Fractured & Weathered Basement Reservoirs in East and West Africa – A High Risk but Potentially High Reward Oil & Gas Play

Tako Koning, P. Geol.
Gaffney, Cline & Associates, Luanda, Angola

Fractured and weathered basement rocks are important oil and gas reservoirs in various basins in the worldwide. This author has followed this subject very closely for 30 years since working in the early 1980's as a development geologist on the Beruk Northeast basement oil field in Central Sumatra, Indonesia. He has been involved in evaluating other such fields over the years. He has also given many presentations on basement oil and gas fields at conferences worldwide. He hereby shares his knowledge and experience.

There is no oil or gas production in sub-Sahara Africa from fractured or weathered basement reservoirs. However, very few wells have been taken deep enough into basement to evaluate its potential.

West Africa

In West Africa, about 600,000 barrels of oil was produced in the early 1970's from a small oil pool in the Central Block, onshore Cabinda, Angola. The reservoir is fractured basement. Due to civil war security issues, the play was not followed up. But the potential certainly exists elsewhere in Angola and other areas including Congo DRC, Congo (Brazzaville) and Gabon where rich Bucomazi lacustrine oil source rocks lay on the flanks of basement highs or overlay them.

East Africa

East Africa is a vastly underexplored area and many years of exploration is required for the area's full potential to be defined. The basement oil and gas play is beginning to emerge in East Africa. Oil shows have been recorded in the basement underlying the Lake Albert graben in Uganda. Further drilling and testing is required. Elsewhere in East Africa, there are strong possibilities of Lake Albert look-alike basins where oil-prone mature lacustrine shales may overly basement and oil may have migrated downwards into basement or laterally into basement on the flanks of the grabens.

Select Analogues

Since until now there have been no commercial discoveries of oil and gas in basement in sub-Sahara Africa, except for the small oil pool in Cabinda, one must look at analogues elsewhere worldwide as examples of successful, commercial basement oil and gas fields. These analogues then serve as models to be targeted in exploring for basement in sub-Sahara Africa.

1.) **Viet Nam**

Most of Viet Nam's oil production is from fractured granite basement in the Cuu Long basin with six major oil fields producing primarily from basement. Overlying and adjacent Oligocene lacustrine shales generated the oil which migrated into the fractured basement. The Bach Ho (White Tiger) is a giant field with recoverable reserves of 1.0 – 1.4 billion barrels of oil. Other fields include Rong, Rang Dong, Ruby and Su Tu Den with oil reserves ranging from 100 to 400 million barrels (reference: Hoan Vu JOC, AAPG 2004).

The Ca Ngu Vang (CNV) field, discovered in 2002 is the deepest oil-bearing structure in the basin, where the top of basement is at a depth of 3,700 meters. Indeed, the SOCO-operated CNV-3X well was the longest measured

depth well drilled in Viet Nam (6,123 meters) with over 2,000 meters of basement penetrated in a near-horizontal well emplacement and was tested at 13,040 BOEPD.

2**.) China**

The Dongshenpu field, onshore central China is an example of a Chinese "buried hill" basement oil field. This field was discovered in 1983 and the reservoir consists of Pre-Cambrian granites, granulites, diabases and hornblendic metamorphics (Guang & Zuan, AAPG, 1991). The rocks have no primary porosity but the porous reservoirs are due to weathering and fracturing. The discovery well tested at 1,570 BOPD and subsequent development drilling has proven the oil column to be 400 meters thick.

3.) **Indonesia**

To date in Indonesia, oil production from basement rocks has been minimal but major gas discoveries in South Sumatra including the giant-size Suban gas field have been made in pre-Tertiary basement reservoirs. Gas reserves in basement are estimated in the range of 5 TCF (trillion cubic feet) according to Hennings et al, 2012. This has led to further exploration for gas in basement due to the need for more gas as the Indonesia economy continues to grow.

The largest basement oil pool in Indonesia is the Tanjung oil field in Kalimantan. This field has produced over 70 million barrels of oil from overlying Eocene sandstones and conglomerates but it has also produced over 20 million barrels of oil from pre-Tertiary basement rocks including weathered volcanic, pyroclastics and metasediments.

4.) **North Africa**

Major gas reserves have been found in basement reservoirs in Libya and Algeria. Oil has been produced from basement reservoirs in the Egypt's offshore Zeit Bay field, Gulf of Suez. Specific numbers on the amount of oil produced from basement is not known to this author, but it is believed to be in relatively modest amounts, perhaps in the order of about 20 million barrels.

Best Practices for Exploring & Producing Basement Reservoirs

Best practices include the following:

1.) Production wells should be drilled near-perpendicular to the dominant fracture system.

2.) Exploration wells should also be drilled highly deviated rather than vertical in order to optimally intersect the dominant fracture systems.

3.) Highly focused 3D seismic such as CBM (Controlled Beam Migration) is needed to define the fracture systems in basement.

4.) Extensive core coverage is necessary 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 basement reservoirs they are dealing with.

5.) Development wells must be sufficiently deep to fully drain the reservoir. Wells should not just "tag" into the top of basement. For example wells in the La Paz field, Venezuela which produces from basement were typically drilled 500 meters into the basement.

In a general sense, fractured granites and quartzites are the optimum reservoirs. Weathered "rotten" granites can also be excellent reservoirs as can be observed in outcrop in tropical areas. 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 content of schists also negates the creation of secondary porosity by weathering. Likewise, granites and quartzites are more likely to provide attractive, highly porous "granite wash" sands whereas eroded schists do not produce such good reservoirs.

Acknowledgements

The author worked worldwide as a geologist and manager for Texaco for three decades (1973 – 2002). Thereafter he has worked as an oil & gas consultant for the past ten years in Luanda, Angola. In 1982 he was involved with the development of the Caltex (Chevron-Texaco) Beruk North East basement oil pool in central Sumatra and has had an abiding interest in basement reservoirs since that time. More recently he has also evaluated the oil potential of basement rocks underlying the Lake Albert Basin, Uganda. The author has

presented papers on basement reservoirs at conferences in various locations including Jakarta, Singapore, Calgary, Houston, Pittsburgh, Lagos, Abuja, Luanda and Cape Town.

He would especially like to acknowledge Roger T. Eubank, Caltex chief geologist, an inspirational geologist and team leader in Sumatra in the early 1980's, who encouraged his team members to present papers at conferences and to help disseminate information about the petroleum geology of Sumatra including information on Sumatra's basement.

References

Eubank, R.T. and Makki, A.C., 1981, "Structural Geology of the Central Sumatra Back-Arc Basin", Proceedings of the 10th Annual Convention of the Indonesia Petroleum Association, Jakarta, p 152 – 196.

Gung, T.X. and Zuan, H., 1991, "Buried-hill Discoveries of the Damintun Depression in North China, American Association of Petroleum Geologists Bulletin", v. 75, no.4, p.780-794.

Hennings et al, 2012, "Relationship Between Fractures, Fault Zones, Stress, and Reservoir Productivity in the Suban Gas Field, Sumatra, Indonesia", AAPG Bulletin, v.96, No.4, April 2012, pp. 753-772.

Hung, N.D. and Le, H.V., 2004, "Petroleum Geology of Cuu Long Basin – Offshore Viet Nam", American Association of Petroleum Geologists Search and Discovery Article #10062

Koning, T., 2003, "Oil and Gas Production from Basement Reservoirs – Examples from Indonesia, USA and Venezuela", Special Publication of the Geological Society of London on "Hydrocarbons in Crystalline Rocks".

Koning, T., 2000, "Oil and Gas Production from Basement Reservoirs – Examples from Indonesia, USA and Venezuela", Proceedings of the 16th annual World Petroleum Congress, Calgary.

Koning, T. and Darmono, F.X., 1984, "The Geology of the Beruk Northeast Field, Central Sumatra – Oil Production from Pre-Tertiary Basement Rocks", Proceedings from the 13th Annual Convention, Indonesian Petroleum Association , Jakarta.

Landes, K.K., et al, 1960, "Petroleum Resources in Basement Rocks", American Association of Petroleum Geologists, Bulletin 44, p. 1682 – 1691.