STREAM 3D project

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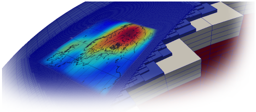
Overview

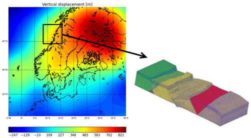
Introduction

Background and Motivations

Key processes of sedimentary basin evolution:

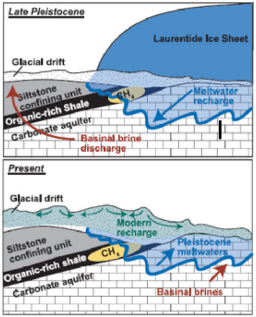
- geomechanics and dynamic evolution of stress and deformations;
- transport of dissolved chemicals;
- geochemical reactive processes.





The effects of glaciations on the subsurface:

- the mechanical compaction due to the load of ice sheets;
- the deformation of the lithosphere by isostasy;
- the subglacial meltwater;



Mathematical model

Poromechanics

$$
\begin{aligned}
-\nabla \cdot \left(2\mu\varepsilon(\mathbf{u}) + \nabla \cdot \mathbf{u}\right) + \alpha \nabla p &= \rho \mathbf{g}\,, \\
\partial_t \left(\frac{p}{M} + \alpha \nabla \cdot \mathbf{u}\right) + \nabla \cdot \mathbf{u_d} &= S_f\,, \\
\mathbf{K}^{-1}\mathbf{u_d} + \nabla p &= \rho_f \mathbf{g}\,,
\end{aligned}
$$

Temperature Dynamics

$$C_T \frac{\partial T}{\partial t} + (\phi \rho_l c_l \mathbf{v_l} + (1-\phi)\rho_s c_s \mathbf{v_s}) \cdot \nabla T - K_T \nabla^2 T = Q \,.$$

Chemical transport

$$C_T \frac{\partial C}{\partial t} + \mathbf{u_D} \cdot \nabla C - D \nabla^2 T = Q_c \, .$$

Coupled model

Poromechanics - Temperature Dynamics - Chemical transport

$$
\begin{aligned}
-\nabla \cdot (2\mu\varepsilon(\mathbf{u}) + \nabla \cdot \mathbf{u}) + \alpha \nabla p &= \rho \mathbf{g}\,, \\
\partial_t \left(\frac{p}{M} + \alpha \nabla \cdot \mathbf{u} \right) + \nabla \cdot \mathbf{u_d} &= S_f\,, \\
\mathbf{K}^{-1}\mathbf{u_d} + \nabla p &= \rho_f \mathbf{g}\,, \\
C_T \frac{\partial T}{\partial t} + (\phi \rho_l c_l \mathbf{v_l} + (1-\phi)\rho_s c_s \mathbf{v_s}) \cdot \nabla T - K_T \nabla^2 T &= Q\,. \\
C_T \frac{\partial C}{\partial t} + \mathbf{u_D} \cdot \nabla C - D \nabla^2 T &= Q_c\,.
\end{aligned}
$$

Constitutive law

$$\mu = 1.002\,10^{-3}\,(1 + \alpha_1(T) + \alpha_2(C_M))$$

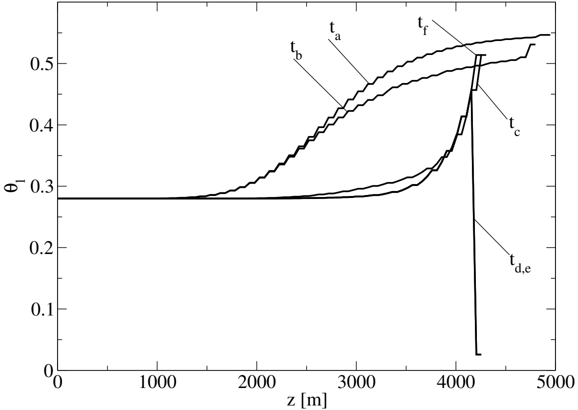
$$\rho_l = \rho_0(1 + \beta_1(T) + \beta_2(C_M))\,.$$

Ice fraction

$$\theta_l = S_i \phi_i$$

$$S_i = \begin{cases} 1 & T > T_L \,, \\ (1 - S_{lres}) \exp\left[-\left(\frac{T - T_L}{w}\right)^2\right] + S_{lres} & T_L > T > T_{lres} \,, \\ S_{lres} & T < T_{lres} \,. \end{cases}$$

Geometric VS Algebraic



Numerical Plattofrm

Numerical platform

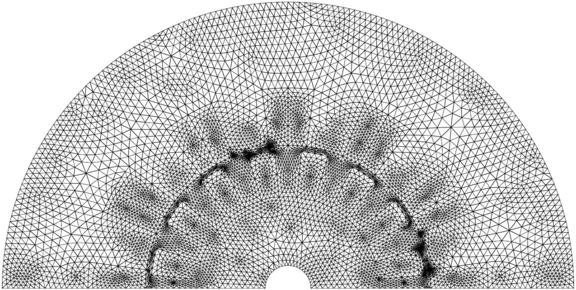
GetFem

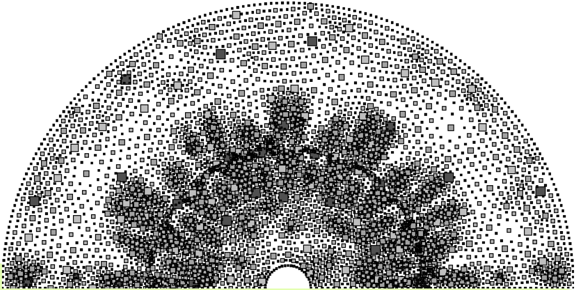
- c++ finite element platform
- Generic assembly language
- Level-set and finite element cut by one or several level-set (Xfem)

SAMG library
Algebraic Multigrid Methods for Systems

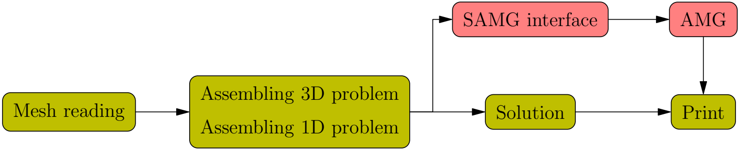
- solution of large linear systems
- higly scalable
- easy to integrate

Geometric VS Algebraic





Integration



- Simple interface (CSR matrix)
- Same programming language

Conclusion