On the Diversity of Multiphase Processes in Volcanic Systems

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My favorite (French) Lagrangian particle…Stokes number = ?

Volcanic/magmatic systems have a DUAL NATURE

Explosive eruptions can have volumes of up to10^3 km^3

Many penetrate the tropopause

Rise time of days

Magma bodies up to $5x10^5$ km^3

Persist for 10^6 years

Factory for crust building

- Discrete phases
  - Ash, crystals, ρ ~10^3 kg/m^3, 1-100mm size
  - Bubbles
- Continuous (carrier) phases
  - Air, volcanic gas, ρ ~ 1 kg/m^3, η ~ 1Pa s
  - Silicate melt, ρ ~ 10^3 kg/m^3, η ~ 1 – 10^8 Pa s

Volcanic/magmatic systems have a DUAL NATURE

Re # up to ~10^7, *St* # variable

Entrainment, buoyancy reversals

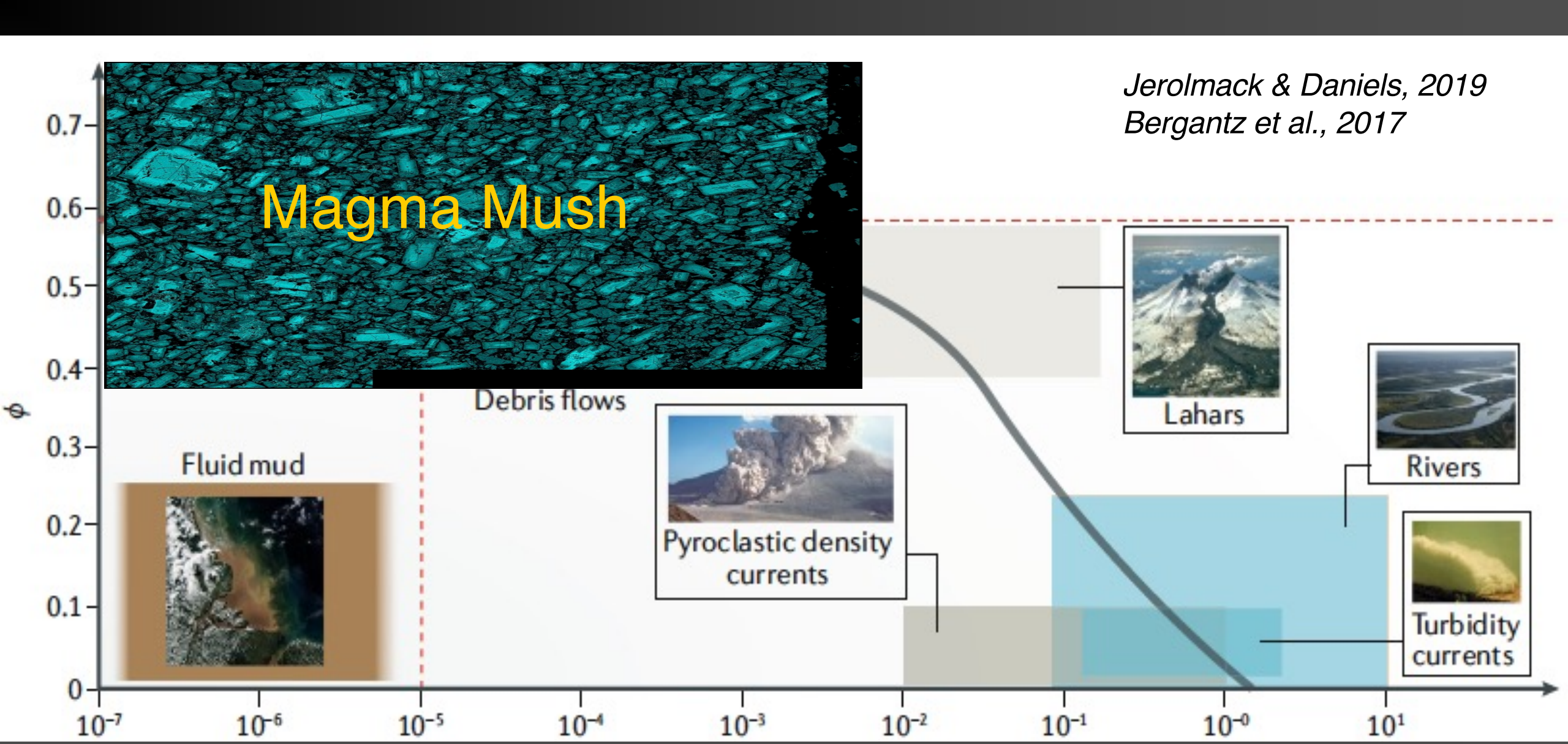
Sedimentation in both atmosphere and gravity currents

Re # < 10^2, *St* # < 1

Double-diffusion, sedimentation, “compaction”, particle R-T instabilities

Crystal-rich “mush”


Crystal-rich “mush”
Crystal shape, size vary
Strong crystal fabric
Localized and distributed deformation



solid, frictional force chains

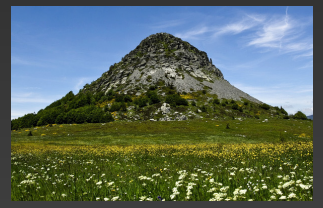
$$I_{vg} = \frac{3\eta_f \dot{\gamma}}{2\Delta\rho g \alpha d}$$

fluid, collisional

22 DEM-CFD simulations with 14,000 particles

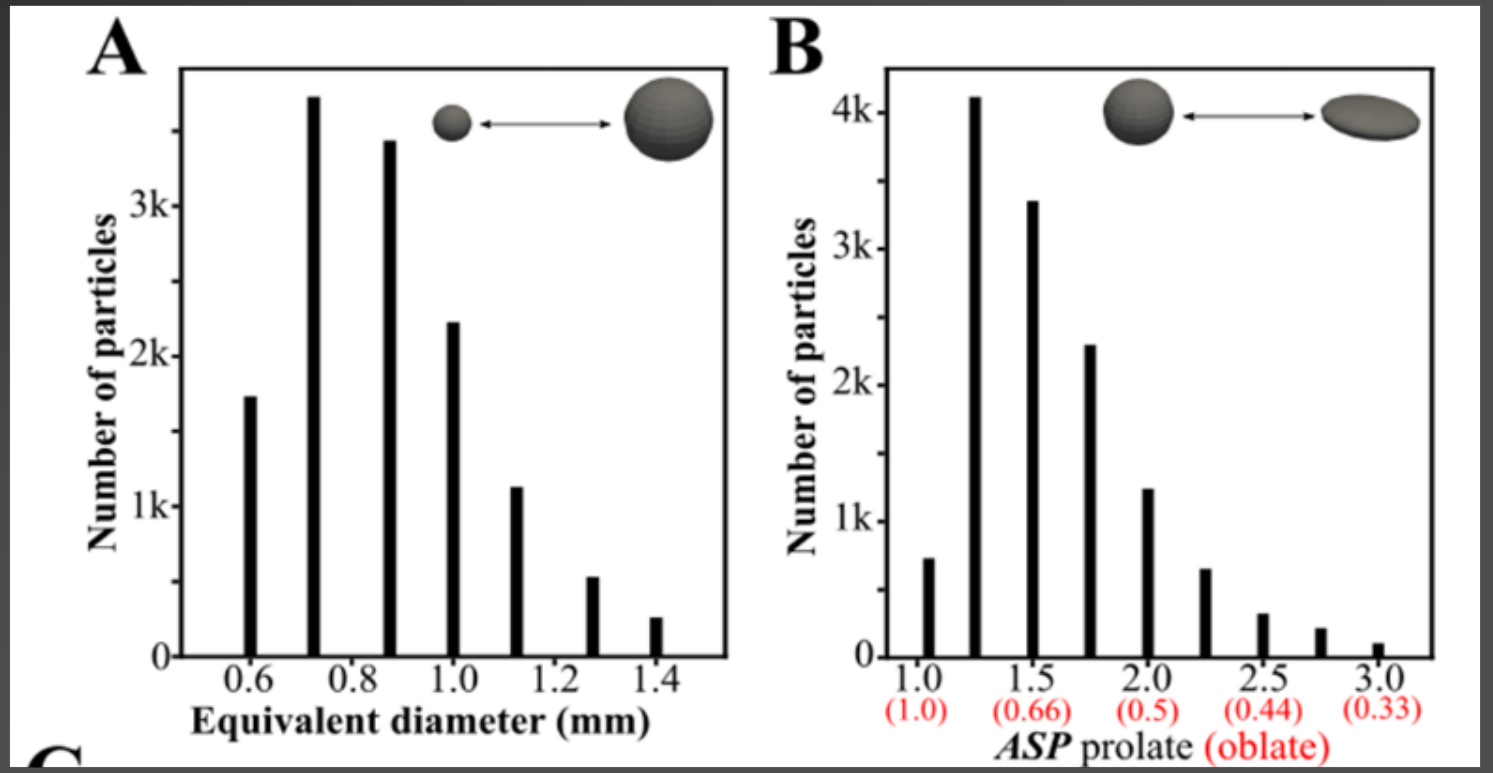
Particle shapes used a superquadratic template

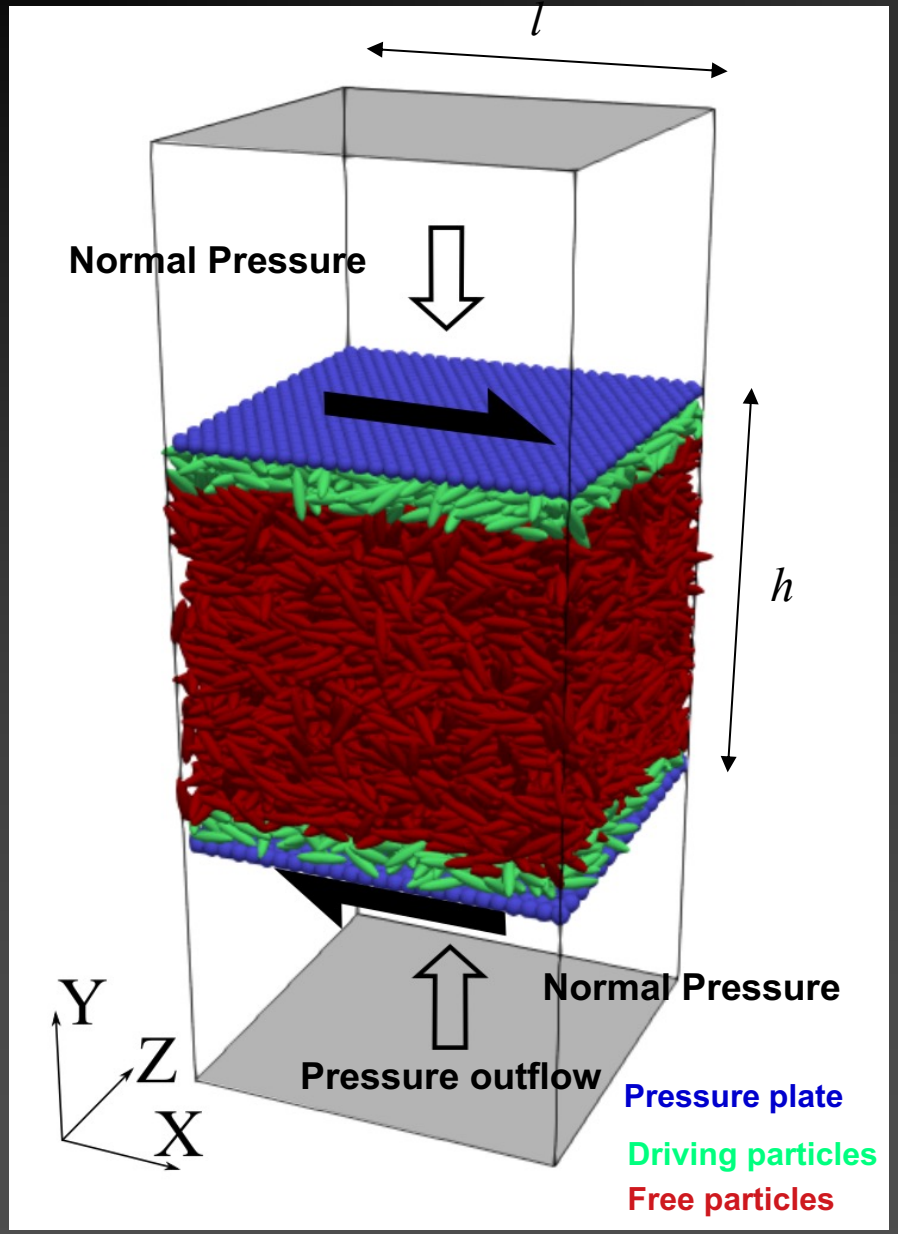
Fluid is unresolved and solved with FVM, DEM with C & S



Mt Gerbier de Jonc

Size and aspect ratio distributions based on measurements from Monika Rùsiecka and Laurent Arbaret (ISTO) Orléans





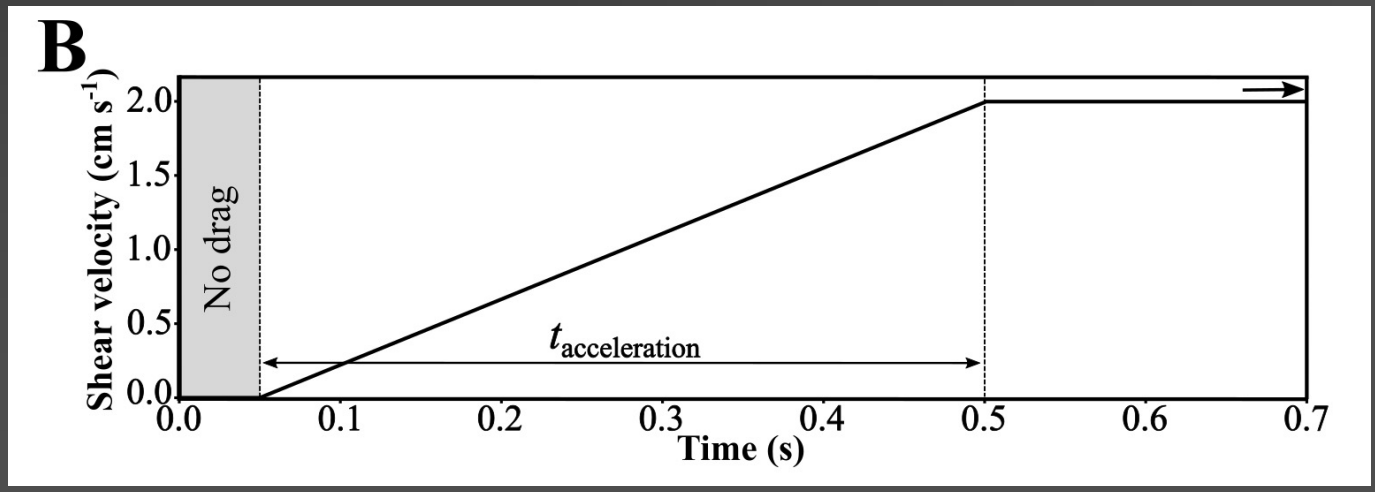
Experiment: Shearing (simple shear)

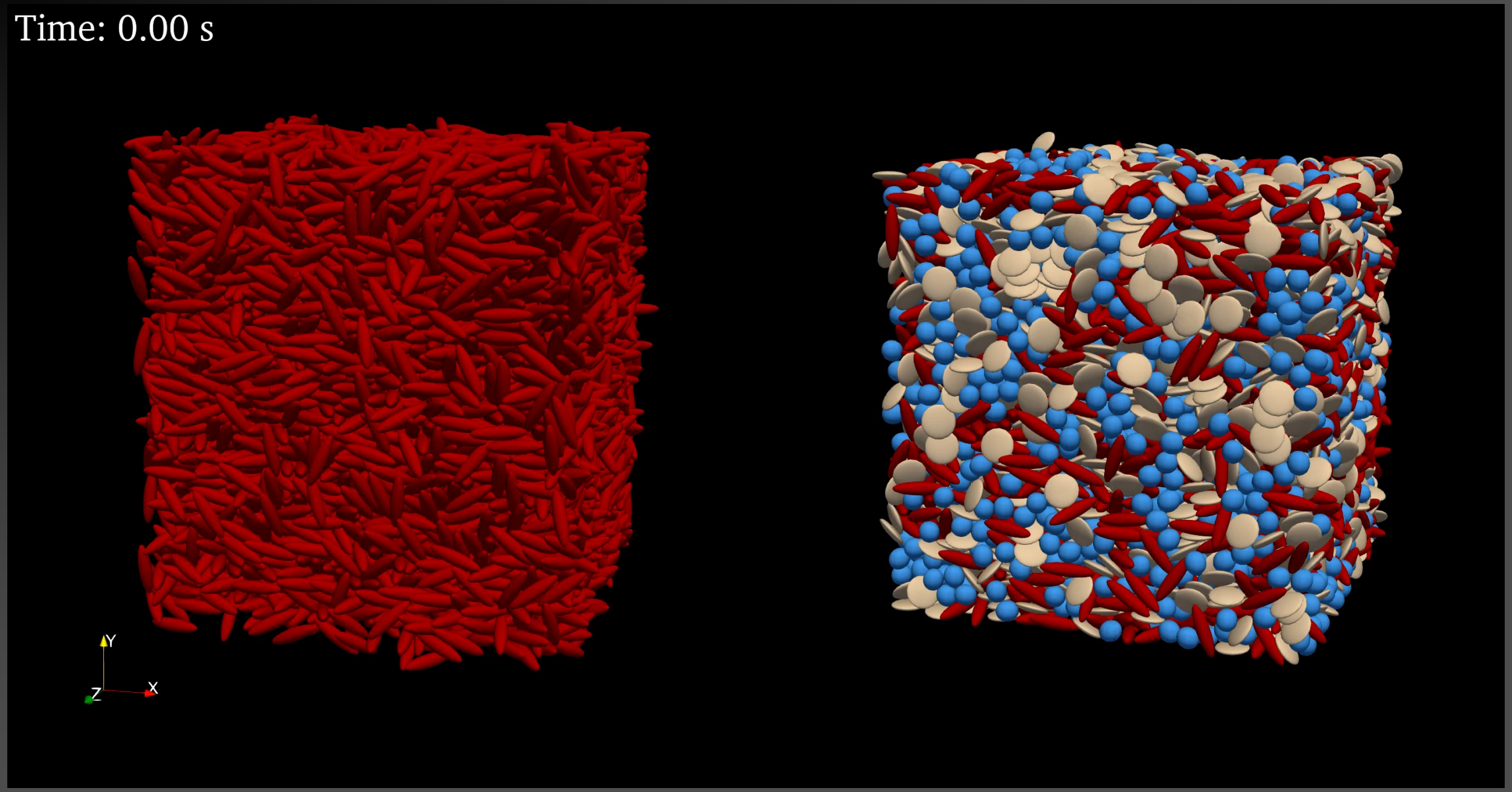
Melt: ρ = 2500 kg/m^3 ; η = 10 Pa s

Crystals: ρ = 2700 kg/m^3

Sample: l = 2 cm; w = 2 cm; h ≈ 2 cm

Strain: γ = 1; V = 0.02 m/s ; P = 1000 Pa



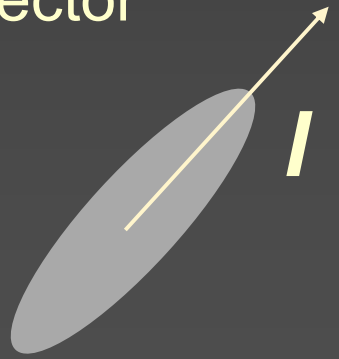

Time: 0.00 s
Y
Z
X

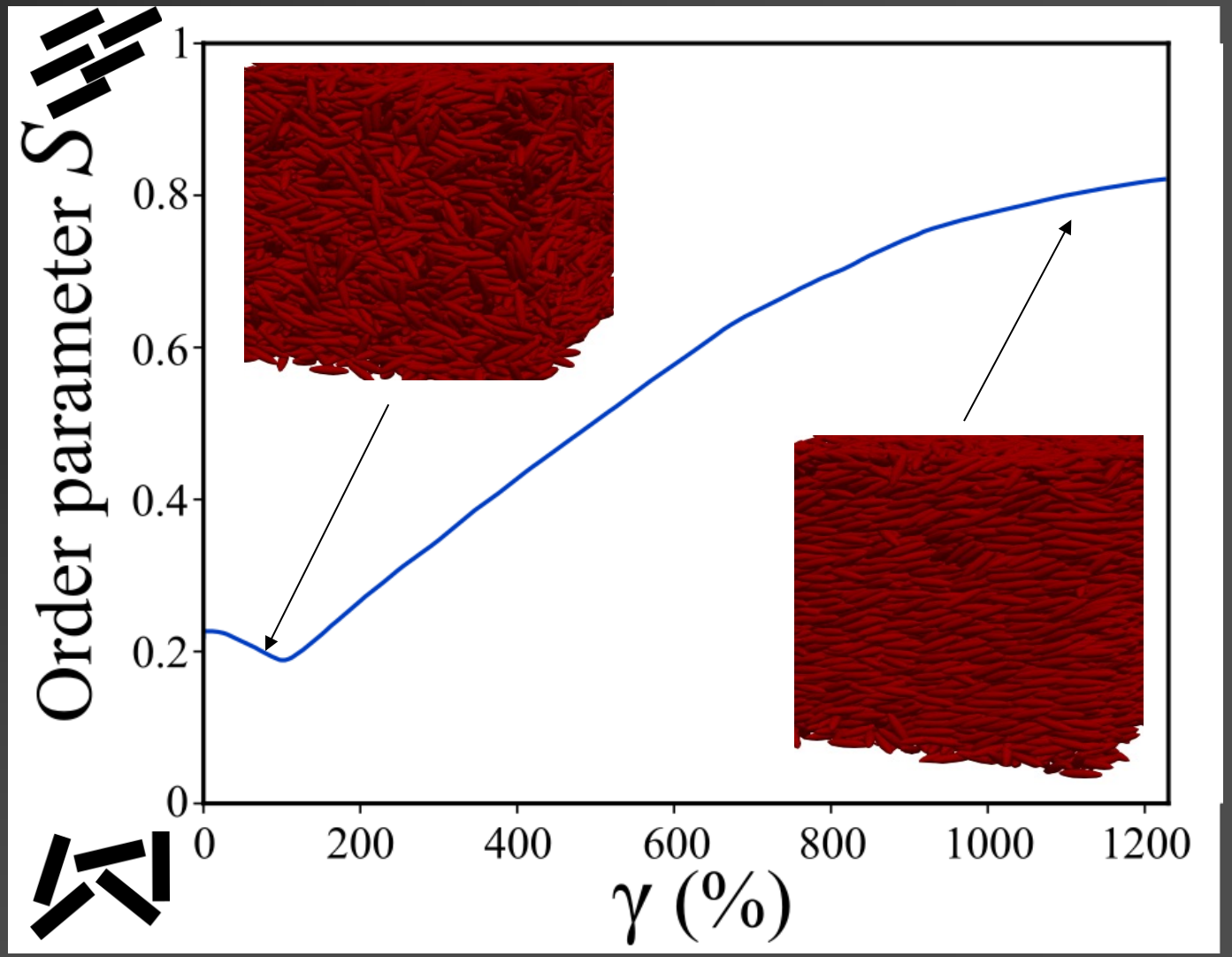
Ordering quantified using the order parameter ***S***:

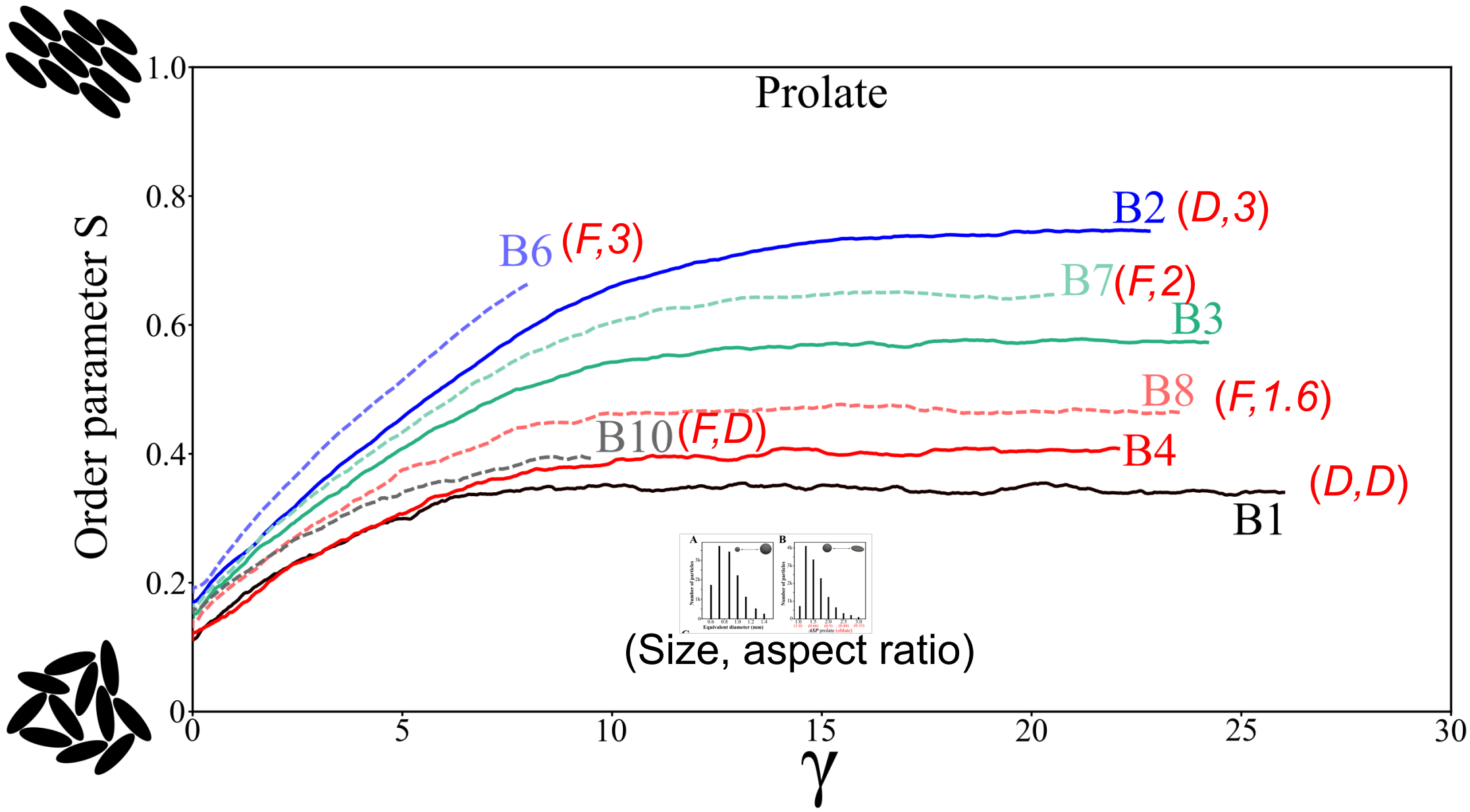
S = largest eigenvalue of order tensor Q
(Guo et al., 2013)

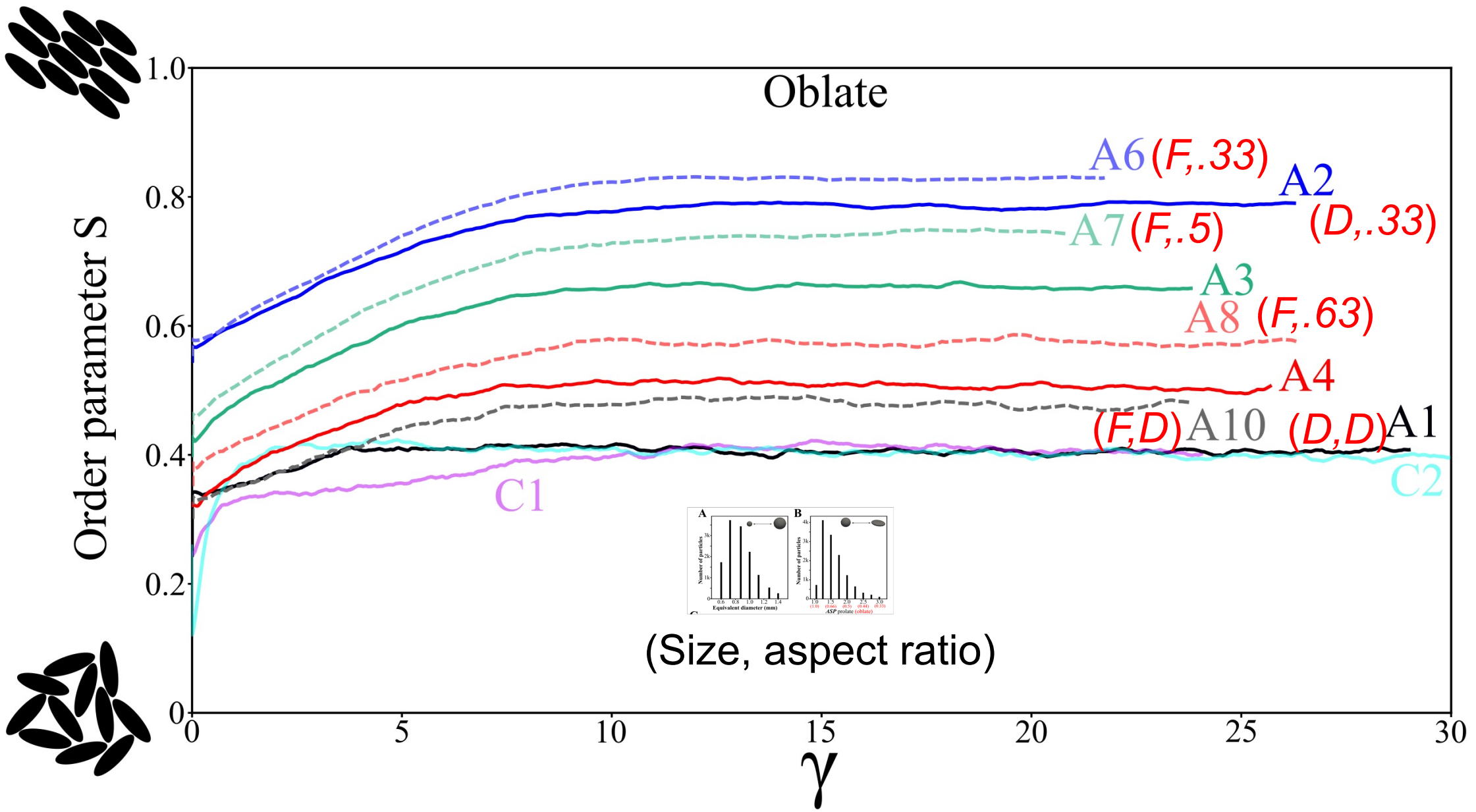
$$Q=\frac{3}{2N}\sum_{n=1}^{N}\left[\boldsymbol{l}\otimes\boldsymbol{l}-\frac{1}{3}\delta_{ij}\right]$$

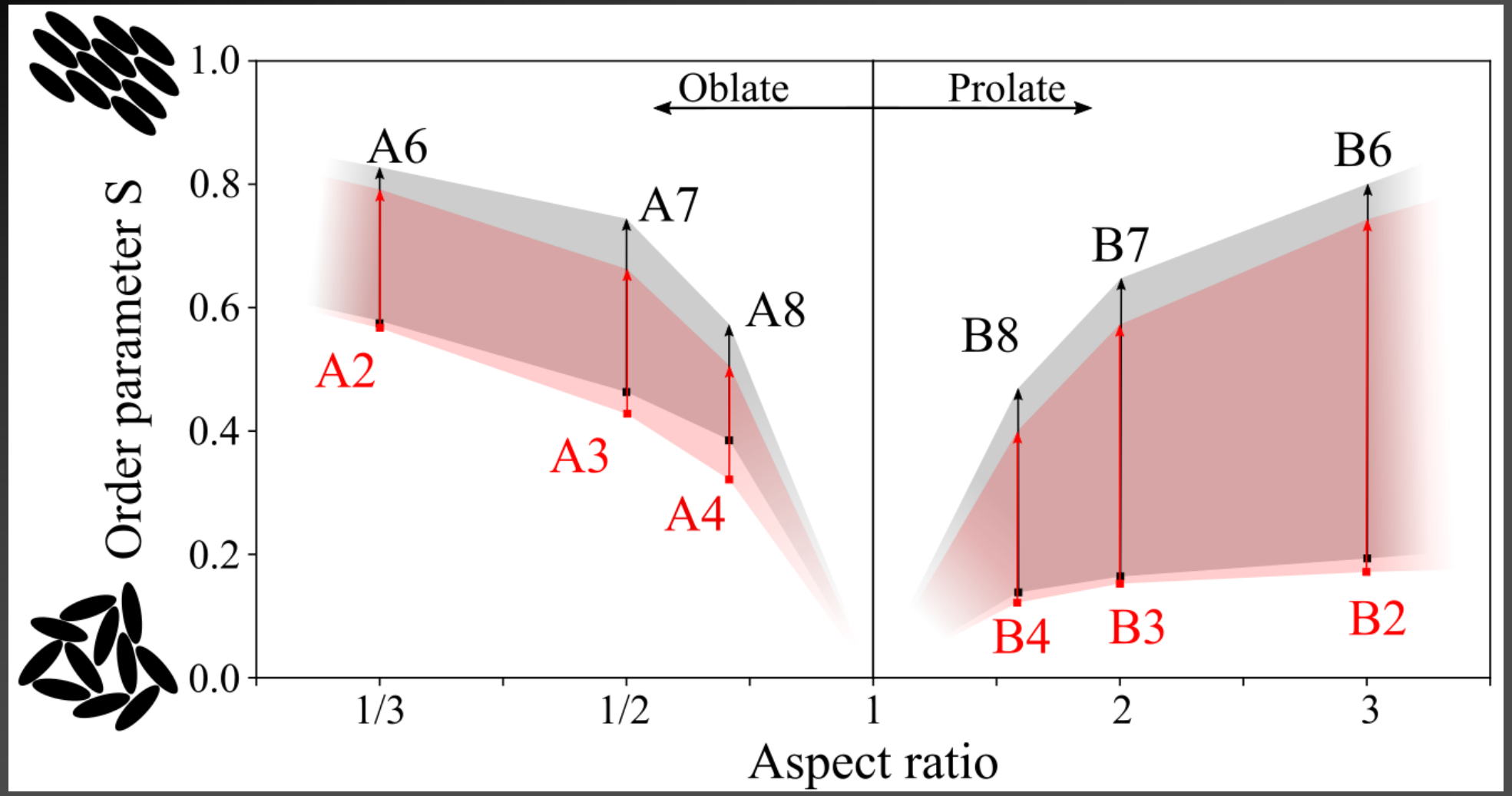
N = number of particles
l = orientation vector
δ = unit tensor



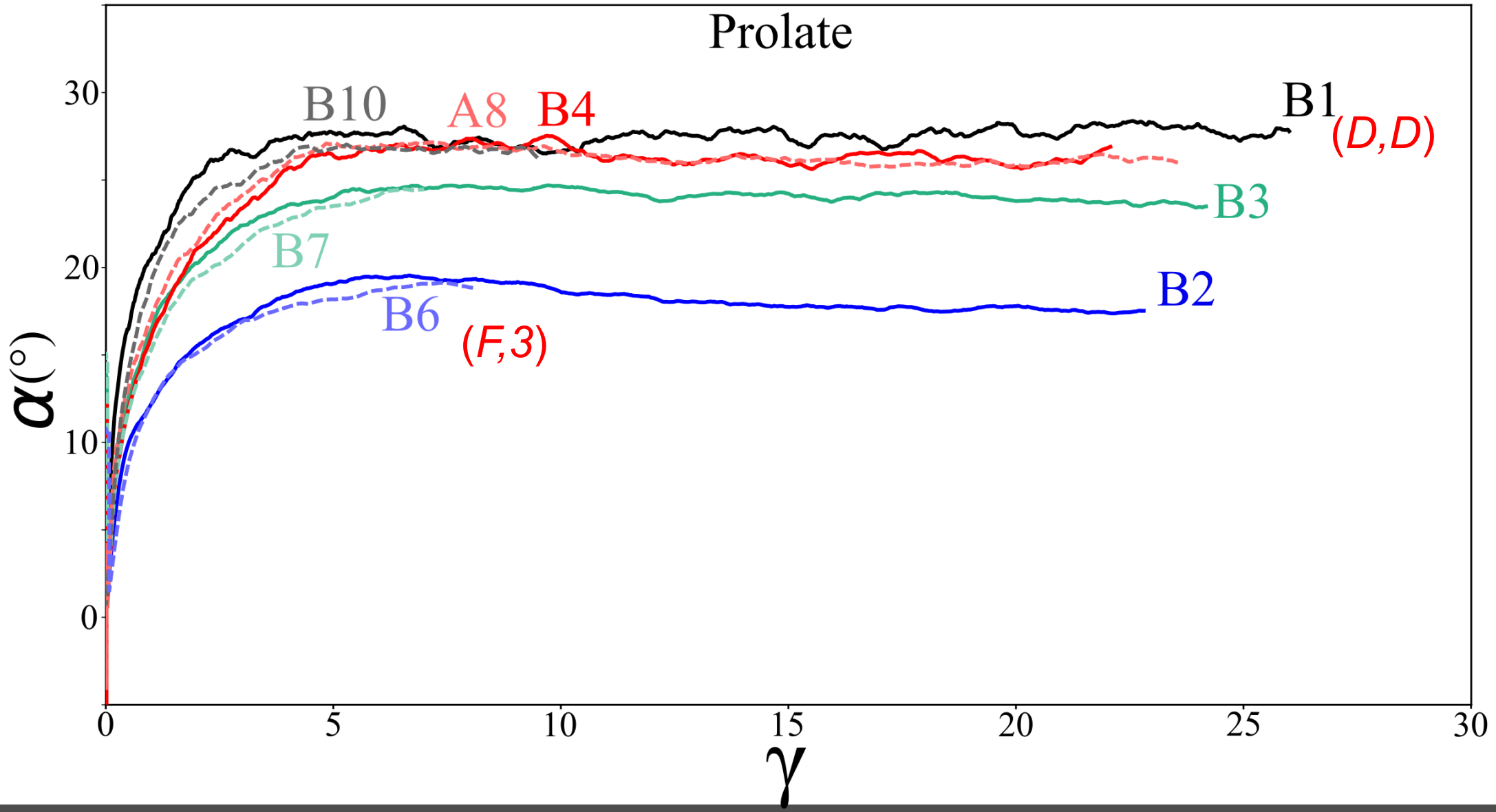



Prolate
Order parameter S
1.0
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
γ
B2 (D,3)
B6 (F,3)
B7(F,2)
B3
B8 (F,1.6)
B10(F,D)
B4
(D,D)
B1
(Size, aspect ratio)


Oblate
A6 (F,.33)
A2
(D,.33)
A7 (F,.5)
A3
A8 (F,.63)
A4
(F,D) A10
(D,D) A1
C1
C2
(Size, aspect ratio)
Order parameter S
γ
1.0
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30



Red shading is size distributed, black shading one size


Prolate
B10
A8
B4
B1
(D,D)
B3
B7
B2
B6
(F,3)
α(°)
γ
0
10
20
30
0
5
10
15
20
25
30

Caveats:

Strong localization and fluctuations even after local coarse-grain averaging (non-affine)

What triggers localized vs distributed deformation?

Clusters?