GC Possible Nanotechnology Applications in Petroleum Reservoirs*

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Search and Discovery Article #40396 (2009)
Posted March 20, 2009

*Adapted from the Geophysical Corner column, prepared by the author, in AAPG Explorer, February, 2009, and entitled “Thinking Nano Is a Big Thing”. Editor of Geophysical Corner is Bob A. Hardage. Managing Editor of AAPG Explorer is Vern Stefanic; Larry Nation is Communications Director.

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General Statement

Let’s think small. Real small – because an exciting science referred to as nanotechnology is being introduced into reservoir characterization and monitoring. The sizes of devices and sensors that can now be fabricated to react in measurable ways when they contact a specific fluid, chemical or biological agent have been reduced so that they can be injected into some hydrocarbon reservoirs and become part of the fluid flow through the reservoir system. The term “nano” indicates the minute size of everything related to this technology. Common terminology appearing in descriptions of this new reservoir-monitoring science includes nanodevices, nanosensors and nanorobots.

Nanodevices

Physical sizes of nanodevices are shown in Figure 1. The sensors range in size from that of a microelectromechanical-system (MEMS) device (as large as 100 micrometers [µm]) down to a “buckyball” (1 nanometer [nm] in diameter) – a range of five orders of magnitude. A buckyball is a spherical cage of carbon atoms, commonly 60 atoms ($C60$) but sometimes more, capable of encasing a molecule or ion that can be designed to react in a predesigned way whenever it contacts a target molecule.

A buckytube, or nanotube (Figure 1), is an elongated cylinder of carbon atoms having a diameter a bit more than one nm and a length ranging from one µm to several millimeters. A nanotube also can contain process-activated molecules. Similar to a buckyball’s behavior, the reaction of a nanotube offers a host of possibilities that may provide diagnostic information about reservoir flow and connectivity, including:

- Convert to a filament with high electrical conductivity.
- Change color.
- Start a catalytic action.
- Become chemically inactive.
- Become heat resistant.

The target molecule that initiates the desired reaction can, in theory, be tailored to be a wide range of molecules found in, or associated with, producing hydrocarbon systems. Nanodevices, perhaps, can be made that initiate their predesigned action after set periods of calendar time to measure how far they have progressed through a reservoir – and to identify in which XYZ coordinates they reside after that time period.

Possible Applications

To put the possibility of injecting nanodevices into reservoirs into perspective, a comparison between reservoir pore sizes and diameters of nanodevices is helpful.
One such comparison is illustrated in Figure 2 to show that for some reservoirs pore space is adequate for some nanodevices to move through the reservoir as components of natural reservoir-fluid flow. Some reservoirs will not have pore sizes large enough to allow nanodevices to disperse through them efficiently, contrary to the scenario shown in Figure 3.

Because nanotubes can be designed to become efficient electrical conductors, electromagnetic (EM) measurements may be the branch of geophysics that first develops applications of nanotechnology in reservoir characterization. A possible application is illustrated in Figure 3. In this hypothetical case, nanodevices are injected into a reservoir, and at predesigned time delays (arbitrarily set at 1, 2, 3, 4 and 5 arbitrary calendar-time units in this example), the positions of the injected conductive nanodevices are measured by an appropriate crosswell EM or surface-based EM procedure. The objective is to determine, in three-dimensional space, the internal flow paths that exist within a reservoir system as that reservoir is being produced. If nanodevices can be designed to become miniature acoustic pingers, as some envision and hope, the progress of the nanodevices through a reservoir can perhaps be measured by crosswell seismic methods.

Conclusion

All of these possible applications, and others, are being discussed and proposed by scientists who develop nanodevices and by geoscientists and engineers who wish to use the devices in reservoir characterization. Reservoir engineers and geoscientists describe what they want to measure, and nanotechnology scientists decide whether, and how, an appropriate nanodevice can be manufactured that will generate the required data.

It will be some years before nanoscience can be put into practice in reservoir characterization. The purpose of this article is to provide a brief, layperson description of the concepts so that people who are intrigued by the possibilities can monitor development of the technology. A group of oil companies has formed the Advanced Energy Consortium to support development of nanotechnology at the University of Texas at Austin and Rice University. This consortium has established a Web site at http://www.beg.utexas.edu/aec/index.htm.

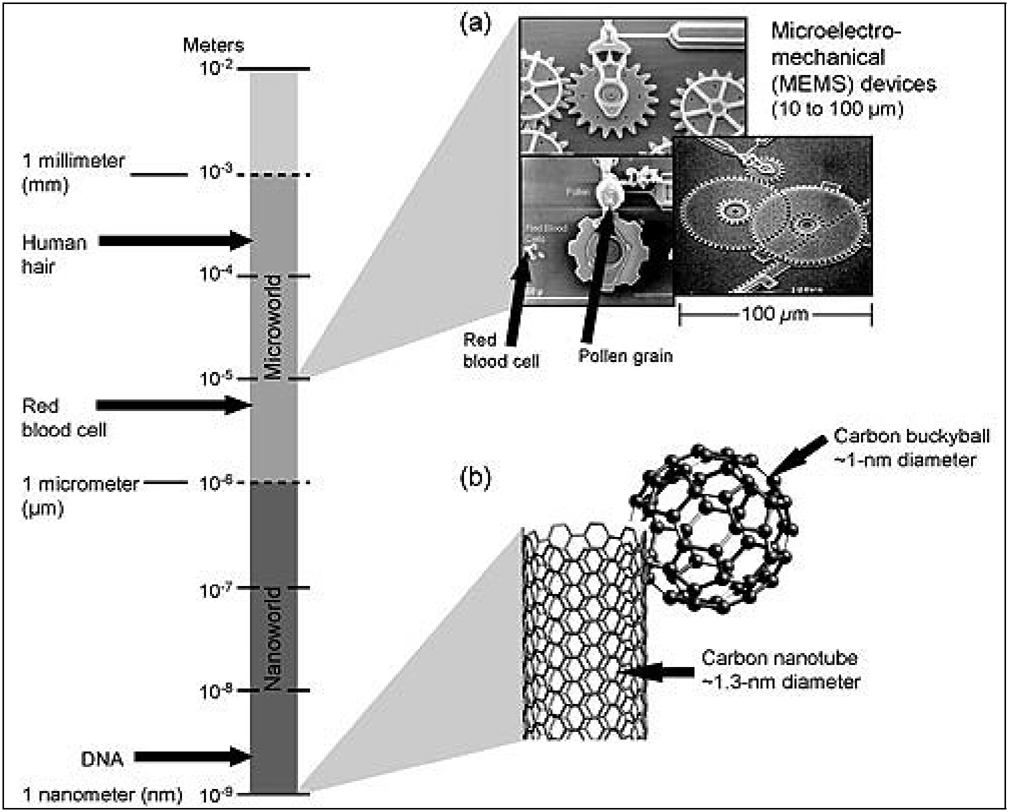
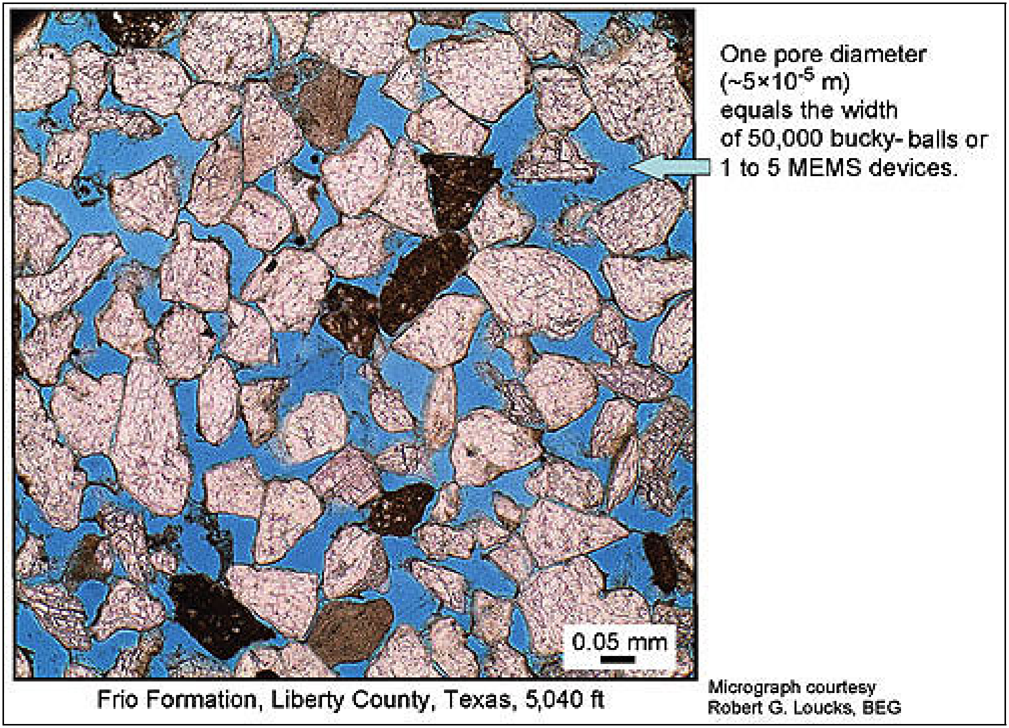


Figure 1. Logarithmic scale on left shows size range of selected natural objects (human hair, red blood cell, DNA molecule). Objects are compared with size range of manufactured nanodevices, extending from MEMS devices (top) to buckyballs (bottom).



One pore diameter
(~5×10^{-5} m)
equals the width
of 50,000 bucky- balls or
1 to 5 MEMS devices.

Frio Formation, Liberty County, Texas, 5,040 ft

Micrograph courtesy
Robert G. Loucks, BEG

Figure 2. Thin section photomicrograph of Frio reservoir comparing pore dimensions with sizes of nanodevices. Porosity of reservoir interval ranges between 20 and 30 percent.

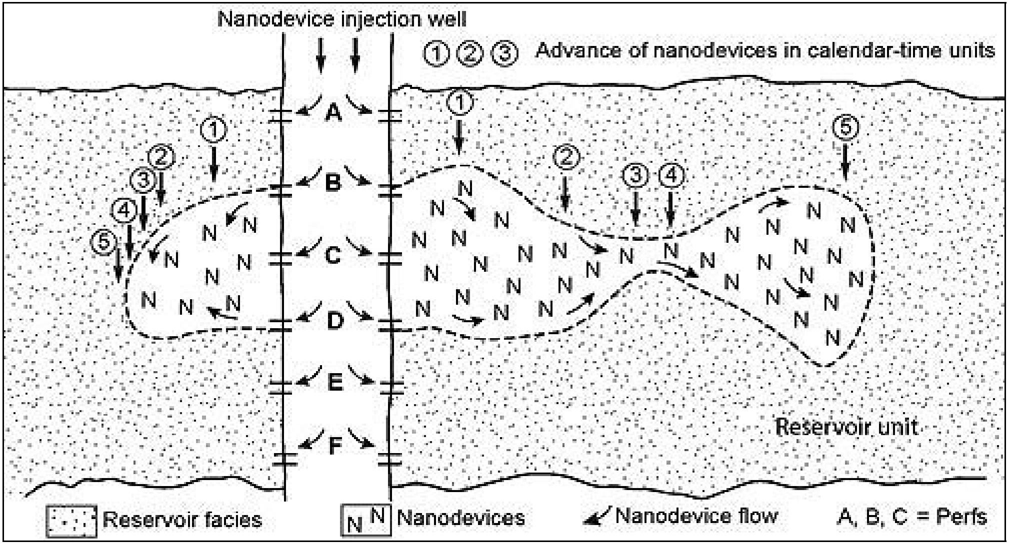


Figure 3. One concept for use of nanotechnology in reservoir characterization. Nanodevices (N) are injected in perfs A through F and move through a reservoir. At calendar-delay times of 1, 2, 3, 4 and 5 time intervals, spatial distribution of the nanodevices is measured by EM or seismic methods to determine their XYZ coordinates, allowing inferences to be made about fluid-flow paths, compartment boundaries and reservoir connectivity.