$$\vec{v} = \frac{\vec{Q}}{\phi}$$

$$\frac{\partial(\rho\phi)}{\partial t} + \nabla\cdot(\rho\vec{Q}) = 0$$

$$\underbrace{\phi\frac{\partial\rho}{\partial t} + \rho\frac{\partial\phi}{\partial t}} + \underbrace{\nabla\rho\cdot\vec{Q}} + \rho\nabla\cdot\vec{Q} = 0$$

$$\rho = \rho(p(\vec{x})), \quad \phi = \phi(p(\vec{x}))$$

$$\left[\phi\rho\left[\underbrace{\frac{1}{\phi}\frac{\partial\phi}{\partial p}}_{c_R}\frac{\partial p}{\partial t} + \underbrace{\frac{1}{\rho}\frac{\partial\rho}{\partial p}}_{c}\frac{\partial p}{\partial t}\right] + \frac{\partial\rho}{\partial p}\nabla p\cdot\vec{Q} + \rho\nabla\cdot\vec{Q} = 0\right]\frac{1}{\rho}$$

$$\phi\,[\underbrace{c_R + c}_{c_t}]\frac{\partial p}{\partial t} + \underbrace{\frac{1}{\rho}\frac{\partial\rho}{\partial p}}_{c}\nabla p\cdot\vec{Q} + \nabla\cdot\vec{Q} = 0$$

$$\vec{Q} = -\frac{\bar{k}}{\mu}\left(\nabla p - \cancelto{0}{\rho \vec{g}}\right)$$ homo, iso, no gravity

$$\phi c_t \frac{\partial p}{\partial t} - c\, \nabla p \cdot \left(\frac{k}{\mu} \nabla p\right) - \nabla \cdot \left(\frac{k}{\mu} \nabla p\right) = 0$$

$$\frac{\mu \phi c_t}{k} \frac{\partial p}{\partial t} = \nabla \cdot (\nabla p) + c\left(\cancelto{0}{\nabla p \cdot \nabla p}\right)$$ small & constant compressibility

$$\boxed{\frac{\partial p}{\partial t} = \frac{1}{\alpha} \nabla \cdot (\nabla p)} \longleftarrow$$ Heat equation

"Pressure diffusivity eqn"

$$\alpha = \frac{\mu \phi c_t}{k}$$