**ABSTRACT**

# Fracture Reservoir Exploration

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Fracture reservoirs have been overlooked because they are virtually invisible to seismic. Recent advances in the understanding of strike-slip fault damage zones and the use of a non-seismic technologies that can map fracture reservoirs on the surface have revealed fracture reservoirs are an exploration play with enormous high-production potential. Exploration for conventual reservoirs is at a mature stage in the US because seismic technology has been successfully used to find most of them, but exploration for fracture reservoirs is at the "frontier" stage. Furthermore, oil in horizontal resource plays has a discovery cost in the $25-65+ per BO range. Fracture reservoir oil will likely have a discovery cost of $1-3 per BO. The history of the fracture reservoir play is a fascinating story with important and surprising implications for current oil & gas exploration.

The story begins with the sharp increase in oil prices in 1980 triggered by the OPEC oil embargo. This caused the Carter Administration and Congress to recoup the increase in oil producer's revenue through the Crude Oil Windfall Profit Tax Act of 1980. During this period oil companies could either pay taxes on their profits or use some percentage of their profits for tax-free exploration research. Some of this research was focused on investigating new non-seismic technologies that could potentially be utilized for delineation of reservoirs where seismic methods did not work. The primary companies engaged in this research were Exxon, Marathon, Texaco, Sun, and Conoco. They worked independently and did not share their finding with each other. Arnie Ostrander's small research team were the only geoscientists to see the combined results of these extensive efforts. Results of testing a new non-seismic resistivity technology was unexpected: 30 undrilled prospects were drilled: this technology predicted 27 would be dry holes (and they were), and 3 would discover oil (and they did). The technology was 100% correct in its predictions. This is stunning, considering the average success rate of US wildcat wells predicted with traditional seismic data at that time was only 15%. Arnie Ostrander is the only active member of that non-seismic research team that was operational in the late 1980's and early 1990's.

In 1998 Arnie Ostrander met oil- & gas-finder Norm Foster, who was the former president of AAPG and developer of the overlooked concept of fracture reservoirs. Norm defined a **fracture reservoir** as "*a reservoir in which most of the permeability and some of the porosity is provide by open fractures*" and a **fracture trap** as "*a trap in which lateral boundaries of the trap are provided by change from fracture reservoir to unfractured or less fractured rock".* Since most fracture reservoirs are developed along strike-slip faults and have little to no vertical relief, they are effectively invisible to seismic. When Norm concluded, after a rigorous test of the technologies' predictive power, that the resistivity technology detected and mapped fracture reservoirs, he formed an exploration company with Arnie. They immediately begin applying the resistivity technology to exploration for fracture reservoirs with remarkable success, but sadly Norm became ill and passed away.

In 2022, Arnie contacted Monte Swan after reading his abstract linking Niobrara high-production 'sweet spots' to basement strike-slip faults. This led to the recognition of the concept of 'fault damage zones' which gives needed insight into the enigmatic nature of fracture reservoirs. Fault damage zones were generally not described or classified until 2002 when Kim, et.al. proposed a classification dividing fault damage zones along strike-slip faults into three types, i.e., 'tip, linking and wall' damage zones. Monte and Arnie added 'intersections'

as a fourth type. The damage zones explain the geometry of Norm's fracture reservoirs and how such highly-fractured and productive reservoirs develop along strike-slip faults. Being virtually invisible to seismic, fracture reservoirs have been discovered for years by chance, e.g., the Albion Scipio 125 million barrel fracture reservoir oil field in Michigan was discovered by a psychic, and out of 550 wells drilled only 150 are producers. The key to discovering fracture reservoirs is the integrations of non-seismic exploration technologies capable of detecting and mapping microseeps rising vertically above these reservoirs. The way the resistivity technology detects and maps fracture reservoirs at depth from the surface is by measuring changes in resistivity caused by microseepage of gases rising vertically off pressurized fracture reservoirs. This gives explorationists the ability to identify and outline the surface expression of microseep columns, which lead vertically down to an oil or gas fracture reservoirs.

Microseepage at the surface is characterized by anomalously-reduced Eh/pH which alters mineralogy and chemistry in contrast to normal Earth's surface of 'background' oxidized-Eh/pH soil, sediment and rock. Many explorationists remain skeptical about the benefits of microseepage methods for detecting hydrocarbons at the surface and for good reasons. The signal to noise ratio of microbial and hydrocarbon gas due to the heterogeneity of the seep microfractures often requires more samples than is economically reasonable for recon exploration. This is true even though these technologies are excellent at detecting and mapping the seeps and are proven to increase discovery rates > 80%. Resistivity technology solves these problems by measuring a much larger spatial sample area than an individual soil sample, thereby significantly improving the signal-to-noise ratio, resulting in this tool being an inexpensive recon tool as-well-as giving results in real time. After a fracture reservoir has been detected and mapped by resistivity, microbial and hydrocarbon gas surveys are recommended to confirm the reservoir is charged. This integrative exploration approach has shown that fracture reservoirs as exploration targets open up thousands of high-production vertical and horizontal plays in both mature and frontier basins.

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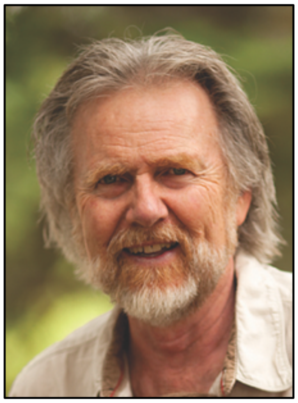

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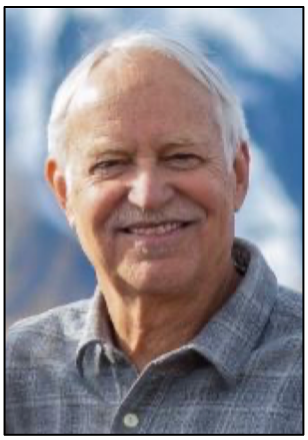
Monte Swan is co-founder of the MagmaChem Research Institute, funded by 100 mineral and petroleum companies and the USGS, currenting focusing on lithium brine and hydrogen research and exploration. Monte has been an adjunct professor of geology, given more than 80 short courses and seminars, and written 100 publications, abstracts, and books. He has been a member and presented papers and short courses to numerous professional geologic associations. Monte has also been the Science Advisor for Enercat Technology for 9 years investigating the science behind the Enercat Tool and focusing on how it works.



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Arnie Ostrander is a non-seismic oil & gas exploration consultant and researcher. His research with Exxon, Marathon, Texaco, and other major oil companies demonstrated to him the potential of using the non-seismic resistivity technologi**es** for oil exploration in plays where seismic data does not work. Arnie's focus has been the utilization of these methodologies for delineation of high-volume, high-profit, and underdeveloped fracture reservoirs. His current focus is prospect generation of oil field prospects where the average vertical well is greater than 500,000 BO.