

Upper Mega Aquifer (Arabian Peninsula) – groundwater delineation of sub-aquifer interaction by hydrochemical and REE+Y patterns



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Arabian Peninsula – Resources

inland-aquifer

hyper-arid

low population

local (intense) agriculture

exploitation deep aquifers
with fossile (???) water

uncertainties: volume and
recharge of resources

coastal-aquifers

semi-arid

dense population

intense agriculture

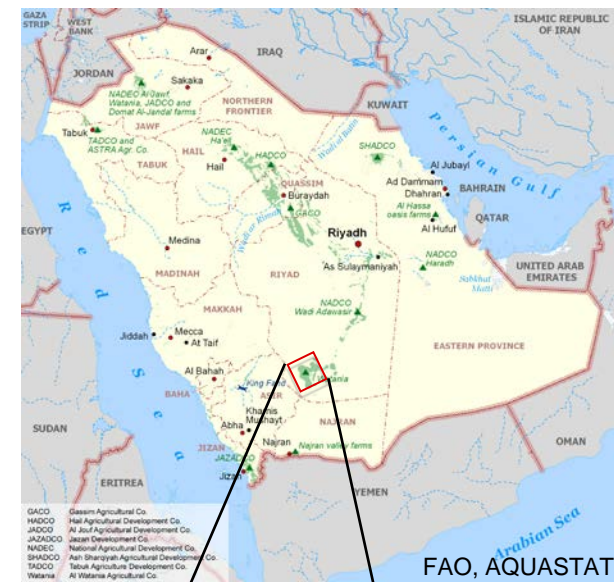
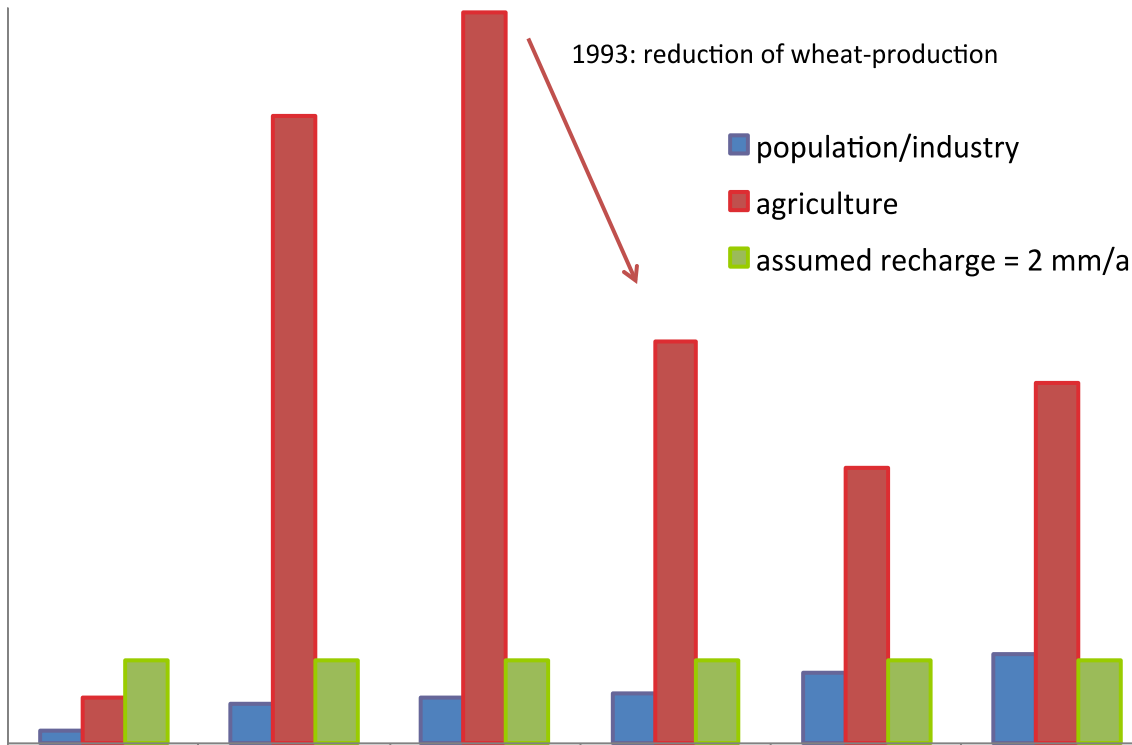
exploitation shallow aquifers

overuse results in
seawater-intrusion

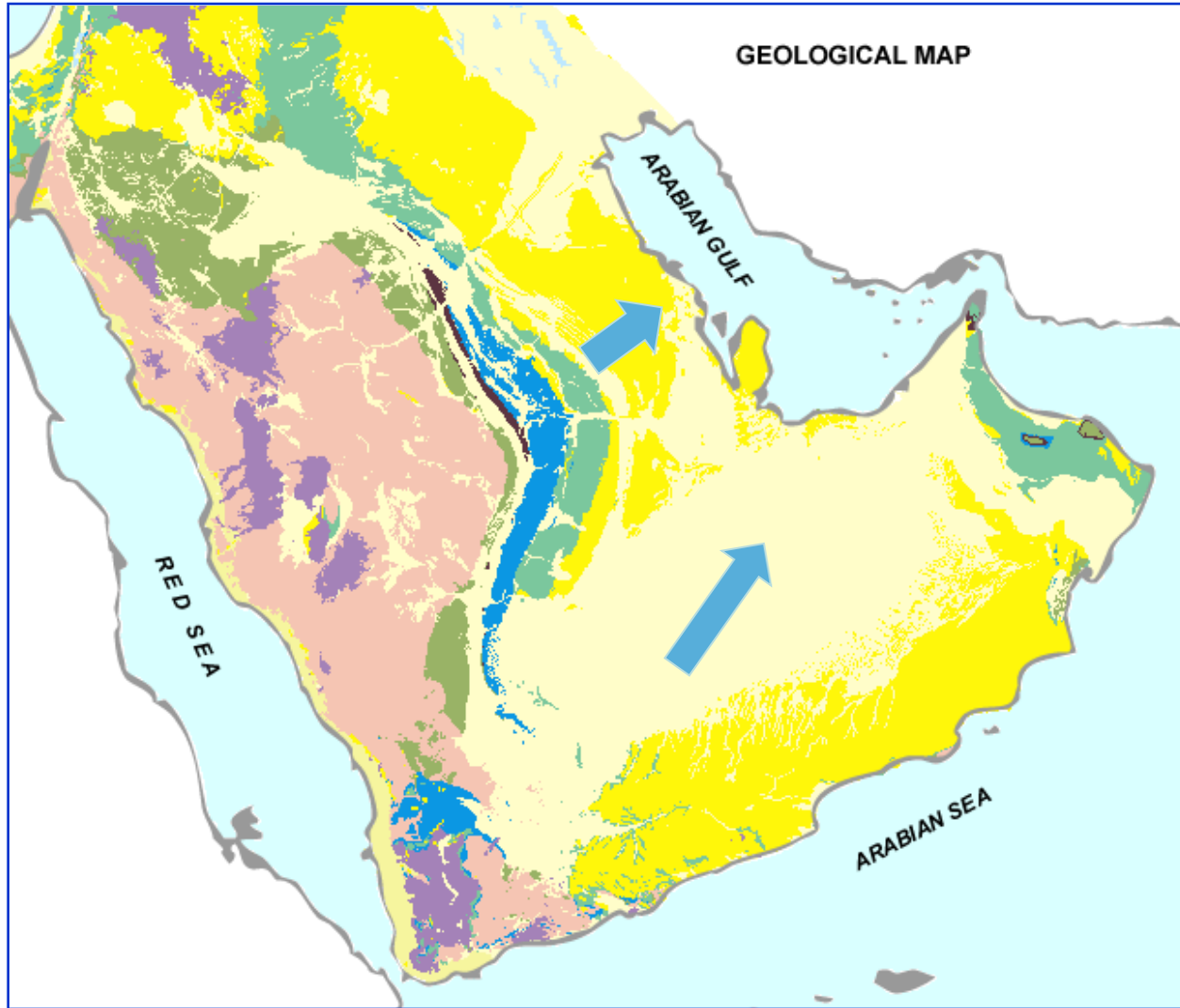
Google Earth

demand vs. recharge

total stored water volume:	500 km ³
demand by agriculture:	15 km ³ /a
desalinisation of seawater	1.3 km ³ /a
assumed groundwater recharge	2.4 km ³ /a ?



Geological frame of the Upper Mega Aquifer

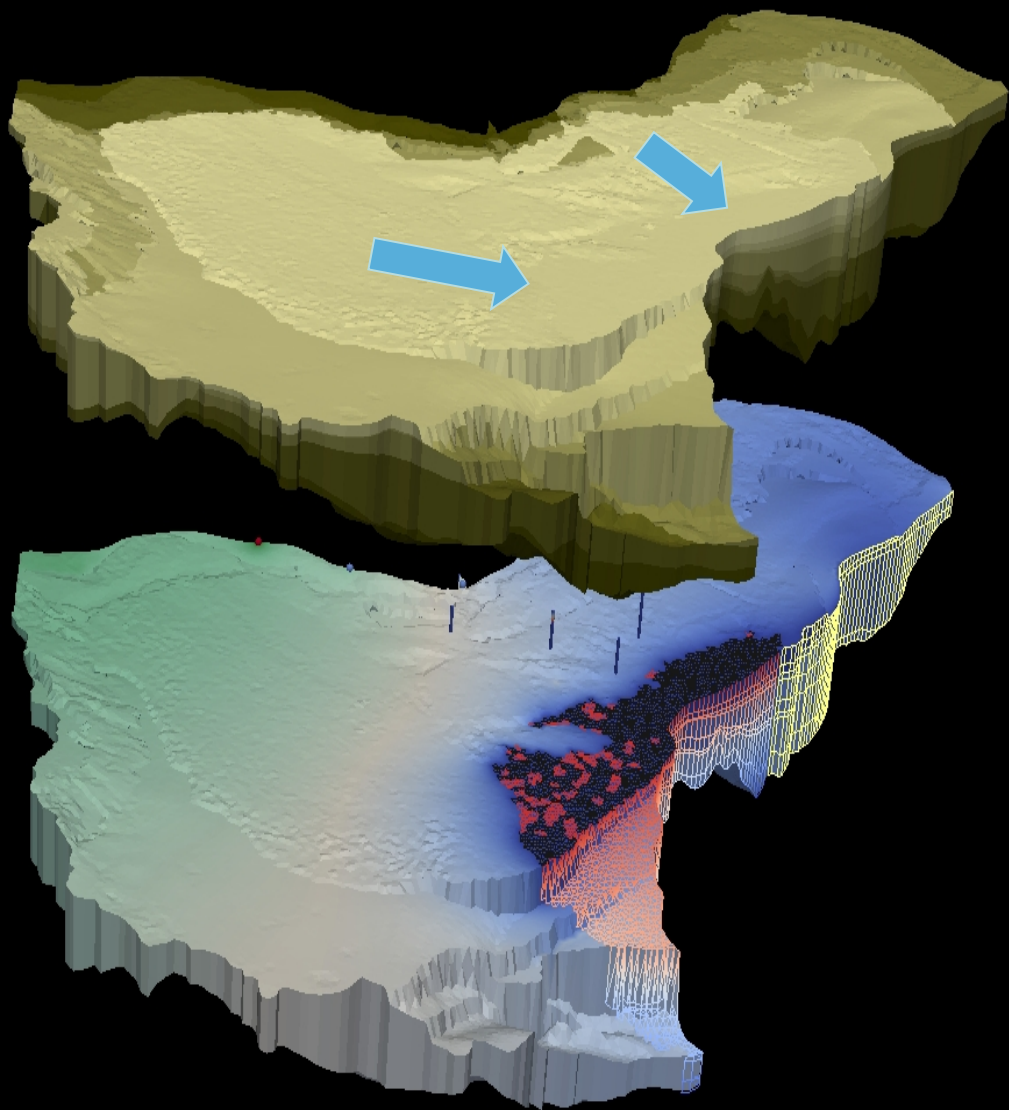


- Quaternary
- relevant aquifers**
 - Neogene, Dammam, Umm Er Radhumma
 - Wasia, Biyadh

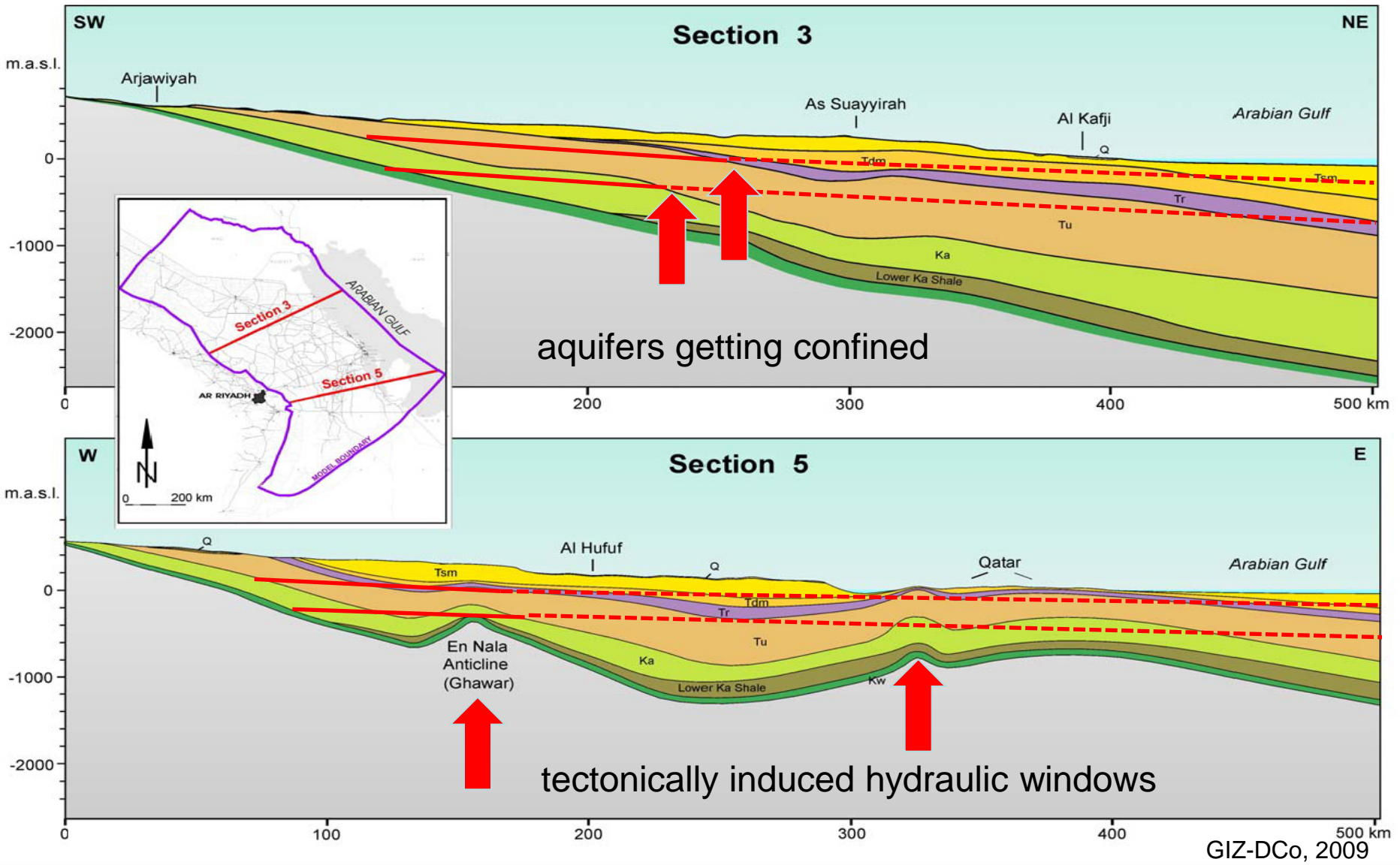
Geological frame of the Upper Mega Aquifer

Age	Formation	Lithology	Thickness (m)	Aquifer		K [m/s]
				North	South	
NEOGENE	Quaternary	surface deposits		Neogene		$1 \cdot 10^{-7} - 1 \cdot 10^{-2}$
	Plio.	Hofuf				
	Miocene	Dam	140-500			
		Hadruk				
PALEOGENE	Eocene	Dammam	120-450	Dammam		$1 \cdot 10^{-6} - 1 \cdot 10^{-2}$
		Rus	100-270			
	Paleocene	Umm Er Radhuma	405-800	Umm Er Radhuma		$1 \cdot 10^{-7} - 1 \cdot 10^{-2}$
		Aruma	200-250			
CRETACEOUS	Wasia	300-500	Wasia - Biyadh		$3 \cdot 10^{-4} - 5 \cdot 10^{-4}$	
	Shu'aiba	<60				
	Biyadh	300-500				

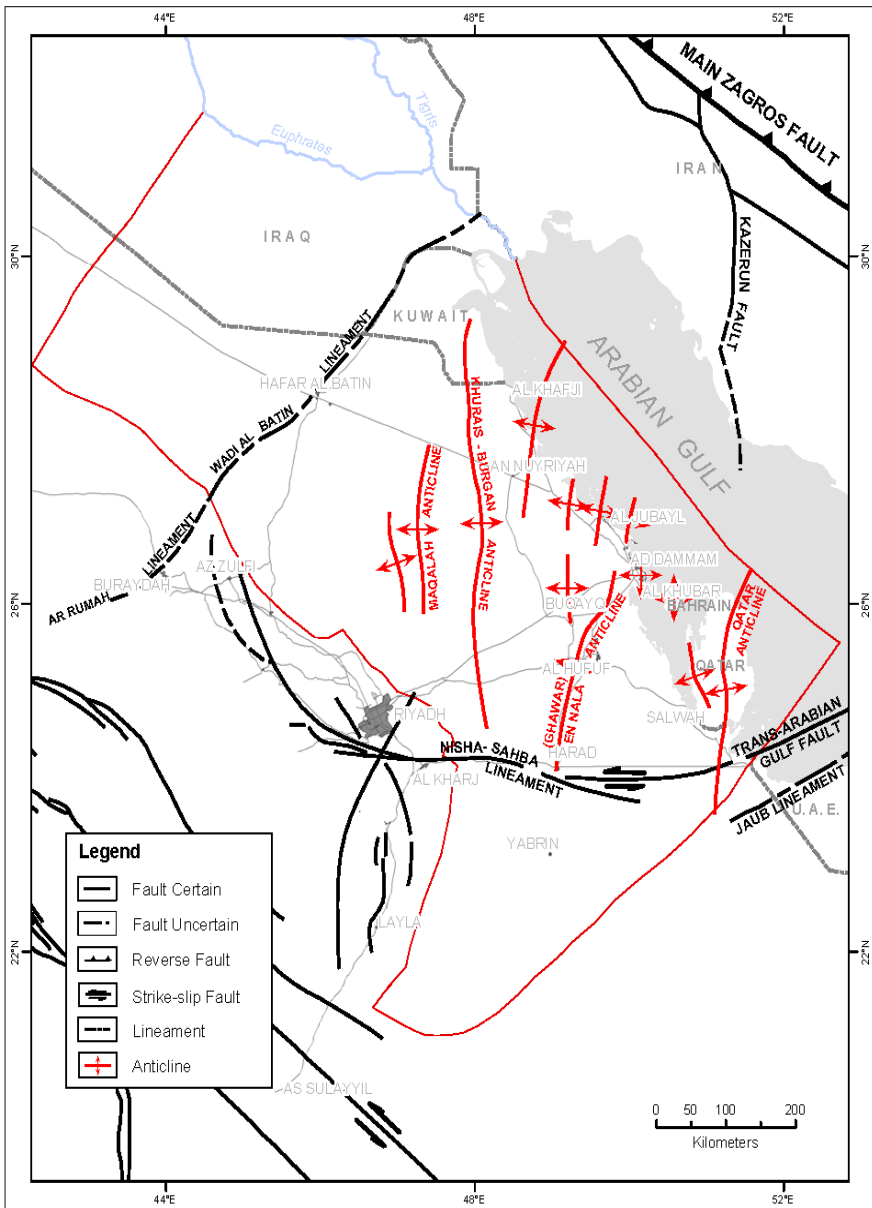
GIZ-DCo, 2009



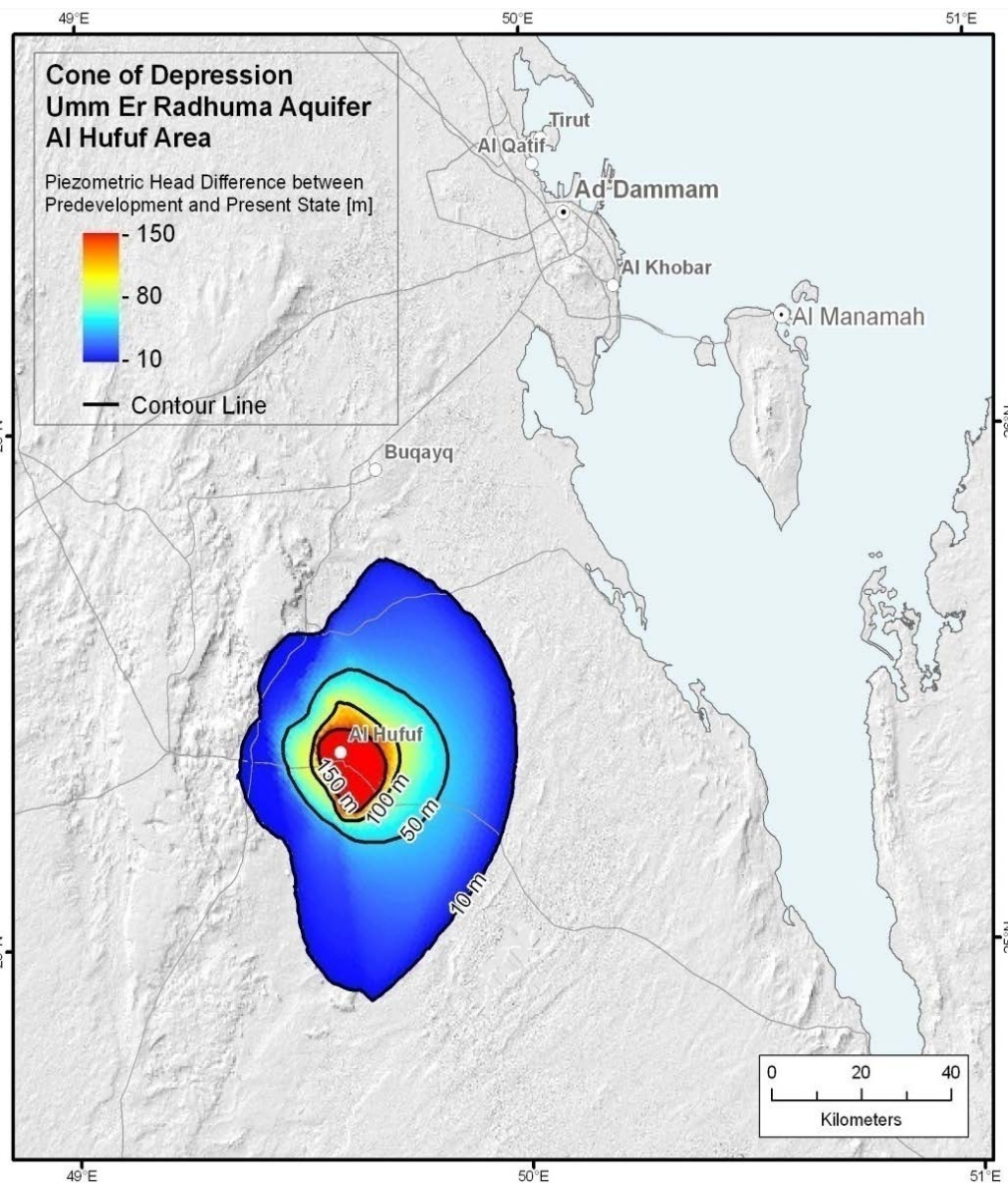
Geological frame of the Upper Mega Aquifer



GIZ-DCo, 2009



GIZ-DCo, 2009



GIZ-DCo, 2009

analyses of aquifer characteristics

48°0'0"E

50°0'0"E



study area



26°0'0"N

26°0'0"N

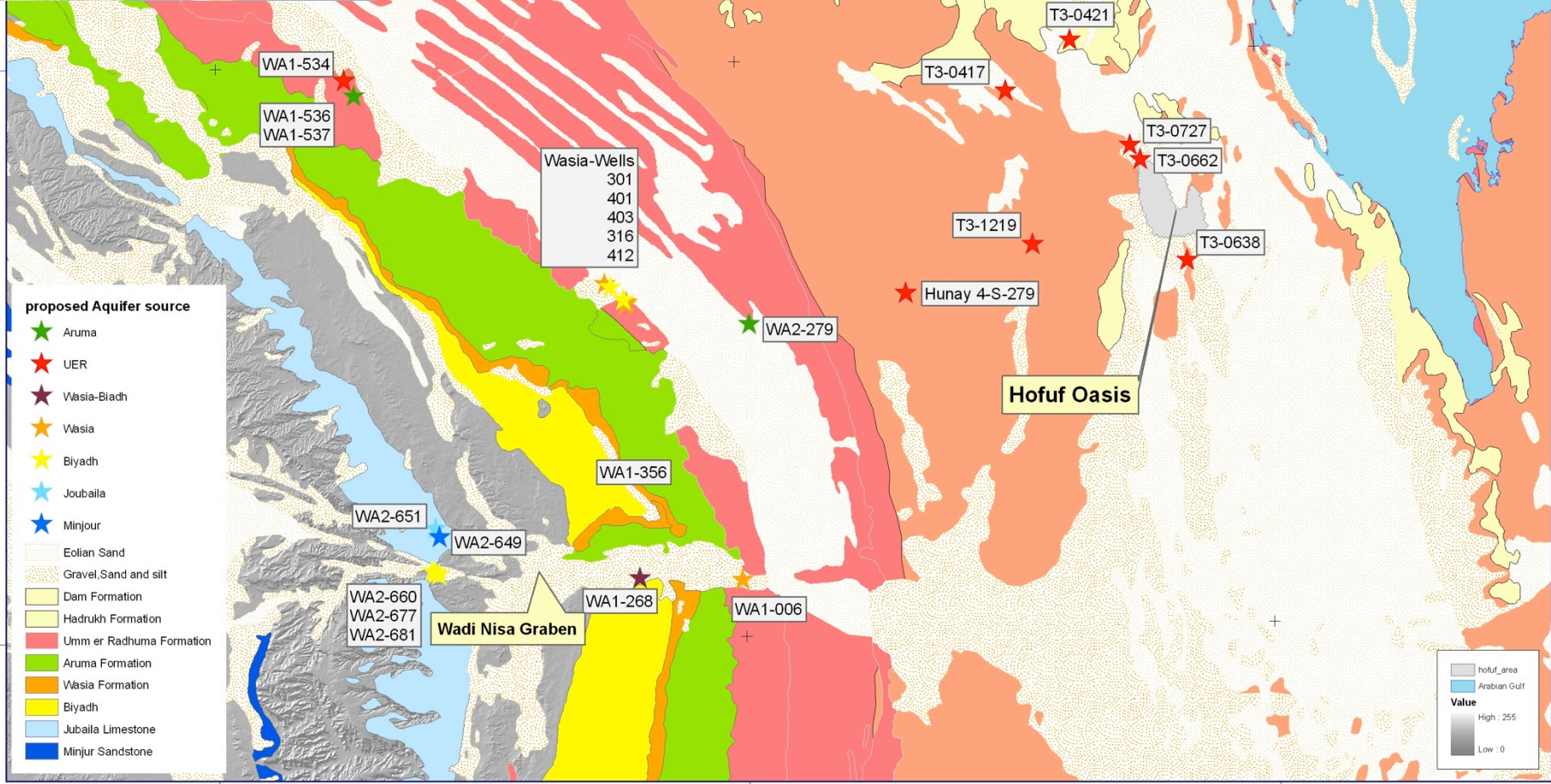
24°0'0"N

24°0'0"N

46°0'0"E

48°0'0"E

50°0'0"E



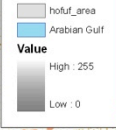
proposed Aquifer source

- ★ Aruma
- ★ UER
- ★ Wasia-Biadh
- ★ Wasia
- ★ Biyadh
- ★ Joubaila
- ★ Minjour
- Eolian Sand
- Gravel, Sand and silt
- Dam Formation
- Hadruk Formation
- Umm er Radhuma Formation
- Aruma Formation
- Wasia Formation
- Biyadh
- Jubaila Limestone
- Minjur Sandstone

Wasia-Wells	
301	
401	
403	
316	
412	

Wadi Nisa Graben

Hofuf Oasis



What happens to a drop of rain when it contacts sediments or rocks?



Composition is changed by:

dissolution of easily accessible and soluble salts

solubility: silicates < calcite < gypsum < halite

Ion exchange

Adsorption

Alteration minerals

Outstanding features of REY

- abundant as uranium
- occur as tracers, particularly in calcite and gypsum which are important for the mineralization of natural waters.
- behave chemically similar, but are slightly fractionated in geochemical processes but never separated

1 H hydrogen 1.007 84(2)																	18 He helium 4.002 603(2)																		
3 Li lithium 6.941(2)	4 Be beryllium 9.012 183(2)											5 B boron 10.811(7)	6 C carbon 12.0109(7)	7 N nitrogen 14.0064(2)	8 O oxygen 15.999(4)	9 F fluorine 18.998 432(2)	10 Ne neon 20.1797(6)																		
11 Na sodium 22.989 769(2)	12 Mg magnesium 24.30508(6)											13 Al aluminum 26.981 538(6)	14 Si silicon 28.0855(3)	15 P phosphorus 30.973 761(2)	16 S sulfur 32.065(5)	17 Cl chlorine 35.453(6)	18 Ar argon 39.948(1)																		
19 K potassium 39.0983(1)	20 Ca calcium 40.078(4)	21 Sc scandium 44.955 912(6)	22 Ti titanium 47.88(7)	23 V vanadium 50.9415(1)	24 Cr chromium 51.9961(6)	25 Mn manganese 54.938044(3)	26 Fe iron 55.845(2)	27 Co cobalt 58.933 195(5)	28 Ni nickel 58.6934(4)	29 Cu copper 63.546(3)	30 Zn zinc 65.38(4)	31 Ga gallium 69.723(1)	32 Ge germanium 72.64(1)	33 As arsenic 74.921 602(2)	34 Se selenium 78.96(4)	35 Br bromine 79.904(1)	36 Kr krypton 83.799(2)																		
37 Rb rubidium 85.4678(3)	38 Sr strontium 87.62(1)	39 Y yttrium 88.905 84(2)	40 Zr zirconium 91.224(2)	41 Nb niobium 92.906 38(2)	42 Mo molybdenum 95.94(1)	43 Tc technetium 97.907(2)	44 Ru ruthenium 101.07(2)	45 Rh rhodium 102.905 5(2)	46 Pd palladium 106.42(1)	47 Ag silver 107.8682(1)	48 Cd cadmium 112.411(2)	49 In indium 114.818(5)	50 Sn tin 118.710(1)	51 Sb antimony 121.760(1)	52 Te tellurium 127.60(3)	53 I iodine 126.905 47(3)	54 Xe xenon 131.29(4)																		
55 Cs caesium 132.905 45(3)	56 Ba barium 137.327(1)	lanthanoids		72 Hf hafnium 178.49(2)	73 Ta tantalum 180.94788(1)	74 W tungsten 183.84(1)	75 Re rhenium 186.207(1)	76 Os osmium 190.23(2)	77 Ir iridium 192.222(1)	78 Pt platinum 195.084(1)	79 Au gold 196.966 569(4)	80 Hg mercury 200.59(2)	81 Tl thallium 204.38(3)	82 Pb lead 207.2(1)	83 Bi bismuth 208.980 4(1)	84 Po polonium [209]	85 At astatine [210]	86 Rn radon [222]																	
87 Fr francium [223]	88 Ra radium [226]	actinoids		104 Rf rutherfordium [261]	105 Db dubnium [262]	106 Sg seaborgium [266]	107 Bh bohrium [264]	108 Hs hassium [265]	109 Mt meitnerium [268]	110 Ds darmstadtium [271]	111 Uu ununium [272]																								
																		57 La lanthanum 138.905(2)	58 Ce cerium 140.12(1)	59 Pr praseodymium 140.907 6(2)	60 Nd neodymium 144.24(1)	61 Pm promethium [145]	62 Sm samarium 150.36(2)	63 Eu europium 151.964(1)	64 Gd gadolinium 157.25(1)	65 Tb terbium 158.925 3(2)	66 Dy dysprosium 162.500(1)	67 Ho holmium 164.930 32(2)	68 Er erbium 167.258(1)	69 Tm thulium 168.934 2(2)	70 Yb ytterbium 173.054(2)	71 Lu lutetium 174.967(1)			
89 Ac actinium [227]	90 Th thorium [232]	91 Pa protactinium [231]	92 U uranium [238]	93 Np neptunium [237]	94 Pu plutonium [244]	95 Am americium [243]	96 Cm curium [247]	97 Bk berkelium [247]	98 Cf californium [251]	99 Es einsteinium [252]	100 Fm fermium [257]	101 Md mendelevium [258]	102 No nobelium [259]	103 Lr lawrencium [260]																					

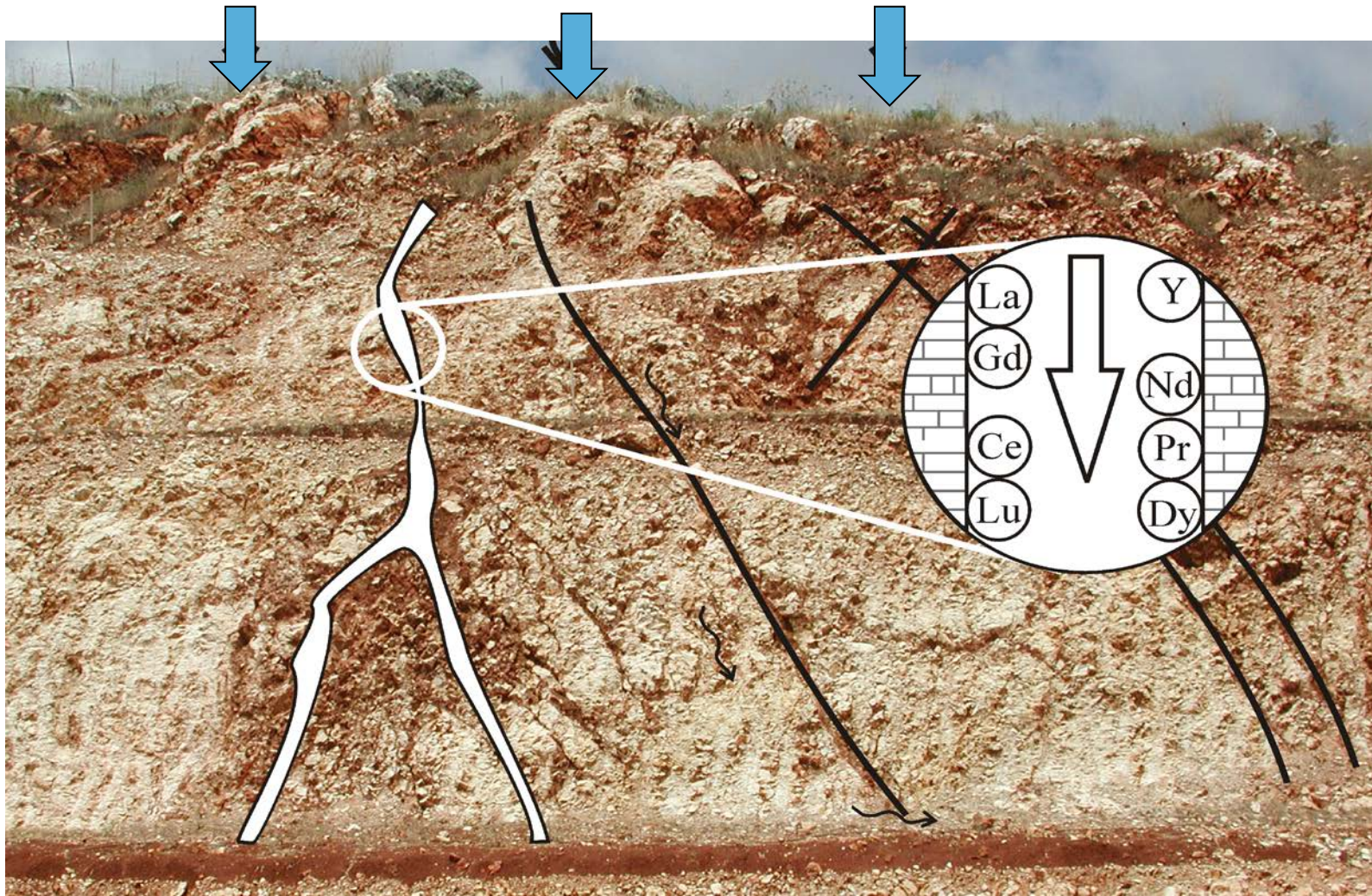
La/Ca weight ratio:

Limestone (calcite): $\sim 10^{-6}$

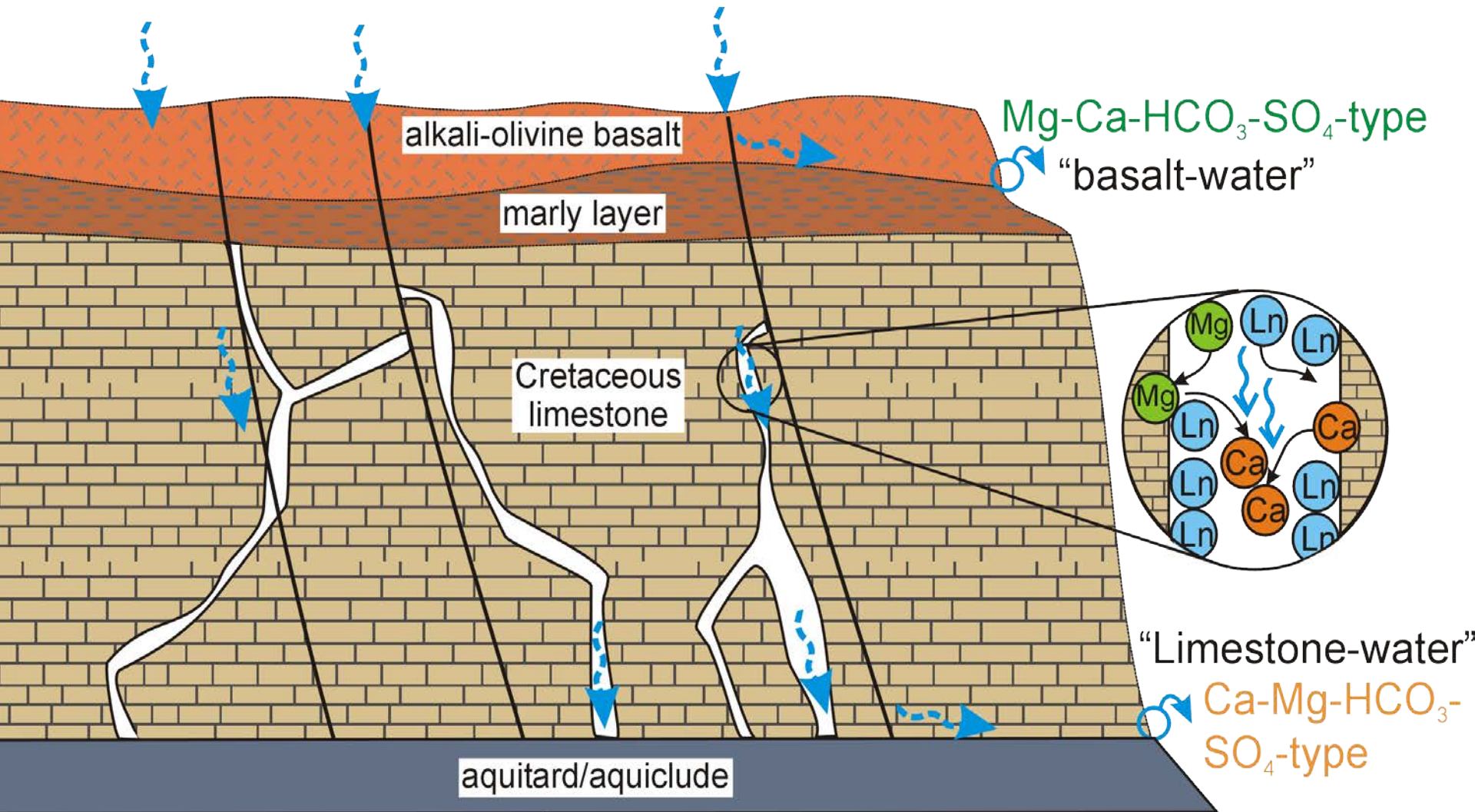
Groundwater from limestones: $\sim 10^{-8}$

High-charged trace elements reach saturation in water much earlier than their carriers.

Adsorption of trace elements – covering aquifer walls

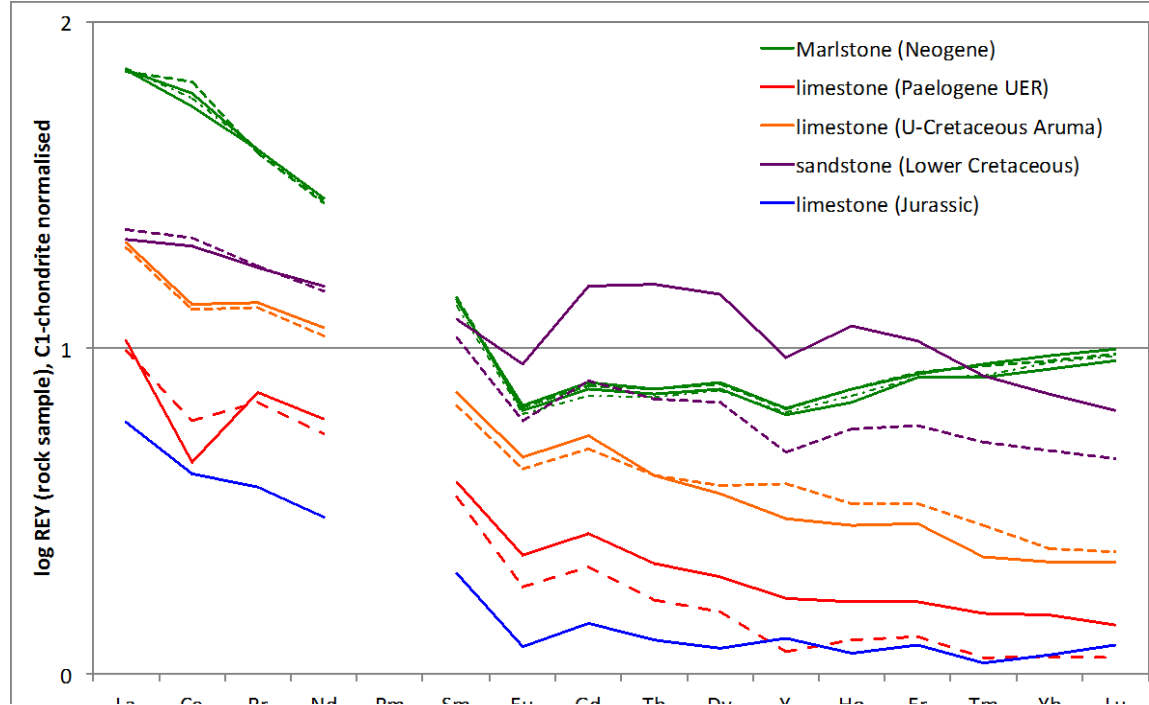


trans-aquifer flow: keeping the origin in mind

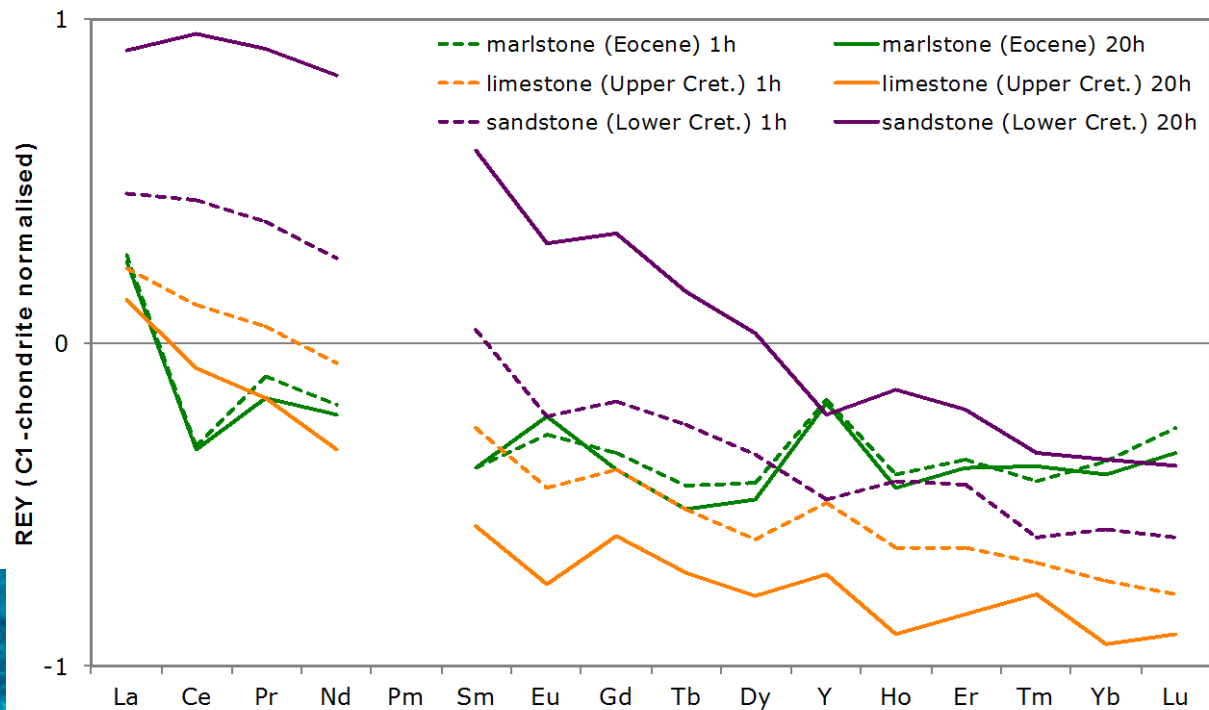


REY-fingerprints of rocks and leachates

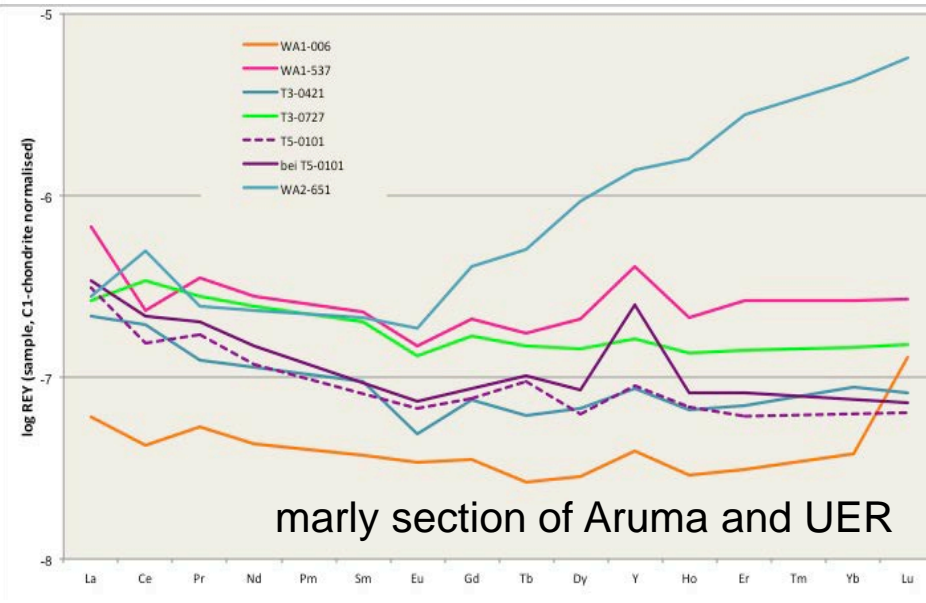
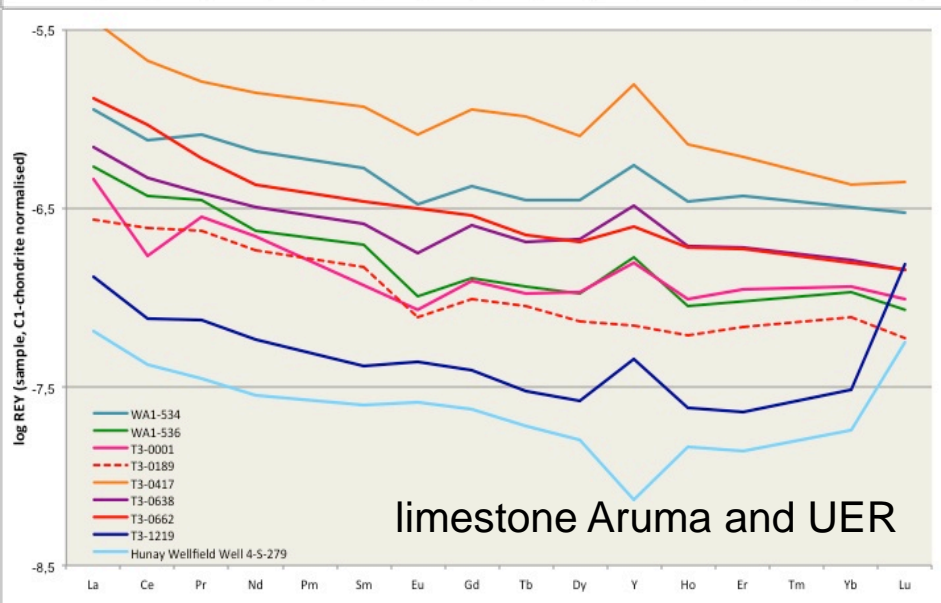
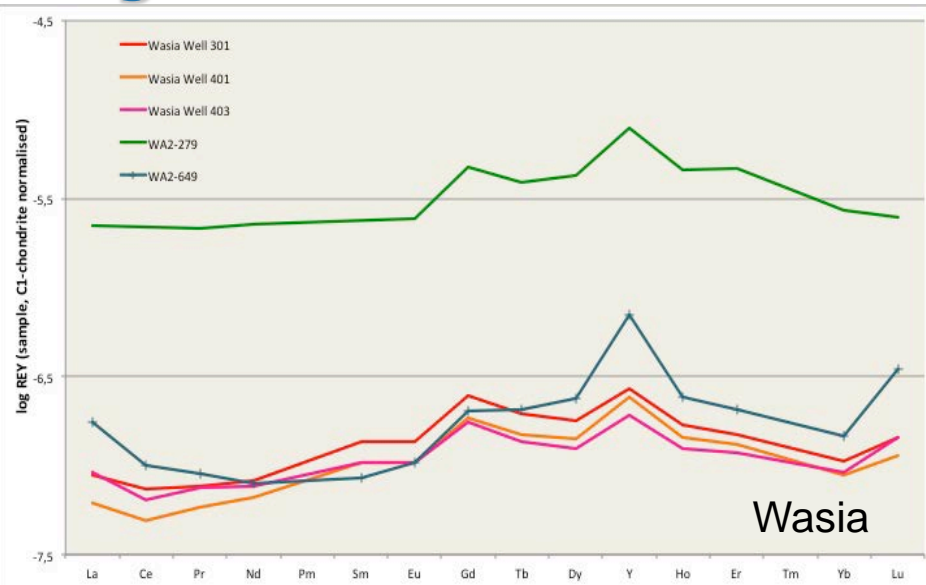
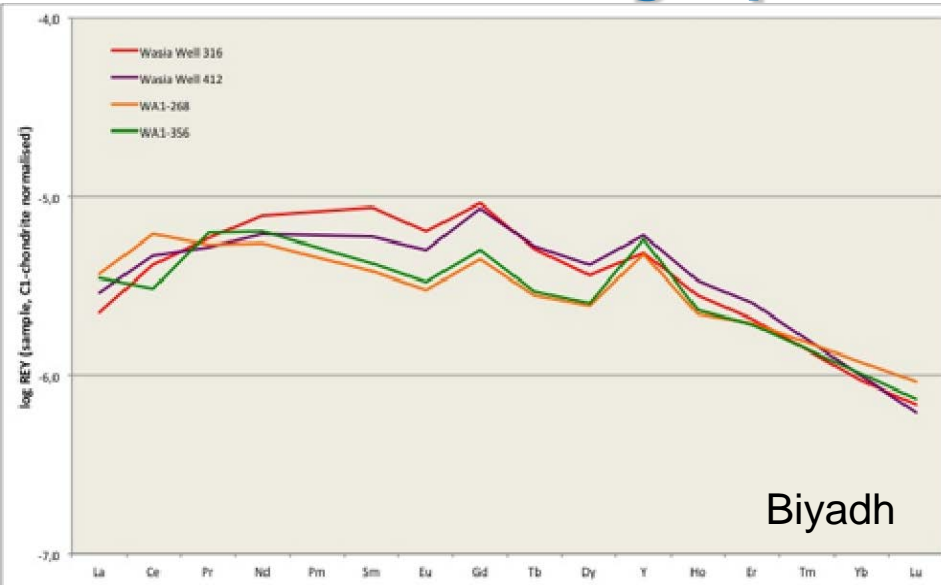
REY-pattern of local aquifer rocks



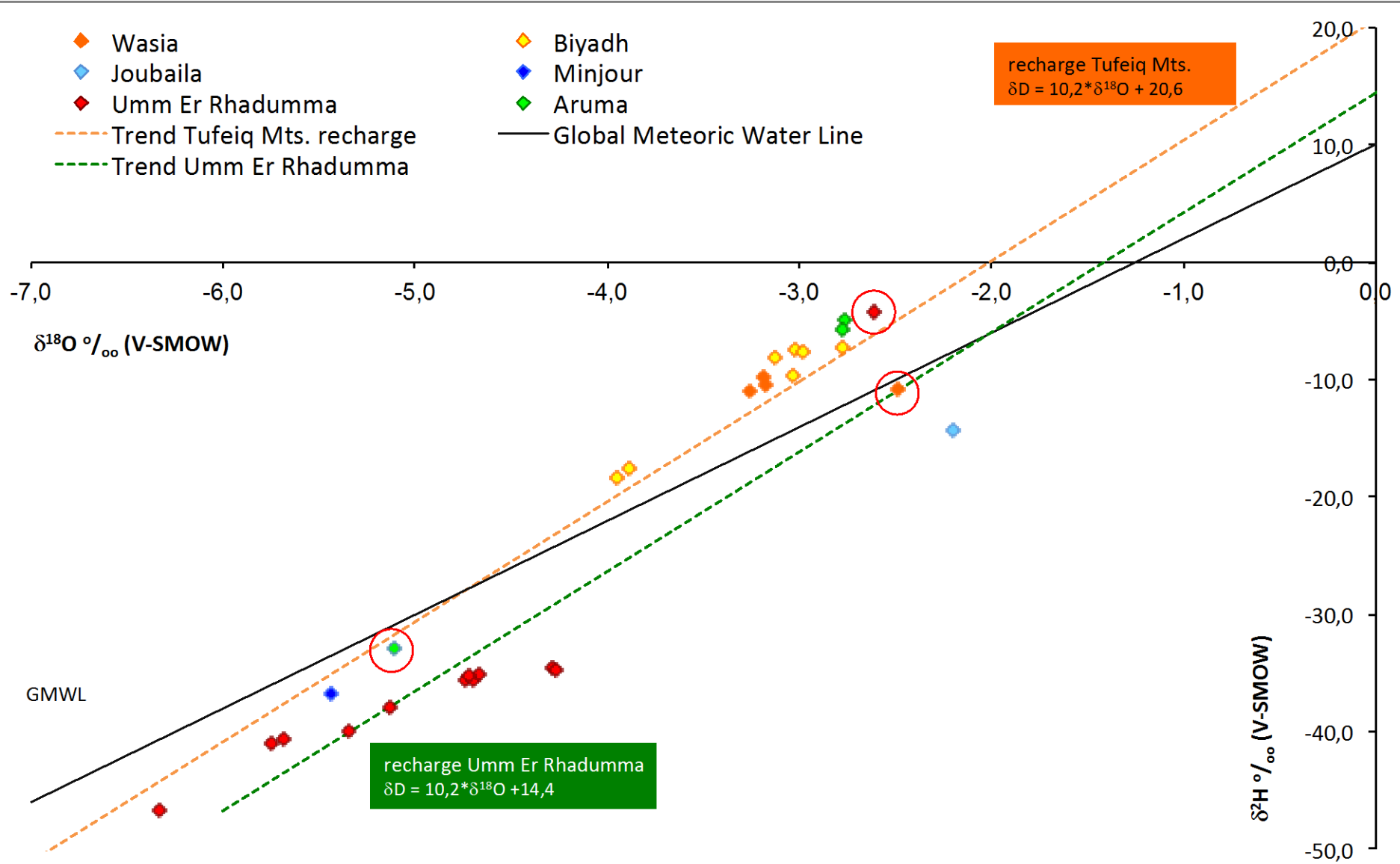
REY-pattern of **leachates** of local aquifer rocks



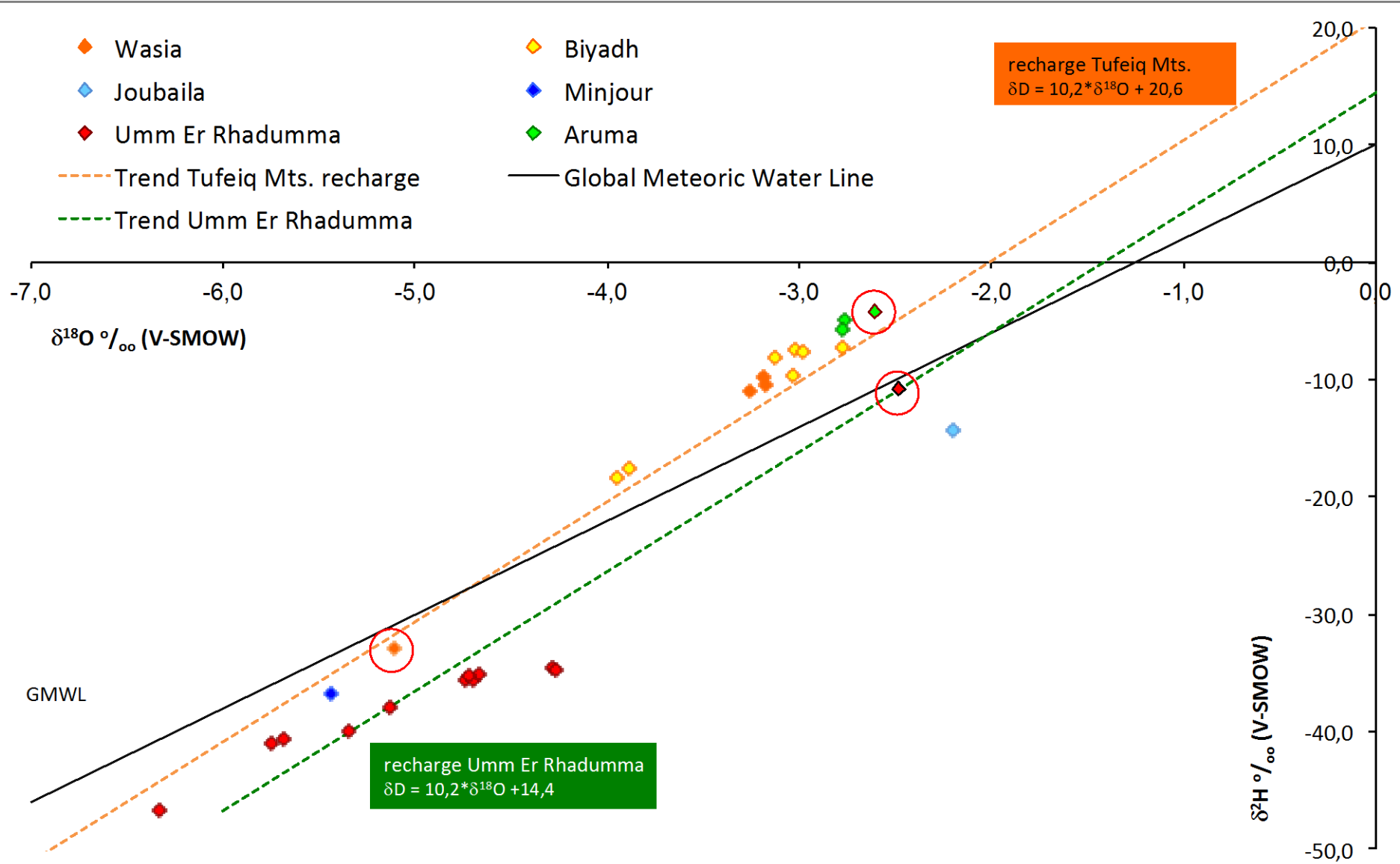
REY-fingerprints of groundwaters



stable isotope composition acc. to well DB



stable isotope composition (acc. REE+Y)

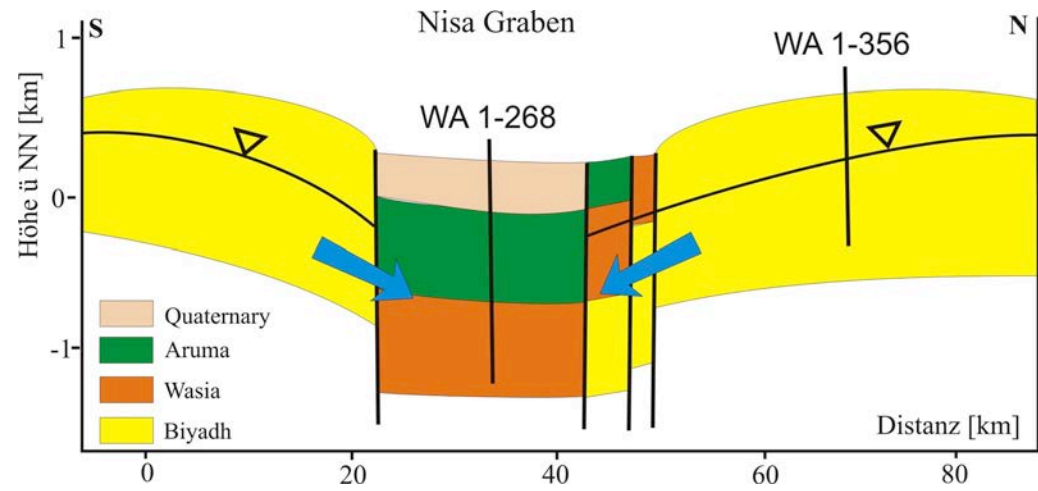
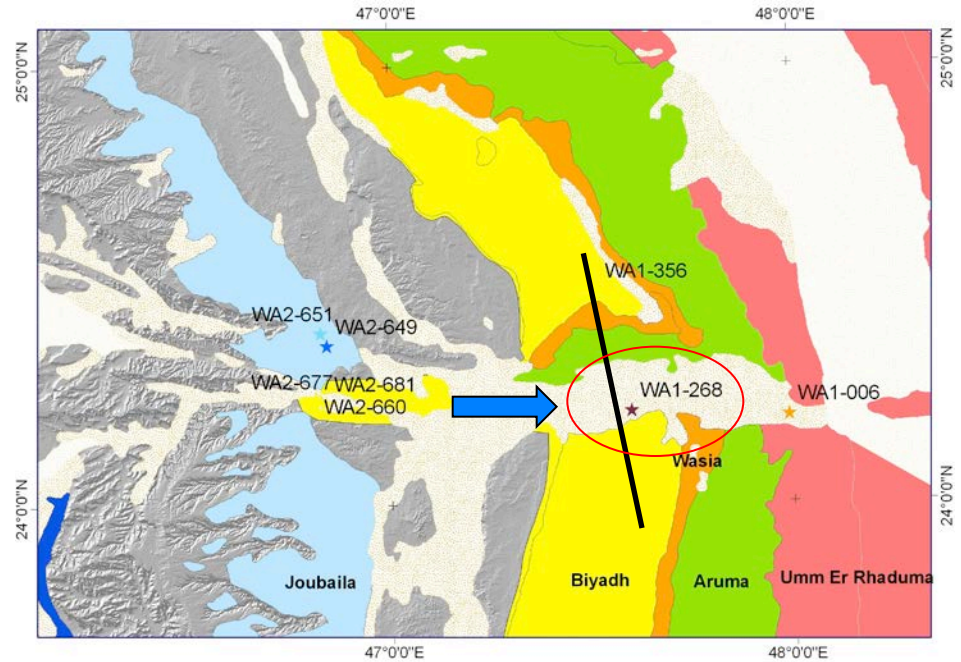


Example: Reconfiguration of adjacent aquifers

Well WA 1-268 is considered to be from Wasia-Biyadh Fmt.

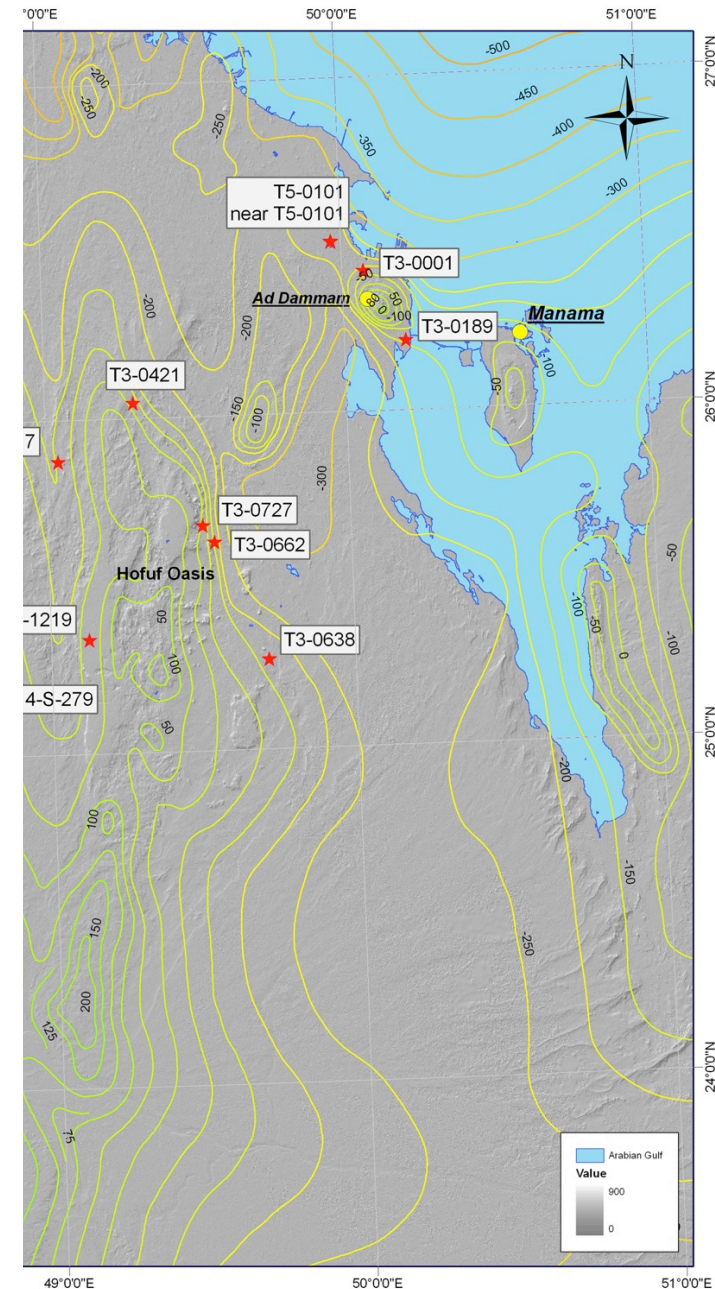
Recharge area additionally in the graben shoulders, because:

- REY indicate recharge in outcropping Biyadh Fmt.
- Stable isotopes contradict Upper Nisa Graben as only recharge location



Comparison aq. of abstraction vs. origin

well	aquifer of extraction	REY-indication for source rocks
Wasia Well 301	Wasia	Wasia
Wasia Well 401	Wasia	Wasia
Wasia Well 403	Wasia	Wasia
Wasia Well 412	Biyadh	Biyadh
Wasia Well 316	Biyadh	Biyadh
WA2-660	Biyadh	Wasia-Biyadh
WA2-677	Biyadh	Wasia-Biyadh
WA2-681	Biyadh	Wasia-Biyadh
WA1-268	Wasia-Biyadh	Biyadh
WA1-006	Aruma	UER+Biyadh
WA1-356	Biyadh	Biyadh
WA2-651	Joubaila	Joubaila
WA2-649	Minjour	Wasia
WA2-279	Aruma	Wasia
Hunay Wellfield Well 4-S-279	UER	UER
T3-1219	UER	UER
T3-0638	UER	UER+Dammam
T3-0662	UER	UER+Dammam
T3-0727	UER	UER+Dammam
T3-0189	UER	UER+Dammam
T5-0101	Wasia	UER+Dammam
near T5-0101	Wasia	UER+Dammam
T3-0001	UER	UER+Dammam
T3-0421	UER	UER+Dammam
T3-0417	UER	UER
WA1-536	Aruma	UER
WA1-534	UER	UER
WA1-537	Aruma	Aruma





Thank you for your attention!