Interaction between joints and normal faults in a graben setting - a field study in Canyonlands National Park, Utah/USA

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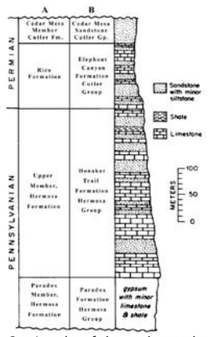
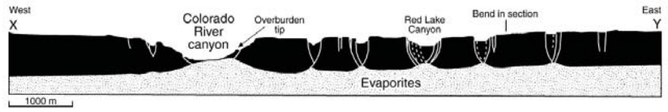
Introduction

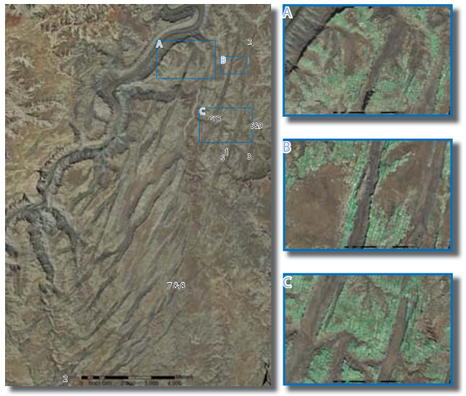
The study area is located in the Canyonlands National Park on the Colorado River Plateau, Utah. Of great importance for the evolution of the graben system is the ~ 460 m thick accumulation of Pennsylvanian evaporites, overlain by up to 500 m of brittle sand- and limestones. Due to an uplift event the entire area shows intense jointing, that is believed to be older than the grabens. Graben formation started about 60,000 ago. The most accepted hypothesis for the evolution of the grabens is a gravitational gliding of the brittle rocks over the evaporite layer (2-4° dip), permitted by the cutting in of the colorado river.
The image below shows an interpretation based crosscut through the northern grabens by Schultz-Ela and Walsh (2002).



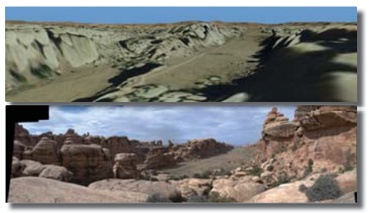
Stratigraphy of the study area by (A) Lewis and Campell (1965) and (B) Huntoon (1982) taken from McGill et al (2000).



Pre-fieldwork



A quite good knowledge base of the area was achieved in the diplom mapping of Jasmin Mertens (2006). New high resolution orthoimages from 2009 (see images to the left) offer an amazing possibility for GIS mapping and so over 20,000 joints were mapped to derive statistical information about joint orientation and lenght, restricted to certain areas of interest.



Why is it necessary to go to the field? Both images to the left show the same view: (1) in a combination of high resolution airborn imagery and a digital elevation model (top) and (2) the actual situation in the field (bottom).

Fieldwork impressions

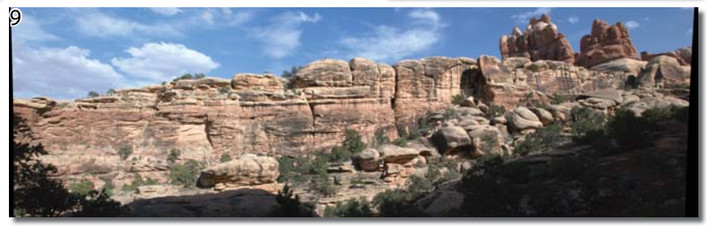
1: Panorama of the Devils Lane Canyon, view south. A large relay ramp is visible on the left side.
2: Crosscut through a young graben showing small displacement. Cross Canyon.
3: Uneroded remnants whithin a graben give insights to the grabens displacement.

4: Heijn using the laser scanner, which can measure the azimuth, inclination, horizontal distance, vertical distance and shot distance with an accuracy of 30 cm.
5: The 100 Mhz ground penetrating radar antenna mounted to our jeep to measure along a graben wall.

6: A 5 cm thick calcite layer filling a nearly uneroded joint.

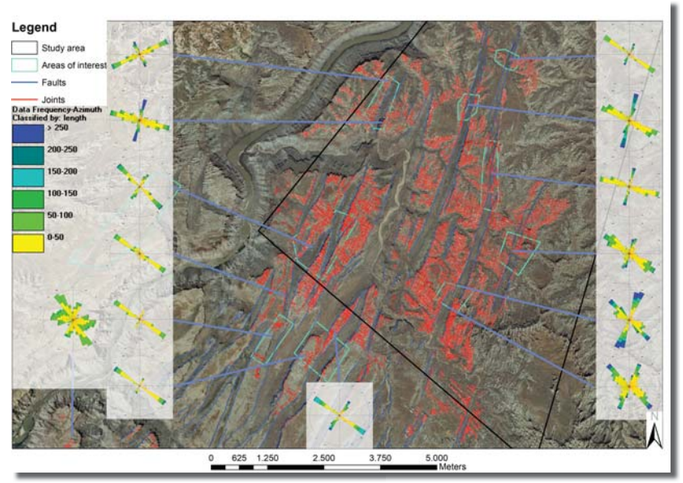
7: A large sinkhole at a graben wall indicates fluid pathways along either the fault or the joints.

8: The large block in the middle shows a horizontal offset due to the graben formation. A sinkhole developed between this block and the graben wall.



9: The panorama shows a smooth graben wall with large open joints. Since we can correlate layers in the graben wall and at the graben floor, an evaluation of the displacement is possible (using the laser scanner).

Post-fieldwork



The map above shows the entire study area, outlined in black. More than 20,000 joints are mapped in red and the faults (blue) were adopted from Jasmin Mertens' mapping. For different areas of interest (turquoise) the joint orientation is plotted as roseplots, the colors indicating the joints lengths.

Over 7000 m of GPR profiles were taken in the study area using 100 MHz and 400 MHz antennas. Profiles crossing graben walls are the most promising, since within the grabens sediment thickness mostly exceed the penetration depth of the antennas and groundwater limits the range adittionally. The image to the right shows a profile line (length: 34 m) within a wash that crosses a graben wall. The GPR profile (right) shows an increase in sediment thickness towards the graben (from right to left) as well as at least two faults with small displacement (less than 1 m).

Outlook

An upcoming part of this project is the analogue modeling of normal fault-joint interaction using brittle, cohesive hemihydrate powder (gypsum).

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References

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