PROSPECTING, EXPLORATION AND DEVELOPMENT OF OIL, GAS AND OIL AND GAS FIELDS

Review article

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Giant and major-size oil and gas fields worldwide in basement reservoirs: state-of-the-art and future prospects

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Oil and gas occurs in basement reservoirs in many parts of the world. The reserves of basement fields are as small as one or two million barrels of oil or gas-equivalent such as the Beruk Northeast pool in Sumatra, Indonesia to over 1.0 billion barrels of oil as in Viet Nam's Bach Ho field and Libya's Augila-Naafora field. This paper focuses on three giant-size oil and gas fields and six major-size fields. Exploration for oil and gas in basement has been remarkably successful in the past decade with important discoveries in basement in Indonesia, United Kingdom, Norway, Chad, and Argentina. In order to successfully develop basement oil and gas fields and also to avoid costly mistakes, all available geological, geophysical, reservoir engineering and economic data must be closely studied. Also, it is very important to study analogues worldwide of basement oil and gas fields in order to understand why some fields are very successful and others turn out to be technical and economic failures.

Keywords: giant and major-size oil and gas fields, crystalline basement, reservoirs

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Introduction

Basement rocks contain important oil and gas reservoirs in a number of basins in the world including Asia (Indonesia, China, Viet Nam, & India), Russia, Middle East (Yemen), Africa (Libya & Egypt), South America (Venezuela & Brazil), USA (California, Kansas, Oklahoma & Texas), and the North Sea (UK West of Shetlands & Norway) (Figure 1). The basement reservoirs include fractured and weathered granites, quartzites, metamorphics and volcanics.

The basement oil and gas play has intensified in the past decade with significant basement discoveries in the United Kingdom (Lancaster and Lincoln oil fields), Norway (Rolvsnes oil field), basement oil discoveries in Chad (Central Africa), Argentina and a major gas discovery made in 2019 in fractured basement in Indonesia.

The author has followed this subject closely for almost four decades since being involved in 1982 with the development of the Beruk Northeast basement oil pool in Indonesia (Koning & Darmono, 1984). He has presented papers on basement oil and gas at conferences and symposiums in Asia (Singapore & Jakarta), Middle East (Istanbul), Africa (Lagos, Abuja, Luanda & Cape Town), Europe (London & Kazan, Russia) and in North America (Calgary, Houston & Pittsburgh). He hereby shares his knowledge and experience.

The biggest oil and gas fields among the basement fields occur within basement which is heavily naturally fractured. The opinion of this author is that the best rock types are fractured quartzites or granites since they are brittle and thus fracture optimally (Koning, 2019). Fractured gneisses are poorer reservoirs since they can be massive, dense or slabby with open fractures parallel to the direction of foliation. Rocks such as gneisses and schists are ductile and tend to "smear" and not fracture when subjected to tectonic stress. Phyllites and slates are the least attractive since such rocks are not brittle, rather they are thinly bedded, fissile and ductile and naturally fracture poorly.

Weathered granitic basement can also be an excellent reservoir such as in the Augila-Naafora oil field in Libya as described later in this paper.

The following is the preference scale for basement reservoir rock types:

- Fractured quartzites…….*Most preferred rock type*
- Fractured granites
- Fractured carbonates
- Weathered granites
- Fractured gneisses
- Weathered gneisses
- Fractured or weathered basalts
- Fractured schists
- Weathered schists………*Least preferred rock type*

Oil and gas fields in basement require the same geological criteria as conventional oil and gas fields which includes reservoir rocks (naturally fractured or weathered basement), oil & gas source rocks adjacent to or overlying basement, oil and gas migration paths, structural closure, and cap rocks which seal off the basement reservoirs.

Giant and major oil & gas fields

Giant-size oil and gas fields are defined as fields with greater than 0.5 billion barrels of oil reserves or gas-to-oil equivalent reserves. Major-size oil and gas fields are fields with reserves ranging from 100 million barrels to 0.5 billion barrels of oil or gas-to-oil equivalent. In this paper, the

Fig. 1. Global distribution of oil & gas fields in basement reservoirs (Koning, 2019).

following giant and major oil and gas fields occurring in basement reservoirs are reviewed including:

Bach Ho (White Tiger): a giant-size oil field, offshore Viet Nam

Suban: a giant-size gas field, onshore South Sumatra Indonesia

Kali Berau Dalan: a major-size recent gas discovery, onshore South Sumatra, Indonesia

Dongshenpu: a major-size oil field, onshore China

Oymash: a major-size oil field, onshore Kazakhstan

Habban: a major-size oil field, onshore Yemen

Augila-Naafora: a giant-size oil field, onshore Libya

La Paz: a major-size oil field, onshore Venezuela

Mara: a major-size oil field, onshore Venezuela

Viet Nam

The largest oil field in Viet Nam is the giant-size Bach Ho (White Tiger) basement oil field. Other basement oil fields in Viet Nam include Ca Ngu Vang, Rong (Dragon), Rang Dong, Ruby, Su Tu Vang and the Su Tu Den fields. The primary basement reservoir rock is naturally fractured Precambrian granite as shown in Figure 2.

Fig. 2. Outcrop of Precambrian granite at LongHai, Viet Nam. Note the dominant fractures highlighted in red and the set of secondary oblique fractures highlighted in yellow (SOCO 2011 website).

Viet Nam: Bach Ho (White Tiger) Oil Field

This is a giant oil field with estimated reserves of 1.0 to 1.4 billion barrels recoverable (Hung & Le, 2004). The field was discovered in Viet Nam's Cuu Long Basin by Mobil in 1975 with oil found in Oligocene sediments draping a major basement structural high (Figure 3). Due to the political situation, Mobil, a USA oil company was not able to develop the field and exited from Viet Nam. However, in 1988 VietSovPetro discovered oil in fractured and weathered Precambrian granite basement. Oil production peaked at about 280,000 barrels of oil per day in 2005. The oil production is 90% from the basement reservoirs and 10% from the Oligocene sediments. Bach Ho's production declined to 140,000 barrels of oil per day in 2009 and has continued to decline to 65,000 barrels of oil per day in 2018.

The oil is stored in macrofractures, microfractures, and vuggy pores within the fractures. Matrix porosity within the granite is negligible. Most of the fractures inside basement are at high dip angles of 40–75 degrees. Porosity in the fractures is only 2–3% but permeabilities are excellent at ten to thousands of millidarcies. Flow rates have been measured at up to 14,000 barrels of oil per day per well. Bach Ho's giant-size reserves are due to excellent storage and permeabilities in the fractures and also due to the oil column having a very large thickness of 1,500 meters.

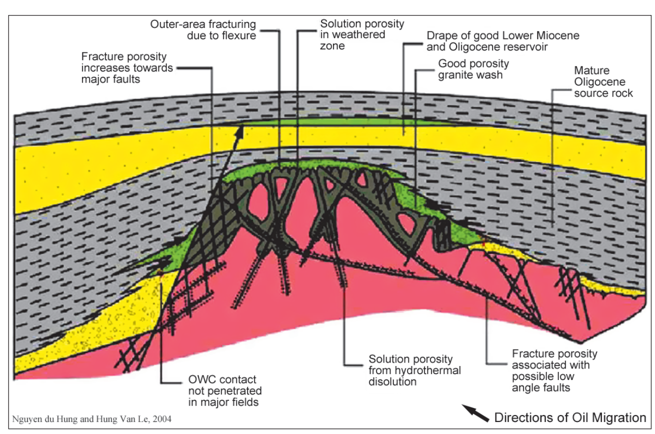

Fig. 3. A two-dimensional model of the play concept for the Cuu Long Basin, Viet Nam (Hung & Le, 2004)

Indonesia: Suban Gas Field, South Sumatra

The Suban gas field was discovered in 1998 by drilling through shallower gas-bearing sediments and deep into basement. An estimated 6 trillion cubic feet of gas was discovered in fractured pre-Tertiary age granites. Gas production which commenced in 2003 is primarily from basement and is also obtained from the overlaying granite wash sands of the Talang Aker formation and fractured carbonates of the Miocene-age Batu Raja formation. The gas column in the basement is approximately 1,250 meters in thickness and a water aquifer underlays the gas. Very prolific basement gas wells were drilled on the basis of the wells being highly deviated and oriented perpendicular to the dominant fracture system. The success of Suban has led to further exploration for gas in basement in Sumatra due to the need for more gas as the Indonesian economy continues to expand. Gas from the Suban Field has been pipelined to the huge Duri heavy oil steam flood project in Central Sumatra as well as to Singapore for electricity generation. The American oil company Conoco Phillips is the operator of the field.

Hennings et al. (2012) in a comprehensive paper on Suban which states that bulk reservoir performance is governed by the local stress architecture that acts on existing faults and their fracture damage zones to alter their permeability and consequently on their access to distributed gas (Figures 4, 5). Studies on Suban indicated that the reservoir potential is most enhanced in areas that have large numbers of thrust-fault stress where fewer fractures with high shear-to-normal stress ratios exist. The operator determined that achieving the highest well productivity relies on tapping into critically stressed faults and their associated fracture damage zones. Two wellbores including Suban-10 and Suban-11 were drilled based on this concept and each showed a three-to-seven-fold improvement in gas flow potential. Indeed, Suban-10 was placed on production in 2007 at a constrained rate of 150 million cubic feet of gas per day (Talisman Energy, 2007).

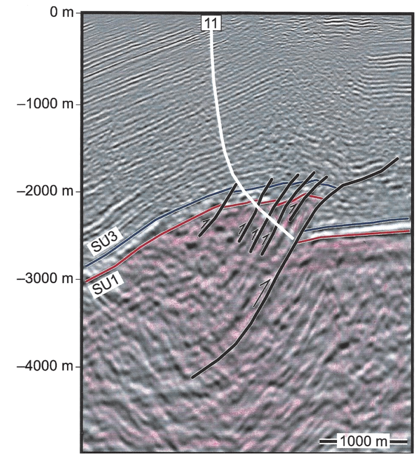

Fig. 5. Seismic line showing the location of the Suban-11 development well. Basement is in red. These up thrust faults are associated with regional strike-slip faulting. The well was drilled to intersect perpendicularly the faults. Suban wells 10 and 11 were especially successful with Suban-10 placed on production at 150 million cubic feet of gas per day (Hennings et al., 2012, Talisman Energy, 2007).

Indonesia: Kali Berau Dalam Gas Discovery, South Sumatra

In 2019, the Spanish oil company Repsol announced that their Kali Berau Dalam-2 exploration well had made a major gas discovery in fractured pre-Tertiary basement rocks. The well was drilled in the Sakakemang Block. Repsol as operator has a 45% working interest, Malaysia's state oil company Petronas holds a 45% interest and the Japanese firm of Mitsui & Company holds 10%. This discovery extends the basement gas play 60 kilometers to the northeast of the Suban Field. The well was reported to have flowed at a rate of 45 million cubic feet of gas per day.

Repsol announced that the discovery found at least 2 trillion cubic of gas. On an oil equivalency basis this equals 330 million barrels of oil. For Indonesia the Kali Berau Dalam discovery is very significant since it is the largest oil or gas discovery in the past 18 years since the Cepu discovery in 2001. Indeed, petroleum industry analysts have stated that this discovery is one of the ten biggest discoveries in the world made in 2019.

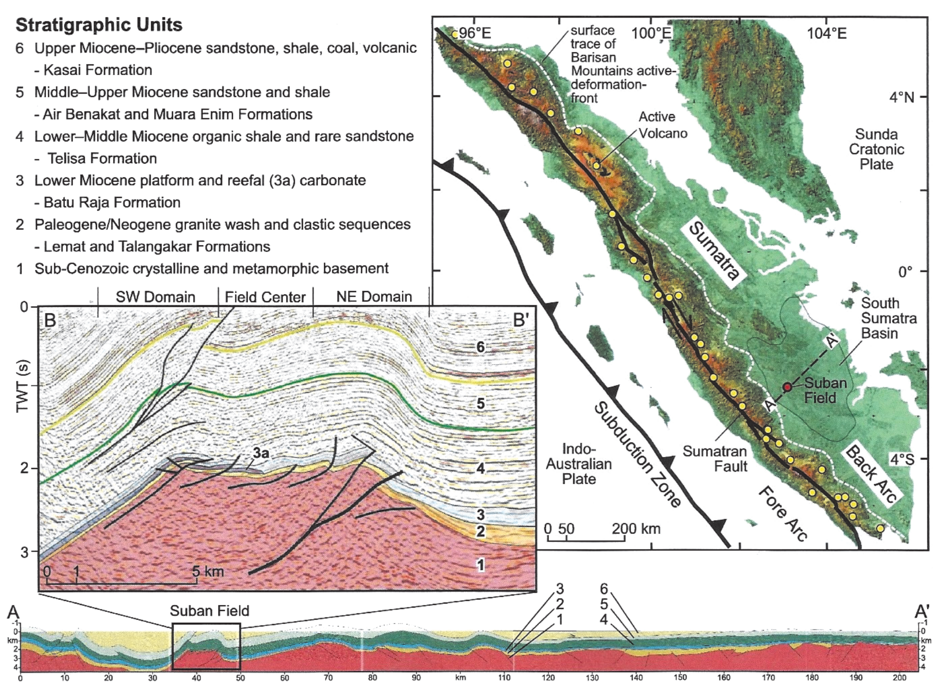

Fig. 4. Regional setting of the Suban gas field, South Sumatra. The seismic section intersects the crest of the Suban Field (Hennings et al., 2012).

China: Dongshenpu Oil Field

This field is located onshore central China and like the Yaerxia oil field is an example of a Chinese "buried hill" basement oil field (XiaoGuang & Zuan, 1991). The Dongshenpu oil field was discovered in 1983 and the reservoir consists of Precambrian (Archean) granites, granulites, diabases, and hornblende gneisses (Figure 6). The rocks have no primary porosity but porous reservoirs were developed by weathering and natural fracturing.

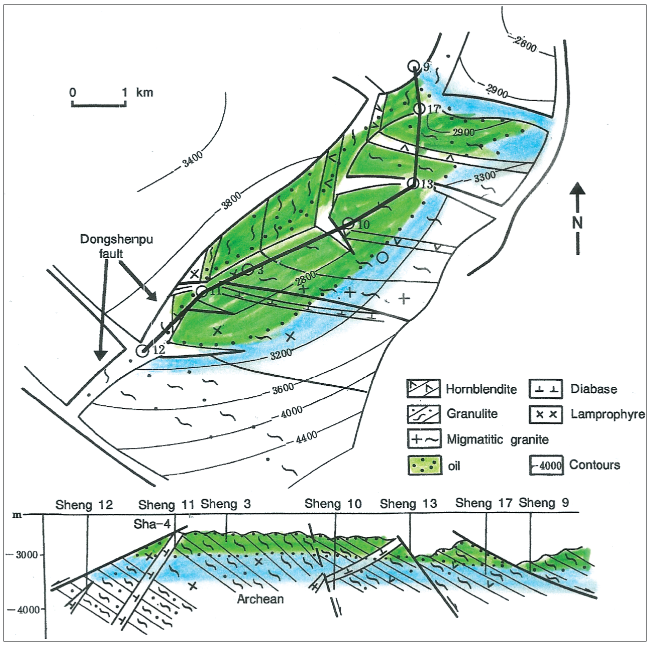

Fig. 6. Structural cross-section through the Dongshenpu oil field. The oil column, shown in green, is separated from the underlying water zone, shown in blue, by the oil-water contact at 3,060–3,100 meters (XiaoGuang & Zuan, 1991).

The discovery well tested at 1,570 barrels of oil per day and subsequent development drilling has found the oil column to be 400 meters thick. The top of the buried hill is at a depth of 2,600 meters. The oil-water interface is basically uniform at 3,060–3,100 meters depth. The reserves in this field were estimated at approximately 190 million barrels of oil.

Kazakhstan: Oymash Oil Field

The Oymash oil field (Figure 7) was discovered in 1980 with oil found in Precambrian (Middle Paleozoic) granite and Triassic and Lower Jurassic sediments (Krupin & Rykus, 2011). Individual wells have been tested from basement at rates of up to 248 m3/day (1,560 barrels of oil per day). The granite is both fractured and weathered with an open porosity of 5.2%. The oil column in Oymash is 190 meters. The initial oil reserves in the field were estimated to be 20 million tons (150 million barrels of oil). The reserves in basement is estimated at 18 million tons (135 million barrels of oil) since approximately 90% of the oil in Oymash occurs within the basement.

YEMEN: Habban Oil Field

Yemen's crude oil production averaged 270,000 barrels of oil per day from 1993 until 2020 from two major sedimentary basins, Masilah and Sabatyn. Approximately 50% of the production is from Precambrian basement. Thus, basement's share of the production was 135,000 barrels of oil per day. Yemen's basement play is very successful due to major fault zones resulting in a high degree of basement fracturing (Neff, 2014). Also, Yemen has a world class mature oil and gas source rock which is the Jurassic-age Madir shale.

The Habban basement oil field was discovered in 2005 by Austria-based OMV Exploration & Production. The first successful exploration well was drilled to a total depth of 3,020 meters and tested 2,552 barrels of oil per day from fractured granites and granitic gneisses. By 2009, Habban was producing 32,000 barrels of oil per day. The field has a very thick oil column of 750 meters.

Africa's basement rocks

The vast interior core of Africa consists of Precambrian granite which when fractured or weathered is an optimum basement reservoir for oil and gas (Figure 8). One of the biggest basement oil fields worldwide, Augila-Naafora in Libya is reservoired in granite. Similarly, important oil discoveries made in Chad in the past decade all occur in Precambrian granite.

Libya: Augila-Naafora Oil Field

This field is a multi-billion barrels accumulation discovered in the mid-1960's in the Sirte Basin (Figure 9). The field is a prominent horst block created at the onset of rifting in Middle to Upper Cretaceous time (Harding, 1984). The reservoirs consist of hydrothermally altered fractured and weathered Precambrian granite and flanking Cretaceous

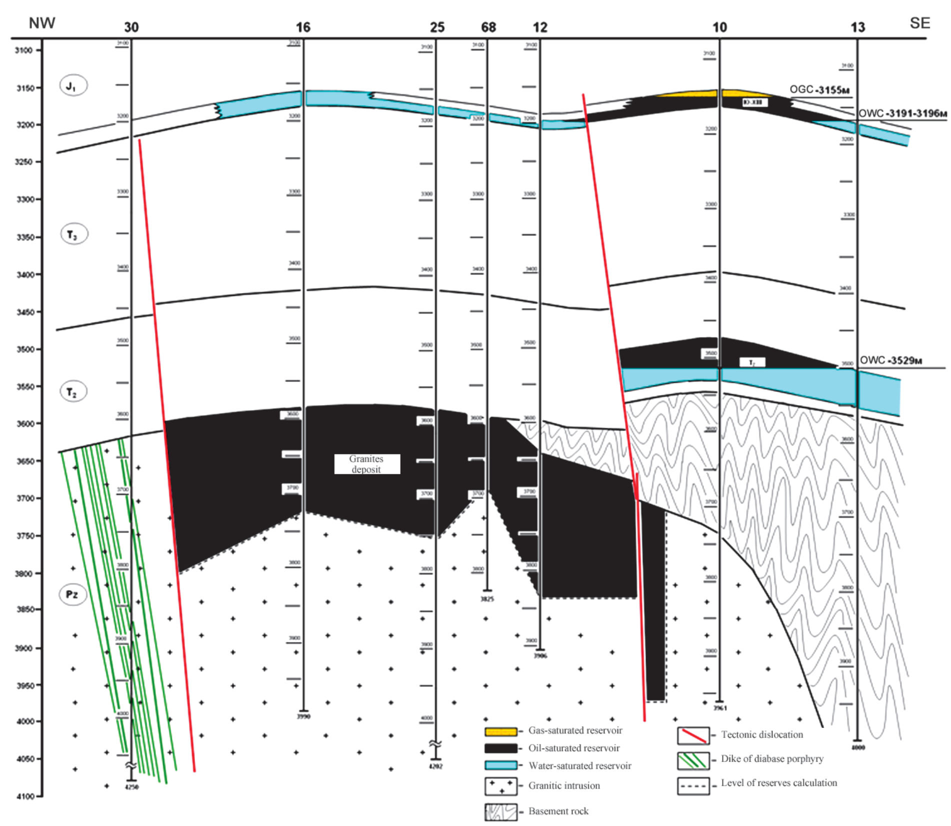

Fig. 7. Structural cross-section through the Oymash field showing distribution of oil in the basement and in the overlying sediments

Fig. 8. This is an example of typical basement rocks in Africa and consists of intensely fractured Precambrian granite in a fracture corridor. These rocks represent an excellent basement reservoir. This outcrop is located in the interior of Angola (Koning, 2014).

sandstones and carbonates. Thick mature oil source rocks onlap the basement high and also act as the ultimate seal to the accumulation. The oil source rocks are Cretaceous-age basinal marine dark shales.

Augila-Naafora has two names but consists of one field. The northeast part of the field, Naafora was discovered by Amoseas (Chevron & Texaco) in 1965 on Concession 51. The southwest part of the field, Augila was discovered in 1966 on Concession 102 by the USA oil company Occidental Petroleum. The D102 well drilled by Occidental into the crest of the structure proved basement to be bald with Cretaceous shales resting directly on granitic basement. The well was tested and flowed 7,627 barrels of oil per day from the basement.

Primary porosity in the granite is low (2–3%) but hydrothermal alteration and weathering have led to about 6% porosity in the weathered zone and a maximum of about 11% according to Belgasem et al. (1991). The weathering at the top of basement varies from as little as 5 meters to as much as 200 meters. There are sufficient open fractures in the basement structure to ensure effective fluids communication throughout the accumulation and to guarantee high oil production rates.

Historic public data on the reserves and production rates of Libya's oil fields is scarce. The current operator of Augila-Naafora is the Libya National Oil Corporation who since becoming operator in 1969 has published no information on the field. The best information is from Williams (1972) and Hallett (2002) who wrote that the original oil-in-place is in the order of 9.0 billion barrels of oil. Cumulative production by 1981 was 739 million barrels (Oil & Gas Journal, 1982). According to Hallett (2002) the estimates of the original reserves vary from 1.5 billion barrels of oil to 2.2 billion barrels of oil, which is equivalent to a recovery factor ranging from 17% to 25%. Assuming that the portion of the reserves from basement is approximately 50% (the other 50% being

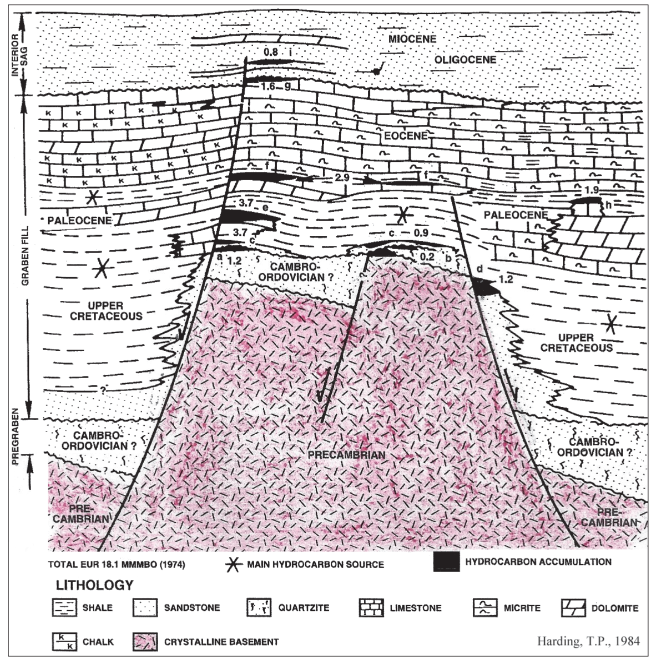

Fig. 9. Typical horst structure, Sirte Basin, Libya (Harding, 1984)

from the flanking sediments), this is equivalent to 0.75 billion to 1.1 billion barrels of oil reserves in the basement reservoir.

Accordingly, in the view of this author, Augila-Naafora is one of the largest basement oil fields in the world and is a prime analogue for geoscientists who are searching for major oil or gas accumulations in basement.

Venezuela: La Paz and Mara Oil Fields

The La Paz oil field is one of the most famous and well-documented fractured reservoirs in the world. La Paz is located in the Maracaibo Basin west of Lake Maracaibo, Venezuela. The field was discovered by Shell Oil in 1922 and up to the year of 1992 had produced 830 million barrels of oil from fractured Cretaceous limestones and from the underlying fractured basement (Landes et al., 1960, Talukdar et al., 1994, Koning, 2003, Koning, 2014). The field's peak production was 160,000 barrels of oil per day (Nelson et al., 2000).

For geoscientist and engineers who are interested in basement reservoirs, the development of La Paz is very relevant. The discovery of oil in the underlying basement was not made until 1953, 31 years after the discovery of oil in the overlying sedimentary formations. After the discovery of the oil in the Cretaceous limestones, due to the very strong oil production performance of the reservoir, the reservoir engineers and geoscientists carried out extensive materials balance studies and predicted that the reservoir was obtaining production support from a deeper reservoir. Accordingly, in 1953, 31 years after the discovery of La Paz, well P-86 was drilled into the underlying basement and discovered oil in the basement. P-86 was drilled to a depth of 2,710 meters (8,890 feet) and penetrated 332 meters (1,089 feet) of basement and was tested at 3,900 barrels of oil per day. Up-to-date data is not available on the oil production from La Paz or any of Venezuela's oil and gas fields. However, by 1993 approximately 246 million barrels of oil had been produced from the basement in La Paz.

Very relevant for those involved with exploring for and producing oil or gas from basement reservoirs is the work done by a multidisciplinary team led by R.A. Nelson. Their analysis of the La Paz field (Nelson et al., 2000) indicated that the higher oil flow rates seems to be related to fracture swarms surrounding numerous faults within the field that were developed during the strike-slip origin of the current structure.

The Mara field was discovered in 1945 by Shell and is located 12 km to the northeast of La Paz (Figure 10). The two fields are separated by a structural saddle and also tight limestones (Figure 11). The initial exploration found oil in fractured Cretaceous La Luna limestones. However, in 1953, Mara's first basement well was drilled and penetrated 332 meters (1,090 feet) of basement, consisting of fractured granites and metamorphics, and tested 6,500 barrels of oil per day. The strongest oil producer in basement in Mara is DM-12 which had an IP (initial production rate) of 17,000 barrels of oil per day from basement. Mara has an estimated ultimate potential recovery of 525 million barrels of oil from fractured granitic basement as well as fractured Cretaceous limestones (Young, 1993). By 1955, basement oil production from La Paz and Mara amounted to 80,000 barrels of oil per day (Smith, 1956).

Up-to-date production data is not available on Mara but up to 1991 the field produced 407 million barrels of oil (Young, 1993). Assuming 75% of the oil is from basement and 25% from the overlying limestones, then the reserves attributable to basement is 305 million barrels of oil.

Oil columns in giant and major basement fields

Based on the information available on all of the fields reviewed in this paper, it is evident that all of the oil and gas has been generated by mature sedimentary oil and gas source rocks which lay adjacent to or overlay the basement highs. Also, this review studied the nature of the faulting in these fields. Strike-slip faults are superior to normal or reverse faults since strike-slip has both lateral and vertical motion which increases the intensity of the fracturing.

A very important factor which contributes to large reserves of oil and gas in basement fields is that the basement structures can be described as "profound" meaning that the structures are large and well-defined. In almost all of the basement fields described in this paper, oil-water and gas-water contacts are present. The review of the fields in this paper indicates that the depth of fracturing down into basement determines the ultimate oil or gas column height as well as the richness, thickness and maturity of the source rocks adjacent to or overlaying the basement structures.

The oil and gas columns are summarized in the Table.

Best practices and future prospects

Exploration wells should be drilled highly deviated rather than vertical in order to optimally intersect the dominant fracture system. Production wells should be drilled perpendicular or near-perpendicular to the dominant fracture system.

Highly focused wide azimuth 3 dimensional (3D) seismic such as CGG – Veritas' CBM (Controlled Beam Migration) is needed to define the fracture systems in basement oil & gas fields (Koning, 2014; Koning, 2019).

Coring in fractured basement is difficult due to the jamming of core barrels and lost circulation zones. Coring is not welcomed by the drilling engineers. Nonetheless, 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 geological history of the reservoir.

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 through most of the reservoir.

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 of 6 trillion cubic feet of gas was subsequently discovered in 1998 by Gulf Canada and Talisman Energy by drilling deep into basement.

In some documented cases worldwide, the top of basement is tight due to cementation of open fractures by secondary silica cement. However, deeper down by about approximately 30 meters (130 feet) the fractures are open and store oil or gas. This serves as a reminder that all wells should drill at least 200 meters (660 feet) into basement in order to fully evaluate the basement and not "leave behind" an important oil or gas deposit.

Field	Oil or Gas Column m (ft) Contact	Oil-water or gas-water
Bach Ho (White Tiger), Viet Nam	1,500 m (4,920 ft) oil	No contact is identified
Chad (buried hill fields)	1,500 m (4,920 ft) oil	No information
Suban, Indonesia	1,250 m (4,100 ft) gas	Gas-water contact is defined
Habban, Yemen	750 m (2,475 ft) oil	No information
Octogono, Argentina	450 m (1,475 ft) oil	Oil-water contact is defined
Dongshenpu, China	400 m (1,310 ft) oil	Oil-water contact is defined
La Paz, Venezuela	305 m (1,000 ft) oil	Oil-water contact is defined
Zeit Bay, Egypt	260 m (855 ft) oil	No information
Oymash, Kazakhstan	190 m (625 ft) oil	Oil-water contact is defined

Table. The oil and gas columns

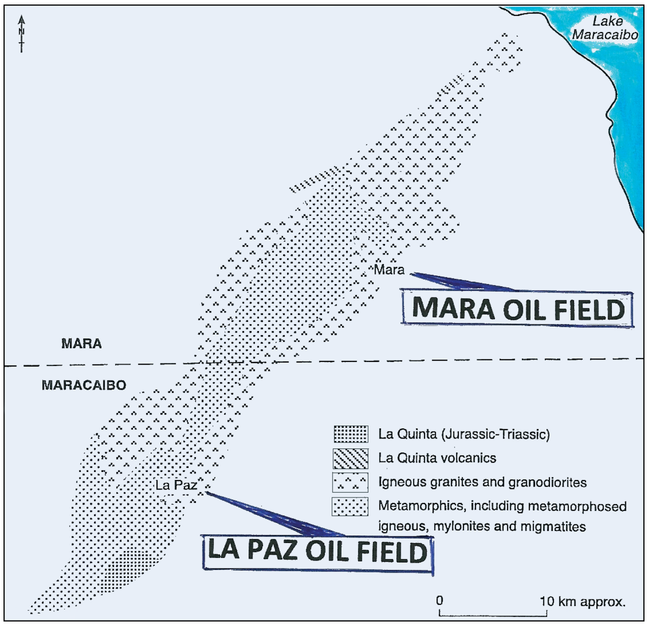

Fig. 10. Summary map showing the main basement lithologies of the La Paz and Mara oil fields, Venezuela (Landes et al., 1960)

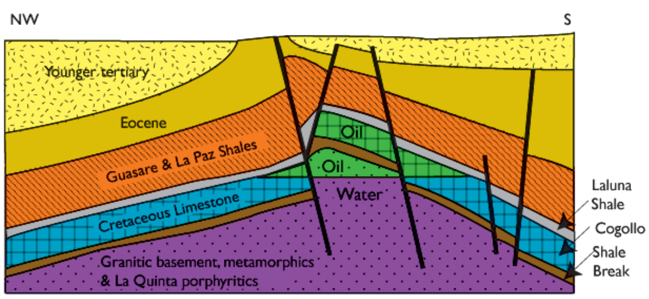

Fig. 11. Structural cross-section through the La Paz oil field. The fractured basement reservoir is in pressure communication with the overlying fractured limestones hence a common oil-water contact is in the field (Smith, 1956; Landes et al., 1960; Talukdar et al., 1994; modified by Koning, 2000; Koning, 2003).

There are a number of cases worldwide, such as the major-size La Paz Field in Venezuela where oil in the basement was discovered much later (31 years) in the life of the field with the attention initially focused on producing oil from the overlying sedimentary reservoirs. A second example of this is the Octogono oil field, Neuquen Basin, Argentina which was discovered in 1918 and produced oil from shallow sediments overlying basement. Finally, almost a century later, basement was drilled and evaluated and now provides reserves and production upside. 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 (Velo et al., 2014). The La Paz and Octogono fields highlight that operators of oil & gas fields producing from sediments draped over basement highs should consider drilling a well down into the basement. High resolution 3D seismic will help with defining the best location to optimally intersect the fractured or weathered basement.

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. The high mafic minerals in schists, phyllites and slates 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.

Geologists, geophysicists, reservoir engineers, and economists must study proven analogues of basement oil and gas fields worldwide in order to fully understand any basement discoveries worldwide that they are attempting to develop.

Conclusions

In the past, oil and gas fields in basement were discovered mostly by accident. The conventional way of thinking in the past was that basement is mostly tight and did not warrant exploring. However, as shown in this paper, giant-size and major-size oil fields do occur in basement. This author believes that significant oil and gas fields remain to be discovered worldwide in basement.

Basement reservoirs are very unusual in comparison to conventional sedimentary rock oil and gas reservoirs since the basement reservoirs are in crystalline rocks. Accordingly, for geoscientists and reservoir engineers to successfully work with basement rocks, a special "mind set" is required which is open to all of the complexities associated with crystalline rocks.

Understanding basement reservoirs is not only important for oil and gas, but this knowledge is also very relevant to the great need to reduce the world's Green House Gases (GHG). Carbon dioxide (CO_2) can be captured and injected into fractured or weathered basement and thereby can be safely and permanently stored.

Also, a commodity which is increasingly in short supply worldwide is helium. Economic helium is derived from the radioactive decay of uranium and thorium in basement rocks and granite washes. In Canada's western province of Saskatchewan, significant programs have commenced exploring for helium in basement reservoirs.

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

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Обзорная статья

Гигантские и крупные месторождения нефти и газа по всему миру в залежах кристаллического фундамента: уровень развития и перспективы на будущее

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Нефть и газ находятся в залежах кристаллического фундамента во многих частях планеты. Запасы месторождений фундамента составляют от одного или двух миллионов баррелей нефти или эквивалента газа, как например в бассейне Beruk Northeast на Суматре, Индонезия, до более 1,0 миллиарда баррелей нефти, как на месторождении Bach Ho во Вьетнаме или месторождении Augila-Naafora в Ливии. Эта статья посвящена трем гигантским и шести крупным месторождениям нефти и газа. В последнее десятилетие разведка нефти и газа в кристаллическом фундаменте была чрезвычайно успешной: в Индонезии, Великобритании, Норвегии, Чад и Аргентине были сделаны важные открытия. Для успешной разработки нефтяных и газовых месторождений, а также для избежания дорогостоящих ошибок, необходимо внимательно изучить все доступные геологические, геофизические, инженерно-геологические и экономические данные. Также очень важно изучить мировые аналоги нефтегазовых месторождений в фундаменте, чтобы понять, почему одни месторождения очень успешны, а другие оказываются техническими и экономическими неудачными.

Ключевые слова: гигантские и крупные месторождения нефти и газа, кристаллический фундамент, залежь

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