Tectonic geomorphological investigations of antiforms using differential geometry (Permam Anticline, Northern Iraq)

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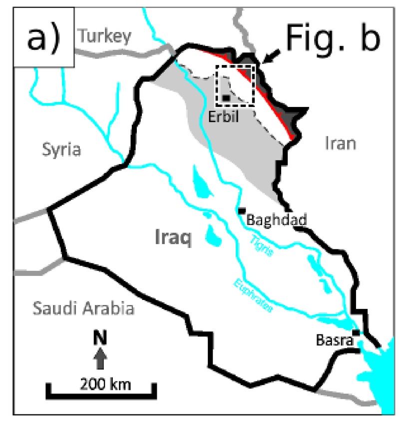
I. INTRODUCTION

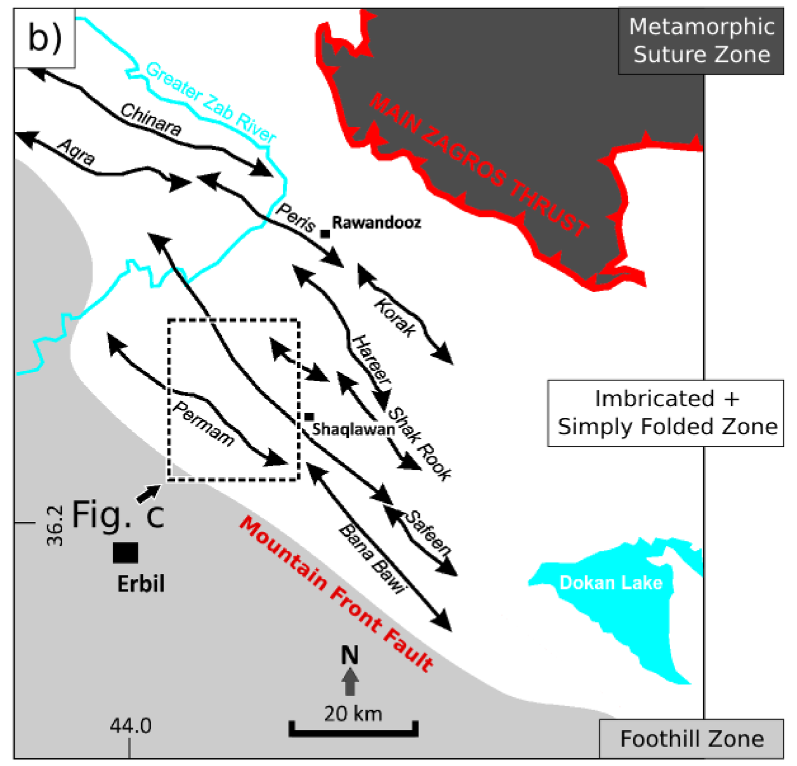
The first step in the investigation of fold mechanics is the description and understanding of fold geometry. Given the increasing availability of 3D data sets through remote sensing techniques, this is best done by numerically analyzing and classifying geologic structures using methods from differential geometry. Until now, curvature analyses have been used by structural geologists to describe the geometry of folded surfaces, to quantify strain, to predict fracture orientations and densities or to analyze geomorphological features.

In this study, we analyze the antiformal and synformal structures of a part of the Zagros fold and thrust belt relevant for hydrocarbon exploration. Numerical curvature computations based upon SRTM surface data are carried out in MATLAB. By systematically varying two key parameters in the calculation, the geomorpho-logical signals of various wavelengths are enhanced.

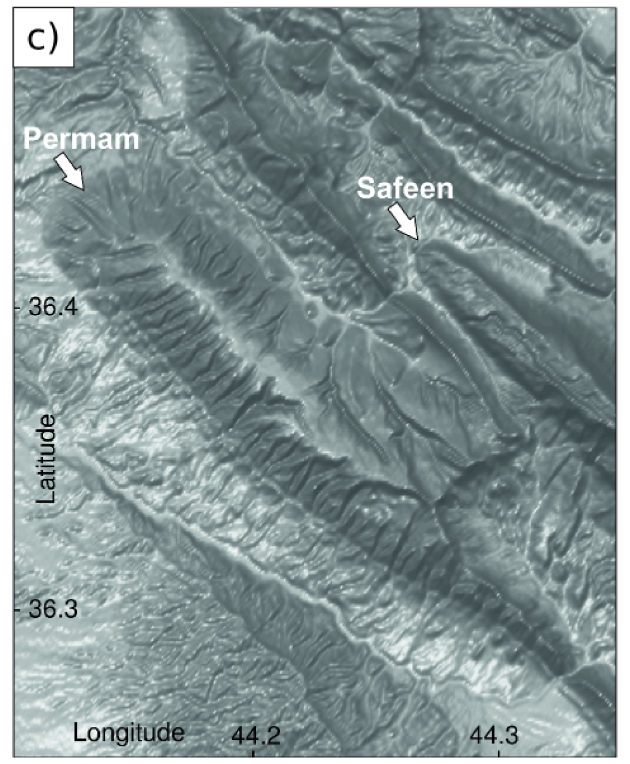
II. OVERVIEW



The study area is located NE of the city of Erbil in the *Kurdistan region* (a). It is situated in the Simply Folded Belt, which is characterized by thin-skinned deformation and the absence of major thrusts. The NW-SE striking antiforms (b and c) control the landscape evolution and have a flat top resulting in box-shaped folds.



Tectonic units and major antiforms in the Kurdistan region



SRTM digital elevation model of the study area

REMOTE SENSING → CURVATURE DISTRIBUTION → GEOMORPHOLOGICAL INTERPRETATION

III. NUMERICAL CURVATURE ANALYSIS

A. What is curvature?

The curvature tensor expresses *how much a surface deviates from being flat*. The key quantity for curvature computations is the shape operator. Its eigenvalues (and eigenvectors) are the maximal and minimal curvature values (and directions)

⇨ k_{min} and k_{max}.

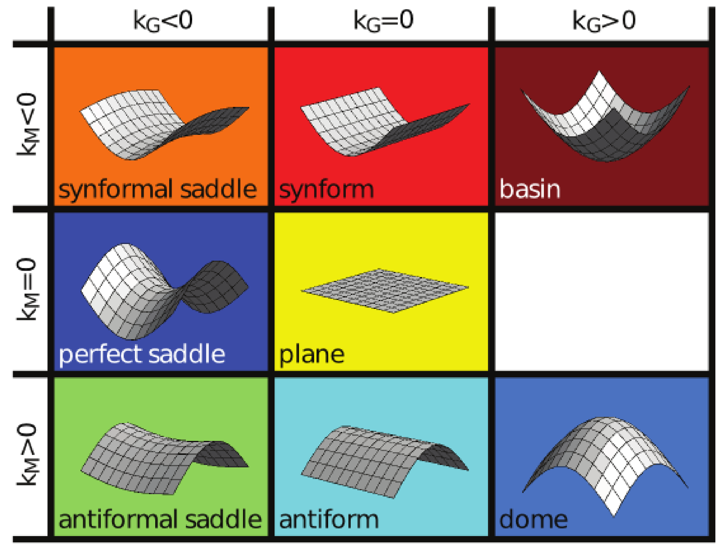
Important curvature quantities:

⇨ *Mean curvature* $k_M = \frac{k_{min} + k_{max}}{2}$

⇨ *Gaussian curvature* $k_G = k_{min} \cdot k_{max}$

B. Geological curvature

= interrelation between Gaussian curvature k_G and Mean curvature k_M (Mynatt et al., 2007)



C. Variable parameters

In practical situations, measurement errors and unwanted surface undulations have to be filtered out in the numerical computations.

⇨ *cut-off wavelength* s

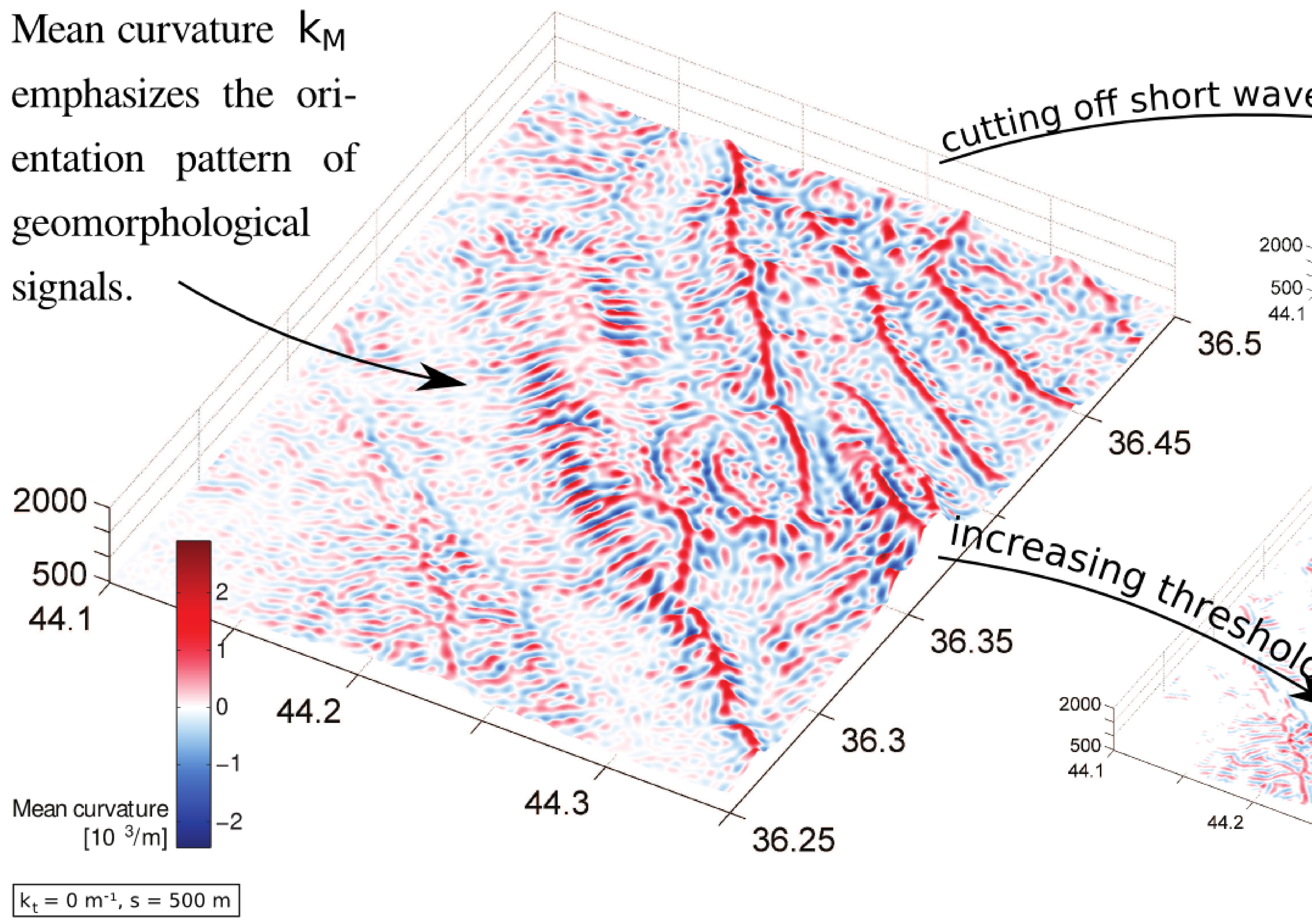
A low-pass filter is applied to the DEM prior to curvature computations.

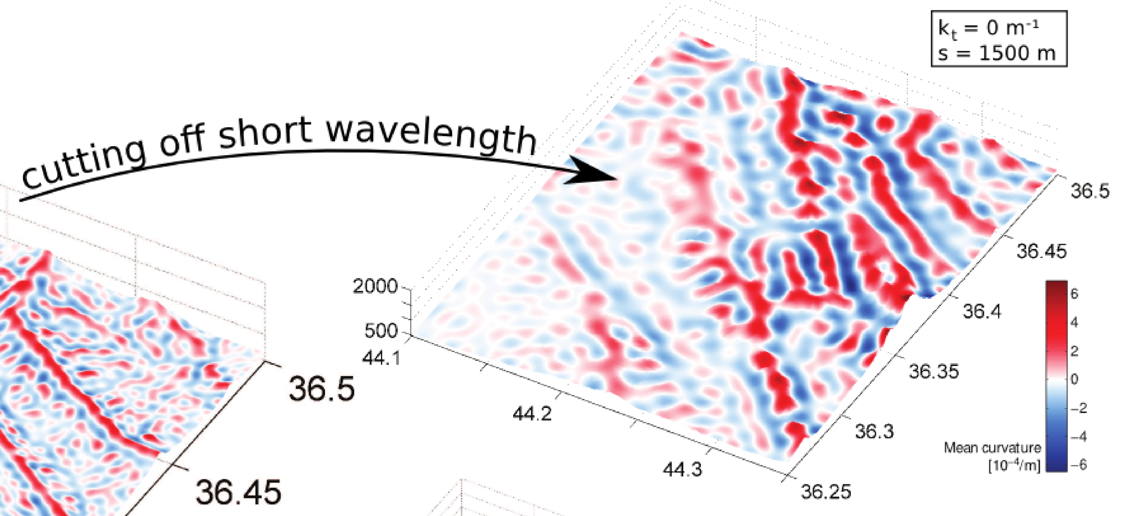
⇨ *curvature threshold* k_t

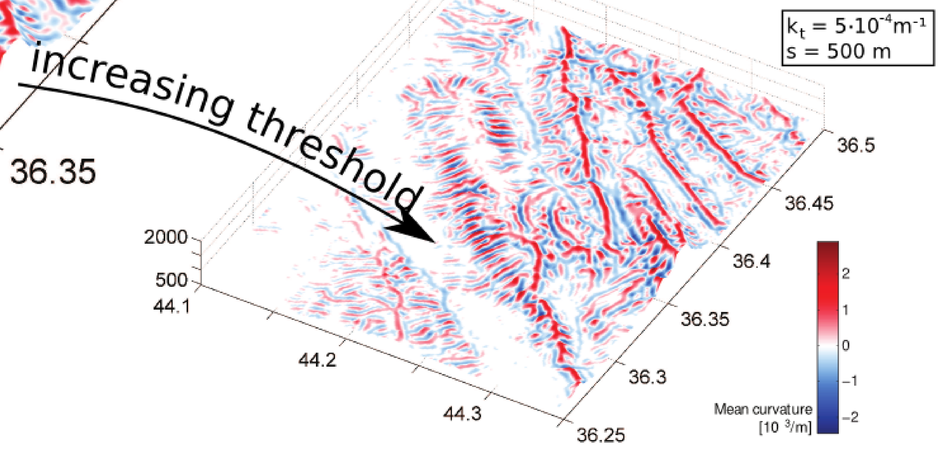
Small curvature values are suppressed by setting them to 0. For example, if $|k_{max}| < k_t$, then $k_{max} \mapsto 0$.

D. Mean curvature distribution of the Permam Anticline

Mean curvature k_M emphasizes the orientation pattern of geomorphological signals.







Structures with a long wave-length can be analyzed with-out the interference of surface undulations.

⇨ *large-scale fold structure* and anticline (red) and syn-cline (blue, white) succession are enhanced

Geological shapes are approximated by ideal cylindrical shapes.

⇨ relatively flat areas are classified the same (white), *erosional pattern* remain visible

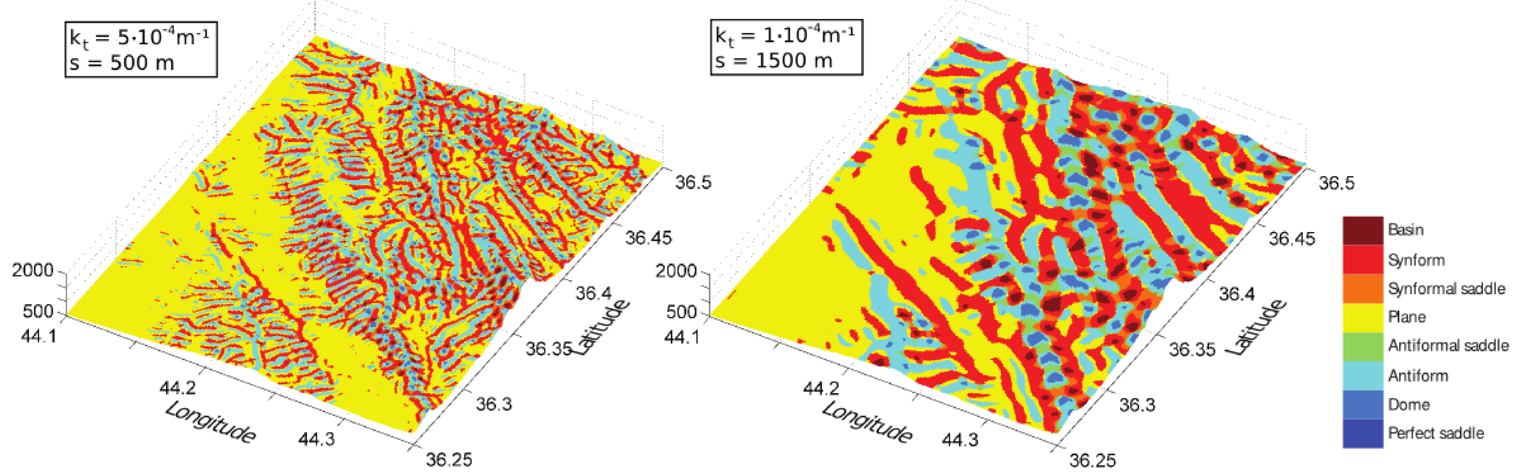
IV. DISCUSSION & CONCLUSIONS

The **topography** of the Permam Anticline follows well the geological anticlinal structure. The *small-scale* erosional pattern shows that the Permam Anticline is much flatter in its hinge area than surrounding anticlines which form hogbacks (sharp edges are visualized by large positive mean curvature). On a *large scale*, the succession of anticlines and synclines is very well visible in the curvature distribution. Synclines appear flat as they are covered by Quaternary sediments. The NW-SE trending fold traces are hardly interrupted by erosion structures perpendicular to this trend.

⇨ *Gaussian curvature* k_G distinguishes cylindrical from non-cylindrical shapes.

⇨ *Mean curvature* k_M distinguishes synformal from antiformal shapes.

Geological curvature combines both quantitative signals and offers a tool for a *qualitative* classification of geological shapes. Curvature analyses of DEMs from the Zagros fold and thrust belt demonstrate the importance of a proper adjustment of the two variable parameters s and k_t depending on the aim of the interpretation.



References

Burtscher A., Frehner M., Grasemann B. (to appear). AAPG Bulletin.
Lisle R., Toimil N. (2007). Geology.
Mynatt I., Bergbauer S., Pollard D. (2007). J. Struct. Geol.

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