

The Hydrochemistry of the Spring at Ain bu Sukhanah, U.A.E.

Faig Elschami

*Department of Geology, College of Science,
United Arab Emirates University, U.A.E.*

ABSTRACT. The spring Ain bu Sukhanah is artesian in character and has an average discharge of (160 l/Sec). The water reaches the spring along fractured beds of the underlying Miocene gypsum sequence. The spring water is brackish with the type Ca-Sodium-Chloride. The hydrochemical composition of the spring water reflects an old marine genesis.

Mixing of spring water with the circulating meteoric water is reflected in the hydrochemical composition.

The hot spring Ain bu Sukhanah, locally known as Ain al Faydah, lies approximately 15 kms. south of Al Ain city, and 2 kms. west of the Jabal Hafit margin (Fig. 1). It is approached by the Tormac road which leads from south Al Ain and subsequently follows the Omani border towards Liwa Oases. The spring is situated on the gently sloping gravel and sand plain lying between the slopes of Jabal Hafit on the east and the dune fields which cover much of Abu Dhabi Emirate on the west. The spring has annual discharge of approximately 160 l/s. The water is very clear, and, according to Terratest (1975) has a constant temperature of 39.3°C. The main outflow pool of the spring is dug out to a depth of about ten meters. The rise of water to the surface is attributed to natural artesian conditions, the water running down deep underground and rising along the fractures. The spring water issues from three main sites. However, in spite of the attention of several scientists in the last ten years, the source of the water of the spring remains speculative, even though field observations favour one particular provenance. The research reported here therefore set out to establish:

- (1) the origin of the spring water and to gain understanding of the hydrological cycles.

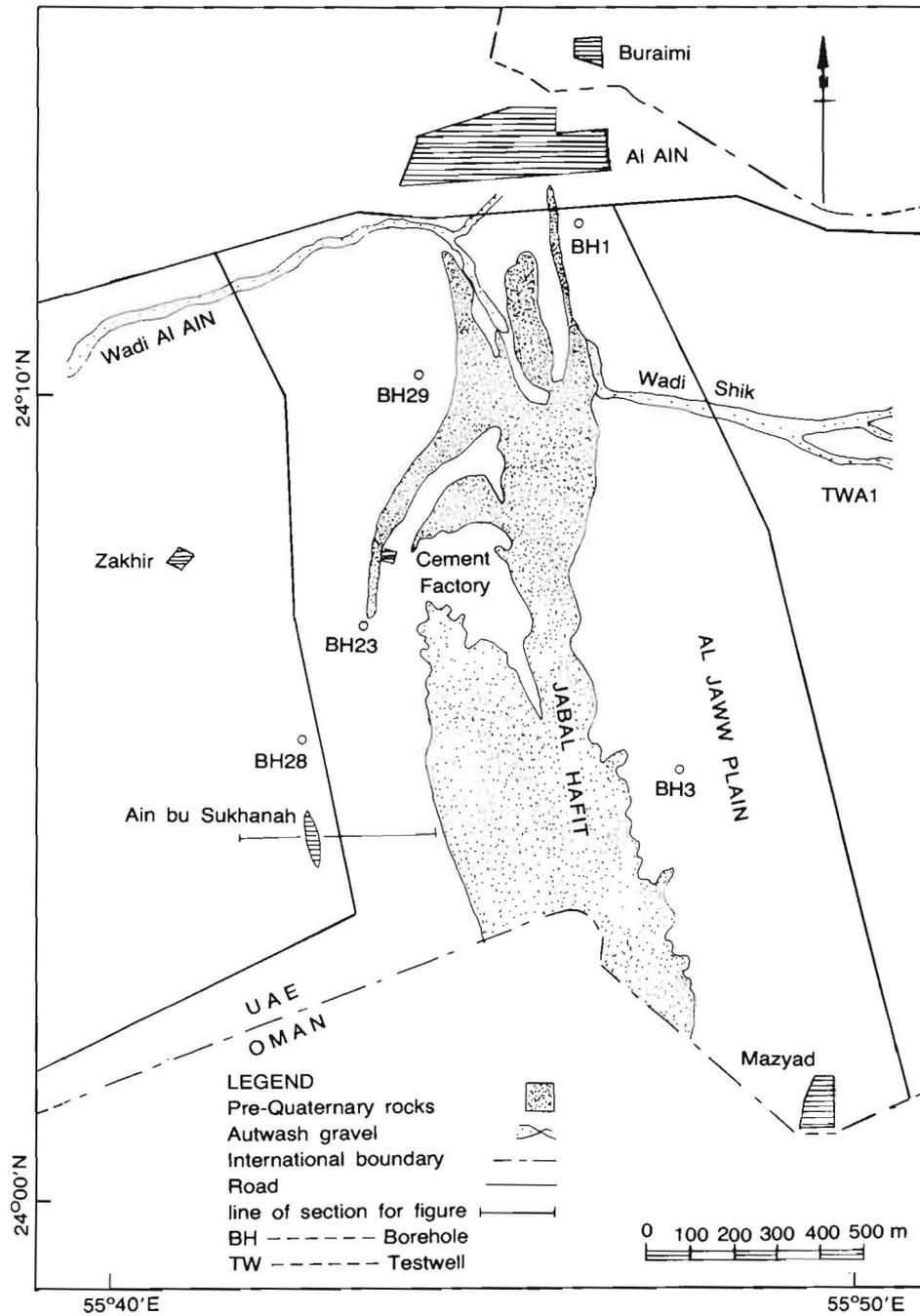


Fig. 1. Location map of the spring at Ain bu Sukhanah

- (2) to study the hydrochemical composition and the hydrogeochemical formation of the spring water.

Previous Work

The hydrochemistry and the hydrogeology of the spring discussed by Gibb (1970).

Radioactivity at the site was discovered by an airborne spectrometric survey in 1972-73 (Terratest 1973).

Terratest returned in 1974 to carry out further work at the site (Terratest 1974). This included laying out a surveyed grid in the vicinity of the spring, levelling in the standing water level in adjacent wells and bores, a radon soil-gas survey and sampling and analysis of radioactive waters at and around the spring. Further work (Terratest 1975) consisted of the coredrilling of five holes totalling 1568 metres and analysis of the sediments and their containing ground water.

Hunting (1979) carried out a ground geophysical survey in the vicinity of the spring and sampling and analysis of radioactive waters at and around the spring.

Geological setting

Hunting (1979) discussed in detail the geology of the Al Ain area (Fig. 2).

The bedrock of the Al Ain area consists of interbedded limestone, dolomite, marl and clay with evaporites towards the top. Exposed rocks range from uppermost cretaceous to Miocene in Age.

The limestones consist in Jabal Hafit of crystalline limestone with abundant fossil debris.

The marls, interbedded with the limestones, are gypsiferous. The upper part of this sequence is exposed on the flank of Jabal Hafit, east of Ain bu Sukhanah and underlies the plain around the spring. It is presented in (Fig. 3).

The lower part of this succession consists of interbedded Middle Eocene limestones, clays and clay stones with minor limestone conglomerate (Terratest 1975). Terratest drew particular attention to the following aspects of these rocks:

- (a) The limestone typically have black organic precipitates along joint and

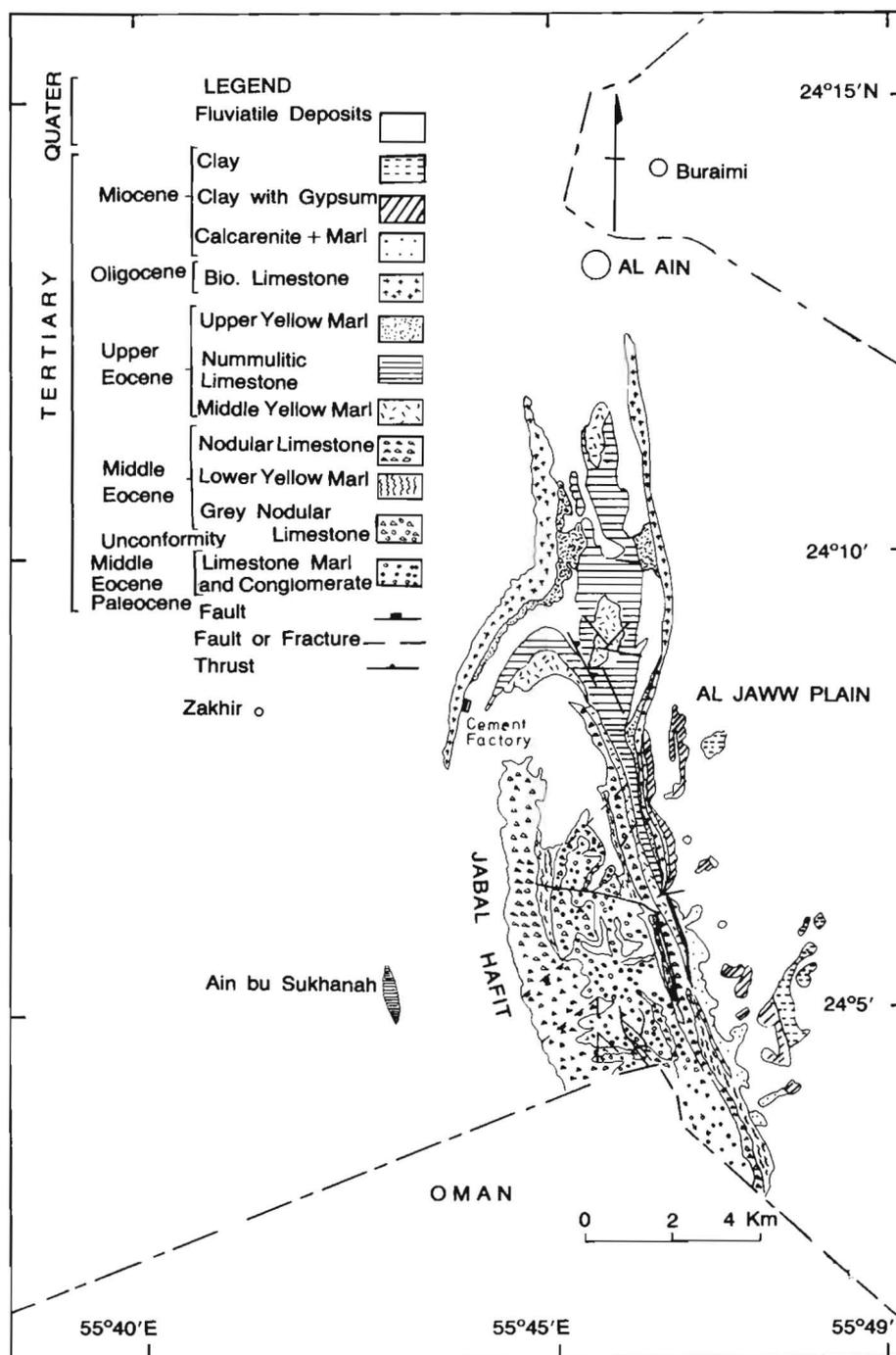


Fig. 2. Geological situation of close surrounding of Ain bu Sukhanah spring, (after Hunting, 1979)

bedding planes of this material contained 20.7 ppm uranium (Terratest 1975).

- (b) One of the limestone beds intersected contained a porous zone lacking black precipitate (Fig. 2) which was interpreted as the aquifer for the radioactive water.
- (c) One of the upper clay units (Unit 5, Fig. 3) contained abnormally high chromium content. Because the spring water also has high chromium content, it was concluded that it had passed through this clay.

The Eocene sequence is presumed to be overlain by the strike extension of the Oligocene limestones and marls exposed west of the cement factory.

The Oligocene rocks, in turn, are overlain by Miocene gypsum and clay intersected in Borehole 23 of Gibb (1970). The upper part of this sequence lacks gypsum. The lower part consists of interbedded massive gypsum, locally fissured and with minor halite.

Hydrogeological condition of the Spring

The yield of the Ain bu Sukhanah has been estimate to be upwards of (160 l/sec) and having flowed at this rate for almost a year, it shows no sign of admintion in quantity. The water temperature at the mouth of the artesian spring is about 39.3°C. Ain bu Sukhanah issues from a porous or more fissured bed of the underlying Miocene gypsum sequence.

Terratest (1974) and Hunting (1979) all considered the water of the spring to have a deep inflow close to the margin of Jabal Hafit and lying to the south-east of the spring. This choice was based on temperature and standing water level in this region compared to other parts of the Ain bu Sukhanah area. Correlation between holes survey of the piezometric pressure in each aquifer is carried out. It has been noticed that the water level of the spring pool is higher than at most of the sites to the east measured by Terratest (1974).

Terratest (1974) is suggesting the presence of fracture in the west edge of the mountain and a narrow permeable zone within the Sabkha deposits (Fig. 3) which helps to explain how the artesian water might be led from the site of its deep inflow towards the spring.

The fact that the spring is artesian in character, is attributed to the hydraulic head which stands higher than the ground surface around the spring. The most likely explanation of this excess pressure is that it is caused by a free head of water

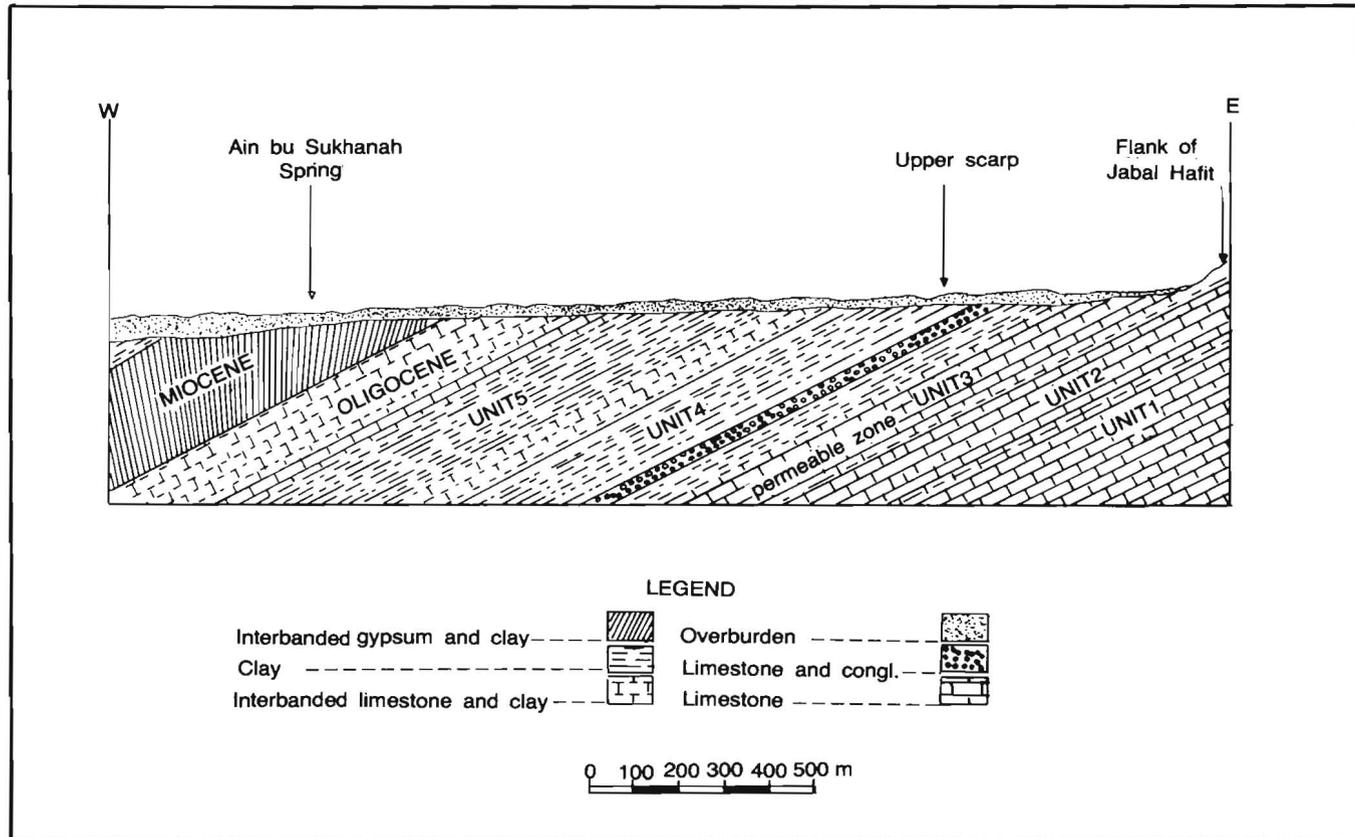


Fig. 3. Geological cross section between east flank of Jabal Hafit and Ain bu Sukhanah

maintained by precipitation and run-off at an elevation higher than the spring. All the ground to the west is lower than the spring outlet; therefore the water has to come from the east, that is from within Jabal Hafit, Al Jaww plain or the margin of the Oman mountains.

The hydrology and structure of the area and the chemistry of the spring water provide additional constraints on the route taken by the water towards the spring.

Procedures

Three sites within the Ain bu Sukhanah pool were selected for sampling (Fig. 4). Site 1 was adjacent to the steps leading to the garden, Site 2 over the main inlet of water into the pool in its centre and Site 3 over the subsidiary inlet.

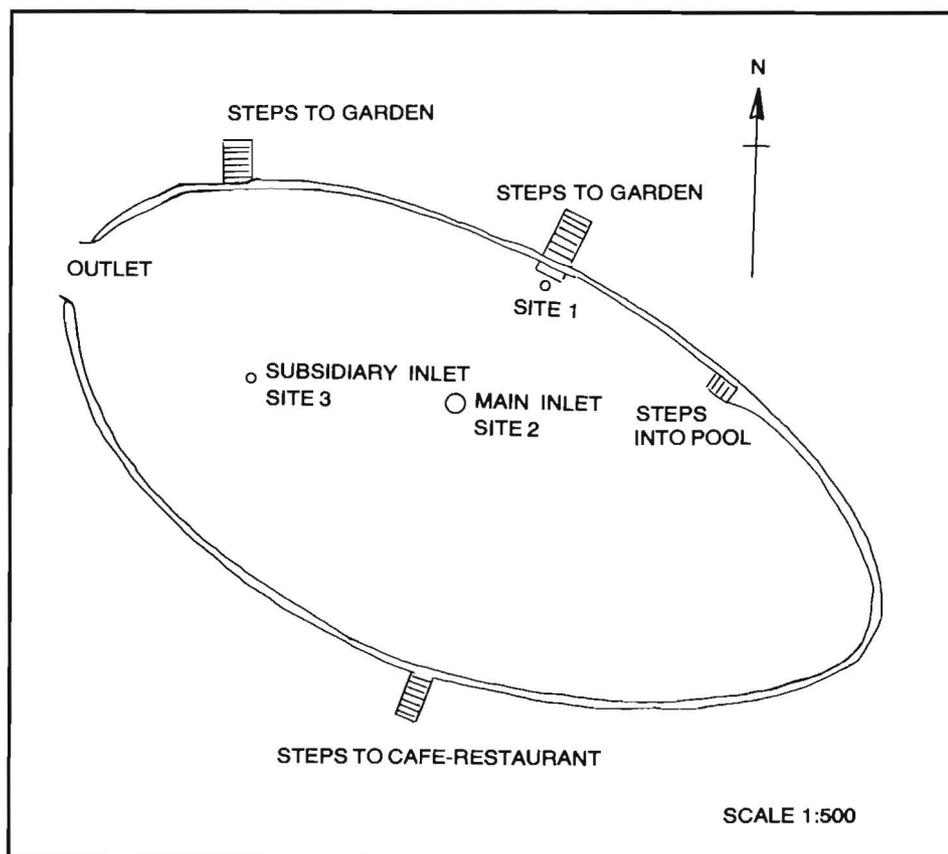


Fig. 4. Water sampling sites Ain bu Sukhanah pool

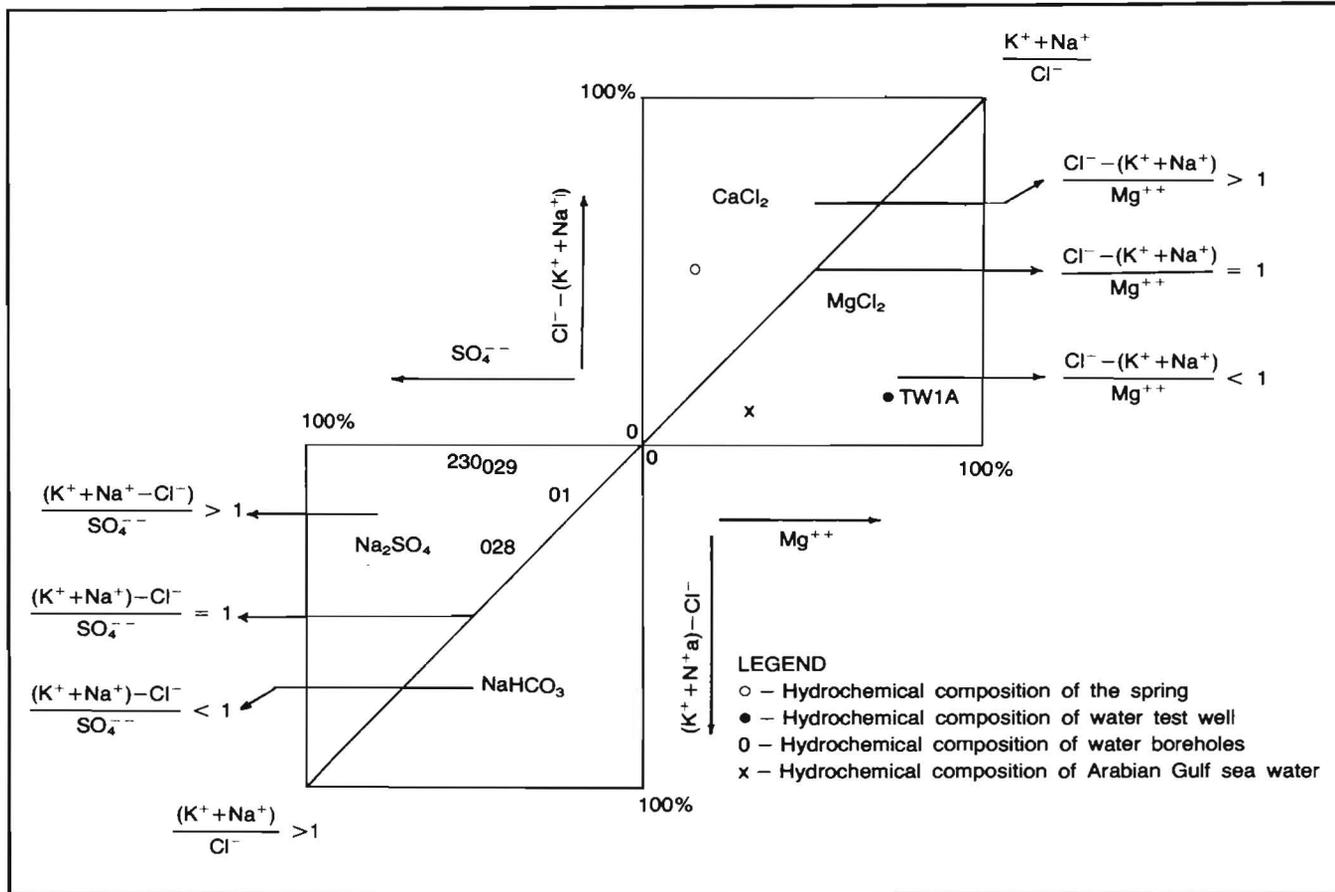


Fig. 5. Sulin's graph for representation of the hydrochemical composition of the Ain bu Sukhanah spring and some Al Ain groundwaters

One litre samples were collected at depths of one metre below the surface and on the bottom of the pool (Site 1) and within the inlet depressions (Sites 2 and 3) on four separate days of February 1987, in order to check day-to-day variation. Seven reference waters also collected, six from the closed wells to the spring and one from the Arabian Gulf.

Hydrochemical composition of the water of the spring

The major element chemistry of Ain bu Sukhanah water, sea water from the Arabian Gulf and other Al Ain ground waters is compared in (Table 1, 2).

The total salinity of this spring water is 5490 mg/l with total dissolved solids of 5500 mg/l at 180°C. The water is slightly alkaline in reaction where the pH-value is 7.7. The concentration of the chloride ions (4000 ppm) dominates among the main anionic composition, which is successively followed by the sulphates (561 ppm) and the bicarbonates (100 ppm). Among the main cationic concentration the sodium ions occupy the highest concentration (1600 ppm), followed by calcium (1100 ppm), magnesium (158 ppm) and potassium ions (7.5 ppm). The hydrochemical formula indicates that the water type is Ca-sodium chloride.

The results of water analysis of the six closed wells to the spring are very similar to those of Gibb (1970) and Terratest (1975), therefore only the results of Gibb and Terratest are taken into consideration (Table 2).

Gibb's Test Well 1A and Borehole 1 intersect recharge groundwater shown by low total dissolved solids and high proportions of magnesium and bicarbonate compared to other ions present. Gibb's Borehole 23 intersected typical brackish groundwater contained within gypsum aquitards north of Ain bu Sukhanah. Borehole 28, which is farther west is included to show the wide range of groundwater compositions which is possible in the surface deposits. The locations of wells are shown in (Fig. 1).

The purpose of this comparison is to demonstrate the close chemical similarity of Ain bu Sukhanah water with ordinary groundwater of the west flank of Jabal Hafit. Gibb (1970) states that the water achieves this composition by the ordinary processes of salination and by equilibrating with salts contained in the Miocene evaporites. There is nothing inconsistent therefore in the chemistry of Ain bu Sukhanah water with the hypothesis of passage through fissured gypsum beds towards the surface. The increased proportions of sodium and chloride over calcium and sulphate encourages this view rather than otherwise by indicating passage through deeper parts of the sequence.

Table 1. Hydrochemical composition of Ain bu Sukhanah

pH	T.D.S. at 180°C in g/l	Concentration Units	K	Na	Ca	Mg	Cl	SO ₄	HCO ₃	Hydrochemical Formula
7.5	5.5	ppm	58	1600	1100	158	4000	561	100	<div style="text-align: center;">Cl 89.45</div> <hr/> <div style="display: flex; justify-content: space-around;"> Na 44.90 Ca 43.6 </div>
		epm	1.4	56.5	54.9	12.9	112.8	11.6	1.6	
		epm%	1.1	44.9	43.6	10.3	89.4	9.2	1.2	

Faig Elschami

Hydrochemical Parameters						Hypothetical Salt-Combinations in %				
$\frac{rK}{rCl}$	$\frac{rNa}{rCl}$	$\frac{rCa}{rCl}$	$\frac{rMg}{rCl}$	$\frac{rSO_4}{rCl}$	$\frac{rCl - (rK + Na)}{rMg}$	KCl	NaCl	CaCl ₂	MgSO ₄	Mg(HCO ₃) ₂
0.012	0.5	0.48	0.11	0.103	4.19	1.16	44.9	43.6	9.25	1.29

Table 2. Major element chemistry of some Al Ain groundwaters

Location	Source	pH	T.D.S. at 180°C in mg.	milligrams per litre								
				K	Na	Ca	Mg	Br	F	Cl	SO ₄	HCO ₃
TW 1A	Gibb, 1970	8.0	304	2	24	19	48	—	—	93	20	172
BH ₁	Gibb, 1970	7.9	640	3.5	81	85	39	—	—	70	150	367
BH ₂₃	Gibb, 1970	7.4	7680	23.9	1500	790	231	—	—	2265	2700	248
BH ₂₈	Gibb, 1970	7.5	16888	113.0	4900	335	410	—	—	5060	5600	416
BH ₂₉	Gibb, 1970	7.7	8156	19.9	1700	825	191	—	—	2462	2800	221
BH ₃	Terratest, 1975	10.1	—	—	2050	785	—	—	—	3700	500	—
Arabian Gulf Water	Author 1989	8.15	41825	125	28	368	1459	103	0.38	21975	2900	122

Terratest (1974) used the minor element chemistry of the water and associated sediments to suggest additional constraints on the route taken by the water. For example, the high chromium content of the water was taken to indicate passage through Unit 5 of Fig. 3 which also has high chromium (Terratest 1975); the unusual content of rare earths was used to suggest passage through a uranium deposit. One might in addition cite high bromide (Terratest 1974) to indicate contact with oilfield brine and high phosphorus (Terratest 1974) to indicate interchange with phosphatic Eocene and Oligocene marls. The trouble with these interferences is that they are inconclusive because so little is known about the chemistry of the subsurface. For example, in reaching Ain bu Sukhanah, the water may have passed through any of the Oman ophiolites, Juweiza formation of Miocene marls, all of which are known to have high chromium as much as Unit 5 of (Fig. 3). Perhaps slightly more confidence can be placed in the exceptionally high strontium found in the sediments associated with the spring (Terratest 1973). Evaporitic sequences are known to contain high levels of this element which is rare in other environments. The Miocene evaporite sequence of the Al Ain area contains bedded strontium sulphate.

Genesis and hydrogeochemical formation of the Ain bu Sukhanah

The hydrochemical composition of the spring reflects the marine genesis of water, where the equivalent concentration of both potassium and sodium is

less than that of the chlorides $\frac{r(K + Na)}{rCl} < 1$. The representation of the

hydrochemical composition on Sulin's graph (Fig. 5) shows that it belongs to the $CaCl_2$ type of formation (Sulin 1946), where the excess of chloride ions after the formation of KCl and NaCl salts is still greater than the concentration

of magnesium ions in water (Table 1) $\frac{rCl - r(K+Na)}{rMg} > 1$. The $CaCl_2$ type

of Sulin's graph represents a genesis of an old marine formation, related to the oil accumulation. Similarly the hydrochemical composition falls in triangle number V_R in Ovitchinikov's graph of reduction condition (Fig. 6), which is the same triangle for the chemical composition of typical oil-water formation of old marine genesis. Although the old marine water genesis of the spring is mixed with the circulating water of meteoric origin during discharges, the water type (Ca-sodium-chloride) is still the same as that of oil-water formation. These facts indicate that the water of Ain bu Sukhanah spring is related to oil accumulation within the district, at the west flank of Jabal Hafit, where Terratest (1975) reports black organic precipitates in Eocene limestone intersected in boreholes south-east of Ain bu Sukhanah.

To explain the hydrogeochemical formation of the hot spring water the hydrochemical parameters are calculated (Table 1). The values of the parameters,

$\frac{rK}{rCl}$, $\frac{rNa}{rCl}$, $\frac{rMg}{rCl}$, $\frac{rCa}{rCl}$, and $\frac{rSO_4}{rCl}$ are compared with the values of the

same parameters in the chemical composition of the normal sea water of the Arabian Gulf. A relative decrease in the concentration of potassium, sodium, magnesium and sulphate ions is noticed in the hydrochemical constitute of Ain bu Sukhanah, while the concentration of calcium ions increases relatively. Such hydrogeochemical composition is formed when the marine water genesis had been subjected to deep reduction conditions due to continuous marine sedimentation for a long period of geological time (El Kiki and Hassan 1974 and El Kiki 1977). The hypothetical salt combination in the spring water is similar to that of the normal sea water, namely, KCl, CaCl₂, MgSO₄ and Mg(HCO₃)₂.

Conclusions

The spring is artesian. The water of the spring rises up through fractured beds of the underlying Miocene gypsum sequence. The hydrochemical composition reflects the marine genesis of the CaCl₂ type of the old marine water formation. The water type, inspite of mixing, still reflects Ca-sodium-chloride of the typical oil water formation. The hydrochemical representation of the studied spring on Ovitchinikov's graph of reduction condition indicates their relation to the oil water formation.

The study of the hydrochemical parameters indicates that the hydrogeological formation of the spring is attained due to the subjection of the marine water genesis to deep reduction conditions under continuous marine sedimentation for a long period of geological time. Such condition gives rise to the formation of oil hydrocarbons and the related water of the CaCl₂, or the Ca-sodium-chloride type, with the typical hypothetical salt combination of KCl, NaCl, CaCl₂, MgSO₄ and Mg(HCO₃)₂.

References

- El-Kiki, F.E.** (1977) Evaluation of trace elements and tritium content in some mineral springs in Egypt. Proc. of Trace Elements in Drinking water, *Agriculture and Human Life*, Cairo.
- El-Kiki, F.E. and Hassan, H.M.** (1974) Hydrochemical characters and hydrogeochemical formation of the deep water-bearing sandstones horizons in Dakhla Oasis. *Bull. Fac. of Science*, Cairo Univ., No. 47.
- Gibb, S.A.** (1970) Water Resources Survey. Supp. to Interim Report: Sub-surface investigations in the Al Ain area. (Unpubl.).
- Hunting Geology and Geophysics Ltd.** (1979) Report on a mineral survey of the United Arab Emirates. Vol. 1-2: (Unpubl.).
- Terratest Ltd.** (1973) Abu Dhabi Mineral Survey. Final report. (Unpubl.).
- Terratest Ltd.** (1974) Abu Dhabi Mineral Survey. Stage II. Detailed Investigation of Promising Areas Progress Report. Phase I. Ain bu Sukhanah, Jabal Dana. (Unpubl.).
- Terratest Ltd.** (1975) Abu Dhabi Mineral Survey. Stage II. Detailed Investigation of Promising Areas. Final Report. Phase II. Ain bu Sukhanah. (Unpubl.).

(Received 26/10/1988;
in revised form 18/09/1989)

هيدروولوجية عين بوسخنة العين - المنطقة الشرقية - دولة الإمارات العربية المتحدة

فائق الشامي

قسم الجيولوجيا - كلية العلوم - جامعة الإمارات العربية المتحدة - دولة الإمارات العربية المتحدة

تضمن هذا البحث دراسة الوضع الهيدروولوجي لعين بوسخنة حيث شملت جيومورفولوجية المنطقة المجاورة للعين، الجيولوجيا والتراكيب الجيولوجية، هيدروولوجية العين، التركيب الكيميائي لمياه العين والتكوين الهيدروجيوكيميائي.

تقع عين بوسخنة على بعد ١٥ كيلومتراً إلى الجنوب من مدينة العين وعلى بعد ٢ كيلومتراً إلى الغرب من جبل حفيت.

ان عين بوسخنة تنبثق من صخور ذات مسامية وكسور تقع أسفل تتابع الجبس الميوسيني وتعتبر العين ارتوازية.

ان الوضع الهيدروولوجي والتركيب للمنطقة ونتائج تحليل مياه العين أعطت معلومات اضافية عن المسلك تحت السطحي لعين بوسخنة. ولقد أجريت مقارنة بين نتائج تحليل مياه عين بوسخنة ونتائج تحليل مياه الآبار المجاورة.

ان الغرض من هذه المقارنة لتوضيح مدى مطابقة مياه العين مع مياه الآبار الموجودة إلى الغرب من جبل حفيت. ولقد تبين أن أسباب ملوحة مياه هذه العين ناتج عن عملية الاذابة للتبخرات الميوسينية.

ان تصريف عين بوسخنة قدر بمعدل ٥ مليون متر مكعب سنوياً، درجة الحرارة عند فوهة العين ٣٩ درجة مئوية.

الملوحة الكلية لمياه العين تبلغ ٥,٥ جرام في اللتر الواحد، وتعتبر خفيفة الحامضية. كما ان تركيز الكلوريد هو أعلى تركيز (٤٠٠٠ مليجرام) بين الانيونات الاخرى بينما تركيز الصوديوم هو أعلى تركيز (١٦٠٠ مليجرام) بين الكاتيونات الاخرى ويتبعه الكالسيوم، المغنيسيوم والبوتاسيوم على التوالي.

ان المعادلة الكيميائية تبين بأن مياه العين من نوع كلوريد - كالسيوم - صوديوم - ومن التركيب الهيدروكيميائي للعين اتضح بأن مياهها ذات أصل بحري. ومن جراف سولن تبين أن مياه العين من نوع كلوريد الكالسيوم والذي يعكس الأصل البحري القديم ذات العلاقة بالتكوينات البترولية في بعض المناطق المجاورة ونفس النتائج حصل عليها من جراف أو أفتنشكوف حيث وقع التركيب الهيدروكيميائي في مثلث البيئة المختزلة والذي يشير إلى الأصل البحري القديم لمياه العين.

على الرغم من أن مياه عين بوسخنة ذات الأصل البحري القديم لا يزال قائماً إلا أن هناك إختلاط لمياهها بالمياه الجوية.

ومن المتغيرات الهيدروكيميائية يتضح بأن التكوين الهيدروجيولوجي قد تعرض إلى عملية إختزال تحت ترسيب بحري متواصل لفترة جيولوجية طويلة، ان هذا الوضع أدى إلى تكوين الهيدروكربون والمياه من نوع كلوريدات الكالسيوم أو كلوريدات كالسيوم، صوديوم.