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Hydrogeological, Hydrochemical and Hydrogeochemical Investigations of the Three Main Springs of Khatt South of Ras Al Khaimah in the Northern part of the United Arab Emirates

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ABSTRACT. This paper deals with hydrogeological, hydrochemical and hydrogeochemical investigations of the three main springs of Khatt, which issue from the karstic limestone formation at the foot of the Musandam range South of Ras Al Khaimah.

The hydrochemical composition of the spring reflects the meteoric genesis of the thermal springs, with Na_2SO_4 type water.

Tritium and carbon-14 data indicate, that the spring is probably receiving water from deeper sources.

The aim of the given work is the study of the hydrogeology, hydrochemistry and hydrogeochemistry of the three main springs of Khatt in the northern United Arab Emirates. They are located at the western foot of the north-south aligned mountains and about 20 km south of Ras Al-Khaimah (Fig. 1). At the eastern border of Khatt and as such immediately at the foot of the mountains the three springs discharge from the karstic limestone (Fig. 2). Water samples were collected from the mentioned springs for analyses of the macro and micro components, forming the chemical composition of the water springs. The discharge of all springs by means of gauged vessel and timing was determined the total discharge of all springs thus resulting amounted to 13.3. l/sec. This is distributed on the three springs as follows: northern springs 5.5 l/sec, middle spring 3.8 l/sec and southern spring 40 l/sec.

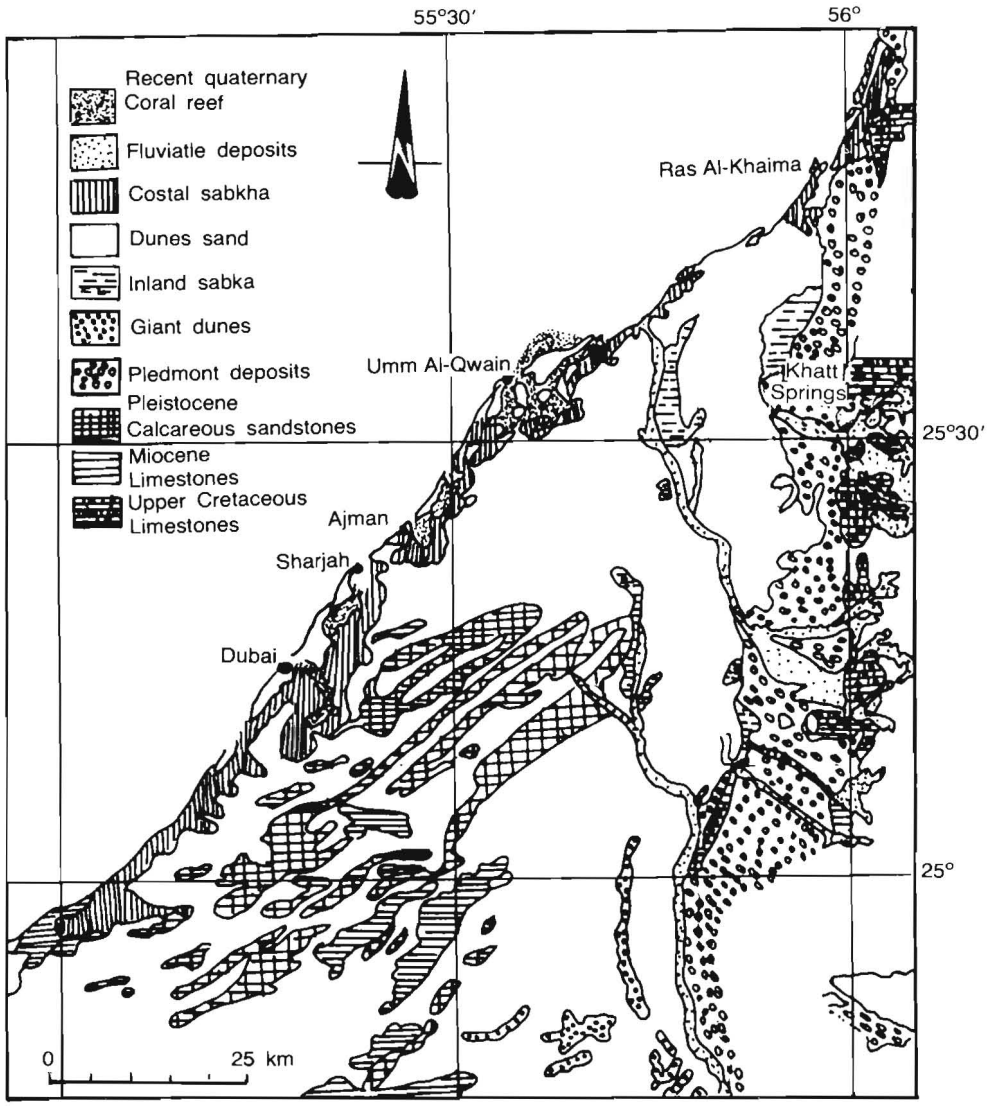

Fig. 1. Geological situation of close surrounding of Khatt springs (after Hunting, 1979)

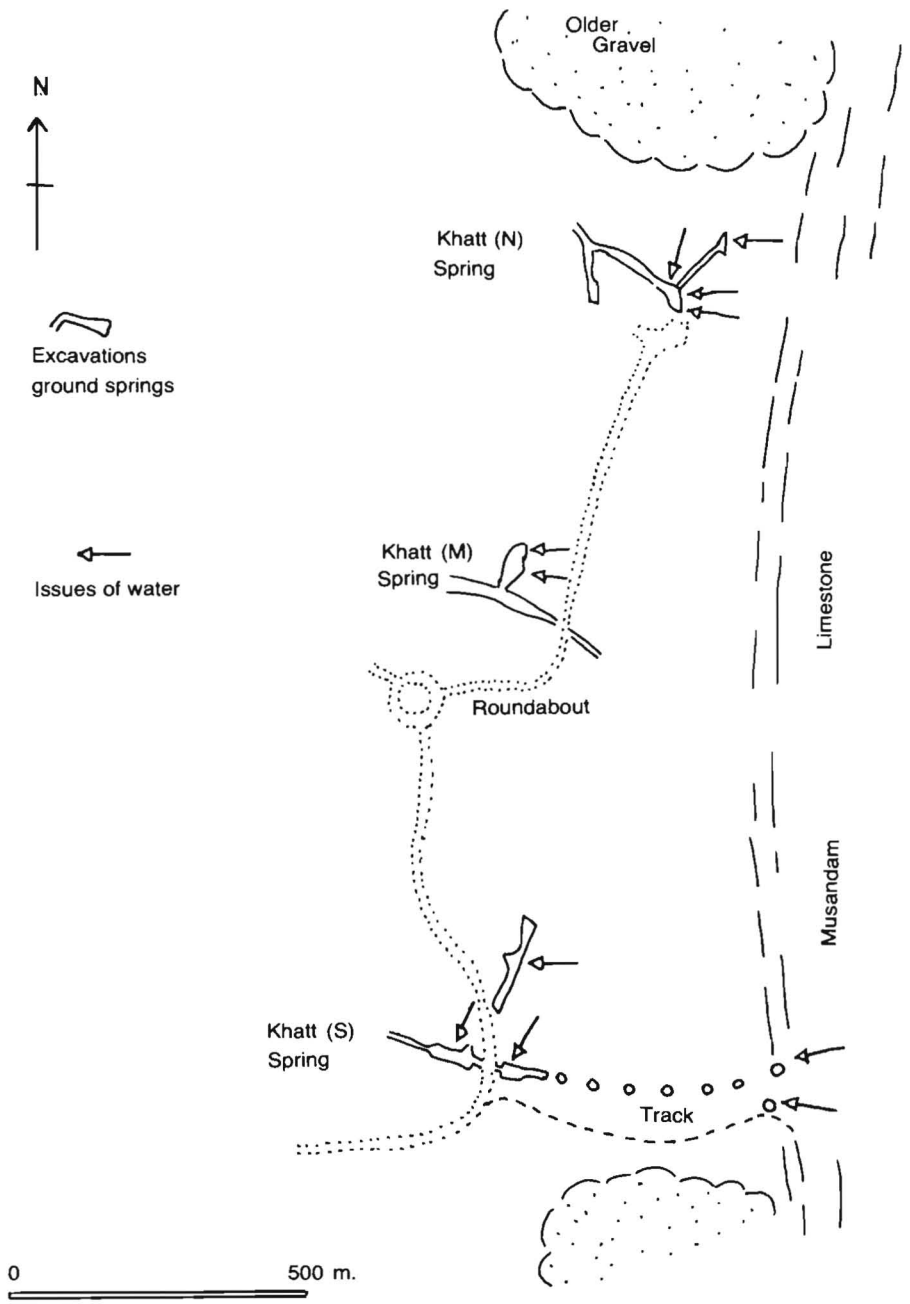

Fig. 2. Spring sources at Khatt

Methods of Study

Field, office and laboratory studies have been carried out by the author for five months since 5/5/87. Water samples were collected and chemically analysed, Physical and physical-chemical investigations have been done, namely; the temperature measurements were carried out with a thermic probe indicating exactly to 1/10°C., and ph-value was electrometrically measured. For the spectrum analysis of the thermal water of Khatt the solid residue from evaporation dried at a temperature of 180°C. was taken. A quartz-spectroscope was employed. Stimulation was effected by means of the electric arc. The spectres thus resulting were photographed and evaluated.

Previous Work

Halcrow (1969) gave a description of the Khatt springs and the geology of the closed area to the springs. No detailed study was given about the hydrogeological setting, the cause of high temperature of the springs, hydrochemical and hydrogeochemical investigations. The Ministry of Agriculture and Fisheries has carried out isotopic study with the help of I.A.E.A. in Vienna (1988).

Geological situation of the close surroundings of Khatt

The rocks cropping out of the surface near Khatt (Fig. 1) belong to the youngest part of the Hagar super group, which was defined by Hudson *et al.* (1959). The Musandam group forms an extensive limestone succession of Jurassic to Lower Cretaceous age that covers most of the Musandam peninsula and is equivalent to the Musandam limestone of Lees (1928). In the type area, a montonous sequence of dark grey shallow-marine carbonates totals some 1475 m in thickness. In the north-east of Khatt, the lower part of the Musandam limestone conformably overlies the Elphinstone group in an 860 m thick sequence consisting of a variety of pale coloured limestones ranging from oolitic, skeletal, pelletal to bioclastic in thickly bedded to massive units and strongly fissured and Karstic.

Adjacent to the limestones, marking the foot of the mountains, a vast gravel-plane extends in a westward direction. These gravels mostly consist of groughly rounded limestone-pebbles. At a distance of 600 m to 900 m away from the foot of the mountains the uppermost 3 m are made up of gravel silt. Only at a depth of 3 m the limestone-gravels are present. At three small projections of the mountain-range north and south of Khatt dark red-brown gravels with totally different components crop out. These gravel were deposited during the pluvial periods at the beginning of the Quaternary.

In the eastern part of the village of Khatt, limestone-gravels of a thickness of 1-2 m overlay the "older gravels". A significant features of the older gravels also is

their high proportion of fine grains which renders them significantly less permeable than the limestone-gravels.

Structural set-up of the western foot of the mountains

In several field trips by foot the general geological tectonical situation at the foot of the mountains was investigated from a point 10 km south of Khatt up to the water-work of Al-Breirat near Ras Khaimah. The furthermost advance into the mountains amounted to about 10 km. In the whole area under investigation the typical set-up of fold mountains, in which the limestones are strongly folded, can be observed. The fold-axis and the general strike of the strata vary within 10° with alternating dip to the east of west.

The foot of the mountains is built up by steeply inclined strata dipping with about 80° to the west (Fig. 3). About 1 km east of the foot of the mountain the first anticline is situated, which further to the east is followed by several not as distinctly folded anti-and synclinal structures. Apart from the folding of the rocks also fracture-structures like simple faults and overfaults are present. More extended and regionally significant fault zones, however, which might be related to the occurrence of the thermal springs at Khatt, have not been found.

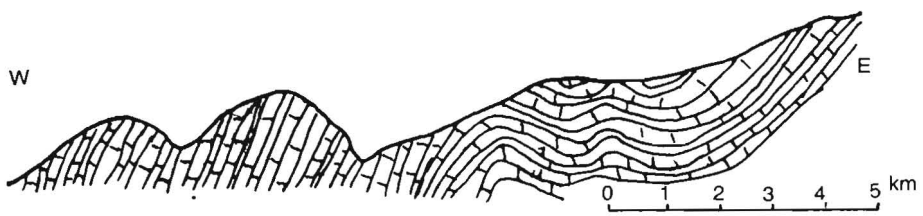

Fig. 3. Sketch of the tectonical cross section through the foot of the mountains south of Khatt

Hydrogeology

The springs issue from the karstic limestone. The rain falling on the mountains percolates great depths in the limestone and the groundwater moves slowly in a westward direction. The reason for the occurrence of the springs is that the groundwater in the karstic limestone enters into the older gravels, which lie adjacent to the limestones in that area. Due to the percentage of fine grained material in the gravels the water cannot move easily through the older gravels. The major part of the groundwater coming from the karstic limestones cannot continue its passage to the west through the less permeable "older gravels", because of this

the water is stopped and the groundwater table rises up to a point, where the "older gravels" have already been eroded (Fig. 4).

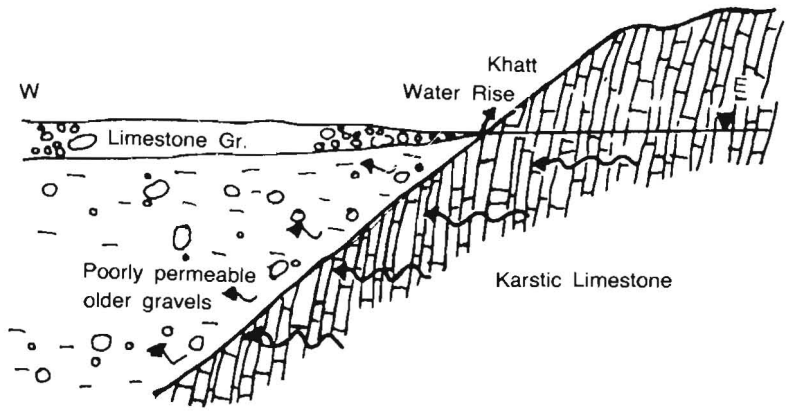

Fig. 4. Schematic cross section explaining the hydrogeological condition of Khatt springs

The temperature of the spring waters

The temperature for the three important springs was measured as northern spring 39.9°C., middle spring 39.9°C. and southern spring 39.2°C. It is thought that the higher temperature of the spring waters is due to the presence of a geothermal anomaly, which means that in the area east of Khatt the warmth of the earth increases more than average with increasing depth.

Hydrochemical composition of the thermal water of the springs

Three samples were collected for analysis from Khatt northern spring, middle spring and southern spring. The results of the analyses of three springs are very similar therefore only the results of the northern spring are taken into consideration. The aim of the analysis for the given study is to determine the concentration of the main bulk in the chemical composition namely, K, Na, Mg, Ca, Cl SO_4 and HCO_3 ions, as well as the concentration of the trace elements in thermal spring waters (Table 1).

The total salinity (The sumation of dissolved solid matter) of the thermal spring water amounts to 1519 mg/1 and accordingly it can be defined as a mineral water. The water is slightly alkaline in reaction, where the ph-value is 7,5.

Isotopic Studies

A water sample taken from the Khatt northern spring has been analysed for C^{14} and tritium to enable an estimation of the age of the water. It appeared that

Table 1. Hydrochemical composition of Khatt spring

Total Salinity in g/l	T.D.S. at 180°C in g/l	Concentration units	K	Na	Mg	Ca	Sr	Fe	Fl	Cl	Br	I	NO_2	NO_3	SO_4	HCO_3	Error %
1.519	1.394	ppm	7.95	375.1	32.1	84.8	3.21	0.08	0.73	541.9	1.25	0.088	0.006	3.6	192.2	248.2	0.02
		epm	0.2	16.3	2.6	4.2	0.73	0.002	0.04	15.3	0.01	0.0007	0.0001	0.0581	4.002	4.07	
		epm %	0.87	69.5	11.25	18.03	0.30	0.01	0.14	65.13	0.07	–	–	0.25	17.05	17.34	

Hydrochemical formula	r k / r Cl	r Mg / r Cl	r Na / r Cl	r Ca / r Cl	r SO_4 / r Cl	rNa−Cl / r SO_4	r Cl / r Br	Hypothetical salt combinations in %				
								NaCl	Na_2SO_4	$MgSO_4$	$CaSO_4$	$Ca(HCO_3)_2$
Cl HCO_3 SO_4 65.13 17.37 17.05 Na Ca 69.53 18.03	0.013	0.172	1.06	0.276	2.261	0.3	1530	65.13	4.4	11.25	1.4	0.71

Note: Total dissolved solid (T.D.S) means solid residue from evaporation at 180°C

the water of the spring had an average age of at least 8225 years. The analysis showed that the water of the spring had undergone some mixing with meteoric water of recent age, so it can be concluded that the bulk of the water discharged at Khatt spring is even older than 8225 years. This means that this spring draws water from a paleo-aquifer that may not seem to be replenished.

Hydrogeochemical formation of the thermal springs

The hydrochemical composition of Khatt thermal springs reflects the continental genesis of the water of Khatt, where the parameter

$$\frac{r\,(Na - Cl)}{r\,SO_4} < 1.$$

It belongs to Na_2SO_4 type of Sulin's classification, where the parameter

$\frac{r\,(K + Na) - Cl}{r\,SO_4} < 1$ indicates meteroric genesis of deep percolating water. The representation of the hydrochemical composition on Ovitchinikov's graph of oxidation condition shows that the water of the spring falls in IV zone, which represents meteoric water leaching to lagoonal deposition. The hypothetical salt combinations of water are NaCl, Na_2SO_4, $MgSO_4$, $CaSO_4$ and $Ca(HCO_3)_2$ most of which are NaCl and $MgSO_4$. This water could be old sea water, which had undergone some mixing with meteoric water. The hydrochemical formula, water type (Ca-Sodium-SO_4 − HCO_3 − Chloride) and the study of the hydrochemical parameters

$$\frac{r\,Na}{Cl}, \frac{R\,Ca}{r\,Cl}, \frac{r\,Mg}{r\,Cl}, \frac{r\,SO_4}{r\,Cl}, \text{ and } \frac{r\,Cl}{r\,Br}$$

show a decrease in the concentration of magnesium due to Ca-Mg exchange and increase in the concentration of calcium and sulphate. The value of $\frac{r\,Na}{r\,Cl}$ is greater than one, proving the meteoric genesis of water where the concentration of sodium ions increases due to their leaching from absorbed state to clayed sediments and prevailing continental conditions (Ovitchinikov, 1963). The value of the parameter $\frac{r\,Cl}{r\,Br}$ in the spring water is higher than that of sea water, proving the mixing of the spring water with that of meteoric water leads to dilution to the concentration of the trace lelements.

Summary and Conclusions

The three main springs of Khatt discharge from the karstic limestone. The hydrochemical composition reflects the meteoric genesis of the Na_2SO_4 type of the

waters. The water type is Ca-sodium, SO_4-HCO_3-chloride due to the deeply percolating water of meteoric genesis enriched with sodium calcium and chloride ions as the hydrochemical parameters indicate. The hydrochemical representation of the studied springs on the Ovitchinikov's graph of oxidation condition indicate their relation to the deep water formation.

The study of the hydrochemical parameters indicates that the hydrogeological formation of the springs is attained due to the subjection of the meteoric water genesis to oxidation conditions under continuous lagoonal deposits for a long period of geological time. Such conditions rise to form a water Na_2SO_4 type, with the hypothetical salt combination of NaCl, Na_2SO_4, $MgSO_4$, $CaSO_4$, $CaSO_4$ and $Ca(HCO_3)_2$ most of which are NaCl and $MgSO_4$.

The result of tritium and carbon-14 showed that spring water had undergone some mixing with meteoric water of recent age and the spring draws water from a paleo-aquifer.

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دراسة هيدروجيولوجية الخصائص الهيدروكيميائية والتكوين الهيدروجيوكيميائي لعين خت في رأس الخيمة بالامارات الشمالية

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يتضمن هذا البحث دراسة هيدروجيولوجية، الخصائص الهيدروكيميائية والتكوين الهيدروجيوكيميائي لعين خت في رأس الخيمة بالإمارات الشمالية.

ان عين خت تتكون من ثلاثة عيون حيث يتم تفريغ مياهها من الحجر الجيري الكارستي. ومن دراسة التكوين الهيدروجيوكيميائي يتضح ان مياه العين تتميز بوجود نوع مياه كبريتات الصوديوم من أصل جوى ان نوع مياه كالسيوم ـ صوديوم ـ كبريتات ـ بيكربونات ـ كلوريد يعزى إلى تغلغل المياه الغنية بأيونات الصوديوم والكالسيوم والكلوريد كما توضح المعاملات الكيميائية. وطبقاً للمعاملات الكيميائية تبين ان التكوين الهيدروجيولوجي للعين ربما تم تحت ترسبات في بيئة لا جونية استمر فترة زمنية جيولوجية طويلة، حيث تعرضت المياه الجوفية لظروف الأكسدة. ان مثل هذه الظروف أدت إلى افراز نوع المياه كبريتات الصوديوم والأملاح الافتراضية المركبة مثل كلوريد الصوديوم، كبريتات الصوديوم، كبريتات المغنيسيوم، كبريتات الكالسيوم وبيكربونات الكالسيوم ـ وأن ملح كلوريد الصوديوم وكبريتات المغنسيوم لها السواد الأعظم.

ولهذا فإن المياه من المحتمل أن تكون من أصل مياه بحر قديمة والتي قد تعرضت لعملية خلط مع مياه حديثة.

ان نتائج تحليل التريتيوم والكربون ـ ١٤ تيشير إلى أن مياه عين خت حدث لها خلط مع مياه حديثة التكوين وأنها تستمد المياه من خزان قديم عمره أكبر من ٨٢٢٥ سنة.