EXPLORATION OF GEOTHERMAL RESOURCES IN YEMEN

presented to:

SECOND AFRICAN GEOTHERMAL CONFERENCE

24 NOVEMDER 2008

ENTEBBE- UGANDA

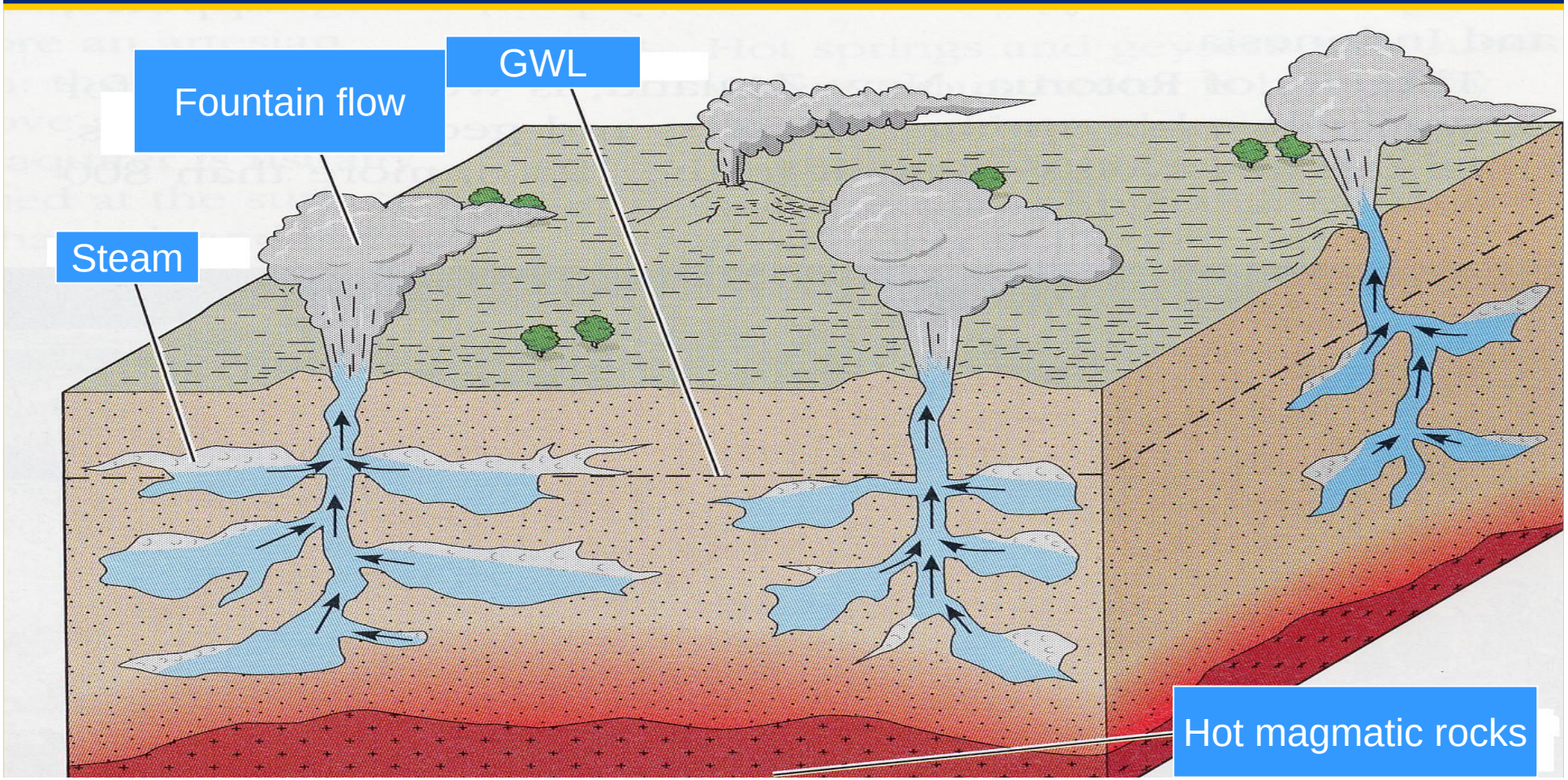
Prepared by:

NOORI GAMAL, Senior Hydrogeologist

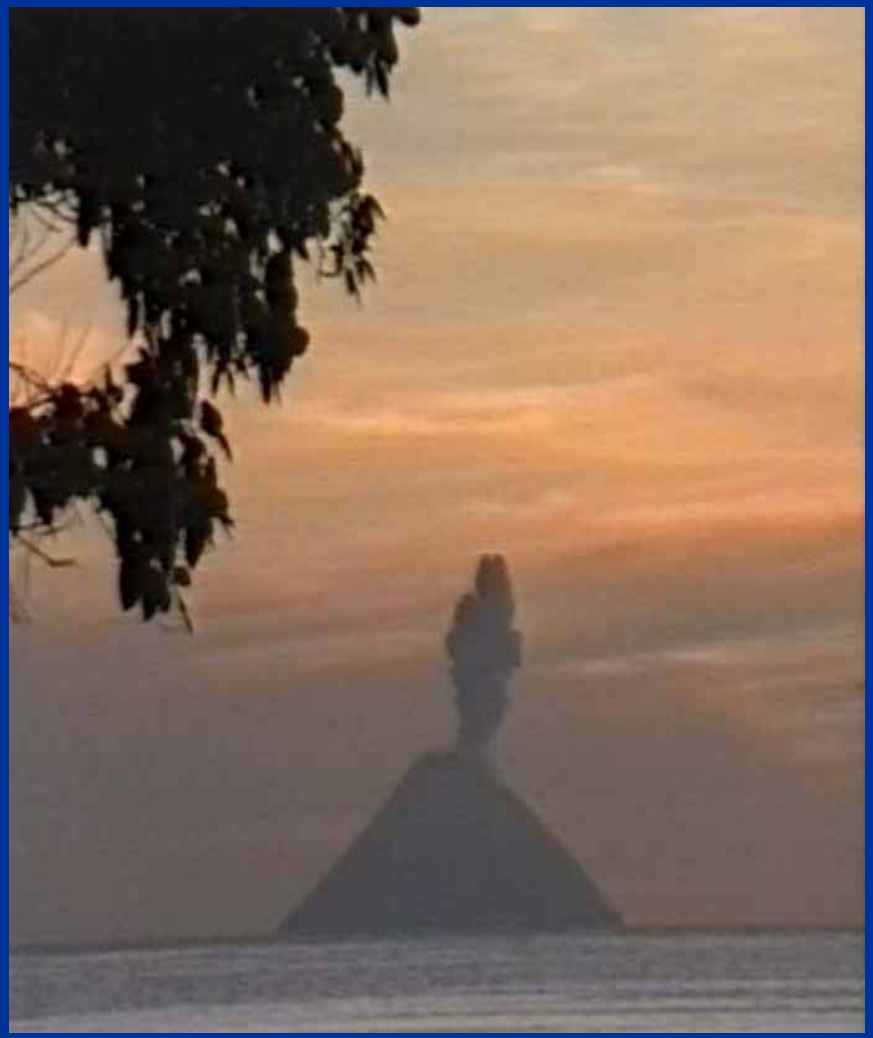
MINISTRY OF WATER AND ENVIRONMENT

THE REPUBLIC OF YEMEN

Earth is a big reservoir of heat, still getting cooler while loosing its underground temperature flowing to the surface



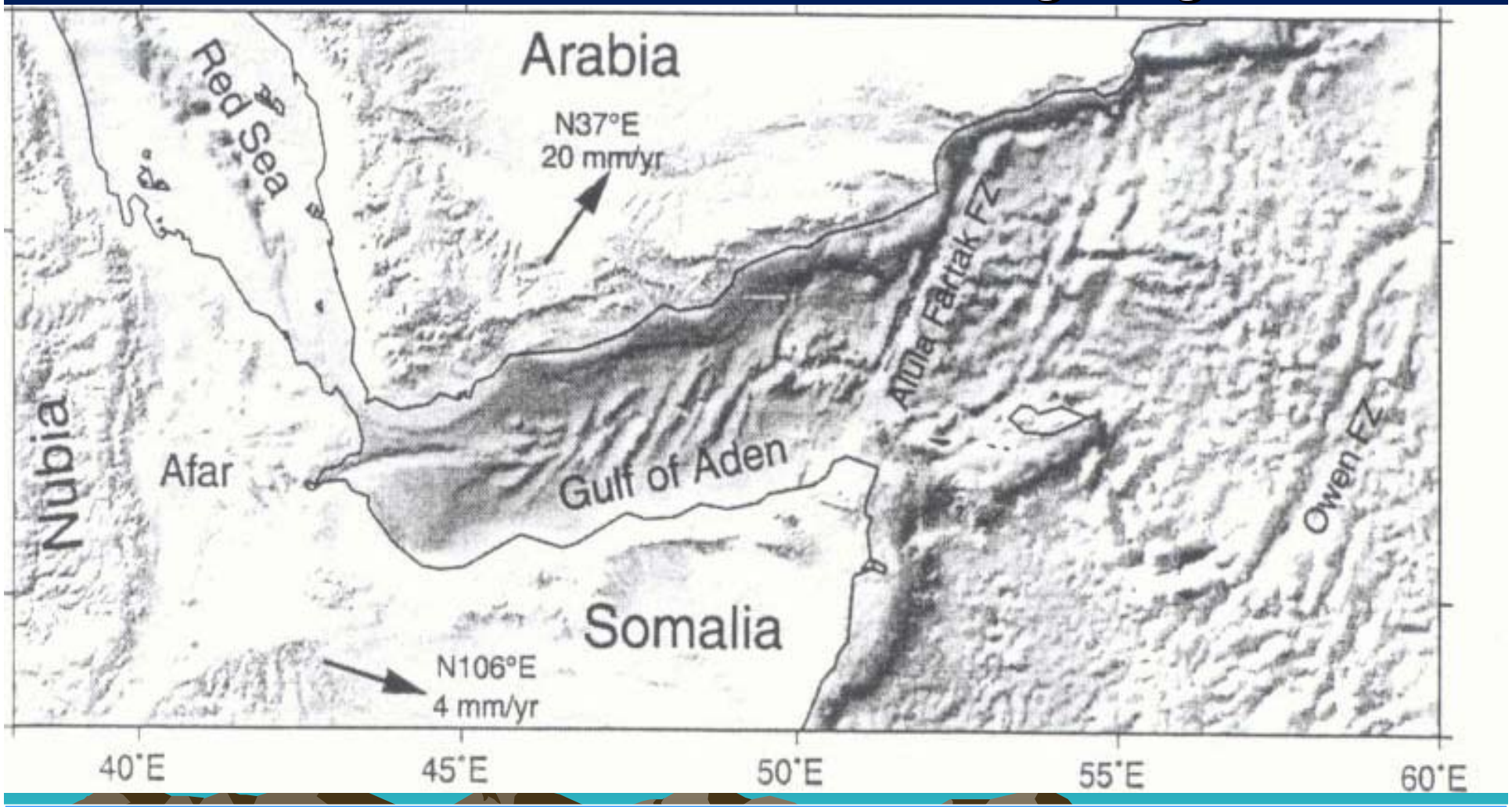
Earth core consists of very hot fusible substances, while the solid earth crust is just few tens kilometers of thickness



Many areas still witness volcanic eruptions and geysers storms while steam and vapor is burst up in other areas

These events are clear and visible evident confirming the availability of huge stock of geothermal energy

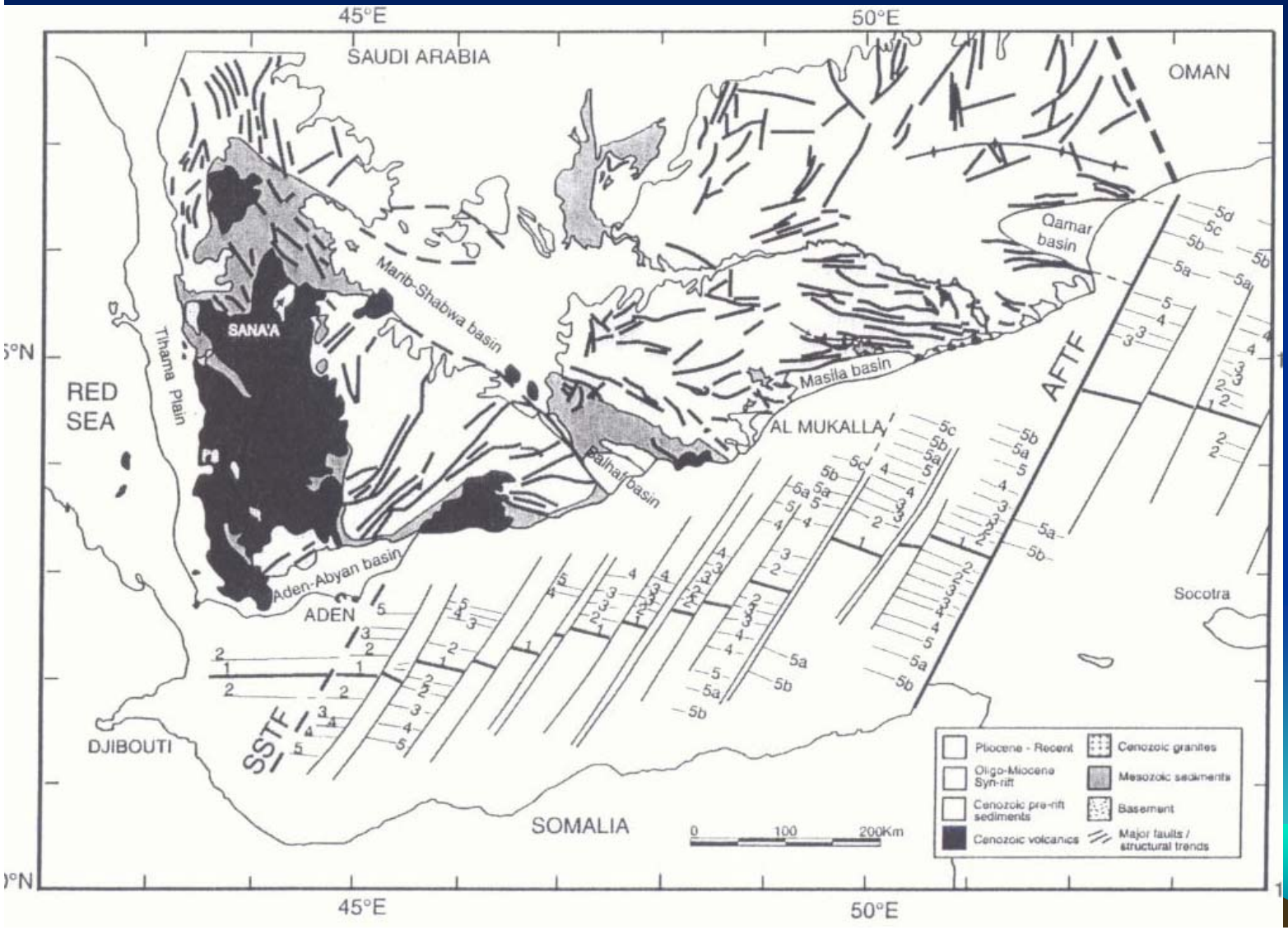
Topographic and Bathymetric Map of The Gulf of Aden and Surrounding Regions



N 106 E
4 mm/yr

Direction and Rate of Motion of Arabia and Somalia with respect to Africa

Simplified Geological map of Yemen, on Northern Margin of the Gulf of Aden and Magnetic Anomalies from Audin (1999), Cochran (1981)and Sahota(1990)

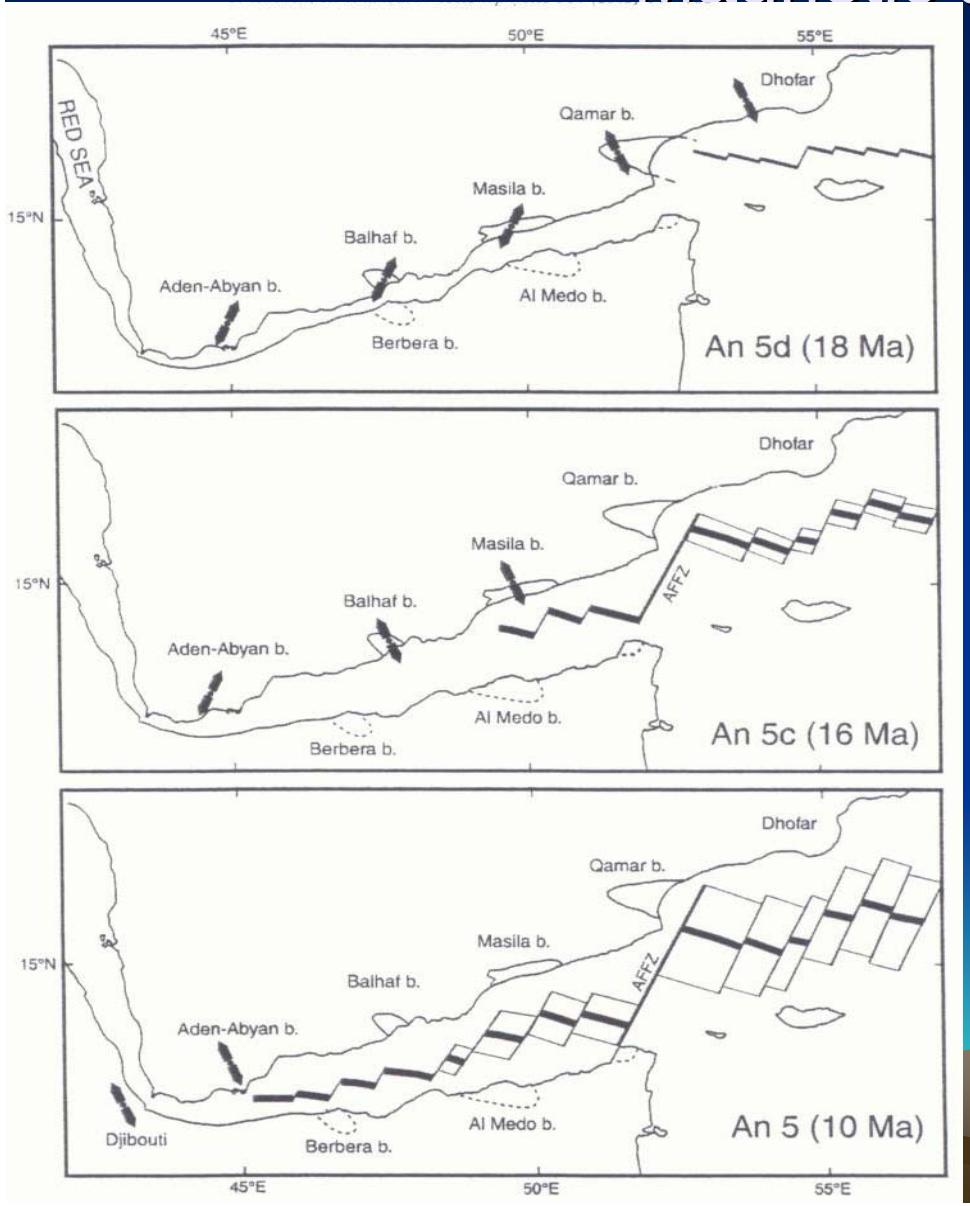


Thick line: oceanic ridge axis

SSTF: Sukra El-Sheikh transform fault

AFTF: Alula-FartakTransform Fault

Reconstructions of The Gulf of Aden at the Time Magnetic anomalies



5D(18 Ma), 5C (16Ma), 5 (10 Ma) and possible distribution through time of the syn-rift extension

Bir Ali Caldera Lake

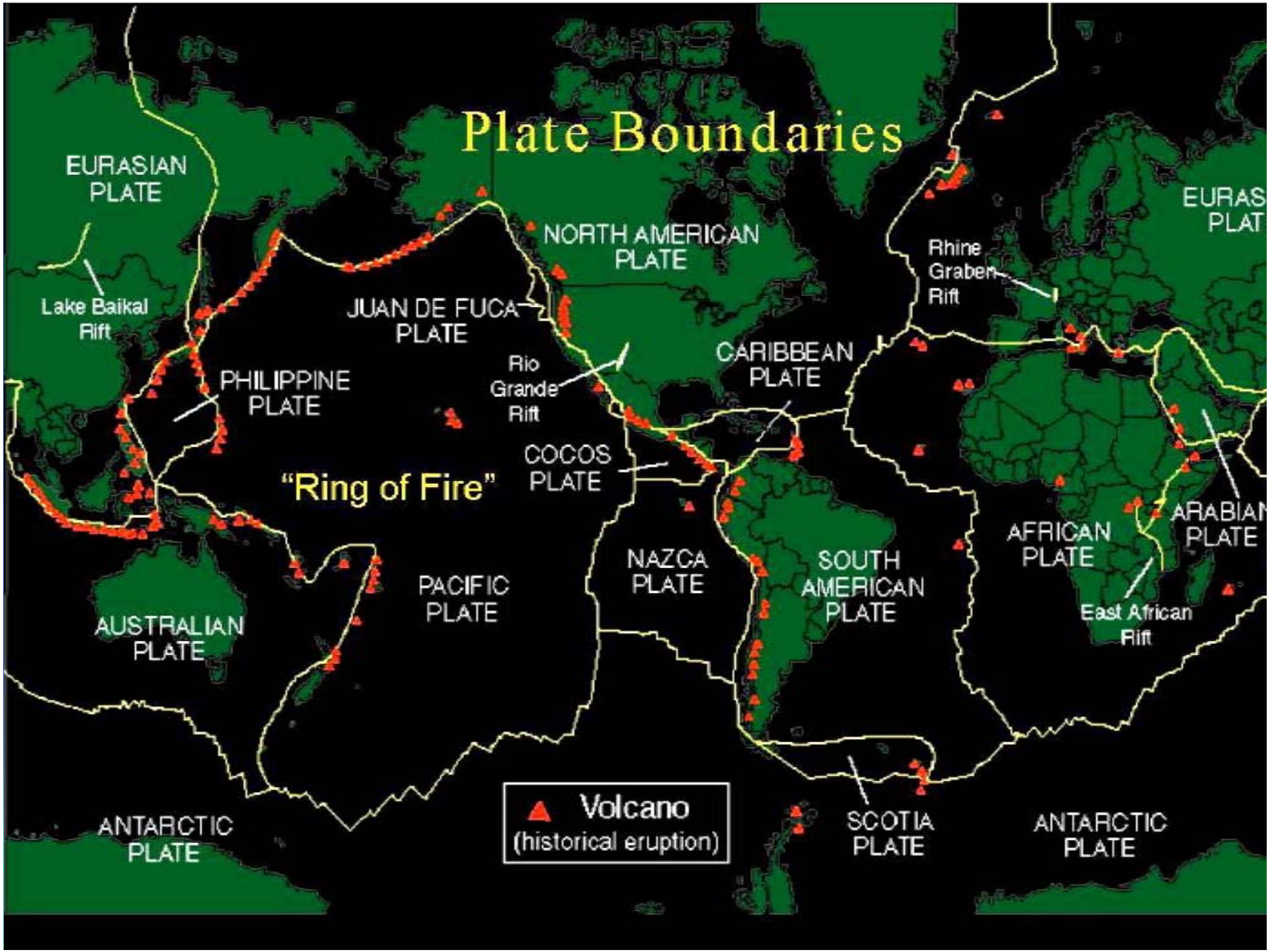
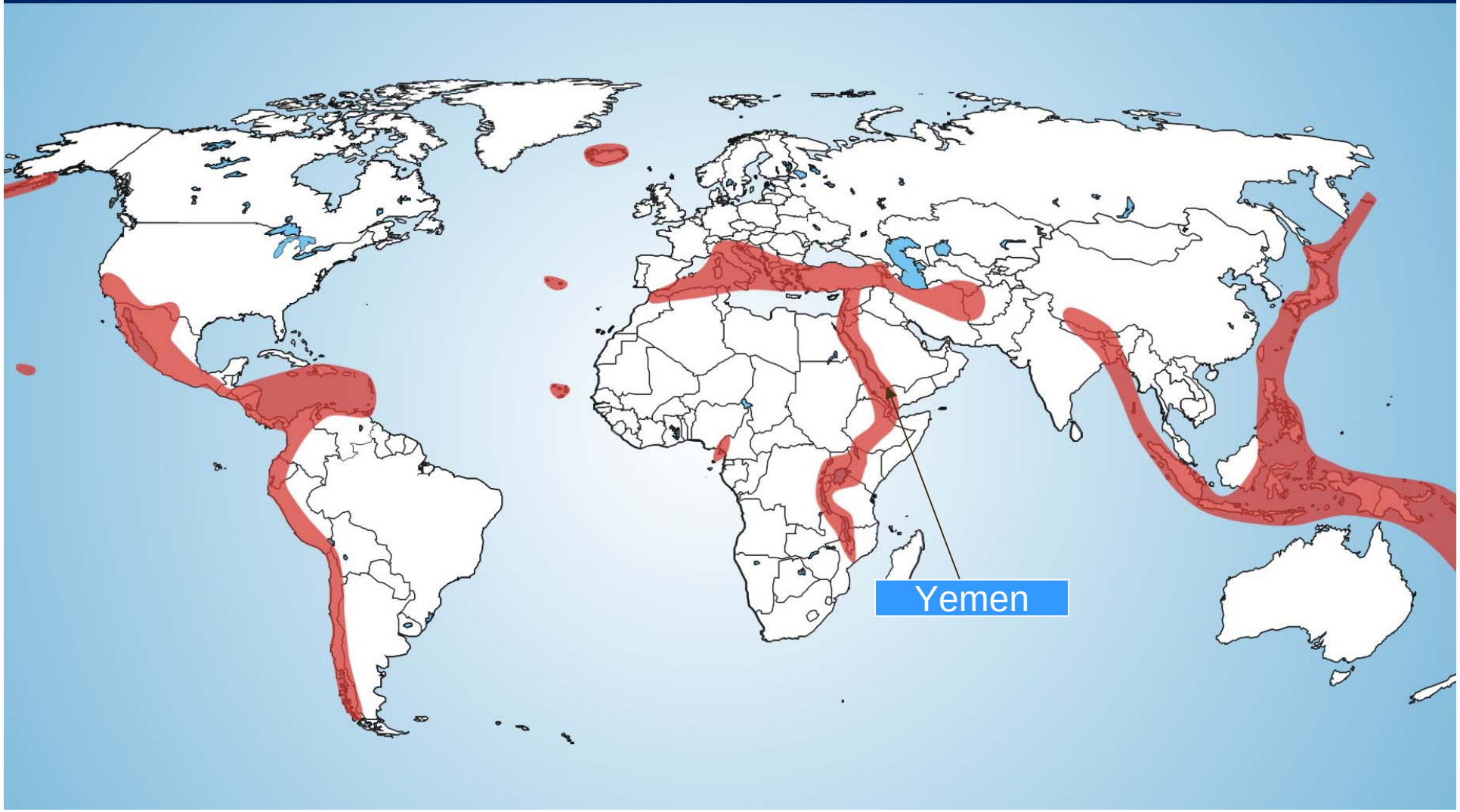


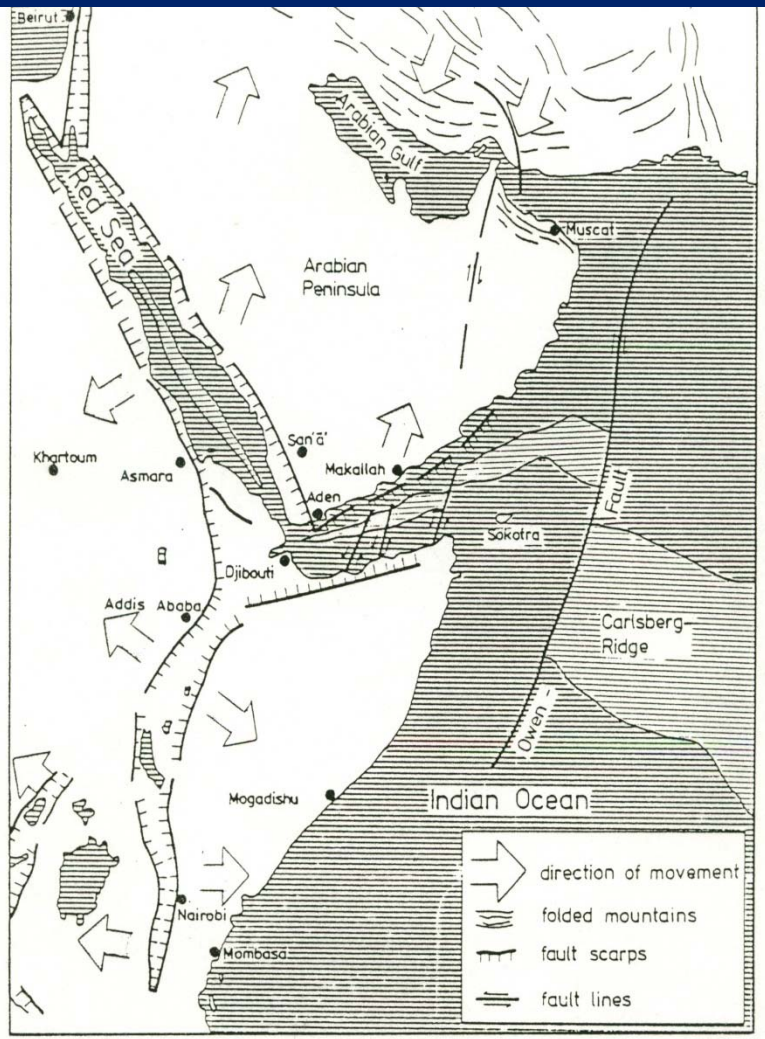
Plate Boundaries
EURASIAN PLATE
Lake Baikal Rift
NORTH AMERICAN PLATE
JUAN DE FUCA PLATE
PHILIPPINE PLATE
Rio Grande Rift
CARIBBEAN PLATE
COCOS PLATE
"Ring of Fire"
Rhine Graben Rift
EURAS PLAT
AFRICAN PLATE
ARABIAN PLATE
East African Rift
NAZCA PLATE
SOUTH AMERICAN PLATE
PACIFIC PLATE
AUSTRALIAN PLATE
ANTARCTIC PLATE
Volcano
(historical eruption)
SCOTIA PLATE
ANTARCTIC PLATE

Among other areas, Yemen and Eastern Africa are sensitive zones to volcanism and tectonics



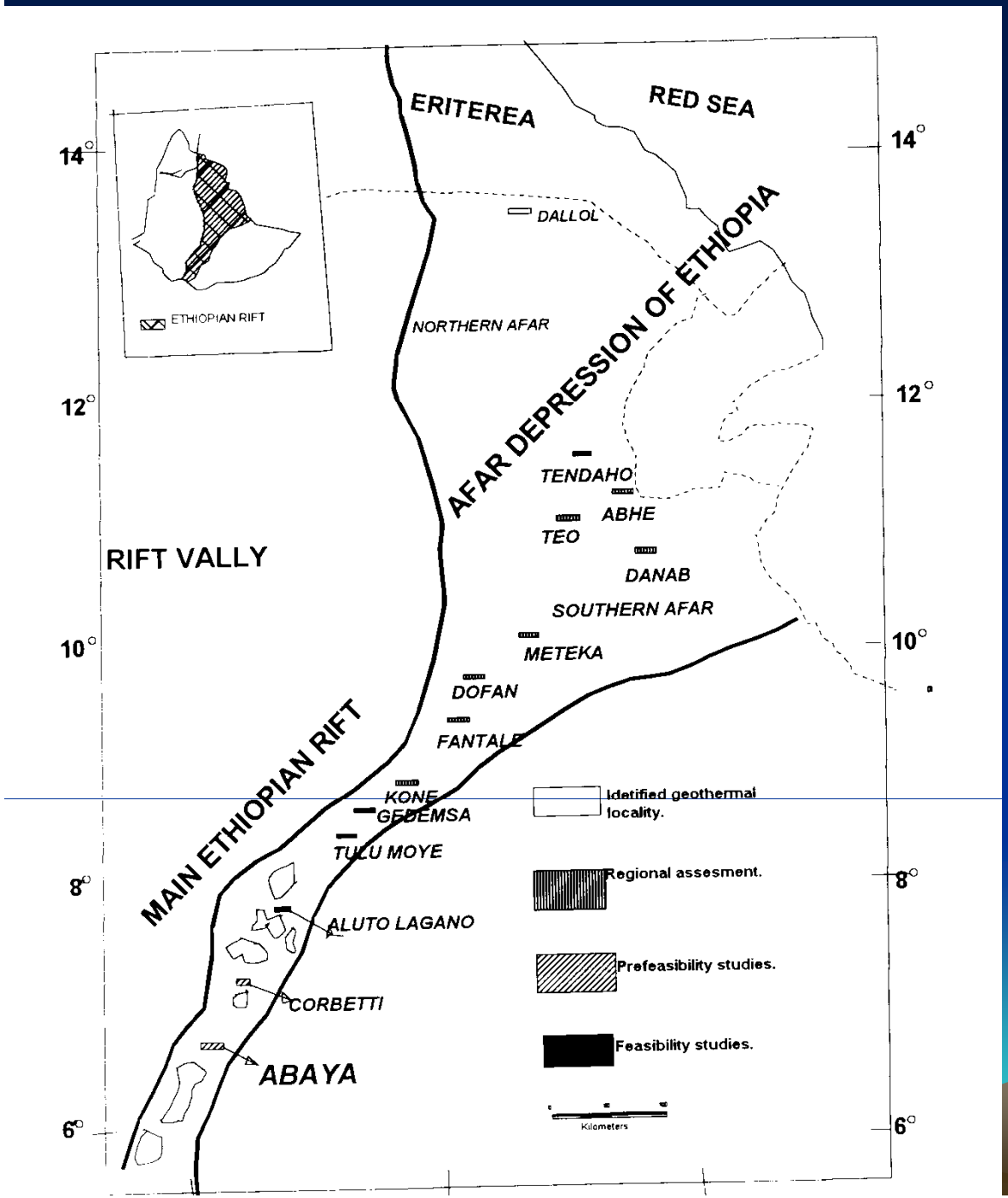
Zones of Rift Valley in Arabian Peninsula and African Horn

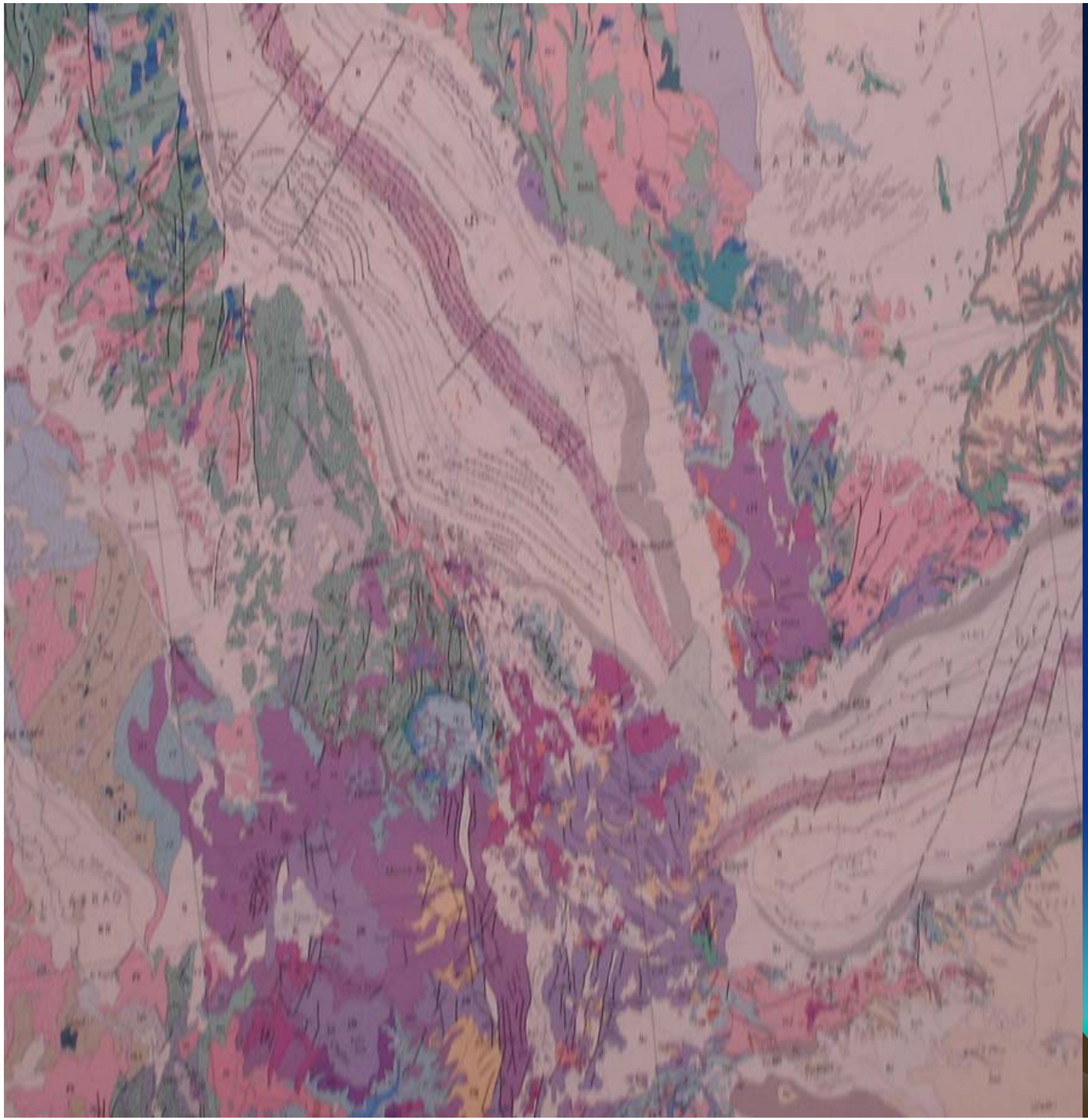
divergence of Arabian and African Plates and convergence of Arabian and Asian Plates



The trend of Rift Valley in Tanzania and Kenya

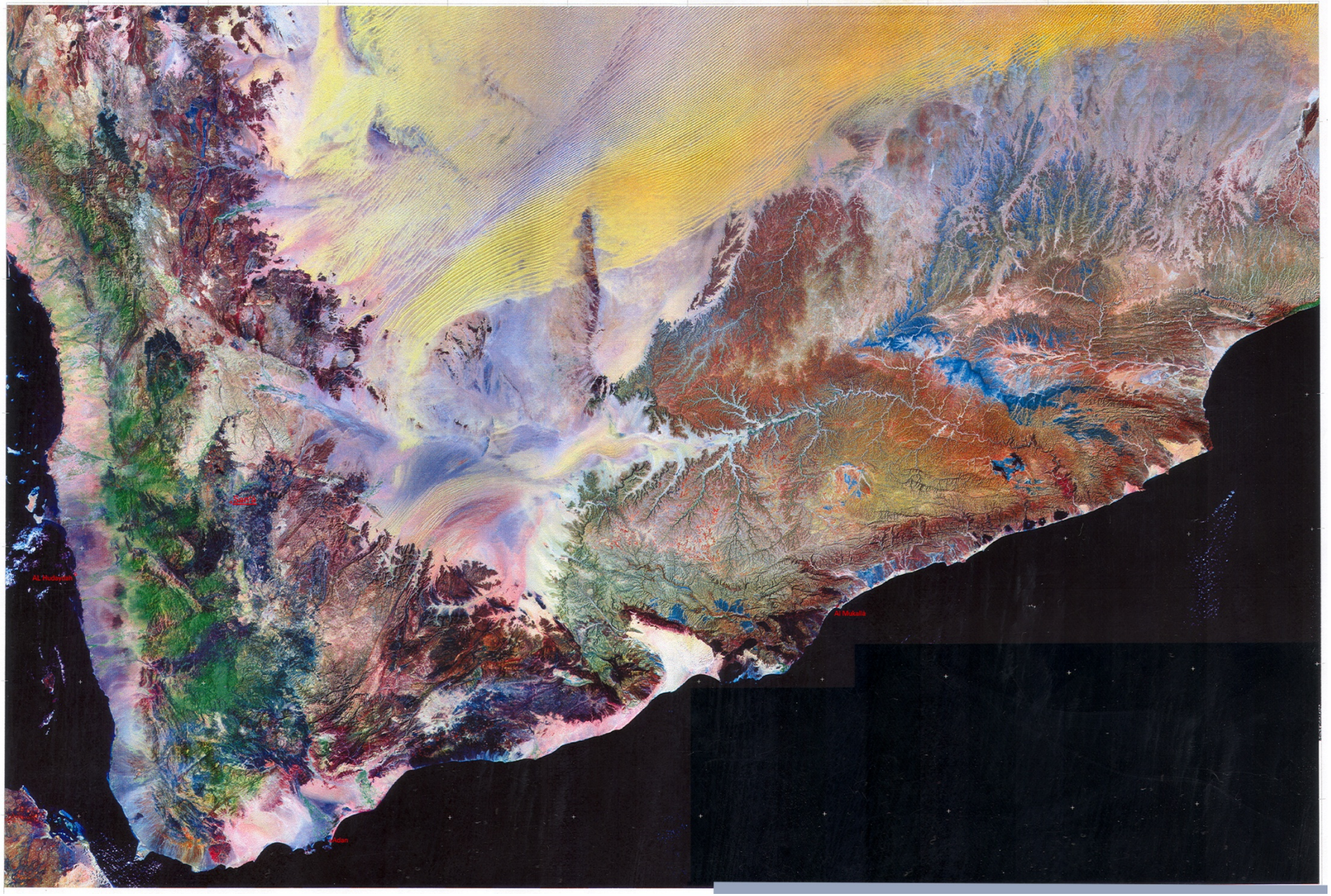
The trend of Rift Valley and promising sites in Ethiopia



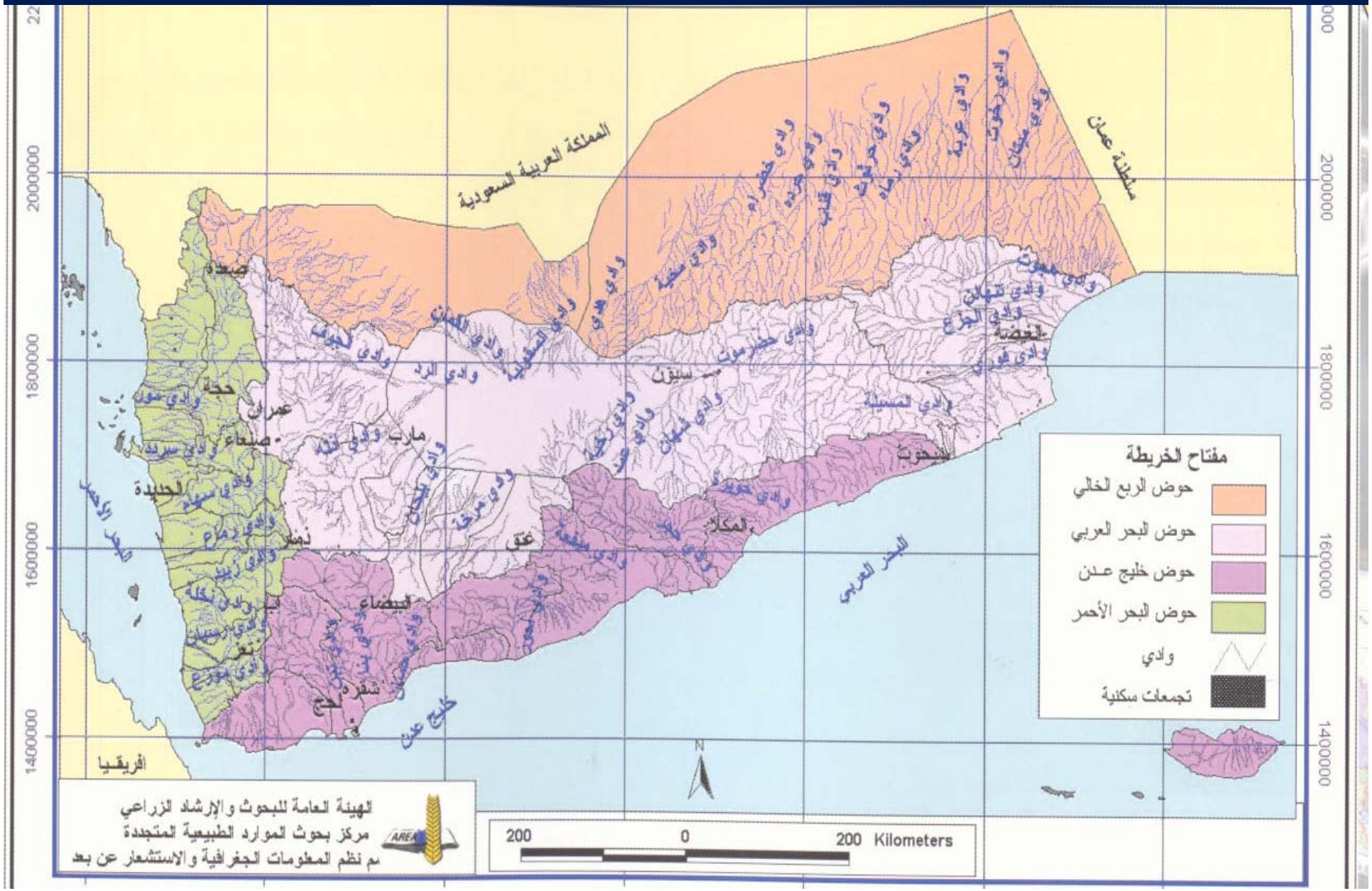


Geological Symmetry proves the Rifting Between Yemen and Eastern Africa

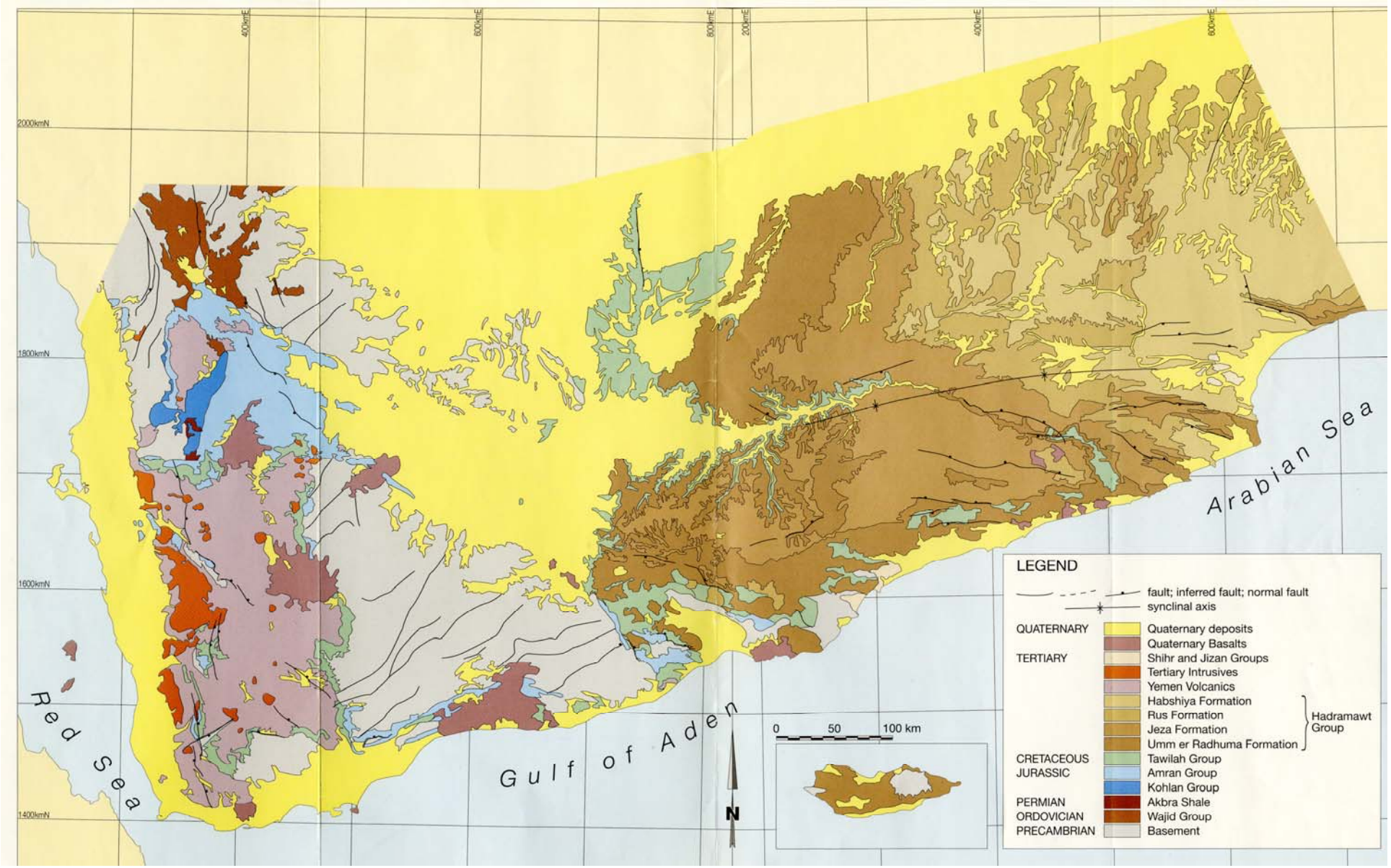
Yemen from space



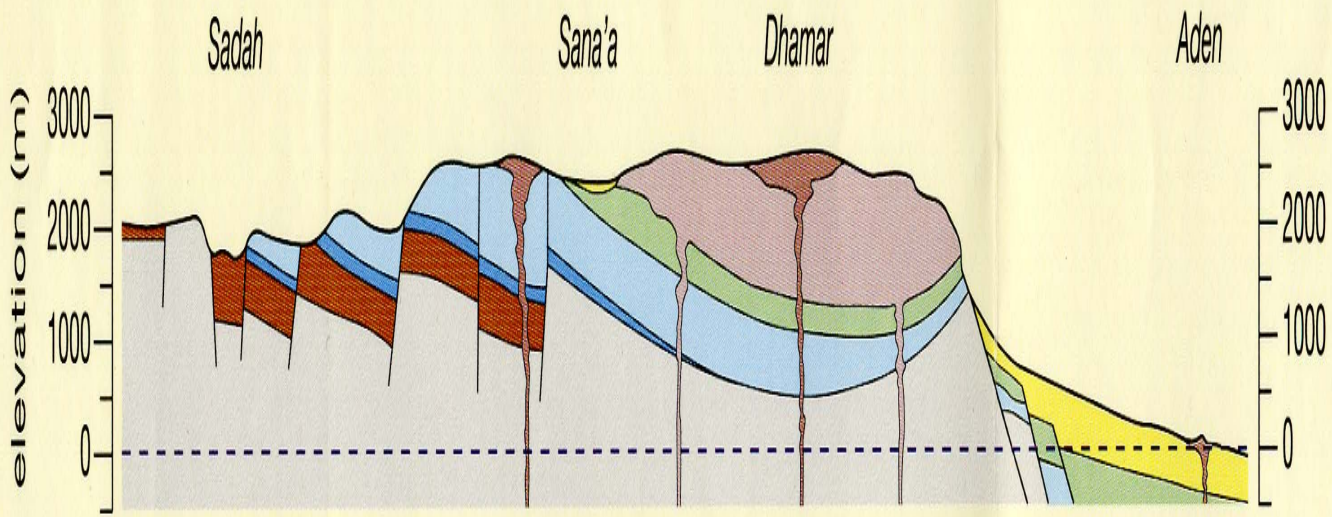
Surface-water Basins



Geological map of Yemen



Geological cross- section North - South



Section B-B'

LEGEND

- Quaternary and Neogene Deposits
- Quaternary Basalts
- Tertiary Intrusives
- Yemen Volcanics
- Hadramawt Group
- Tawilah Group
- Amran Group
- Kohlan Group
- Wajid Group
- Precambrian Basement

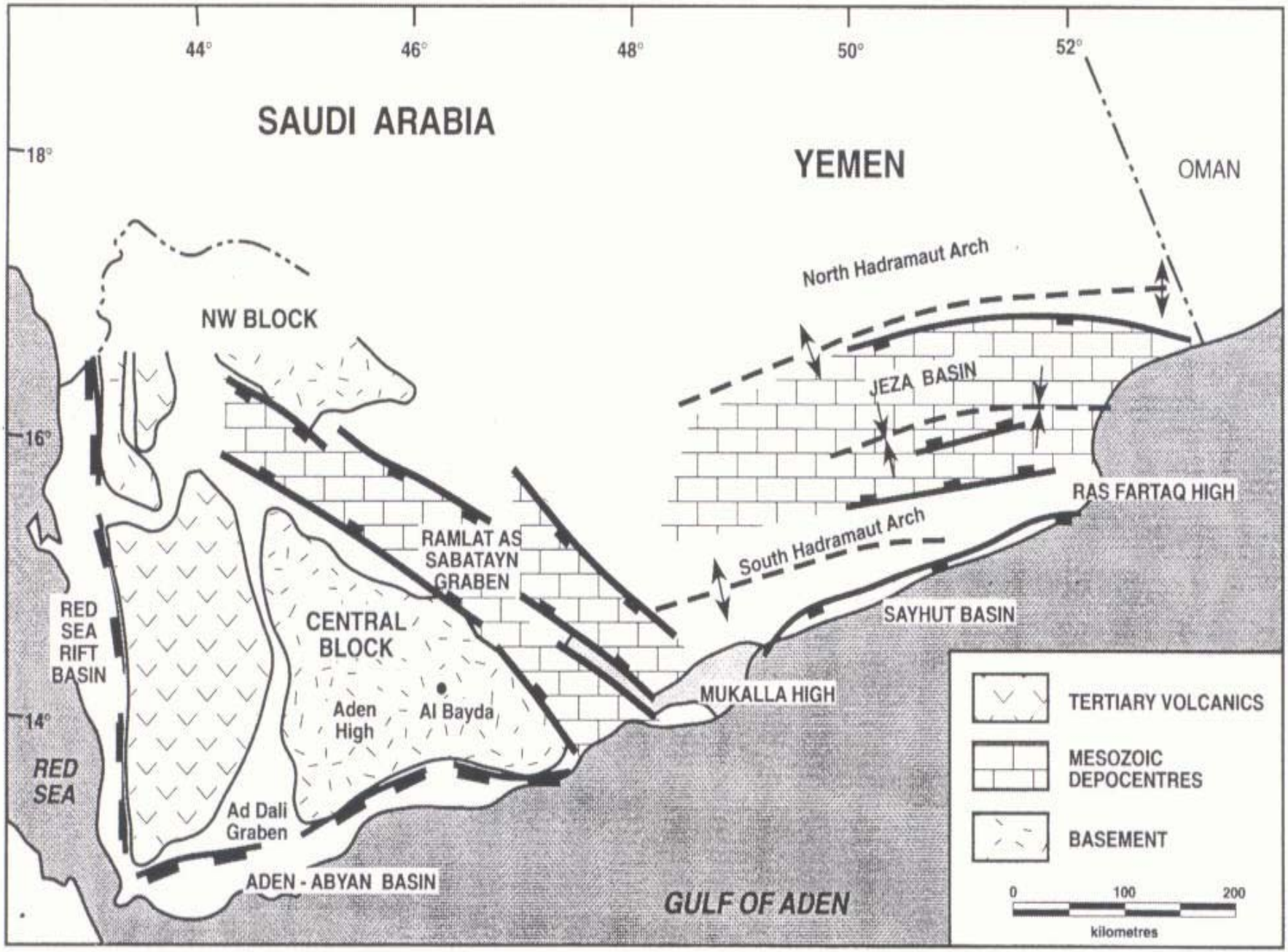
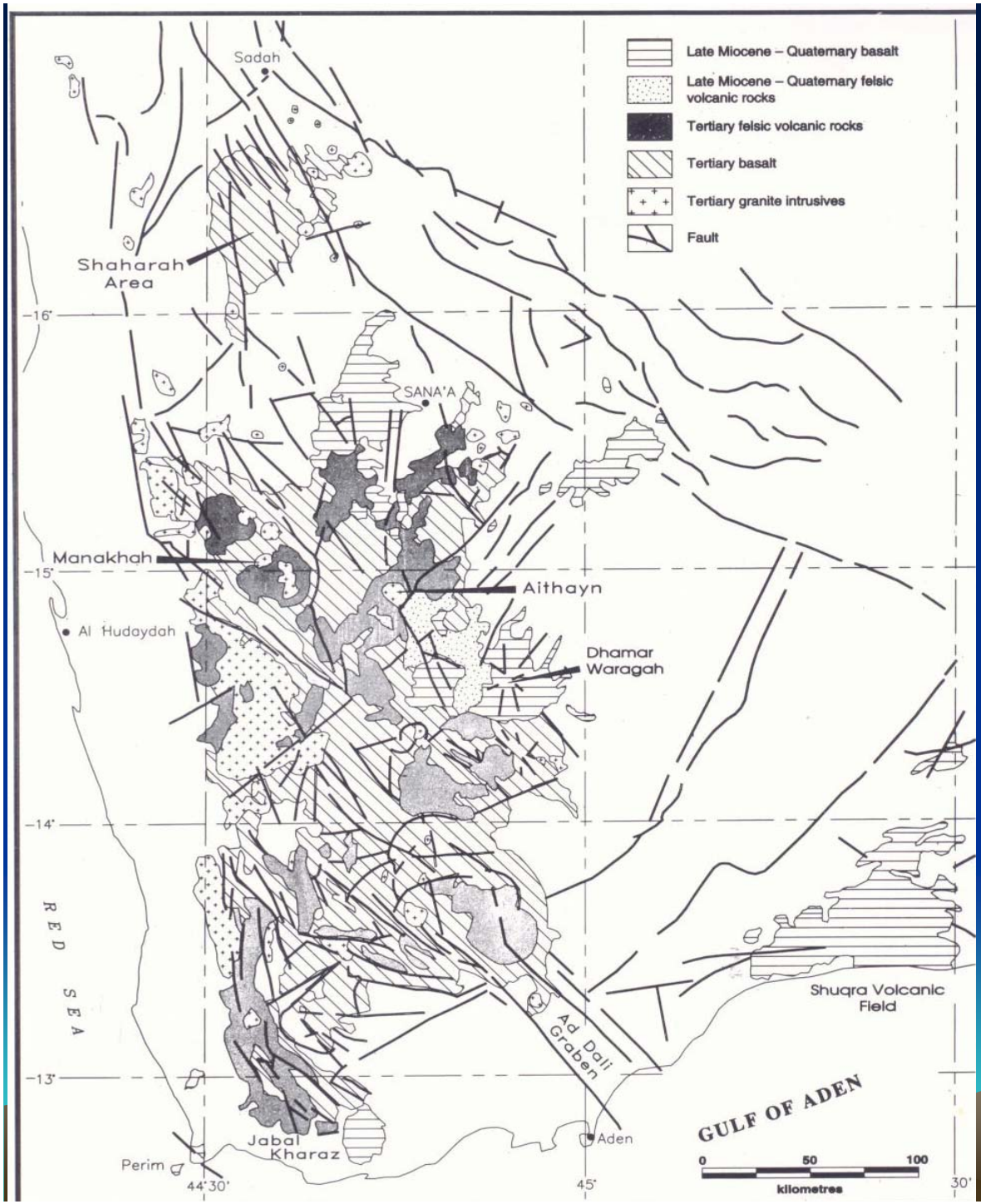


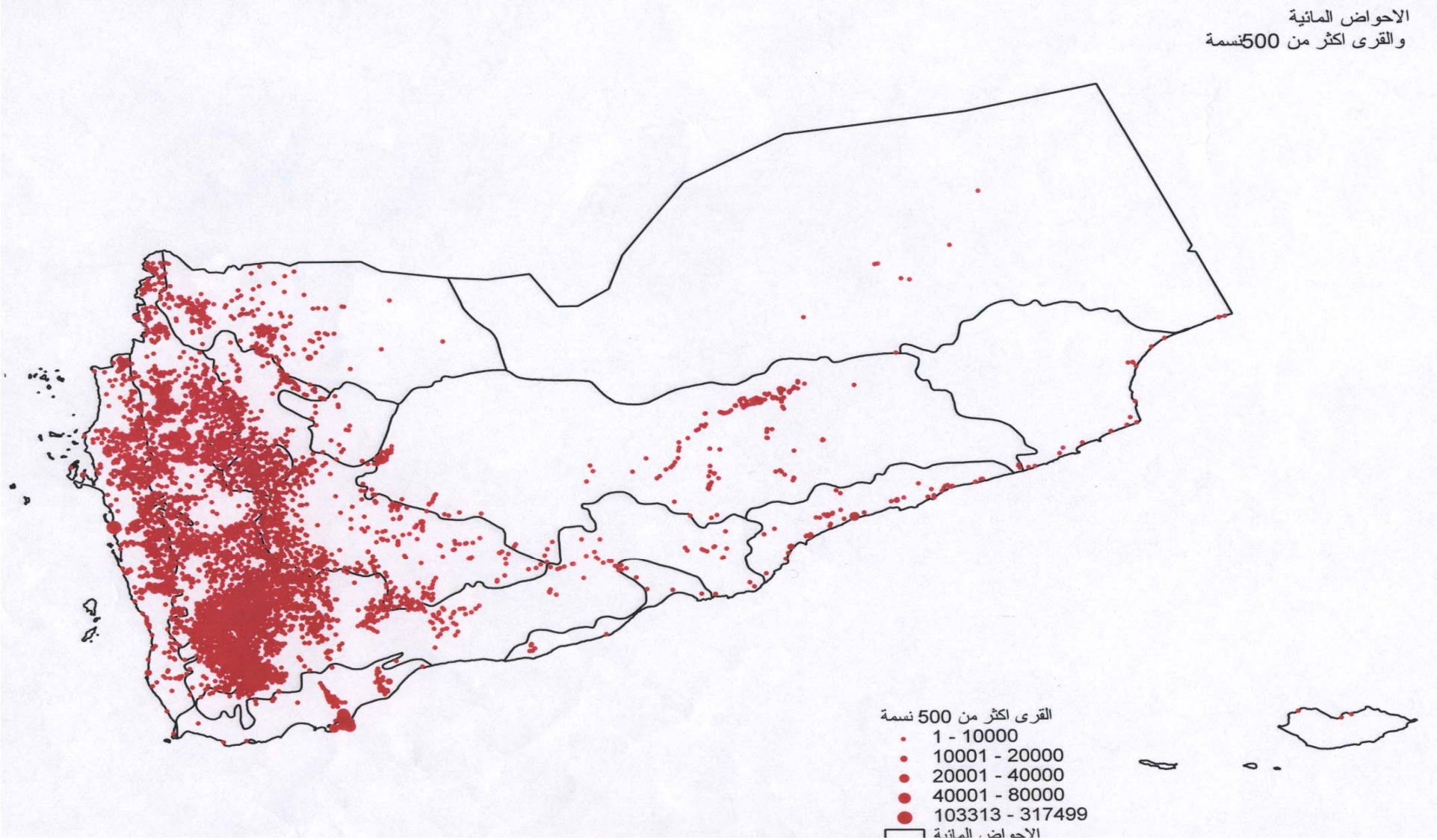
Figure 17. Tectonic features of Yemen (McClay 1993, unpublished data).



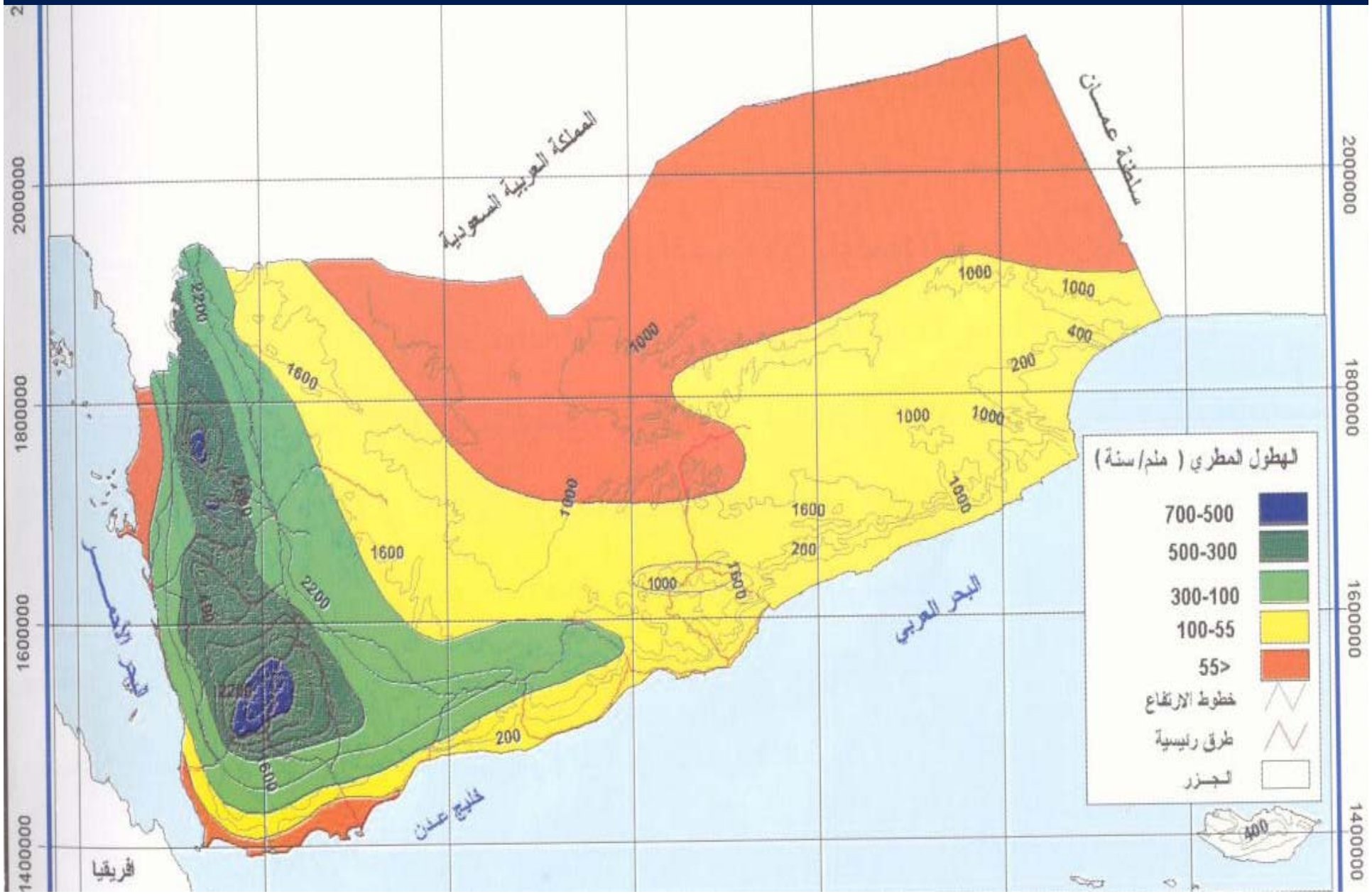
Tertiary Volcanic Map of Western Yemen (Robertson, 1992)

Water Management Regions

Demographic Distribution

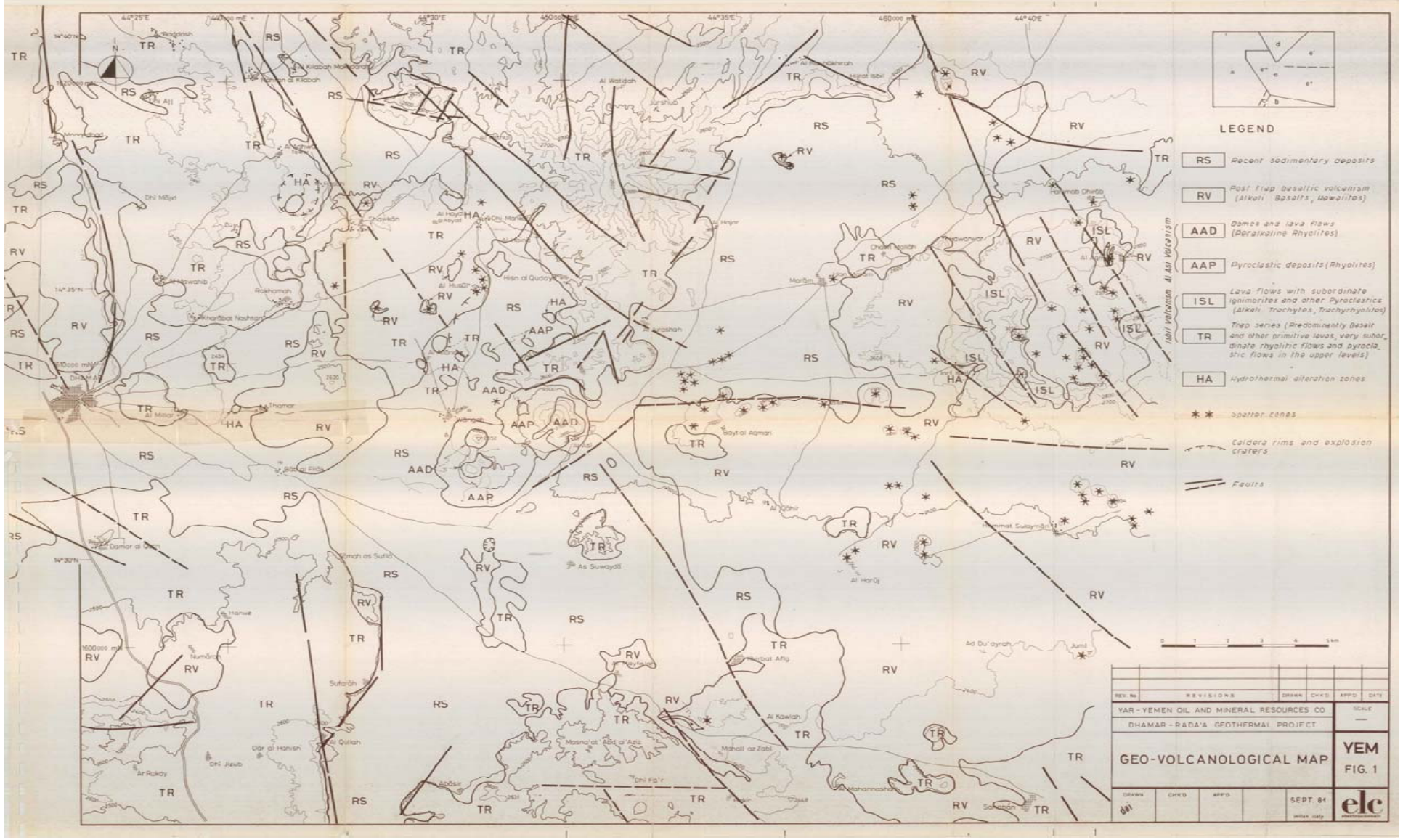


Relationship between Rainfall and Altitude

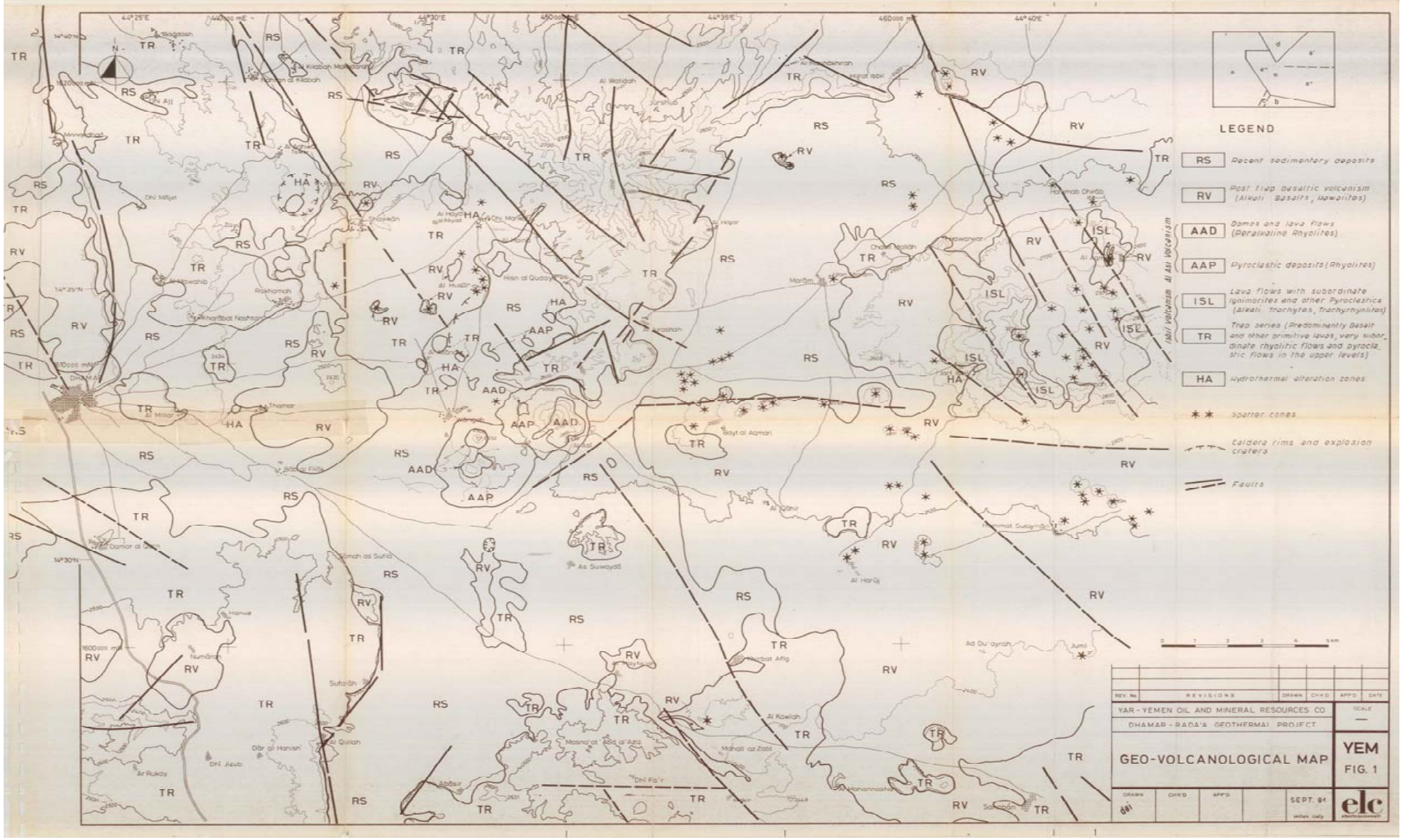


Physiography of Rada-Dhamar Volcanic Field

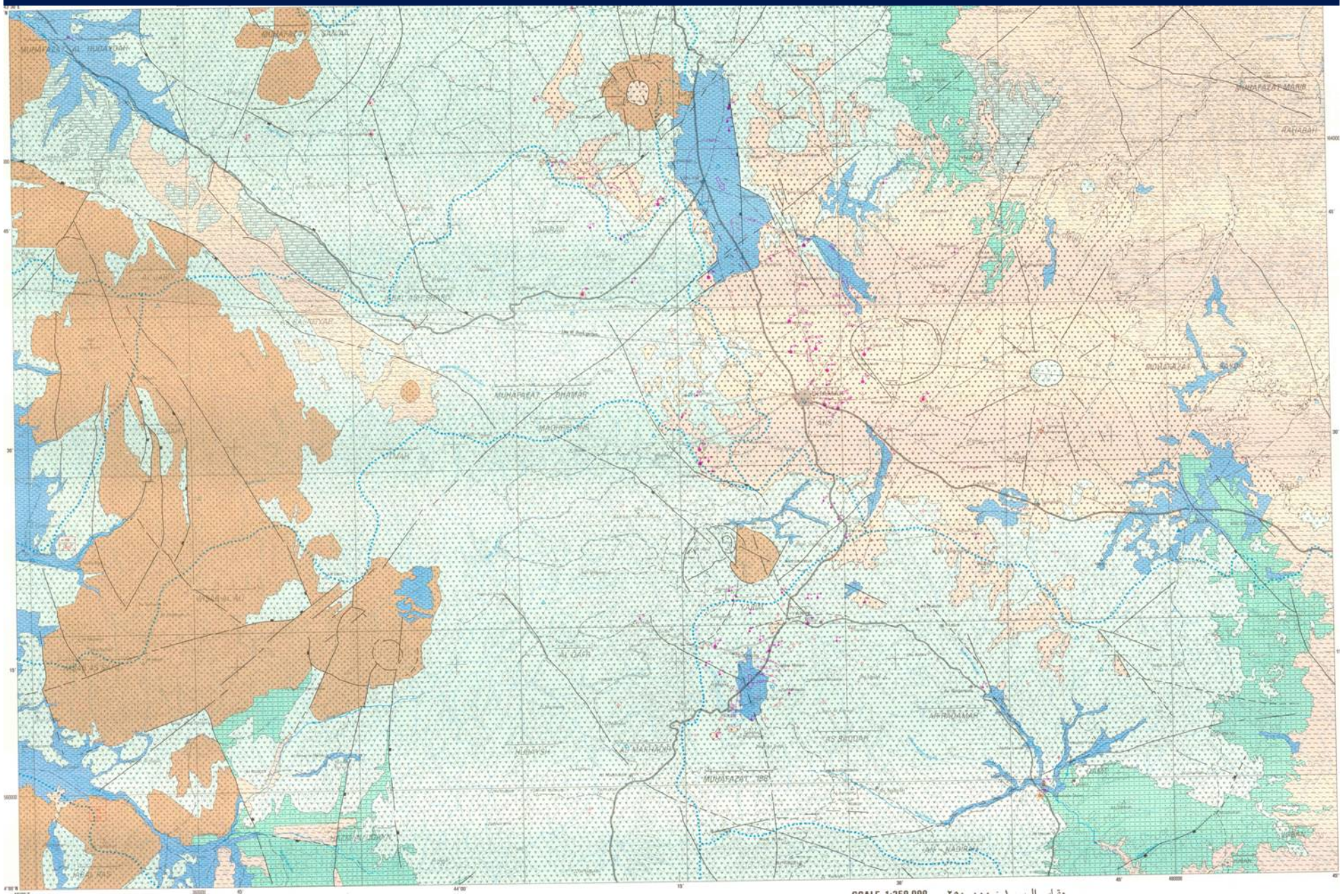
Geo-volcanological Map of Dhamar-Rada Geothermal Field



Geo-volcanological Map of Dhamar-Rada Geothermal Field

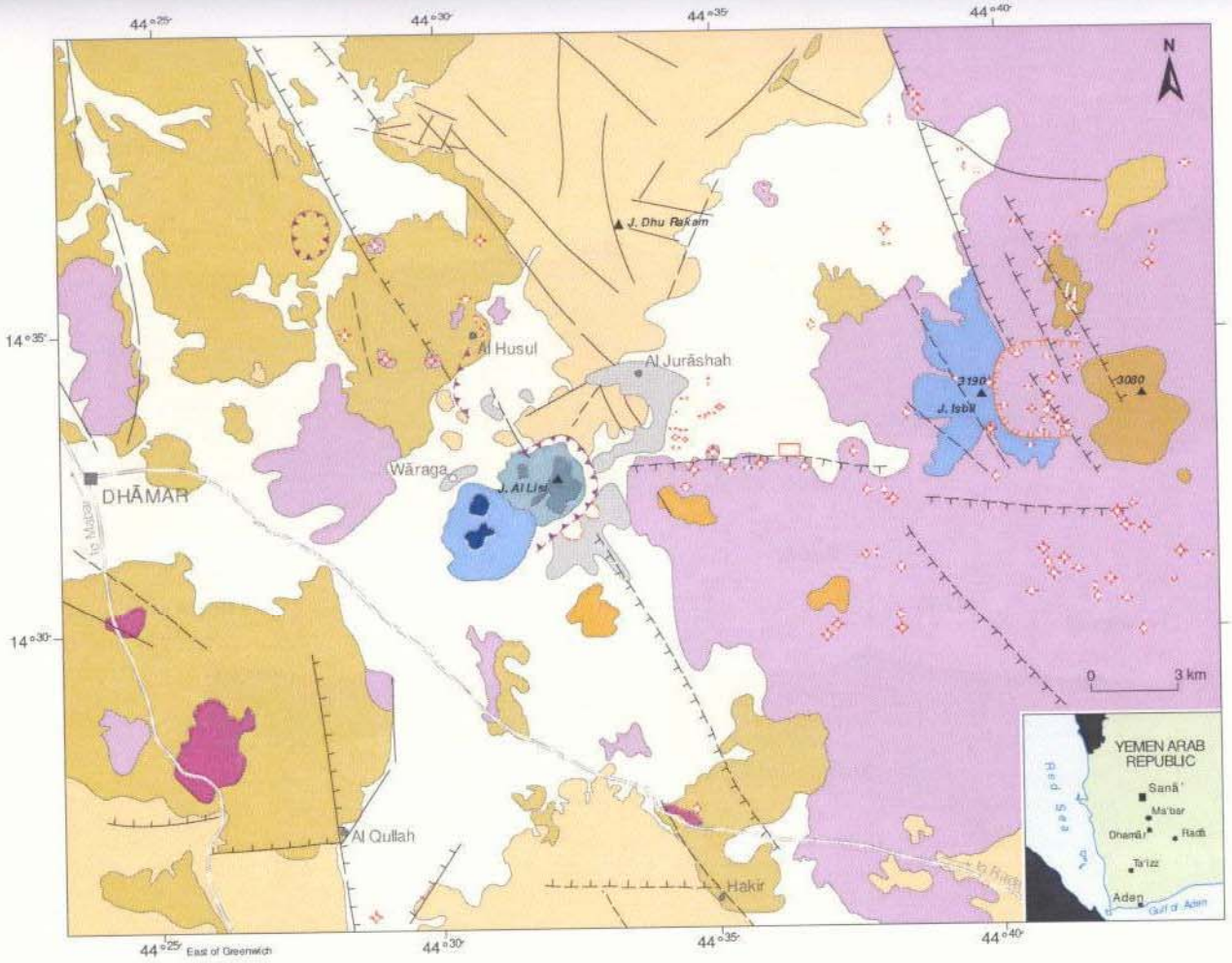


Hydrogeological map of Dhamar area



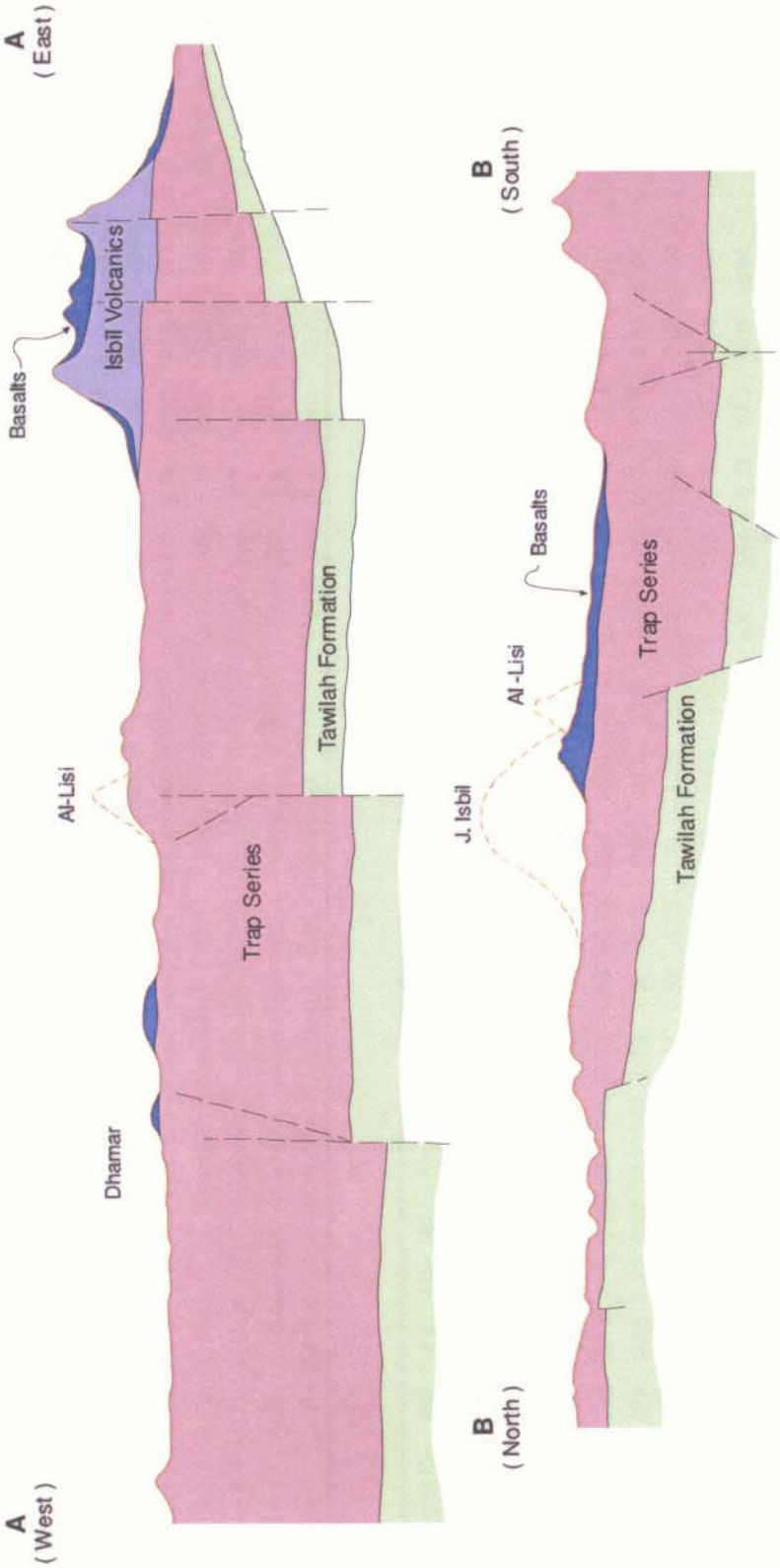
2 Geology and structures in Al-Lisi - Isbil volcanic field

Modified after Chiesa et al. (1983b)



eological cross sections cutting Al-Lisi - Isbil volcanic field

urce: ELC 1981b, unfortunately, scale and exact location were not specified.



EN

Y AND
BOARD
ND

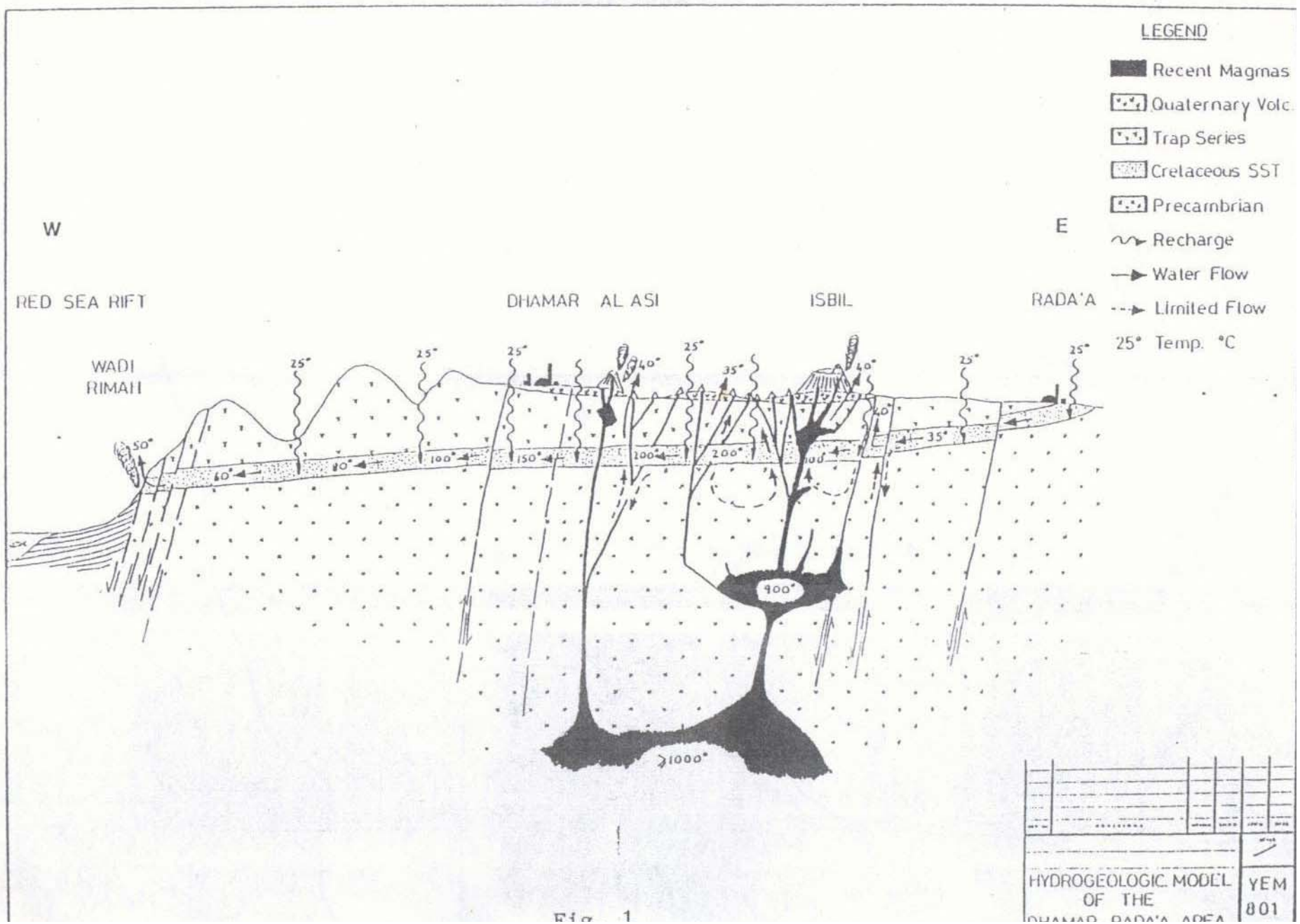

LEGEND
Recent Magmas
Quaternary Volc.
Trap Series
Cretaceous SST
Precambrian
Recharge
Water Flow
Limited Flow
25° Temp. °C
W
E
RED SEA RIFT
DHAMAR AL ASI
ISBIL
RADA'A
WADI RIMAH
25°
40°
35°
50°
60°
80°
100°
150°
200°
900°
>1000°
HYDROGEOLOGIC MODEL OF THE DHAMAR RADA'A AREA
YEM 801

Fig. 1

Then climbing

Gases and fumaroles are spread everywhere in the slope of the Volcano.

Be Careful !!!

Don’t sit down on sulfur Acid rocks

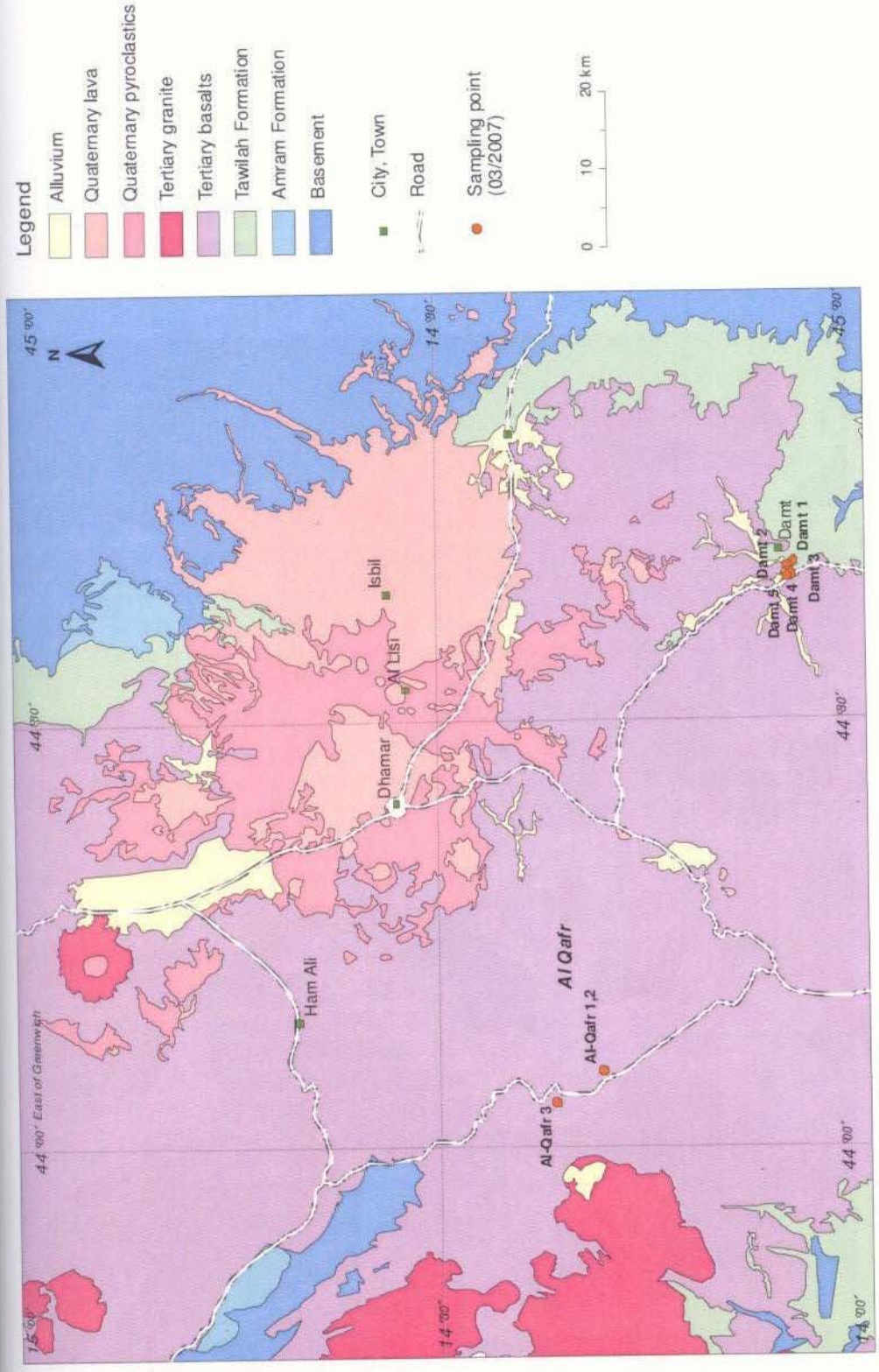
Traditional Steam Spa.

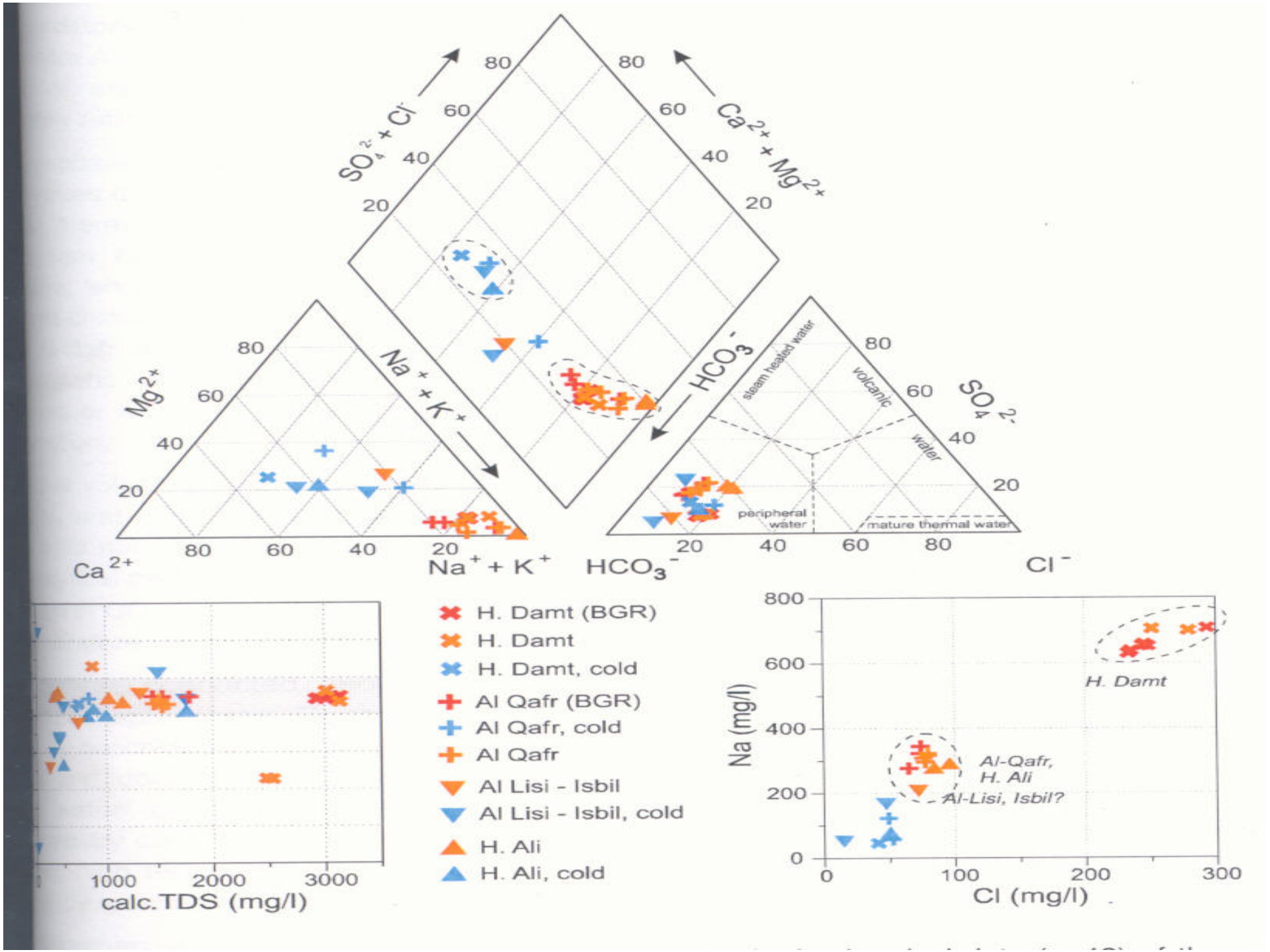
Be Careful !!

Don’t stand up because poisonous gas is accumulated in the top of the cave

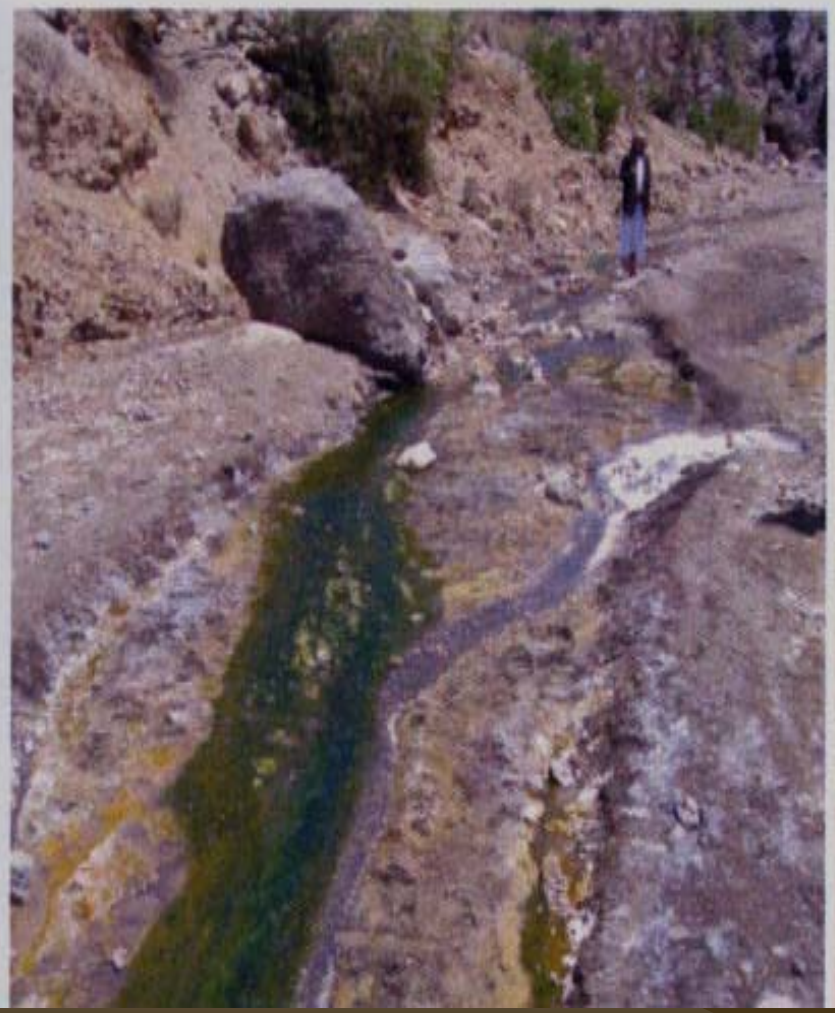
Simplified geological map of Dhamar – Damt – Al-Qafr area

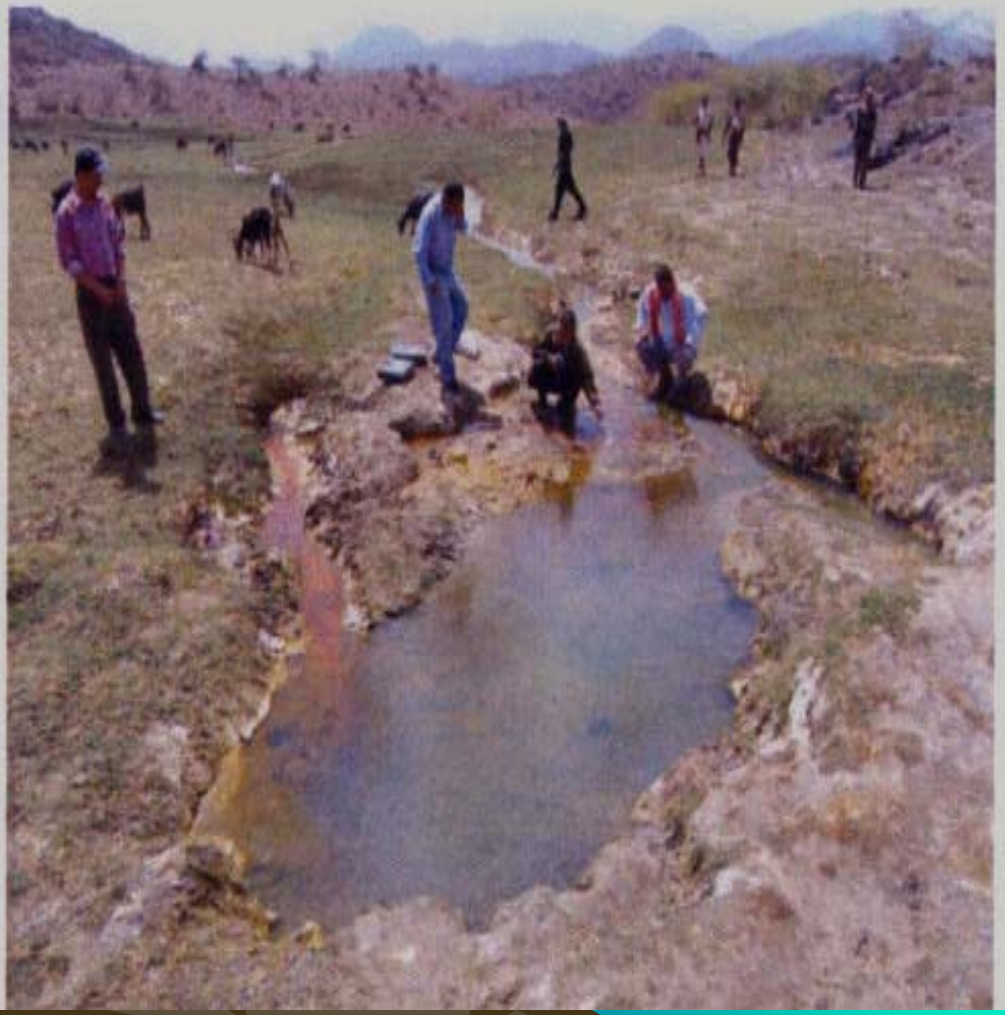
Modified after Geological Map 1:250.000 (ROBERTSON, 1993)




$SO_4^{2-} + Cl^-$
$Ca^{2+} + Mg^{2+}$
$Na^+ + K^+$
HCO_3^-
Mg^{2+}
Ca^{2+}
SO_4^{2-}
Cl^-
steam heated water
volcanic
water
peripheral water
mature thermal water
calc.TDS (mg/l)
H. Damt (BGR)
H. Damt
H. Damt, cold
Al Qafr (BGR)
Al Qafr, cold
Al Qafr
Al Lisi - Isbil
Al Lisi - Isbil, cold
H. Ali
H. Ali, cold
Na (mg/l)
Cl (mg/l)
H. Damt
Al-Qafr,
H. Ali
Al-Lisi, Isbil?

Al Namaja Wetland





Uses of geothermal energy

Generating electricity

.Balneologic physio-therapy

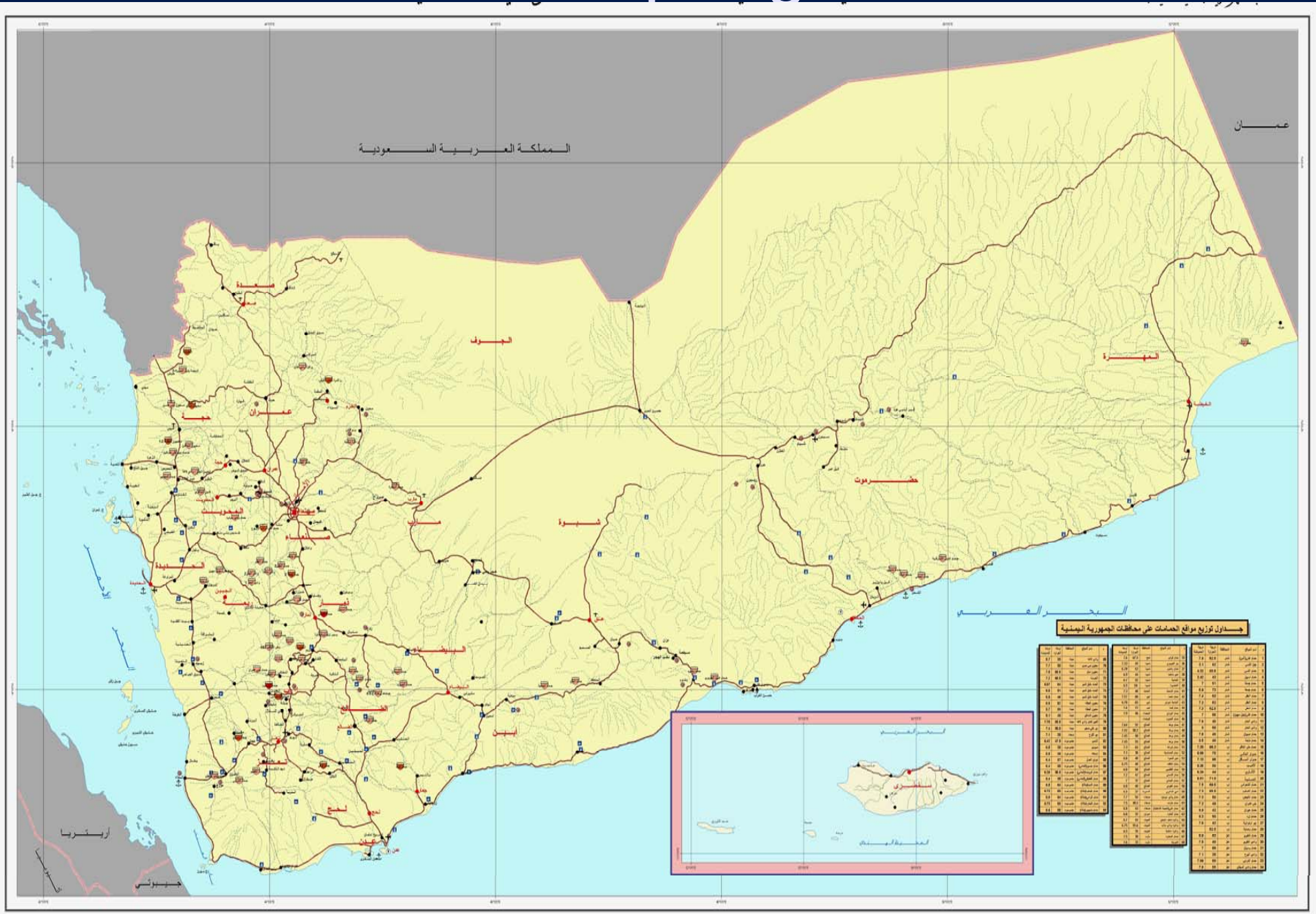
.Heating buildings in areas of cold weather

.Warming of green houses

Extracting some acids and chemical gases:CO_2 , H_2S , HCl , HF

Drying of vegetables, fish and other .industrial products

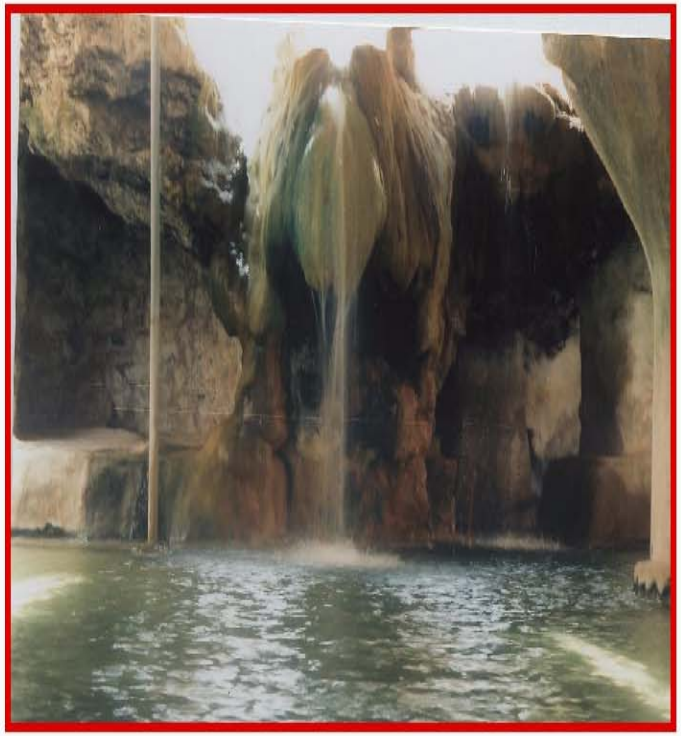
Hot springs

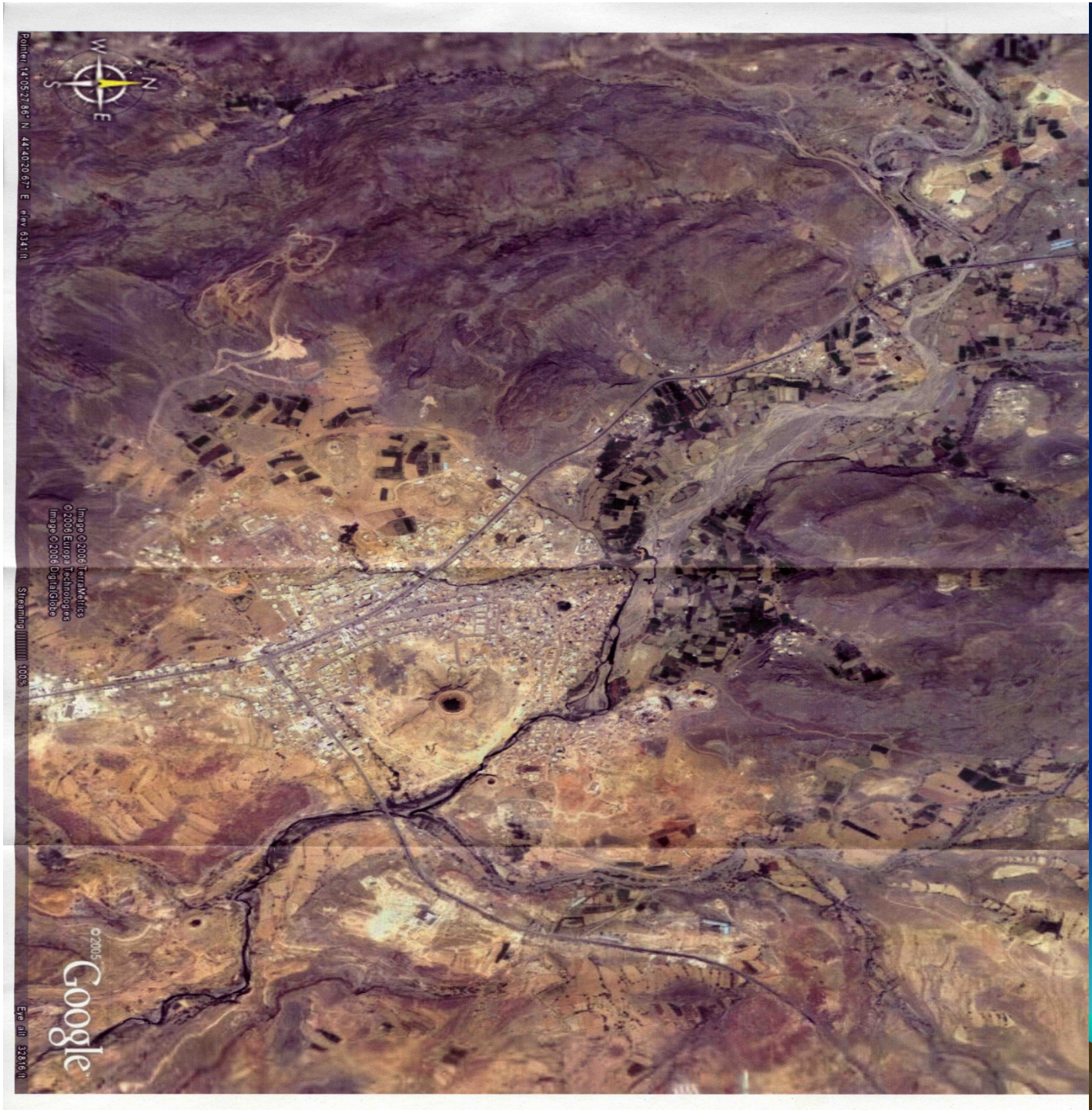

المملكة العربية السعودية
عمان
المهرة
حضرموت
الجوف
مأرب
شبوة
عمران
حجة
صعدة
الحديدة
تعز
لحج
أبين
البحر العربي
جدول توزيع مواقع الحمامات على محافظات الجمهورية اليمنية
سقطرى
المحيط الهندي
أريتريا
جيبوتي

م	اسم الموقع	المحافظة	درجة الحرارة	درجة الحموضة
1	حمام علي(آنس)	ذمار	62.5	7.8
2	جبل النسي	ذمار	82	3.1
3	حمام النسي	ذمار	88.6	4.32
4	حمام اسبيل	ذمار	43	3.42
5	حمام جمعة	ذمار	51	7
6	حمام جمعة	ذمار	73	6.9
7	حمام العقر	ذمار	63	7.4
8	حمام العقر	ذمار	62	7.2
9	حمام العقر	ذمار	62.5	7.3
10	حمام علي(جبل مهين)	ذمار	56	7
11	وادي الحار	ذمار	45	7.8
12	وادي الحار	ذمار	50	8
13	حمام صبيان	ذمار	48	7.6
14	حمام ملحة	ذمار	48	8.5
15	حمام مش الكافر	إب	96.3	7.35
16	حوار العالي	إب	75	6.56
17	حوار السافل	إب	96	7.13
18	الأديب	إب	58	6.35
19	الأثاري	إب	44	6.34
20	الصلبة	إب	71.5	6.51
21	حمام الشعراني	إب	69.5	7.5
22	حمام الاسلوم	إب	85.5	7.3
23	حمام الاجهوم	إب	50	7.3
24	بني عمران	إب	49	7.2
25	حمام هيران	إب	42	8.9
26	حمام زره	إب	50	8.3
27	بير ارتوازية	إب	42	7.6
28	حمام رصابة	إب	52.5	
29	حمام الطوير	تعز	63	6.9
30	وادي الطوير	تعز	40	7.5
31	حمام رسيان	تعز	66	7
32	وادي البرح	تعز	35	7.1
33	حمام الدرايي	تعز	60	7.89
34	حمام وادي المجش	تعز	55	7.6

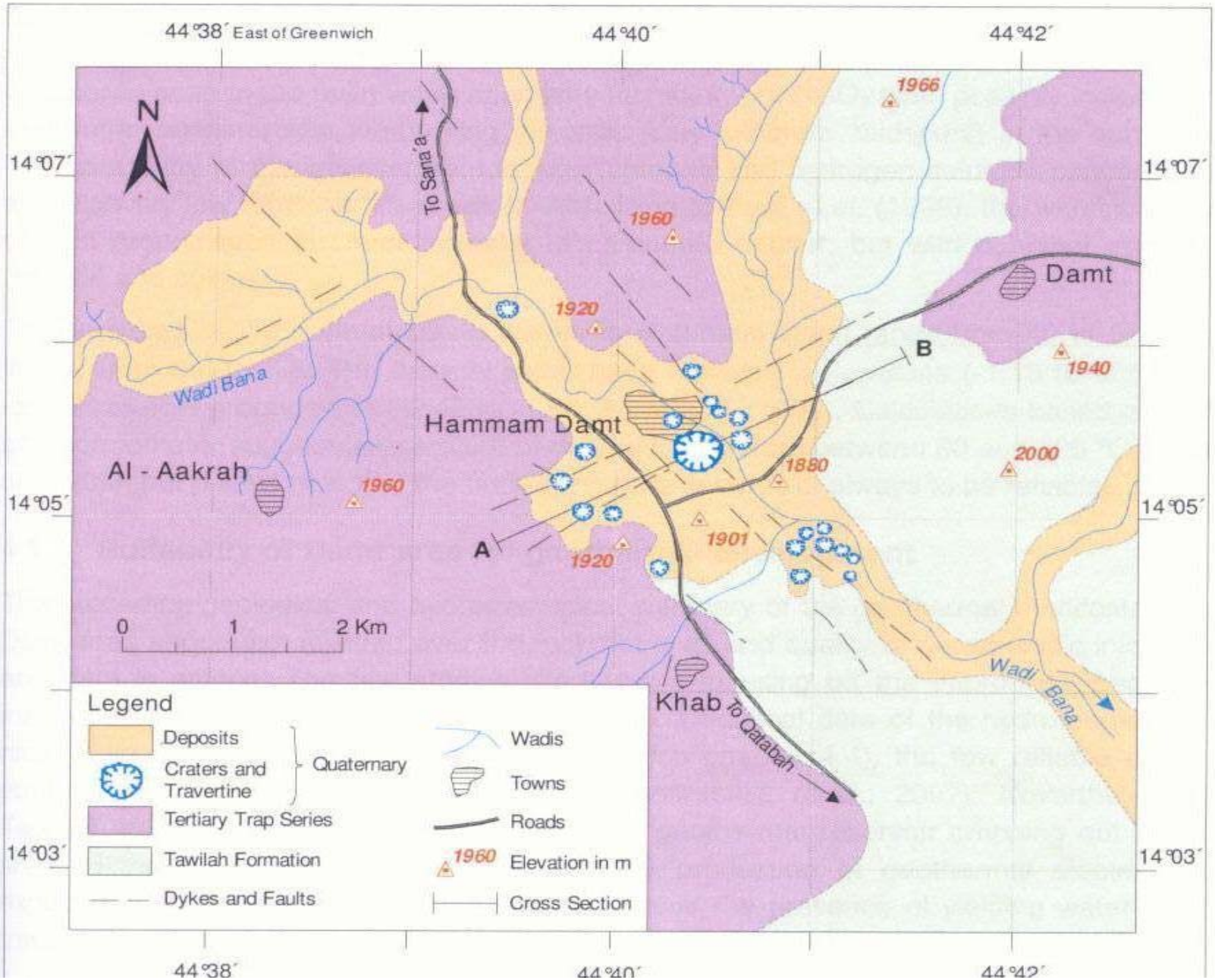
م	إسم الموقع	المحافظة	درجة الحرارة	درجة الحموضة
35	حمام كرش	لحج	67.5	7.6
36	بير الجويري	شبوة	45	7.33
37	حمام رضوم	شبوة	53	6.78
38	عين بلسعيد	شبوة	44	6.9
39	الحامية	شبوة	52	6.7
40	الخضيرة	شبوة	50	6.5
41	حمام السخنة	الحديدة	48	7.3
42	حمام انخب	ابين	60	7.57
43	الحامية عيران	ابين	65	6.78
44	حمام كبت	ابين	72	7.6
45	حمام البردان	البيضاء	50	7.9
46	حمام الجبوب	البيضاء		
47	حمام برهد	الضالع	52	7.64
48	حمام برهد	الضالع	50.2	7.42
49	حمام برهد	الضالع	50	7.45
50	حمام برهد	الضالع	55	7.45
51	حمام شرعة	الضالع	64	7.3
52	حمام الحساسية	الضالع	38	7.1
53	عين البخرة	الضالع	48	6.8
54	حمام عاطف	الضالع	48	6.75
55	حمام الطثيمي	الضالع	50	6.8
56	حمام الاسدي	الضالع	47	7.2
57	حمام الحمدي	الضالع	37	7
58	حمام العودي	الضالع	40	6.8
59	عين الباعري	المحويت	37	6.5
60	حمام وادي سردود	صنعاء	54	7.7
61	حمام جارف	صنعاء	48.5	7.5
62	حمام علي(الحيمة الداخلية)	صنعاء	43	6.8
63	حمام الخارد	عمران	32	6.8
64	واغرة شعب دغيش	الجوف	44	6.7
65	واغرة وادي سذاب	الجوف	55.6	6.75
66	واغرة املاحة	الجوف	35	6.5
67	حمام المخدرة	مأرب	30	7.5
68	الحريبة	مأرب	33	7.6

م	إسم الموقع	المحافظة	درجة الحرارة
69	وادي لاعة	حجة	35
70	معيون بني حسن	حجة	50
71	معيون اسلم	حجة	69.5
72	الخرشة	حجة	65.5
73	الحما- بكيل الأمير	حجة	64
74	الحما- بكيل الأمير	حجة	51
75	الحما- بكيل الأمير	حجة	46
76	معيون الحقلة	حجة	82
77	معيون الحقلة	حجة	69
78	معيون الدافن	حجة	40
79	العين الحار وادي لاعة	حجة	55.5
80	بير علي صغير	حجة	50.5
81	بير الثوح	صعدة	38
82	الديس	حضرموت	47.5
83	صويبر	حضرموت	30
84	صنعاء	حضرموت	46
85	ذوبان العسل	حضرموت	57
86	حمام حسين(الحامي)	حضرموت	58
87	حمام الروضة(الحامي)	حضرموت	58.5
88	حمام القعيطي(الحامي)	حضرموت	38
89	حمام الدنيا(نبالة)	حضرموت	64
90	حمام عوض (نبالة)	حضرموت	65
91	حمام الرامي(نبالة)	حضرموت	64
92	حمام النجار (نبالة)	حضرموت	65
93	حمام باشهير (نبالة)	حضرموت	58





Google image for Damt resort and Travertine cones


44°38′ East of Greenwich
44°40′
44°42′
14°07′
14°05′
14°03′
N
To Sana'a
1966
1960
1920
Damt
B
1940
Wadi Bana
Hammam Damt
Al - Aakrah
1960
1880
2000
A
1920
1901
0 1 2 Km
Khab
To Qatabah
Wadi Bana
Legend
Deposits
Craters and Travertine
Quaternary
Tertiary Trap Series
Tawilah Formation
Dykes and Faults
Wadis
Towns
Roads
1960 Elevation in m
Cross Section

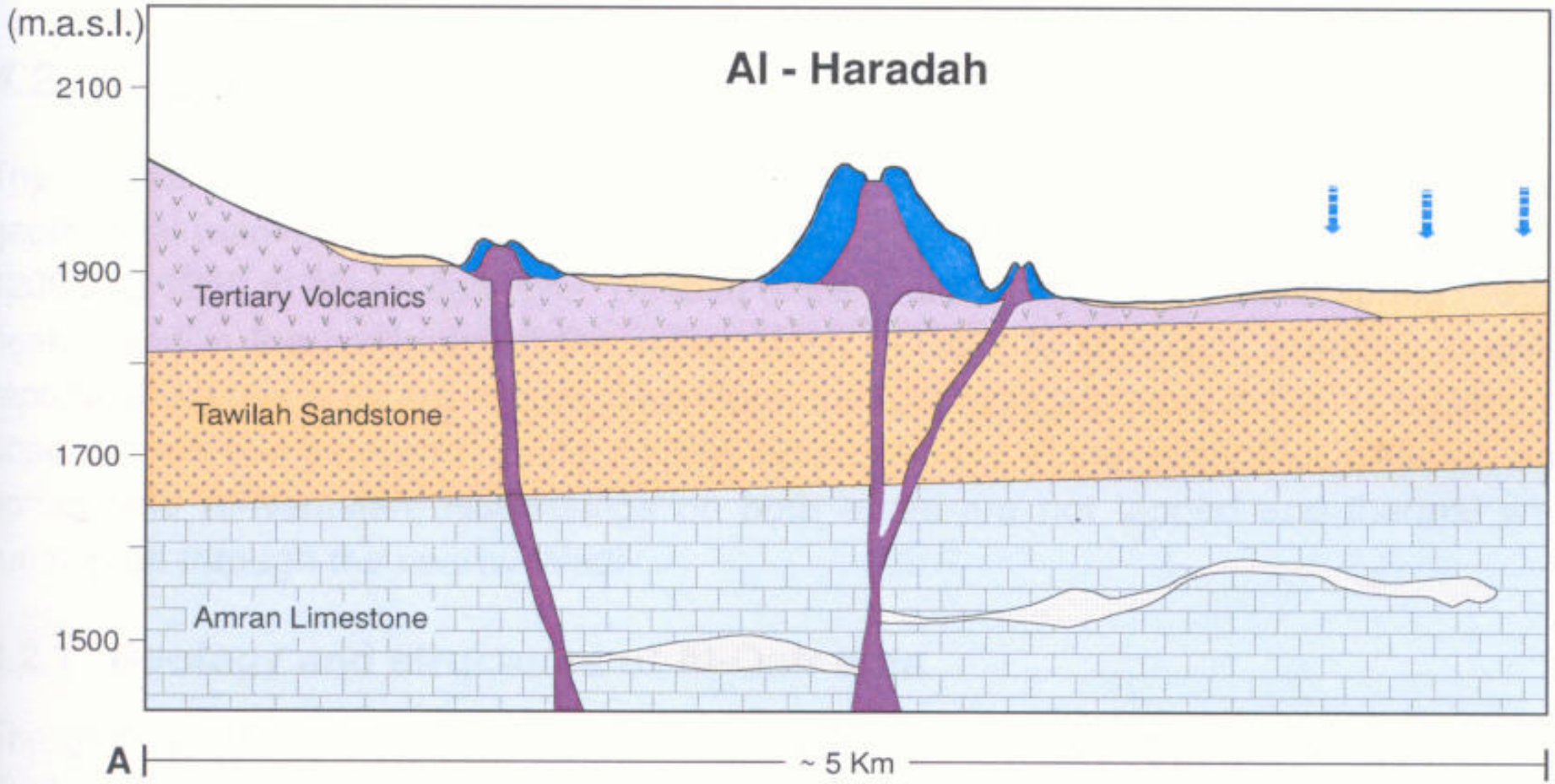
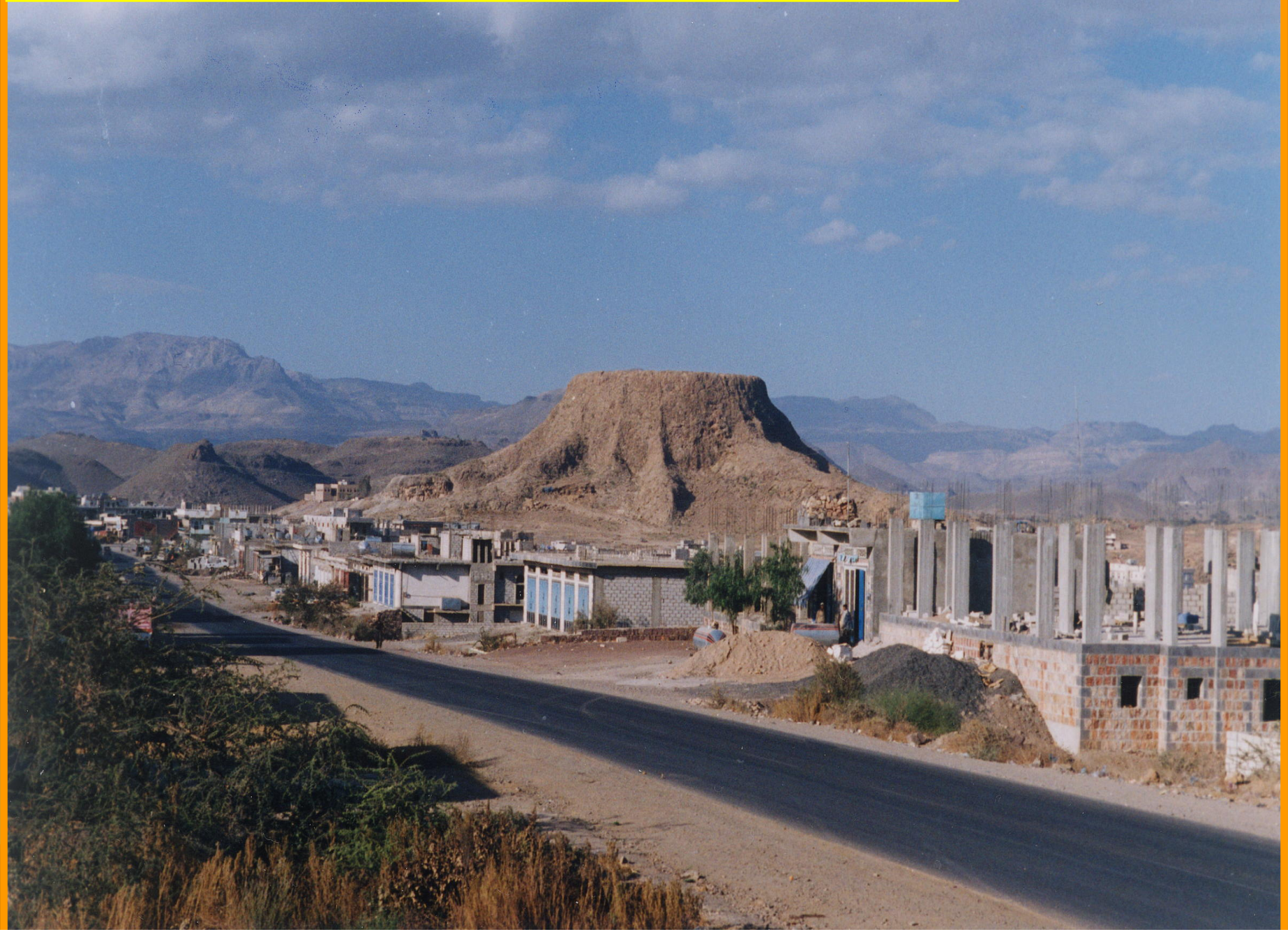


Fig. 4: Conceptual geological cross section of Hammam Damt area (modified after EL-ANBAA and FARA, 1993; ROBERTSON, 1993; HOUBEN, 2006). Location of profile is given in Figure 3.

Spectacular Travertine Cone at Damt



Water seen from the top of the cone

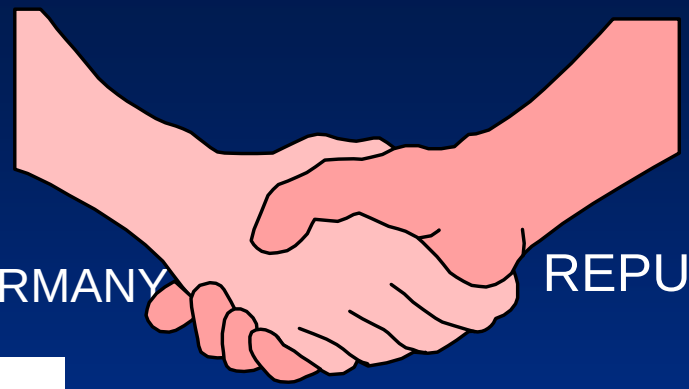
Meeting with Local Authorities

حفيظ الله قائداً،
وزعيماً وحدوياً
مخلصاً.

مستقبل افضل لاولادنا

Geothermal Exploration and Promotion in Yemen

GEF Trust Fund



FEDERAL REPUBLIC OF GERMANY

REPUBLIC OF YEMEN

GEOTHERM

Geological Survey and Mineral Resources Board

Ministry of Water and Environment

Institute for Geosciences and Natural Resources

BGR

Italy

CNR – National Research Council
Institute of Geosciences and Earth Resources

Very Recent

FINANCING PLAN ($)

PPG Project*	
GEF Total	1,000,000
Co-financing	
GEF IA/ExA	
Government	430,000
Others	670,000
Total	2,100,000

FOR JOINT PARTNERSHIP**
GEF PROJECT/COMPONENTS
(**MILESTONES DATES:**

PIF APPROVAL:	09/2007
MSP EFFECTIVENESS:	09/2008
MSP START:	09/2008
MSP CLOSING:	09/2011
TE/PC REPORT*	03/2012

“Current status and future prospects of Renewable Energy in Yemen”

Potential of Renewable Energies

Solar Energy	app. 2200 kWh/m2/a av. 8 sunshine hours / day
Wind Energy	mean annual wind speed app. 8.5 m/s (coastal areas)
Geothermal Energy	heat flow app. 60 mW/cm2

ideal “natural” conditions
for widespread use of RE

Present situation

Solar water heaters: **< 1000 units (2m², 120 l)**

2 local manufacturers

10 companies importing products from China/Europe

Photovoltaic systems:

Telecommunication sector **app. 1.5 MWp**

Private installations < **0.8 MWp**

App. 10 companies sharing the market

Wind turbines:

Private, decentralized generators (< 1kW) **< 70 kW**

No grid connected applications

Geothermal stakeholder gathering in ArGeo-1 Addis Ababa, December 2006

Gaining experience from Africa

And Attracting Europe for Support

National Seismological Center

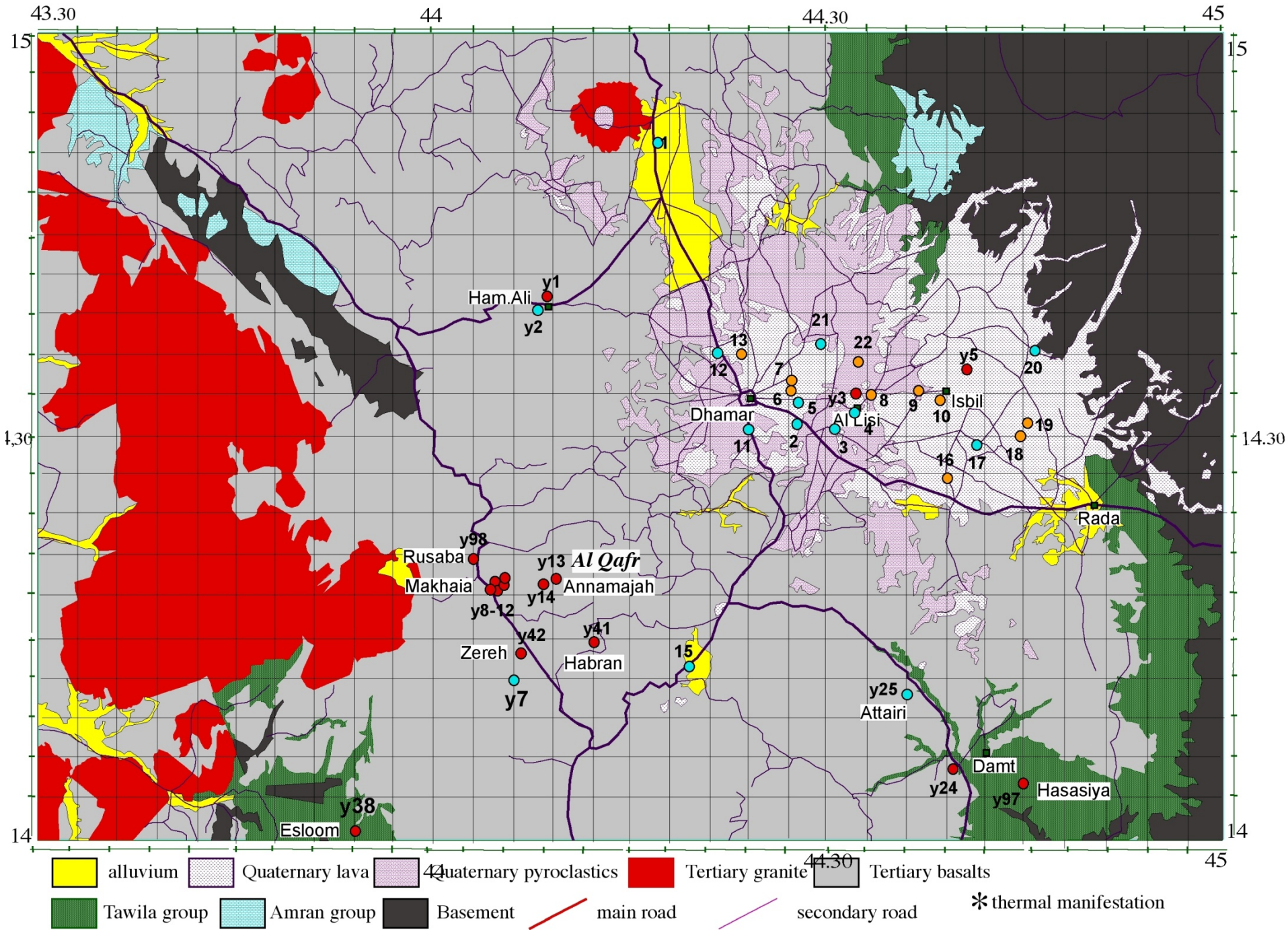
Looking from a distance

Italian Scientist Decided to make photo but he was photogra phed

Characteristics of Thermal Fluids

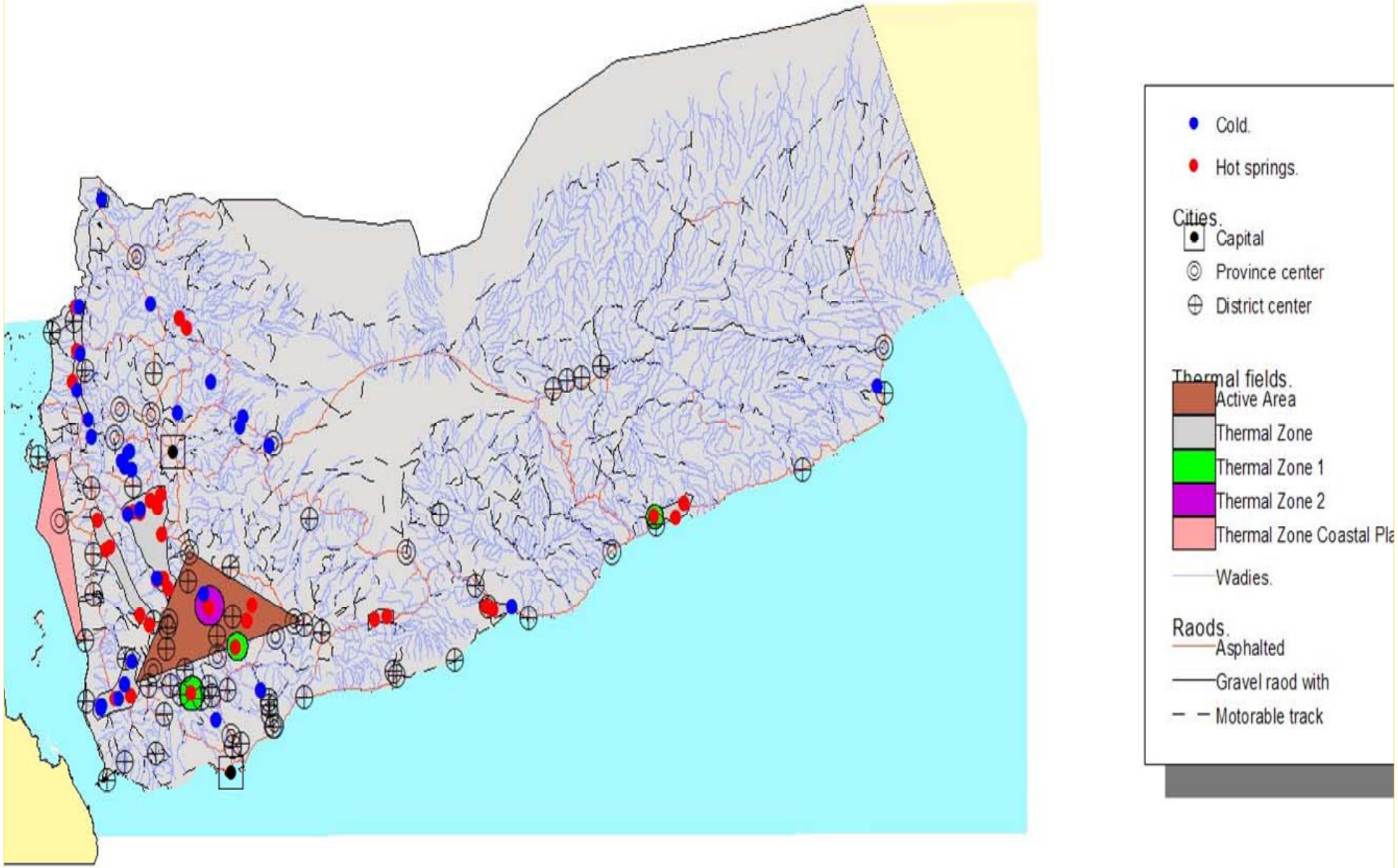
Samp.	Name of wells	Depth of wells	T°C	pH	cond.	TDS	Ca	Mg	Na	K	HCO_3	SO_4	Cl	NH_4	NO_3	B	SiO_2	F	Br	Li
4	Al Lisi well	150	29.0	7.01	1116	593	31.0	13.0	118	3.7	417	2	9	0.04	0.95	0.48	35.0	0.56	0.02	0.46
6	Jabel Al Dar	350	45.0	7.00	1267	874	25.0	7.5	212	4.4	616	6	3	0.06	0.03	0.06	27.0	0.12	0.02	0.14
7	Beer Gra'yah	120	30.0	7.94	593	400	9.0	9.0	91	3.9	282	3	2	0,01	0.04	0.31	15.0	0.10	0.03	0.02
8	Al Makhafish	160	33.0	7.18	963	550	40.0	15.0	91	5.1	390	3	6	0,01	0.87	0.59	30.0	0.24	0.04	0.27
9	Al Ku'aa	240	36.0	6.99	733	519	51.0	25.0	48	8.2	384	1	2	0,01	1.67	2.10	33.0	0.14	0.01	0.04
10	Isbil well	180	38.0	7.05	633	410	38.0	19.0	40	8.9	301	1	2	0,01	1.59	0.36	35.0	0.15	0.01	0.03
12	Al-Wesabi Factory	180	28.0	8.05	511	301	34.0	9.0	34	2.6	212	3	6	0,01	2.82	0.06	9.0	0.05	0.03	0.01
13	Al Meshooaf	200	43.0	7.83	344	170	19.0	3.5	21	2.1	121	1	2	0.02	1.28	0.22	10.0	0.05	0.01	0.01
15	Sanaban	240	35.0	7.80	427	304	7.5	4.2	71	1.7	215	2	3	0,01	0.11	0.06	11.0	0.45	0.03	0.01
16	Gomol	150	29.0	6.55	1412	731	57.0	19.0	115	9.0	515	2	14	0,01	0.91	1.70	42.0	0.18	0.04	0.25
17	Sainm	280	37.0	7.64	700	333	17.0	9.0	61	5.5	232	2	6	0,01	1.29	3.70	36.0	0.21	0.02	0.04
18	Al Haemedy	215	38.0	7.02	660	691	33.0	22.0	121	15.0	495	2	3	0,01	0.77	1.40	13.0	0.31	0.02	0.34
19	Al Abal	170	28.0	7.49	586	361	31.0	13.0	47	3.1	263	2	2	0,01	2.21	4.80	18.0	0.19	0.02	0.02
22	Al Mufajara	146	33.0	7.09	367	268	34.0	6.5	28	2.0	181	9	7	0.02	5.02	0.87	28.0	1.06	0.08	0.01
29	Mufaid	180	40.0	7.25	386	215	27.0	6.0	22	3.6	152	2	2	0.06	3.80	0.46	36.5	0.14	0.04	0.01
33	Beer Mudafer	210	42.0	7.29	586	473	52.0	15.0	54	8.4	303	20	21	0,01	25.00	0.17	39.2	1.30	0.17	0.02
34	Almarbou	230	43.0	7.58	510	368	40.0	12.0	41	8.3	229	19	19	0,01	22.00	0.34	45.2	1.14	0.16	0.02
36	Qafa Aldymah		31.0	6.32	365	266	30.0	9.5	29	1.7	168	13	15	0.03	20.00	0.34	29.0	3.20	0.14	0.05
38	Qsm Alwatham	270	35.0	6.86	371	275	33.0	8.2	25	5.0	152	37	15	0,01	0.98	0.11	44.2	1.80	0.15	0.02
49	Bani Rakapan	192	41.0	9.07	325	214	2.7	0.03	62	1.8	107	22	18	0,01	17.00	0.76	17.5	0.32	0.31	0.01
54	El Wathah	140	32.5	7.77	405	268	26.0	7.2	34	6.5	157	20	17	0,01	21.00	1.01	25.5	1.80	0.21	0.01
55	El Najd	240	39.0	7.77	471	299	21.0	10.0	59	6.4	160	25	18	0,01	39.00	0.60	18.8	3.40	0.24	0.02
61	El Bakalah	320	38.5	7.91	617	414	21.0	7.6	96	8.8	203	26	52	0,01	22.00	1.30	32.0	4.10	0.28	0.06
62	El Homaida	300	56.0	7.16	666	513	27.0	5.5	110	13.0	295	28	34	0.13	14.00	1.20	49.3	5.70	0.20	0.09
63	El Uglah	234	59.0	6.48	2120	1809	102.0	35.0	352	46.0	1019	124	131	0.26	9.80	5.70	25.0	2.30	0.63	0.88
67	El Harug	130	30.0	6.50	1760	1202	90.0	29.0	252	12.0	475	30	314	0.03	11.00	6.50	24.0	3.30	0.96	0.55
68	El Duhaimi		34.5	6.50	1986	1316	67.0	21.0	330	21.0	476	53	348	0.01	12.00	7.70	19.8	4.50	1.20	0.68
69	El Atheel	200	36.5	6.65	1885	968	121.0	39.0	112	17.0	426	48	205	0,01	15.00	2.20	31.5	0.91	0.76	0.09
72	Taher	150	21.0	7.28	923	438	72.0	14.0	30	2.4	268	32	20	0.03	11.00	0.68	8.5	0.22	0.24	0.01

Chemical composition of geothermal waters Al-Lisi - Isbel area


43.30
44
44.30
45
15
14.30
14
Ham.Ali
y1
y2
Dhamar
Al Lisi
Isbil
Rada
Rusaba
y98
Makhaia
y8-12
y13
Al Qafr
Annamajah
y14
y42
Zereh
y7
y41
Habran
y25
Attairi
Damt
y24
y97
Hasasiya
y38
Esloom
alluvium
Quaternary lava
Quaternary pyroclastics
Tertiary granite
Tertiary basalts
Tawila group
Amran group
Basement
main road
secondary road
thermal manifestation

Here the Temperature is 97 ºC

Promising Geothermal Fields



Yemen, Icelandic REI sign document to invest in generating electricity by geothermal

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SANA'A, April 06 (Saba)- G C for Electricity signed on Sunday a document with Icelandic Reykjavik Energy (REI) to generate electricity.

The company would conduct a study for the sources of geothermal at al-Lisi mountain in Dhmmar governorate and drilling works in the location.

The company would invest in setting up the first geothermal station in the mountain at a capacity of 100 Mgw after finalizing the study

a meeting co-chaired by Minister of Electricity and Energy Mustafa Bahran and his Icelandic counterpart Ossur Skarphéinsson

renewable sources of energy in Yemen : solar power, geothermal and wind power.

efforts of Yemen to utilize these sources to generate electricity to meet the growing needs for energy in the country.

Thank You for Your Attention