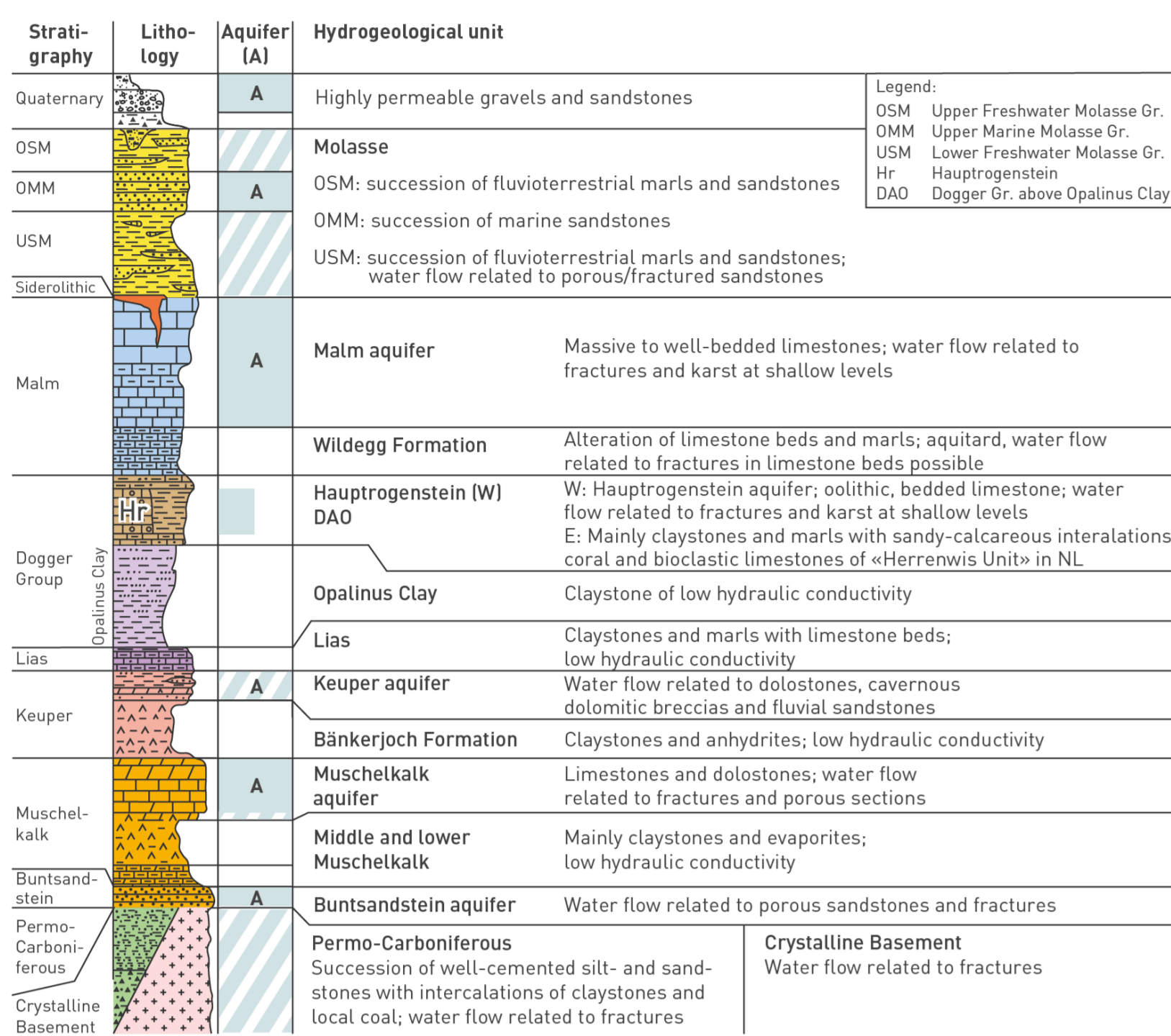


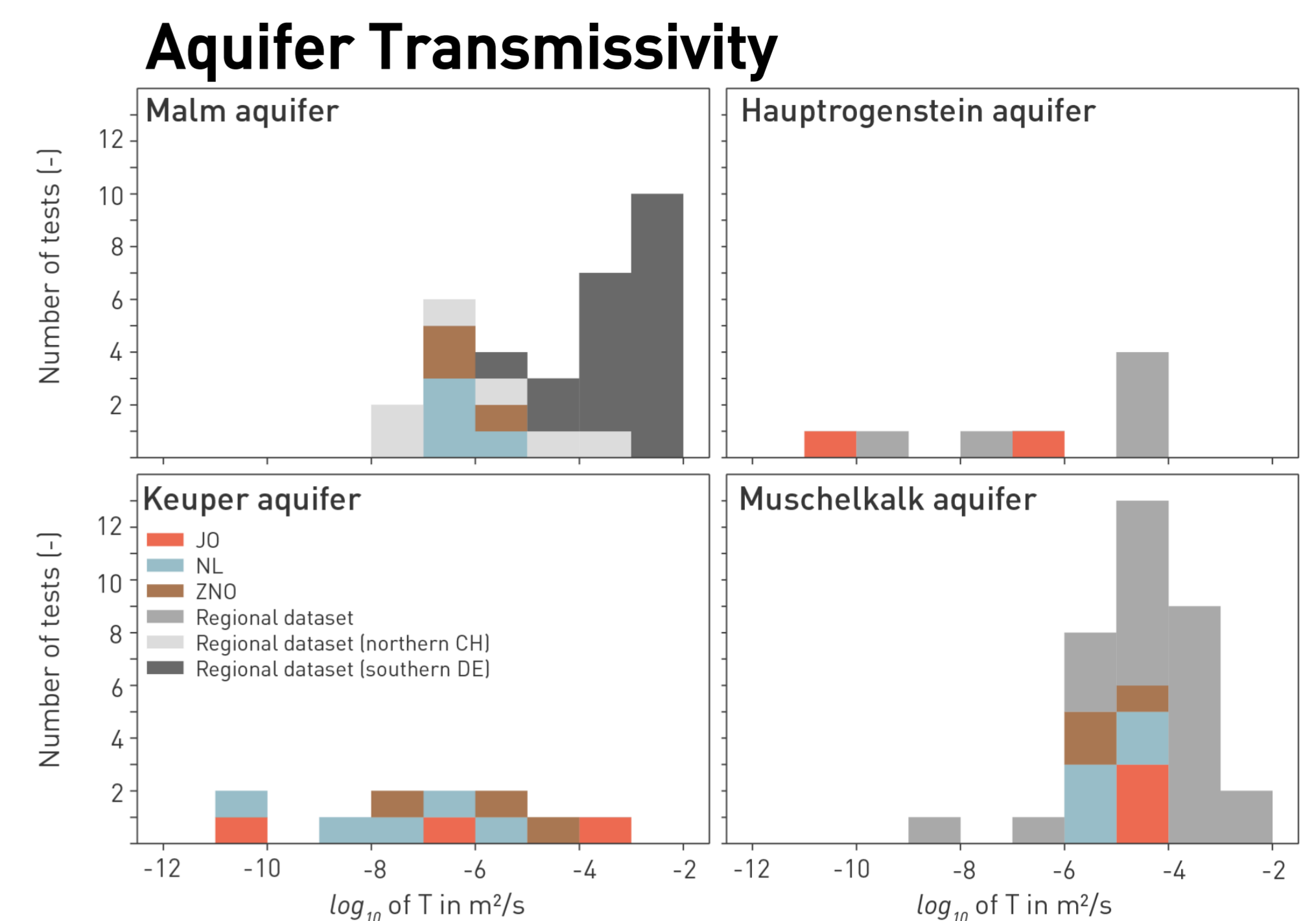
Exploring the dynamics of aquifer - aquitard systems: new insights from ^{81}Kr model ages

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Overview on hydrostratigraphy and in-situ hydraulic packer testing of aquifers



- Hydrostratigraphy of Northern Switzerland refined during Nagra's recent siting programme
- Host rock Opalinus Clay sandwiched in between local and regional aquifers
- Comparably uniform properties of regional Malm and Muschelkalk aquifers in the siting areas
- Large variability of local Keuper aquifer related to local lithofacies (partly fluvial deposits)
- Flow dynamics in the aquifers?
- Study of aquifer-aquitard interaction to support characterisation of geological barrier



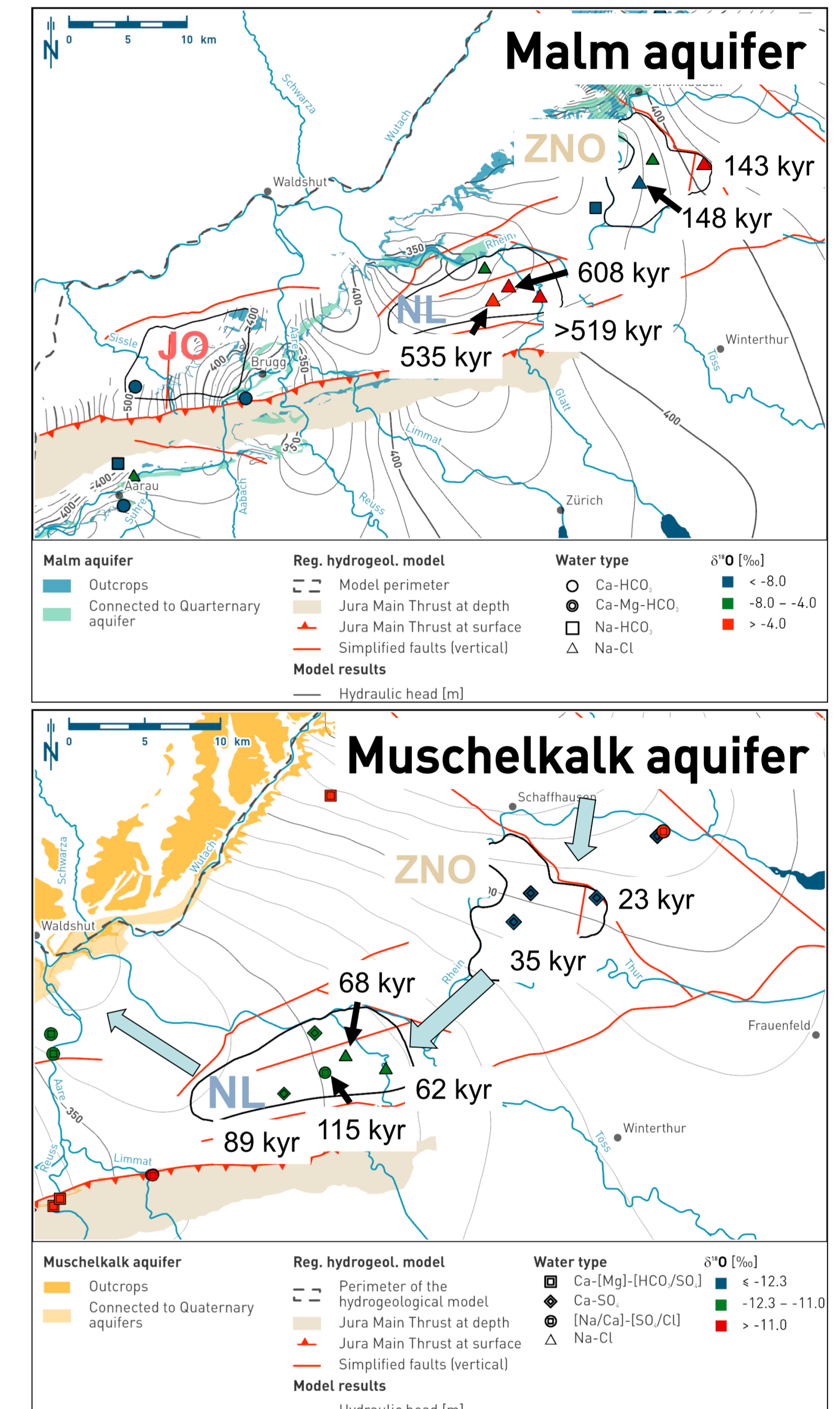
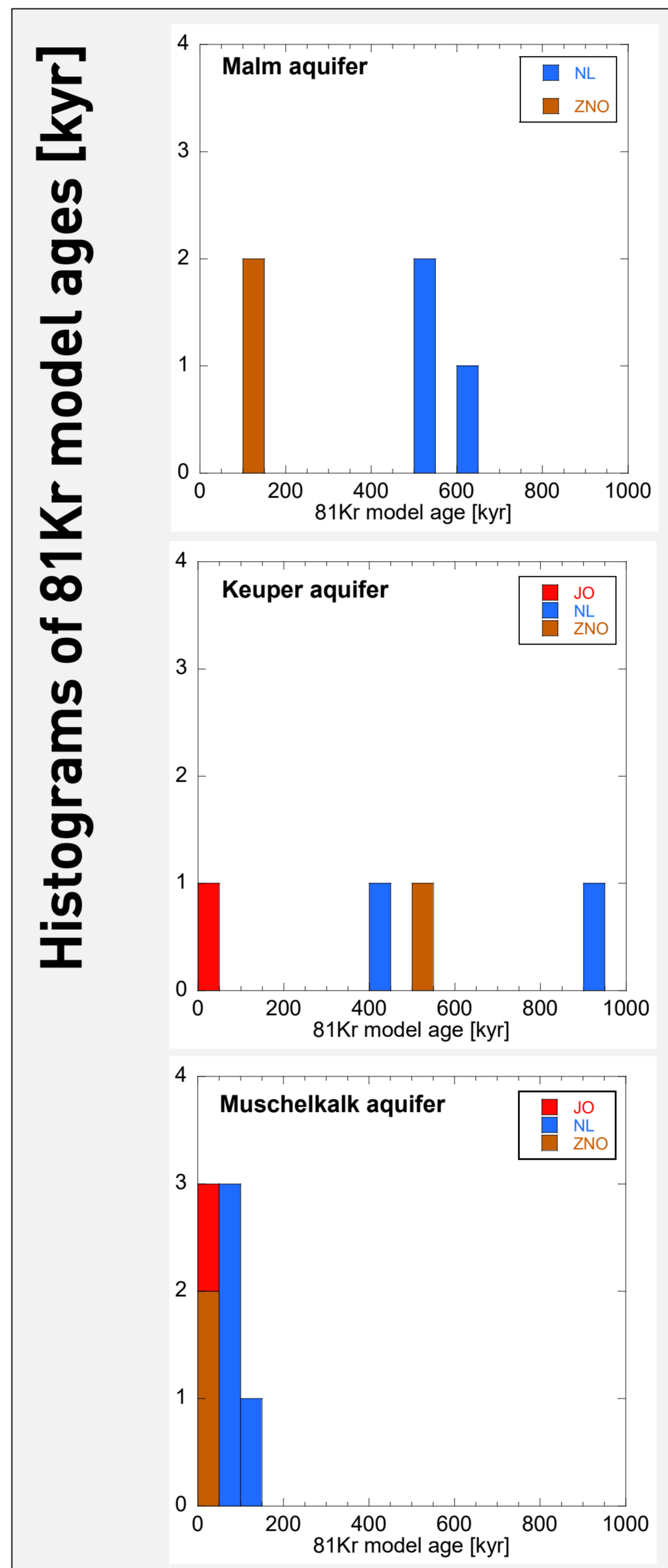
^{81}Kr model age: Method and results

Method

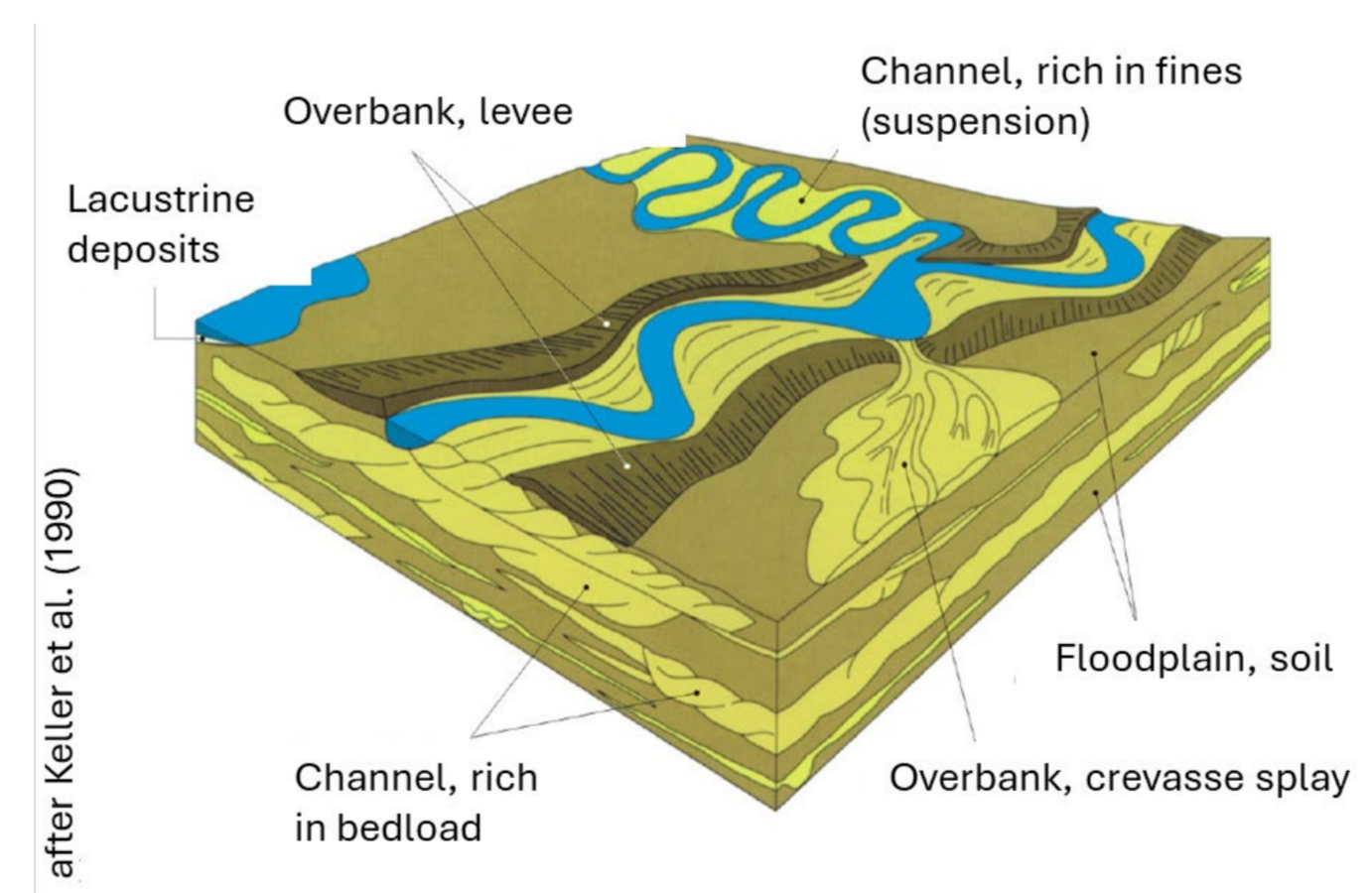
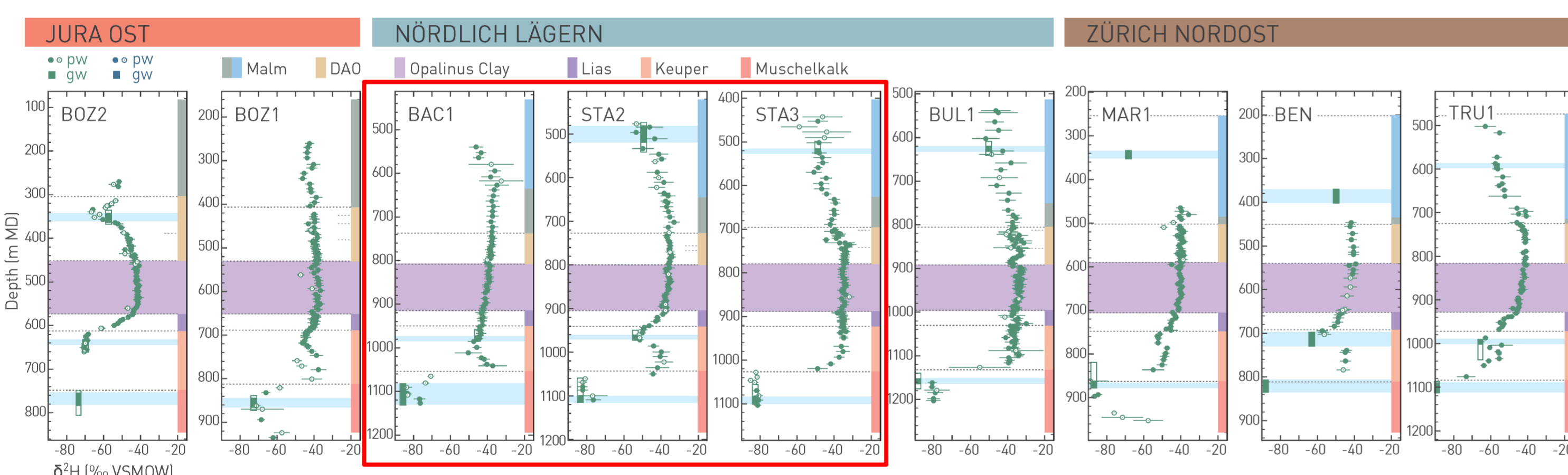
- Comparably novel method for dating old groundwaters – now available for siting programmes
- ^{81}Kr : radioactive noble gas produced in the atmosphere
- $t_{1/2} = 229$ kyr
- Measurement of $^{81}\text{Kr}/\text{Kr}$ -ratio
- Complementary analyses of other noble gas isotopes
 - Robust sample quality assessment
 - Correction of any contamination of the samples

Results

- Groundwater model ages between <20 to >900 kyr
- Aquifer and partly site-specific values agree with other hydrogeochemical and hydrogeological data
- **Malm aquifer**: model ages >100 kyr. Particularly high values in NL region. Shorter residence times in ZNO in agreement with other hydrogeochemical indications => Presentation 329 Wanner et al.
- **Keuper aquifer**: Large range of model ages – as expected from hydrogeological characterisation
- **Muschelkalk aquifer**: shorter model ages than in shallower Malm aquifer agree with higher transmissivities. Model ages correlate with other hydrogeochemical tracers such as $\delta^{18}\text{O}$. Values support flow field from hydrogeological model.



Aquifer – aquitard interaction: Consistent porewater tracers, ^{81}Kr -model ages and hydrostratigraphy



Keuper aquifer: Lithostratigraphic concept of the Ergolz Mb. Hydrogeologically relevant lithofacies within the fluvial system

General observations

- Shape of the profiles of natural tracers in porewater results from the interaction with groundwater in the aquifers. The vertical extent of porewater alteration is indicative for the interaction time.
- The vertical extent of interaction zone qualitatively agrees with the ^{81}Kr model ages (reflecting 'time since infiltration')
 - Comparably short model ages coincide with steep gradients (e.g. Muschelkalk, BOZ2 Keuper)
 - Flat gradients in porewater relate to high model ages of groundwater (e.g. Malm aquifer in boreholes STA2, STA3 and BUL1)

Case study Keuper aquifer

- Boreholes BAC1, STA2 and STA3 located within a few kilometres
- Lithology, transmissivity, model age and tracer profiles

	BAC1	STA2	STA3
T [m ² /s]	2E-07	1E-06	1E-10
Dominant lithofacies	Overbank	Channel	Floodplain
^{81}Kr model age [kyr]	929	406	-
Chloride [g/L]	9.8	3.9	-

- **STA2**: Comparably active system. Porewater overprinted by groundwater.
- **BAC1**: Quasi stagnant system. Groundwater extensively overprinted by porewater.

Take home

- Novel ^{81}Kr method to date old groundwater
- High model ages in deep aquifers

- Hydrogeochemical investigations provide key data to understand transport in aquifer-aquitard systems