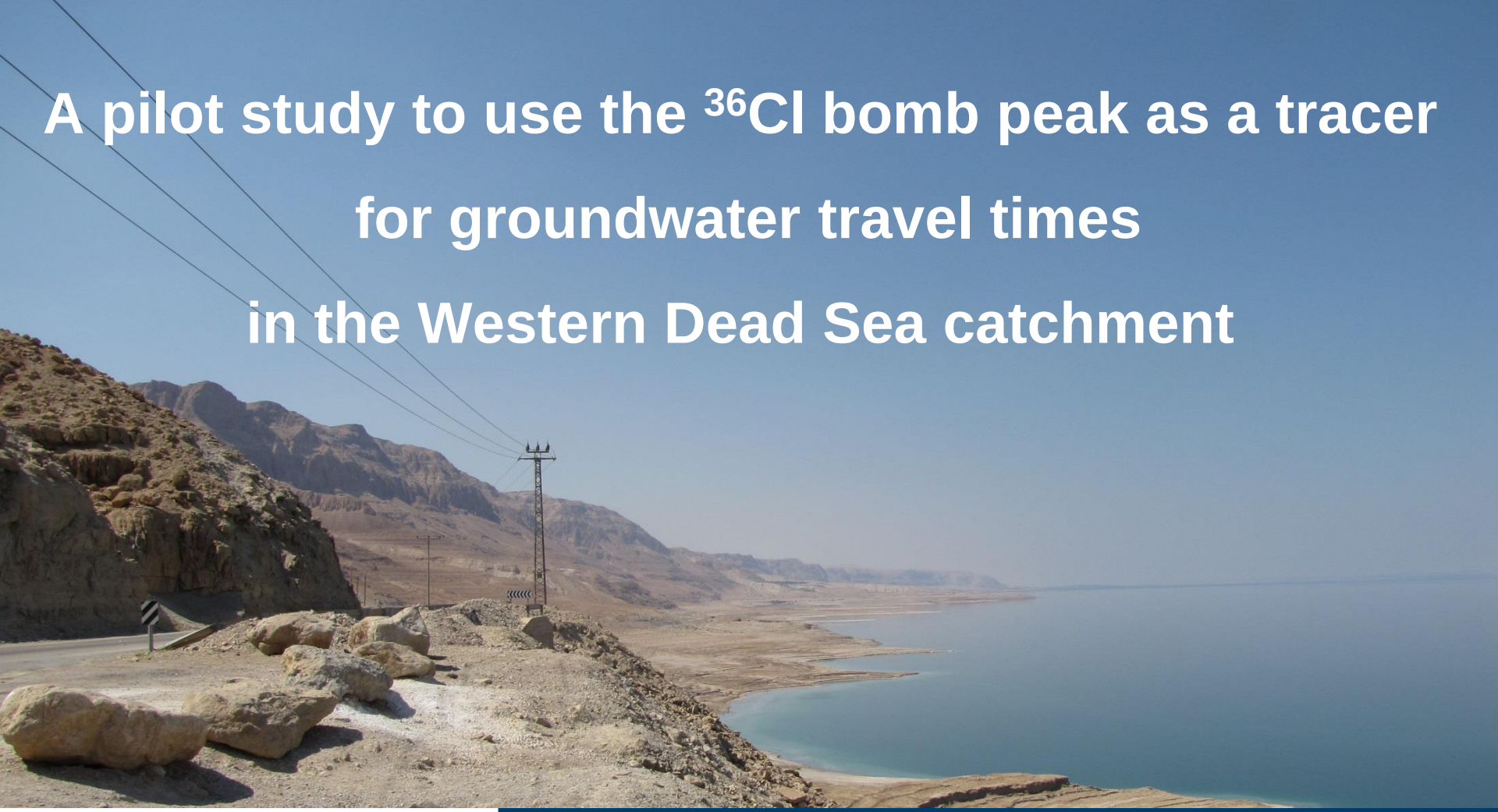
A pilot study to use the ^{36}Cl bomb peak as a tracer for groundwater travel times in the Western Dead Sea catchment



Cornelia Wilske, Axel Suckow, Tino Roediger, Stefan Geyer, Stephan M. Weise, Silke Merchel, Georg Rugel, Stefan Pavetich, Broder J. Merkel, Christian Siebert

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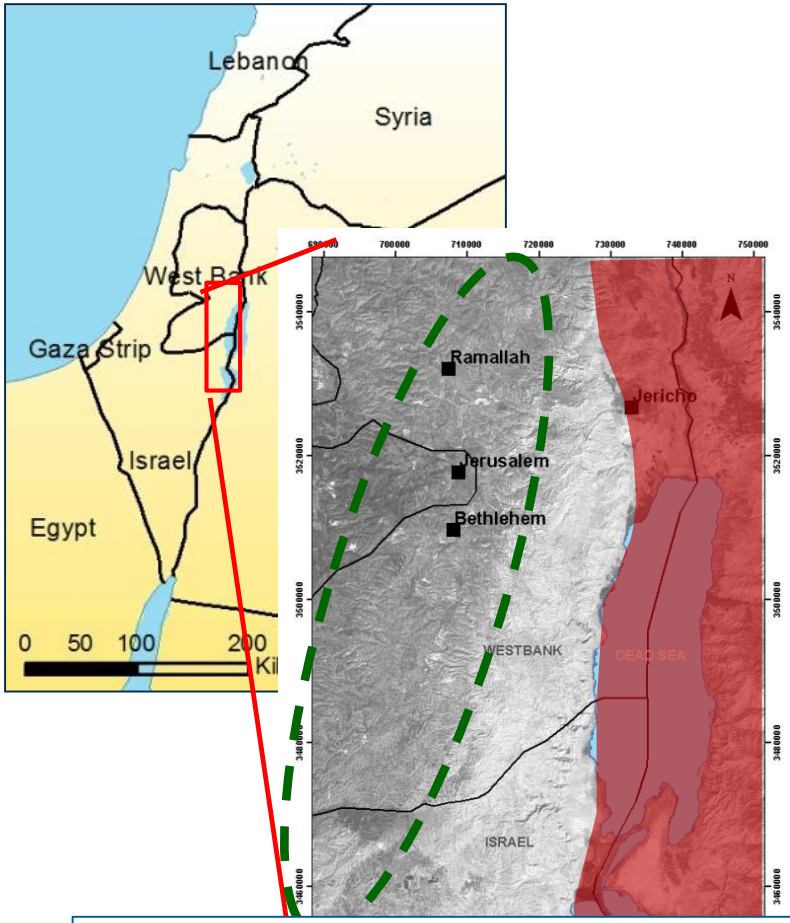
Western Dead Sea aquifer system



RECHARGE AREA

DISCHARGE AREA

- No surface fresh water reservoirs
- Precipitation only in the winter season : 800 mm (Mountains) to <100 mm (Lower Jordan Valley)

Motivation

Estimation of groundwater resources in a stressed aquifer systems

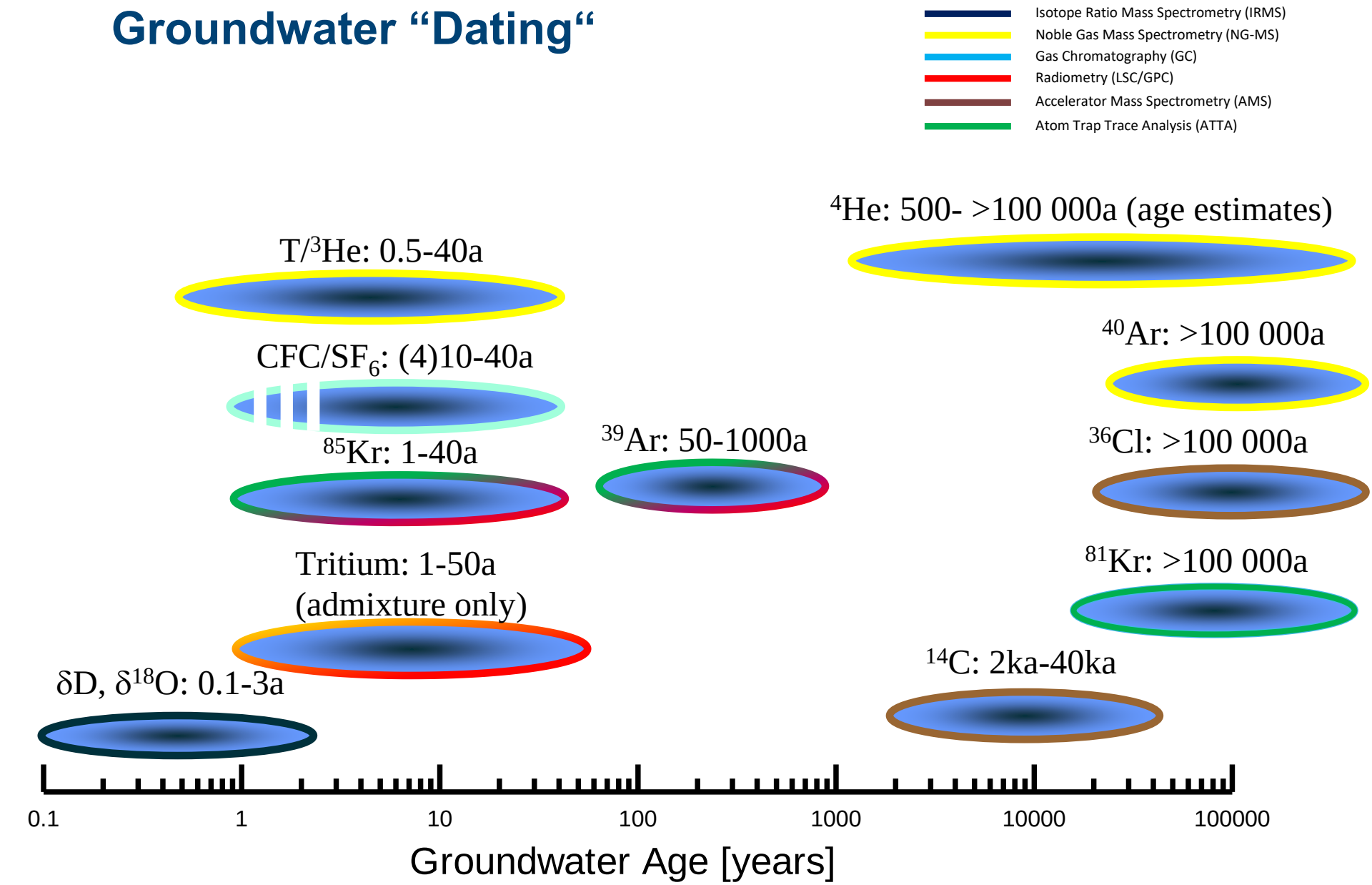
Research question

1. How long does the groundwater stay in the aquifer?

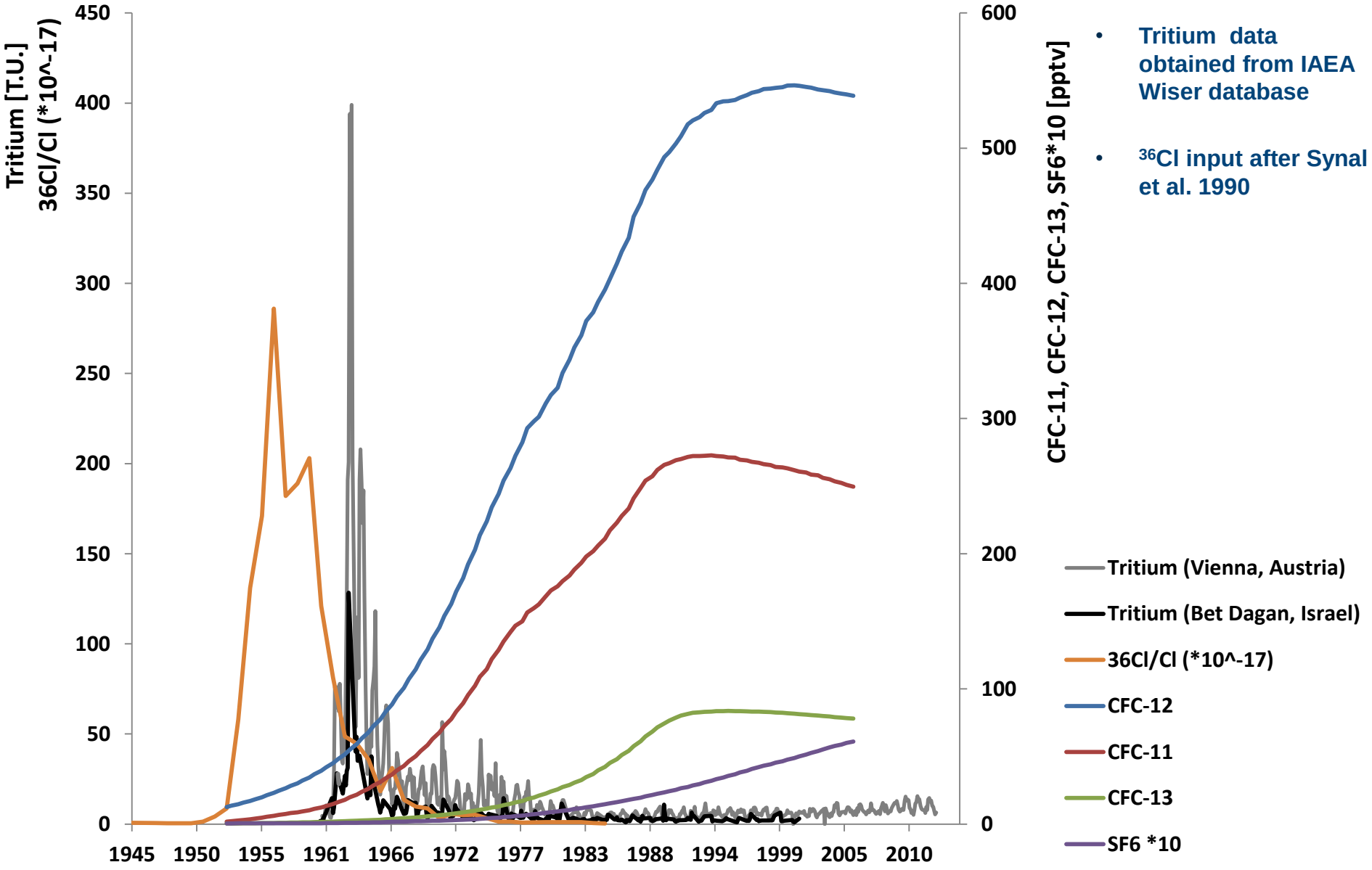
2. Is it possible to estimate mean residence times in a complex geological setting?

3. How can we use ^{36}Cl as tool for answering our questions?

Groundwater "Dating"

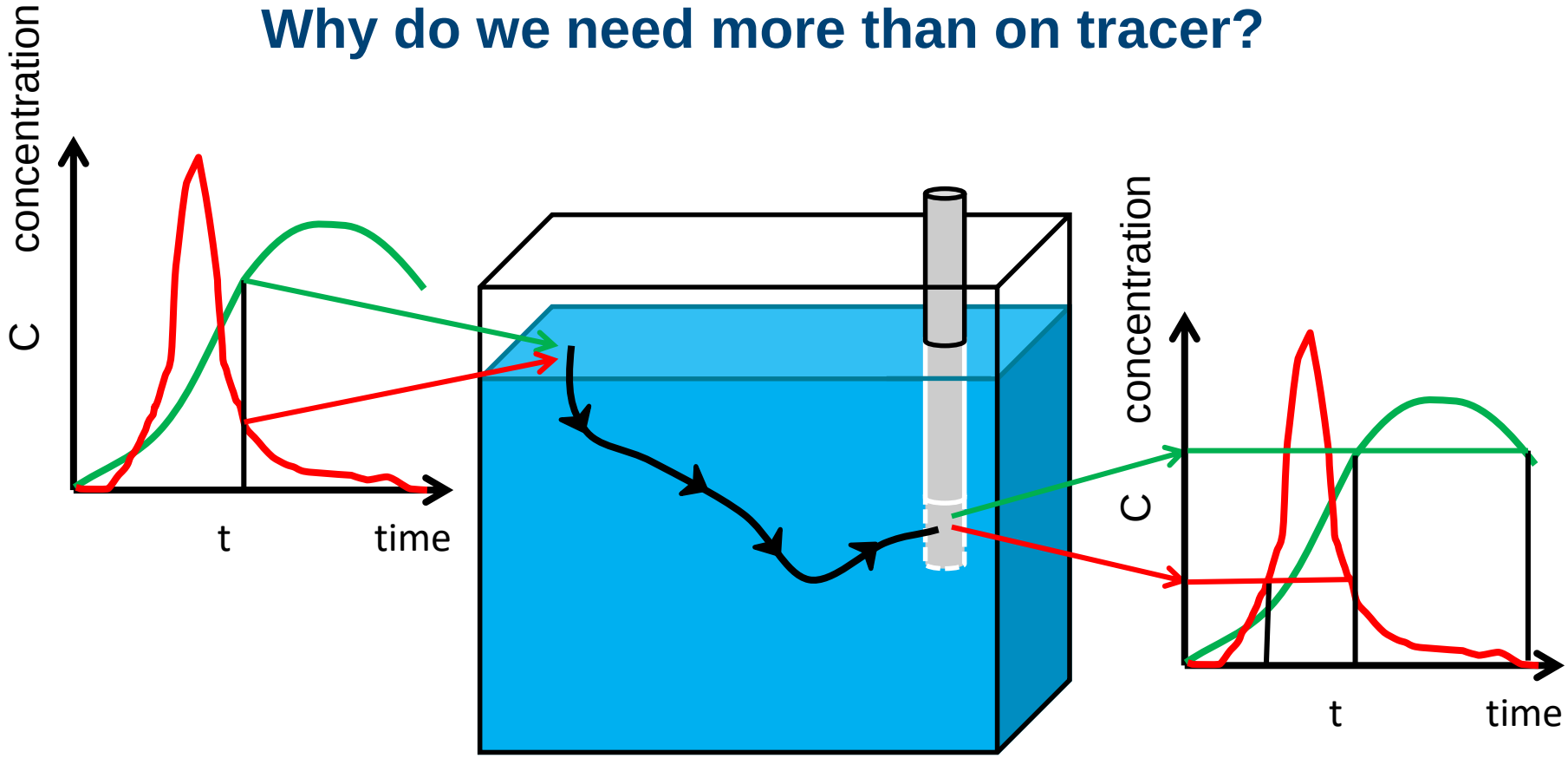


Atmospheric input



- Tritium data obtained from IAEA Wiser database
- ^{36}Cl input after Synal et al. 1990

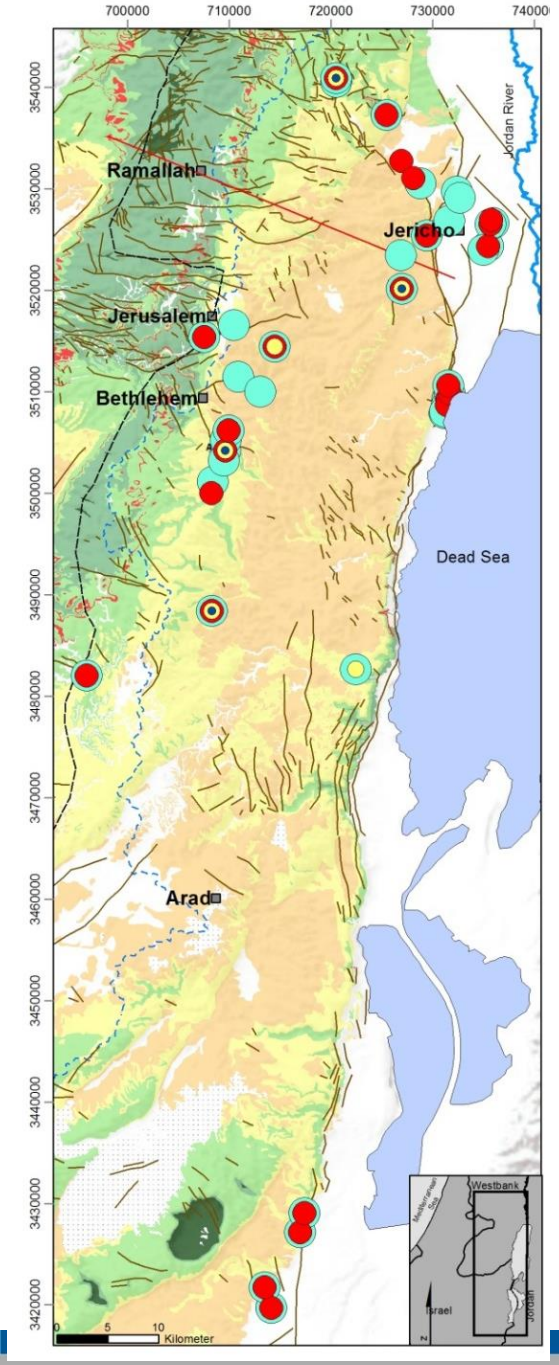
Why do we need more than on tracer?

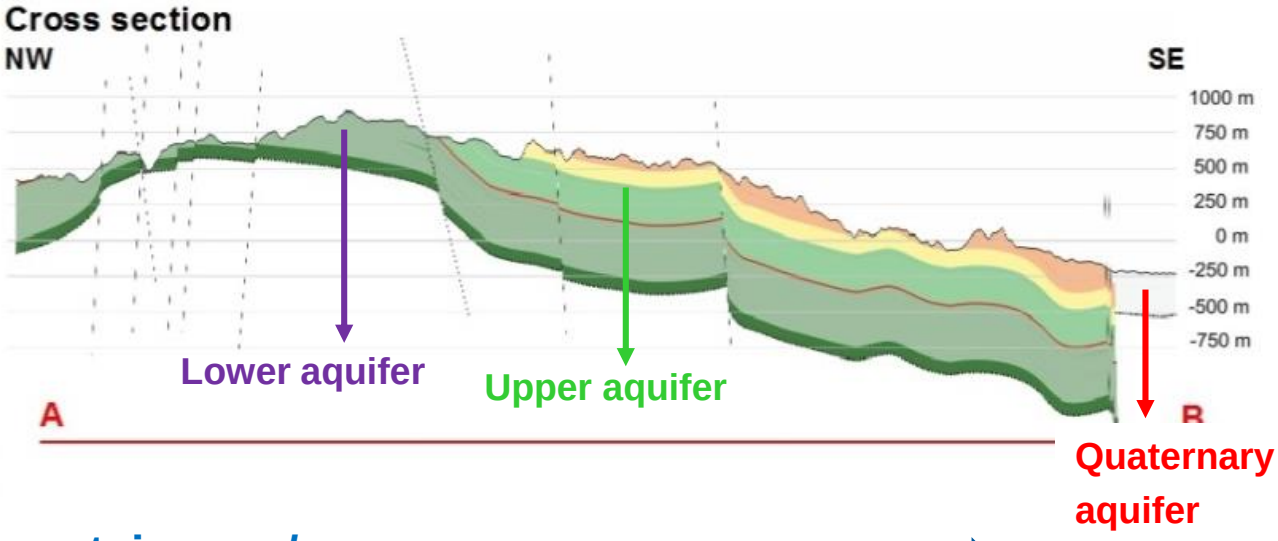


Suckow (2014): *The age of groundwater – Definitions, models and why we do not need this term*. Applied Geochemistry **50**, pp. 222-230.

Application of a Lumped parameter model (Suckow 2012)

Sampling locations & parameters



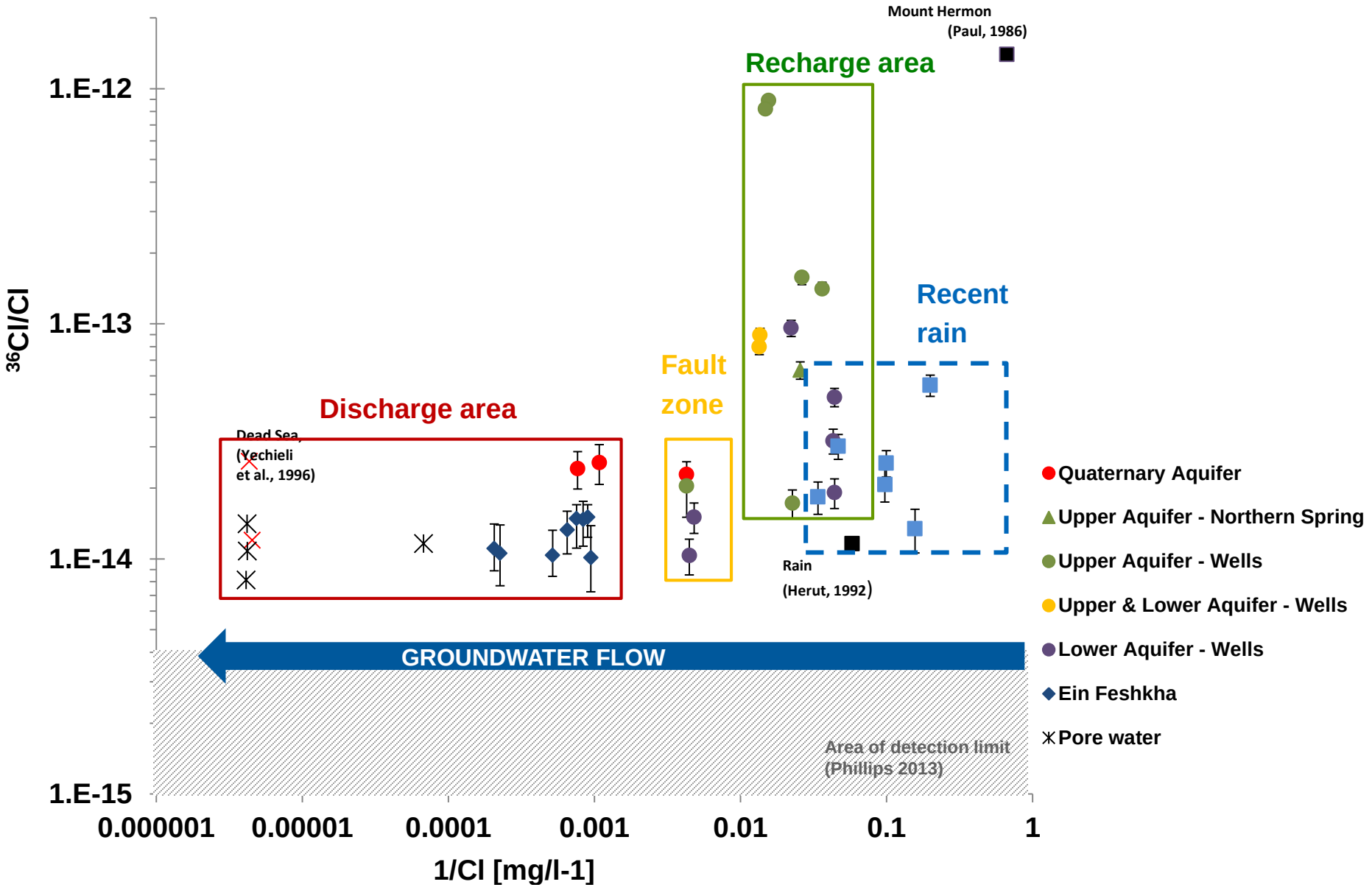


Mountain area/ Recharge zone

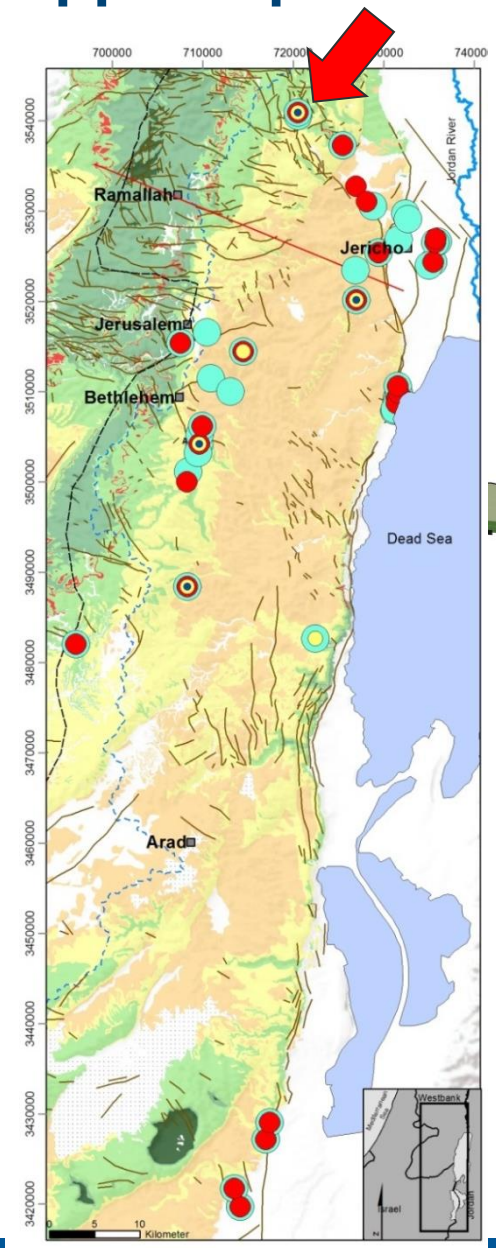
GROUNDWATER FLOW → **Jordan Valley**

- **Noble gas**
- **Gas tracers (CFC-12, CFC-11,SF_6)**
- **$^{36}Cl/Cl$**
- **Tritium**

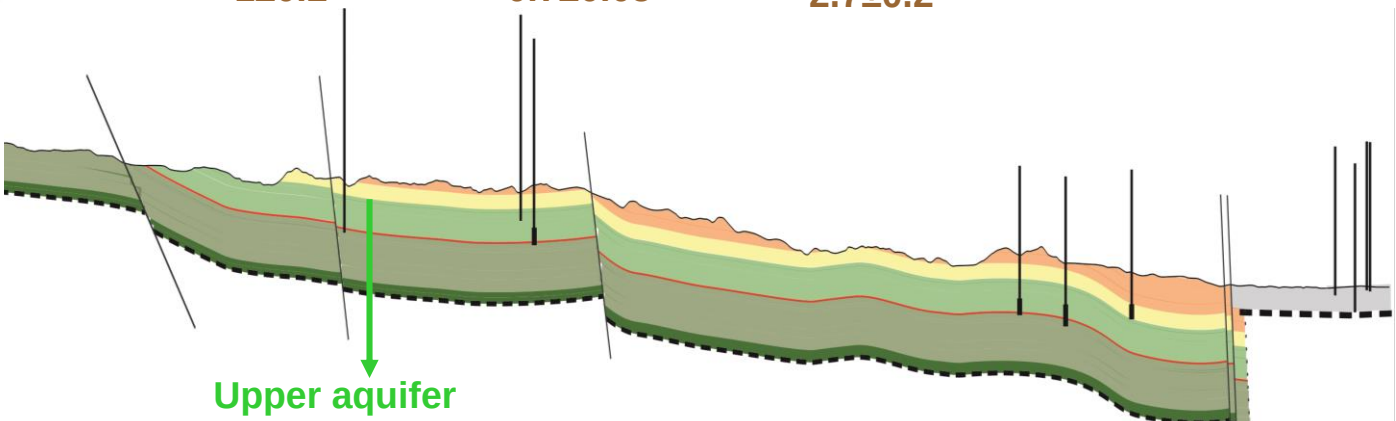
Groundwater analyses: $^{36}Cl/Cl$ & Chloride concentration



Upper aquifer - Samia 2



Samia 2	Herodion 1	Mizpe Jericho 2	Jericho 2
$1.6x10^{-13}$	$1.4x10^{-13}$	$8x10^{-14}$	$2.0x10^{-14}$
2	1.2	1.5	2
1.2 ± 0.1	1 ± 0.2	0.1 ± 0.1	
1±0.2	0.7±0.05	2.7±0.2	



Upper aquifer

Mountain area/ Recharge zone

GROUNDWATER FLOW

Jordan Valley

Location

$^{36}Cl/Cl$

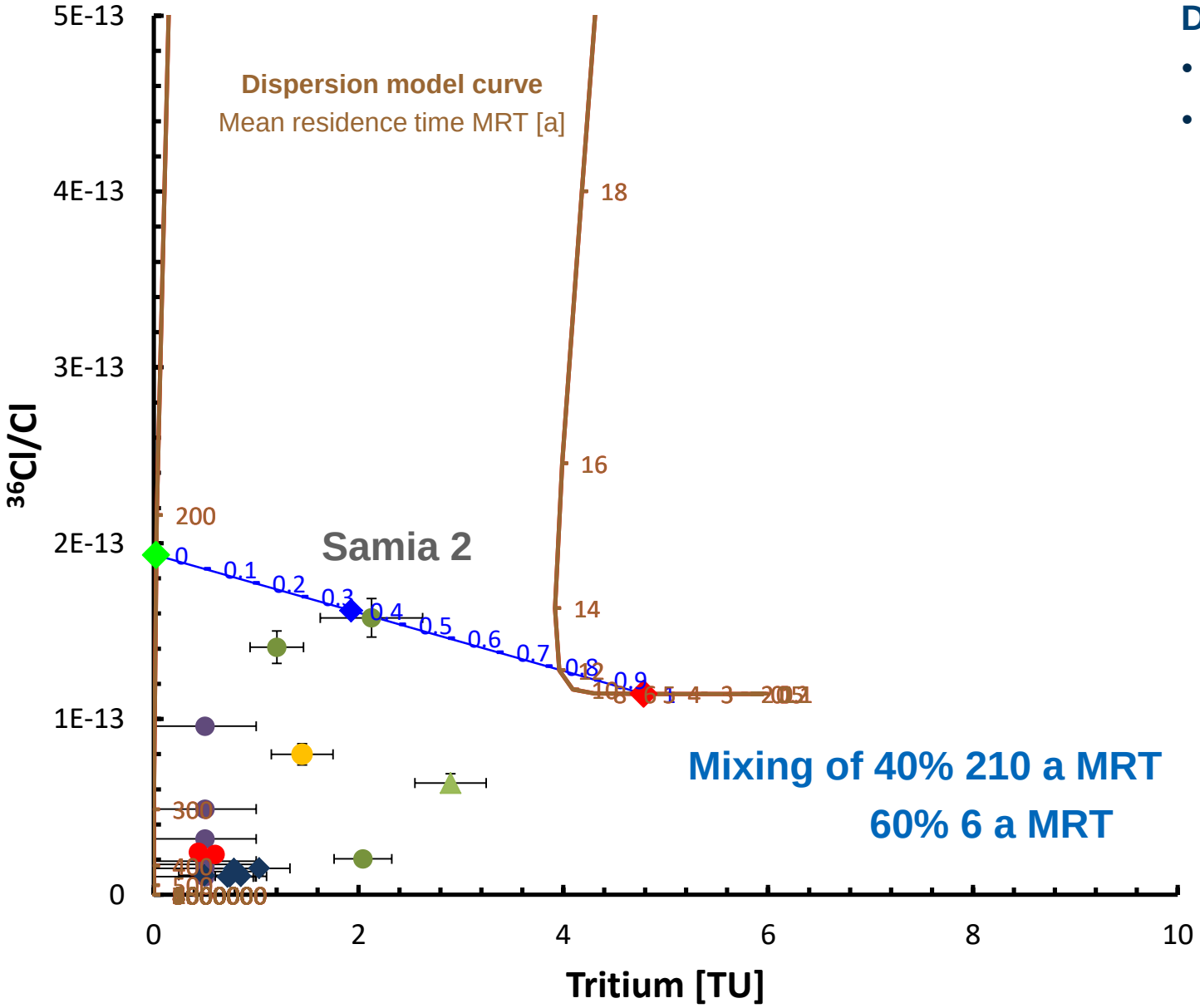
Tritium [TU]

SF_6 [fmol/l]

CFC-12 [pmol/l]

Upper aquifer - Samia 2

$^{36}Cl/Cl$ vs. Tritium

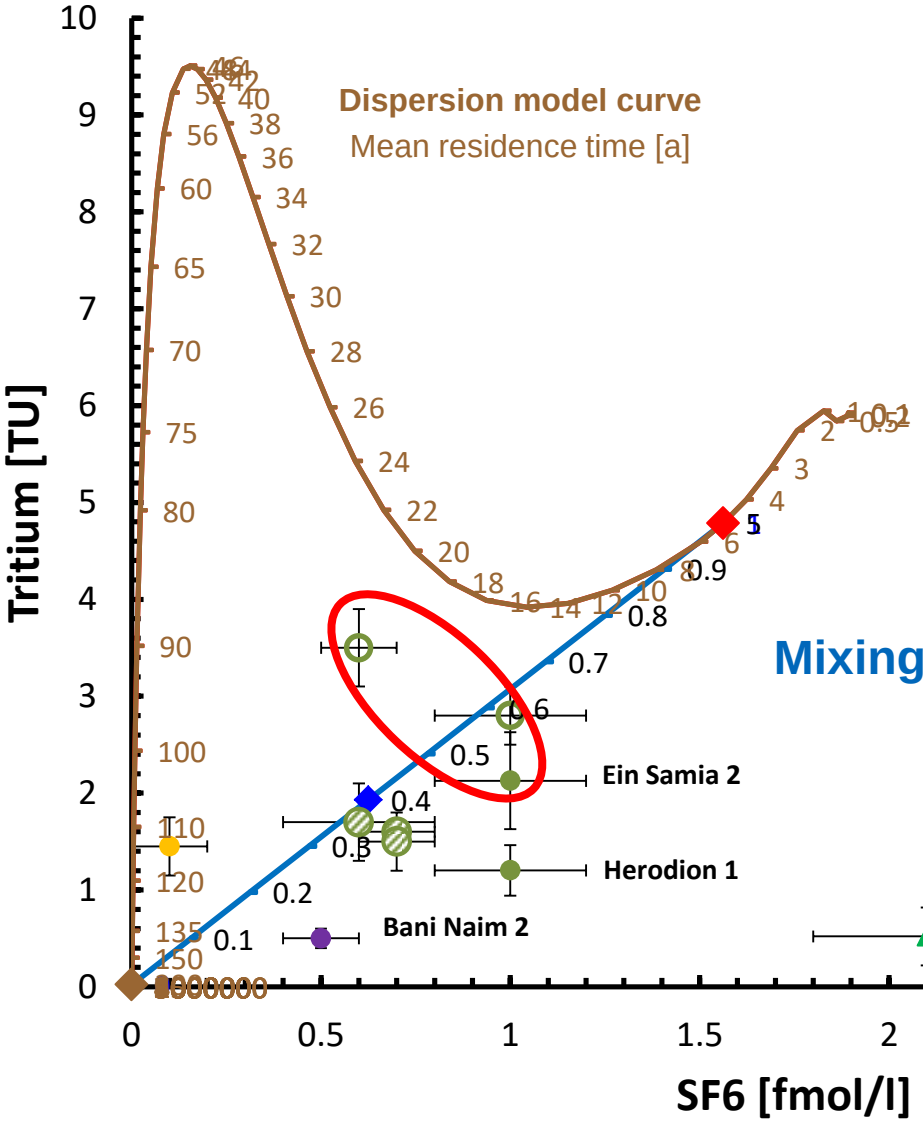


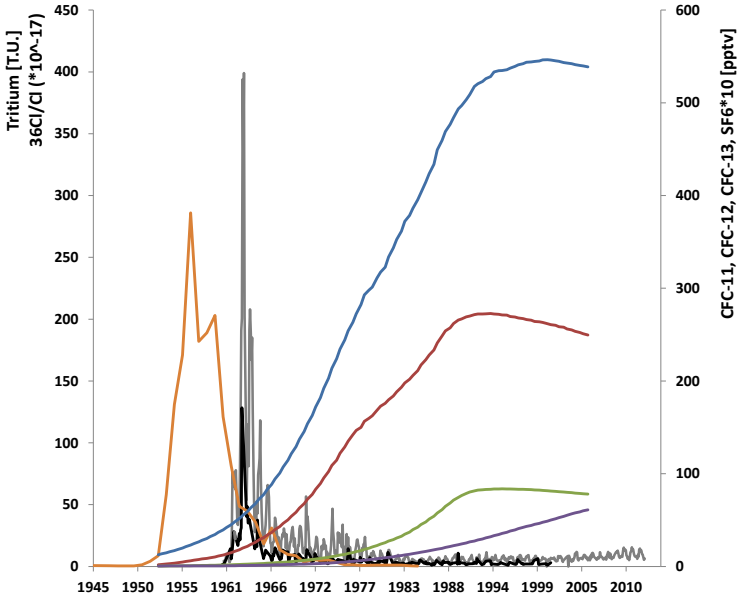
Dispersion model

- Tritium input * 0.6
- $^{36}Cl/Cl$ input * 3

Upper aquifer - Samia 2

SF_6 vs. Tritium





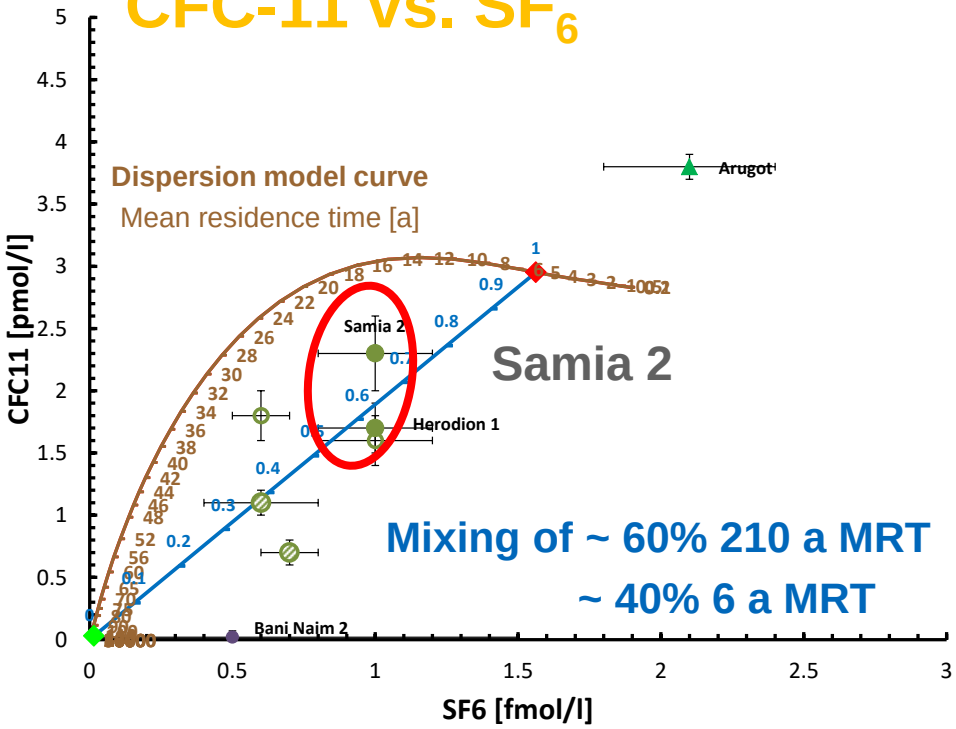
Mixing of ~50% 210 a MRT

~ 50% 6 a MRT

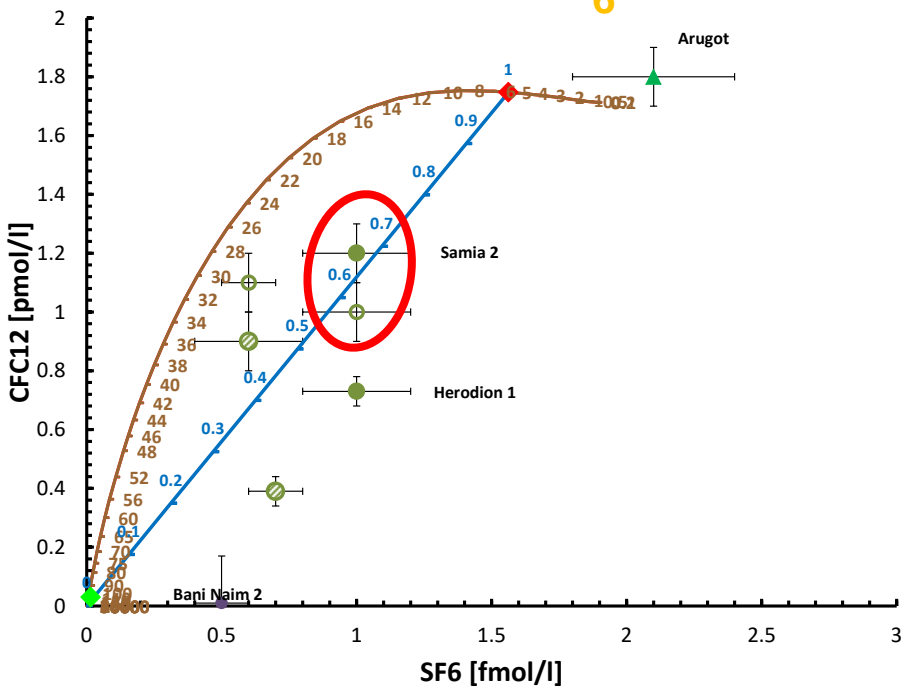
- Upper JGA - Wells
- Upper JGA - Southern springs
- Lower JGA - Wells
- Upper & lower JGA - Well
- Samia (Lange, 2011)
- Herodion 1 (Lange, 2011)

Upper aquifer - Samia 2

CFC-11 vs. SF_6



CFC-12 vs. SF_6

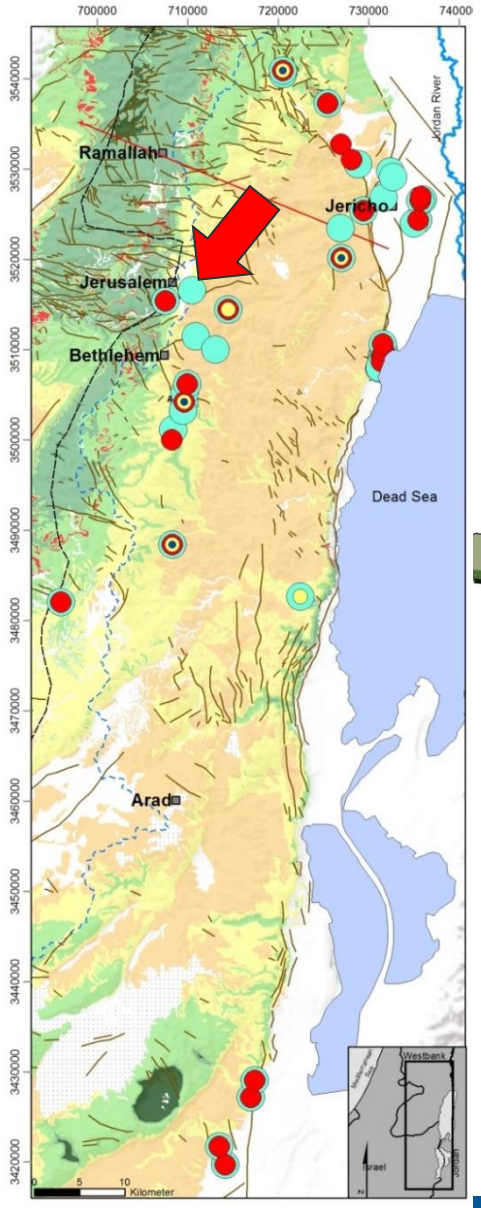


- Upper JGA - Wells
- Upper JGA - Southern springs
- Lower JGA - Wells
- Upper & lower JGA - Well
- Samia (Lange, 2011)
- Herodion 1 (Lange, 2011)

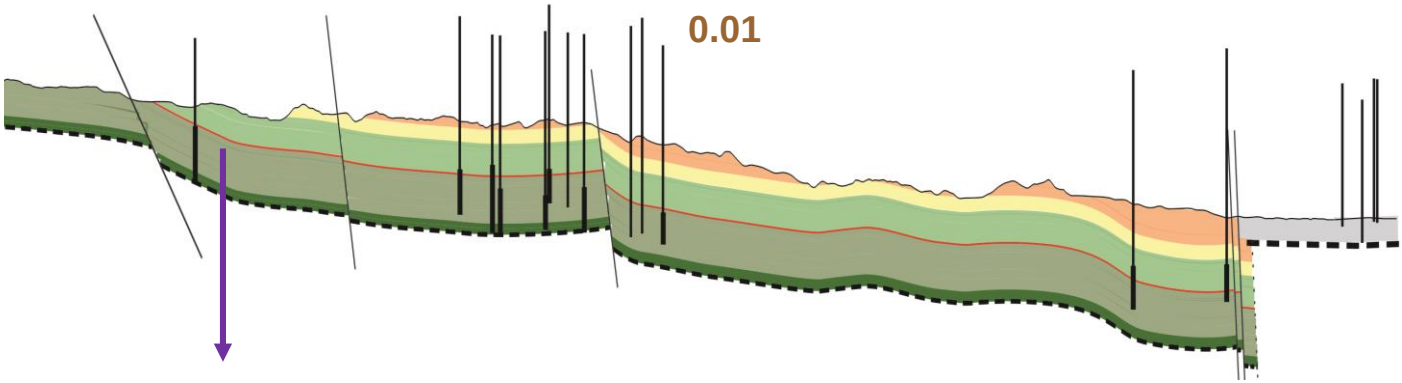
Model parameter

- Dispersion model
- Infiltration temperature : 20°C
- Altitude: 700 m a.s.l.
- Tritium input * 0.6
- ^{36}Cl input * 3

Lower aquifer - Jerusalem 1



Jerusalem 1	PWA 3	Bani Naim 2	Jericho 4
8.9×10^{-13}	4.9×10^{-14}	1.9×10^{-14}	1.5×10^{-14}
1.7	<0.5	<0.5	< 0.6
		0.5 ± 0.1	
		0.01	



Lower aquifer

Location

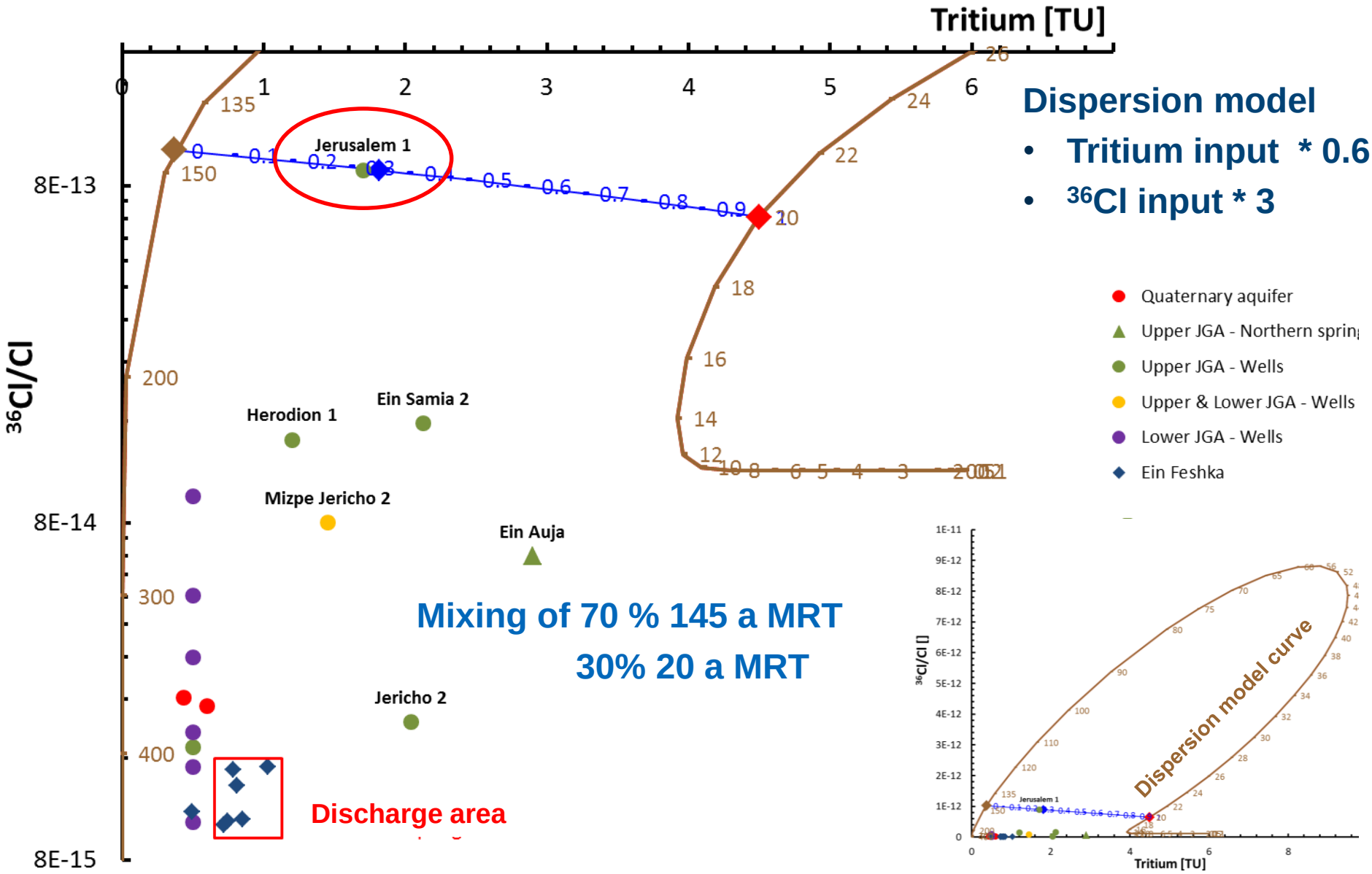
$^{36}Cl/Cl$

Tritium [TU]

SF_6 [fmol/l]

CFC-12 [pmol/l]

Lower aquifer - Jerusalem 1



- **Bomb-produced ^{36}Cl successfully used to calibrate lumped parameter model**
- **Complex geological setting: only multi-tracer approach gives reliable results**

Recharge area – Lower Aquifer (Cretaceous)

Jerusalem 1 **Mixing of 70 % 145 a MRT**
30% 20 a MRT

→ **Travel times confirmed by 4 tracers**

Recharge area - Upper Aquifer (Cretaceous)

Samia 2 **Mixing of ~50% 210 a MRT**
~ 50% 6 a MRT

- **Improvement of groundwater flow model and further estimation of groundwater quantity calculations**
- **Estimation of groundwater vulnerability in regard to flow path extension in the karst environment**
- **Need of further classifications of groundwater components >50 a, including determination of spring water**

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