MIGRATION OF PETROLEUM THROUGH SANDS AND SHALES

CARL E. BLEIL and ROBERT A. HOWARD, University of Oklahoma, Norman

It has been known for some time that under certain circumstances water will displace petroleum from a shale into a more coarse sand. Some of the earliest work in this field was done by A. W. McCoy (1). Others have contributed to the investigation of replacement phenomena but almost all such experimentation has been of a qualitative nature. The findings reported here are some of the first quantitative evidences published.

To understand the processes involved, consider an interface between two different sized matrices when there is a distribution of sizes about an average for each matrix. A little reflection will show that not all pore sizes will be the same at the interface and in particular there will be a large pore A and a small pore B in some portion of the interface.

Now if fluid in the large pore is water, and fluid in the small pore is oil, the ratio of the surface tensions with respect to the solid (glass or quartz) is of the order of magnitude of 3 to 1, the water having the larger surface tension. The pressure exerted at the interface of the two fluids and the solid is proportional to $1/r$ where r is the radius of the capillary opening. Thus the pressure tending to move the water into the small pore at B is larger than at A. Neglecting other effects, the water will move into the small-particle matrix at B displacing the oil into the large-particle matrix at A and replacement will have begun. Further replacement will continue until all interfaces between the water and any contiguous oil body are the same size.

To study replacement, glass bottles approximately 2 x 2 x 5 inches were used as experimental cells. A typical cell was prepared as follows:

1. A matrix of coarse glass beads or sand was placed in the bottom of the cell.
2. Enough water was added just to saturate the matrix, precaution being taken to keep air bubbles to a minimum.
3. Dry ground paraffin or paraffin in the form of beads was added to fine glass beads or shale in a separate container, thoroughly mixed, and added to the experimental cell.
4. Water was added to saturate the entire cell, care being taken to keep out air and water pockets.
5. The cell was then placed in a constant temperature oven about 5°C above the melting point of the paraffin. The paraffin was then a liquid hydrocarbon within the small interstices of the fine matrix.

Experiment proved that replacement occured when as little as 0.1% of the total pore space available in the fine glass bead matrix was filled with paraffin. After 72 hours in the oven, samples of the coarse matrix were analyzed using solvent extraction with re-distilled, commercially pure carbon disulfide. The change in the index of refraction due to the dissolved paraffin was measured. All samples were dried to remove water before the paraffin was extracted.

A modification of this technique consisted of placing the fine matrix plus paraffin in the oven to melt the paraffin before adding the mixture to the experimental cell. Thus two otherwise identical experiments could be set up: one with oil-wet fines and the other with water-wet fines. It was found that no consistent differences occured.

Difficulties were encountered in obtaining uniform packing, assuring uniform distribution, and quantitative recovery of the paraffin from the various portions of the matrix. However, several special experiments were performed particularly to test the ramifications of the techniques employed, and to obtain satisfactory elimination of the difficulties.

It should be pointed out that for all the experiments so far described migration has occurred in opposition to the force of gravity. If the force of gravity aids rather than opposes the capillary forces as, say, in a tilted bed with the source shale lying below the sand, the oil may move directly into and up through the sand, or it may move up the shale and then into the sand. Photographs have been obtained of a model in which the latter effect was observed to take place. If the source bed overlies the shale a similar effect may appear with the oil moving directly into the sand or moving up the shale into the sand at the top and back down through the sand. It is important to note that both gravitational and capillary forces contribute to the migration.

In conclusion, these data re-emphasize the importance which interfacial effects have in the problem of petroleum migration. It is difficult to see that interfacial phenomena can play anything but a major role in petroleum migration.

BIBLIOGRAPHY

1. McCoy, A. W. 1919. Notes on principles of oil accumulation. J .Geol. *27*: 252-262.