Exploration of deep groundwater systems in mega-fans
Example from Northern Namibia

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Kalahari Basin and Cuvelai-Etosha-Basin
Namibia: water scarcity

Faseke et al. (2016), Acacia Project
Current water supply: shallow groundwater

- perched aquifer (KOH-0): hand-dug wells, low yield, microbial contamination
- Ohangwena 1 aquifer (KOH-1): often unsuitable for supply due to salinity

Hamutoko et al. (2019), Hydrogeol. J.
Vast aquifer found in Namibia could last for centuries

By Matt McInerney
Science reporter, BBC World Service

20 July 2012

A newly discovered water source in Namibia could have a major impact on development in the driest country in sub-Saharan Africa.

Estimates suggest the aquifer could supply the north of the country for 400 years at current rates of consumption.

Scientists say the water is up to 10,000 years old but is cleaner to drink than many modern sources.

However, there are concerns that unauthorised drilling could threaten the new supply.

Huge resource

For the people of northern Namibia water is something that they either have too much of or too little.

Scientists urge sustainable development of Namibia's newly found aquifer

The aquifer straddling the border with Angola could provide water for 400 years, but despite the excitement scientists warn it is not a panacea for Namibia.
Exploring an unknown deep aquifer

(a) What is the extent of the system?
   → geophysics

(b) Where does gw come from and go to?
   Is there any recharge? And if yes, how much?
   What is the sustainable yield?
   → numerical model

(c) Is the water quality adequate?
   → water sampling

(d) What geology is behind it?

(a) to (c): presented at IAH Dubrovnik,
see also Wallner et al. (2017), Hydrogeol. J.
Conceptual model of the aquifer system

Wallner et al. (2017)
The mega-fan theory

- fan-shaped, **large** alluvial fans (100-600 km radius), “inland deltas”
- single outlet (apex), quickly avulsing river
- very low angle, very flat
- important agricultural areas (e.g. Ganges plains)
- hosts of (deep) aquifers?
Core drilling WW203302

Rig: AGBO G 600
Drilled: June to December 2013
Wireline cores:
- 400 m (losses < 5%, mainly top 8 m)
- 100 mm ID, 3 m length

- geochemistry
- mineralogy
  - bulk minerals
  - heavy minerals
  - clay minerals
- granulometry
- electron microscopy
- porosity
- permeability
- trace fossils
- $\delta^{13}C$ isotopes
- age dating
- calcrete analysis
- …
Sediment chemostratigraphy

Andoni Fm.
At 270 m boundary: change of sedimentation pattern → different river, switch from Kunene to Cubango (?)
Source rocks: heavy minerals

Above 270 m: acidic granitic-gneissic source rock
Below 270 m: mafic, Ti-rich source rock
→ not one, but two stacked mega-fans!
Interactions of mega-fans

U-Pb-age dating: Calcretes

Core covers 60 Mio. a → almost complete Tertiary

→ continuous sedimentation (≈ 6.66 m/Ma), no hiatus at 270 m

→ mega-fan boundary at 270 m = river capture: 42 Ma (Mid Eocene)
KOH-2: local channels or regional aquifer?

Lindenmaier et al. (2014), Sinha (2014)
Vertical hydraulic conductivity & fine fraction

Falling head permeameter (German standard DIN18130)

Sampling depth [m below surface]

Hydraulic conductivity [m/s]
(falling head test)

Grain size fraction < 63 μm [wt.-%]

Falling head permeameter (German standard DIN18130)
Conclusions

• deep KOH-2 aquifer discovered only in 1998
• Game changer for water supply of northern Namibia
• Mega-fan sedimentation has shaped aquifers and aquitards
• Here: two mega-fans stacked on top of each other!
• Understanding geology helps understanding hydrogeology

Outlook:
• So far only few studies on mega-fan hydrogeology
  (Sone, India & Ohangwena, Namibia)
• There must be more deep undiscovered aquifers out there
• Urgently needed to quench the thirst of the 21st century

• Exploration of deep & large systems costly & time-consuming
→ large-scale interdisciplinary projects needed
Thank you very much for your attention!

Funded by:

Groundwater for the North of Namibia
BMZ 2009.2096.7
Satellite remote sensing – ground movement

Radar Interferometry: TerraSAR-X

Bi-weekly measurements (DLR) between June 2015-February 2016 (continued), resolution 3 m x 3 m

Red = uplift, blue = subsidence