



Karst aquifer complexity— a
different approach, Dalmatia,
Croatia

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Parsons Brinckerhoff

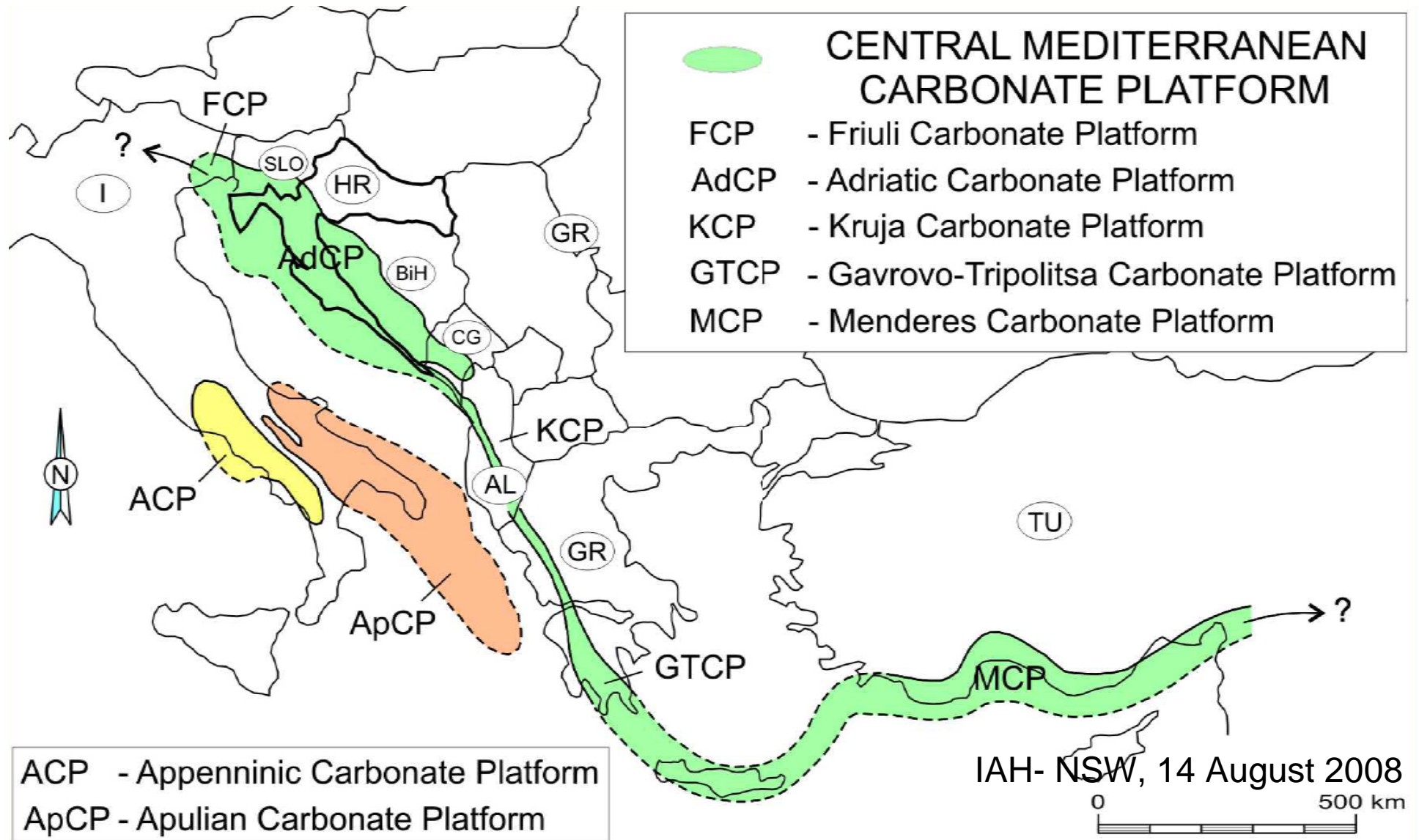
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Overview

- Mediterranean typical karst area
- Intercalated limestone with dolomite, thrust on impermeable flysch sequence
- Karst aquifer behaves as fractured rock aquifer
- Difficult to assess water levels, aquifer properties, available storage, groundwater flow direction
- Use of remote sensing interpretation, geology mapping, geophysics (seismics and electric methods), tracers



Mediterranean Carbonate Platform

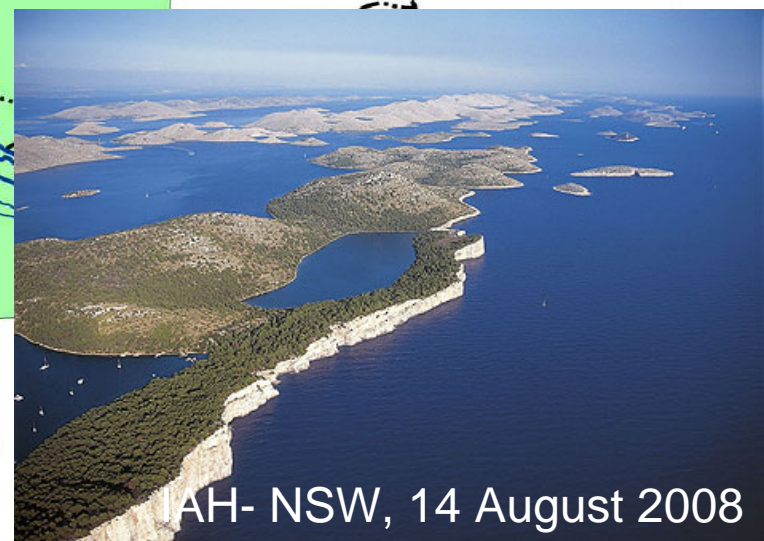
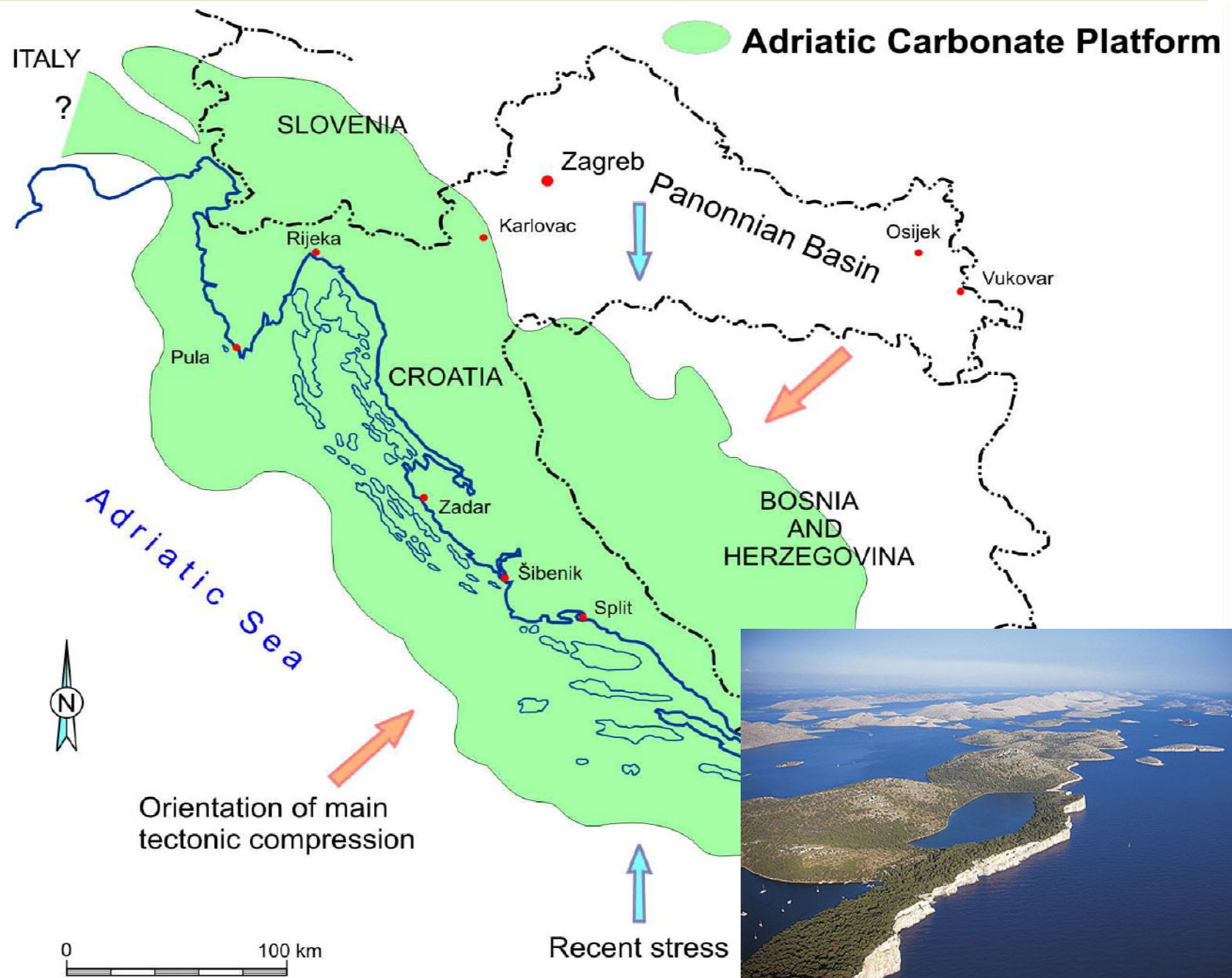




0 50 100 km



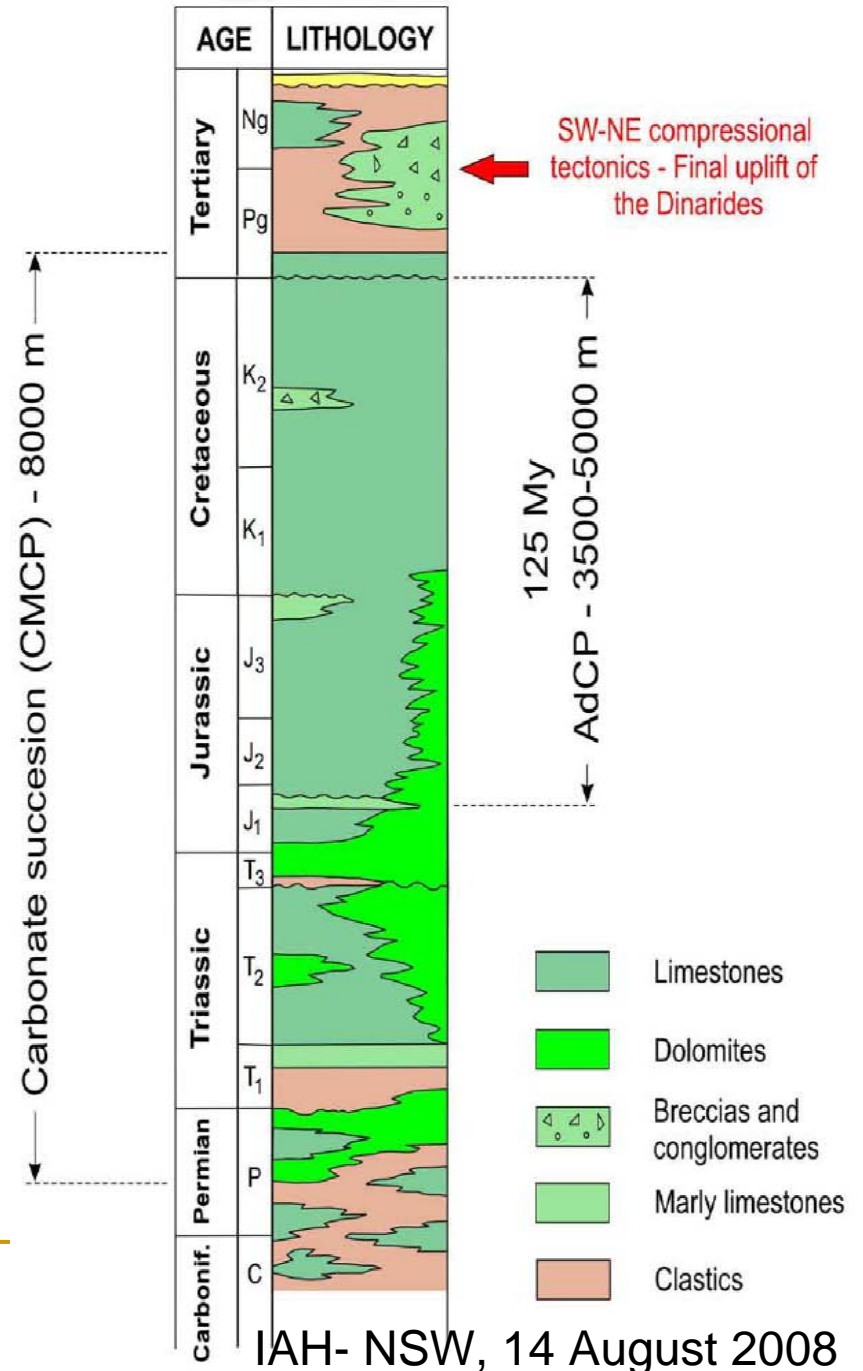
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Schematic geology

Condition for karstification:

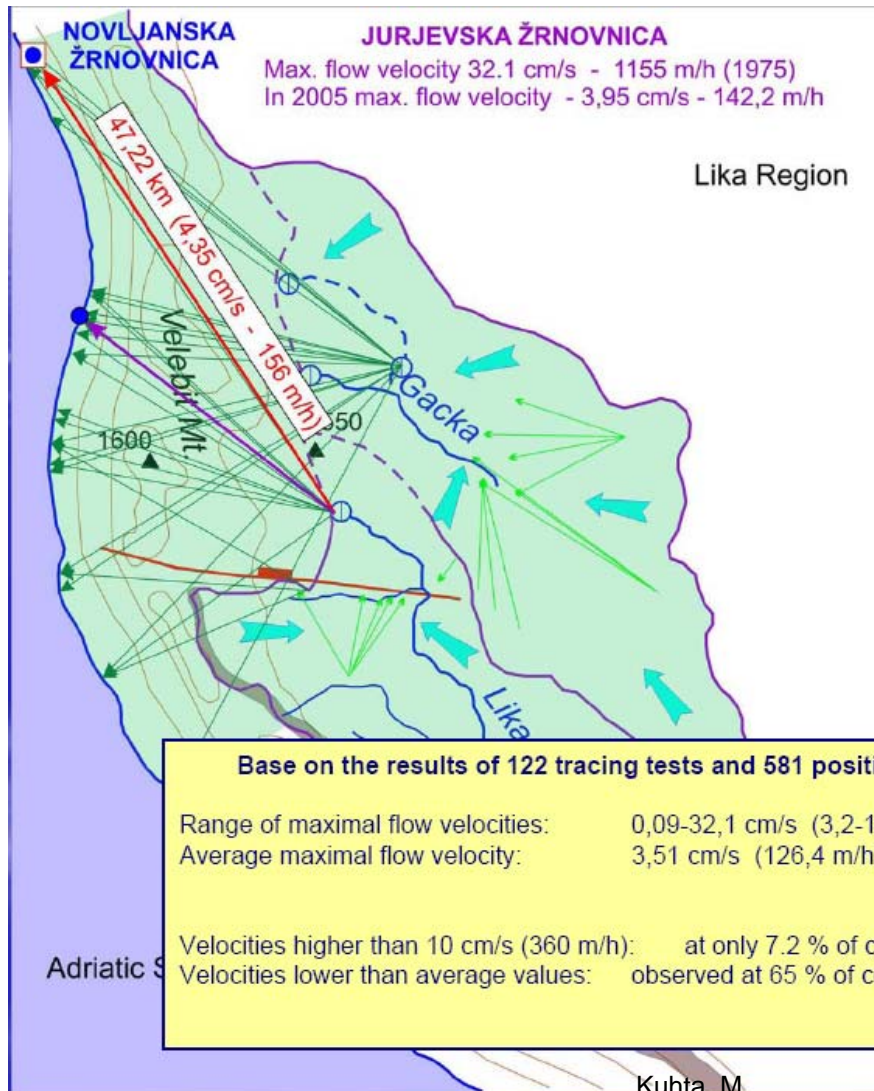
- Thick carbonate deposits
- Intense tectonic deformation



Karst investigation methods

- geological and morpho-structural analysis
- groundwater tracing tests (uranine)
- hydrogeochemical methods (stable isotopes)
- hydrological research
- geophysical investigation
- continual monitoring of physical-chemical parameters on main springs

Tracer testing



Base on the results of 122 tracing tests and 581 positive connections

Range of maximal flow velocities:	0,09-32,1 cm/s (3,2-1155,6 m/h)
Average maximal flow velocity:	3,51 cm/s (126,4 m/h)
Velocities higher than 10 cm/s (360 m/h):	at only 7.2 % of connections
Velocities lower than average values:	observed at 65 % of connections

Vrulja

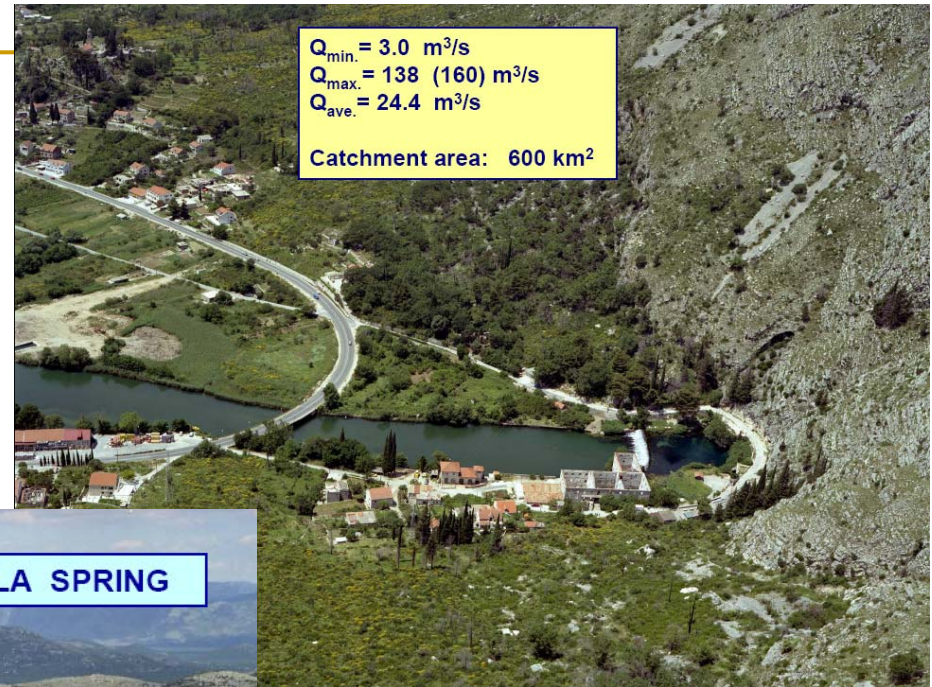


- Mixing of cold-warm, saline-fresh water
-

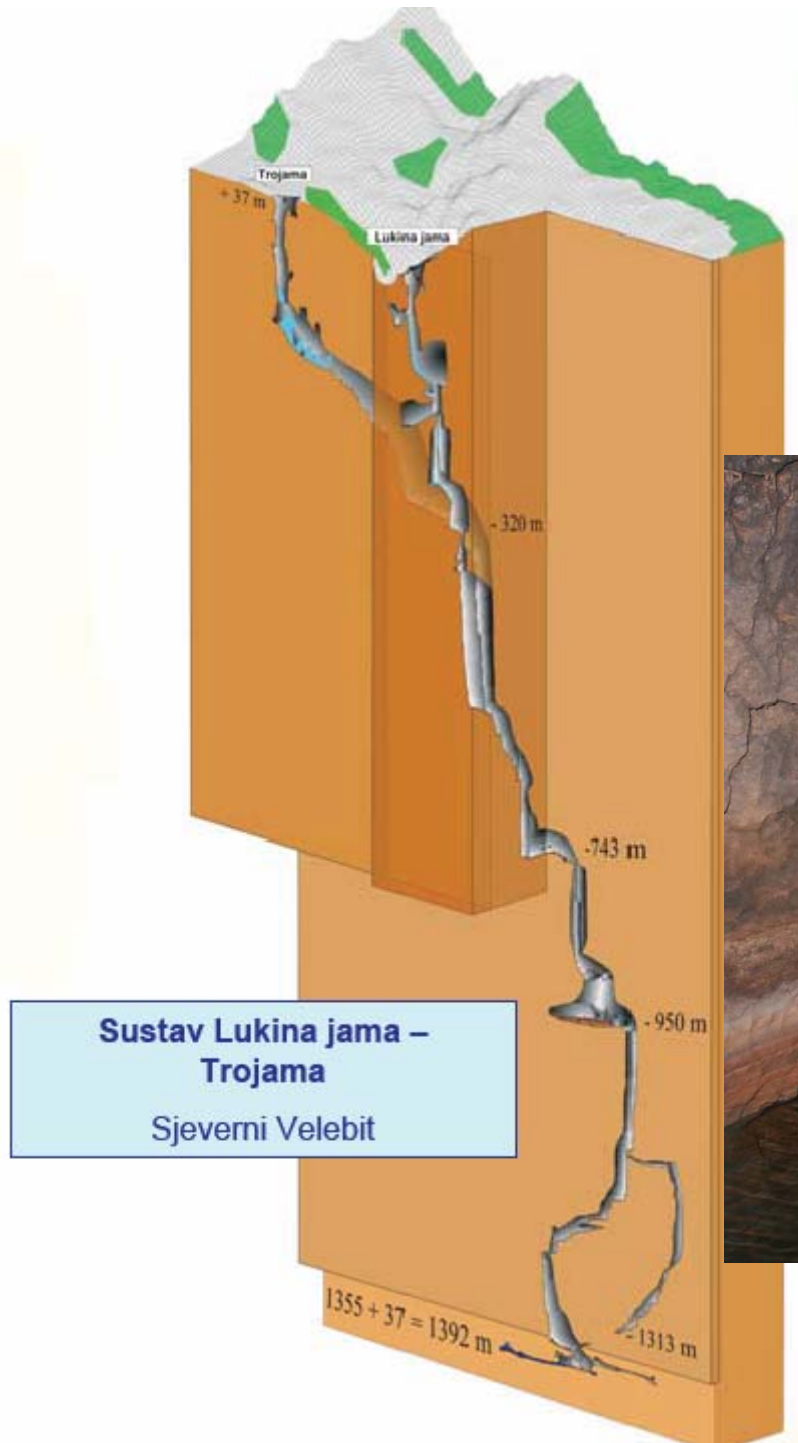


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Ombra spring discharge point



Caves –direct measurement





KARREN



Large parts of karst cover the mountain area
(Mt. Dinara 1831 m a.s.l.)



Blind valley

Red lake



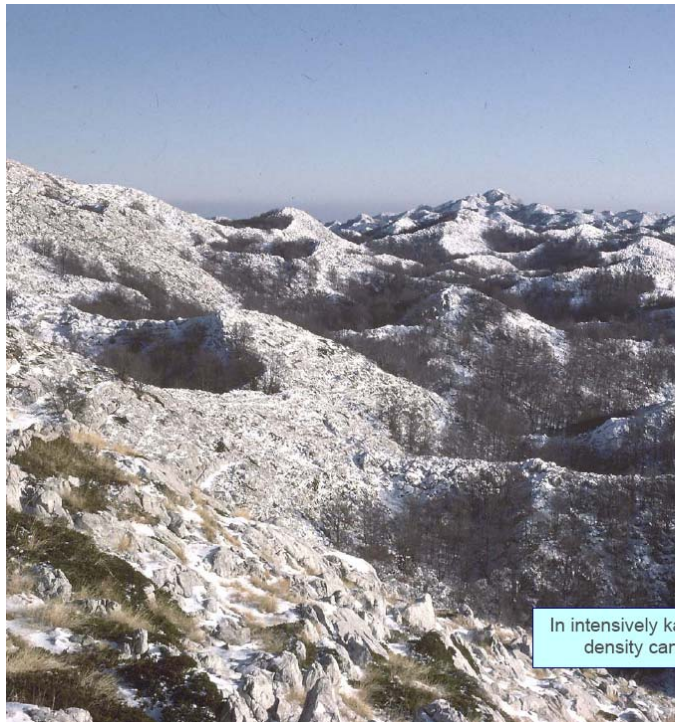
250m

282 m

-532m

Case Study- Problem

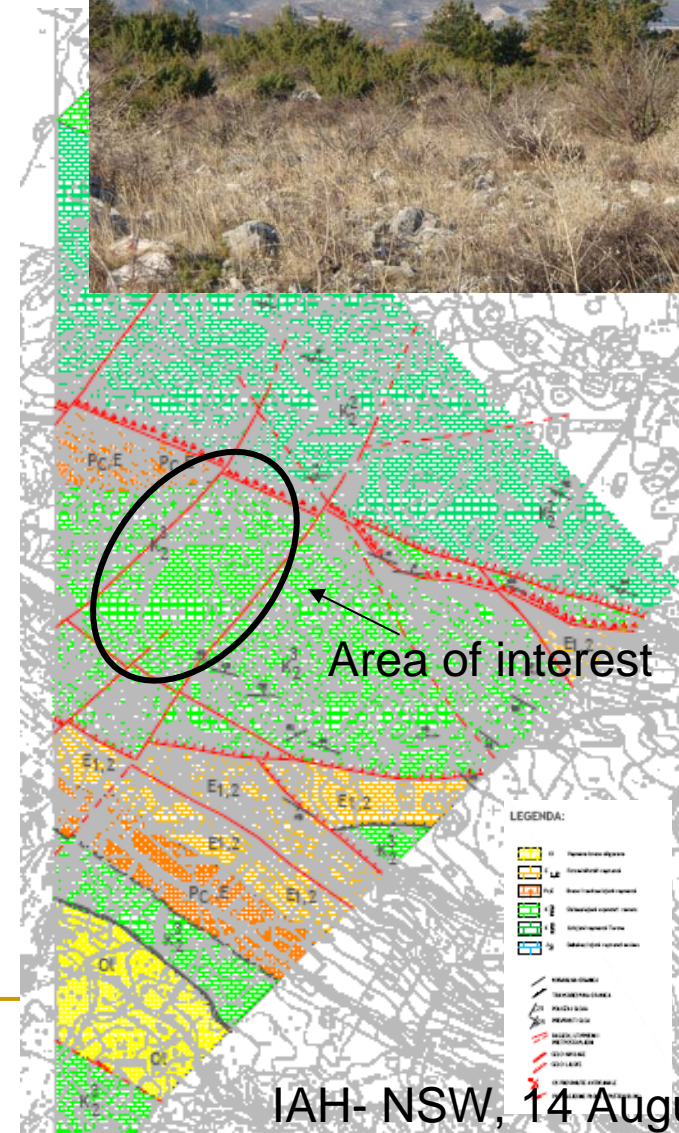
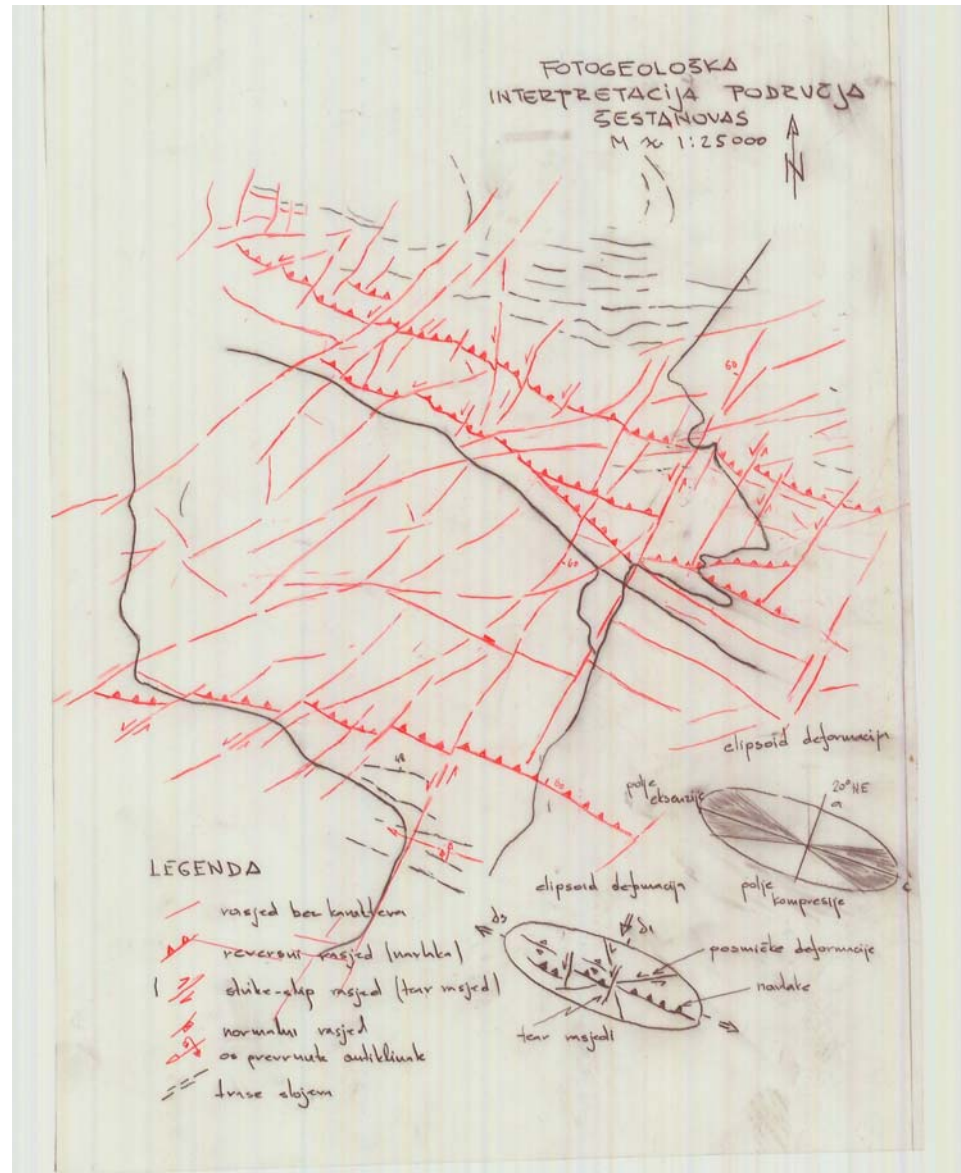
- Water resource for the irrigation purpose
- Known permanent discharge springs
- No permanent surface water



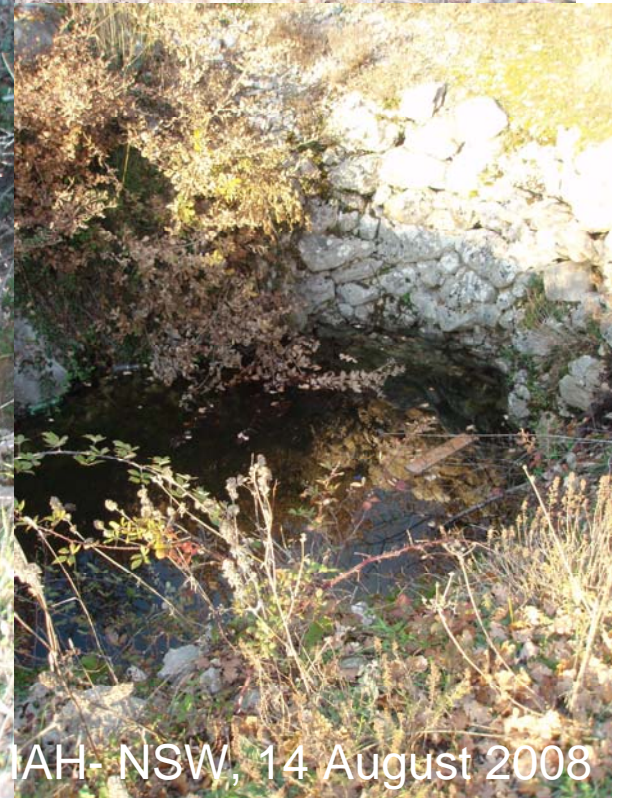
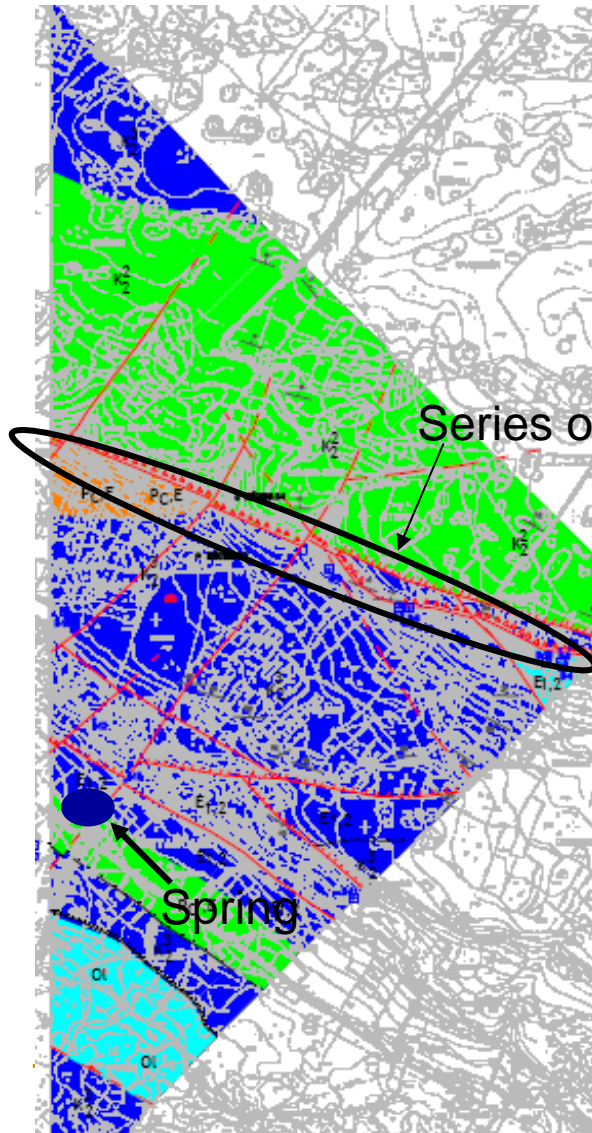
Methods

- Detailed geology mapping
- Aerophoto structural interpretation
- Mapping of springs and wells
- Geophysical methods:
 - electromagnetic sounding
 - electrical imaging
 - seismic refraction

Aerophoto imagery



Spring and well mapping



Basic chemistry

- Water dominated by carbonates
- Low EC up to 400
- pH neutral
- Temperature is constant around 12C



Geophysics

- Geoelectric resistivity imaging – based on the specific resistance of different rocks , Wenner array used with 5m spacing and 60m depth coverage
- Refraction seismics- based on the refraction of seismic waves on the contact of two units, velocity of seismic waves measured and location of elastic discontinuity to define the spatial changes in physical-chemical characteristics of rocks
- EM sounding TDEM-material resistance measured by inducing electricity on surface and measuring the resistivity of the materials to electrical flow

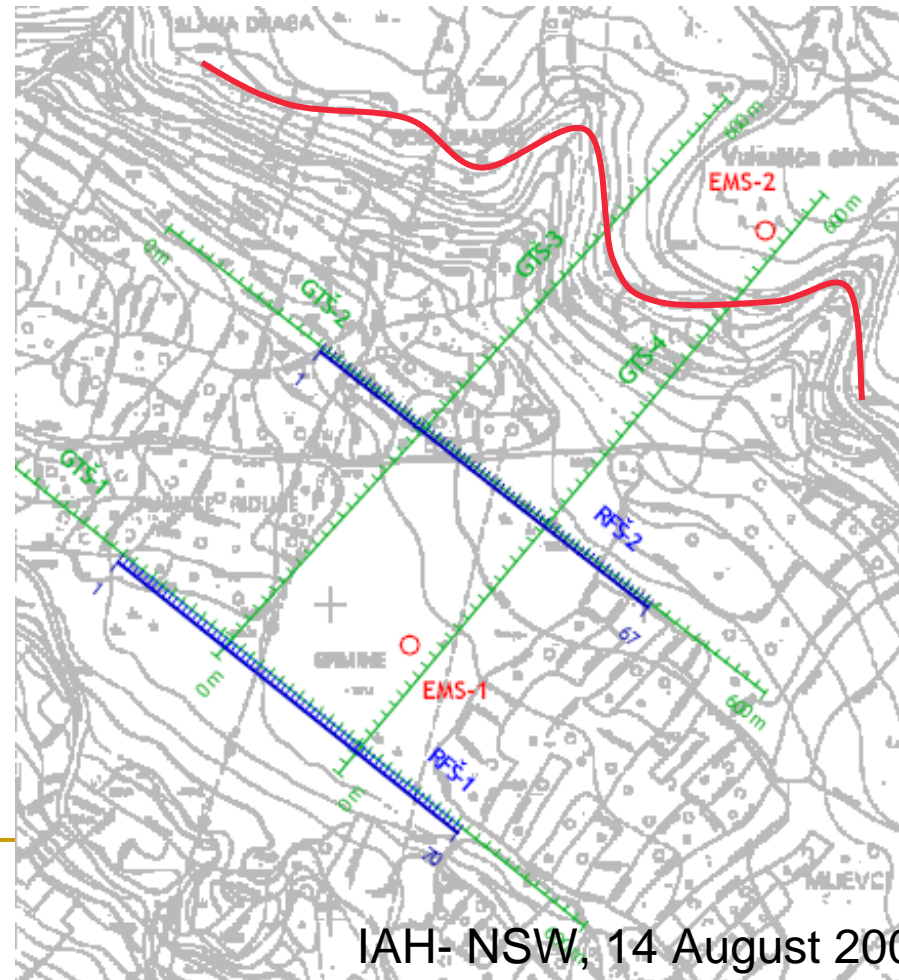
Resistivity Imaging

- Location of profiles to define the thrust and fractures

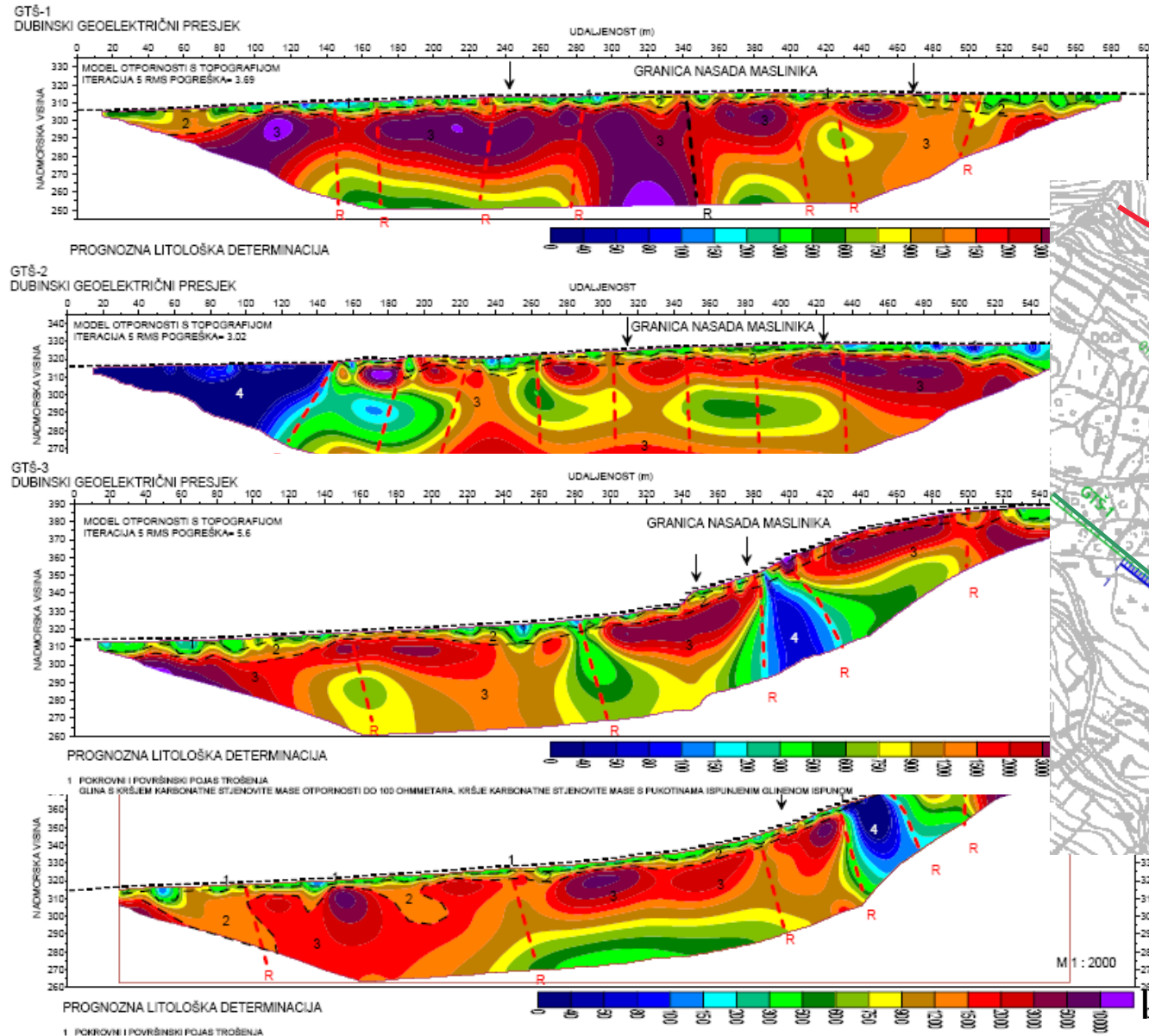


Refraction seismics

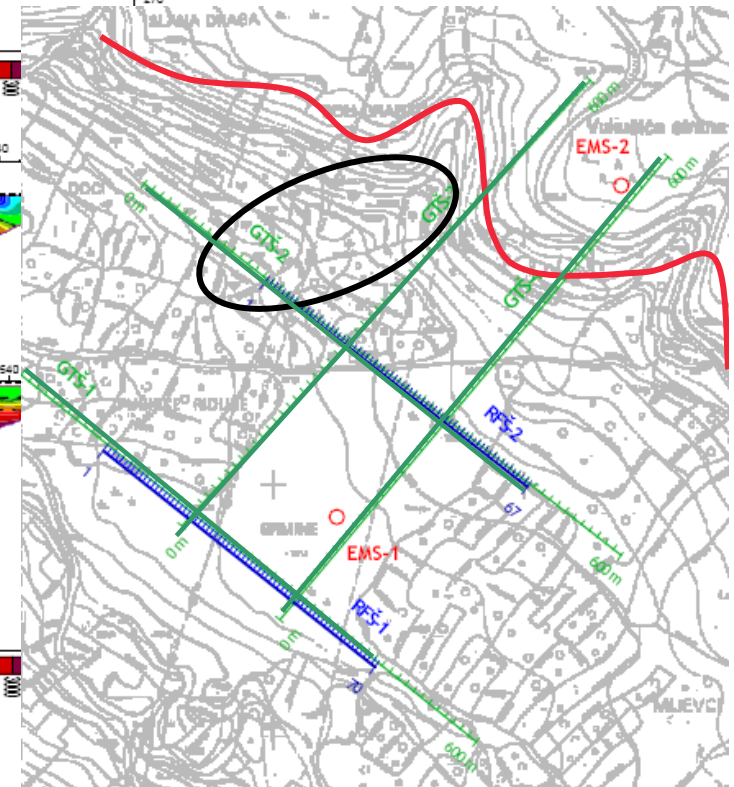
- Refraction profiles over the geoelectrical to confirm the location of fractures



Results of resistivity imaging



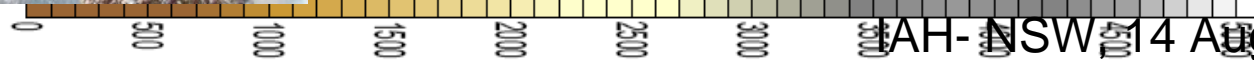
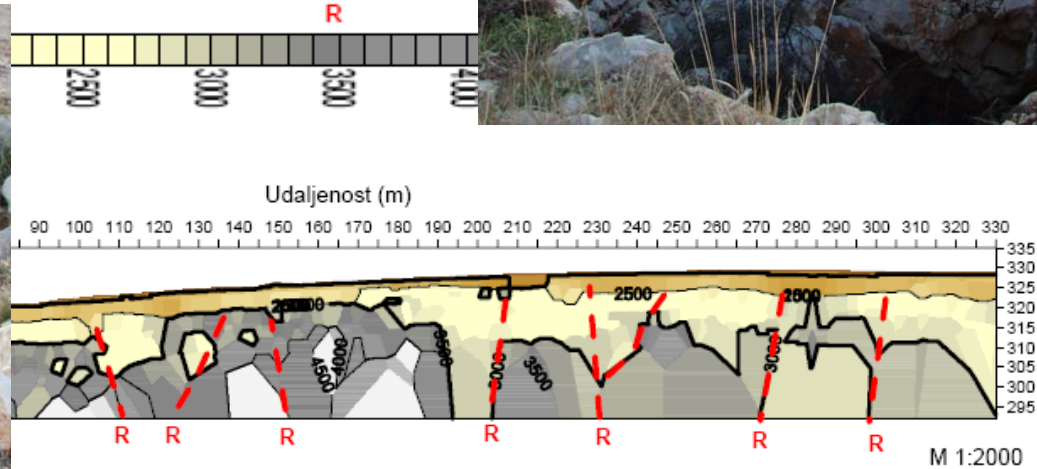
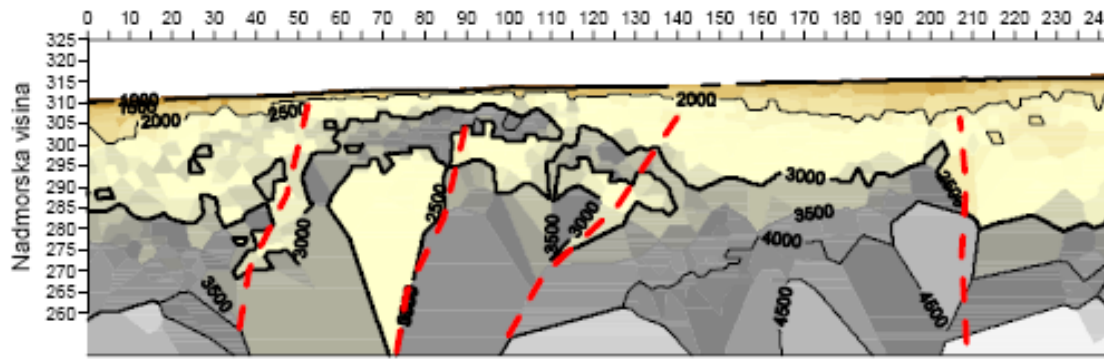
overlay to



Seismic refraction

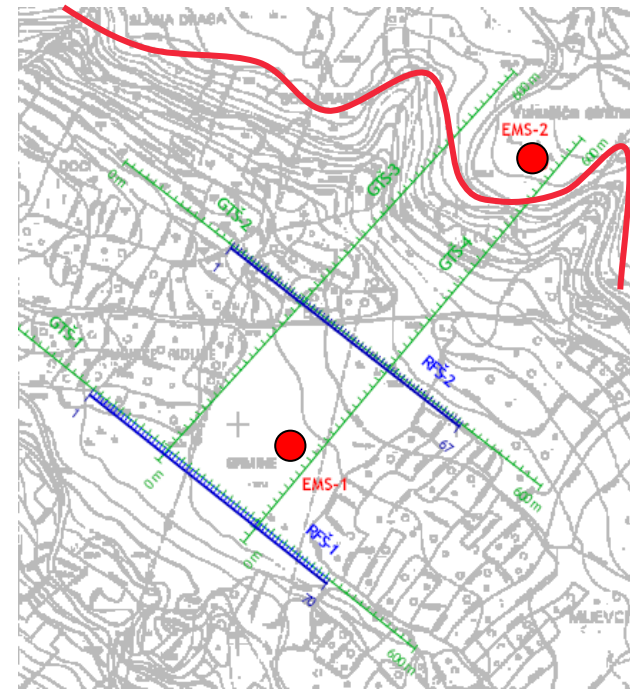
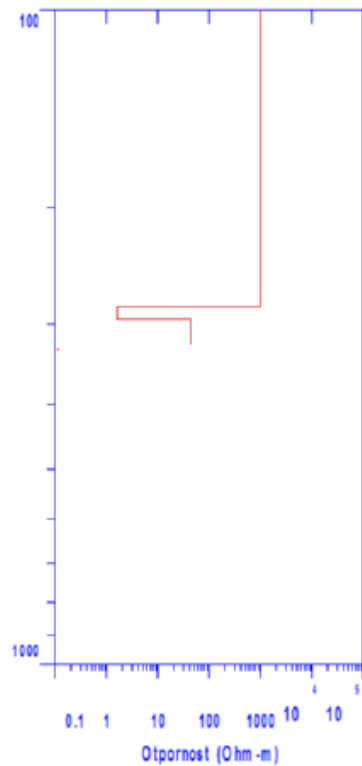
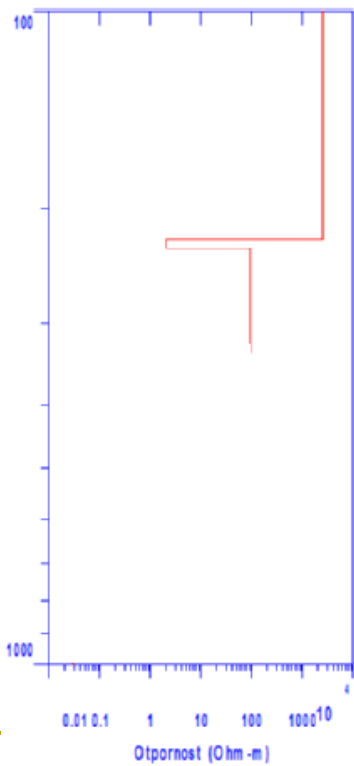


■ Profiles

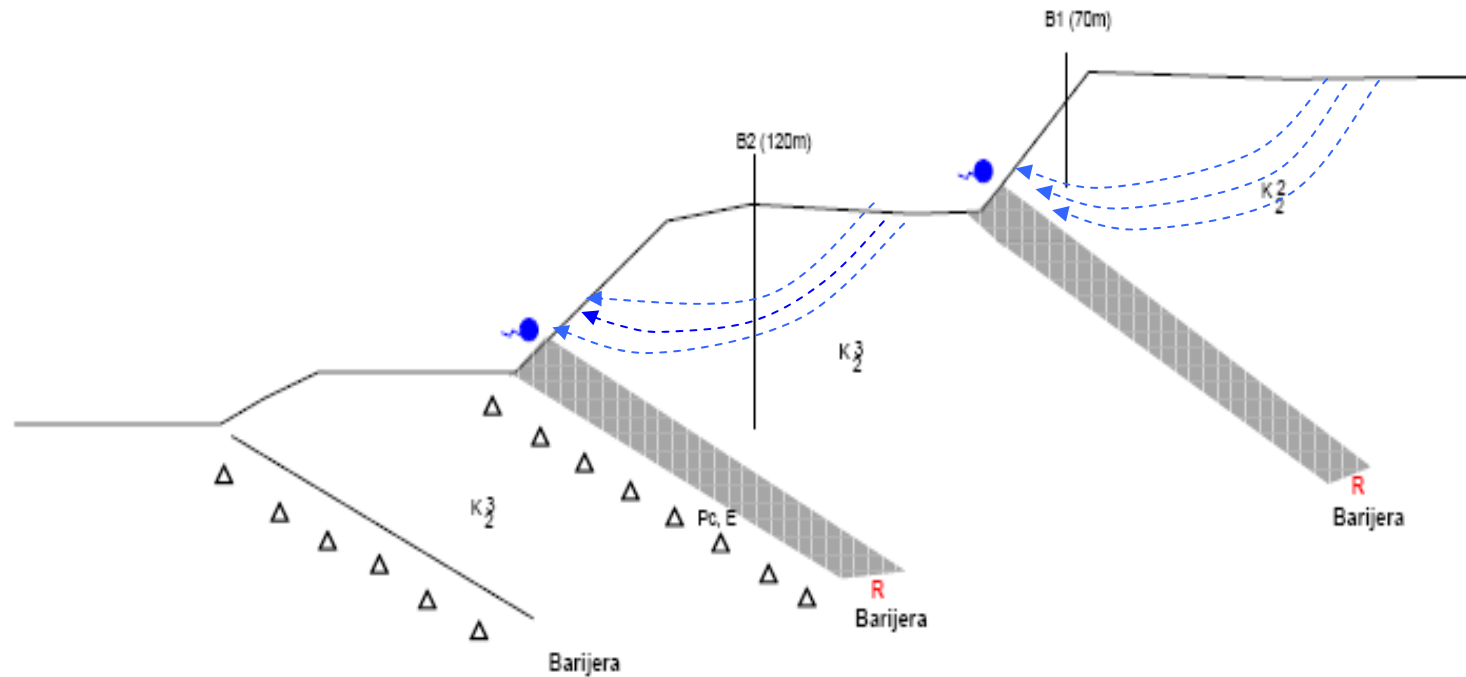


EM sounding

- Profiles and results



Conceptual model





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