Fracture networks

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Background

Topology of Fracture Networks

C. A. Andresen, A. Hansen, R. Le Goc, P. Davy & S. M. Hope

arXiv:1203.4510

Topic

Use of network theory to compare real and artificial fracture outcrops

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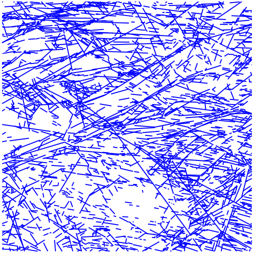
Outcrops

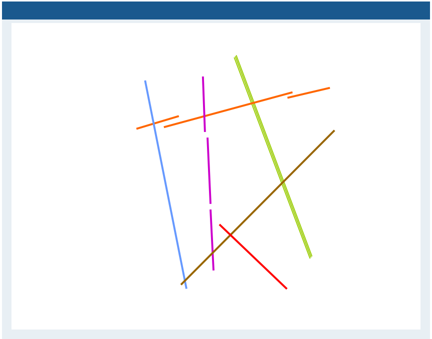
Data

- Fracture in the rock surface
- A 2D map of fracture lines
- Reconnected data

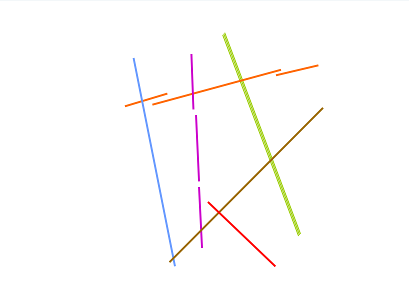
Hornelen basin

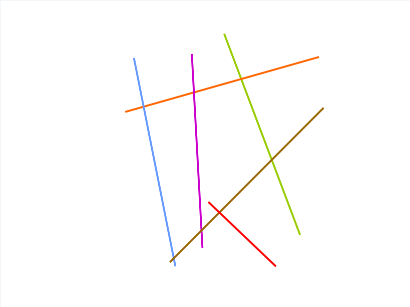


Reconnected data



Reconnected data



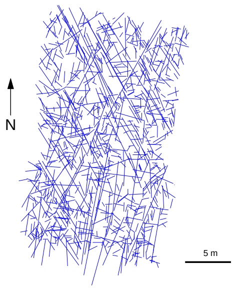


Swedish outcrops

Data

- Eight outcrop samples
- Supplied by *Svensk Kärnbränslehantering AB*
- From Laxemar and Simpevarp areas in south-east Sweden
- Samples cover between 250 and 600 m^2
- Includes all fractures longer than 0.5 m

Sample outcrop

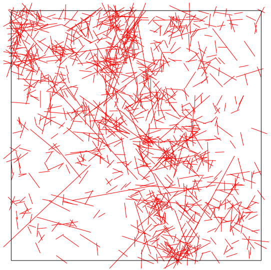


DFN model

Properties

- Position
- Length
- Angle

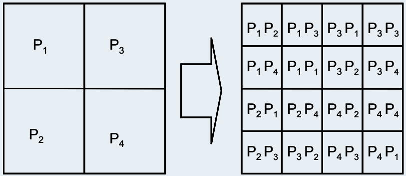
Generated outcrop



Darcel, Bour, Davy, & de Dreuzy (2003), *Water Resour. Res.* **39** (10), 1272-1284

Position

- Generate a multi-fractal structure
- Subdivide the system, in several layers, and assign a probability to each subdivision
- Use the mass-dimension, D_2, to control the probability assignment



Length

Generate the lengths of the fracture based on a power-law distribution

$$p(l) = Cl^{-\alpha_l}. \quad (1)$$

Different angular distribution

Angular distribution

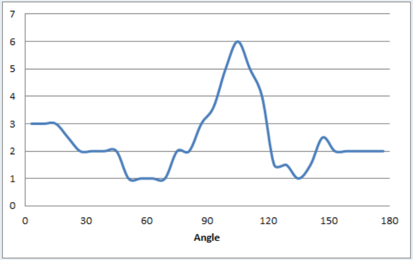
- Uniform
- Outcrop based

Different angular distribution

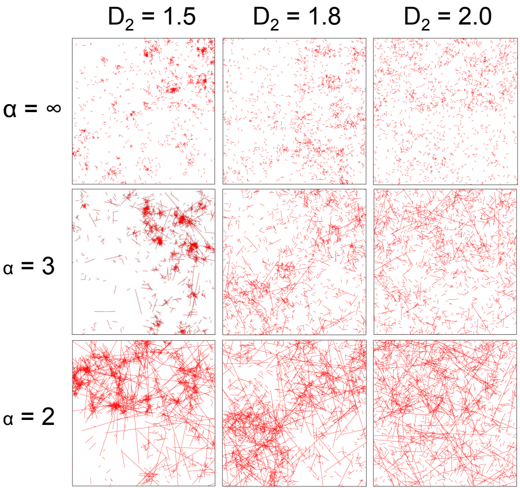
Angular distribution

- Uniform
- Outcrop based

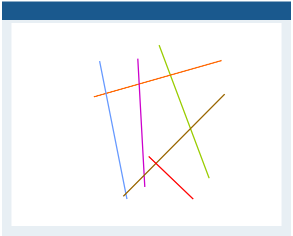
Swedish data



Generated data



From outcrop to graph



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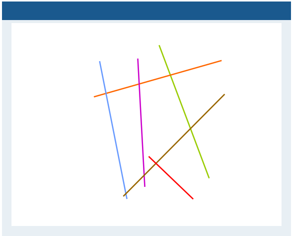
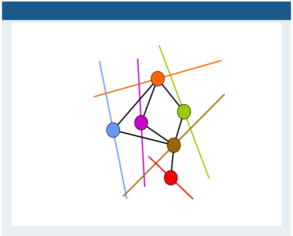
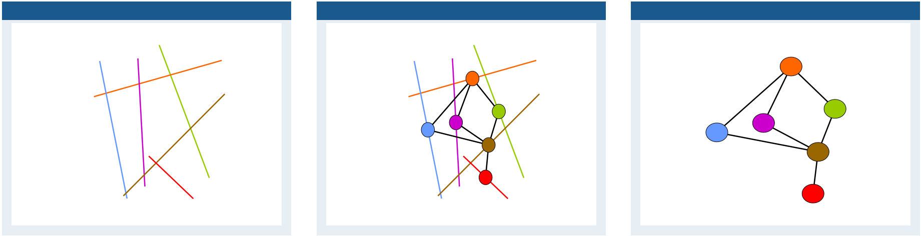
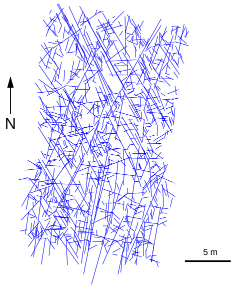




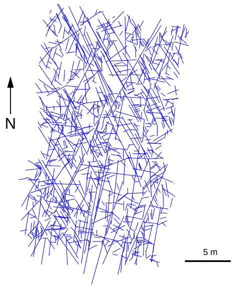
From outcrop to graph

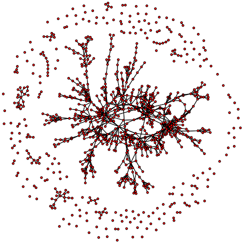


Outcrop with corresponding graph



Outcrop with corresponding graph





Network Properties

- Degree
- Clustering
- Efficiency
- Small-world networks
- Degree-degree correlation matrix

Clustering

Clustering gives a measure of how nodes are interconected.

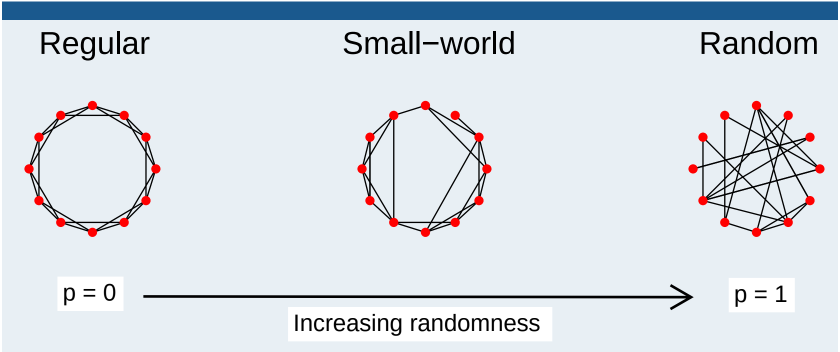
$$C = \frac{1}{N}\sum_{i=1}^{i=N} C_i = \frac{1}{N}\sum_{i=1}^{i=N}, \frac{2K_{nn,i}}{k_i(k_i-1)}. \quad (2)$$

Efficiency

Efficiency is a global measure of how well connected different parts of the network are.

$$E = \frac{1}{N(N-1)} \sum_{(i,j)\in N, i\neq j} \frac{1}{d_{ij}}, \quad (3)$$

Small-world networks



Degree-degree correlation matrix

Maslov-Sneppen

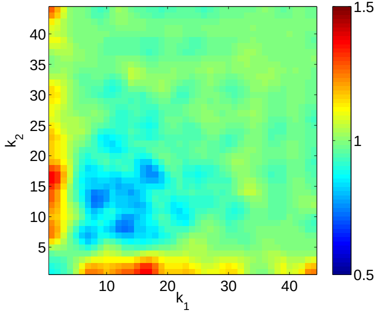
$$C\left(k_1, k_2\right) = \frac{P\left(k_1, k_2\right)}{P_R\left(k_1, k_2\right)} \qquad (4)$$

Degree-degree correlation matrix

Maslov-Sneppen

$$C(k_1, k_2) = \frac{P(k_1, k_2)}{P_R(k_1, k_2)} \qquad (4)$$

Disassortative



Swedish outcrops

Sample	Nodes	Links	k_{max}	$\bar{k}$
AMS000025	787	858	23	2.18
AMS000026	716	520	20	1.45
AMS000205	973	1188	32	2.44
AMS000206	737	487	11	1.32
AMS000208	955	1297	31	2.72
AMS000209	955	1162	27	2.43
AMS100234	946	1549	44	3.27
AMS100235	785	1392	44	3.55
Average	857	1057	29	2.42

Swedish outcrops

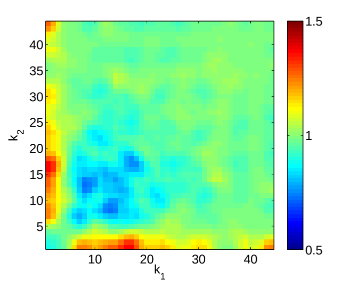
Sample	C	C_{RW}	C_{RA}	E	E_{RW}	E_{RA}
AMS000025	0.17	0.0048	0.0018	0.046	0.10	0.10
AMS000026	0.09	0.0033	0.0009	0.019	0.05	0.03
AMS000205	0.19	0.0043	0.0017	0.032	0.12	0.12
AMS000206	0.12	0.0013	0.0007	0.004	0.03	0.02
AMS000208	0.23	0.0067	0.0021	0.079	0.14	0.14
AMS000209	0.18	0.0050	0.0018	0.068	0.12	0.12
AMS100234	0.24	0.0138	0.0029	0.133	0.16	0.17
AMS100235	0.24	0.0180	0.0039	0.141	0.18	0.19
Average	0.18	0.0072	0.0020	0.065	0.11	0.11

DFN generated outcrops

α_l	C	C_{RW}	C_{RA}	E	E_{RW}	E_{RA}
2.00	0.08	0.019	0.047	0.028	0.042	0.11
2.25	0.11	0.013	0.031	0.027	0.049	0.11
2.50	0.17	0.013	0.019	0.037	0.083	0.10
2.75	0.26	0.014	0.014	0.050	0.134	0.09
3.00	0.31	0.013	0.008	0.050	0.154	0.07

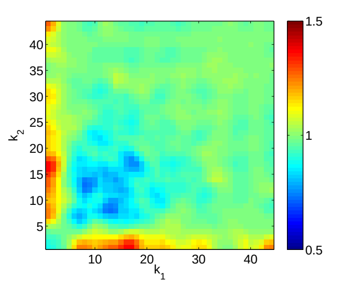
Degree-degree correlation matrix

Outcrop



Degree-degree correlation matrix

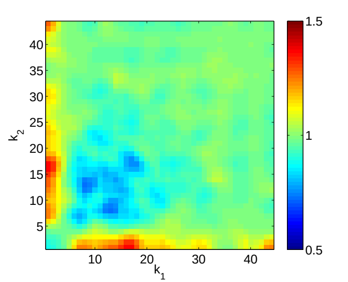
Outcrop



Dissassortative

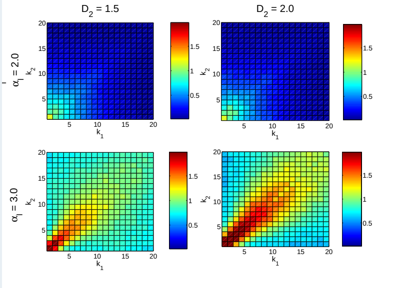
Degree-degree correlation matrix

Outcrop



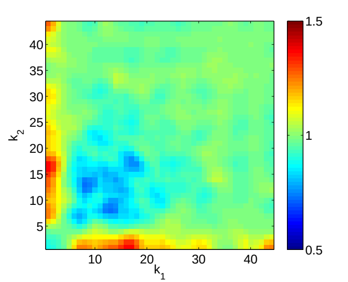
Dissassortative

DFN model



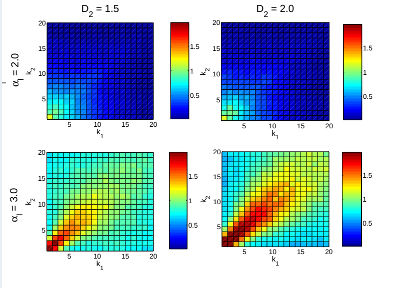
Degree-degree correlation matrix

Outcrop



Dissassortative

DFN model



Assortative

Conclusion

- Significant difference between real and artificial outcrops (dissassortative/assortative)

Conclusion

- Significant difference between real and artificial outcrops (dissassortative/assortative)
- DFN model must be improved with correlations between position, length and angle.

Thank you