Numerical modeling of two-phase flow in geodynamics : State of the art, benchmark and perspectives

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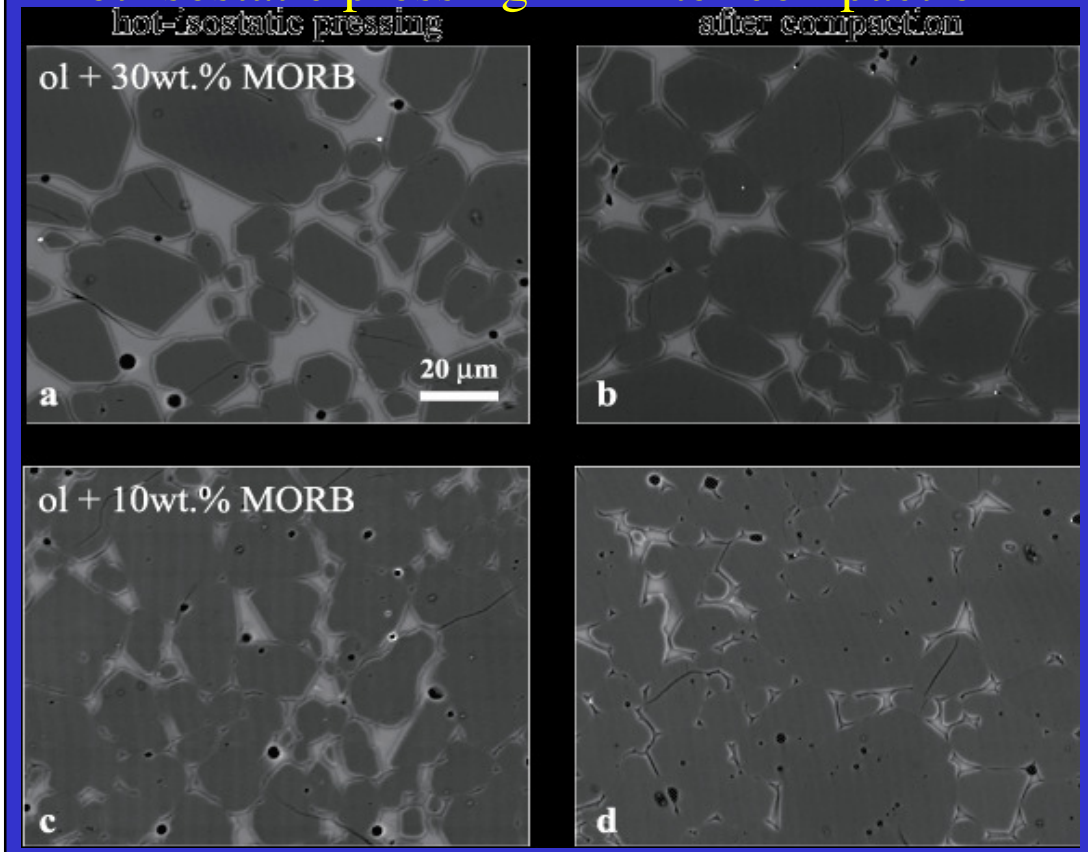
A DEFINITION of TWO-PHASE FLOW

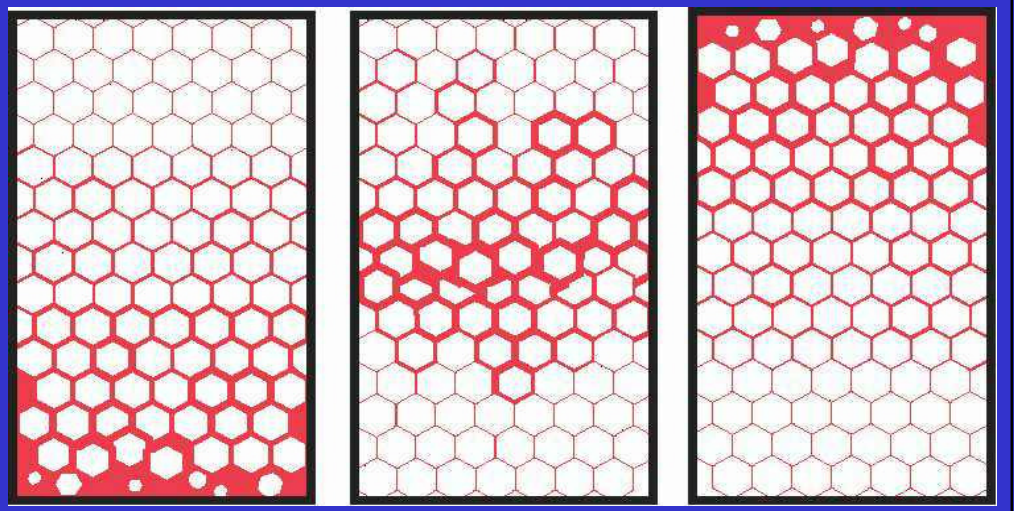
The **simultaneous** flow of two immiscible *fluids* (phases) within common boundaries.

Hot-isostatic pressing

After compaction



Renner et al., G3, 2003

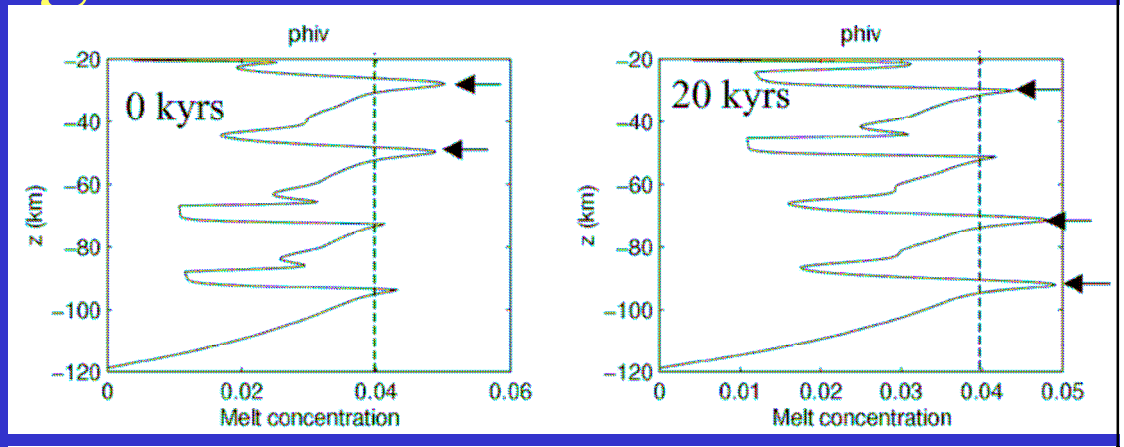


Gravitational percolation

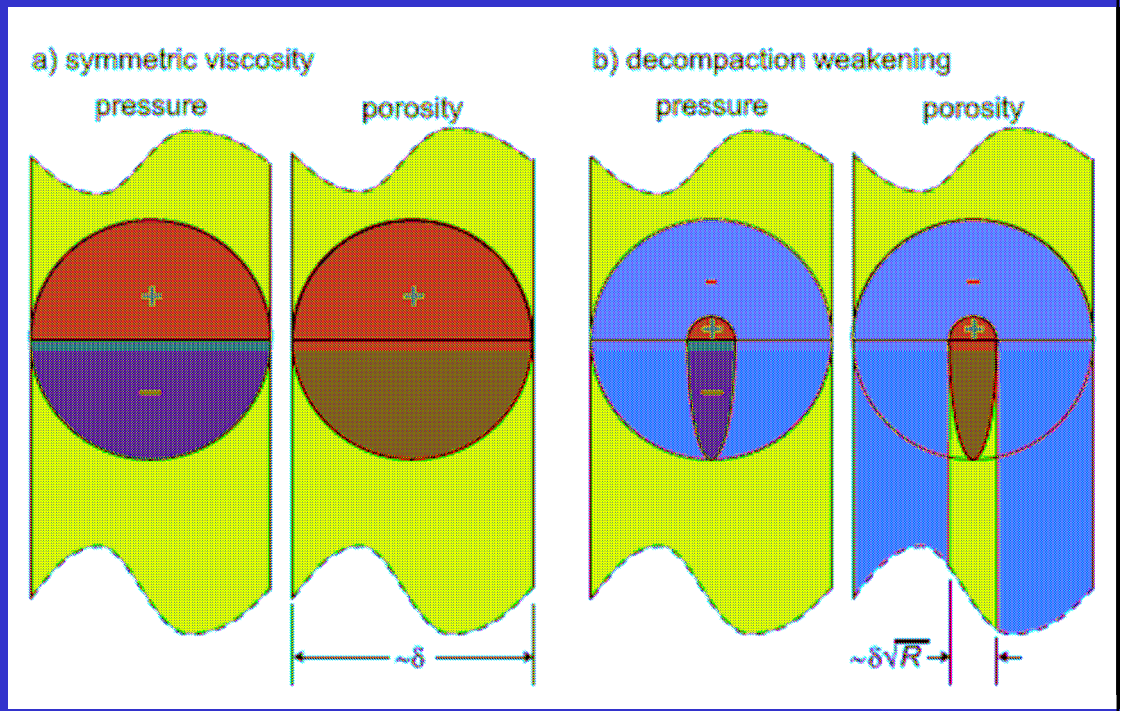
TWO-PHASE FLOW PROBLEMS in GEOSCIENCES

Melt migration & segregation

- Schmeling, *A model of episodic melt extraction for plumes*, J.G.R., 2006



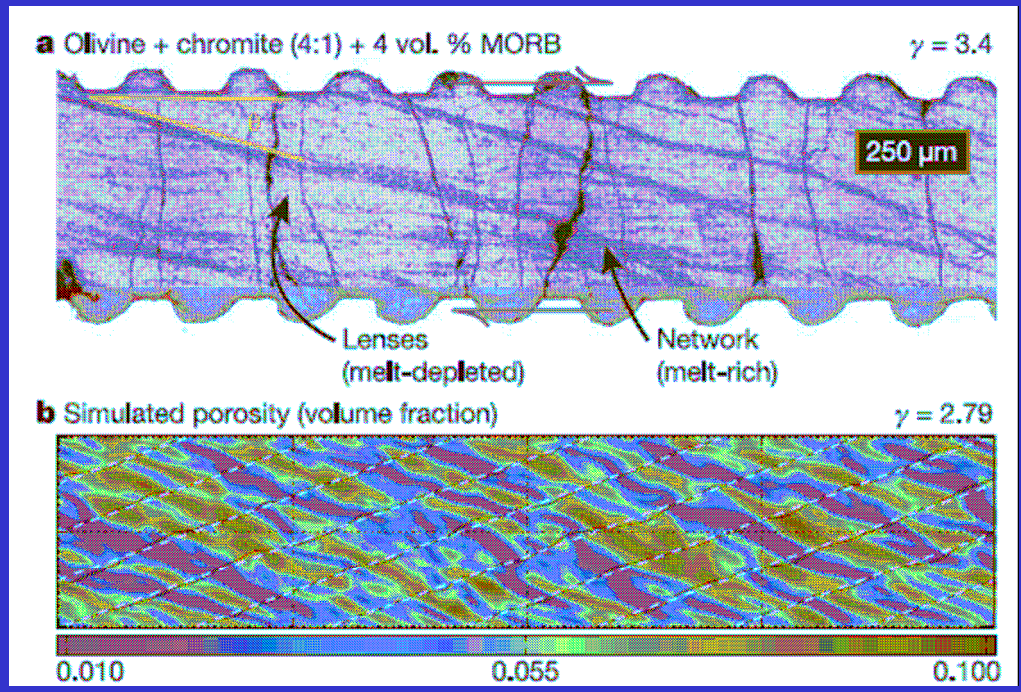
- Connolly & Podladchikov, *Decompaction weakening and channeling instability in ductile porous media*, J.G.R., 2007



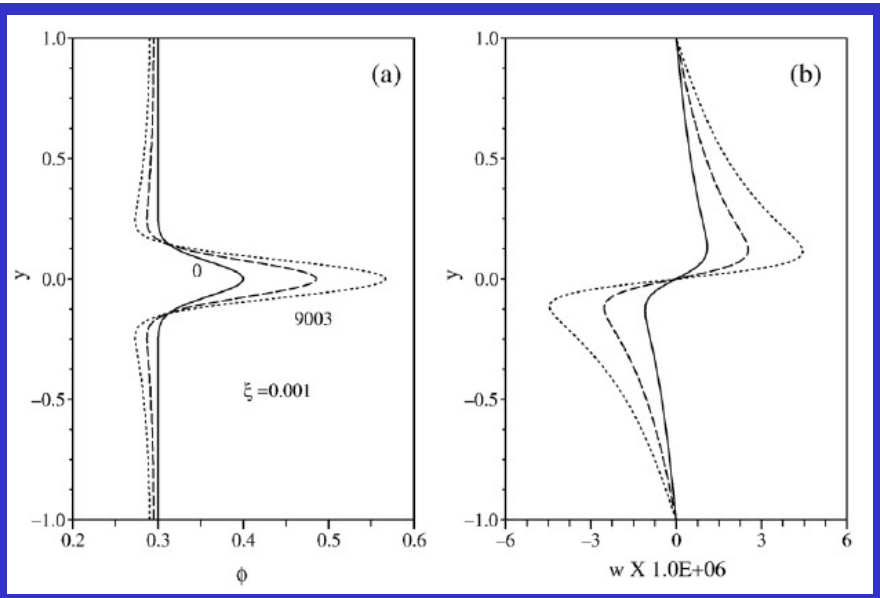
TWO-PHASE FLOW PROBLEMS in GEOSCIENCES

Melt segregation

• Katz et al., *The dynamics of melt and shear localization in partially molten aggregates* Nature, 2006



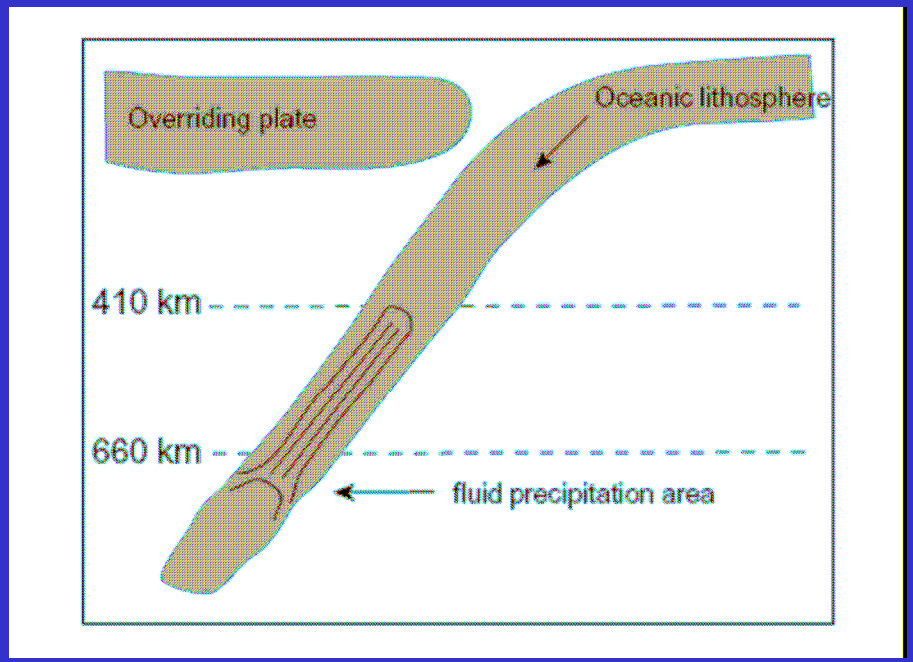
• Hier-Majumder et al., *Role of grain boundaries in magma migration and storage*, E.P.S.L., 2006

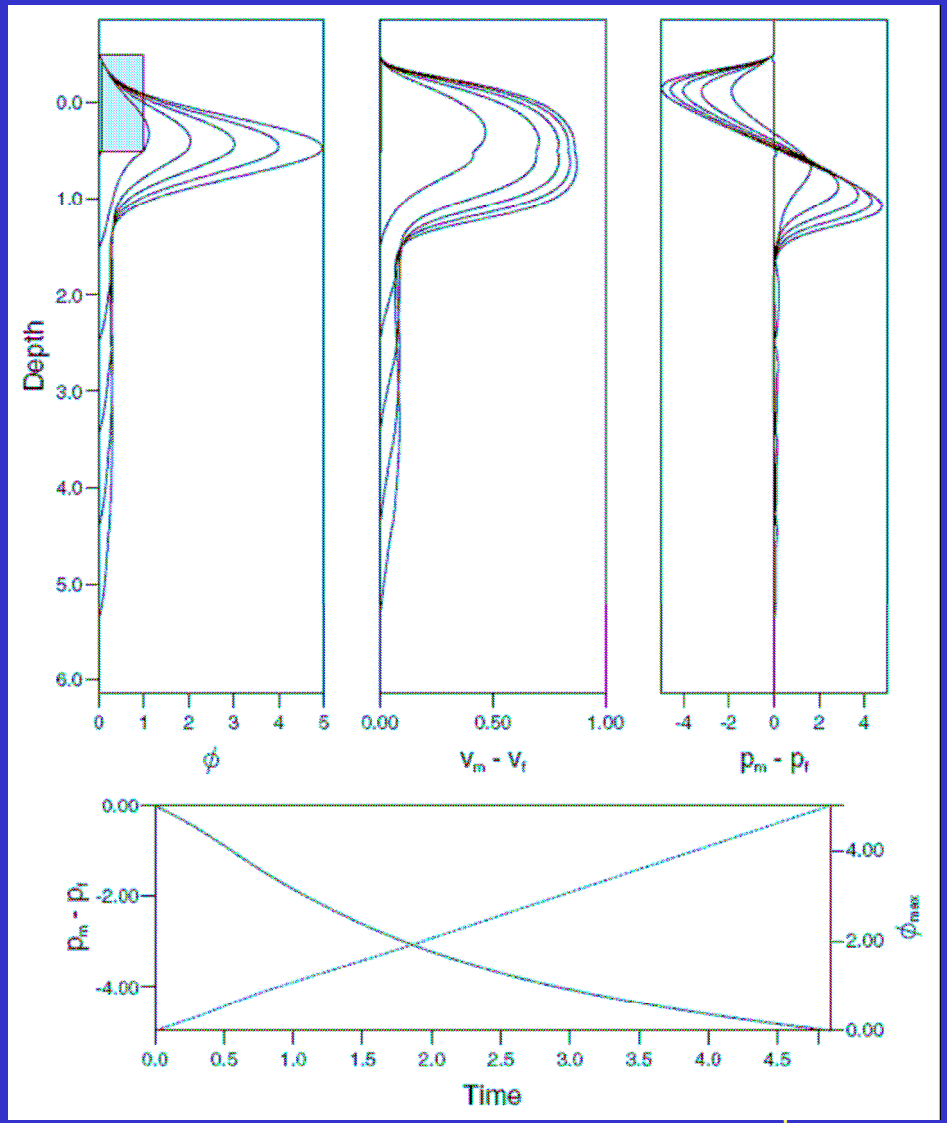


TWO-PHASE FLOW PROBLEMS in GEOSCIENCES

Deep Water migration

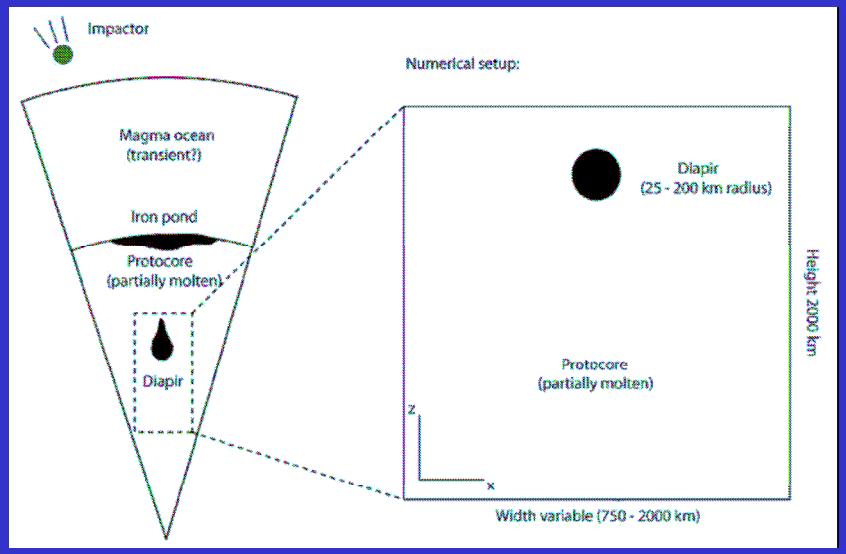
Richard et al., *Slab dehydration and fluid migration at the base of the upper mantle*, ,G.J.Intl., 2007

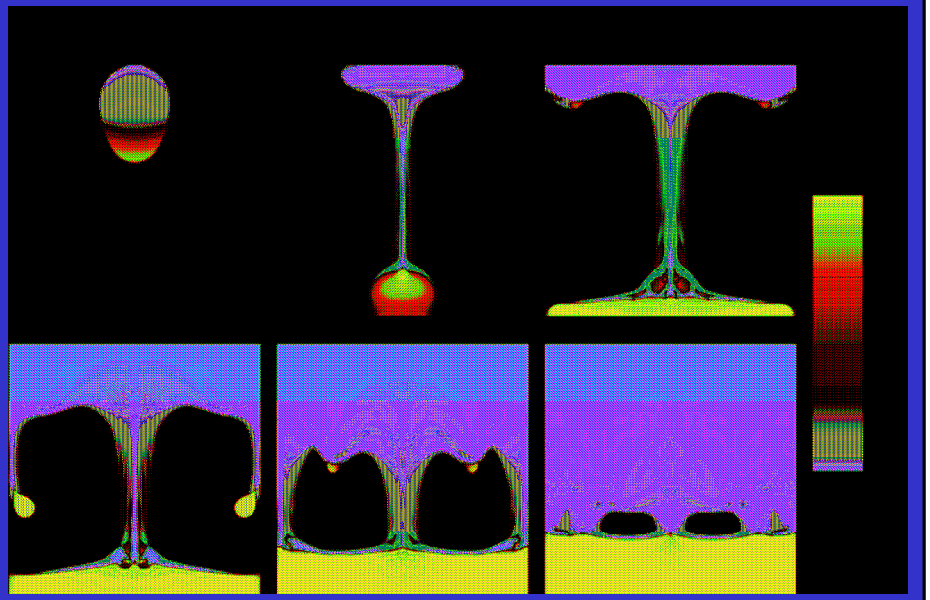




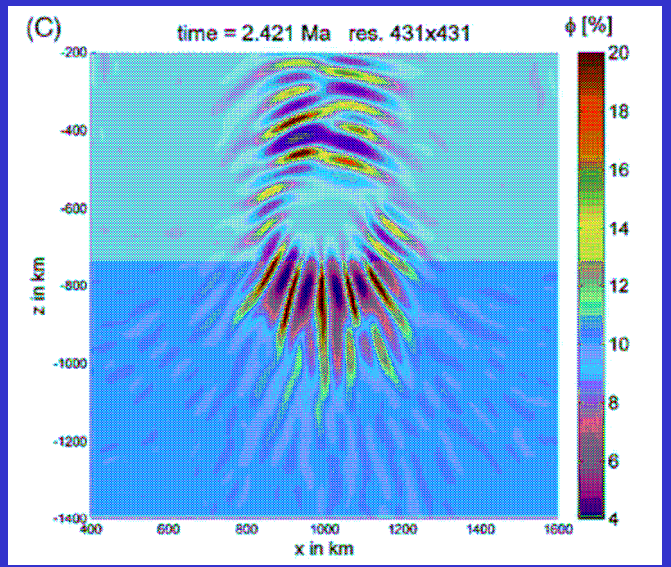
TWO-PHASE FLOW PROBLEMS in GEOSCIENCES

Core formation

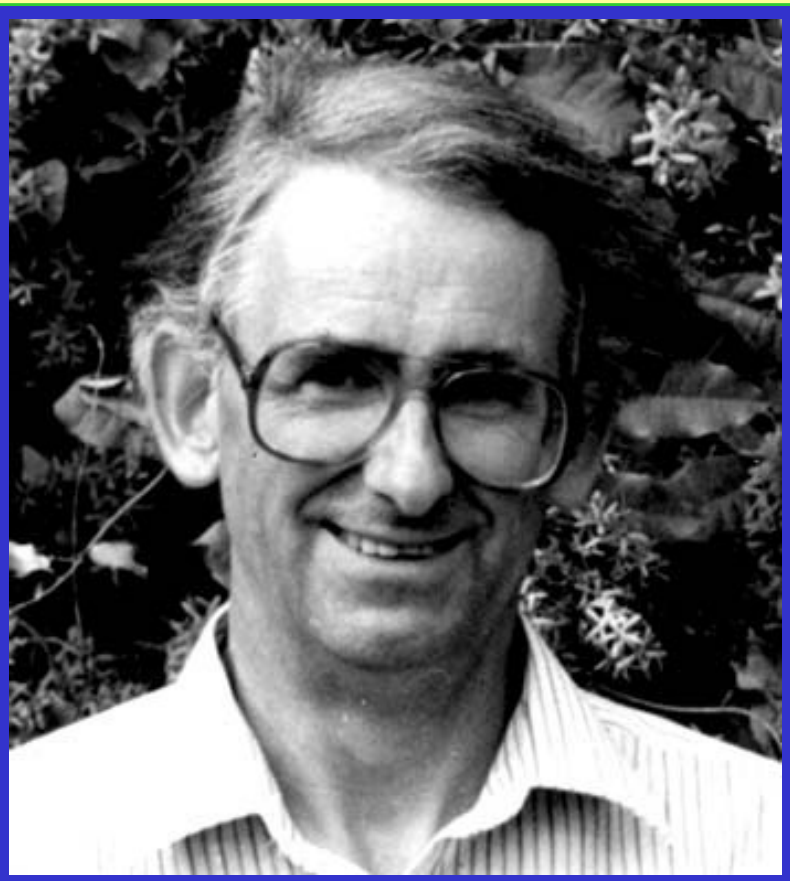




- Ricard et al., *Runaway core-mantle segregation of terrestrial planets*, submitted to G.J.Intl., 2008
- Golabek et al., *Earth's core formation aided by flow channelling instabilities induced by iron diapirs*, E.P.S.L., 2008



A very brief HISTORY of TWO-PHASE FLOW THEORY in GEOSCIENCES



•1984 McKenzie, Journal of Petrology
Scott & Stevenson,
GRL

•2001 Bercovici, Ricard & Schubert, JGR

MATHEMATICAL FORMULATIONS

Force balance equation

Bercovici, Ricard & Schubert, 2001

$$-\frac{\eta_f}{k_0\phi^{n-1}}\delta\mathbf{v}+(1-\phi)\delta\rho\mathbf{g}$$
$$+\nabla\bullet(1-\phi)\eta_m\left[\nabla\mathbf{v}_m+\nabla\mathbf{v}_m{}^t\right]$$
$$-\nabla\left[(1-\phi)\left(\frac{K}{\phi}-\frac{2}{3}\right)\eta_m\nabla\bullet\mathbf{v}_m\right]=0$$

McKenzie, 1984

$$-\frac{\eta_f}{k_0\phi^{n-1}}\delta\mathbf{v}+(1-\phi)\delta\rho\mathbf{g}$$
$$+\nabla\bullet(1-\phi)\eta^*\left[\nabla\mathbf{v}_m+\nabla\mathbf{v}_m{}^t\right]$$
$$-\nabla\left[(1-\phi)\left(\frac{\xi}{\eta^*}-\frac{2}{3}\right)\eta^*\nabla\bullet\mathbf{v}_m\right]=0$$

ξ Bulk viscosity η shear viscosity

K geometric parameter ϕ porosity

TIME FOR A NUMERICAL BENCHMARK

If you have (or almost have) a 2D code solving for the two-phase flow equations and you want to benchmark it.

Please, join us !

(richard@geophysik.uni-frankfurt.de)

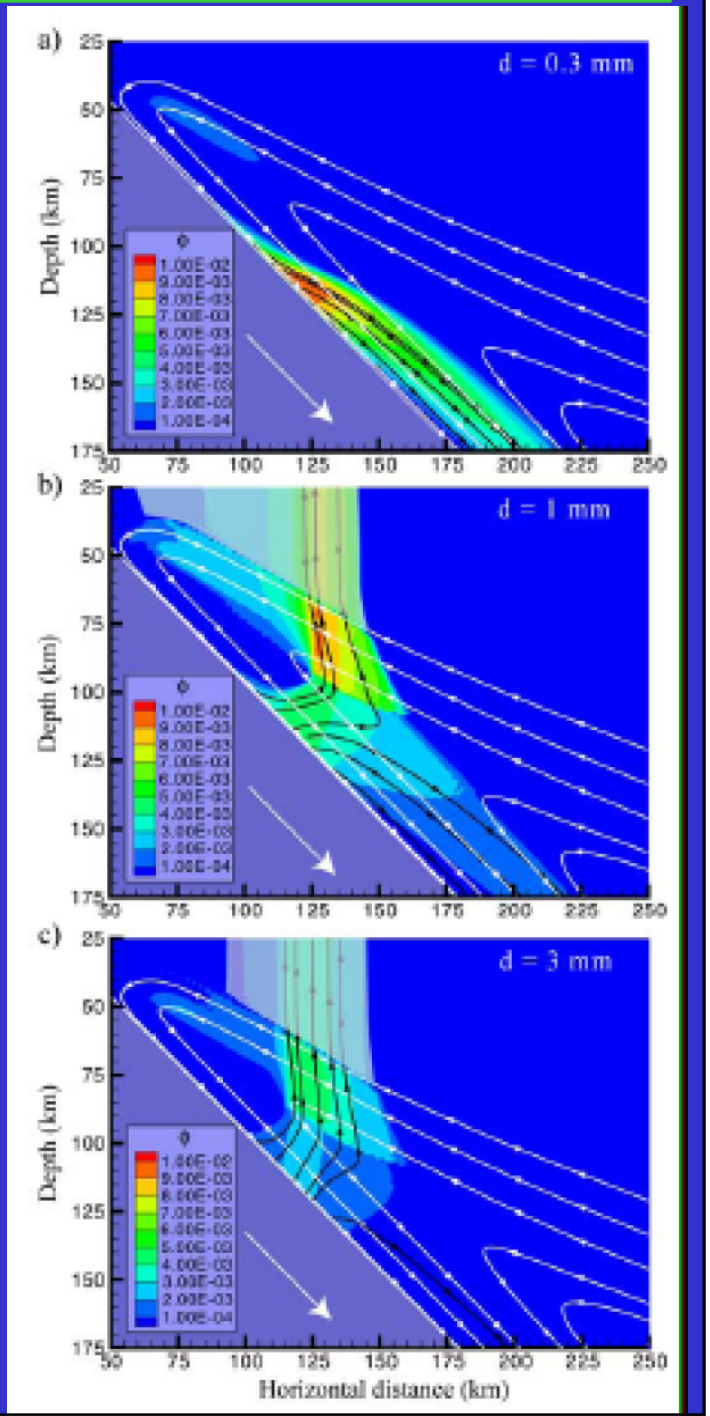
Benchmark members :

A.M. Cagnioncle, R. Katz, M. Rabinowicz, Y. Ricard, G. Richard, H. Schmeling, M. Spiegelman, Hernlung, Hier-Majumder

FUTUR DIRECTIONS & PROBLEMS

Towards Subduction Zones modeling

- Source terms effects
- Visco-elastic rheology
- Coupling between Compaction and Temperature (Sramek et al, GJI, 2007)
- Multi-phase flow (melt+rocky matrix+water)



Cagnioncle et al., J.G.R., 2007

TWO-PHASE FLOW BIBLIO

Melt generation & migration

- Mathematical Formulation (McKenzie, JoP, 1984)
- 1D Solutions: Solitary Wave (Scott & Stevenson, GRL, 1984, Olson & Christensen, JGR, 1986)
- Partial melting (Ribe, EPSL, 1985)
- Ridge settings (Rabinowicz et al., EPSL, 1984; McKenzie, EPSL, 1985)
- Deformable matrix (Ribe, GJRAS, 1985; Spiegelman & McKenzie, EPSL, 1987; Phipps Morgan, GRL, 1987)
- Source term (melting) & 2D approach (Spiegelman, JFM, 1993)