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Springs in Saudi Arabia

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ABSTRACT. Over hundred of years an appreciable number of springs have been known in the Arabian Peninsula on which ancient settlements, major towns, and villages were dependent for both domestic uses and irrigation purposes. During the last two decades, water demand has increased dramatically due to the rapid economic development of the Kingdom. As a result, the flow of most of the springs has decreased, even to the extent that some of them have become dry.

This paper deals with more than fifty springs located in different areas of the Kingdom, both on the Arabian Shield and the Arabian Shelf. Based on the field observations and investigations, springs were classified into five groups : alluvial, sub-basaltic, fracture, solution openings and inter-stratification-related springs. The characteristics of each group has been summarized and discussed.

Introduction

The Kingdom of Saudi Arabia extends over an area of about 2.25 million square kilometers. Most of this area lies within an extremely arid environment where Arabia forms the eastern extension of the great Sahara that extends from west Africa into western Asia. The average amount of annual rainfall varies between 50 and 100 mm over most of the country (Fig. 1). In the Red Sea escarpment, mainly in Taif area, the average annual rainfall varies between 100 and 200 mm; the same amount being recorded for the area lying to the north of Riyadh and within the Hail region as well. In the south-west of the Kingdom and the Asir region, annual rainfall amounts to between 200 and 600 mm. Pan evaporation rate generally ranges between 2,000 and 3,000 mm per annum.

Geomorphologically, the Kingdom of Saudi Arabia is divided into the Arabian Shield and the Arabian Shelf. The Shield is mainly composed of complex assemblages of crystalline and crystallophyllian rocks primarily of Precambrian-Cambrian ages with volcanic flows of Tertiary-Quaternary age extending to recent events. The Shield is restricted geographically to the western and south-western areas of the Kingdom. The Arabian Shelf is mainly occupied by a sedimentary sequence lying unconformably on the basement rocks of the Shield and dipping towards the Arabian Gulf. The sedimentary sequence starts with deposits of Cambrian age and ends with the Quaternary recent deposits of the Gulf.

Both the Shield and the Shelf are devoid of perennial rivers. Water resources within the Shield are limited to wadis that are intermittent streams that flow seasonally and sporadically for a few days. Some of these wadis flow eastwards toward the Arabian Shelf, but most of them flow westwards toward the Red Sea. The wadis form important limited sources of groundwater in the western and south-western regions of the Kingdom.

Within the Arabian Shelf, groundwater is obtained from a number of aquifers ranging through Cambrian and up to the Pliocene formations. The principal aquifers are the Saq, Wajiid, Tabuk, Minjur and Dhurma, Wasia and Biaydh, Umm er Radhuma, Dammam and Neogene aquifers.

This paper is intended to shed light specially on springs, issues of ground water, which have been historically important sources of water for Arabia since early historie times. Some of these springs were known to occur at the time of Prophet Ibrahim (peace be upon him), may be even earlier. Most of the settlements along Arabian caravan routes and Bedouin migration depended on springs as an important source

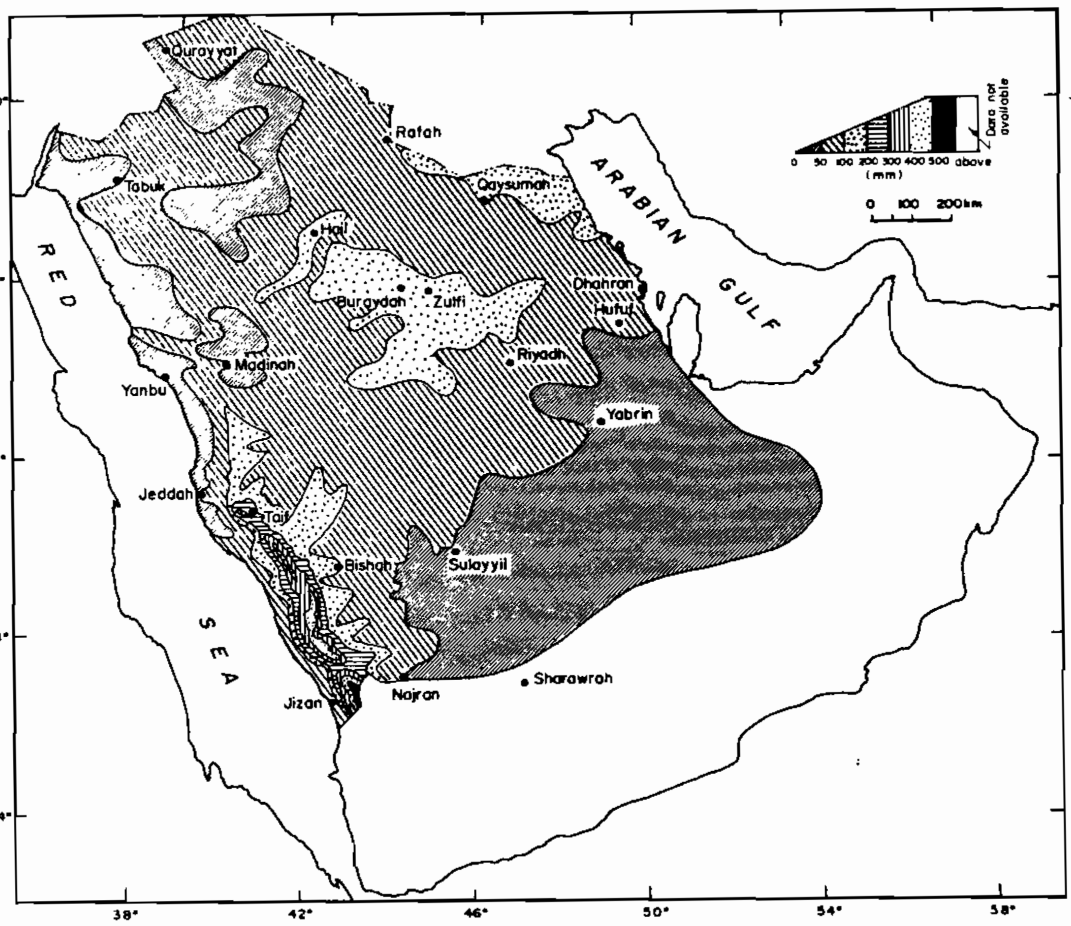

FIG 1. Average annual rainfall in Saudi Arabia.

of water. Throughout time, grass, and water have been the major conerns of a Bedouin in Arabia.

Method of Study

Most of the springs occurring in the Kingdom of Saudi Arabia were inventoried during this study. The field inventory included: location of springs, geological and structural environments, field measurements of temperature, and electrical conductivity of water. Discharge of springs were measured whenever possible using the float method. Laboratory analysis included the determination of the total dissolved solids (TDS).

Results and Interpretation

All the inventoried springs are shown in Table 1. The table includes the location of spring district of area, the name of spring, and geological and hydrogeological condition. The locations of these springs are shown on Figure 2.

The springs occurring in Saudi Arabia can be grouped according to their geology or nature into: alluvial, subbasaltic, fracture, solution opening, and interstratified types.

Alluvial Springs

Alluvial springs mainly occur within the Arabian Shield and are associated with wadi deposits that reach a maximum thickness of some 50 m. In places where the groundwater is shallow and the substratum is not deep, groundwater flows intermittently or has a perennial nature. Under such natural situations a ganat is often constructed (Amin *et al.* 1983, Larsen *et al.* 1982); the inventoried alluvial springs of this study belong to such situations. They are mainly located in Wadi Fatimah, Wadi Al Fara, the Al-Kamil and Taif areas, and Wadi Naaman. Alluvial springs are characterized by a variability of discharge depending on the water table elevation. The temperature of the alluvial

TABLE 1. The investigated springs (1989).

Area	Name of spring	T°(C)	EC µmohs/cm	TDS mg/l	Discharge m^3/s
A : Alluvial Springs					
Wadi Fatimah	Mudiq	31.5	1092	800	—
	Salah	33.5	1023	680	—
	Al Sharaich	32.0	1894	1440	—
Wadi Al Fara'a	Al Yaseerah	29.0	1563		1.00
	Umm Al-Eyal	30.2	1360	880	0.07
	Al Mudiq	30.7	1250	760	0.50
	Um Abu-Dhuba	31.3	1122	760	1.00
Al-Khamel	Al-Khamel	31.1	593	300	0.17
	Malah	—	—	—	—
	Muhayee	—	—	—	—
Khulais	Ghurrah	23.6	2540	1920	variable
	Jadha	28.5	2860	—	0.56
Al-Taif	Al Whaht	—	790	560	—
	Al Waheet	—	987	680	—
	Shibra	—	1083	840	—
	Al Jar	—	925	640	—
B : Sub-Basaltic Springs					
Al Madinah Al Munawarah	Al-Zarga	—	—	—	—
Khayber	Raiya	30.3	1940	1160	0.008
	Baharia	30.6	2680	1720	0.033
	Sanpoura	28.4	2880	1920	0.033
Al-Khamel	Al Guharya	33.7	871	560	0.17
C : Fracture Springs (1989)					
Al-Lith	Al-Harrah	80	3500	2200	2.1 l/s
	Jum'at Binihilal	45	5670	2000	3.0 l/s
	Markub	58	5360	3690	0.25 l/s
	Daraka	—	—	—	—
Jizan	Al-Wagrah (1)	57.5	4000	—	—
	Al-Wagrah (2)	55.1	5900	2400	—
	Khulab (1)	50.1	3300	2080	—
	Khulab (2)	—	—	—	—
D : Solution-Opening-Related Springs					
Al-Aflaj	Al-Rayes	—	5240	4120	—
	Lake 2	—	5640	4660	—
	Lake 14	—	4990	3760	—
	Lake 15	—	5130	3960	—
Al-Kharj	Al-Dhila	—	3840	3400	—
Al-Qatif	Safwi	32.0	6240	4000	—
	Awamiyah	32.1	5110	3600	—
	Umm Jidiv	33.4	5200	—	—
	Guda-Taibah	33.8	5470	—	—
	Udah	34.0	3870	2700	—
	Labbaniyah	33.6	4380	2600	0.042
	Gharra	33.0	4380	2600	0.012
	Khabbabah	30.4	3950	2400	—
	Gushoriyah	32.2	3310	2200	—
	Milishiat	30.8	3620	2400	—
E : Interstratification-Related Springs					
Al-Hasa	Juhariah	33.5	2500	1480	—
	Bahlah	32.0	2430	1640	—
	Umm Saba	37.4	2430	1680	—
	Harah	34.5	2470	1440	1.8
	Khudud	31.5	2350	1760	1.7
	Buharıyah	32.0	2280	1560	1.2
	Najem	38.0	2470	1720	—

T : Water Temperature. EC : Electricial Conductivity.
TDS : Total Dissolved Solids. — : Not Available.

ranges between 23.6 and 31°C, the field measured electrical conductivity (EC) varies between 593 and 2,860 µmohos/cm, and the average discharge is between 0.17 and 1.00 m^3/s (Table 1A). The total dissolved solids in these springs range between 300 and 1,920 ppm.

Sub-basaltic Springs

The sub-basaltic springs are restricted to areas with enormous lava flows known in the Arabian Shield as Harrat. They are mainly located in three areas: Madina, Al Kamel and Khayber (Ministry of Agriculture and Water 1984). Madina and Al Kamel springs are situated in the vicinity of Harrat Rahat, and the Khayber springs are associated with Harrat Khayber. In all three areas, springs obtain water from fractured and weathered basalts which in some areas appear vesicular, or from buried alluvial deposits within these basalt folws.

In the Madina area, the investigated spring has been known since the time of Hejira of Prophet Muhammad (peace be upon him) and it acquired its name *Al-Zarqa* after the blue-coloured eyes of Marwān Ibn Abd Al Ḥakam the Omayyad Caliph, when he looked into its water and his blue eyes were reflected. Madina springs including Al-Zarqa were dry during our field visit in March 1988. Generally, Madina springs discharges depend on the availability of recharge in Harrat Rahat. For the past two decades, springs discharges have been greatly decreased as a result of a general lowering of groundwater levels and lack of maintenance of its aquiducts. Construction of boreholes and the general drought conditions also may bave contributed to the situation.

In the Al Kamel area, only one spring was identified as originating from weathered basalt. This is Al Guharya spring which flows throughout the year with no remarkable variation in its discharge, contrary to alluvial springs in its vicinity which are most variable depending on the time of the year and direct recharge from rainfall.

Associated with Harrat Khayber, there are more than 150 springs, of which three major springs were sampled during our field investigation. These are Raiya, Baharia and Sanpoura (Table 1B). All three are situated to the east of Khayber. Other major existing springs are Bardida, Samsam, Shubas and Al Salalim, but these were noted by the health authorities to be contaminated by malaria.

The temperature of the sub-basaltic springs ranges between 28.4 and 33.7°C, the field measured EC varies from 1940 to 2,880 µmohos/cm, the average discharge of a spring lies in the range of 0.008 to 0.17 m^3/s

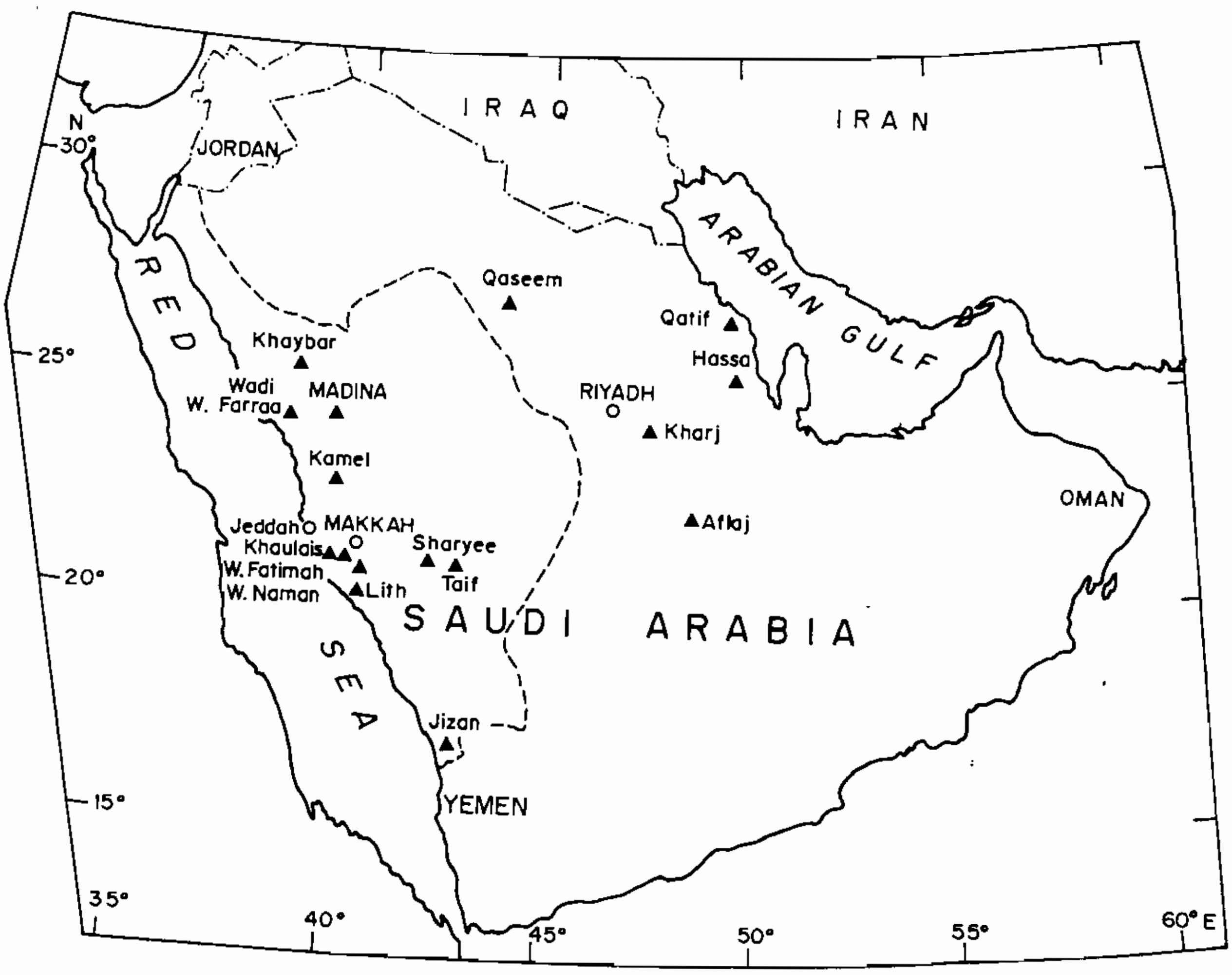

FIG. 2. Locations of major spring areas in Saudi Arabia.

(Table 1B), and the TDS is between 560 and 1,920 ppm.

Fracture Springs

In Saudi Arabia, two major locations of fracture controlled springs exist within the Arabian Shield and in close proximity to the Red Sea coast (Berthier *et al.* 1981, Bhutta 1965a and b). The two locations are in the Al Lith and Jizan areas (Fig. 2).

In Al Lith area four, fracture springs may be seen. These are Al Harra, Markub, Jumaat Bani Hilal, and Darraka. The four springs seem to be aligned on a major fracture trend having a NW-SE orientation. The fracture cut through granitic, dioritic, and biotite-gneissic rocks. The temperature of Al Lith springs varies between 45.5°C in the Jumaat Bani Hilal and up to 85.6°C in the Al Harra spring. The field measured EC ranges between 3,500 and 5,670 μmohos/cm, while the average discharge is between 0.25 and 3 l/s, and the TDS is in the range of 2,200 to 3,680 ppm.

There are four springs in the Jizan area, namely, Al Wagrah, Khulab, Khulab Quwa, and Majara Quwa. These springs appear from fractures cutting through the country rocks. The major fracture direction is NNW-SSE, with the country rocks being mainly schist, diorite, and granodiorite with some basalt and some volcanic extrusions. The temperature of the Jizan spring waters range between 55.1 and 71.1°C, EC varies from 3,300 to 4,000 μmohos/cm, and the TDS is in the range from 2,080 to 2,400 ppm (Table 1C).

Al Lith and Jizan springs can, thus, be grouped as thermal fracture springs.

Solution Opening-related Springs

Solution opening-related springs were encountered during this study mainly in three areas within the Arabian Shelf, namely, Al Aflaj, Al Kharj, and Qatif.

Al Aflaj is underlain principally by carbonates of Upper Jurassic to Lower Cretaceous age. These are

Arab, Hith, Sulaiy, Buwaib, and the clastic Biyadh Formations. The Arab and Hith Formations are believed to be the sources of springs in the area. The action of groundwater on the jointed limestone and anhydrite of these formations is the cause of the solution openings and together with the weight of the overlying sedimentary layers has led to the formation of collapsed structures in Al Aflaj, which, in turn, produced these springs in the middle of the desert. The same solution opening process could have been the origin of Al Kharj springs, but at a less pronounced degree of karstification. The current heavy pumping in Al Kharj has lowered the piezometric surface (Al-Khatib and Khan 1982, Hussein 1982).

In Qatif, the springs emerge from the Dammam Formation of Alat and Khobar, where the main rock unit is limestone, exhibiting in some areas, solution openings with a degree of karstification.In earlier times, most of the Qatif springs were flowing at the ground surface, but over the past years the piezometric surface has been lowered tremendously. This may also have been caused by the drilling of a large number of bore holes tapping the formation at Alat and Khobar.

The waters in Al Aflaj lakes were sampled at four locations (Table 1D). In Al Aflaj, the EC ranges between 4,990 and 5,620 µmohos/cm, and the TDS varies from 3,760 to 4,660 ppm. The total production of Al Aflaj lakes is reported to have been 97 l/s, but since 1979 a remarkable decrease in water levels has been noted, with a decrease of 12 m being recorded in lake El Rayas. During the field study, the Lake El Rayas discharge was 0.16 m^3/s. At earlier times, Al Kharj springs used to issue at some 57 l/s, but this amount has decreased to 4.5 l/s. In the Qatif area, ten springs were inventoried (Table 1D). These are characterized by water temperatures ranging between 30.4 and 34.0°C, EC varies from 3,620 to 6,240 µmohos/cm, and TDS from 2,400 to 4,000 ppm. The average discharge of the Qatif springs is 0.027 m^3/s.

Interstratification-related Springs

This type of spring occurs mainly in the Hassa and Qaseem area. In Hassa, the Neogene strata are the main suppliers of water to the major springs in the area (Abderrahman 1979, Abderrahman and Ukayli 1984, 1986, Al-Naeem 1987). The Neogene includes four members: the Kharj Member mainly consisting of limestone, gypsum and gravels; the Hofuf Member mainly consisting of sandy marl and sandy limestone, the Dam Member consisting of heavily fissured limestone, marl, shale and subordinate sandstones; and the Hadrukh Member consisting of silty sandstone and sandy limestone. The Neogene overlies two Lower Tertiary aquifers, namely the Dammam and Umm er Radhuma. The groundwater in the Neogene complex has a general north-easterly flow direction, and in some areas water in this complex is likely to be partially derived *via* upward leakage from the Umm er Radhuma.

In the Qaseem area, the sedimentary rocks are mainly composed of alternating layers of sandstone, shale, and limestone of Paleozoic-Cenozoic ages. The springs used to receive their water from such interstratified conditions, but none of the previously known springs are supplying water anymore. This is mainly due to the lowering of piezometric surface as consequence of recent heavy pumping for irrigation in the area.

Interstratification-related springs of the Hassa area are characterized by temperature ranging between 31.5 and 38°C, field measured EC varying from 2,280 to 2,200 µmohos/cm, and TDS from 1,440 to 1,760 ppm. The average discharge is about 1.5 m^3/s (Table 1E).

Conclusion

Springs are found in almost all regions of Saudi Arabia, where they are related to different origins. They are mainly alluvial, sub-basaltic, fracture-thermal, solution-opening and interstratification-related springs.

Figure 3 summarizes the main characters of springs in Saudi Arabia. The waters are generally characterized by a wide range of temperature (23.6-86°C), a wide range of field electrical conductivity (593-6,240 µmohos/cm), and, consequently, a wide range of total dissolved solids (560-4,660 ppm). Field measurements explicit that discharge of springs in Saudi Arabia varies between 0.25 l/s and 1.8 m^3/s. Considering the large number of springs, that formerly existed and are still available today, spring waters must be considered as important sources of water in the Kingdom. Consequently, more attention should be given to maintain, protect, and conserve this historical water resource.

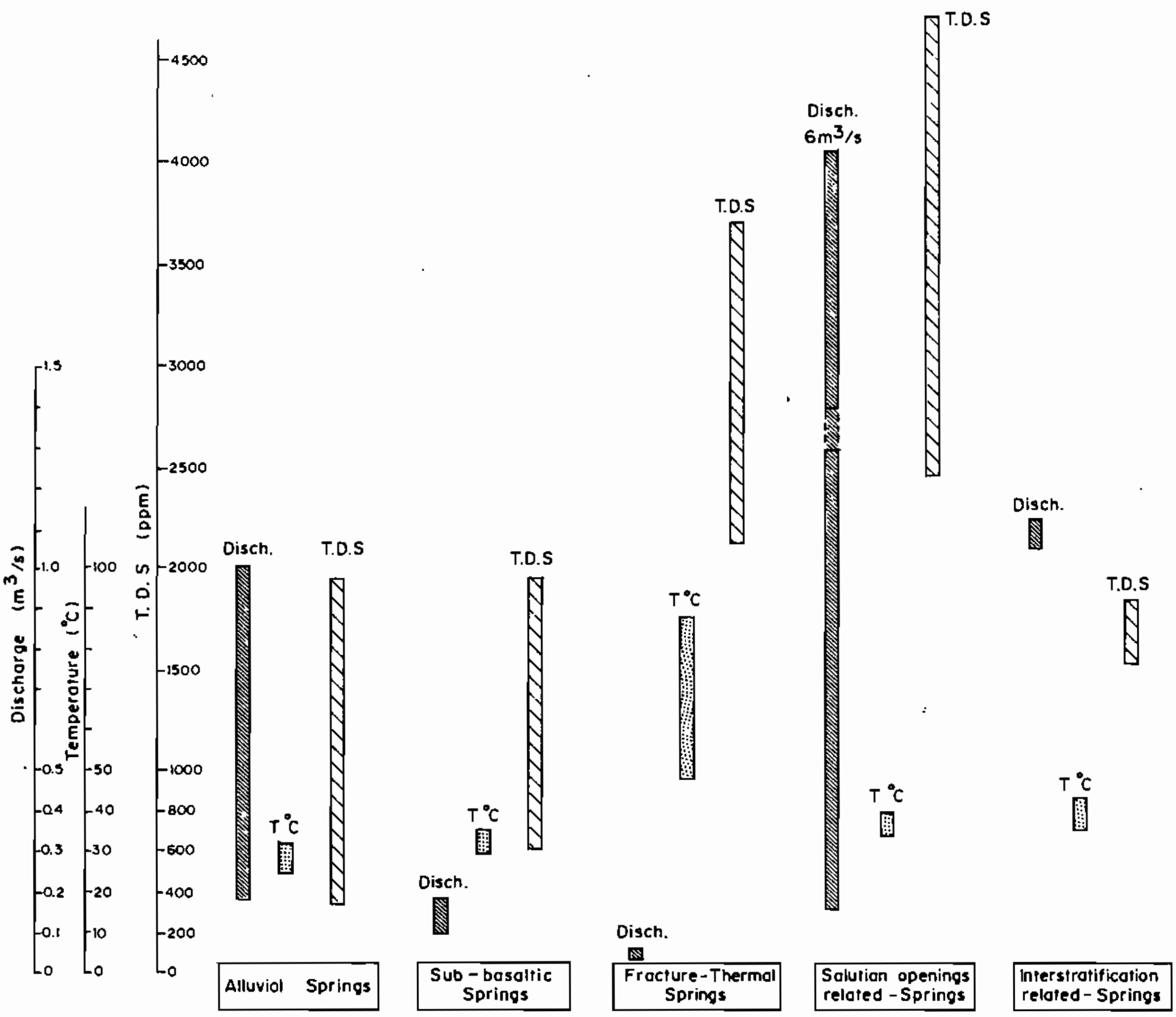

FIG. 3. General characters of springs in Saudi Arabia.

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References

Abderrahman, W. (1979) The effect of irrigation Water Management on the Water Qualities of Major Springs in Al-Hassa Oasis of Saudi Arabia, in reports on the Leichtweiss-Institute Research Team, Technical University Braunschweig, publication No. 38, the water Potential of Al-Hassa Oasis, Braunschweig.

Abderrahman, W. and **Ukayli, M.** (1984) Strategy of Groundwater use in Al-Hassa Region of Saudi Arabia, *Wat. Resour. Dev.* **2**(1): 45-59

Abderrahman, W. and **Ukayli M.** (1986) A proposed Water Operation plan for irrigation projects in Saudi Arabia, the *Arabian J. Sci. Eng.* **11**(4): 381-387.

Al-Khatib, I. and Khan, R.A. (1982) *"Ayun" – Ancient Source of Water Supply in the Kingdom of Saudi Arabia: An Overview,* Report, Ministry of Agriculture and Water, Saudi Arabia, 17 p (unpublished).

Al Naeem, A.A. (1987) *The irrigation and drainage system in the main Oasis of the Eastern Province of Saudi Arabia,* Report, Water Research Center, King Faisal University, Hofuf, 38 p (unpublished).

Amin, M.I. Qazi, R. and **Downing, T.E.** (1983) Efficiency of Infiltration galleries as a source of water in Arid Lands, *Symposium on Water Resources in Saudi Arabia, College of Engineering, King Saud University, Riyadh,* 107-128.

Bertheir, F., Demange, J., Uindt, F. and **Verzier, P.** (1981) Geothermal Resources of the Kingdom of Saudi Arabia. *Saudi Ara-*

bian Deputy Ministry of Mineral Resources Open-File Report BRGM-OF-**01-24,** 116 p.

Bhutta, M.A. (1965a) Field Investigations of the Khulab and Waghrah Hot Springs in Abu Arish, Jizan District, *Saudi Arabian Directorate General of Mineral Resources, Open-File Report* **256,** 16 p.

Bhutta, M.A. (1965b) Investigations of Hot Springs in Wadi Sayah Area, *Saudi Arabian Directorate General of Mineral Resources Open-File Report* **255,** 12 p.

Hussein, A.H. (1982) *Ayoun Al Aflaj: Lakes in the Middle of the desert,* Report, Ministry of Agriculture and Water, Saudi Arabia, 11 p (unpublished).

Larsen, C.E., Beckley, B.S. and **Bierschenk, W.H.** (1982) Reconnaissance Investigations of selected galleries in the Western Province, Report, Ministry of Agriculture and Water, Saudi Arabia, 46 p (unpublished).