

# Deep lying semi-fossil aquifers

From occasional findings towards an exploration strategy

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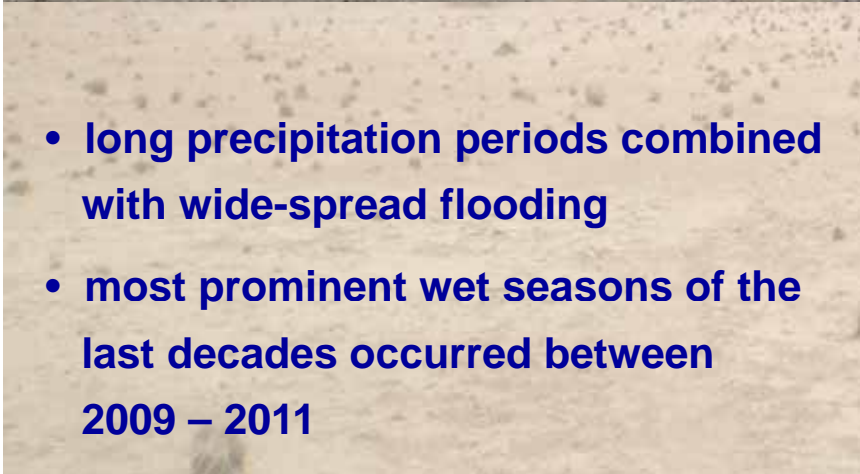
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e-mail: [himmelsbach@bgr.de](mailto:himmelsbach@bgr.de)

## Kalahari – settlement area characterized by extremes



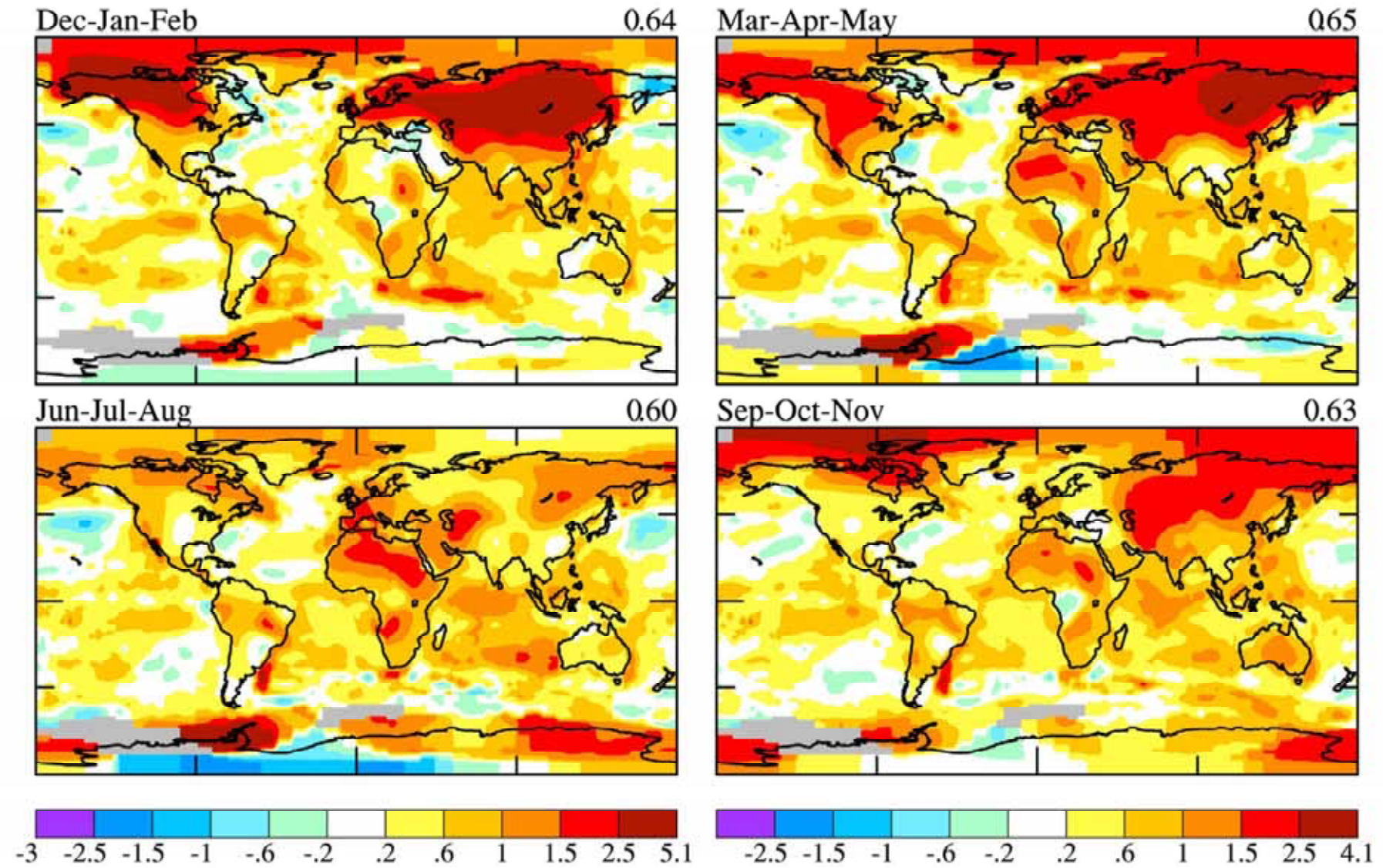
- long periods with successive extreme droughts
- extreme drought in 1992 and 1993
- crop failure and intense loss of livestock



- long precipitation periods combined with wide-spread flooding
- most prominent wet seasons of the last decades occurred between 2009 – 2011



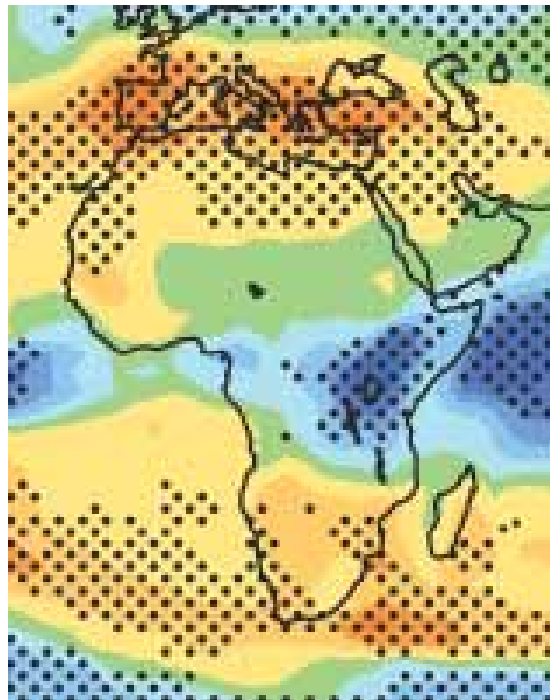
# 1950-2009 Seasonal Surface Temperature Changes Based on Linear Trends (°C)



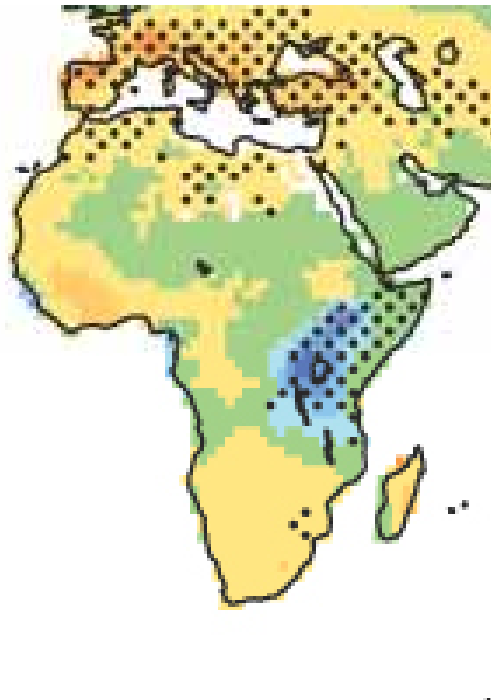
[source: Hansen et al. 2010]

# Averaged modelling predictions (min. 10 simulations) comparison of decades 2080-90 versus 1980-1990

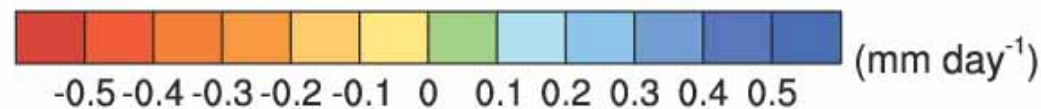
precipitation



discharge



evaporation

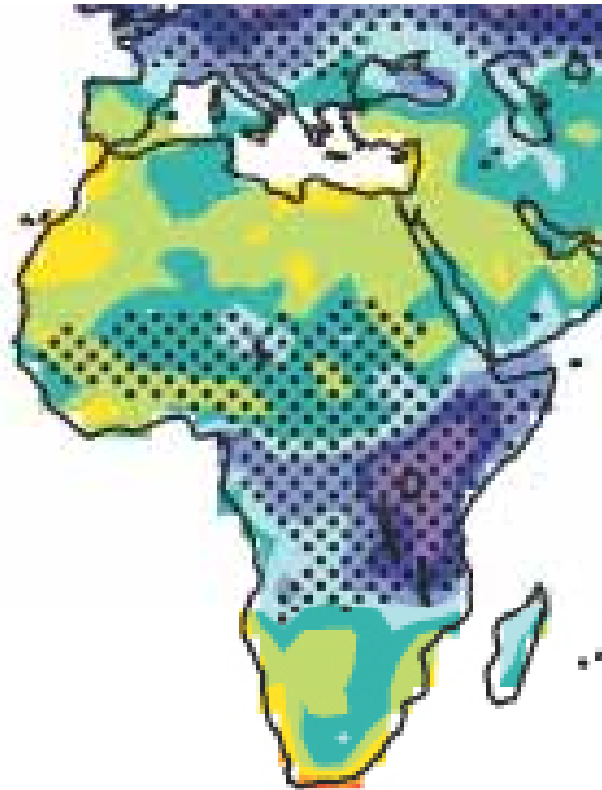


dotted areas: 80% of models coincide with prefix

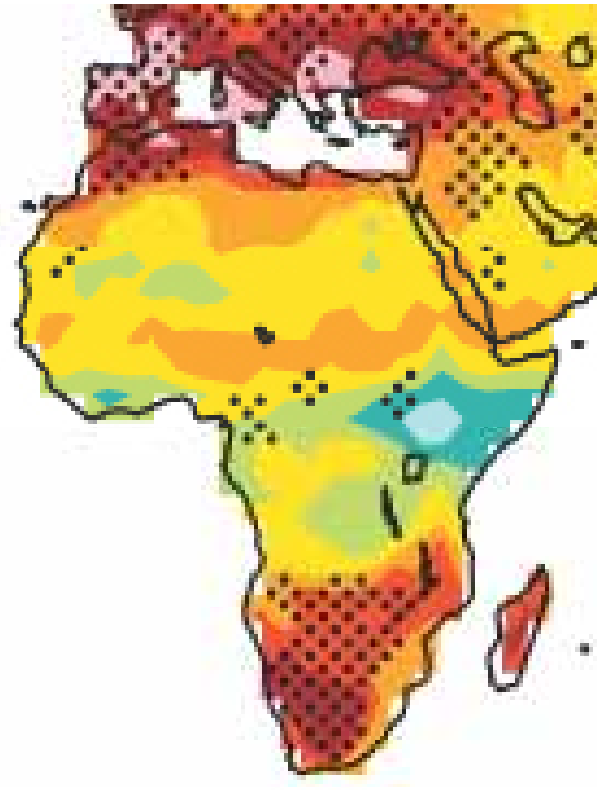
[source: IPCC, 2007: The Physical Science Basis]

# Strong increase in the number of extreme events comparison of decades 2080-90 versus 1980-1990

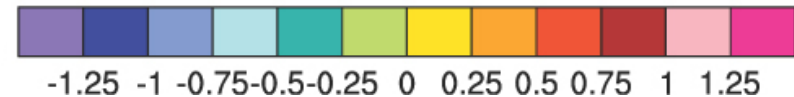
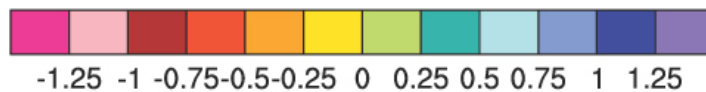
intensity of precipitation



length of drought periods



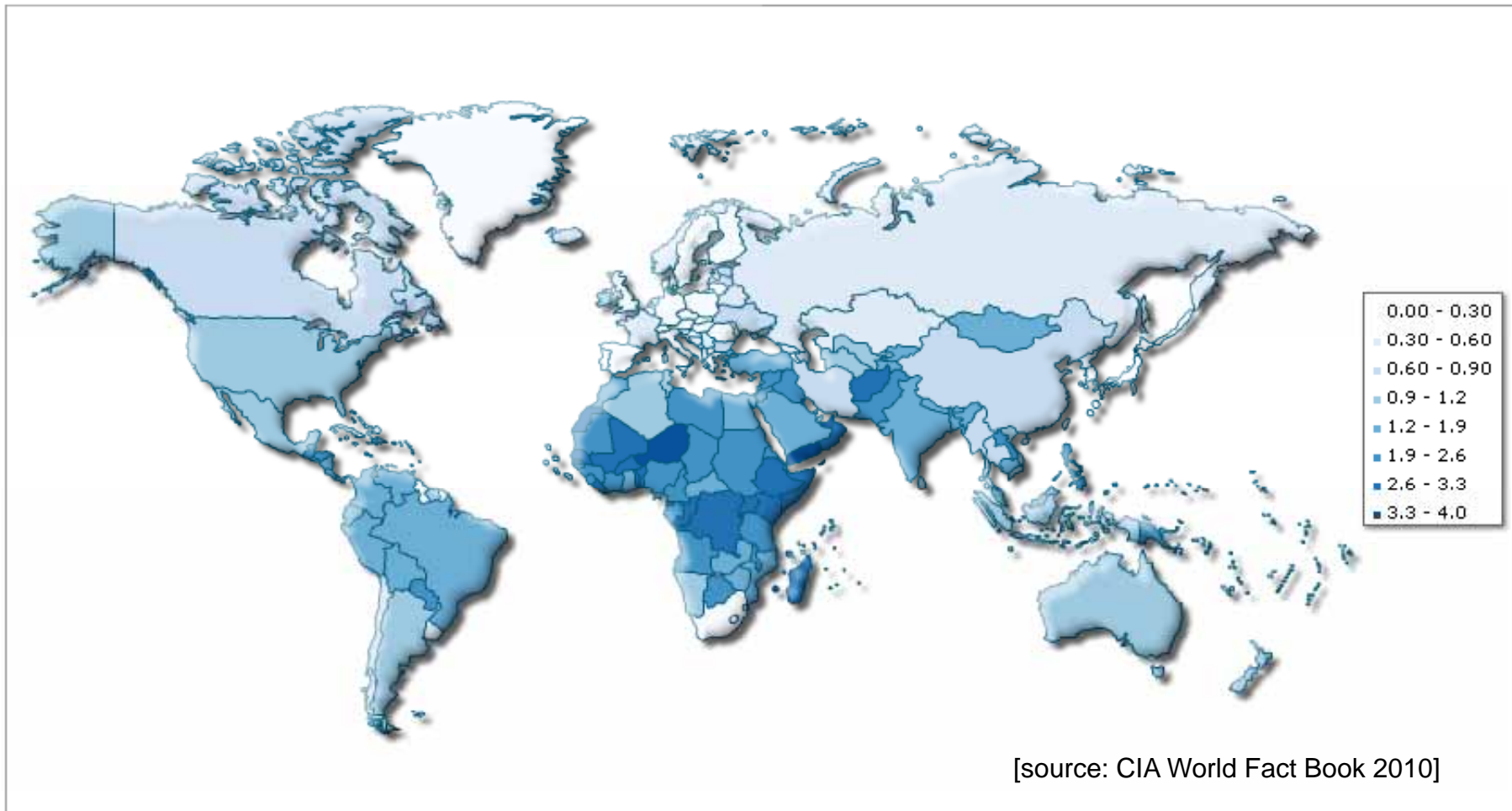
[source: IPCC, 2007: The Physical Science Basis]



(std. dev.)

dotted areas: 5 out of 9 model-runs coincide with prefix

# Africa – continent with the highest population growth



figures for 2009:  
values in [ % ]

**Time for doubling**

Namibia 0,96  
Zimbabwe 1,53  
DR Kongo 3,20

**1 % ~ 70 years**

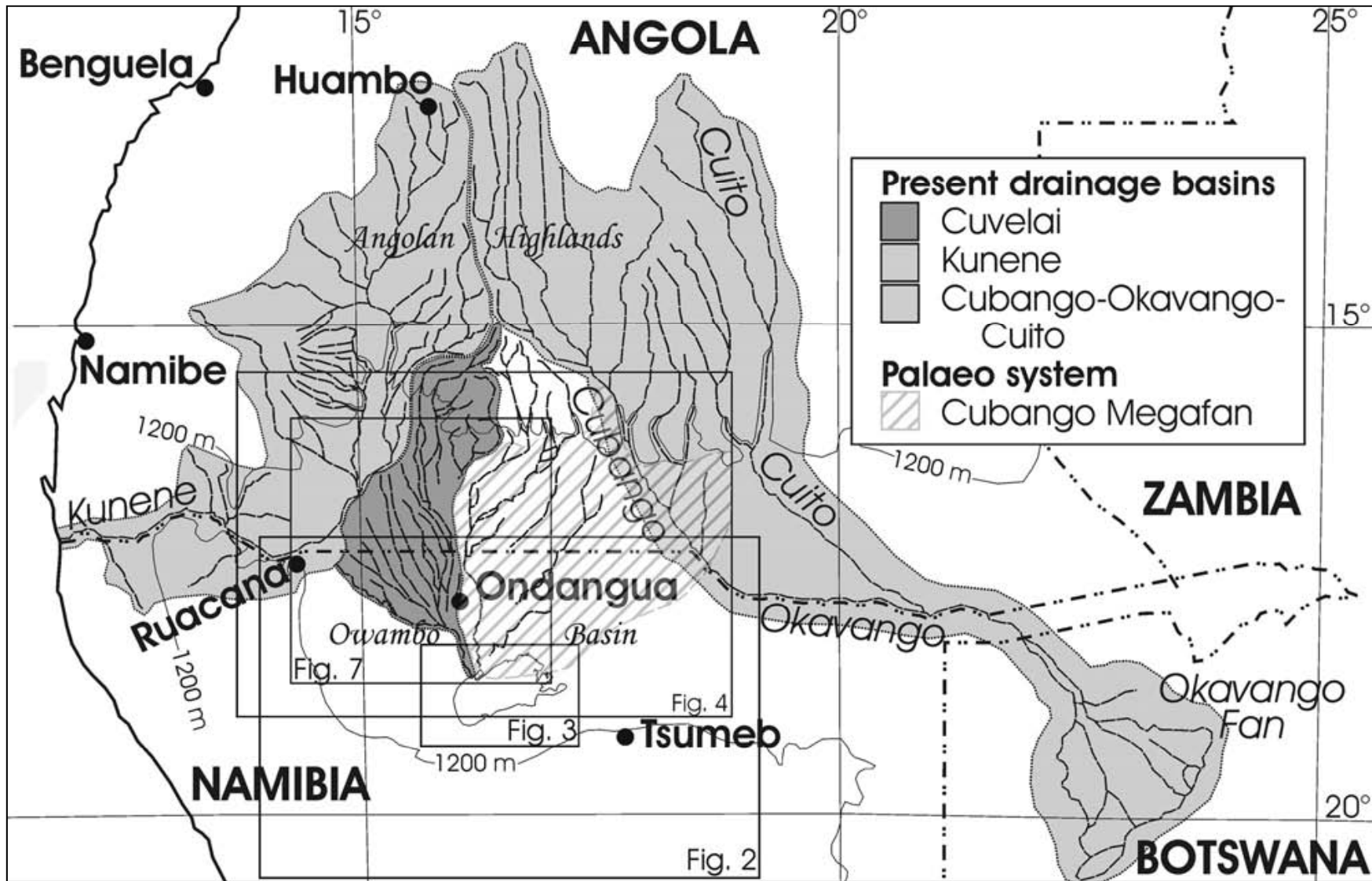
S-Africa 0,28  
Zambia 1,64  
Uganda 2,70

**2% ~ 35 years**

Botswana 1,94  
Angola 2,10  
Kenya 2,70

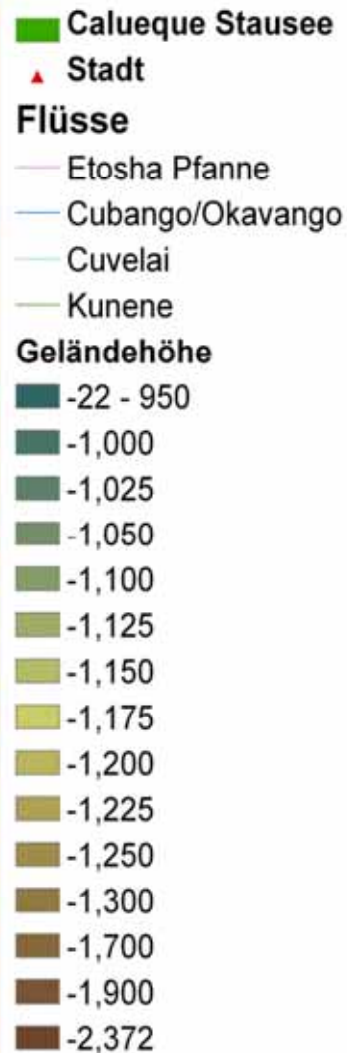
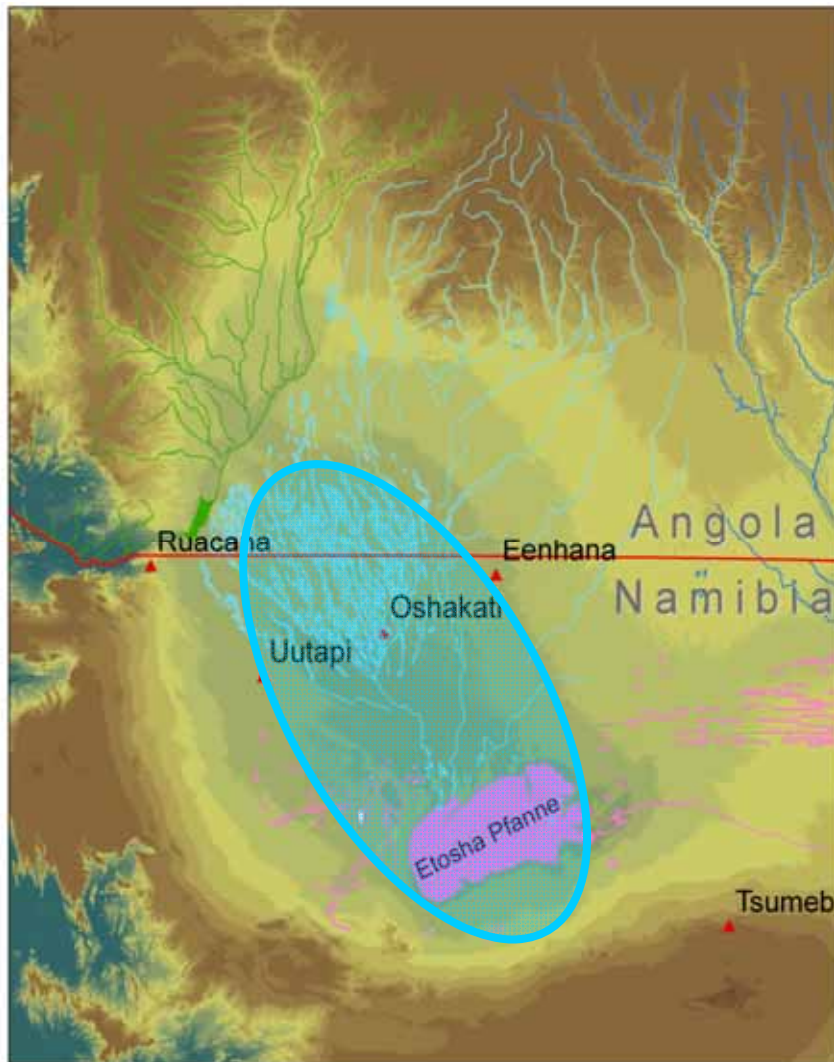
**3% ~ 23 years**

# Catchment areas of the Cuvelai Basin and adjacent regions



[source: Miller et al 2010]

# Actual catchment of the Cuvelai - Basin

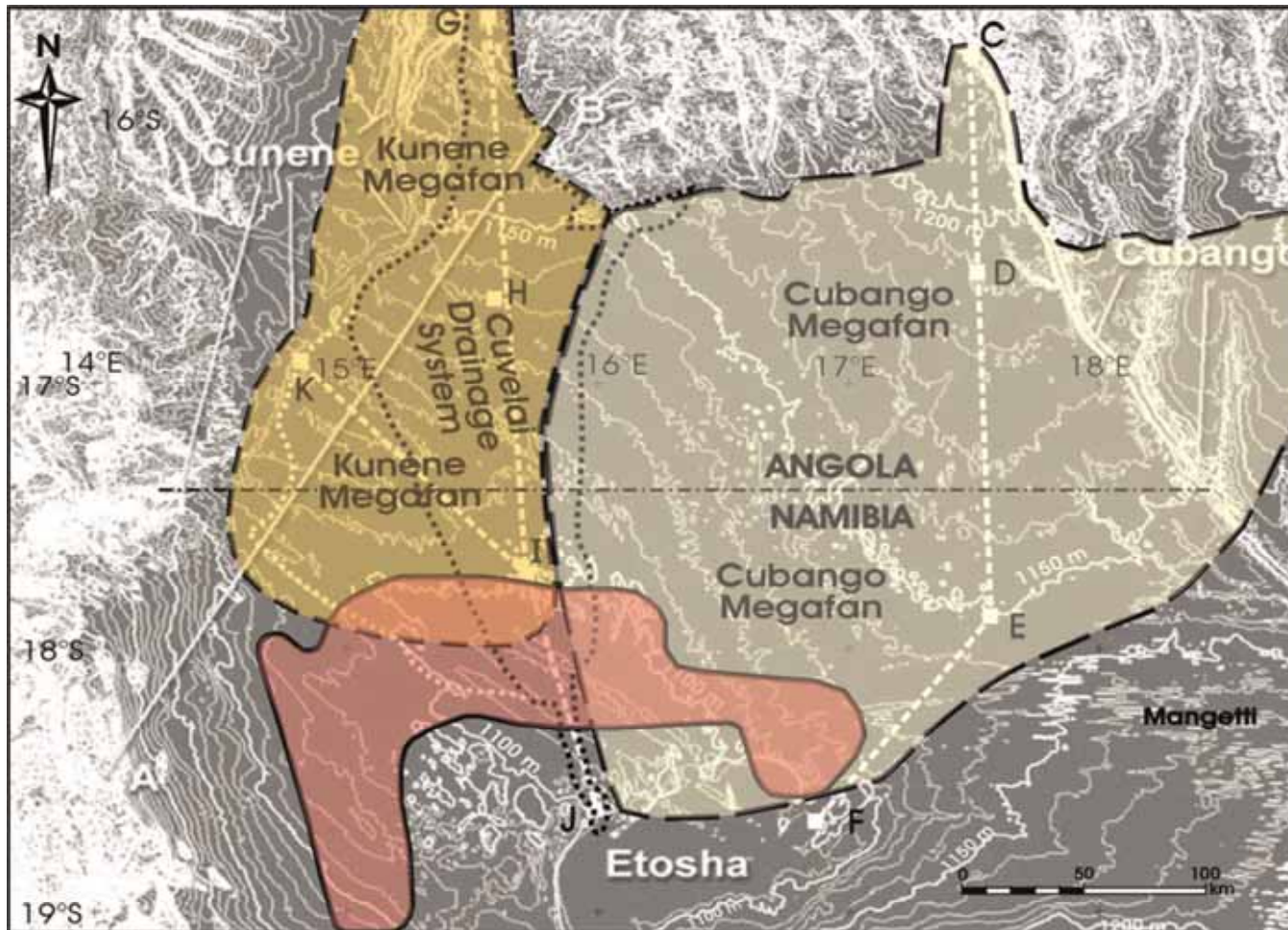


- Etosha Pan – intra - continental endorheic basin
- tectonic subsidence since Cretaceous–Tertiary boundary
- increased sedimentation since 6 Mio. years
- different lake levels can be delineated from ancient shore lines up to 1100 m asl
- older and higher lake levels are questionable
- back-ward erosion truncated Kunene und Cubango (35.000 a) from the basin
- Cubango river nowadays feeds together with Cuito river the Okavango Delta

... Etosha Salt Pan as final drainage level



# Sedimentary fans in the Cuvelai - Basin



[source: Miller et al 2010]

## ALLUVIAL FANS AND DRAINAGE SYSTEMS

..... Cuvélai drainage system  
 ..... Palaeo Cuvélai system

- - - - - Kunene Megafan

————— Cubango Megafan

————— Area with >50% clay or sandy clay in the Kalahari Group

- two prominent sedimentary fans in the Cuvelai - Basin
- represent deltaic sedimentation
- younger Cubango mega-fan buried the elder Kunene fan
- Kunene fan lies now underneath the Cubango mega fan



Relevance for ground-water exploration

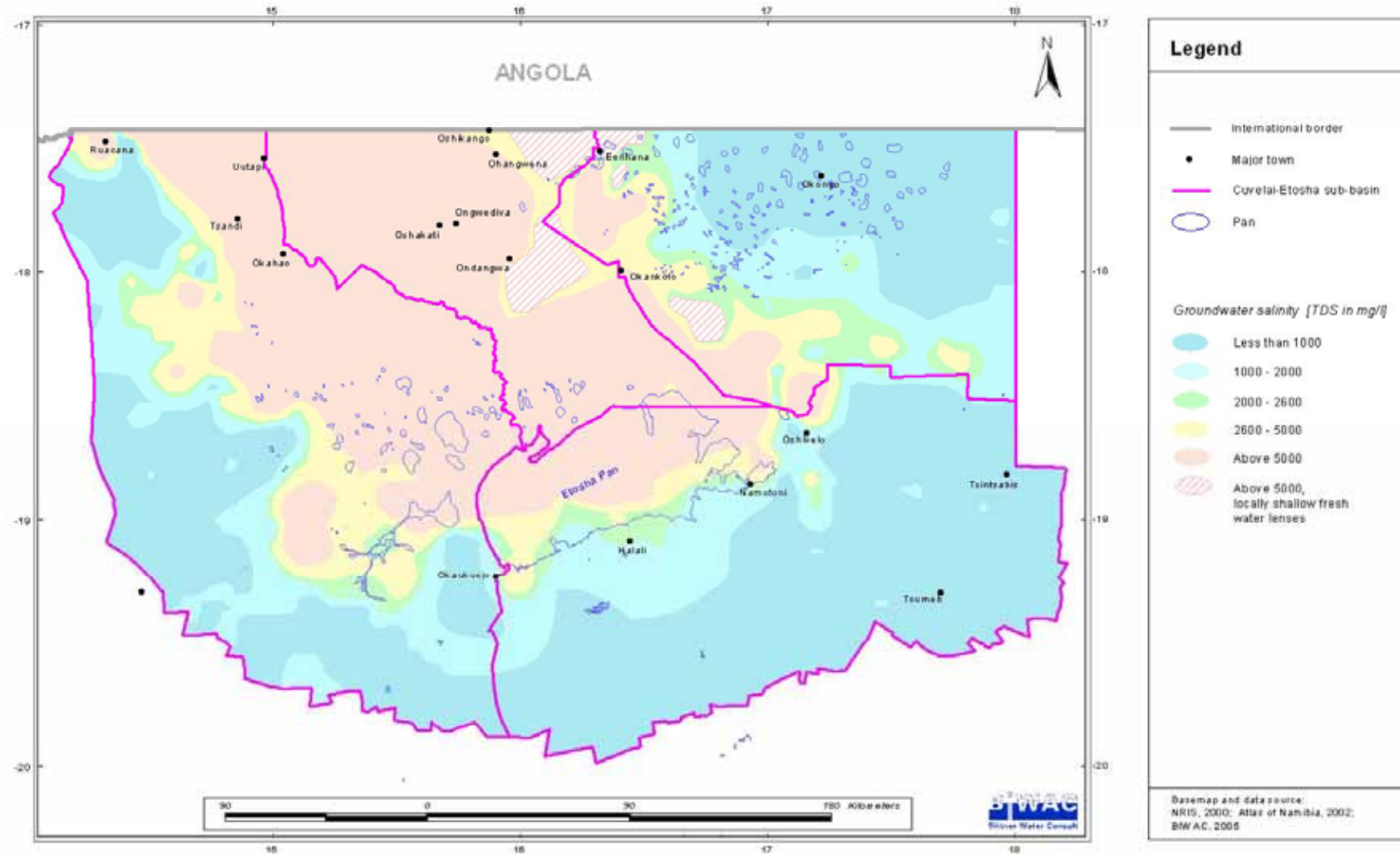
## Example for delta sedimentation (areal picture Okavango)



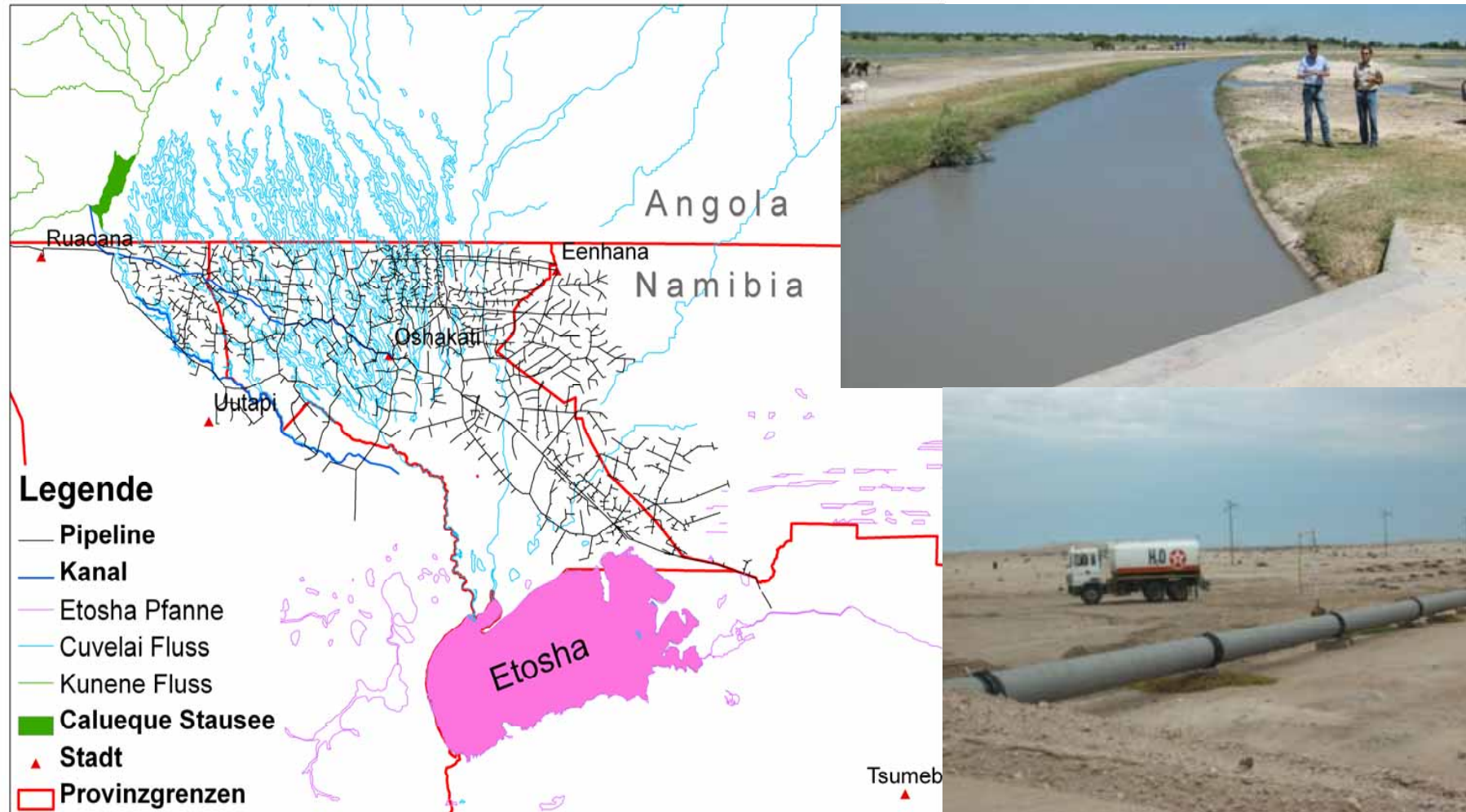
[source: [www.wikipedia.org](http://www.wikipedia.org)]

## Groundwater salinity within north-central Namibia

## Appendix 4.3



# Actual Water Supply – open canals and pipeline system



- inter-catchment transfer of surface water from the Ruacana reservoir lake
- fast growing demand due population growth overruns supply capability by far
- shallow groundwater is due to high salt and fluoride content unsuitable for supply

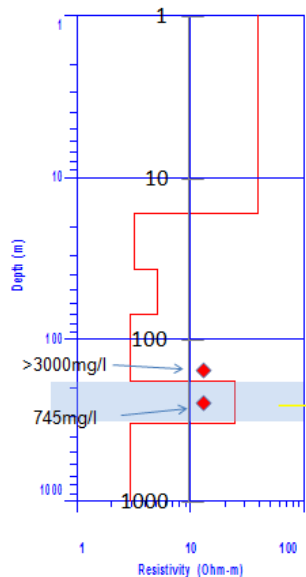
# First finding of deep lying fresh groundwater resources underneath high salinity groundwater bodies



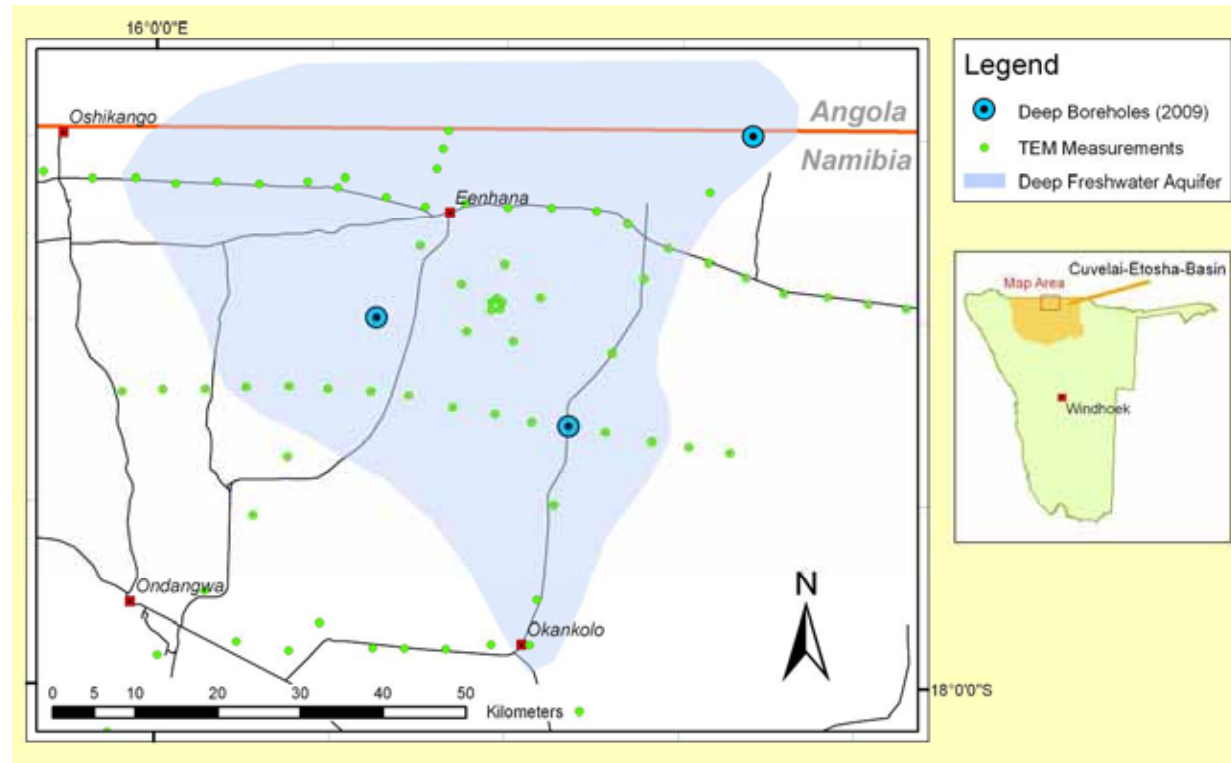
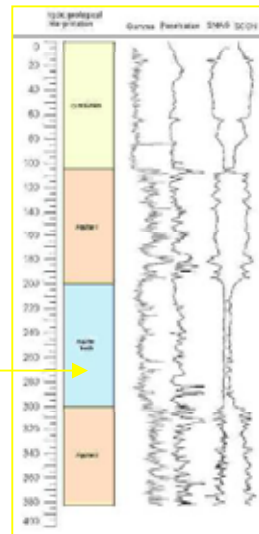
French-German cooperation in Africa – June 2015

# Eploration on the Ohangwena II aquifer in Northern Namibia (Cuvelai-Etosha-Basin, Ohangwena)

## TEM

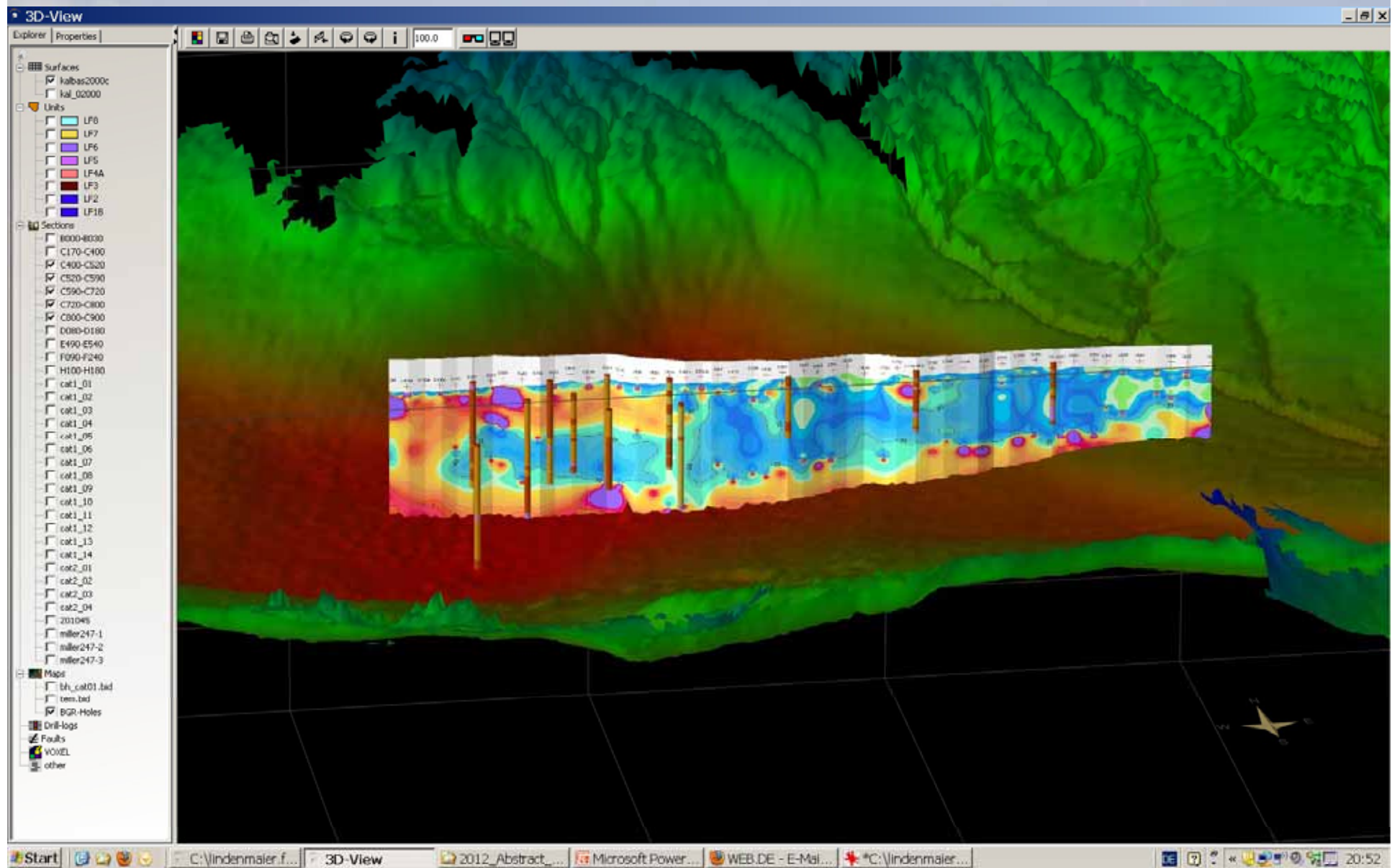


## Fluid Finder

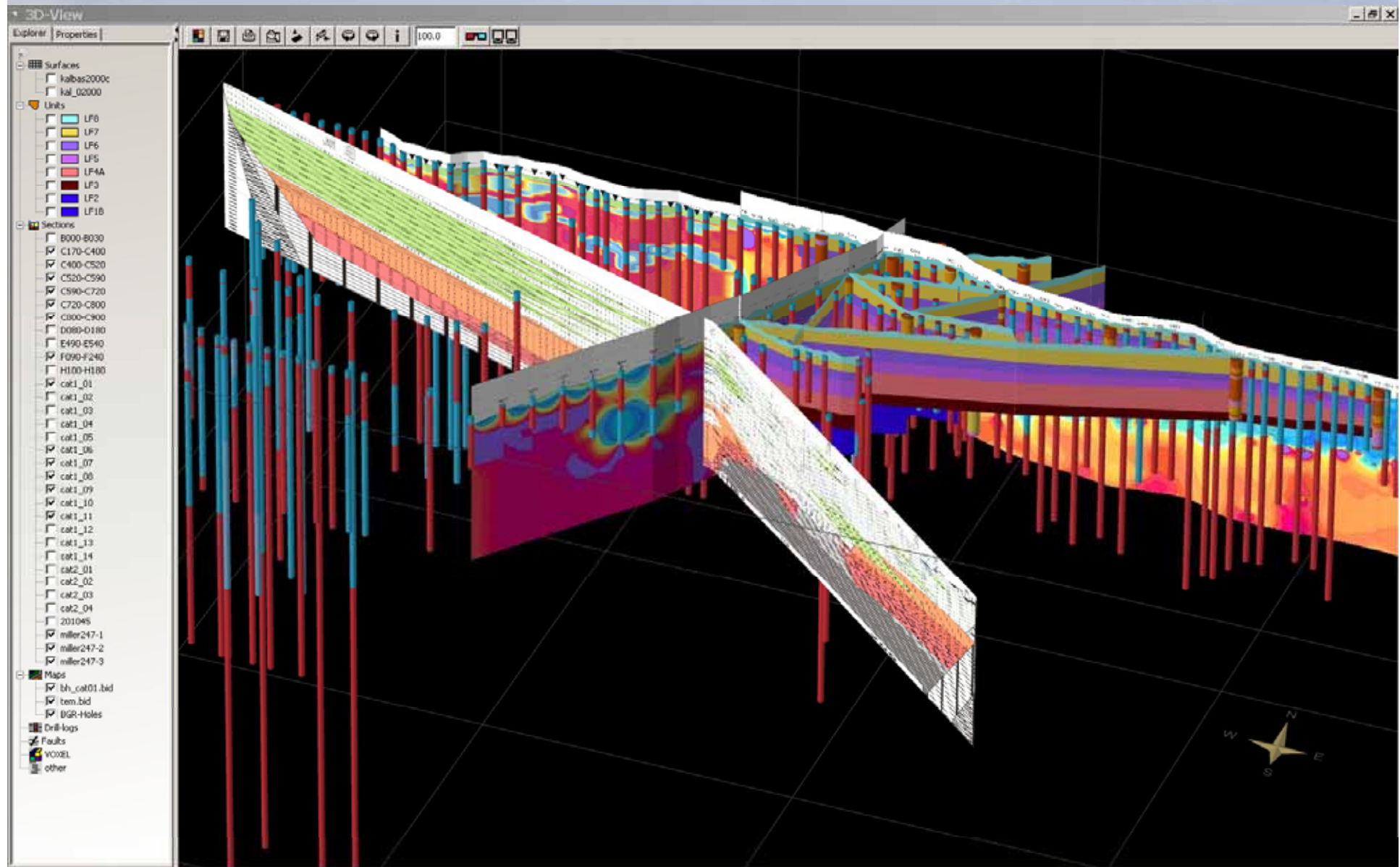


Good agreement between geophysical soundings, drill core evaluation, Groundwater sampling (fluid finder) and hydrogeological modelling

# TEM Profil (E – W) parallel to the axis of the Cuvelai - Basin

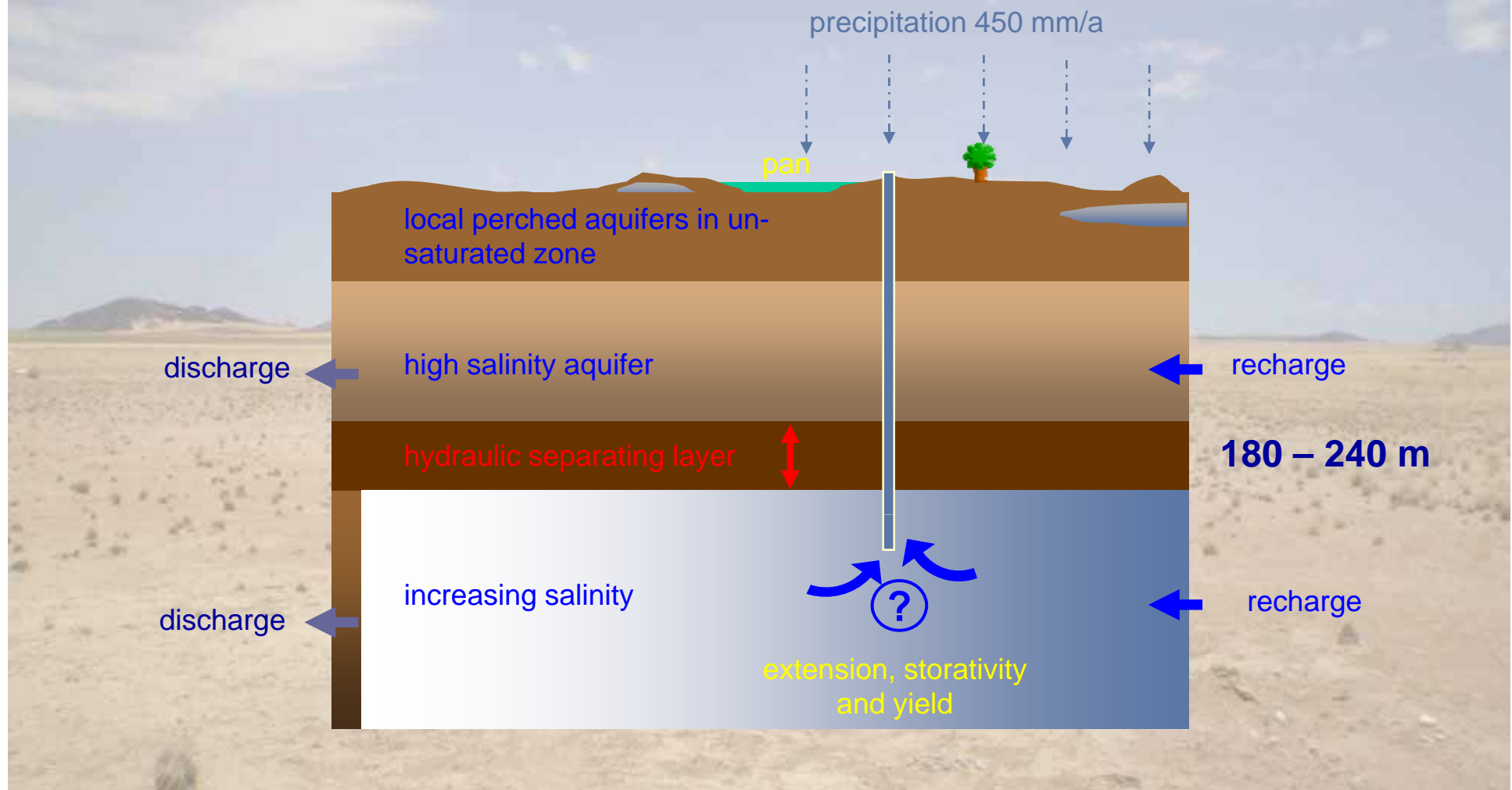


# Combined presentation of TEM soundings and drill core interpretation





# Simplified sketch of groundwater structure and conditions





## Summary

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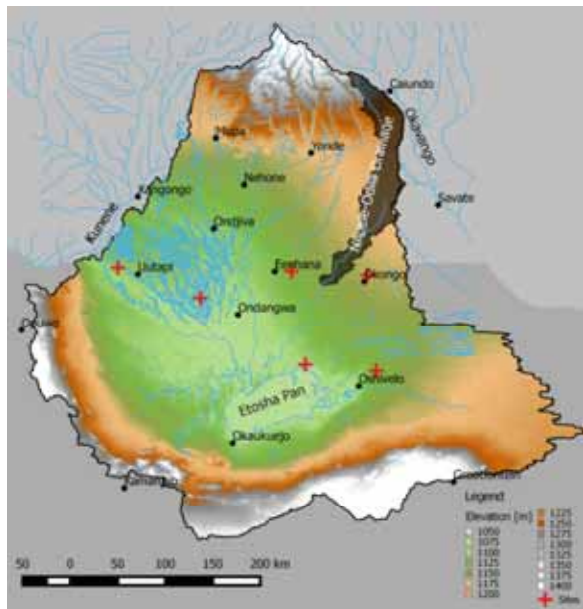
- Most recent findings of deep lying fresh water aquifers are more or less erratic
- Therefore a clear exploration strategy, comparable to the one used by the oil and gas industry, is needed
- Large intra - continental basins in Africa comprise still today unveiled fossil or semi-fossil aquifers
- The latter can only be explored by investigating the tectonic and sedimentary evolution, the paleo-climate and hydrogeological conditions
- Deep lying aquifers represent a strategic resource for a fast growing population and can support climate change adaptation



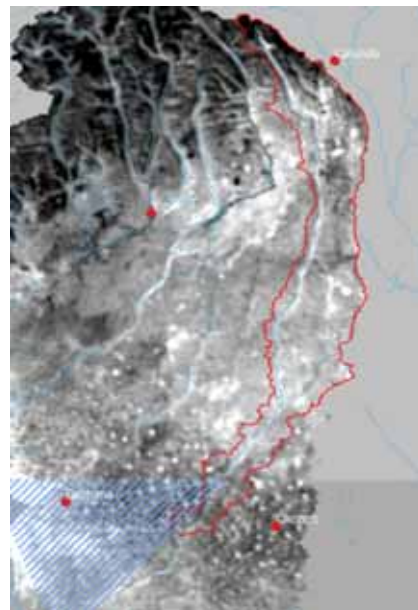
Merci beaucoup pour votre attention!

# Recharge occurs in Angola

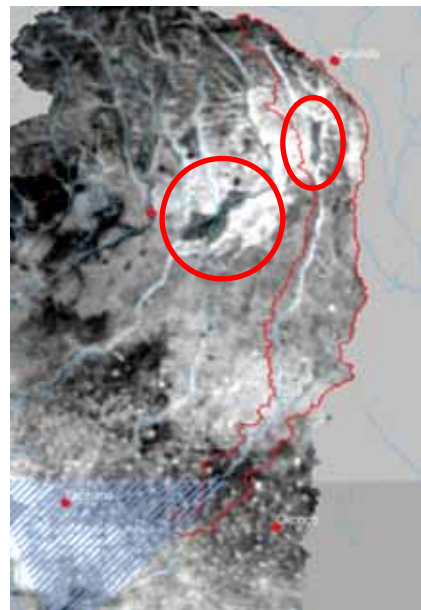
- Satellite images indicate on swampy areas during wet season
- The latter are located in the Angolan Highlands parallel to tectonic lineaments
- Topography and geological maps indicate on favourable infiltration conditions
- Pilot study on the Niipele - Odila catchment



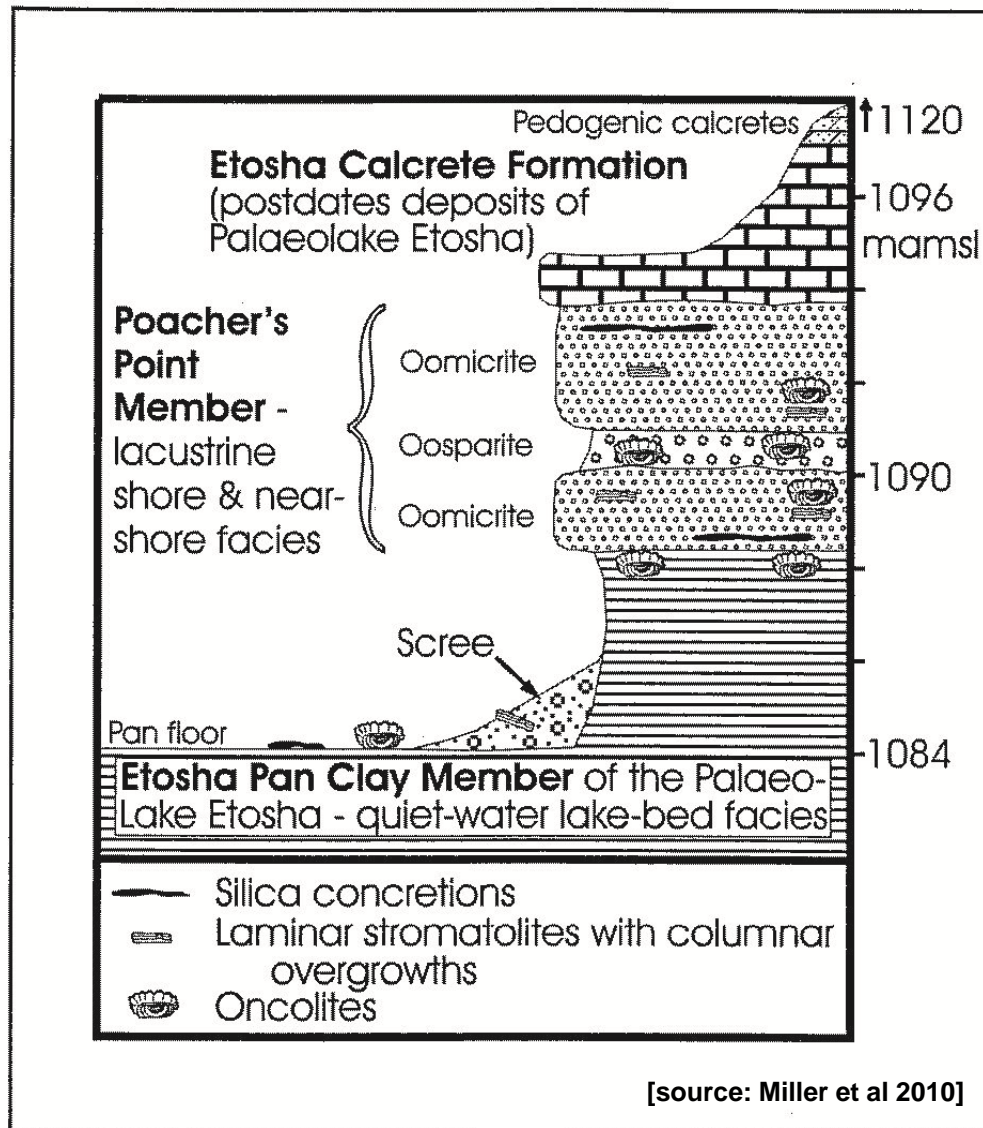
before wet season



after wet season



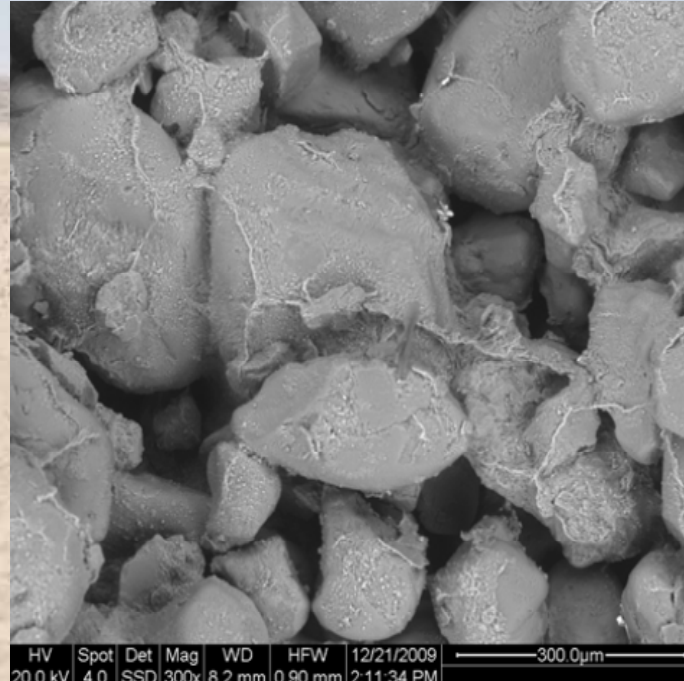
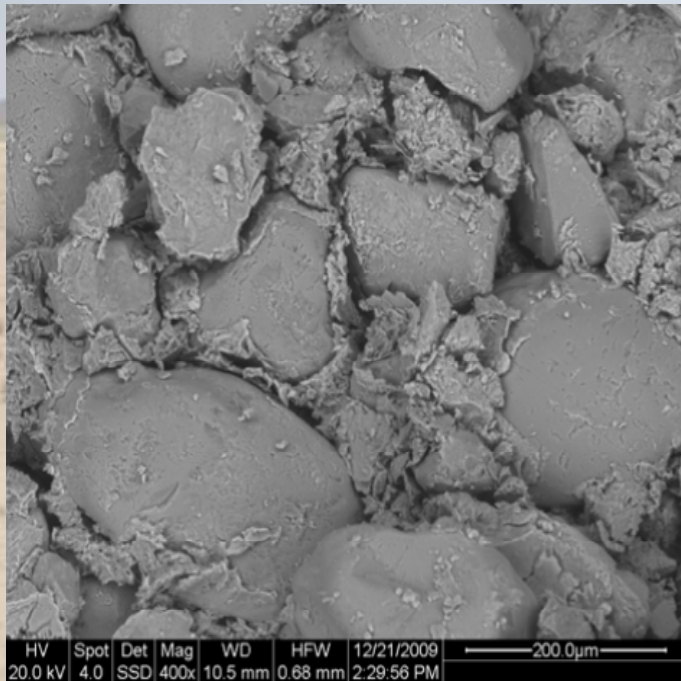
# Sedimentary Succession of Etosha - Pan



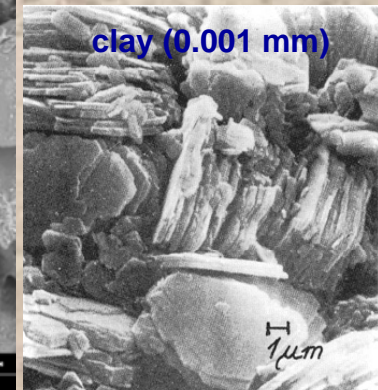
- stratigraphic classification through calcretes und benthos
- highest lake level at 1130 m
- eldest lake-level can't be identified due to wind erosion
- absolute age - determination of the sediments is impossible (e.g. due to radiological dating gap)
- Thick clay layers at the bottom prove water depth of up to 60 m
- repeated fluvial sedimentation and successive drying of the lake
- Repeated intense wind erosion and deflation of large areas and volumes

# Mineralogical investigation of hydraulic barrier

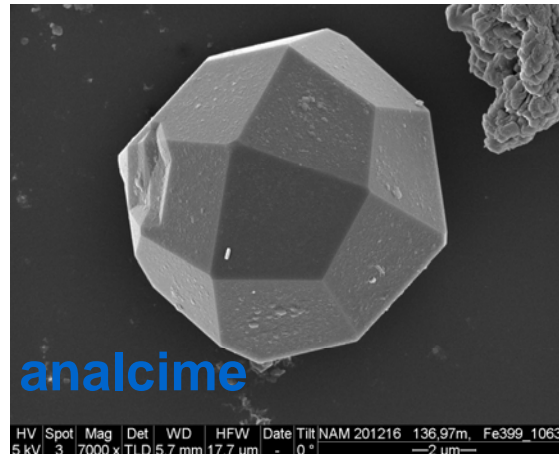
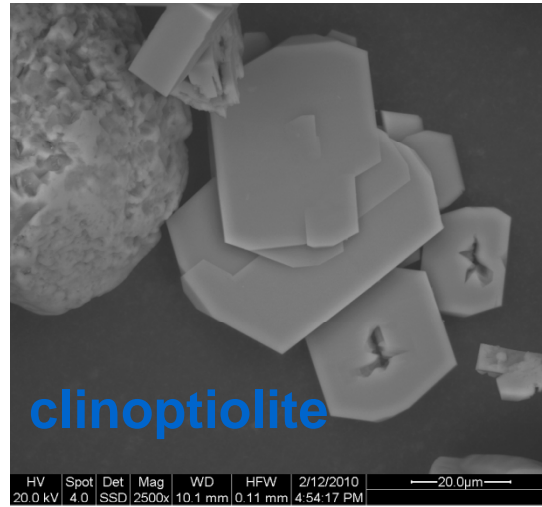
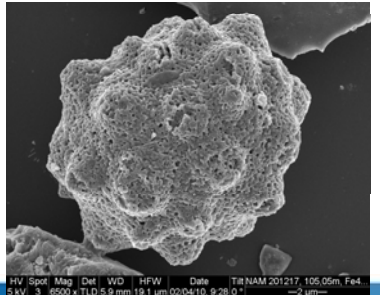
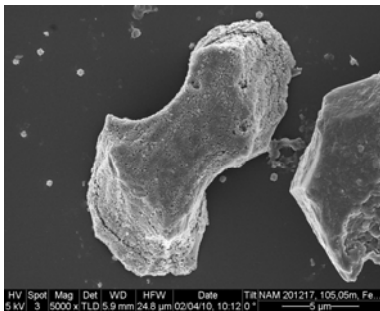
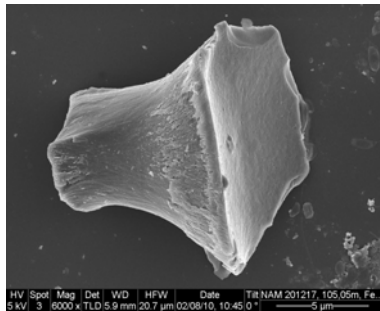
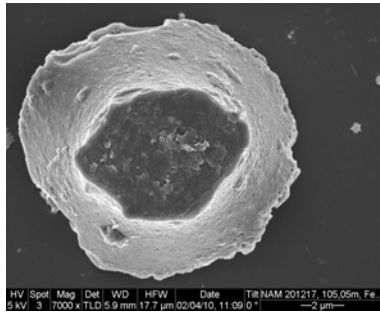
- drilling records: a very fine grained layer with high clay content separates the fresh groundwater body from other aquifers of high salinity on the top and basis respectively
- hydraulic separation is due to swelling clay minerals
- provenance of clay minerals is still unclear (diagenetic process?)



pictures taken by  
raster electron-  
microscope



**Phytolithe, analcim and clinoptiolite as well as fresh water diatoms indicate sedimentation conditions under shallow fresh water conditions**



**Paleo climate conditions were quite different!**