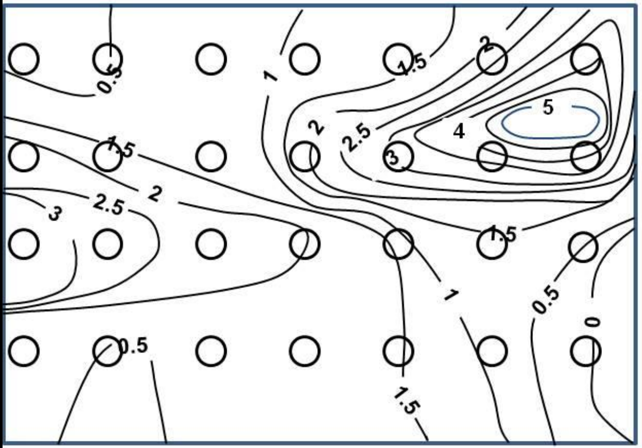
Geostatistical study of the linear Fracture Frequency (FF) in two Chilean copper deposits

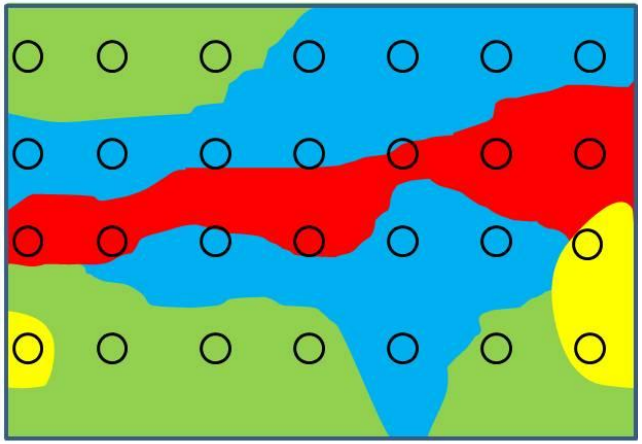
Serge Antoine Séguret, MINES ParisTech, Fontainebleau, France
Cristian Guajardo, Codelco, Chuquicamata, Chile
Ramon Freire, Codelco, Casa Matriz, Chile

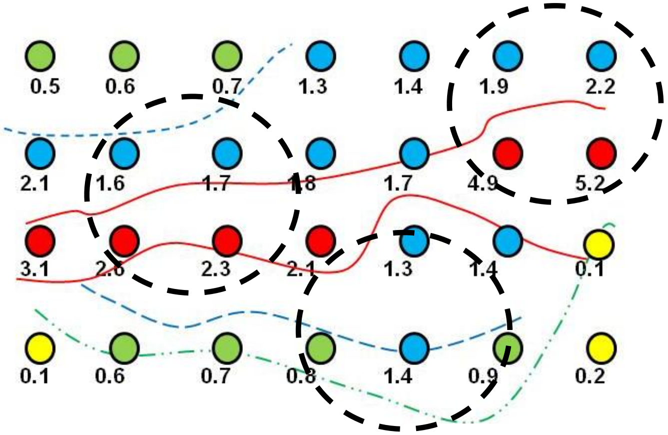
Geostatistics ?

Continuous
(grade)



Categorical
(geol. Unit)





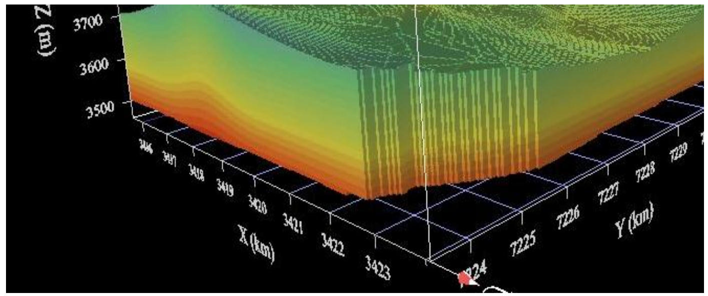
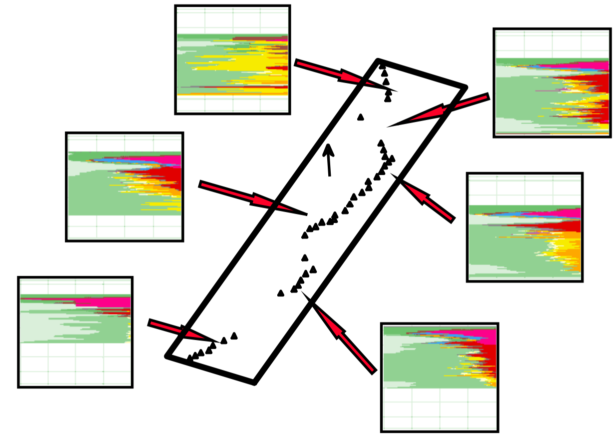
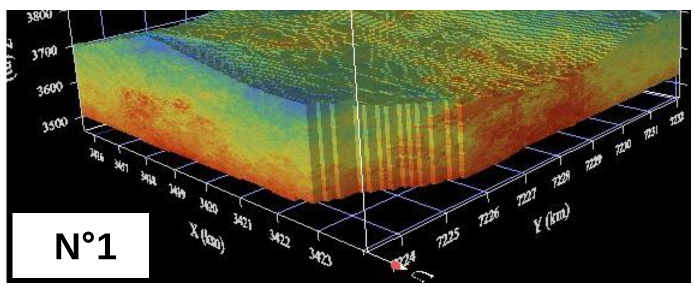
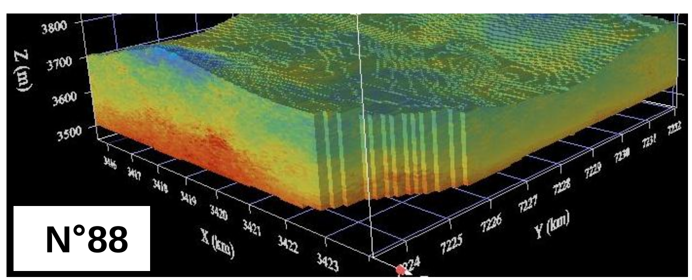
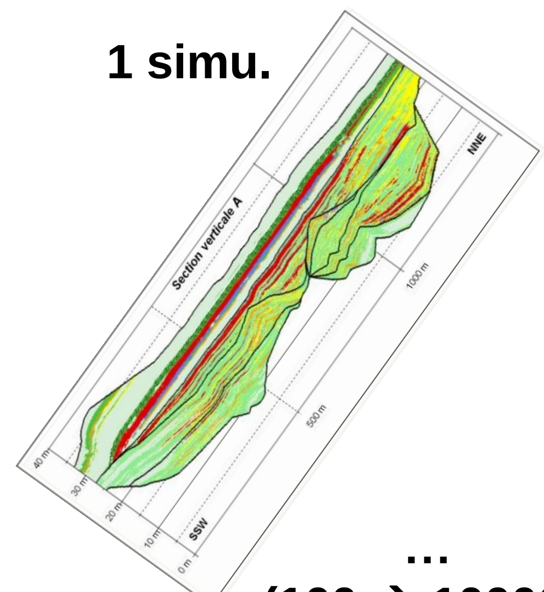
Geostatistics

⟺

Spatial statistics

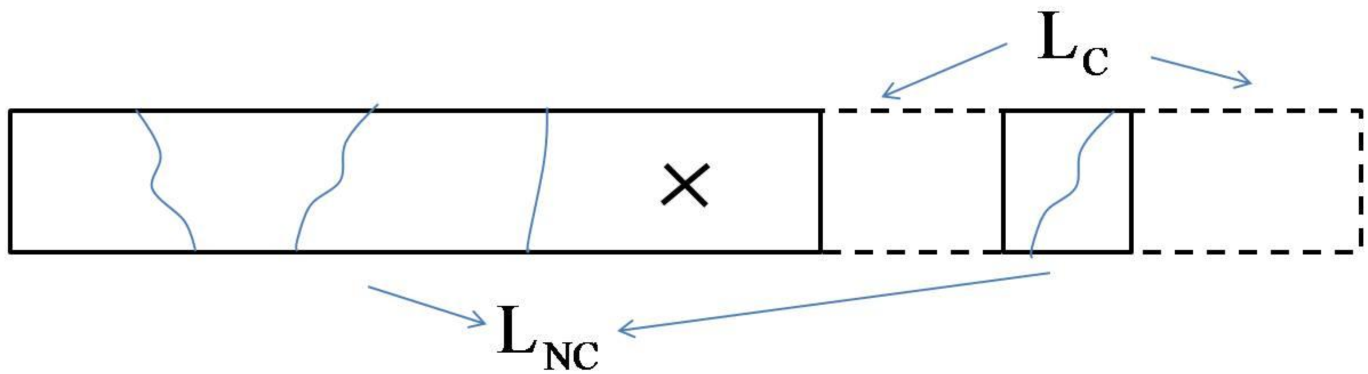
⟺

Modeling spatial uncertainty

	Continuous (grade)	Categorical (geol. Unit)
Geostat. ESTIMATION		
Geostat. SIMULATION	 	1 simu.  … (100 → 10000)

	Contin. V.	Categ. V.
ESTIM.	X	
SIMU.		

Fracture Frequency



L_{NC} : total length of Non Cruhed part of the sample

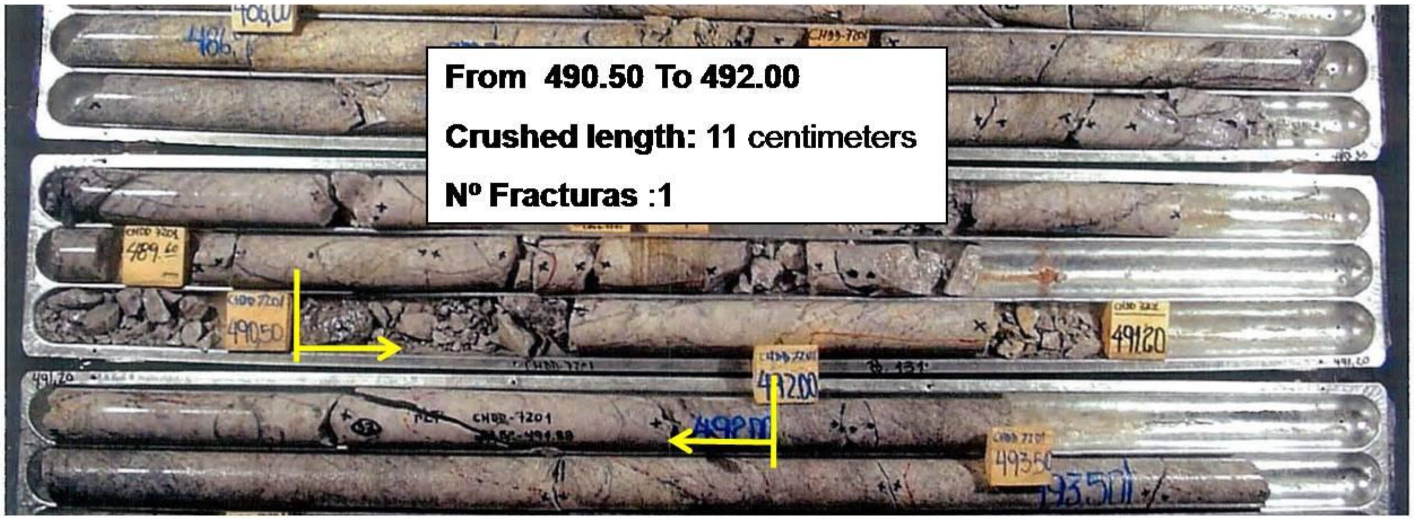
L_C : total length of Cruhed part of the sample

$$L_{NC} + L_C = 1.5\mathrm{m}$$

N_{fract} : number of fractures (corrected or not) along L_{NC}

$$\mathrm{FF}(x) = \frac{N_{\mathrm{fract}}(x)}{L_{\mathrm{NC}}(x)}$$

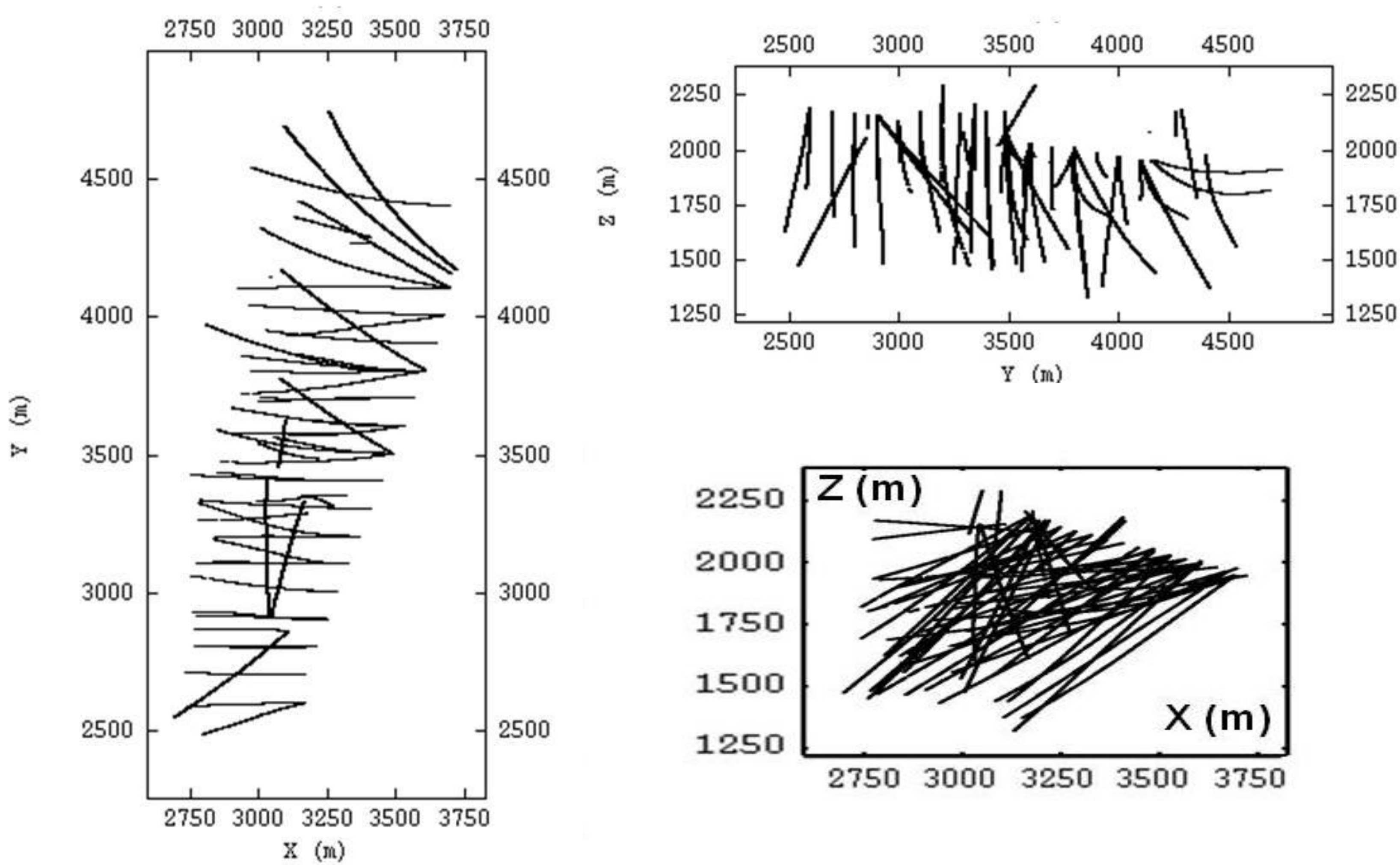
Observation of a natural phenomenon



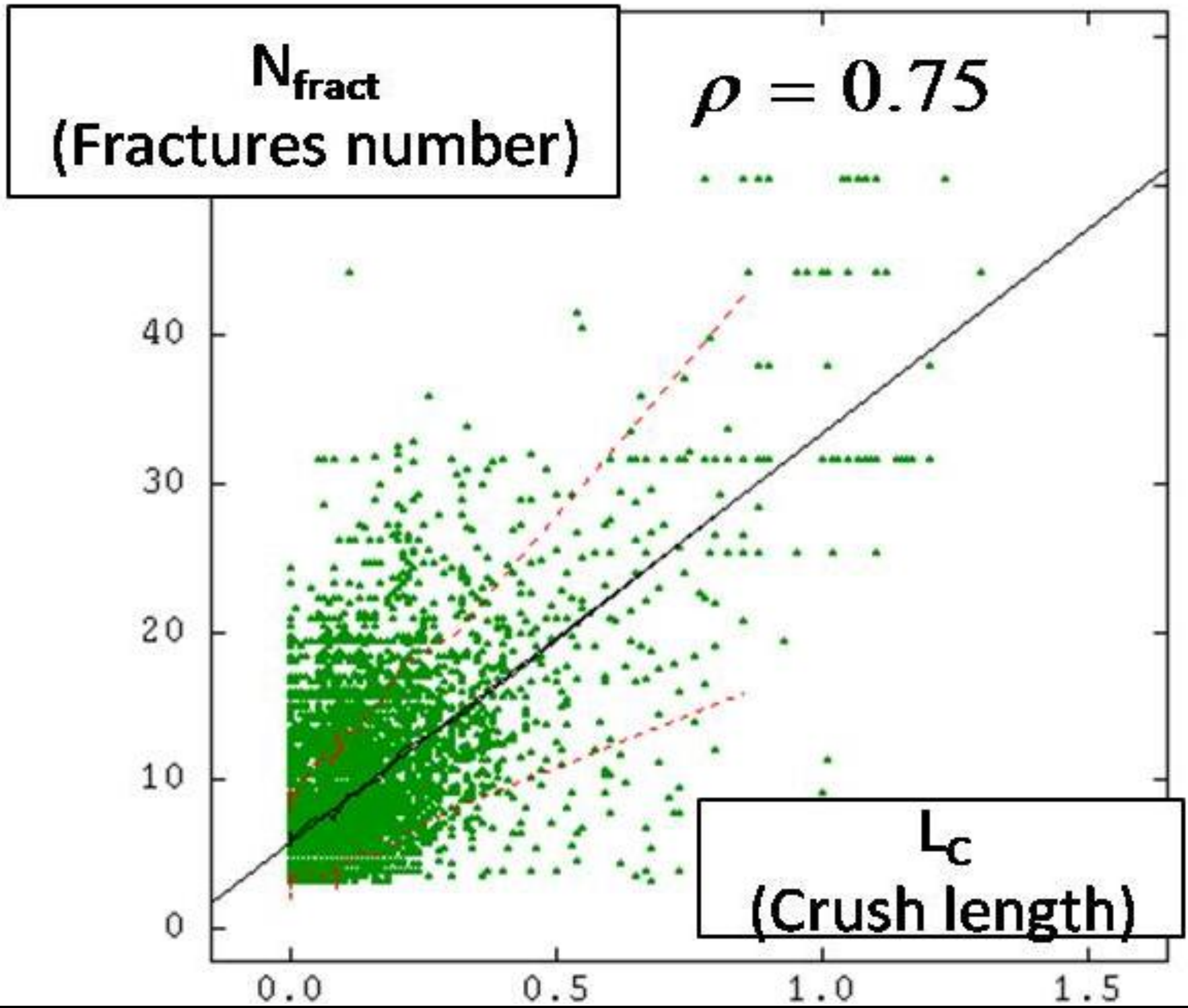
(a)

(b)

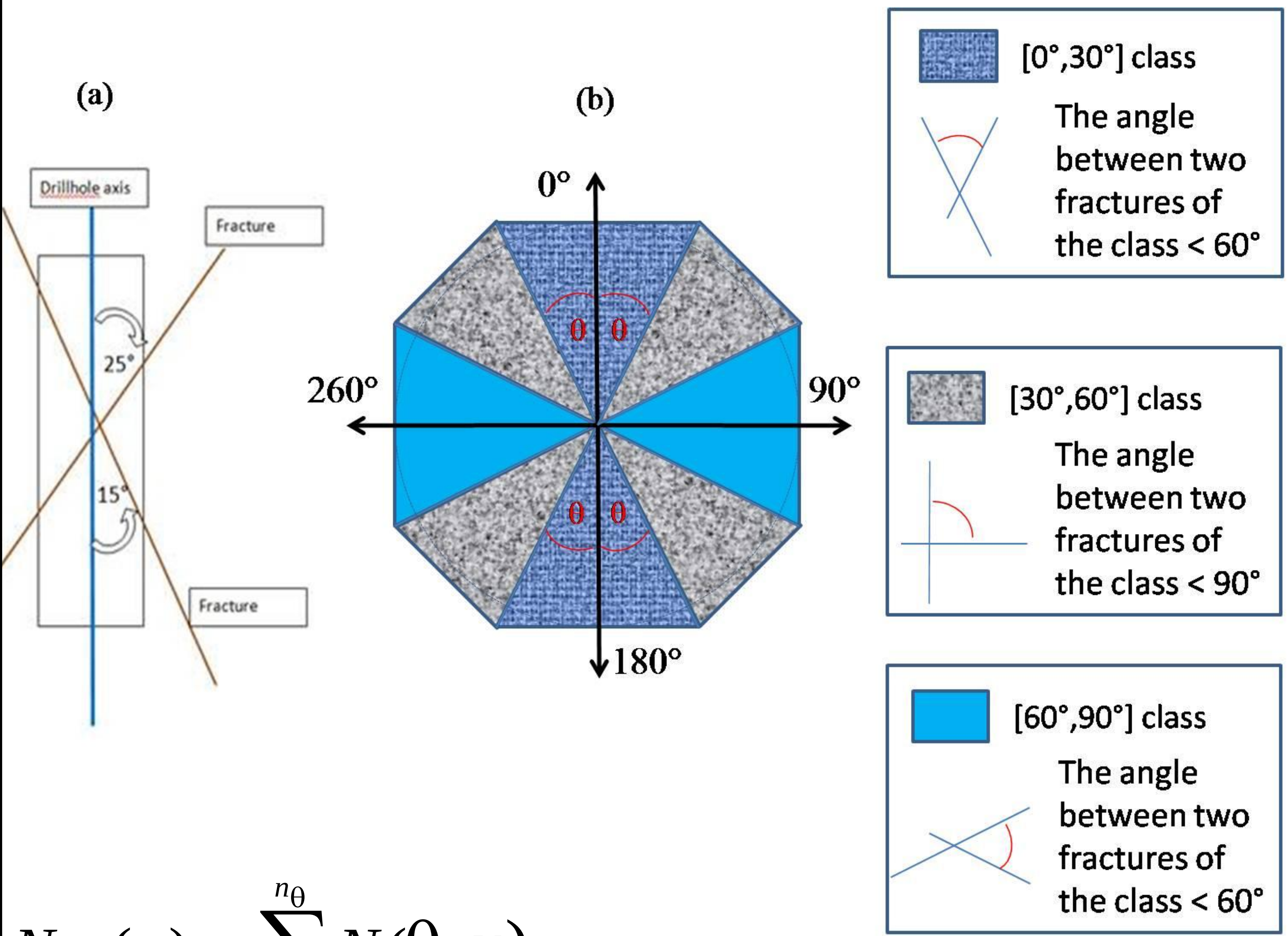
- 13,000 samples
- 1,5 m length
- Underground mine, Codelco
- 1000x2300x1000 m^3



Understanding this link

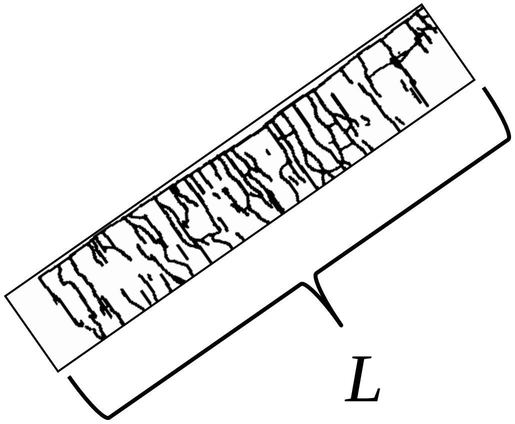


Directional Classes

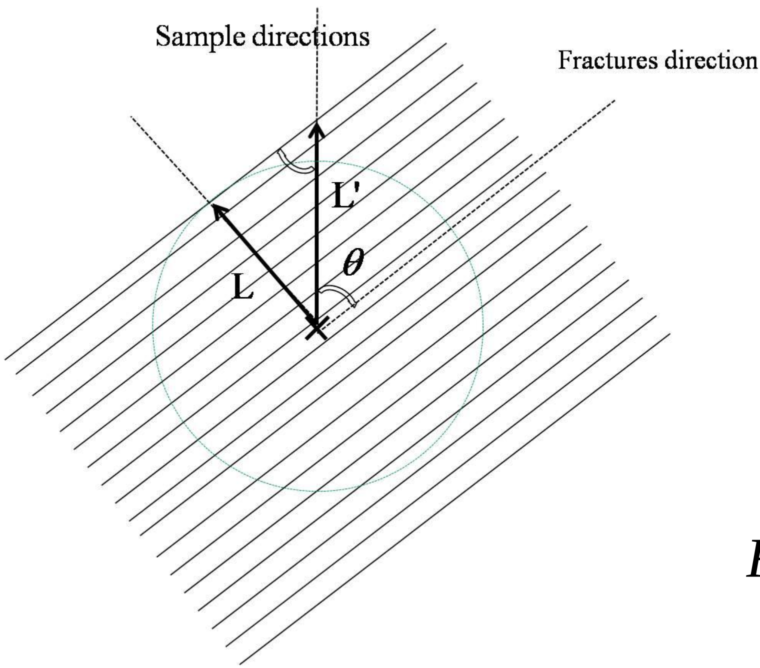


$$N_{tot}(x) = \sum_{\theta=1}^{n_\theta} N(\theta, x)$$

Terzagui Correction



$$FF = \frac{\sum_{n_\theta} n(\theta)}{L}$$



$$FF_{corrected} = \frac{\sum_{n_\theta} \frac{n(\theta)}{\sin(\theta)}}{L}$$

$(Terzaghi, 1965)$

Directional Concentration

$$N_{tot}(x) = \sum_{\theta=1}^{n_\theta} N(\theta, x)$$

$$\sigma_\theta^2(x) = Var_\theta[N(\theta, x)] = E_\theta[(N(\theta, x) - N_{\theta,mean}(x))^2]$$

$$N_{\theta,mean}(x) \approx \frac{N_{tot}(x)}{n_\theta}$$

$$\sigma_\theta^2(x) \approx \frac{1}{n_\theta} \sum_{\theta=1}^{n_\theta} (N(\theta, x) - N_{\theta,mean}(x))^2$$

Directional Concentration

$$0 \le \sigma_\theta^2(x) \le \sigma_{\theta,\max}^2(x) = N_{\theta,mean}(x)^2(n_\theta - 1)$$

$$\sigma_\theta^2(x) = 0$$

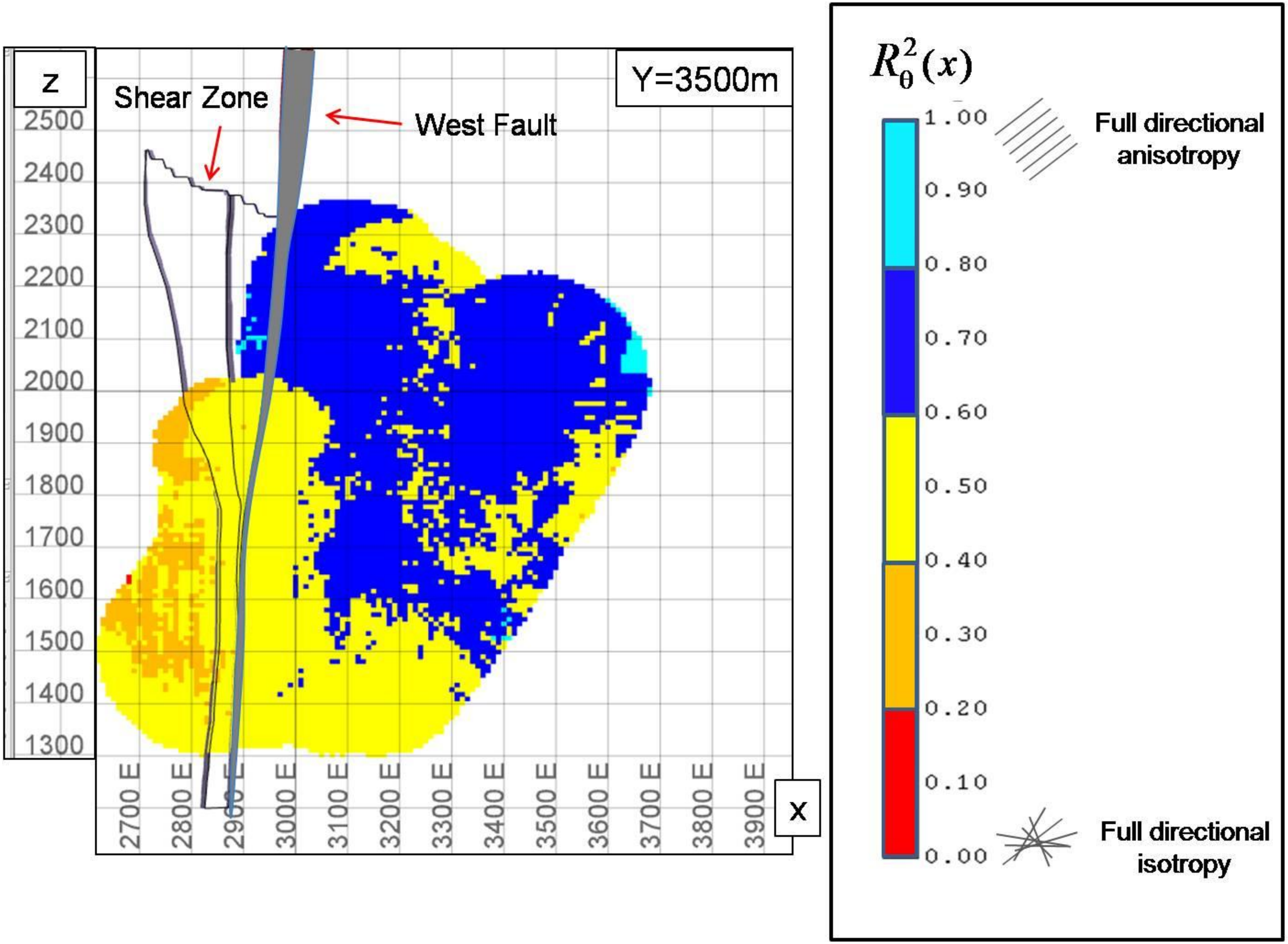
<u>full directional isotropy</u>, all the fractures are equally distributed over the directions

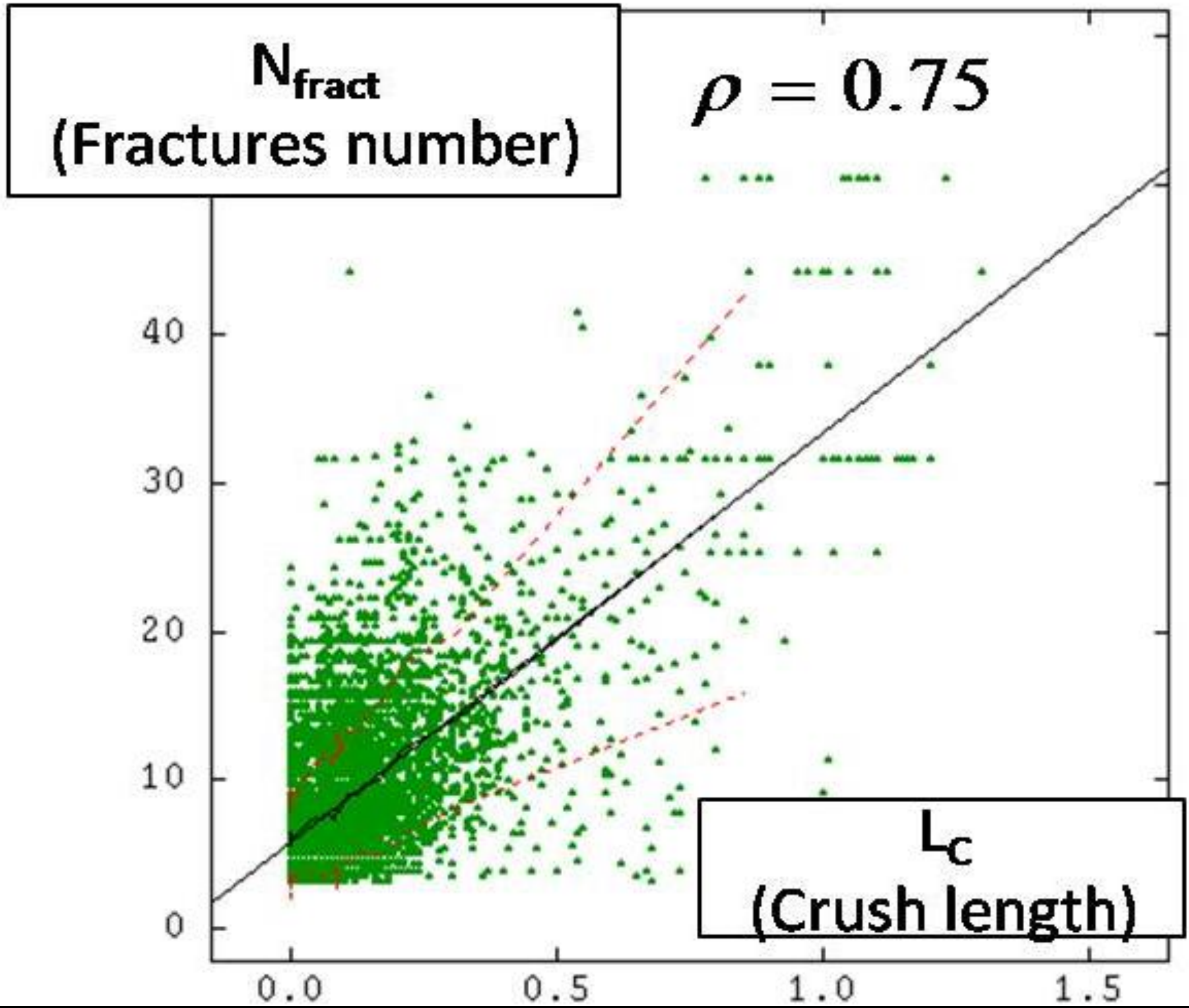
$$\sigma_\theta^2(x) = \sigma_{\theta,\max}^2$$

<u>full directional anisotropy</u>, all the fractures lie along one direction

$$R_\theta^2(x) = \frac{\sigma_\theta^2(x)}{\sigma_{\theta,\max}^2(x)} = \frac{1}{n_\theta(n_\theta - 1)} \sum_{\theta=1}^{n_\theta} \left(\frac{N(\theta, x)}{N_{\theta,mean}(x)} - 1\right)^2$$

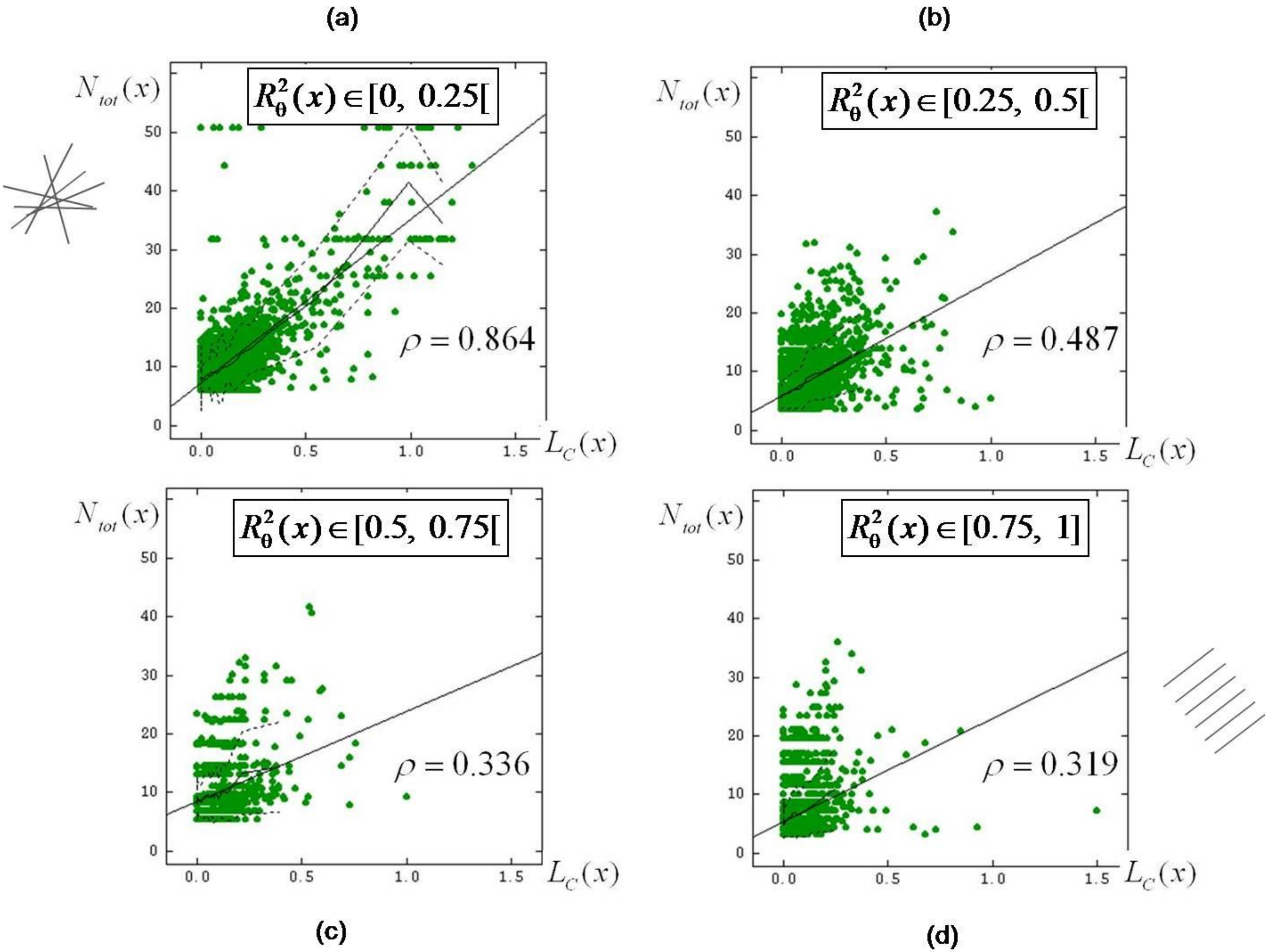
Directional Concentration



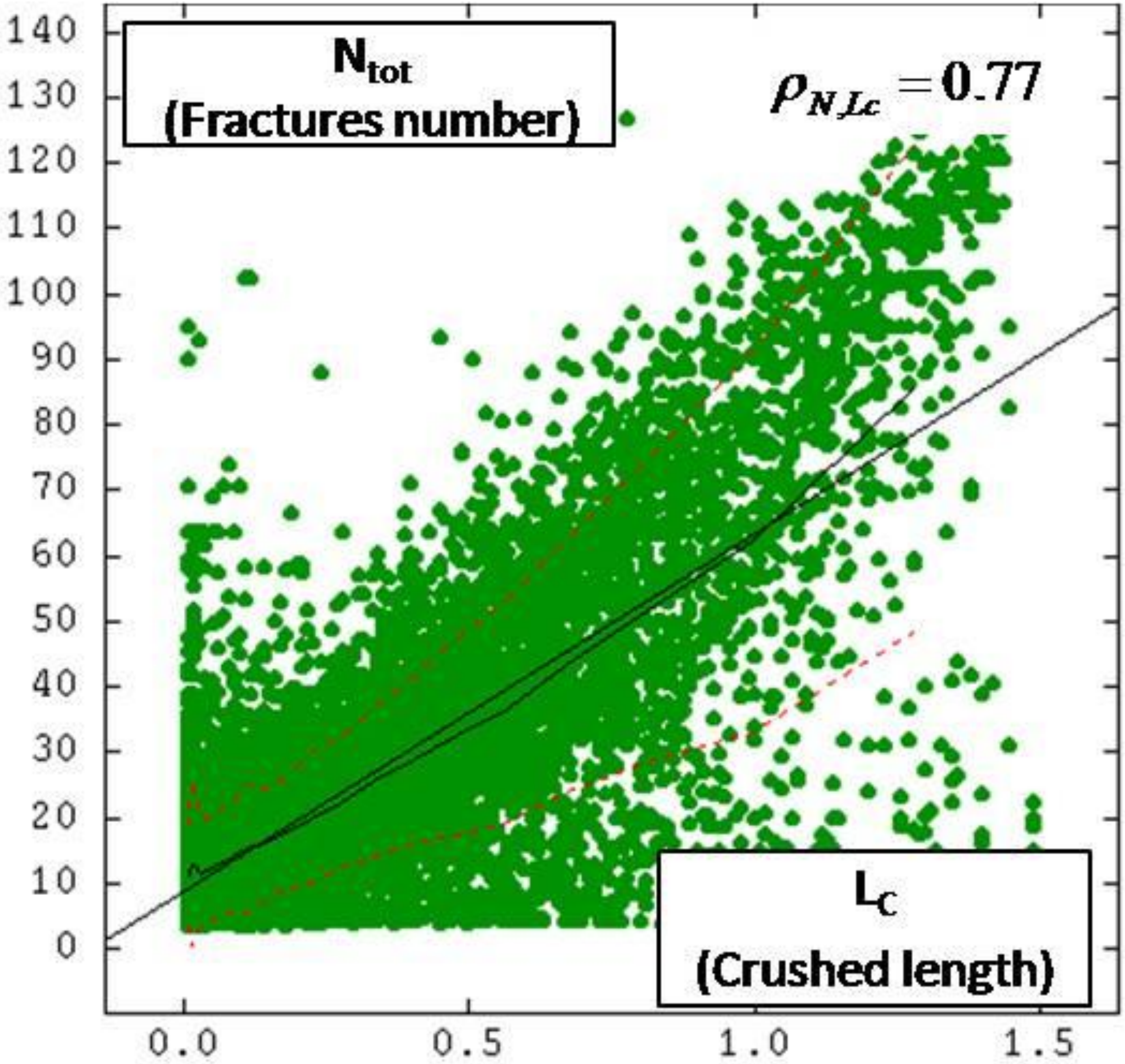


N_{fract}
(Fractures number)
$\rho = 0.75$
40
30
20
10
0
0.0
0.5
1.0
1.5
L_C
(Crush length)

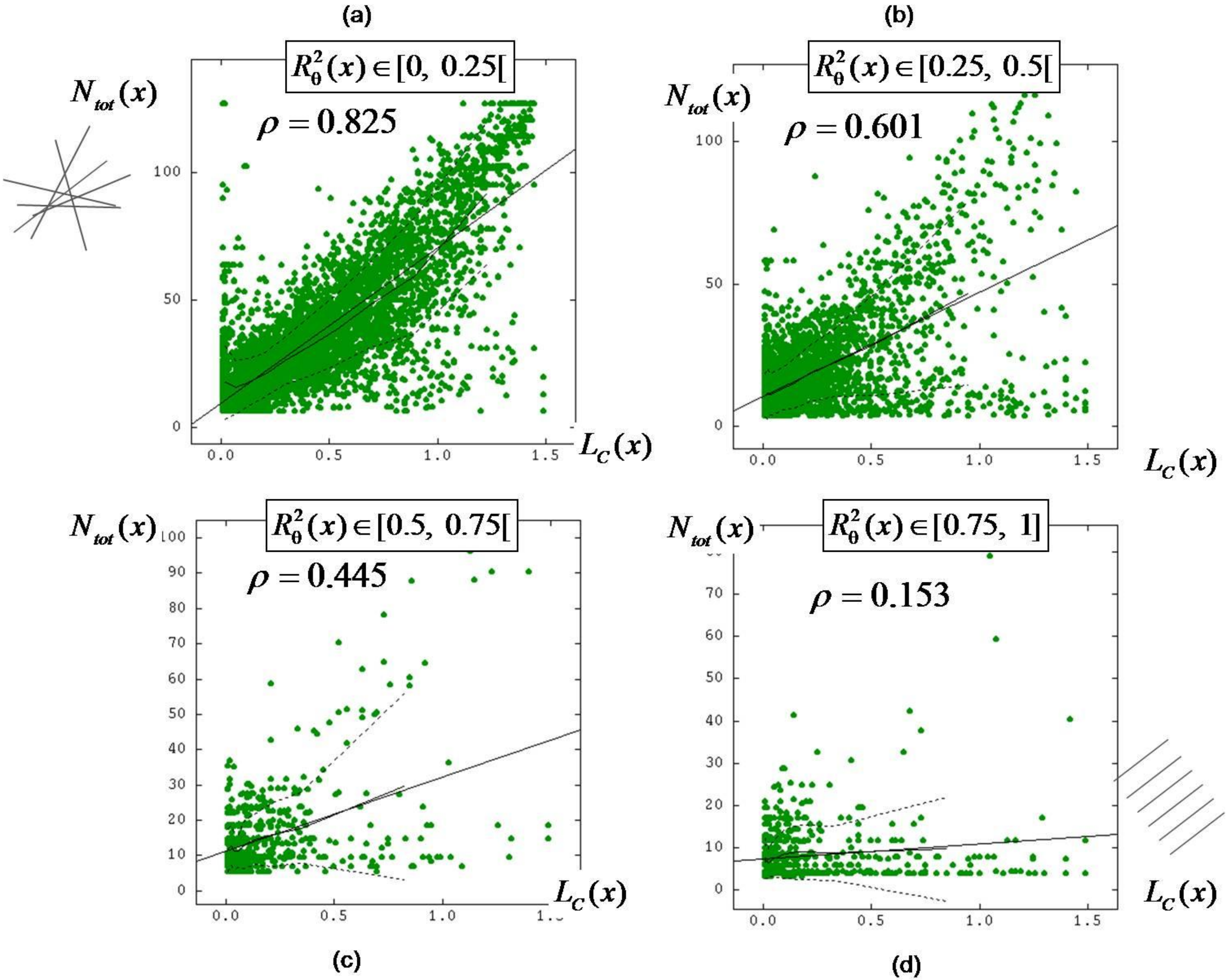
Directional Concentration Classes



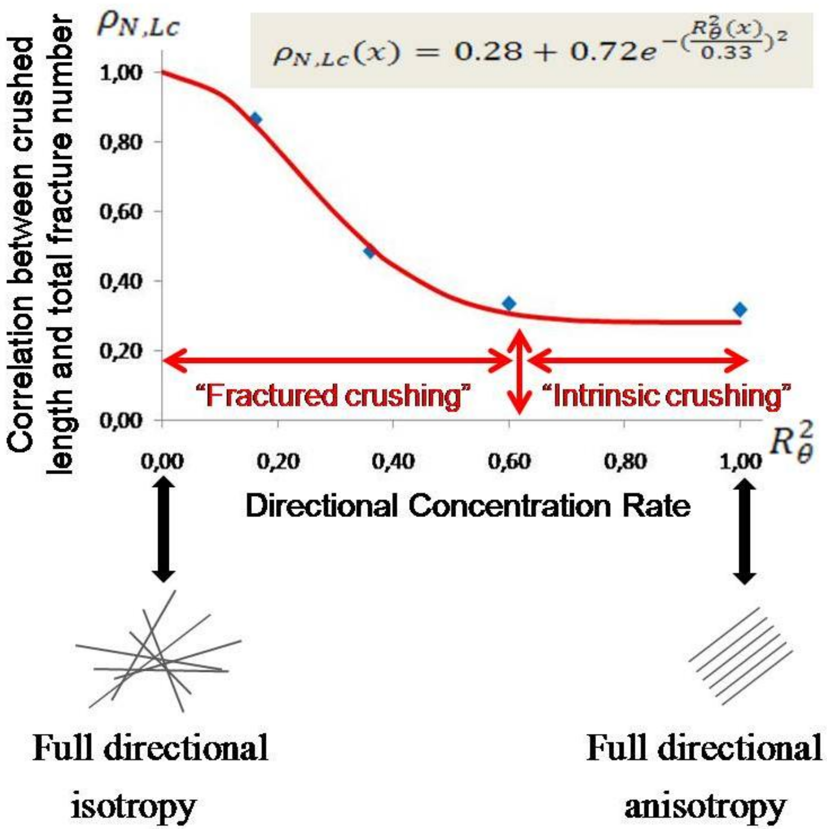
Another deposit



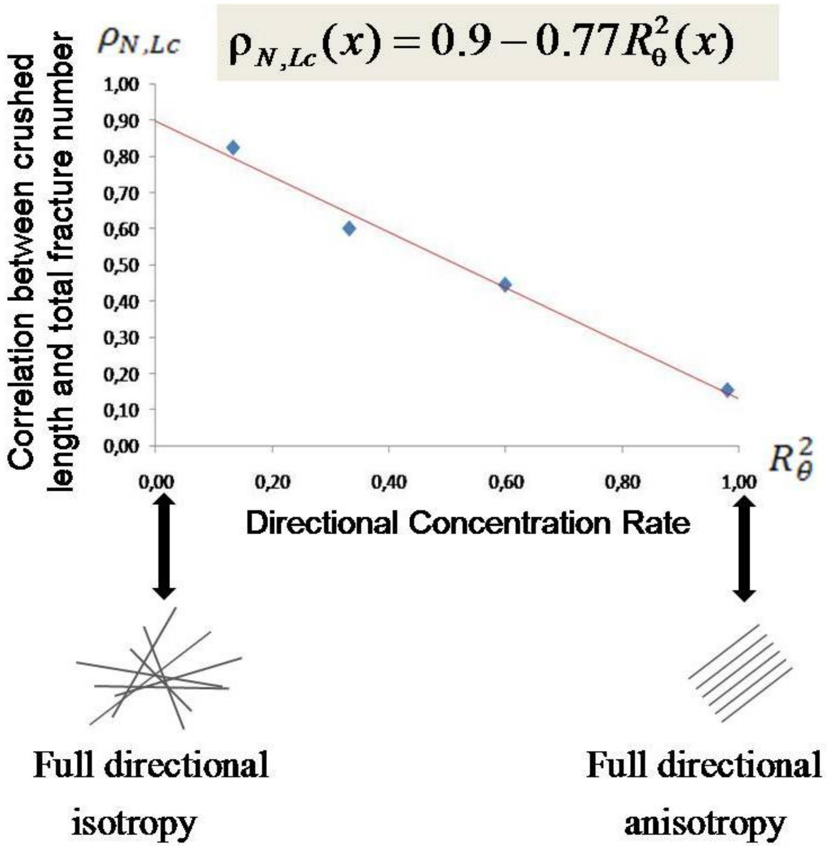
Another deposit



Deposit 1



Deposit 2

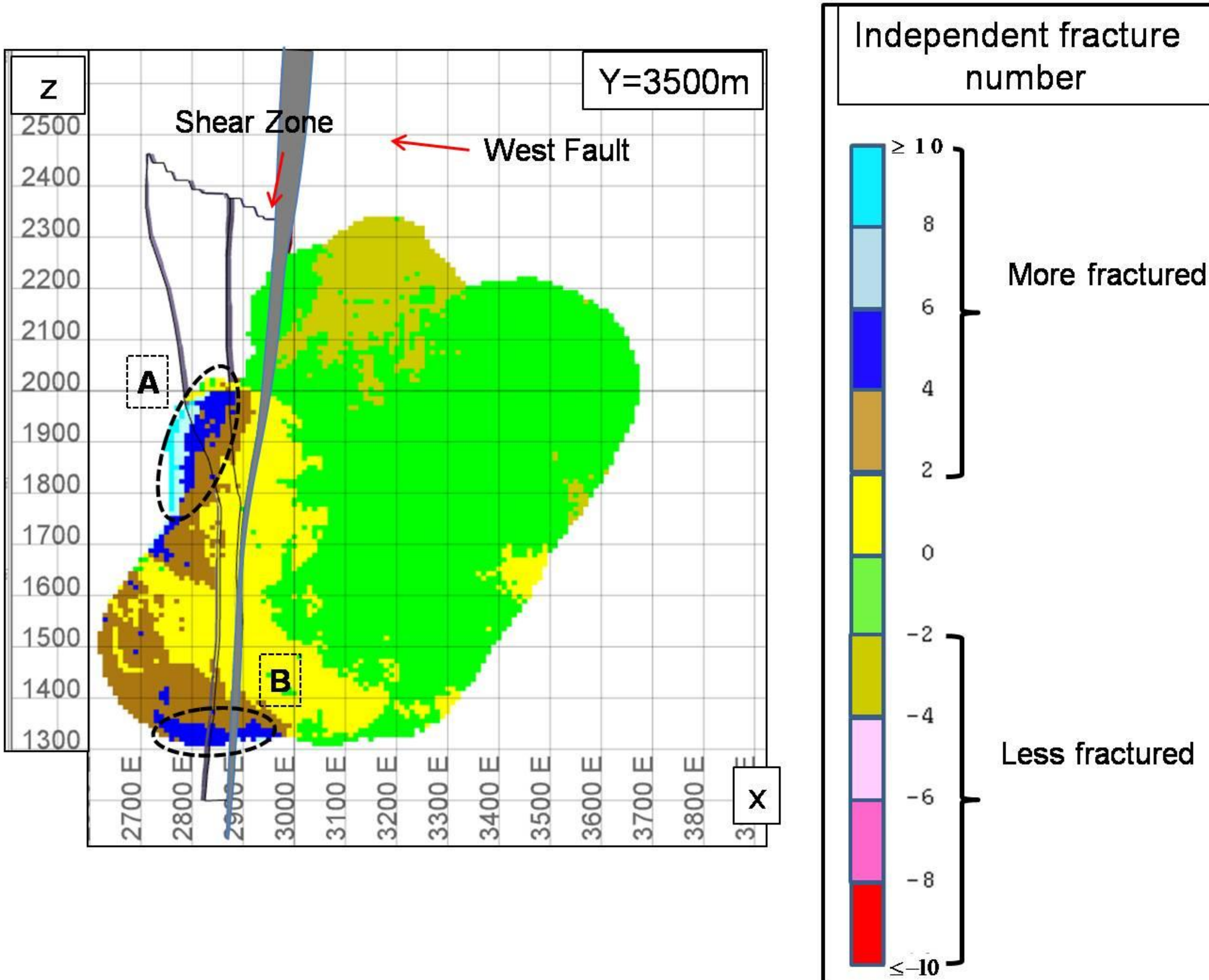


Residual model

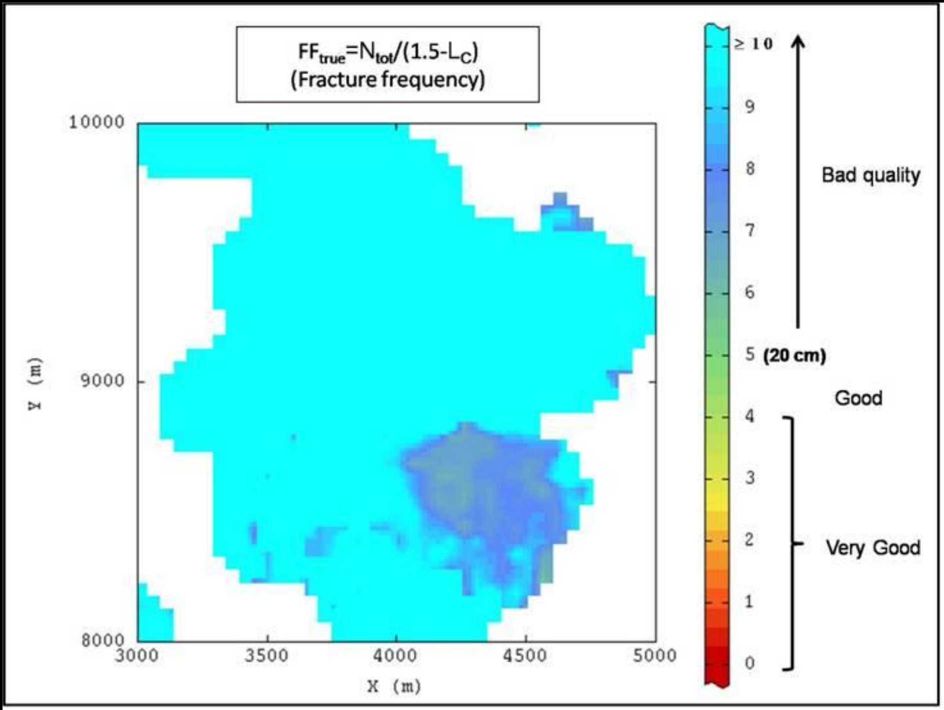
$$N_{tot}(x) = \frac{\sigma_{Ntot}}{\sigma_{Lc}}(\rho_{N,Lc}(x))\left(L_C(x) + \sqrt{1-\rho_{N,Lc}(x)^2}\,RSD(x)\right) + C(\rho_{N,Lc}(x))$$

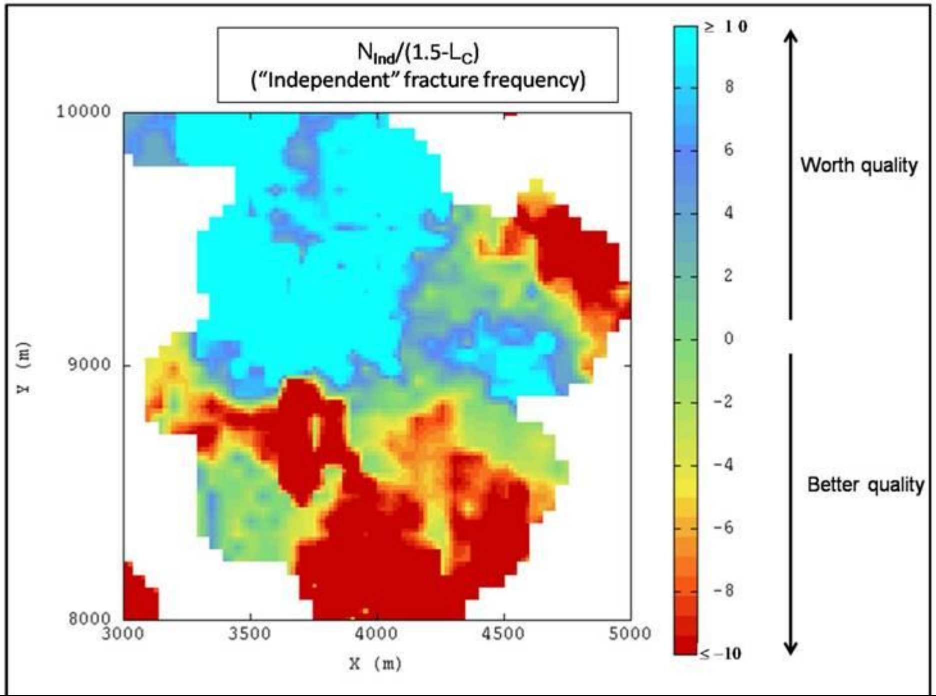
$$\forall x,\ N_{tot}(\mathrm{x}) = N_{corr}(\mathrm{x}) + N_{ind}(\mathrm{x})$$

Independent fractures
Deposit 1



Independent fractures
Deposit 2





Conclusion

• Crushing, a useful regionalized variable

• Directional concentration, mutual organization of the fractures

→Spatial correlation between fracturing and crushing

• Useful in case of rock submitted to alteration

Fracturing, Crushing and Directional Concentration

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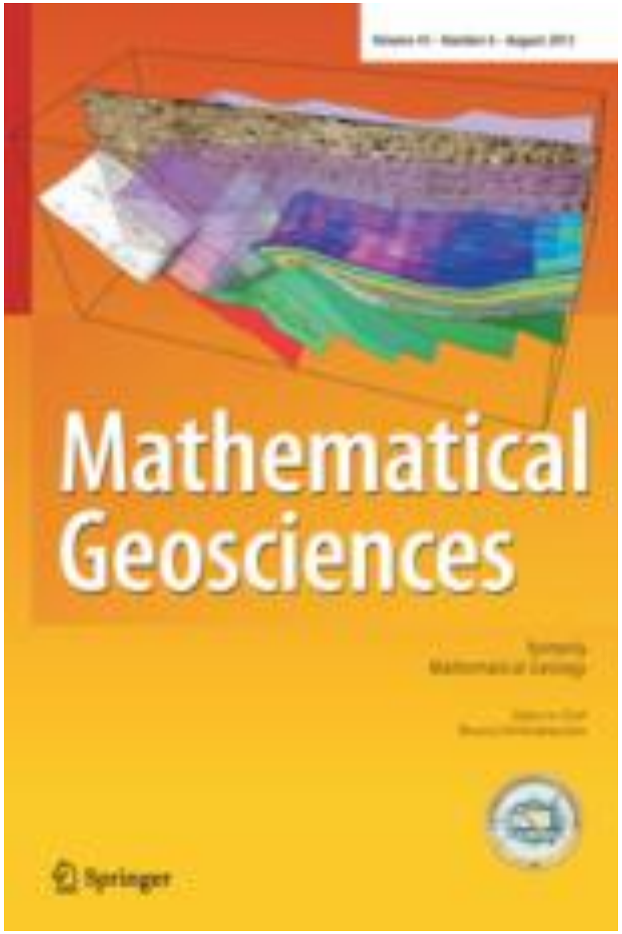

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