

Morphometrics of regmaglypts based on a 3-D Model of the fusion-crusted ordinary chondrite Broek in Waterland (L6)

Keywords: fireball, break-up events, photogrammetry, Land Surface Parameters (LSPs)

Regmaglypts are shallow depressions on meteorite surfaces formed by the ablation processes during atmospheric entry. These features can potentially offer insights in break-up events. However, quantitative methods to analyse regmaglypts have not yet been proposed, so far. Here we present the results of a study to evaluate break-up processes during the luminous flight by analysing regmaglypt morphometrics. We developed a novel approach based on a 3-D shape model of the Broek in Waterland meteorite that was generated using photogrammetry, and analyses of the surface.

Check it out!

Scan the QR-tag with your smartphone to view the 3-D model of this meteorite online via the Delft Meteorite Lab. This meteorite impacted a shed after a fireball appeared during twilight on 11 January 2019 at 17.09 CET. A 3-D model was created shortly after the meteorite was recovered. This model can be used for various applications, such as wind tunnel studies and this pilot study of surface morphologies.



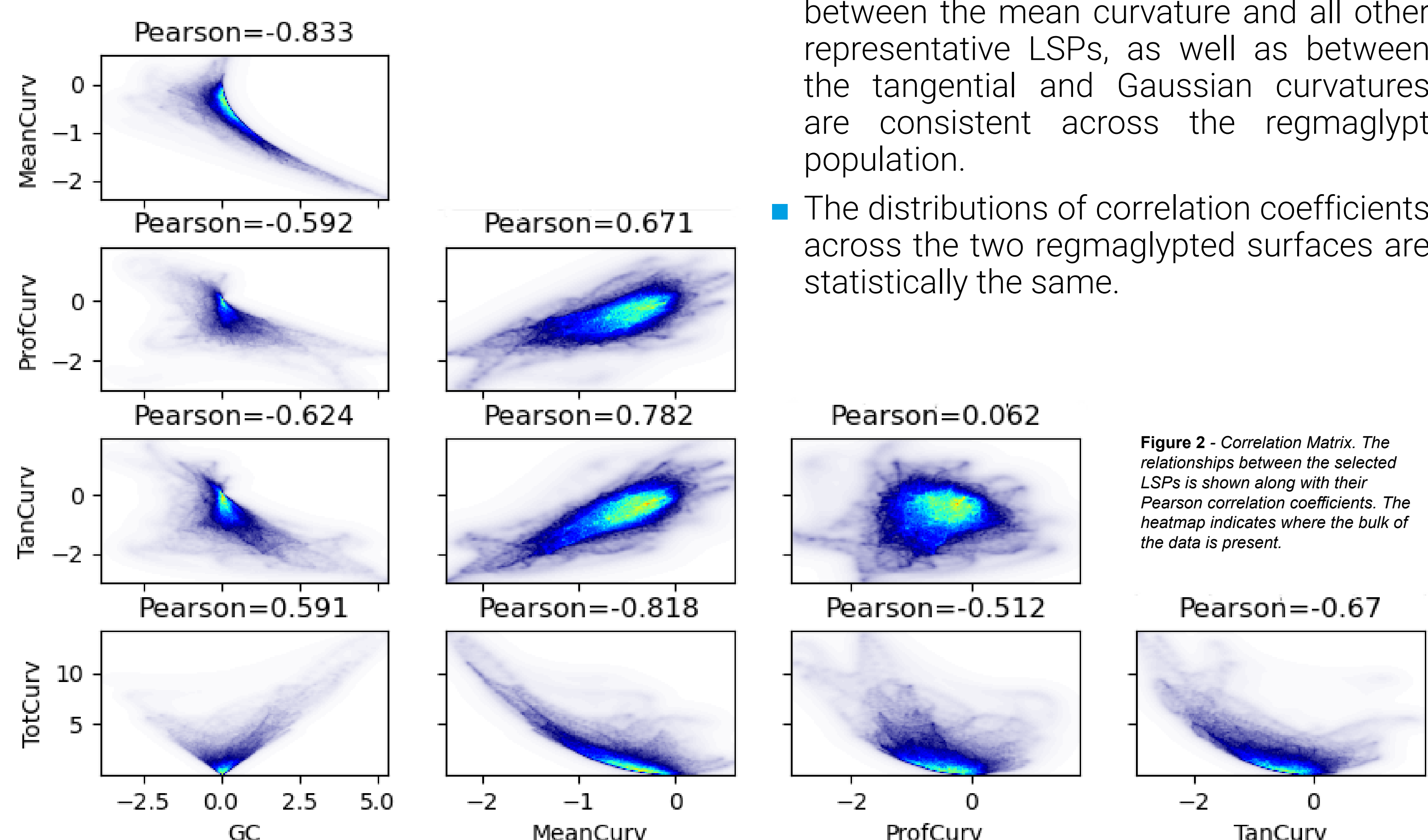
This case study

- Broek in Waterland (L6) ordinary chondrite fell on 11 January 2017 and was imaged while still intact before samples were taken.
- Structure from Motion photogrammetry was used to create a 3-D model based on the collected set of high-quality images.

Approach in steps

1. Digital Elevation Models (DEM) of the regmaglypted surfaces were extracted from 3-D model and smoothed to reduce noise.
2. From the DEM we extracted Land Surface Parameters (LSP) of the surface using GIS analysis tools.
3. Selected LSPs and expert-knowledge were used to delineate regmaglypts. This allowed us to find representative morphometrics.
4. Determined which correlations between LSPs are most consistent throughout the regmaglypt population on each surface.
5. We compared the two populations of correlation coefficients through a t-test ($p < 0.05$):

H0: the means of the populations are equal.
H1: the population means are not equal.



Discussion

The population of correlation coefficients being statistically similar leaves two main options:

1. The two surfaces were formed in the same breakup event.
2. The regmaglypts represent two breakup events but had enough exposure time to develop into a similar end state.

Video footage and eyewitnesses of the atmospheric entry favour the former interpretations, which provides confidence in the use of morphometrics to assess the break-up event sequence.

Lorenz Veithen¹
Sebastiaan de Vet^{1-3*}

¹Delft University of Technology, Aerospace Engineering, section Planetary Exploration; ²Werkgroep Meteoren, the Meteor Section of the Royal Netherlands Association for Meteorology and Astronomy (KNVWS); ³Naturalis Biodiversity Centre, Leiden

Take home message: using 3D shape models of meteorites created by photogrammetry, we can obtain information to study break-up events of ordinary chondrites by comparing the morphometric properties of regmaglypts of secondary fusion crusts.

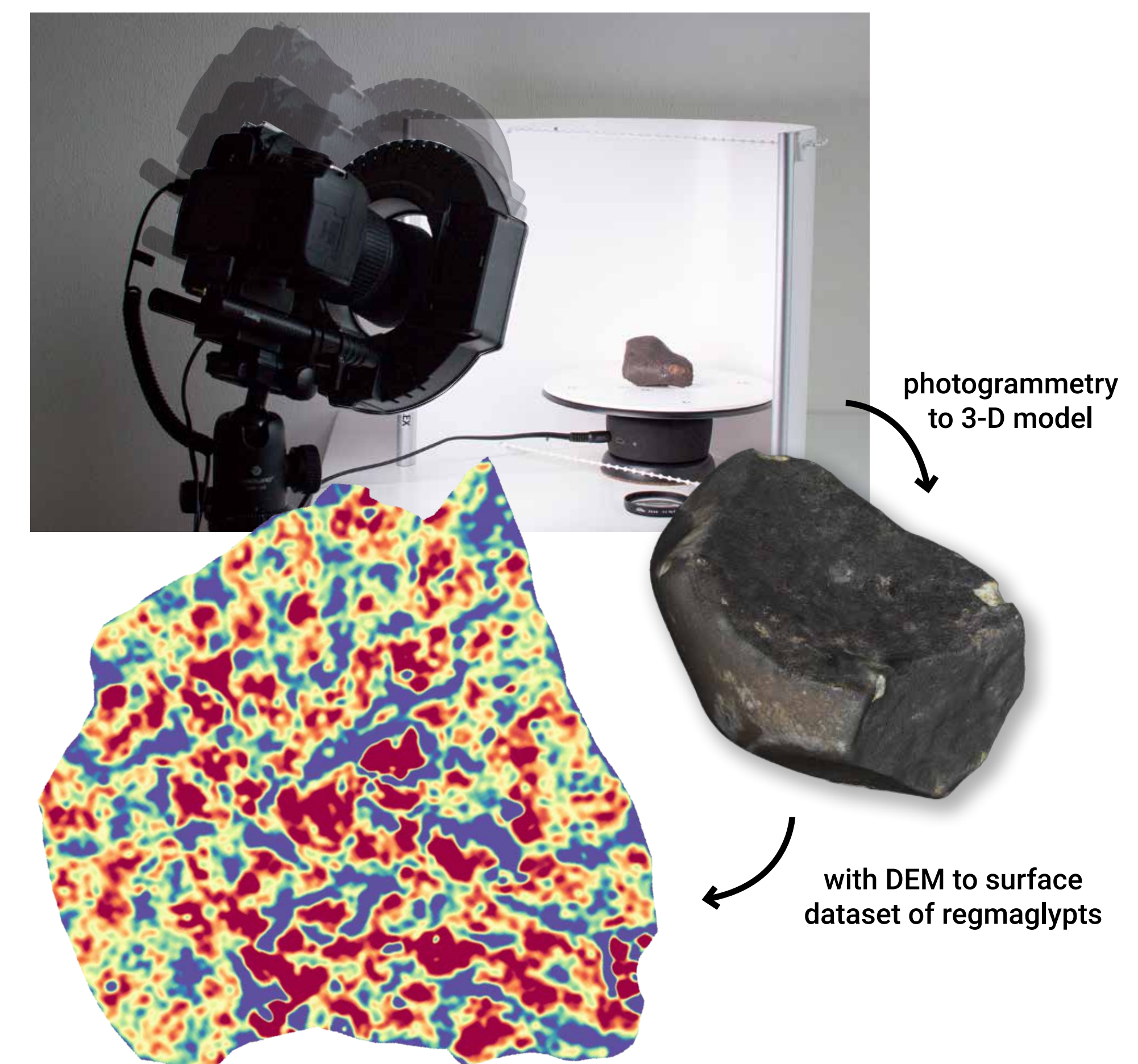


Figure 1 - Overview of the workflow from meteorite to 3-D model and surface analysis. The mean curvature was known to be a good indicator for the regmaglypts ahead of this research. It is the average between the profile and tangential curvatures.

Results

- The Gaussian, mean, profile, tangential, and total curvatures provide good metrics for defining regmaglypts morphometrics.
- The Pearson correlation coefficients between the mean curvature and all other representative LSPs, as well as between the tangential and Gaussian curvatures are consistent across the regmaglypt population.
- The distributions of correlation coefficients across the two regmaglypted surfaces are statistically the same.

Conclusions

- The morphometrics of regmaglypts on fusion-crusted ordinary chondrites can be extracted based on analyses of the microtopography of the surface.
- Representative Land Surface Parameters can be extracted to find correlations across the regmaglypts population on fracture surfaces, to provide information on the sequence of break-up events.
- Furthermore, the proposed GIS approach can also be applied to other fields studying small surface features.