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Exploring in Africa for Oil & Gas in Naturally Fractured Basement Reservoirs

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Introduction

Basement rocks are important oil and gas reservoirs in a number of basins in the world including Indonesia (Sumatra, Kalimantan & Java), China, Viet Nam, the West Siberia Basin, Middle East (Yemen), South America (Venezuela, Brazil & Argentina), USA (California, Texas, Oklahoma & Kansas), and North Sea (UK West of Shetlands). The reservoirs include fractured and weathered granites, quartzites and metamorphics.

This author has followed this subject closely for over 35 years since being involved in the early 1980's with the development of the Beruk Northeast basement oil field in Sumatra. He has also been involved with evaluating basement opportunities in Angola and Uganda. He hereby shares his knowledge and experience.

Africa Oil & Gas Production and Exploration

In Africa, oil and gas is produced from basement reservoirs in North Africa in Libya, Algeria and Egypt. Further southward, significant oil fields are being developed in Chad. Encouraging exploration potential exists along the west coast of Africa (Angola, DRC Congo, Congo Brazzaville & Gabon). East Africa's interior rift basins are vastly underexplored for basement. Oil shows in Uganda's Lake Albert Basin as well as in the Melut Basin in South Sudan provide encouragement to explore this play.

This poster paper focuses on select basement oil fields in Africa and also reviews a number of exploration opportunities. Also reviewed is "best practices" for exploring and developing basement fields.

Zeit Bay Oil Field, Gulf of Suez, Egypt

This field is located in the southwest corner of the Gulf of Suez. The structure covers an area of 2.5 km by 4.5 km. The field was discovered in 1981 when QQ-89-1 intersected gas. An appraisal well, QQ-89-2 found a 260 meters oil column. Approximately 1/3 of the field's reserves occur within fractured granites and the other 2/3's is within the overlying sediments. Flow rates from the basement vary from 700 to 10,000 barrels of oil per day. The basement consists of granites, metavolcanics, meta-sediments and dykes (references Khalit & Piagaht, 1991, Zaharan & Askarty, 1998).

Bongor Basin, Chad

In 2013 China National Petroleum Company (CNCP) made the Lanea-1 oil discovery which was the first discovery of oil in basement in the Bongor Basin. CNPC defined 8 more basement prospects of which 5 proved to be oil and gas discoveries. About 1,000 meters of relief occurs on the Precambrian cored

"buried hills". The oil column in the fields averages about 1,500 meters, the oil is typically very light oil and the average well productivity is approximately 1,500 barrels of oil per day.

The source rocks are Early Cretaceous lacustrine shales with thicknesses varying from 500 to 1,000 meters and Total Organic Carbon (TOC) averages about 3.5%. The top seal for the reservoirs are lacustrine mudstones.

The oil reserves occur about 70% in the basement and 30% in the overlying granite wash. The oil reserves are about 100 million barrels in 4 fields and production commenced in late 2015 (references AAPG Denver 2015 poster paper by BGP/CNPC, also Bai et al, 2016, AAPG Melbourne Conference).

Cabinda, Angola

No commercial deposits of oil or gas have been found anywhere on the west coast of Africa. The only significant discovery to date has been a small oil pool found onshore in Cabinda, the small Angolan enclave located between Congo Brazzaville and the Democratic Republic of Congo (DRC).

Gulf Oil drilled the 61-1 oil discovery in the Cabinda Central block in 1968 which flowed 600,000 barrels of oil on an extended well test in basement. The oil gravity was 23 degrees API. The discovery was surrounded by dry holes hence the pool is a single well pool. The same year, Gulf also drilled a basement oil discovery, 37-3 in the Cabinda North block which tested twice from basement at 60 and 24 barrels of oil per day (references SOCO International 2005 website and Wood MacKenzie 1968 report). The discovery has not been developed. Albeit that these discoveries were non-commercial, they do prove that oil can occur in basement in West Africa.

The lack of discoveries of oil or gas in basement in the basins along the margin of West Africa is surprising in view of the existence of rich oil source rocks (Cretaceous Bucomazi lacustrine shales) and prolific oi production in countries ranging from Angola to the south and Ivory Coast to the north. This author attributes this to the lack of awareness of the basement oil play leading to almost no exploration or development wells being drilled down into basement.

East Africa Rift Basins

In the past decade, the oil industry has been much focused on exploring in the rift basins in East Africa including Uganda, Kenya, Tanzania, Sudan and Ethiopia. Rich Cretaceous oil source rocks are located adjacent to basement highs or overlay them. Hence these basins should be ideal areas to explore for basement oil and gas.

The single reported show of oil in basement in the Lake Albert Rift basin was a press release by Tullow Oil in May, 2009 that Taitai-1 had encountered a thick section of oil stained basement which provides upside at Taitai-1 and elsewhere in the Lake Albert Basin. In addition, along the escarpment of Lake Albert bituminous oil has been reported in fractured basement.

In South Sudan's Melut Rift Basin, 40 wells have penetrated basement, which consists of granite and granite gneiss (reference Bai et al, 2016, AAPG). However, only two wells flowed oil from basement. This author questions if more oil may have been found had wells been drilled deep enough into basement and if the wells had been adequately tested.

Best Practices for Discovering and Producing Oil & Gas from Basement Reservoirs

1) Production wells should be drilled perpendicular or near-perpendicular to the dominant fracture system. Exploration wells should be drilled highly deviated rather than vertical in order to optimally intersect the dominant fracture system.
2) Highly focused 3D seismic such as CBM (Controlled Beam Migration) is needed to define the fracture systems in basement.
3) Although coring in fractured basement is difficult and not welcomed by the drilling engineers, nonetheless extensive core is needed to provide critically important information on the lithologies and reservoir parameters. Some of the cores should also be radiometrically age dated in order for the geologists to understand the complexities of the reservoir.
4) Development wells should be drilled sufficiently deep to fully drain the reservoir. For example, in the La Paz basement oil field, Venezuela, wells are typically drilled 500 meters into basement. In China's Dongshenpu "buried hill" basement field, the oil column is 400 meters thick and development wells typically are drilled though most of the reservoir.
5) Exploration wells should not just "tag" the top of basement since this will not allow for full evaluation of the basement and could result in an important discovery being "left behind". Indeed, the Suban gas field, South Sumatra was not discovered in the mid 1980's by Caltex (Chevron-Texaco) despite a major exploration program since the wells were drilled through the sedimentary section and then merely tagged into basement. The underlying giant basement gas field (5 trillion cubic feet of gas) was subsequently discovered in 2002 by Gulf and Talisman by drilling deep into basement.
6) There are a number of cases worldwide, such as the giant-size La Paz field in Venezuela where oil in the basement was discovered much later (30 years) in the life of the field with the attention initially focused on producing oil from the overlying sedimentary reservoirs. Approximately 400 million barrels of oil has been produced from basement. The initial production rates (IP) average 3,600 barrels of oil per day and the maximum IP is 11,500 barrels of oil per day.
   A second example of this is the Octongo oil field, Nequen Basin, Argentina which was discovered in 1918 and produced oil from shallow sediments overlying basement. Finally, almost a century later basement was evaluated and now provides recent upside. The basement reservoir consists of Paleozoic granites. The source rock is the Vaca Muerta shales and the oil column is about 450 meters thick. Production in 2015 from basement averaged 3,000 barrels of oil per day and continues to increase and has given a new life to this aging field (reference Velo et al, 2014, AAPG).
   The La Paz and Octongo fields highlight that operators of fields producing from sediments draped over basement highs should consider drilling a well down into basement. High resolution 3D seismic will help with defining the best location to optimally intersect the fractured or weathered basement.
7) Weathered "rotten" granites can also be excellent reservoirs as one can observe in outcrops in tropical areas where heavy rainfall can leach out feldspars and less resistant minerals and leave behind an excellent reservoir. Rocks such as schists and gneisses are less attractive since they are ductile and tend to "smear" and not fracture when subjected to tectonic stress. The high mafic contents of schists also negates the creation of secondary porosity by weathering. Likewise, granites and quartzites are more likely to produce attractive, highly porous "granite wash" sands whereas eroded schists and gneisses do not produce such good reservoirs.

Conclusions

While oil and gas fields in basement are still discovered mostly by accident, there are a few companies who have been especially successful in finding oil in basement which are SOCO International in Viet Nam and Yemen and Hurricane Exploration in the UK's West of Shetlands area. Hurricane's success can be viewed as a "basin revival play" for the North Sea.

The conventional way of thinking, certainly in the past, has been that in exploration programs the top of basement is mostly tight and in oil patch lore was regarded as "tombstone". Indeed, the sands near the top of basement were often described tongue-in-cheek as the "suitcase sands" since that signified that the well was near to total depth and likely a dry hole so it was time for the geologist to pack up his suitcase and go home.

However, this author believes that significant oil and gas fields remain to be found in Africa and worldwide. Unconventional geological thinking and risk-taking has led to many of the world's major oil and gas discoveries and such strategies will reward the explorers searching for oil and gas in basement.

Acknowledgements

Since publishing papers on oil and gas-bearing basement reservoirs beginning in 1984, as detailed below, the author has developed an abiding interest in basement fields. He has made numerous presentations on basement fields at conferences in Singapore, Jakarta, London, Istanbul, Luanda - Angola, Nigeria (Lagos & Abuja), Cape Town, and North America (Calgary, Houston & Pittsburgh).

He would like to acknowledge Roger Eubank, Caltex Chief Geologist in Sumatra in the early 1980's who encouraged his team members to present papers at technical conferences and help to disseminate information about the petroleum geology of Sumatra. This led to my first paper on oil in basement.

Lastly, the reader is referred to one of the first papers ever published on oil and gas in basement which was by Dr. K. K. Landes et al in 1960 where he stated: "Commercial oil deposits in basement rocks are not geological "accidents" but are oil accumulations which obey all of the rules or oil sourcing, migration and entrapment; therefore in areas of not too deep basement, oil deposits within basement should be explores with the same professional skill and zeal as accumulations in the overlying sediments".

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