Geophysical Research Abstracts
Vol. 12, EGU2010-4017, 2010
EGU General Assembly 2010


# Resurgence flows in porous media

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Porous media are generally described by the Darcy equation when the length scales are sufficiently large with respect to the pore scale. This approach is also applicable when the media are heterogeneous, i.e., when permeability varies with space which is the most common case. In addition, real media are very often fractured; for a long time, this complex physical problem has been schematized by the double porosity model devised by Barenblatt.

More recently, these fractured media have been addressed with a detailed description of the fractures and of their hydrodynamic interaction with the surrounding porous medium. This approach will be briefly summarized and the main recent progress surveyed (2).

There is another situation which occurs frequently in underground studies. One well is connected to a distant well while it is not connected to closer wells. Such a situation can only be understood if there is a direct link between the two connected wells and if this link has little if any hydrodynamic interaction with the porous medium that it crosses. This link can be a fracture or more likely a set of fractures.

This phenomenon is called resurgence because of the obvious analogy with rivers which suddenly disappear underground and go out at the ground surface again. Similar ideas have already been developed in other fields. In Physics, random networks limited to nearest neighbors have been recently extended to small world models where distant vertices can be related directly by a link. The electrical testing of porous media by electrical probes located at the walls (electrical tomography) has been used frequently in Geophysics since it is a non-invasive technique; this classical technique corresponds exactly to the situation addressed here from a different perspective.

Media with resurgences consist of a double structure (3). The first one which is continuous is described by Darcy law as usual. The second one models the resurgences by capillaries with impermeable walls which relate distant points of the continuous medium. These two structures have already been studied separately in previous works (see (1) and the literature therein). Networks were addressed by graph theory and an extensive literature has been devoted to studies of porous media on the Darcy scale.

For sake of simplicity, a simple physical presentation and elementary solutions are first given for one dimensional structures which display unexpected features such as an apparent back flow which goes against the main pressure gradient.

Then, a general formulation is proposed which involves some non local aspects. When the sizes of the connection zones between the network and the continuous medium are assumed to be small with respect to any linear size in the continuous medium, analytical solutions are obtained in two or three dimensions for spatially periodic structures which are adequate to model spatially homogenous media. The equivalent permeability of the medium is determined.

Some elementary examples are worked out in two and three dimensions. Paradoxical flow patterns are obtained with back flow even with local resurgences (3).

Unsteady problems are presently studied.

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