Lithosphere Geodynamics Problems specific to lithosphere geodynamics:

- Prediction of structure (Lagrangian Frame)
- Large deformation
- Very heterogenous materials
- Very non-linear materials
- Free surface true topography stress gradients moving boundary
- **Open Boundaries**
- Isolation of lithosphere requires assumptions of deeper mantle

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Method¤	Reference Frame¤	Rheology¤	Advantages ¤	Disadvantages¤
EVP – "solid" mechanics based. Finite Element/Finite Difference Methods.¤	Lagrangian¤	 Elastic-viscoplastic[¶] Elastic-plastic[¶] Visco-elastic (Maxwell)[¤] 	 Discrete faults can be described by contact 	 Mesh distortion Remeshing required Complex and numerous formulations for finite strain
			elements¤	ц
EVP –Explicit <i>¶</i>	п	• ¤	• Fast¤	 Restrictive stability
(FLAC)¤				condition¤

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Method¤	Reference Frame ^{II}	Rheology¤	Advantages¤	Disadvantages
EVP – "solid" mechanics	Lagrangian¤	 Elastic-viscoplastic[¬] 	 Elastic stress predictor	Mesh distortion □
based. Finite		 Elastic-plastic	 Associative or non- 	 Remeshing required[¬]
Element/Finite Difference		 Visco-elastic (Maxwell)¤ 	associative plasticity <i></i> ¶	 Complex and numerous
Methods.¤			 Discrete faults can be 	formulations for finite
			described by contact	strainௗ
			elements¤	ц
EVP –Explicit [¬]	п	• ¤	• Fast¤	Restrictive stability
(FLAC)¤				condition¤
Stokes Flow –	Eulerian¤	 Viscous, non-linear	 No grid distortion issues 	Material tracking
Momentumless, fluid		 Rigid-Plastic ¤ 	 No large strain 	required by Lagrangian
dynamics based. Finite			limitations∉	markers (ALE, PIC) [¬]
Element Method. ¤			 Open boundaries (flux)^µ 	 Difficult to resolve
				localized deformation
				(faults)∉
				 Isotropic, associative
				plastic strains only¤

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EVP – "solid" mechanics based. Finite Element/Finite Difference Methods, ¤	Lagrangian¤	 Elastic-viscoplastic[¶] Elastic-plastic[¶] Visco-elastic (Maxwell)[¤] 	 Elastic stress predictor General Associative or non- associative plasticity General Discrete faults can be 	 Mesh distortion I Remeshing required I Complex and numerous formulations for finite
Nichious. A			described by contact elements¤	strain∉ ¤
EVP –Explicit⊄ (FLAC)¤	д	• ¤	• Fast¤	Restrictive stability condition
Stokes Flow – Momentumless, fluid dynamics based. Finite Element Method.¤	Eulerian¤	 Viscous, non-linear[¬] Rigid-Plastic[¬] 	 No grid distortion issues[¶] No large strain limitations[¶] Open boundaries (flux)[¤] 	 Material tracking required by Lagrangian markers (ALE, PIC)[¬] Difficult to resolve localized deformation (faults)[¬] Isotropic, associative plastic strains only[¤]
Particle Methods (Distinct Element Method; Smooth Particle Hydrodynamics) Gridless.¤	Lagrangian¤	• Emergent elastic, plastic, viscous¤	 Accurate representation of discrete strain zones[¬] Variable resolution[¬] No grid distortion issues[¬] Dynamic (momentum)[¬] 	 Rheology is emergent property[¬] Momentum[□]

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Method¤	Reference Frame ¤	Rheology¤	Advantages¤	Disadvantages ^{II}
EVP – "solid" mechanics based. Finite Element/Finite Difference Methods.¤	Lagrangian¤	 Elastic-viscoplastic[¬] Elastic-plastic[¬] Visco-elastic (Maxwell)[¬] 	 Elastic stress predictor[¬] Associative or non- associative plasticity[¬] Discrete faults can be described by contact elements[□] 	 Mesh distortion and a second secon
EVP –Explicit (FLAC)¤	ц	• ¤	• Fast¤	 Restrictive stability condition¤
Stokes Flow – Momentumless, fluid dynamics based. Finite Element Method.¤	Eulerian¤	 Viscous, non-linear[¬] Rigid-Plastic[□] 	 No grid distortion issues[¬] No large strain limitations[¬] Open boundaries (flux)[¤] 	 Material tracking required by Lagrangian markers (ALE, PIC)[¬] Difficult to resolve localized deformation (faults)[¬] Isotropic, associative plastic strains only[¬]
Particle Methods (Distinct Element Method; Smooth Particle Hydrodynamics) Gridless.¤	Lagrangian¤	• Emergent elastic, plastic, viscous¤	 Accurate representation of discrete strain zones Variable resolution No grid distortion issues Dynamic (momentum) ¤ 	 Rheology is emergent property[¬] Momentum[¬]
Thin Sheets – 2D viscous sheet, solved with FEM ¤	Eulerian or Lagrangian¤	• Viscous, non-linear¤	 Reduced Dimensionality by vertical integration of stress and strain^{\(\overline\)} Faults can be included as contact boundaries^{\(\overline\)} 	 No vertical partitioning or resolution of strain – neglect of components of strain rate¤

Note: Nothing on numerical methods here