

eliminate non-productive time (NPT) due to these issues. Solids control equipment and waste management improvements were developed. The use of chemically thinned, fresh water muds was declining in popularity. The use of both organic and inorganic brines as drill-in fluids was being established for regular drilling.

2001 to today – Wellbore stability techniques and wellbore strengthening products and systems became the industry norm. A move toward automation has resulted in the development of new testing protocols and equipment. The development of products and systems, both water-based and non-aqueous, are being developed to solve current and future extremes in pressure and temperature. The movement to establish solids-free drilling fluids is ongoing.

ARCHIBALD GEIKIE AND THE ESTABLISHMENT OF THE SCOTTISH SHALE OIL INDUSTRY

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The Scottish geologist Archibald Geikie (1835-1924) played a fundamental, but largely unrecognized, role in the establishment of the Scottish oil shale industry by providing James ‘Paraffin’ Young with the critical information about the location, thickness and likely areal extent of the organic-rich shales during their field visit together in 1858. Young then used the information to establish where to buy leases to extract the shales for commercial oil production ahead of his competitors. Geikie acquired this critical knowledge as a result of his work preparing the first map of *The Geology in the Neighbourhood of Edinburgh* published in 1859 and the accompanying Memoir, published in 1861. In 1866, Young’s Paraffin Light and Mineral Oil Company Limited opened the Addiewell works, the largest oil works in the world at the time. By the late 1860s, there were no fewer than 120 works distilling oil in Scotland, mostly from the shales of the Lothians, to the southeast of Edinburgh. Eventually, more than 22 million gallons of crude oil a year was produced in the Midland Valley of Scotland in an industry that employed nearly 40,000 people. Although the Scottish Shale Oil Industry eventually closed in the 1960s, there is now a renewed interest in extracting oil and gas from British shales. This is, perhaps, the most important legacy of Archibald Geikie’s involvement in the Scottish shale oil industry.

FROM NUCLEAR TECHNOLOGY TO THE PETROLEUM INDUSTRY: THE STORY OF TERRATEK

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The story of how the Salt Lake City company *TerraTek* emerged from nuclear effects research starting in the 1960’s is a story of successfully adapting technology from one application to another application.

PIONEERING WOMEN IN PETROLEUM GEOLOGY—CELEBRATING 100 YEARS!

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If not recorded, vast annals of history are lost. Pioneering women in petroleum geology entered the field very shortly after men became valued and accepted in the oil exploration... and women were first employed in 1917—the year the American Association of Petroleum Geologists was founded! This was a result of men having been conscripted for World War I. And, notably, this was before women’s suffrage.

Women became subsurface geologists at a time when the tools of the trade were rocks (no electric logs, no seismic, no paleontology) and surface surveying equipment. Interestingly, some of the greatest men in the profession were responsible for hiring, training, promoting, and keeping women in this career—names like Sidney Powers, Everette DeGolyer, George Matson, Alex McCoy, Wallace Pratt, and E. T. Dumble. Unfortunately, women were required to quit, usually, when they married and mostly only single women survived in the industry after WW I. Some as entrepreneurs, some as well site geologists, and a few, astoundingly, in corporate management. The rare company, Amerada Petroleum, welcomed married women to continue working.

Soon after World War I women were responsible for the biggest technological advancement in subsurface petroleum exploration...working out stratigraphy with micropaleontology...which, without well logs and seismic, became absolutely essential within all oil companies. This led almost immedi-

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.