ОФП

Program for two phase relative permeability computation based on unsteady-state experimental data.

Company: Ufa branch of the Ugansk Research and Planning Oil Institute of the YUKOS Oil Company (2000-2001)

Languages/Compilers/API: Borland Delphi and Microsoft Fortran 90

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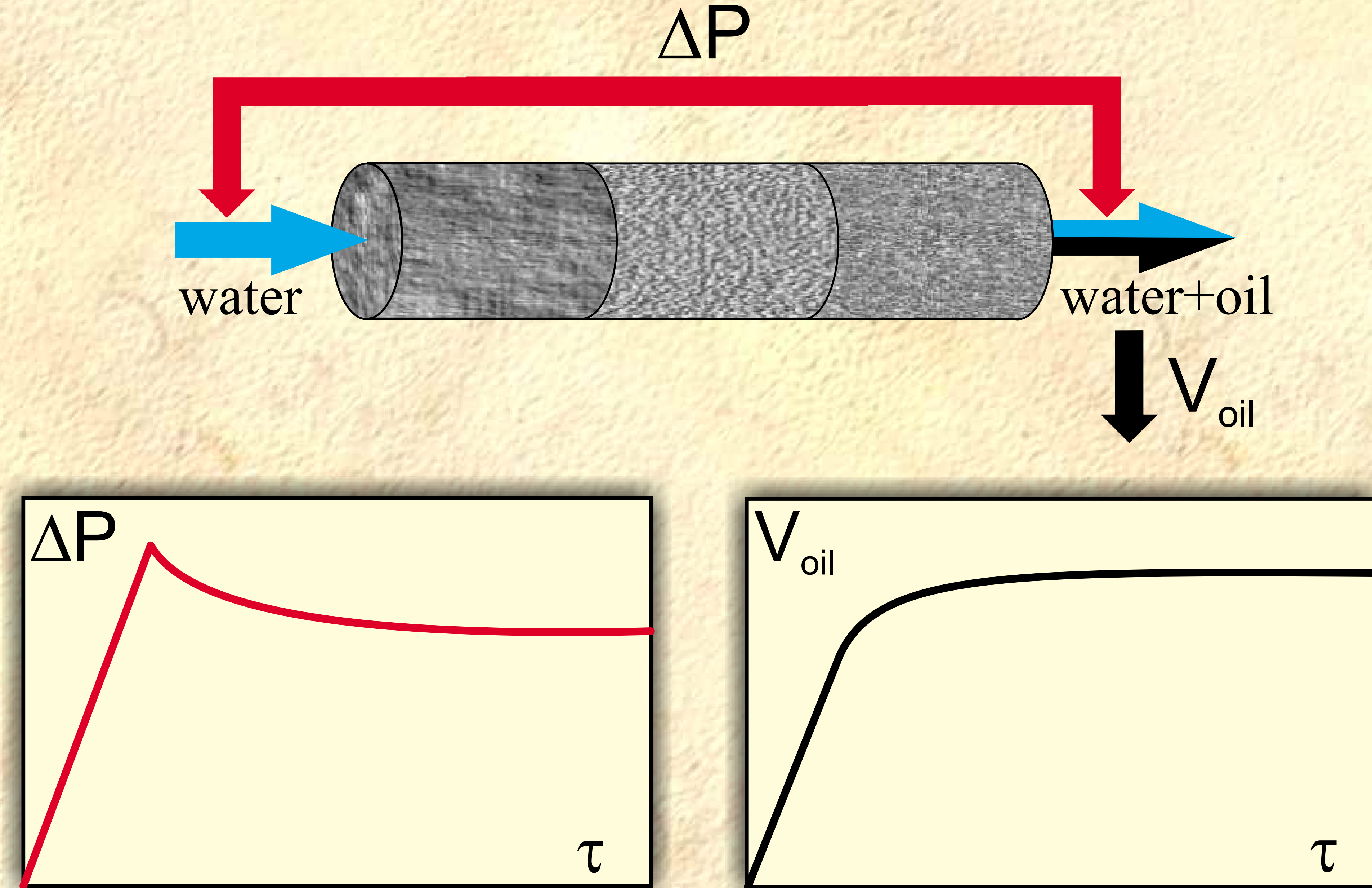
Experiment

Displacement of oil by water in the core sample



Theory

Buckley-Leverett equation

$$\frac{ds}{d\tau} + f'(s)\frac{ds}{d\xi} = 0$$

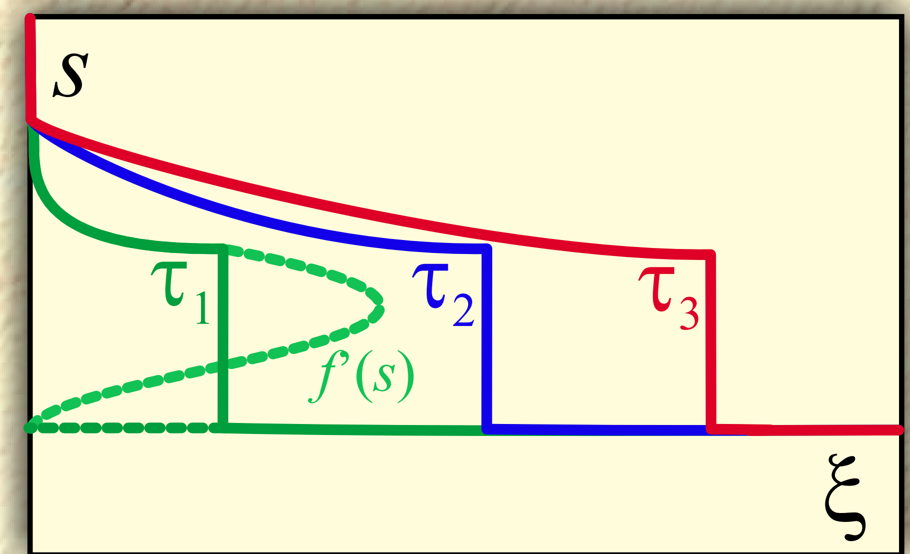
Buckley-Leverett function

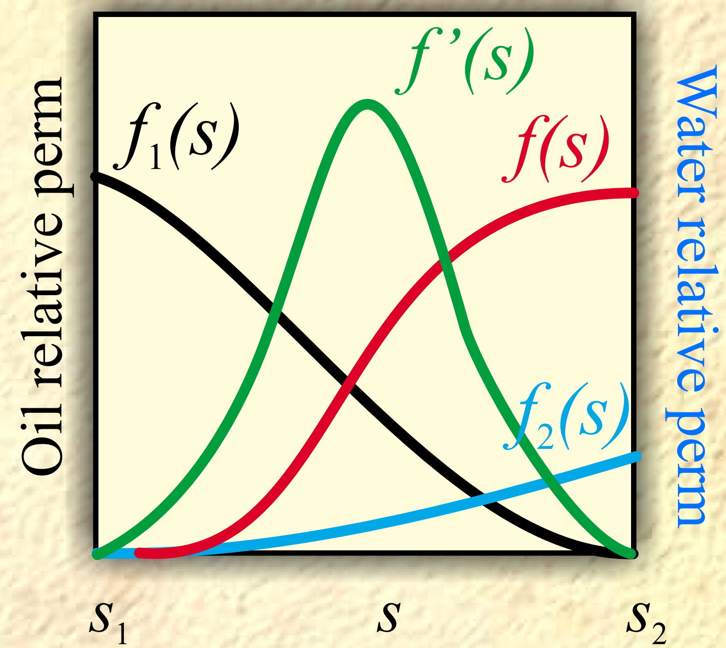
$$f(s) = \frac{f_1(s)}{\varphi(s)}$$

$$\varphi(s) = f_1(s) + \mu_0 f_2(s)$$

s - water saturation,
τ and ξ - dimensionless time and length,
$\mu_0 = \mu_1/\mu_2$ - water and oil viscosities ratio

Solution:





Direct problem

$$\Delta P^{\tau<\tau_c} = -\mu_1 L v \tau \int_{s_c}^{s_2} \frac{f''(s)}{k(s)\cdot\varphi(s)} ds + \mu_2 L v \int_{x_c}^{1} \frac{dx}{k(x)}$$

$$\Delta P^{\tau\geq\tau_c} = -\mu_1 L v \tau \int_{\bar{s}}^{s_2} \frac{f''(s)}{k(s)\cdot\varphi(s)} ds$$

$$V^{\tau\leq\tau_c} = \tau\cdot V_n$$

$$V^{\tau>\tau_c} = \left[\bar{s} - s_1 + \tau\cdot(1 - f(\bar{s}))\right]\cdot V_n$$

τ_c - water break time, s_1 and s_2 - initial and final water saturation, L - core length, ν - displacement rate, k - permeability of the core, $\varphi(s)=f_1(s)+\mu_0 f_2(s)$, V_n - porosity

displacement front saturation $s_c \rightarrow f(s_c) = f'(s_c)\cdot(s_c - s_1)$

saturation at the core end $\bar{s} \rightarrow \tau = 1/f'(\bar{s})$

parametrization of relative permeability functions

$$f_1(s) = F_1 x^{r_1 + r_2 x}$$

$$f_2(s) = F_2 (1-x)^{q_1 + q_2 x}$$

$x=(s-s_1)/(s_2-s_1)$

Analytical vs. Numerical solution

fast applicable to any equation

Inverse problem

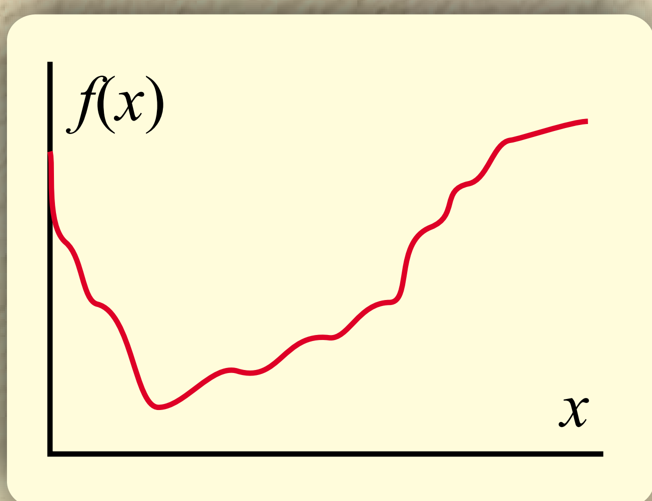
minimization functional

$$\Phi\,(r,q)=\sum_{i=1}^{n}\left(\alpha\left(\frac{V_{c,i}-V_{e,i}}{V_{e,i}}\right)^2+\left(\frac{\Delta p_{c,i}-\Delta p_{e,i}}{\Delta p_{e,i}}\right)^2\right)\rightarrow \min$$

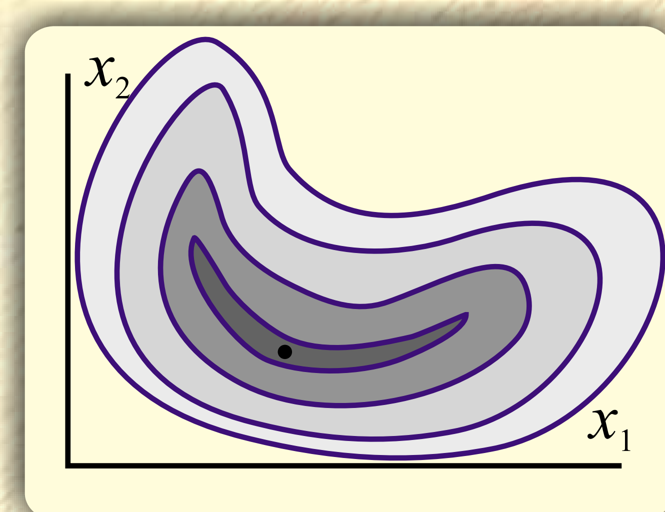
α - scale factor

Optimization methods:

Newton
Gradient and Quasi-Newton: DFP, BFGS
Direct methods: Simplex, Powell
Monte-Carlo
Genetic algorithm

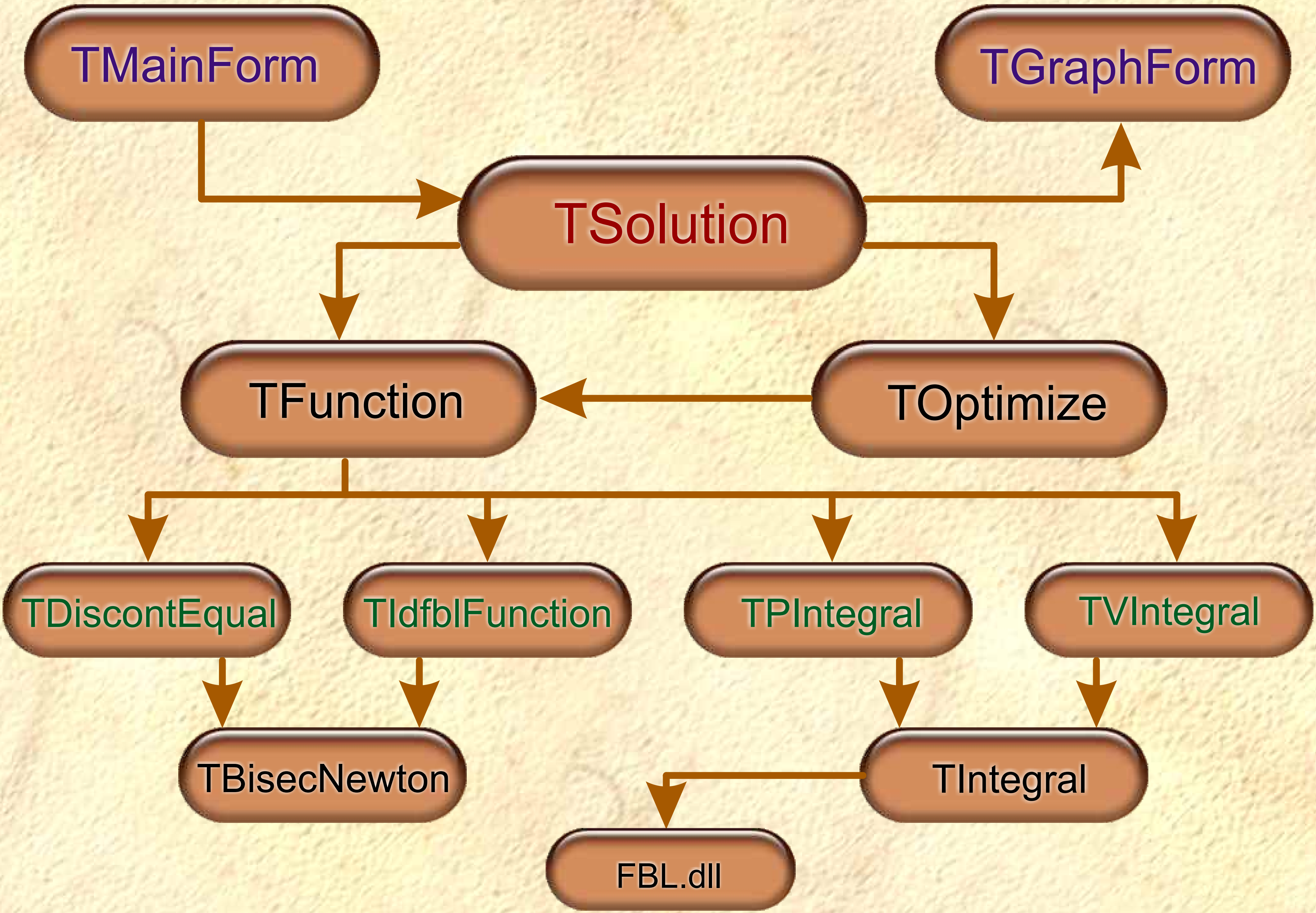


nonsmooth

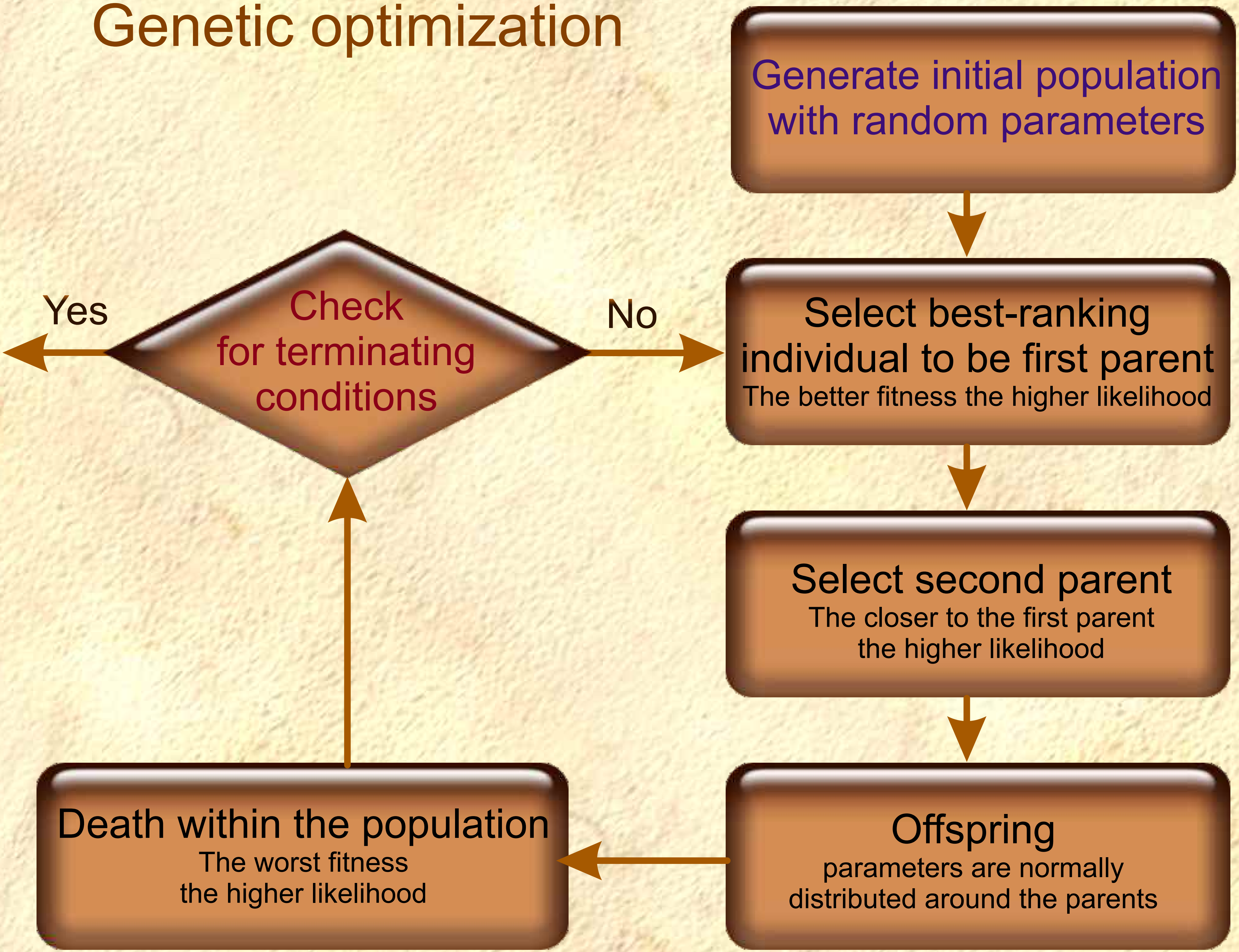


ravine surface

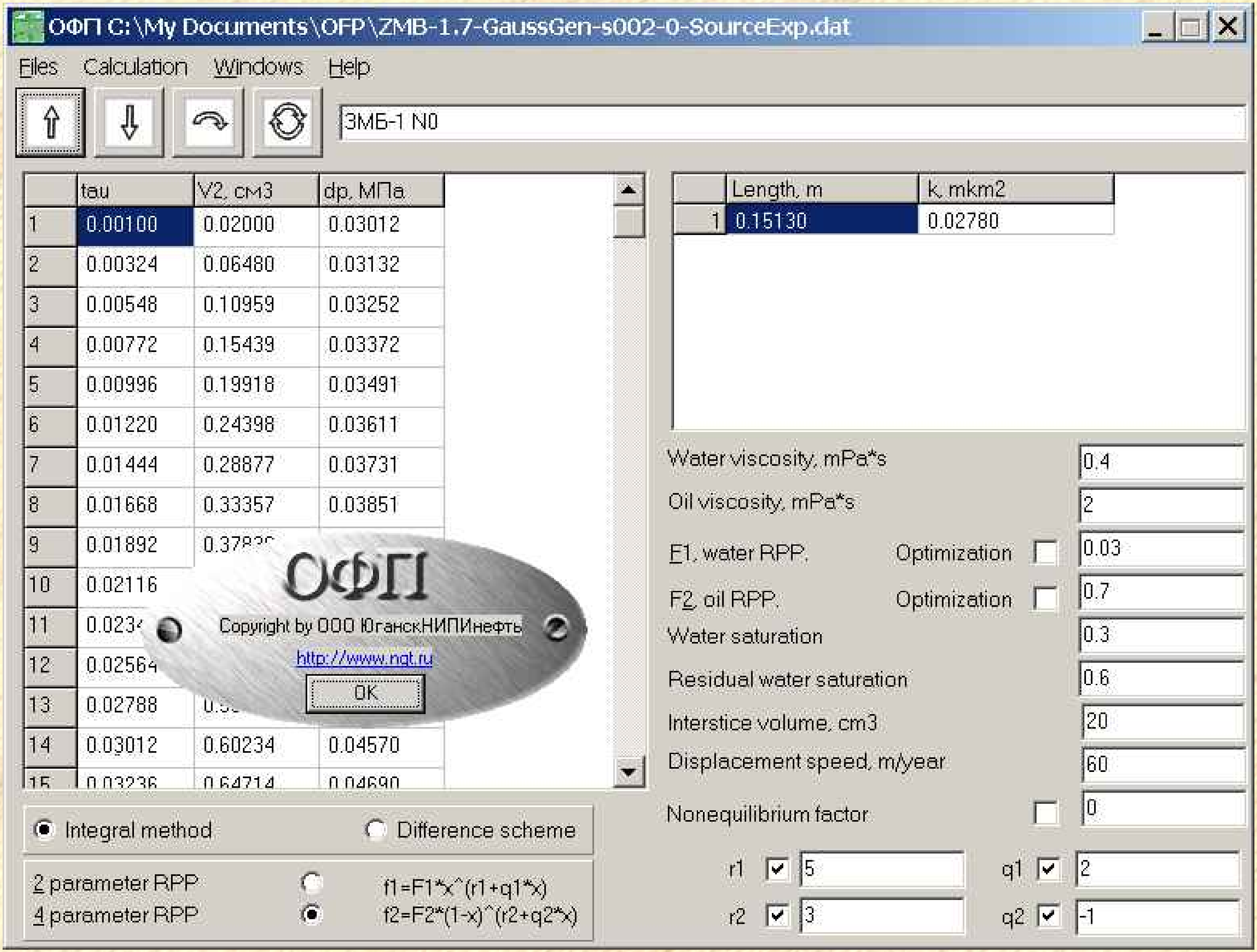
Program structure



Genetic optimization



ОФП interface



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