

Roughness description and characterisation of major fractures in Coniacian chalk at Wellington quarry (Arras, France)

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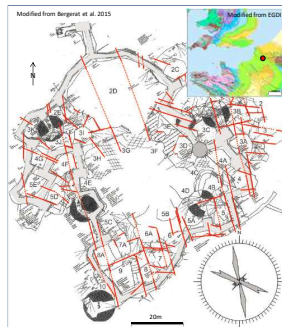
A dozen meters below the city of Arras lies a vast network of about 20km of tunnels initially resulting from the intense production of chalk by room-and-pillar method since the XVIth century. The network was further developed into warrens in the First World War. The architecture of the widespread complex lying under the city clearly benefits from an intelligent use of the main tectonic structures present within the Upper Cretaceous Coniacian chalk rock mass.

The objective of our study was to establish a description of chalk fractures from the small-scale (sub-millimetric) up to the macroscopic scale, associating the analytical quantitative description of joints and faults in terms of roughness, together with qualitative observations of the geological features, within the related tectonic system.

The Wellington quarry

In the southern-most parts of the Wellington quarry complex, the primary networks of subvertical joints and faults, orientated 105-125°N and 160-180°N, allowed for relatively easy rock removal during quarry production and provided planar pillar walls for a naturally stable structure.

So, natural fractures can be directly observed and characterised along the galleries. Samples were hence collected at 12 different spots within the quarry.

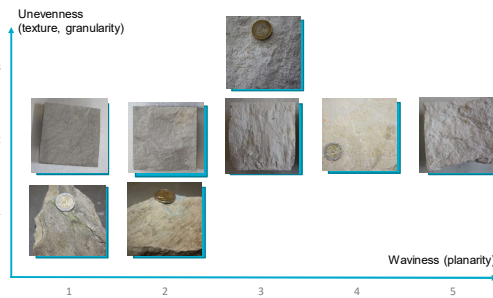


Roughness

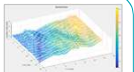


In the lab, small cylinders of 40x40mm were cored from the collected blocks. Series of cylinders were broken in half – either by tensile (Brazilian) or by shear method, to be then compared with the natural faults and joints.

On the natural surfaces, fault planes striations, ridges, twist hackles and plumose structures were observed. To allow for fair scale comparison, all surfaces were divided in 30x30mm squares, then classified based on visual observation and regrouped in terms of unevenness/granularity and waviness/planarity.

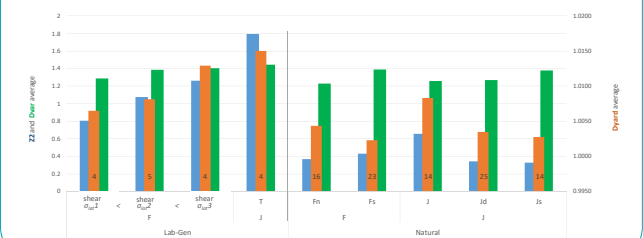


After visual classification, all samples were scanned with a high-precision laser to digitize the 109 fracture surface topographies (ΔX & ΔY : 172 μ m, Z: +/-30 μ m).



Systematic computation of roughness indices was conducted using

- statistical parameters
 - Ra: average height with oa: std. deviation
 - Z2: RMS parameter
- and fractal dimensions
 - Dvar: semi-variogram
 - Dyard: yardstick rule



FAULTS and JOINTS
Fs Fn Js Jd J

SHEAR FRACTURES
 $\sigma_{lat1} < \sigma_{lat2} < \sigma_{lat3}$

TENSILE FRACTURES
T

INCREASING ROUGHNESS

NATURAL FRACTURES

LAB-GENERATED FRACTURES

CONCLUSIONS

Chalk surface topography can be described by various means, which all depend on the scale at which the observation is made. All the observed fractures were classified visually in terms of texture (granularity) and fracture surface waviness prior to roughness indices computations. Z2 and Dyard provide in this study the most consistent results in comparison to visual observations.

Lab-generated fractures display distinctively higher roughness indices than natural fractures. This matches visual observation and is particularly true for natural fault planes that present significantly smoother surfaces, as also seen on samples, with marked oxidation and weathering.

Within the artificially-made series of fractures, for shear fractures, roughness increases with higher lateral confinement, but the highest roughness values are seen on tensile fractures. Within natural fractures, large-scale subvertical joints see the highest roughness, while other joints are only incrementally rougher than fault planes.

Upon observation, natural joints display a roughness comparable to that of lab-generated tensile fractured samples. However, calculated indices distinctively show a gradation: Z2 and Dyard are representative of the trend, with increasing respective average values when looking at: stratigraphic joints, small diaclastic subvertical joints, large subvertical joints and lab-generated tensile joints (in this order). Natural fault planes appear much smoother than lab-generated shear surfaces. Roughness indices clearly rise in the following order: natural shear fault planes, natural normal fault planes, lab-generated shear planes from tests with increasing lateral confinement.