Mixing oil and water: Reinforcing groundwater concepts through comparisons with petroleum migration

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Synopsis: This is a guided brainstorming exercise for discovering similarities and differences between groundwater flow and oil migration. It provides an opportunity for students to make connections between hydrogeology and petroleum geology applications and to consider controls on single and multiphase flow fluid behavior in porous media. This activity can be used as part of a lecture or as an introductory activity during a lab. It requires active student participation and can therefore be used to breakup the pace of a lecture. The activity also provides the opportunity for professors to learn from their students.

Intended audience: The exercise is appropriate for upper division undergraduate courses in hydrogeology, petroleum geology, or economic geology. It is also applicable to upper division undergraduate or graduate level courses in single and multiphase subsurface flow and transport.

Prior to commencing this exercise, students should have mastered:

- concepts of porosity and permeability
- Darcy's law

Students should also have been exposed to concepts of:

- confined and unconfined aquifers
- fluid saturation
- water table or oil water contacts
- wetting and nonwetting fluids

Goals:
Students will explore the concepts of:

- driving forces for fluid flow
- single and multiphase flow
- relative permeability.

In addition, students will:

- acquire knowledge about applications outside groundwater hydrology
- apply groundwater concepts and information to these situations
- develop a better understanding of groundwater flow through synthesis of oil reservoir and freshwater aquifer behavior.

Description: In this exercise, students use their intuition to enumerate similarities and differences between groundwater flow and oil migration. The activity is divided into two parts: (1) brainstorming of ideas, and (2) an expanded discussion of selected topics.

The instructor begins by briefly reviewing the Rules of Brainstorming and then soliciting answers to a question such as: “How is the flow of groundwater in an aquifer similar to or different from the movement of oil in a petroleum reservoir?” or “How are groundwater aquifers and oil reservoirs similar or different?” (A bottle of oil-and-vinegar based salad dressing is useful for generating ideas and discussion.)

The instructor records the similarities and differences suggested by students in two lists. After a sufficient quantity of responses has been gathered, the instructor chooses certain ideas for closer examination and discussion. (The instructor may decide on target topics in advance, or may choose to ‘go with the flow’ to explore interesting ideas that emerge from the students.)
Note: It is useful to challenge students by repeatedly asking “Why” questions such as “Why does a petroleum reservoir behave that way?” or “Why should we expect oil to have a higher relative permeability than water at comparable S_o and S_w saturations?”

Assessment: Evaluation of student learning can be accomplished using true/false or short answer questions on subsequent quizzes or exams. Example questions:

1. State two ways in which an oil reservoir is similar to a *confined* aquifer:
   - upward movement of fluid out of the reservoir/aquifer is impeded by a confining layer
   - fluid pressures contribute to head values that exceed the elevation of the top of the reservoir/aquifer

2. State two ways in which an oil reservoir is similar to an *unconfined* aquifer:
   - there is a free fluid surface at the top/base of the aquifer/reservoir
   - transitional saturations occur above the capillary fringe and oil-water contact.

3. The relative permeability of oil and water is generally less than 1.0 when oil and water share the interconnected pore spaces in a rock. (true)

4. Density-driven fluid movement is generally downward in aquifers and upward in petroleum reservoirs. (true)

References:

Craft, B.C. and M. Hawkins, 1991, Applied Reservoir Engineering, 2nd ed., revised by R.E. Terry, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 431 pp.

Dickey, P.A., 1979, Petroleum Development Geology, PPC Books, Tulsa, Oklahoma, 398 pp.

Selley, R.C., 1998, Elements of Petroleum Geology, Academic Press, San Diego, California, 470 pp.

Online glossaries of oil reservoir terminology:

http://www.glossary.oilfield.slb.com

http://www.spwla.org/library_info/glossary/