A Retrospective on Source Rocks as Reservoir Rocks*

Keith Kvenvolden[1]

Search and Discovery Article #70295 (2017)**
Posted October 9, 2017

*Adapted from article, by the same author with the same title, in *THE AAPG EXPLORER*, Historical Highlights, June, 2017, p. 20-21.

[1]Palo Alto, CA (kvenvolden@earthlink.net)

Introduction

In the Historical Highlights in the March 2017 EXPLORER, AAPG Past President Marlan Downey lamented that, as a petroleum geochemist with Shell Oil's Bellaire Research Laboratory in Houston in the 1960s, he had not fully appreciated the idea that source rocks could serve as reservoir rocks for oil and natural gas. He was not alone.

While Downey was at Shell, I was concurrently at Mobil's Field Research Laboratory in Duncanville, Texas (Figure 1), working with Ellis Bray, Ernest Evans, Jim Cooper (Figure 2), and finally Rodney Squires. During my five years at the Laboratory, much of my research dealt with aspects of source rocks. I knew that the amount of extractable organic matter (EOM) in source rocks could be very high, but recovery required organic solvents and a pulverized sample. I did not understand that the magnitude of the EOM could be significant. I was more interested in the molecular distribution of the normal paraffin hydrocarbons in the extracts and the relationship between these hydrocarbon distributions and those of the accompanying normal fatty acids. These interests distracted me from recognizing that source rocks could be reservoir rocks if one could just figure out how to create permeability in the in-place source rock. Today, of course, that is known as hydraulic fracturing.

One reason petroleum geochemists at that time missed this idea is that we paid too much attention to the available petroleum geology textbooks. Source rocks and reservoir rocks were usually treated in separate chapters; ergo, source rocks and reservoir rocks must be different!

Geochemical Prospecting

Although I missed the significance of source rocks as reservoir rocks, I did have an opportunity to consider petroleum geochemical prospecting. I was asked to review and evaluate the results of Mobil's worldwide efforts to find petroleum deposits by this methodology. My report to management did not win me many points. I wrote that the company's efforts were unfortunately a waste of time and money: there was scant evidence that geochemical prospecting had any impact on their finding petroleum. I pointed out that applying geochemical prospecting without recognizing the geological context of a prospect was a recipe for almost certain failure. Management was not happy with these conclusions.

Because of my report, I was given the “opportunity” to design a soil-gas geochemical prospect in a forest in Arkansas. I laid out the sampling grid to take advantage of the geological context of the area, and I used a sampling probe to penetrate the soil to about two feet, to suck-up a gas sample. Colleagues analyzed each sample, using a gas analyzer, and they plotted the results on a map. The idea was that the soil gas would be combustible and be composed mainly of methane. Initially, I was quite surprised that some samples gave positive results, but then I noticed that the plotted results correlated with the location of pine trees in the forest. I further noticed that when the probe smelled of terpenes (organic compounds commonly released from pine trees), the measured result was positive. I was able to predict accurately the analytical result before the gas measurement was made. I finally convinced my colleagues that we were mapping pine trees and not a petroleum occurrence.

A telephone call back to the Mobil laboratory was met with disbelief, but we were told to come home and bring a pine tree root with us. I wrote-up my report, titled “The Pine Tree Prospect in Polk County, Arkansas.” Again, management was not happy, but the results were finally accepted.

Carbon Isotope Geochemistry

During my last year at Mobil, I was assigned the difficult task of writing-up some of the data that Rodney Squires had generated. Squires, the isotope geochemist at the laboratory, worked diligently to create a huge database of carbon isotopic compositions of crude oil samples from around the world.

However, there were two problems. First, he reported his data in absolute concentrations in parts per million of carbon (C^{13}) minus 10,000, instead of the conventional way of comparing the ratio of C^{13}/C^{12} of the sample to that of a standard. Second, although he would interpret his data for company reports, he refused to publish in the open literature. Mobil had an enlightened policy that encouraged employees to publish non-competitive information in the open literature because this process gave management an important tool for evaluating its employees. I was really uncomfortable having to write a technical paper for outside publication with Squires because I had not participated in any data generation and was not very familiar with the geochemical literature dealing with the carbon isotopic compositions of crude oils. Nevertheless, I was ordered to work with him and get a paper published. The task was not easy for him or me.

The paper we wrote (AAPG Bulletin, 1967, v. 51, p. 1293-1303) described the carbon isotopic compositions of 37 crude oils from the Ellenburger Group (Lower Ordovician) in the Permian basin of West Texas and eastern New Mexico. These isotopic values were compared with those obtained from 66 Permian basin crude oils ranging in age from Middle Ordovician (post-Ellenburger) through Lower Permian (Wolfcamp).

The map (Figure 3) shows well locations from which the crude oil samples were obtained. Crude oils from the Ellenburger were arranged into five groups, based on carbon isotopic composition, geographic position, and stratigraphic relationships. One group of Ellenburger crude oils had unusually light carbon isotopic compositions relative to isotopic values usually found in all other crude oils from around the world.

We concluded that the Ellenburger Group serves as a reservoir for oils of many geologic ages. Squires insisted we report the carbon isotopic compositions in his absolute units. I suggested that we publish using both his units and the equivalent conventional units. He refused and would not release the paper for publication.

Now at my wits' end, I talked to our mutual supervisor, John Zimmerman, who had directed us to work together, and I explained the situation. Zimmerman told me not to worry and to submit the paper for publication using both sets of units, and just ignore Squire's objections. A few days later, Squires called me and said that I could go ahead and publish the paper using both sets of units. Surprised, I asked why he had changed his mind. He responded that Zimmerman had told him that either he let me submit the paper for publication, or he would be fired. He ended our conversation with "They never explained it to me that way before!"

Systems Analysis

During the time I was trying to get the paper on the carbon isotopic compositions of crude oils in the Permian basin published, I was asked by management to give-up organic geochemistry and join a special group of three: a geologist, a mass spectroscopist, and me, to investigate systems analysis.

To sweeten the deal, I was moved from the office I shared with Jim Cooper, to a much larger, single, carpeted office in the headquarters building, symmetrically located in the opposite wing wherein the manager of the entire laboratory resided. The three of us would meet in the generous space of my office to try to figure out what exactly we were supposed to do.

We did come up with an interesting, but impractical idea. We suggested that subsurface mapping could be facilitated by the application of computer technology. We envisioned that well logs could be displayed on the screen and horizon tops could be picked with a light pen; the depth and position of each pick could be plotted on a map, and the various horizons could be contoured automatically, giving the interpreter useful structural subsurface maps. This idea was impractical for the time because computers were very slow and data had to be loaded by punch cards.

When we had submitted our report to management, I happened to see the manager, Nelson Stevens, who was responsible for my transfer from geochemistry and for the formation of our three-member team. I asked him what exactly he had in mind when he formed this team to investigate system analysis. He told me that he really didn't know, but that the term certainly had a "space age" ring to it!

Summary

In retrospect, my five years at Mobil Oil's Field Research Laboratory were quite rewarding in spite of the adventures described above. I was given an incredible foundation in organic geochemistry that I applied in my later research with NASA and the U.S. Geological Survey. I will always be indebted to Bray, Evans, Cooper, and our Mobil support staff for their guidance and mentorship. This story is dedicated to their memories.

References Cited

Kvenvolden, K.A., 1962, Normal paraffin hydrocarbons in sediments from San Francisco Bay, California: AAPG Bulletin, v. 46, p. 1643-1652.

Kvenvolden, K.A., and R.M. Squires, 1967, Carbon isotopic composition of crude oils from Ellenburger Group (Lower Ordovician), Permian basin, West Texas and Eastern New Mexico: AAPG Bulletin, v. 67, p. 1293-1303.

Author

Keith Kvenvolden (Figure 4) grew up in Cheyenne, Wyoming, and went to the Colorado School of Mines, graduating with a degree in Geophysical Engineering, and went to graduate school at Stanford University. He worked for about ten years with various affiliates of the Mobil Oil Corporation, including about five years, starting in 1961, at its Field Research Laboratory in Texas as a petroleum geochemist. In 1966, he left Mobil to join the NASA Apollo Program as an organic geochemist. Ten years later he moved to the USGS to pursue investigations of the organic geochemistry of continental-margin sediments, including studies of methane hydrate. A 65-year Member of AAPG, he published his first technical paper dealing with hydrocarbons in San Francisco Bay sediments in the AAPG Bulletin, 1962, v. 46, p. 1643-1652.

About Historical Highlights

A history-based series, Historical Highlights is an ongoing EXPLORER series that celebrates the "eureka" moments of petroleum geology, the rise of key concepts, the discoveries that made a difference, the perseverance and ingenuity of our colleagues – and/or their luck! – through stories that emphasize the anecdotes, the good yarns, and the human interest side of our E&P profession. If you have such a story – and who doesn't? – and you'd like to share it with your fellow AAPG Members, contact the editor.

Figure 1. Left: The Mobil Oil Corporation Field Research Laboratory headquarters building in Duncanville, on the south side of Dallas, Texas. Right: The office building for the geochemistry unit.

Figure 2. Co-workers of the author at Mobil Oil Corporation Field Research Laboratory. From left: Ellis Bray, Earnest Evans, and Jim Cooper.

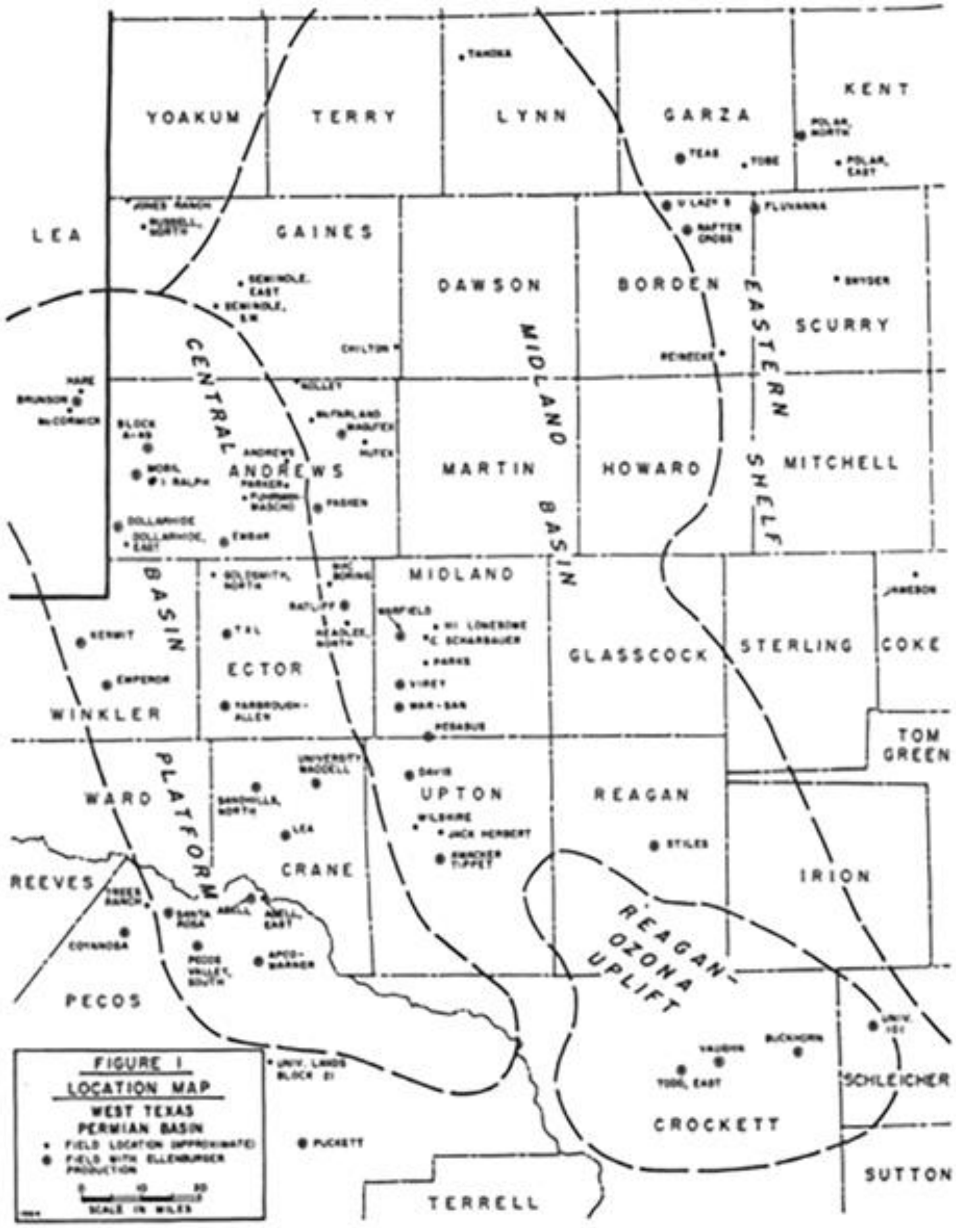

Figure 3. Location map of wells in the Permian basin of West Texas and eastern New Mexico from which crude oil samples were obtained for measurement of carbon isotopic compositions (smaller circles); larger circles—fields with Ellenburger production.

Figure 4. Keith Kvenvolden.