

ately to immense improvement in the economics for drilling and ultimately the establishment of the Society for Economic Paleontology and Mineralogy (SEPM).

World War II created new opportunities again for women to enter the geologic workforce and they did in droves. With the onset of electric logs and seismic, women could venture into exploration using the newest technology. But again, careers were discouraged after the war, both when women married and also because a new social order was developing...a powerful social dynamic of putting the “little ladies” back in the home “free of the burden of working”—the June Cleaver era. For the next thirty years it was a struggle for a woman to get an exploration job...and if they did, it always came bundled with menial tasks and inferior pay.

In the early 1970s, the EEOC threatened oil companies with denying them federal leases if they did not have a “diversity” plan for hiring women and other minorities. An immediate response resulted in the hiring of great numbers of women. Affirmative Action actually worked and had lasting effects. Within a very few years women thought they were only hired for their brains! And by then, they probably were. But, the world had long forgotten the smart and enduring women who were the *real pioneers*.

RANK WILDCAT TERRITORY - NORTH DAKOTA'S DISCOVERY PERIOD

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Post discovery North Dakota was anything, but an oil boom. Amerada first, the communities of Bismarck, Ray, Tioga, and Williston second, and the state's burgeoning petroleum industry third, had several complex issues to deal with once oil was discovered in commercial quantities. Amerada had discovered oil in rank wildcat territory. The communities surrounding the discovery well were initially incapable of providing support to the industry due to a lack of infrastructure. This reality was made worse by the fact that there was no immediate guarantee enough petroleum could be produced from this or additional wells for the market. More importantly there was no current market, i.e. refineries, for that petroleum where it would be produced. The complexities of the petroleum market and North Dakota's infrastructure would also contribute to the delay in development until such a time as production induced the necessary capital investment, not just for additional exploration, but for development of the industry including service companies, housing, and infrastructure. Despite the American Petroleum Institute's claim that North Dakota would be devel-

oped methodically by the industry these complex factors, addressed by industry, community, and state leaders determined the slow development of the Williston Basin; booming only when these issues had been satisfactorily resolved.

THE UNCONVENTIONAL REVOLUTION IN EXPLORATION GEOPHYSICS

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During the last 25 years, 3-D seismic imaging has revolutionized hydrocarbon exploration by delivering an accurate 3-dimensional picture of the subsurface (Fig.1). The image is capable of detecting fluids within the reservoir and has significantly reduced the risk of locating and developing hydrocarbon deposits.

In the late 1990s, deregulation of natural gas prices allowed long-recognized deposits of natural gas locked in tight rocks to be economic. It sparked factory drilling (repeatable high-density evenly spaced) wells and hydraulic fracturing that would help unlock the reservoirs. All that was needed was a geologist to determine depths and limits of the reservoir and engineers to drill and complete the wells. If 3-D seismic data was available, it might have been used to define both the limits of the field and drilling hazards. Generally, the cost and time required to process and interpret 3D Seismic was considered too high to affect the perceived geologic risk of the Factory approach.

Completion costs in unconventional reservoirs account for over 50% of the well costs. It is therefore critical to understand the geometry of how the rock is fracturing and determine optimum well spacing to balance the cost of development with the value of the gas or oil being produced. By extending AVO (Amplitude Versus Offset) to the pre-stack domain, it's possible to simultaneously invert for V_p (pressure-wave velocity), V_s (shear-wave velocity), and density. Armed with these three fundamental rock properties that dictate elastic and inelastic rock response, researchers were able to combine those properties to tie directly to how well a rock will respond to hydraulic fracturing, or which rocks contain a higher Total Organic Carbon (TOC), or other rock properties that control how a rock responds to seismic waves or hydraulic fracturing. Combining these results allows interpreters to map areas of higher productivity and identify bypassed reserves.

Currently hundreds of different seismic attributes that are generated from 3-D seismic data are used to identify the highest productive areas and how to develop them. Micro-seismic mapping has made completion more efficient and safe. While the geophysics involved in unconventional resource development may not be the first thought in the board room, their data has become an accepted early development tool of successful oil and gas companies.

THE EARLY EXPLORATION HISTORY OF THE PEARL RIVER MOUTH BASIN IN THE SOUTH CHINA SEA

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Pearl River Mouth Basin (PRMB) is located in the northern part of the South China Sea, south of Hong Kong and the Guangdong Province, China. It is a Cenozoic depositional basin. The oil search was initiated in the middle of 1970s by the Chinese. With preliminary geophysical surveys and one Jack-up drilling rig, the Ministry of Geology (MOG) had defined the basin geology and drilled 7 exploration wells, of which the Zhu 5 well obtained a commercial flow, symbolizing the oil discovery in the basin.

Due to lack of capital, technology, and offshore operational experience, China decided to open the basin to the foreign investors through a bidding process in early 1980s. This was a brand new approach, and in order to implement this strategy in February 1982, the Ministry of Petroleum Industry (MPI) set up a company, *China National Offshore Oil Corporation (CNOOC)* in charge of the foreign cooperation which represented the Chinese authority dealing with all the activities related to bidding and operation details.

On the first round of offshore bids, the PRMB had attracted 24 oil companies from 11 countries, which signed 13 lease blocks with *CNOOC* under the terms of that the oil company carried out all exploration costs to earn up to 49% of the development working interest in first 15 years of production. Unfortunately, many large prospects came out dry and only 5 small-size oil fields were found from 3 lease blocks. By the combination of drilling results and oil price collapse, the foreign investors started to walk away from the consequent bidding rounds. However, by 1990, the foreign oil companies had 7 oilfield discoveries and decided to develop the fields jointly with the Chinese partner. When these fields were on stream in the middle of 1990s, the PRMB oil production was greatly

boosted and the basin became the most important offshore oil province in China.

Looking back the exploration conducted in the PRMB, the foreign oil companies not only brought the investment and technology to China, but also taught the Chinese how to operate and manage offshore oil business. In China, the foreign cooperation is definitely on a fast track to catch up with the developed countries. The evolution of *CNOOC* as an oil company is a good example, and the early exploration in the PRMB tells the story.

CALIFORNIA AVIATION AND AEROSPACE PETROLEUM BEGINNINGS

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In the first dozen years of the twentieth century, gasoline used in autos, boats, and planes was similar. Fuel chemistry advanced competitively after 1910 when fliers in experimental contraptions gathered at America's first International Air Meet in Los Angeles. Investors then held races aimed at sharpening engine power and fuel range. Performance specifics discussed among hydrocarbon crafters such as M. J. Trumble propelled fellow designers to improve fuels. They tapped shale, secured more geology and altered chemical refining to jimmy the mechanics of high octane mixes. By 1924, Trumble patented a solid fuel near California's Olinda oilfield. He and partners anchored plans for Green River carbons. Royal Dutch geologists traveled West in the 1850's, and by 1910, they were dug in around Olinda's Carbon Canyon. Newhall teams exploited white petroleum in Elsmere Canyon. Aviation fuel (known as *av fuel*) geology rocked out West.

Progress in aviation fuels was driven by competing chemists finding different flashpoints and other features designed to boost performance. Today's av and jet fuels contain thousands of elements for atmospheric adaptation and engine needs. One team durably committed to av fuel and jet fuel since the beginning was Shell. Their earliest roots in California were planted with partners including Captain John Barneson and M. J. Trumble who capitalized *General Petroleum* in 1912. The guts of *GP's Trumble Refinery* in Vernon were moved to Torrance in 1927 as GP became a subsidiary of Standard's Socony, and then Mobil Socony; later Mobil Oil, and then Exxon Mobil. Major Jimmy Doolittle from the U.S. Army Air Corps headed the av fuels division at Shell in the 1930's. *GP's* Tor-