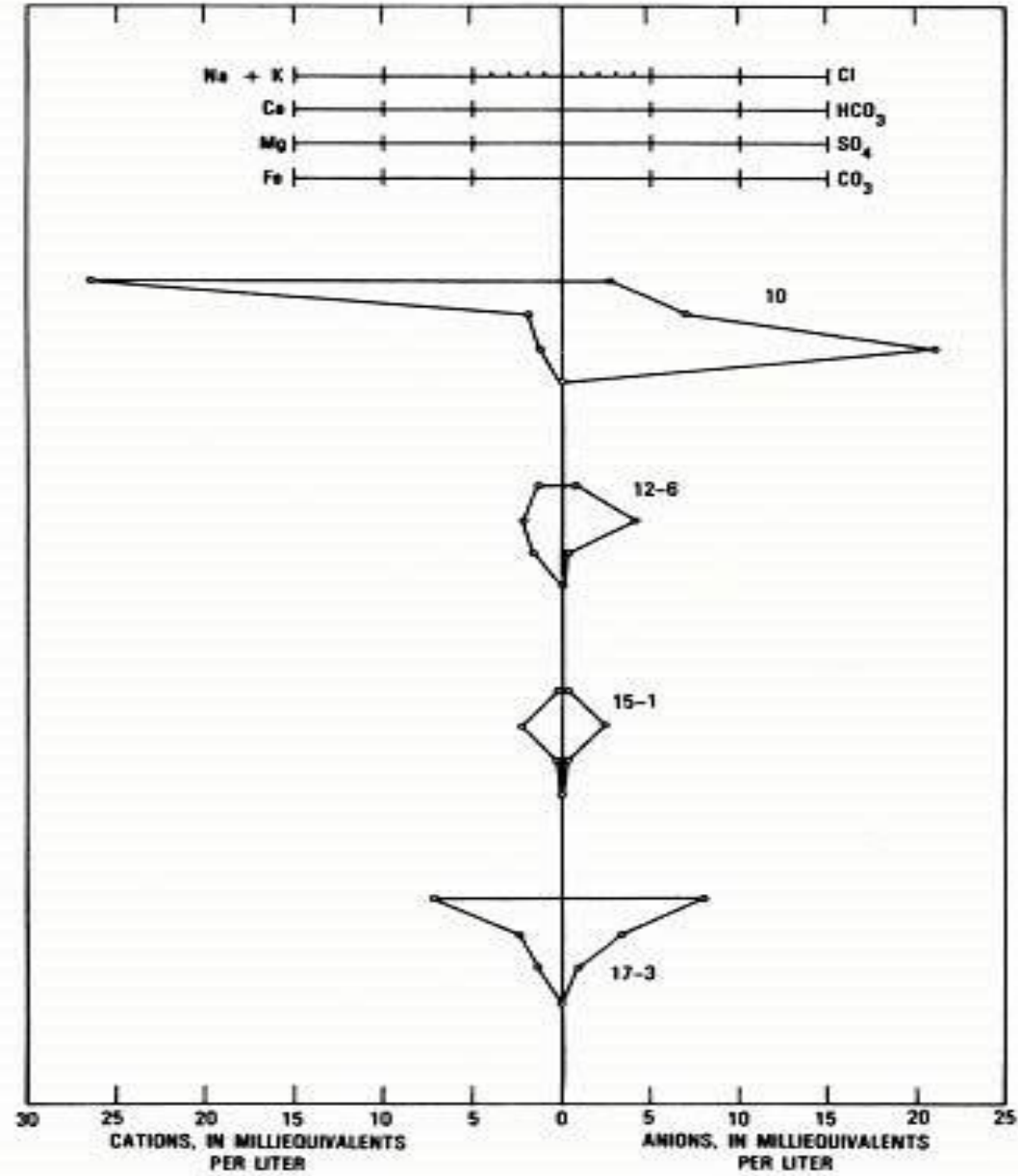


Çelik et al. (2008)

Su Hayattır...

Stiff Diyagramı

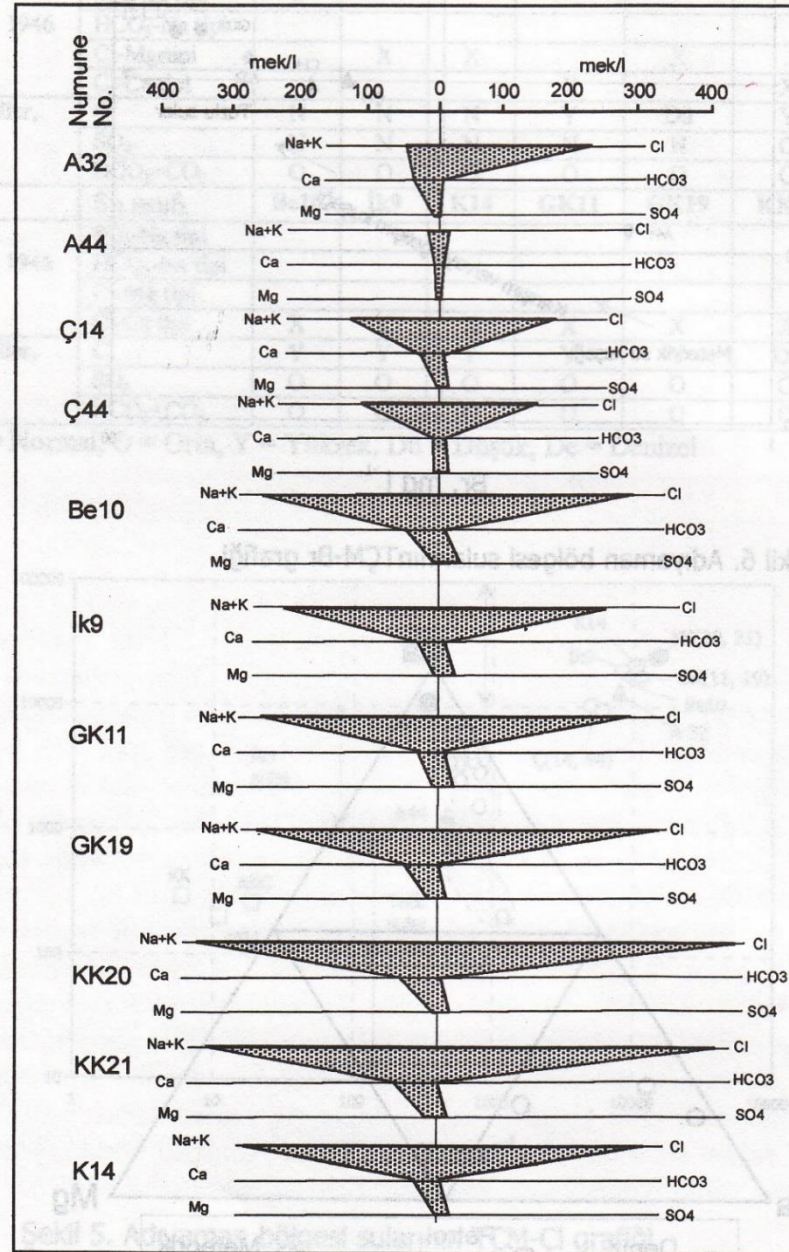
Hem (1985)



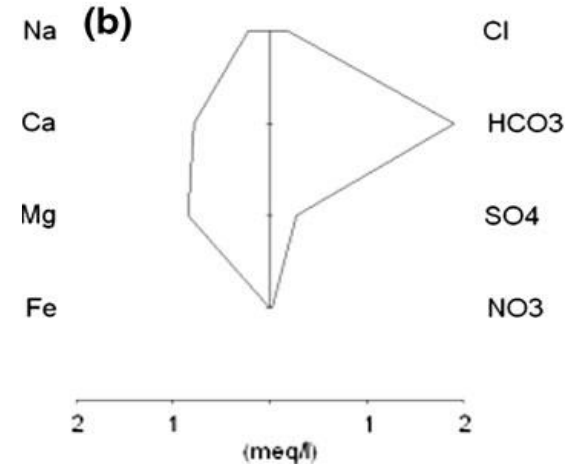
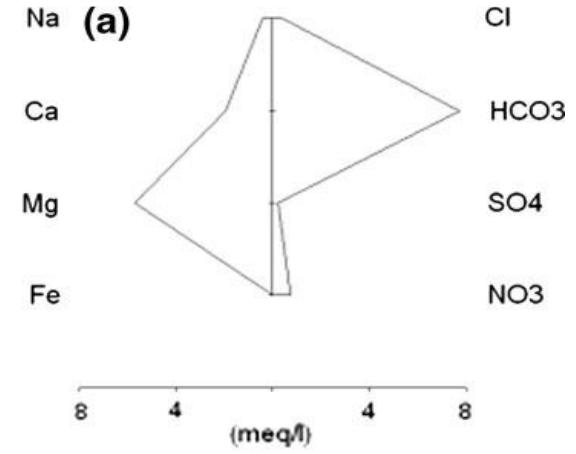
Stiff Diyagramı

(Adıyaman
petrol sahası
örnekleri)

Çelik (2001)



Stiff Diyagramı
(Hatay, Dörtüol
Yeraltı (a)
ve yüzey suyu (b)
örnekleri)

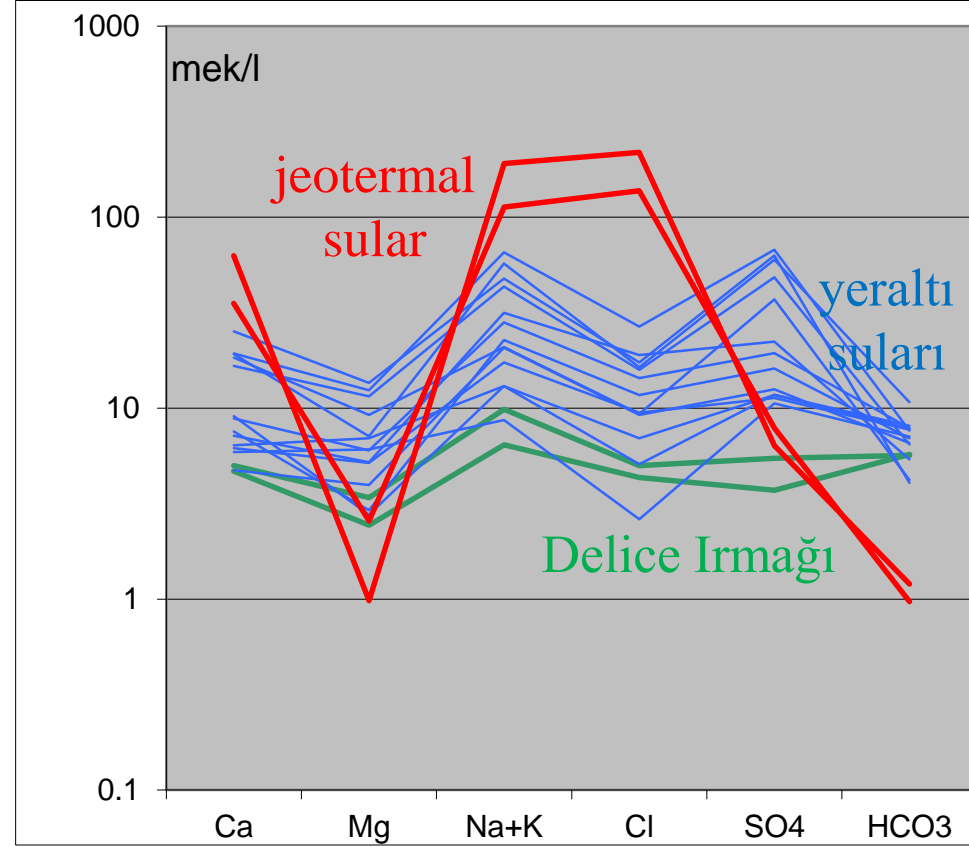


Brehme et al. (2010)

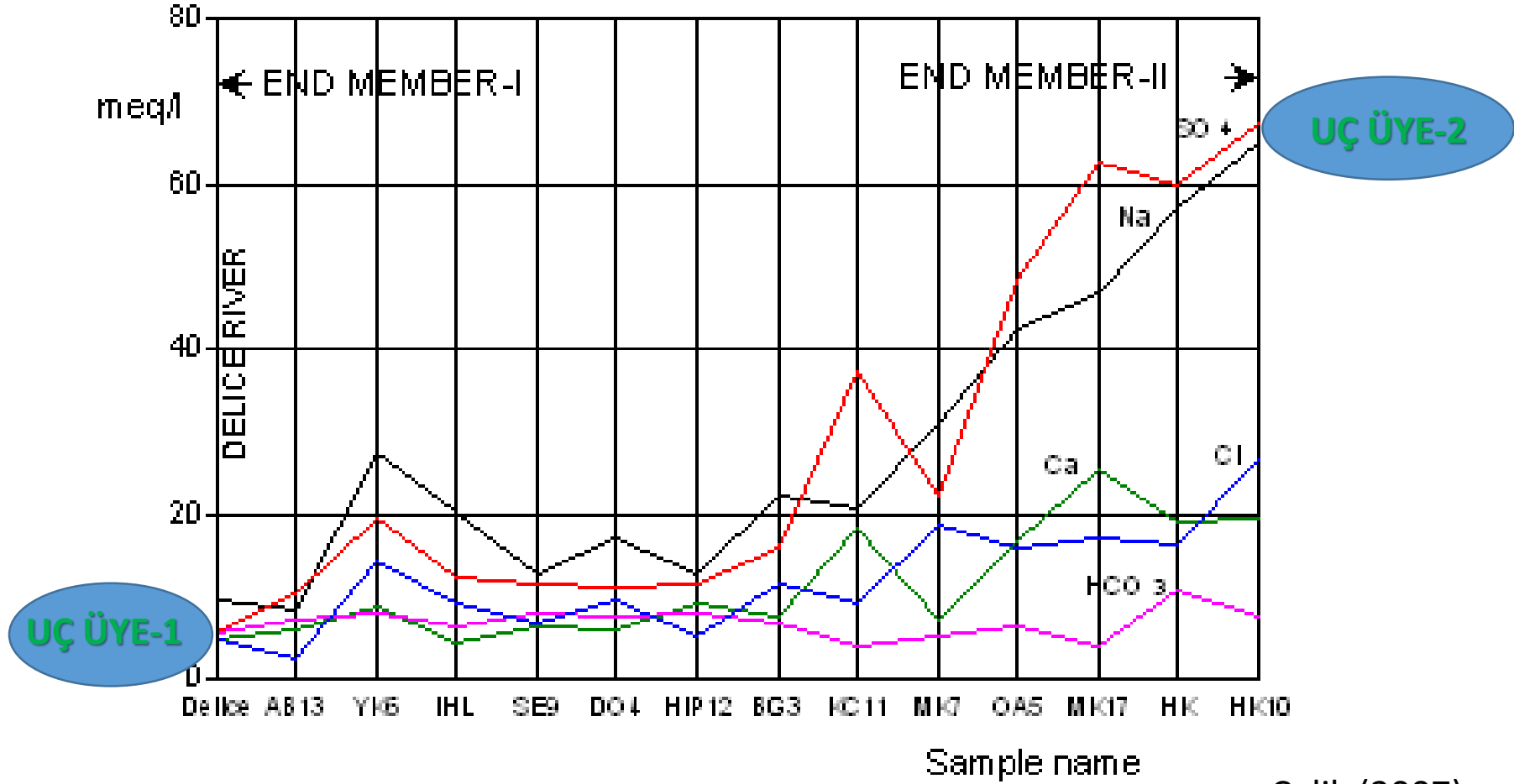
Kompozisyon Diyagramları ve Farklı Suların Karışımı

- Su tipi nedir?, Nasıl bulunur?
- Uç Üye nedir?, Nasıl elde edilir?
- Karışım suyu nedir?, Nasıl hesaplanır ?

Schoeller diyagramı ile uç üyelerin ayrılması (Örnek çalışma)



Uç üyeler



Çelik (2007)

Su Tipi Belirlenmesi

Örnek Çalışma

Table 2 Water types of the wells, trenches and springs

Water points	Cations	Anions	Formation	Water types/hydrochemical facies	Facies number
Trenches					
T-1,T-2,T-7	$\text{Ca}^{2+} > \text{Mg}^{2+} > (\text{Na}^+ + \text{K}^+)$	$\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-}$	Tk	Ca-HCO ₃	I
T-5,T-6	$\text{Mg}^{2+} > (\text{Na}^+ + \text{K}^+) > \text{Ca}^{2+}$	$\text{Cl}^- > \text{HCO}_3^- > \text{SO}_4^{2-}$	Tk	Mg-Na-Cl-HCO ₃	II
T-3,T-4	$(\text{Na}^+ + \text{K}^+) > \text{Mg}^{2+} > \text{Ca}^{2+}$	$\text{Cl}^- > \text{HCO}_3^- > \text{SO}_4^{2-}$	Qa	Na-Cl	III
T-8	$(\text{Na}^+ + \text{K}^+) > \text{Mg}^{2+} > \text{Ca}^{2+}$	$\text{Cl}^- > \text{HCO}_3^- > \text{SO}_4^{2-}$	Tk	Na-Cl	III
Springs					
S-1, 4	$\text{Ca}^{2+} > \text{Mg}^{2+} > (\text{Na}^+ + \text{K}^+)$	$\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-}$	Pzkk	Ca-HCO ₃	I
S-2	$\text{Ca}^{2+} > \text{Mg}^{2+} > (\text{Na}^+ + \text{K}^+)$	$\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-}$	Tk	Ca-Mg-HCO ₃ -Cl	II
Deep wells					
W-1,W-7	$(\text{Na}^+ + \text{K}^+) > \text{Ca}^{2+} > \text{Mg}^{2+}$	$\text{Cl}^- > \text{HCO}_3^- > \text{SO}_4^{2-}$	Pzke	Na-Cl	III
W-6	$\text{Ca}^{2+} > \text{Mg}^{2+} > (\text{Na}^+ + \text{K}^+)$	$\text{HCO}_3^- > \text{SO}_4^{2-} > \text{Cl}^-$	Pzke	Ca-Mg-HCO ₃	I
W-8,W-5	$\text{Ca}^{2+} > (\text{Na}^+ + \text{K}^+) > \text{Mg}^{2+}$	$\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-}$	Pzke	Ca-HCO ₃	I
W-4	$\text{Ca}^{2+} > (\text{Na}^+ + \text{K}^+) > \text{Mg}^{2+}$	$\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-}$	Tk	Ca-HCO ₃	I
W-2	$\text{Ca}^{2+} > (\text{Na}^+ + \text{K}^+) > \text{Mg}^{2+}$	$\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-}$	Pzkk	Ca-HCO ₃	I
W-3	$\text{Ca}^{2+} > \text{Mg}^{2+} > (\text{Na}^+ + \text{K}^+)$	$\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-}$	Pzke	Ca-Mg-HCO ₃	I
Shallow wells					
SW-1	$\text{Mg}^{2+} > \text{Ca}^{2+} > (\text{Na}^+ + \text{K}^+)$	$\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-}$	Tk	Mg-Ca-HCO ₃ -Cl	II
SW-3,7,SW-8	$\text{Ca}^{2+} > \text{Mg}^{2+} > (\text{Na}^+ + \text{K}^+)$	$\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-}$	Tk	Ca-Mg-HCO ₃ -Cl	II
SW-2	$\text{Ca}^{2+} > (\text{Na}^+ + \text{K}^+) > \text{Mg}^{2+}$	$\text{Cl}^- > \text{HCO}_3^- > \text{SO}_4^{2-}$	Tk	Ca-Na-Cl-HCO ₃	II
SW-4,SW-5,6	$\text{Na} + \text{K} > \text{Mg} > \text{Ca}$	$\text{Cl}^- > \text{HCO}_3^- > \text{SO}_4^{2-}$	Tk	Na-Cl	III

Pzkk Kargasekmez Kuvarsit Member, Pzke Kervansaraydağ Formation, Tk Kızılrınmak Formation, Qa Alluvium; ions are meq/l

KOMPOZİSYON DİYAGRAMLARI İLE KARIŞIM

KOMPOZİSYON DİYAGRAMLARI

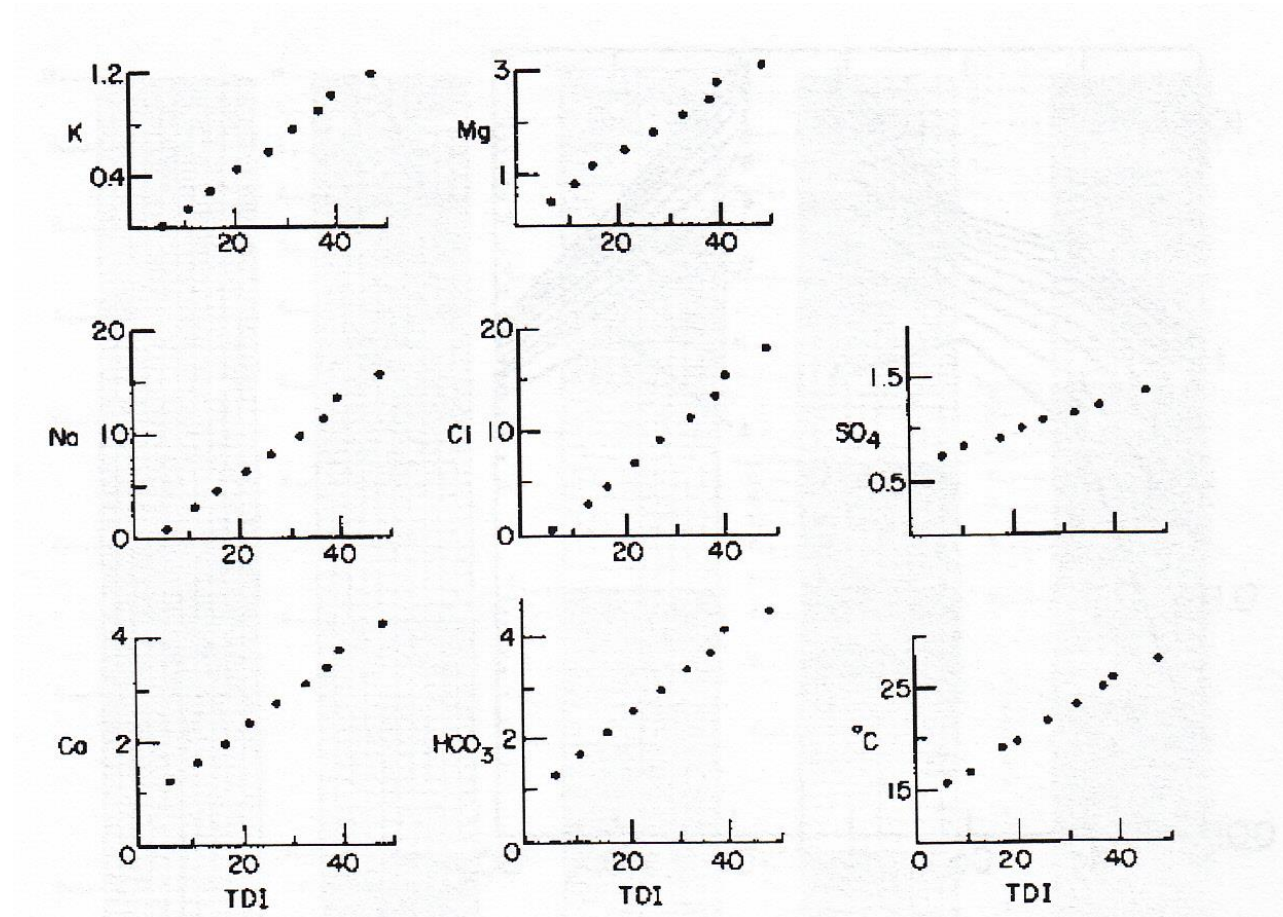


Fig. 6.6 A composition diagram of the Green Mice Springs (Table 6.3). Concentrations are given in meq/l. The compositional interrelations of the nine springs are clearly exhibited: mixing lines indicate a saline warm end member mixes in various proportions with a fresh cold end member.

Mazor (2004)

Kompozisyon Diyagramlarında görülen temel özellikler

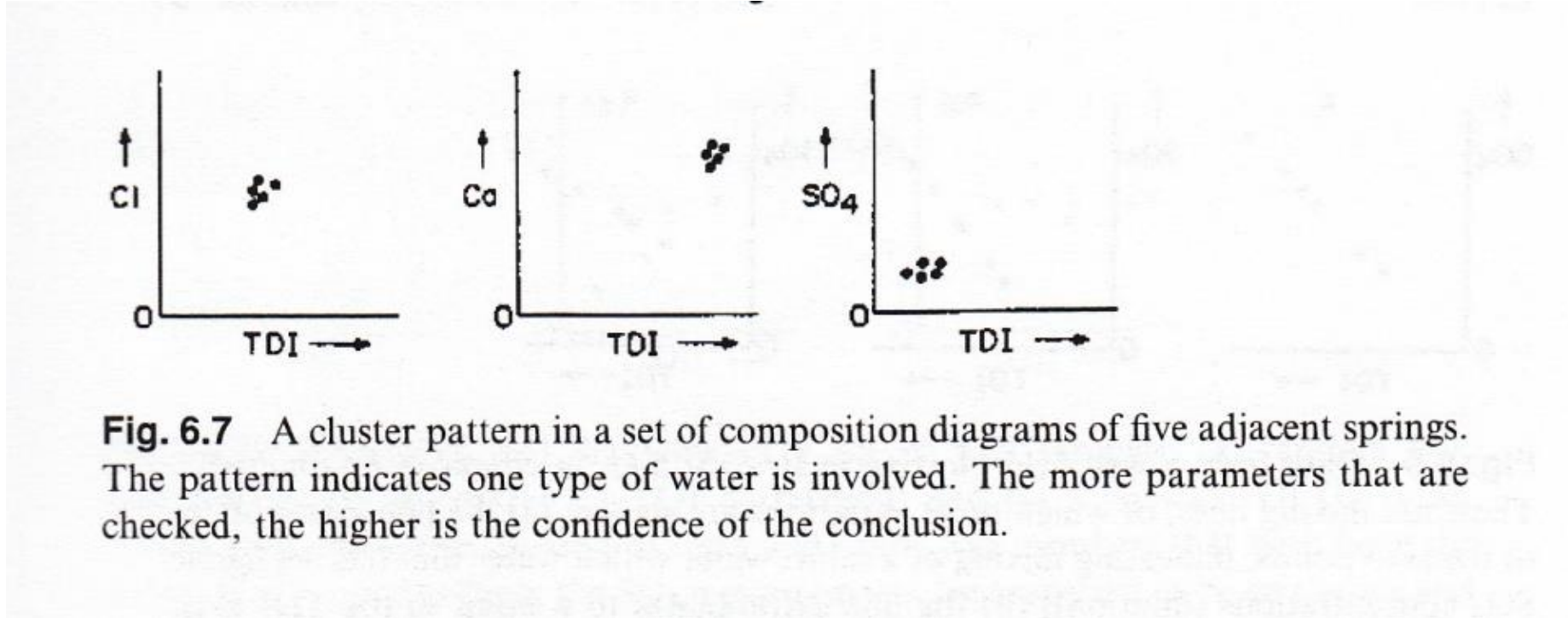


Fig. 6.7 A cluster pattern in a set of composition diagrams of five adjacent springs. The pattern indicates one type of water is involved. The more parameters that are checked, the higher is the confidence of the conclusion.

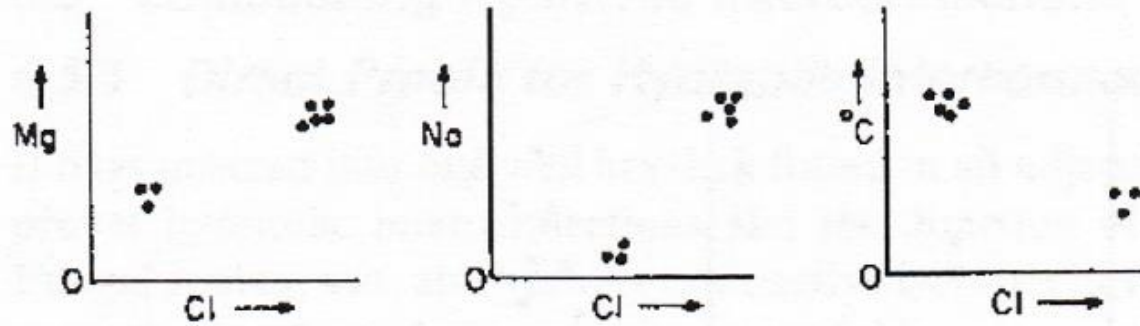


Fig. 6.8 Two clusters in a set of eight adjacent springs. The pattern indicates two distinct types of water occur in the studied region (with no intermixing): a water type of low Cl, Mg, and Na and an elevated temperature, and a water type of high Cl, Mg, and Na and a low temperature.

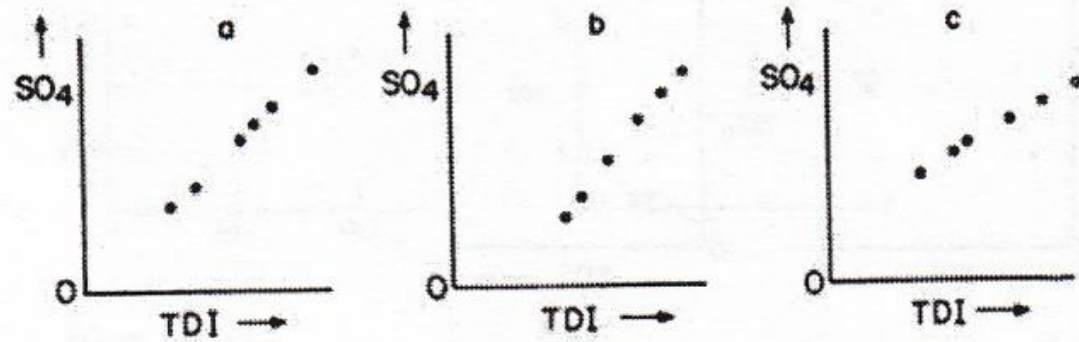


Fig. 6.9 Data from a well field plotting in straight lines in composition diagrams. These are mixing lines, of which three variations are shown: (a) the line extrapolates to the zero points, indicating mixing of a saline water with a water that has negligible SO_4 concentrations (dilution); (b) the line extrapolates to a point in the TDI axis, indicating the fresher end member contains significant concentrations of ions other than SO_4 ; and (c) the line extrapolates to the SO_4 axis, indicating both intermixing waters contain significant concentrations of SO_4 .

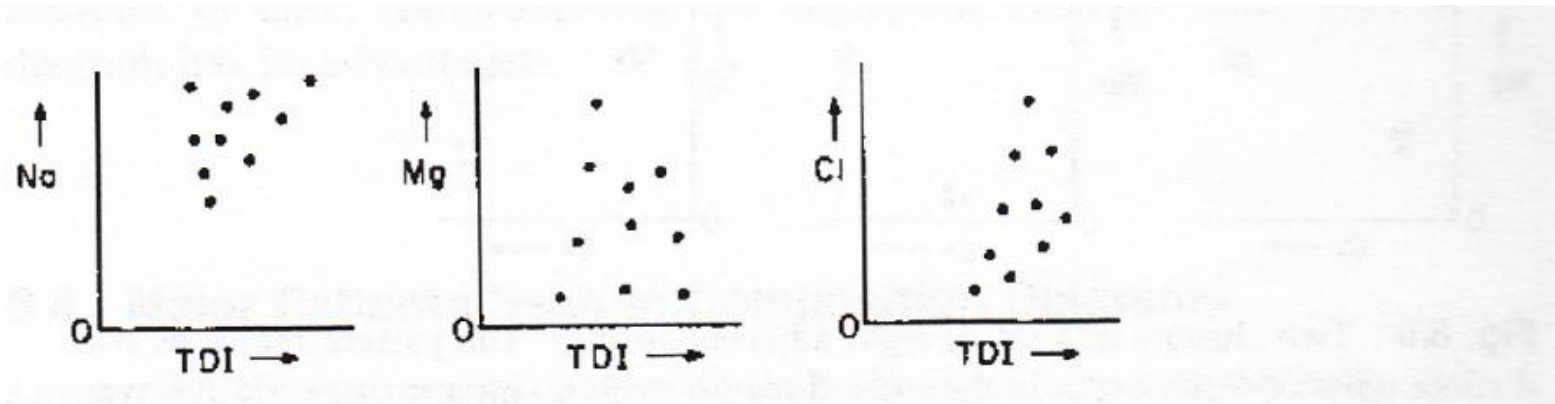


Fig. 6.10 Data of a group of wells falling in triangular areas on compositional diagrams, indicating three distinct water types intermix in varying proportions.

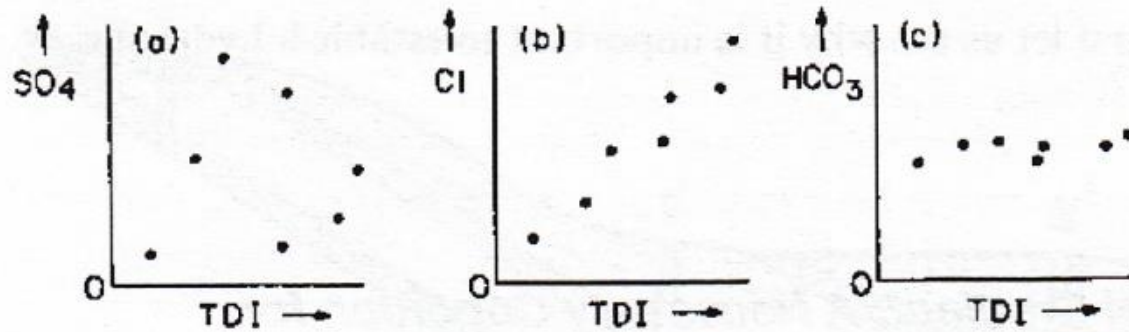
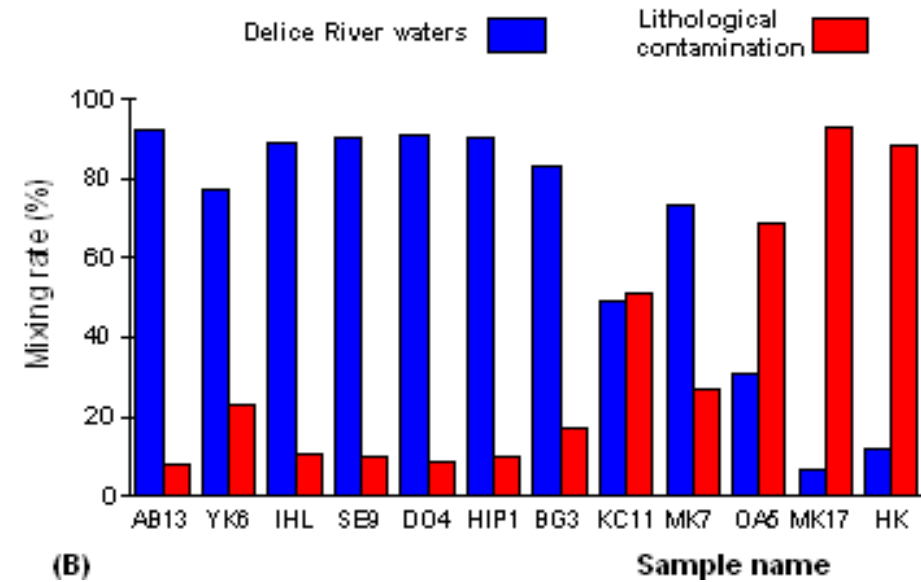
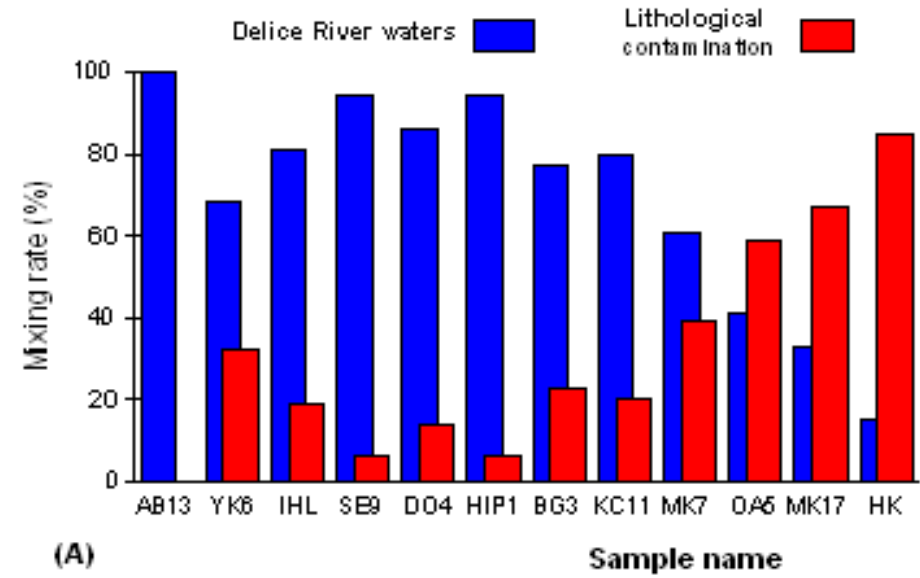


Fig. 6.11 Compositional diagrams of a set of well samples: (a) random SO_4 distribution; (b) a positive Cl -TDI correlation; and (c) a constant HCO_3 value. Possible interpretation: mixing of fresh and saline end members that both have the same HCO_3 concentration; the SO_4 measurements are suspected to be erroneous and should be repeated.

Karışım %'lerinin dağılımı (Örnek çalışma)

Çelik (2007)



Su Hayattır...

Tatlı ve tuzlu sulardan oluşturulan set

Table 6.4 Synthetic Data Generated to Simulate Dilution of a Saline Water by a Fresh Water (meq/l)

Data set	K	Mg	Ca	Na	SO ₄	HCO ₃	Cl	TDI
1	0.2	0.8	1.4	2.6	0.3	2.4	2.3	10.0
2	0.4	1.6	2.8	5.2	0.6	4.8	4.6	20.0
3	0.6	2.4	4.2	7.8	0.9	7.2	6.9	30.0
4	0.8	3.2	5.6	10.4	1.2	9.6	9.2	40.0
5	1.0	4.0	7.0	13.0	1.5	12.0	11.5	50.0

Set 3'ün karışım oranının K'a göre bulunması:

Uç Üyeler:

Set 1= tatlı su,

Set 5= daha tuzlu su

$$1.0x + 0,2 (1-x) = 0,6$$

X = 0,5 (%50); Set3, Tip1 ve Tip3'ten %50

oranında karışım suyudur)

Mazor (2004)

YÜZEY-YERALTI SUYU İLİŞKİSİ; HİDROKİMYASAL YÖNTEM

Akiferden beslenen akarsularda kimyasal kütle dengesi esasına dayalı olarak, genel yeraltı suyu ve yüzey suyu kalitesi (özgül elektriksel iletkenlik (Ei), sıcaklık (T) ve çözünmüş oksijen (DO)) karşılaştırılarak kullanılmaktadır.

Formül:

$$Q_{sw,in} \times WQP + S_{gw,in} \times WQP = Q_{sw,out} \times WQP$$

Burada;

$Q_{sw,in}$: alana giren akarsu akımı, m³/s

WQP: seçilen parametrenin su kalitesi değeri

$S_{gw,in}$: alana giren yeraltı suyu akımı, m³/s

$Q_{sw,out}$: alandan çıkan akarsu akımı, m³/s

Kıyaslama amacıyla birden çok parametre kullanılmalıdır!.

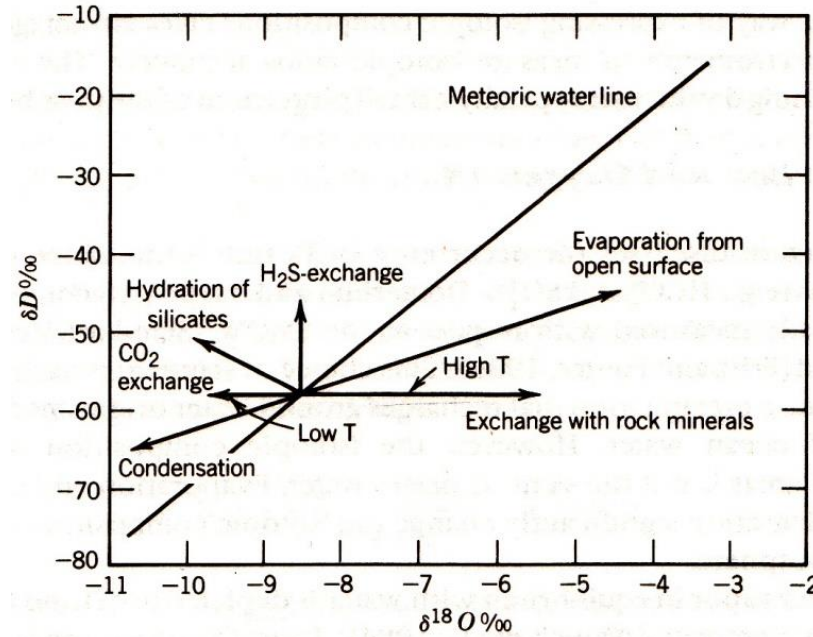
Weight, W.D., Sonderegger, J.L. (2001)

İZOTOPLAR

DURAYLI İZOTOPLAR

	Oksijen-18 (binde)	Döteryum (binde)
Ortalama okyanus suyu	0	0
Okyanus, deniz, yüzey suları	0/+1	0/+10
Akdeniz bölgesi denizleri, Kızıl Deniz	+1/+2	+8/+20
Okyanus, buzullaşma boyunca	+1	+10
Yağmur ve tatlı su	0/-15	0/-110
Kapalı göller	-2/+5	-20/+20

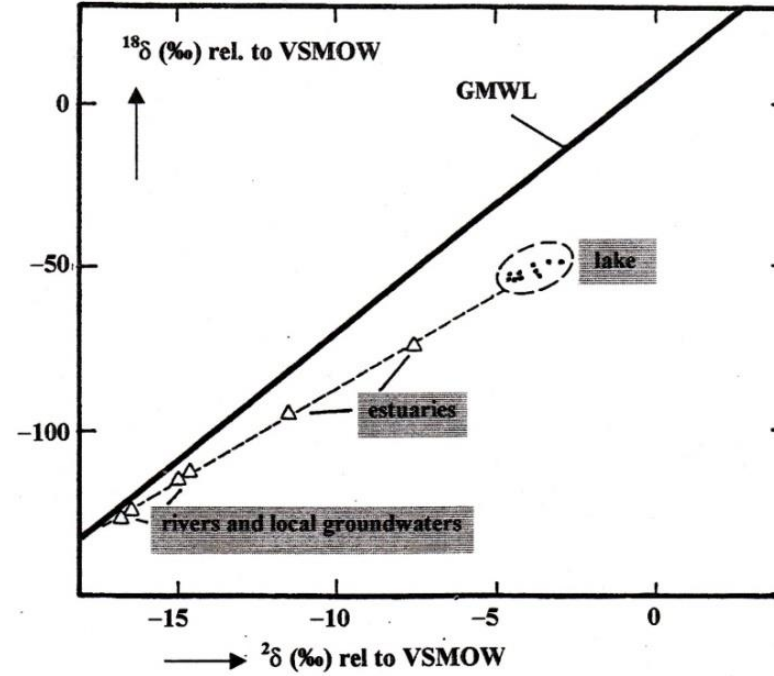
Oksijen-18/Döteryum Grafiği



Genel oksijen-18/döteryum grafiği

Oksijen-18/Döteryum Grafiđi

Buharlařma Doğrusu



Nehir, sıđ yeraltı suları, haliç ve göl ile ilgili oksijen-18/döteryum grafiđi

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