The Wildest Plays on the Planet

Jon Noad
Husky Energy

Summary

The vast majority of the world's hydrocarbons have historically been discovered in what are termed conventional settings. These are often structural closures into which oil or gas has migrated, becoming trapped in layers of porous, reservoir sandstone or limestone beneath an impervious cap rock. Stratigraphic traps in which similar reservoirs are encased in shales make up a smaller proportion of successful hydrocarbon plays, and in recent years we have seen the rise of a variety of unconventional plays. But beyond these accumulations lies a subset of truly "unconventional", simply wacky plays, where the geologist needs an open mind to appreciate the "wildest plays on the planet".

This paper details some wild plays ranging from those hosted in granitic, volcanic or metamorphic basement, to those contained within astroblemes. Other unusual reservoirs include diatomites, diapirs and glacial deposits. Unexpected traps such as caves, synclines and the craters mentioned above are complimented by seals that include tills, tar mats and lava flows. There are also a variety of commercially viable, non-hydrocarbon gases: helium, nitrogen and carbon dioxide to name but three, all of which can be produced directly from the subsurface. By examining these plays it is hoped that the explorers for hydrocarbons may gain new insights into ways to think outside of the box.

Introduction

In reviewing plays around the world, it became clear how important it is for every exploration geologist to keep an open mind. Most of the plays above would probably have management laughing you out of the room, yet they have been responsible for producing hundreds of millions of barrels. While the topic may seem relatively light, the examination of these plays holds important lessons even when looking at the most mundane oil and gas fields. Never forget that there is never a definitive answer in geology, and that many breakthroughs have been attributable to lateral thinking, often with a dash of serendipity thrown in.

Method

The author spent years assiduously reading a variety of trade journals and magazines to build up a portfolio of unusual plays across the globe. Conversations with peers, as well as questions posted on geological fora, underpinned this effort. This paper has provided the opportunity to pull many of these plays together, and to consider some of the overriding lessons that can be learned from examining them.

Examples

Some amazing hydrocarbon plays occur in highly unusual geological settings. These can be subdivided as follows:

Fractured basement:

More than 30 countries have fields that produce from igneous, volcanic or metamorphosed basement. Incredible to imagine oil and gas being produced from granite, yet the Suban Field in Indonesia holds more than 8 Tcf of gas in fractured granites, while fields in Thailand and Libya also have extensive production from granitic basement. Production may exceed 20,000 bbl/d from extensive fracture networks. Typically these reservoirs are more difficult to evaluate than conventional reservoirs, and are often discovered by chance rather than by design. However in Russia and Thailand drilling into crystalline basements has been carried out intentionally. Generally a high proportion of deep seated fractures are subvertical, so horizontal wells may be key to unlocking these resources.

Astroblemes or meteor craters:

Another play which has received significant attention over the past few years is hydrocarbons associated with meteor craters. The largest such structure is Chicxulub, the possible smoking gun from a dinosaur perspective. The shattered carbonate breccia associated with the impact on the K-T boundary is complimented by the sealing ejecta layer, which enabled the aging supergiant Cantarell Field of Mexico to produce more than 2.1 Million barrels per day at peak production. Following the impact, collapse of the carbonate platform deposited a series of coarse breccias which were overlain by finer breccias from the consequent tsunamis.

A further nine astroblemes are known to be producing in North America alone. One of these, the Avak Crater, is located in Barrow in Alaska, and was drilled by the army to fuel the military base there. The concussion that made the crater created folds in surrounding rocks that trapped natural gas beneath impermeable cap rocks. The target rocks are Ordovician and Silurian argillites, which are strongly deformed. Stratigraphy above the crater consists of Jurassic and Cretaceous marine sandstones and shales, with an unconformity separating these from Pliocene gravels. Features of the crater have been defined by gravity data.

Another such feature is the Ames Crater, which was discovered in the Sooner Trend in Oklahoma in 1991, based on some exceptionally productive wells. When examined, cuttings included brecciated granite with good shows, as well as shattered quartz and feldspar with cleavage faces. The crater is more than 10 km across, and is believed to have been caused by a meteorite impact. Following this impact, the crater filled with fine sediments, ultimately producing a thick source rock interval and seal.

Other examples around the world include the Oblon astrobleme in central Ukraine, which is currently being investigated by researchers from the Ivanko-Frankivsk University of Oil and Gas. This is one of three potential astrobleme producers in Ukraine. The Silverpit Crater is located in the North Sea at the top of the Cretaceous Chalk interval. The Viewfield Field in Saskatchewan is considered to represent an impact crater, as is Tookoonooka in Queensland, Australia.

Other unusual reservoirs and traps:

Another unusual geological feature hosting hydrocarbons includes large caves in the Cupello Formation of southern Italy. Extensive karstification of platform carbonates in the late Cretaceous left sinkholes infilled with rubble along with extensive cave systems, later filled with hydrocarbons. Heavy crude oil is produced from fields such as the Rospo Mare Field, which has producible reserves of around 100 Million barrels. Horizontal wells are used to access the maximum quantity of subvertical conduits. Hydrocarbons have also been produced from diatomites, from Precambrian tills in Oman (as well as being trapped beneath them in Lancashire), from volcanic tuffs in Georgia, and from mud diapirs in Southeast Asia, Trinidad and around Baku, in Kazakhstan.

In terms of unusual trap geometries, the Scapa Field is located in a syncline, with the reservoir sands pinching out up dip onto the Claymore tilt block to the northeast, and the same sands pinching out into tight conglomerates to the southwest. Two thinly bedded turbidites form the oil bearing zone within the Scapa Sandstone Member. The asphalt gilsonite of Utah is a desiccated oil filling vertical faults as hydrocarbon dykes, and is used to make photocopy black. Sandstone dykes can also host producible oil and gas. Volcanic traps include the Kudu Field in Namibia, which hosts gas in “frozen” sand dunes. These Cretaceous dunes were covered by Etendeka flood basalts related to the opening of the Atlantic, which have preserved the dune morphology.

There are also several reservoirs recognized as being trapped beneath tar mats. Biogenic tar mats form only at oil-water interfaces. Tars can form above an accumulation where upwardly migrating, asphaltic oil contacts ground water at relatively shallow depths. Such tars can become a seal, which traps migrating oil and also protects it from continuing biodegradation. Tar mats can also form below oil columns, along faults, or wherever hydrodynamic water flow continuously resupplies oxygen and nutrients to active bacteria in contact with crude oil. Examples have been found in Eastern Venezuela (the El Furrial Field), in the famous Ghawar Field, with an associated tilted oil-water contact, in Alaska and in California.

Reservoirs hosting other commercial molecules:

Some plays host less familiar yet also commercially producible molecules. Several structures in the west of Iran are charged with nitrogen, including the Kabir Kuh field (which is an enormous anticline at least 150 miles long). The well Kabir Kuh-1, drilled in the Lorestan Province, encountered high N2 in the Ordovician and Permian. Several theories have been put forward to explain their composition including an underlying thermal anomaly in the crust.

Meanwhile helium is a rare and costly element, and wells in Texas (home of the Federal Helium Reserve), Oklahoma and Kansas are the principal source worldwide, with up to 7.6% helium. However potential supplies have been discovered in South Africa, Canada and the Sahara. In the former, helium is commonly dissolved in groundwater, possibly charged by uranium rich Precambrian rocks, and can be produced along with the water from pervasive faults extending several kilometres below surface. Natural sources are still significantly less costly than production through the heating of monazite sands. Finally several carbon dioxide fields in Utah are used to create dry ice for ice cream manufacture.

Conclusions

The study of the extraordinary opens one's eyes to the possibilities lurking in the ordinary. Examining some wild plays has enabled the formulation of a series of exploration-related rules, and stresses the importance in keeping an open mind. Many fields, not simply the plays described above, required the geologist or geophysicist to look at the data in a new way, and to extrapolate extra information to build a new play concept. It is hoped that this paper will supplement that methodology.
The following exploration guidelines have been highlighted by this study:

- Your trapping mechanism may involve a stratigraphic element even in a structural setting.
- Any reservoir not filled with water has the potential to produce economically, whether it be oil, gas or other molecules entirely.
- As we are learning form the rise of unconventional plays, ANY rock can act as a reservoir, even those that would normally be termed basement, seal or waste rock.
- The role of serendipity in discovering "wild" plays should not be underestimated.
- Keep drilling: there may be more potential resources buried deeper.
- Talk to your colleagues and peers, you never know what you might learn.

Acknowledgements

I would like to thank Drs. Steve Molyneux and Andy Willis for many stimulating conversations on some of the more ostensibly ridiculous plays around the world. These discussions were often enhanced by the consumption of suitable beverages, with play ideas typically scribbled on the nearest beer mat. The makers of these drinks and beer mats are also owed a debt of gratitude by generations of geologists.

References

BaselineDGSI, Geochemical Case Studies.

Batchelor et al, 2002. Hydrocarbon production from fractured basement formations. Unpublished report compiled by GeoScience Limited.

Cannon, J., 2002. Hydrocarbon Potential of Buried Impact Craters. AAPG Houston.

Carpentier of IFP, 2002. abstract from AAPG Meeting, Houston.

Duey, R. 2011. Search For Hydrocarbons Could Turn To Craters. Hart Energy Journal.

Hildebrand et al, 1991. The Chicxulub Crater. Geology.

Mengual,R. et al, 2002. Abstract from AAPG 2002.

Rajmon, D. and Steffens, G.S., 2010. Hydrocarbon Accumulations and Exploration Considerations Associated with Impact Structures. AAPG abstract.

Ned Rozell, 1999. Avak Crater. Alaska Science Forum (article 1460).

Ryder Scott Company website (www.ryderscott.com).

Sorenson, Kelly, and Cantwell of Anadarko Petroleum Corporation, Houston, Texas. Abstract from Kansas Geological Society meeting.

State of Alaska, conservation order no. 275.

USGS press release, January 2001.

http://gisp.gi.alaska.edu/craterbase/avak/avak.htm

http://www.gcn.ou.edu/~jahern/g&m/labs/ames/ames_bouguer.html

http://www.lpl.arizona.edu/SIC/impact_cratering/World_Craters_Web/northamericancraters/Ames.html

http://geowww.gcn.ou.edu/~jahern/ames/ames_impact.html