International Journal of Multidisciplinary Research and Growth Evaluation.

Characteristics of Basement Reservoirs in Indonesia

Benyamin [1*], M Burhannudinnur [2], Dyah Ayu Setyorini [3]
[1-3] Department of Geological Engineering, Universitas Trisakti, Jakarta, Indonesia

* Corresponding Author: **Benyamin**

Article Info

ISSN (online): 2582-7138
Impact Factor: 5.307 (SJIF)
Volume: 05
Issue: 01
January-February 2024
Received: 09-01-2024;
Accepted: 11-02-2024
Page No: 957-964

Abstract
The lack of information regarding reading materials, references and writings regarding the potential of bedrock reservoirs in Indonesia is the main reason for the author in compiling a paper entitled "Potential of Bedrock Reservoirs in Indonesia". Existing publications are in the form of papers in scientific forums both at home and abroad with topics limited to 2 or 3 existing fields and repeated in almost the same versions and authors. Another factor that is no less important is the fact that subsurface data is only stored in each company's database so that it is difficult for other companies to access it, even for companies with work areas that are located next to each other, thus this potential is not developed more widely.
There are around 70 (seventy) potential bedrock reservoirs spread across 9 basins which are included in the category of basins proven to produce hydrocarbons in 15 Production Company operating in Indonesia. This potential is divided into 4 categories: potential that has become a production field, proven from test results but has not yet been developed, potential based on analogous subsurface data (logs, mud logs and indications from shows) and potential that is still in the form of prospects and concepts. The systematic writing is divided into several chapters, each chapter explaining the potential in each basin, plus a chapter which is a resume of the existing potential.

Keywords: Basement, Reservoir, Distribution, Indonesia

1. Introduction

Basement reservoirs are unique reservoirs because they are different from conventional reservoirs, either sandstone or carbonate reservoirs. According to Landers, 1960, in Koning and Darmono, 1984, basement is all igneous and metamorphic rocks (regardless of the age of rocks) which are not aligned closed by sequences of sedimentary rocks (Figure 1).
Basement reservoirs are a group of naturally fractured reservoirs. This is in line with the statement that the largest proportion of proven reserves in the world is found in reservoir rock fractures. Nelson, 2001, recorded more than 370 fields with natural fracture contributing significantly to hydrocarbon production.
There are three reasons that make basement reservoir important. The first reason is the fact that the search for hydrocarbons in conventional reservoirs has become increasingly difficult. Currently, hydrocarbon exploration activities have to be done near existing field for the probability of success to be high.
Second, it is necessary to change the paradigm of searching for basic hydrocarbons from accidental discovery (the same paradigm when looking for hydrocarbons in conventional reservoirs) to a more purposeful one.
The third reason is study of basic reservoir characteristics such as trap type, reservoir type, petrophysics and production behavior of each base rock. The outcome of the study then can be expected to be an answer to the question of where must we be looking for more hydrocarbons.

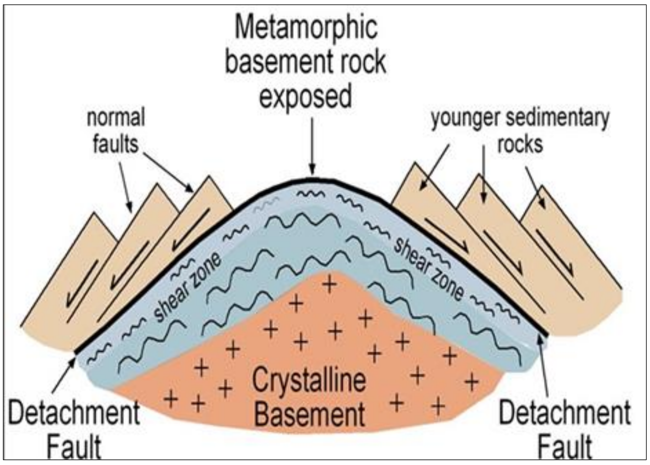

Fig 1: Basement (Modified from Landers, 1960)

Basement Reservoir in Indonesia

Indonesia has an evident potential as oil and gas field, proven by tests result. Everything came from crystalline reservoir, in the form of crystalline rock with rough texture, fine texture, to volcanic rocks.

Indonesia actually has a great potential for crystalline rocks, if not exceptional. And in discussing crystalline rocks in Indonesia, one has to include the potential for volcanic and / or volcaniclastic rocks. The definition or limitation of volcanic and / or volcaniclastics reservoirs in Indonesian region is a reservoir constructed from rocks produced from volcanic eruptions, either direct products (volcaniclastic) or indirect (epiklastik volcanic).

In referance to the basic definition of rock by Landers as previously mentioned, volcanic rocks will not be differentiated here, although in the discussion of pyroclastic rocks there will be a separate classification of volcanic rocks which separate them from the classification of igneous rocks.

In Indonesia there are approximately 70 structures / prospects scattered in 10 basins - nine proven basins and one still in study - (Fig. 2) which potential for basic hydrocarbon reservoirs had been proven. The potential is evident from the results of tests, indications of hydrocarbons from mud log data, and petrophysical analysis or log response.

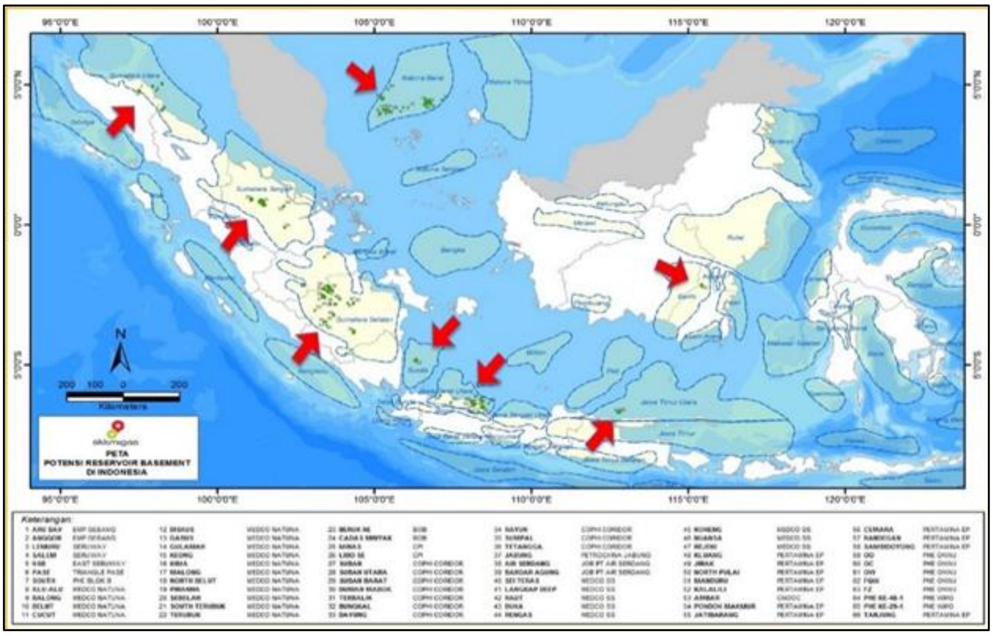

Fig 2: Basement Reservoir Distribution in Indonesia

The nine basins included in the basin category with hydrocarbon production are the basins of North Sumatra, Central Sumatra, South Sumatra, West Natuna, Sunda, North West Java, North East Java, Barito Basin, and Salawati. The potential in the Salawati basin is still being studied.

The width of the basin which has the potential of a basement reservoir is based on the smallest, namely the Sunda basin with an area of 18,840 km2 to the largest one, namely the North East Java basin with an area of 190,300 km2. While the potential number ranges from only one potential (Sunda basin and Barito basin) to the highest, which is 25 potential in the West Natuna basin.

The amount of each potential in each basin has a wide range and there is no correlation between the potential number and the basin area. For example, the Sunda basin with a basin area of 18,840 km2 has one potential, so does the Barito basin with a larger area of 40,660 km2.

Another example is the North East Java basin, with an area as large as 190,300 km2 it has only two potentials, whereas the North West Java basin with a basin area of only 23,340 km2 has 10 potentials (Figure 3).

The lowest percentage potential is one percent in the Barito and Sunda basins to the largest 39 percent in the West Natuna basin (Figure 4).

It can be temporarily concluded that the number of basement reservoir potentials in each basin, the status of each potential, and the hydrocarbons produced, does not depend on the extent of the basin where the potential is located.

The depth of wells that penetrate to the rock base in Indonesia is in the range of 1600 feet to 12500 feet, with locations onshore and offshore. For those who are offshore, the water column depth averages 50-250 feet. The shallow well with a depth of 1634 feet is located in the North East Beruk field, the CPP Working Area in the South Sumatra basin and the deepest well with a depth of 12494 feet is in the 29th structure, the West Madura Offshore Working Area in the

North East Java basin.

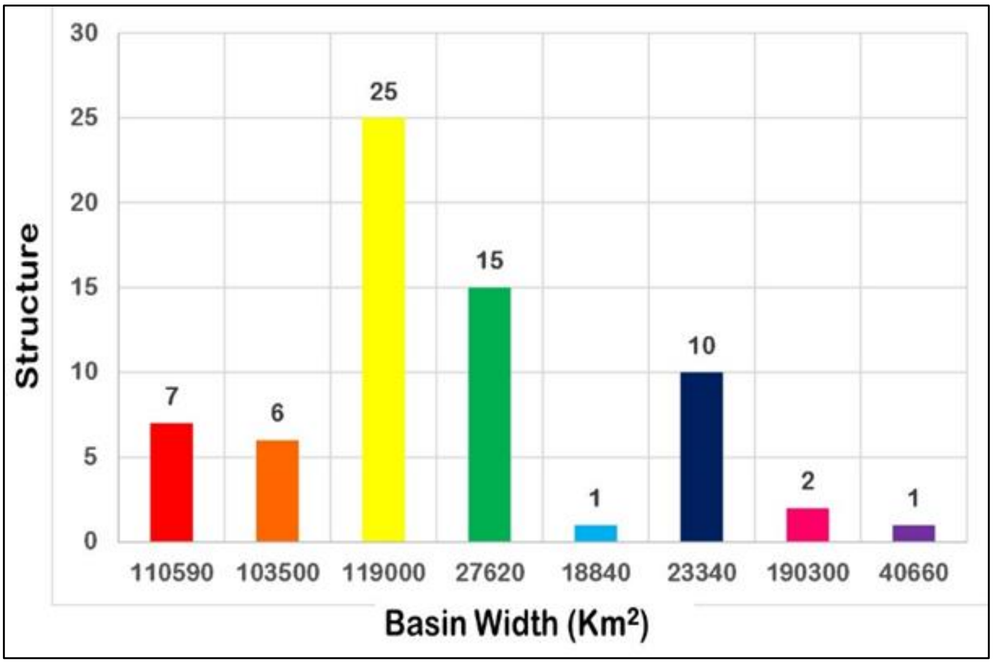

Fig 3: Basin Width Versus Structure

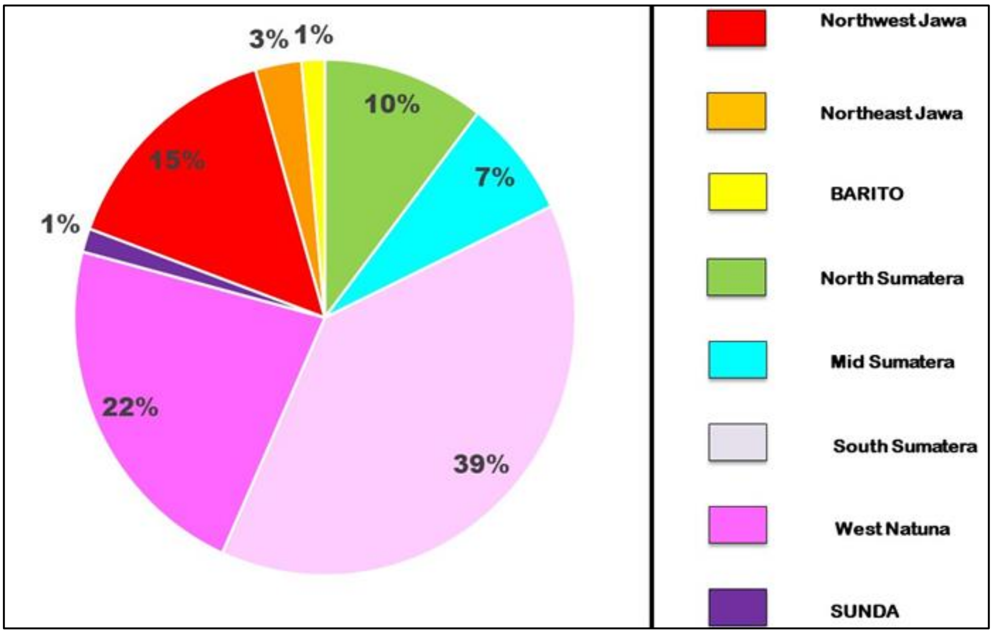

Fig 4: Basin With Basement Reservoirs

The range of basement depth in eight basins that have basement reservoir potential has a range of percentages that are not too wide (20-35 percent). The range can be divided into four, namely a range of 1000 feet to 3000 feet by 20 percent, 3000 feet to 6000 feet (25 percent), 6000 feet to 9000 feet (35 percent) and 9000 feet to 12000 feet (20 percent).

If we use the value of 6000 feet as the middle value of the depth of the rock in the eight basins (the red line in figure 5), then each depth of the basin can be positioned.

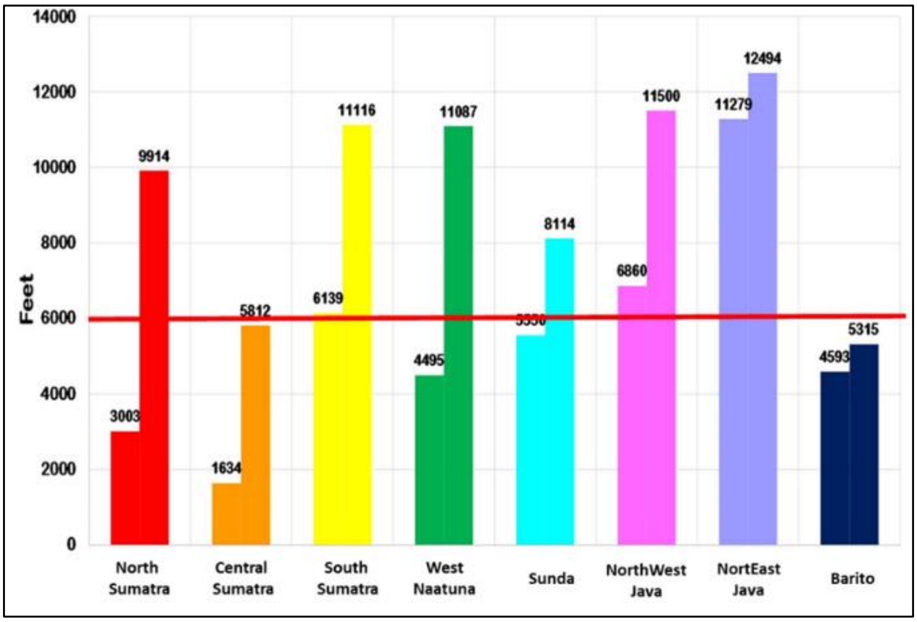

Fig 5: The Depth of Basement Reservoirs

Potential rock reservoirs in the Central Sumatra basin and Barito basins are at the intervals that are not too deep; the South Sumatra basin, North West Java and North East Java are at the deep intervals; while the North Sumatra, West and Sunda Natuna basins have basement reservoir potential at the intervals that are not too deep to deep.

2. Materials and Methods

Basement lithology that has the potential as a hydrocarbon in Indonesia is very varied and very complex. Even in an area that has potential, basement can have lithological variations with mechanism of formation difficult to explain in geological manner.

More than 80 percent of lithology data came from the description of cutting or mud logging data, the remaining 20 percent came from core rock data, half of which are sidewall core data in the form of fullcore data.

Based on the sorting of data from the core that has been carried out by petrographic analysis, log correlation and consideration of several cases of basement lithology that has the potential as a reservoir are simplified into four types, namely Igneous Rocks, Metamorphic Rocks, Volcanic Rocks, and Metasediment Rocks.

Igneous rock, which consists of granite, granodiorite, and diorite (including granite wash), is the most basic type of rock lithology (40 percent). Metamorphic rock consists of schist, phylite, quartzite, and a little gneis (31 percent). Volcanic rocks consist of andesite / basalt and tuff lava (22 percent). Metasediment rocks consist of wacke and or greywacke sandstone and marble which are still seen as rocks of carbonate.

It is more than possible that the basment referred in the definition by Landers in 1960 actually consists of only Igneous Rocks, some Metamorphic Rocks and some Volcanic Rocks, and the rest may or may not meet the basement criteria.

Table 1: Basement lithology variations

North Sumatra	Central Sumatra	South Sumatra	West Natuna	Sunda	North West Java	North East Java	Barito
Granite	Granite	Granite	Granite				
Metamorphic	Metamorphic	Metamorphic	Metamorphic	Metamorphic			
Metasediment	Metasediment	Metasediment			Metasedimen	Metasedimen	
		Volcanic	Volcanic		Volcanic	Volcanic	Volcanic

Composition of the basic rock lithology that has the potential as a hydrocarbon reservoir in each basin is a variation of basic rock lithology consisting of Frozen Rock - which is simplified to Granite, Metamorphic, Metasediment and Volcanic Rock.

Only South Sumatra basin has the fourth complete variation of the basic lithology. Other basins only have two or three lithological variations, some even only one lithology. The North Sumatra Basin for example, consists of three lithologies: Granite, Metamorph and Metasediment; North West Java and North East Java consist of two lithologies: Metasediment and Volcanics; while Sunda and Barito are only one lithology, in the Sunda basin Metamorphic rocks and in Barito Volcanic rocks (Table 1)

Variations in basement reservoir lithology in basins that only have one or two lithologies can not reflect the overall lithological variation of basement in the basin. This limited lithological variation was caused by the low numbers of drilling wells that reached the basement.

Assuming that the variation of rock reservoir lithology in each basin reflects the actual lithological variation, the lithological distribution in each basin is Granite and its variation is in the range of 40-70 percent, Metamorphic (14-40 percent), Metasediment (14 -100 percent), Volcanic rocks (4-100 percent). Figure 6a through Figure 6d shows the distribution of variations in the basement reservoir lithology in each basin.

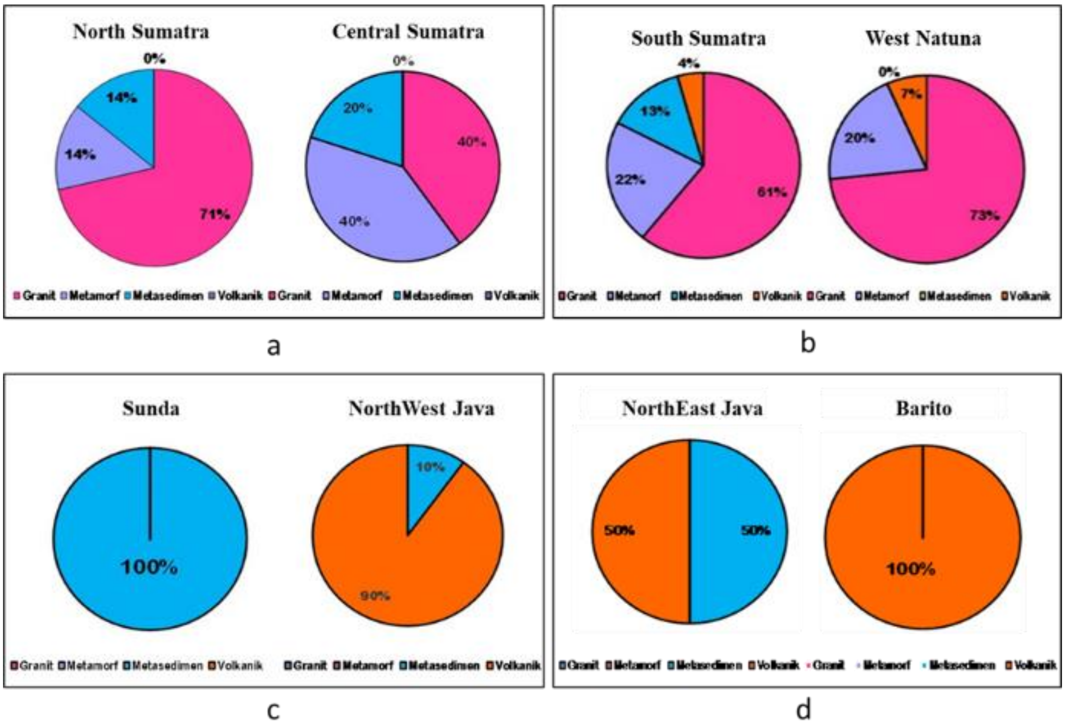

Fig 6: Lithology Variation of Basement Reservoir in each Basin

3. Result and Discussion

The status of the basic reservoir potential is divided into production field, as evidenced by the test results and potential of the show, drilling data such as logs, and other data.

Like the type of lithology, the number of potentials in each basin does not correlate directly with the number of potential statuses as production fields.

For the overall potential, only 42 percent of all potential statuses become production fields (dark green), the rest are still proven from test (light green) and the potential of the show or analogy based on log data, is yellow (Figure 7).

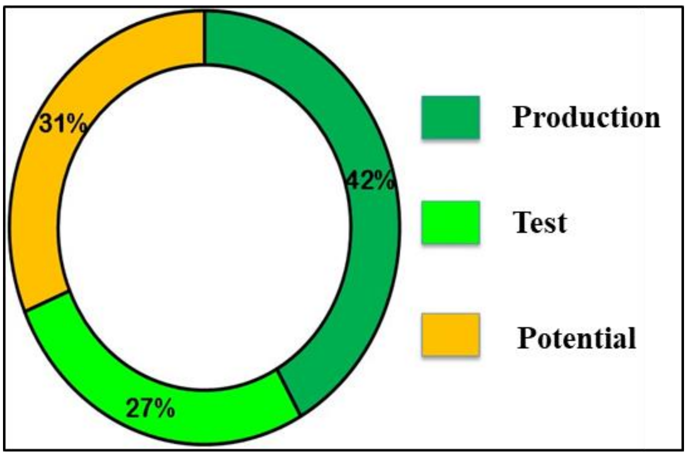

Fig 7: The Status Of Basement Reservoir

Based on statistic data per basin, the highest potential production status is in the South Sumatra basin, which consists of many fields. The status of the proven potential of the most tests is in the North West Java Basin, which also consists of many fields.

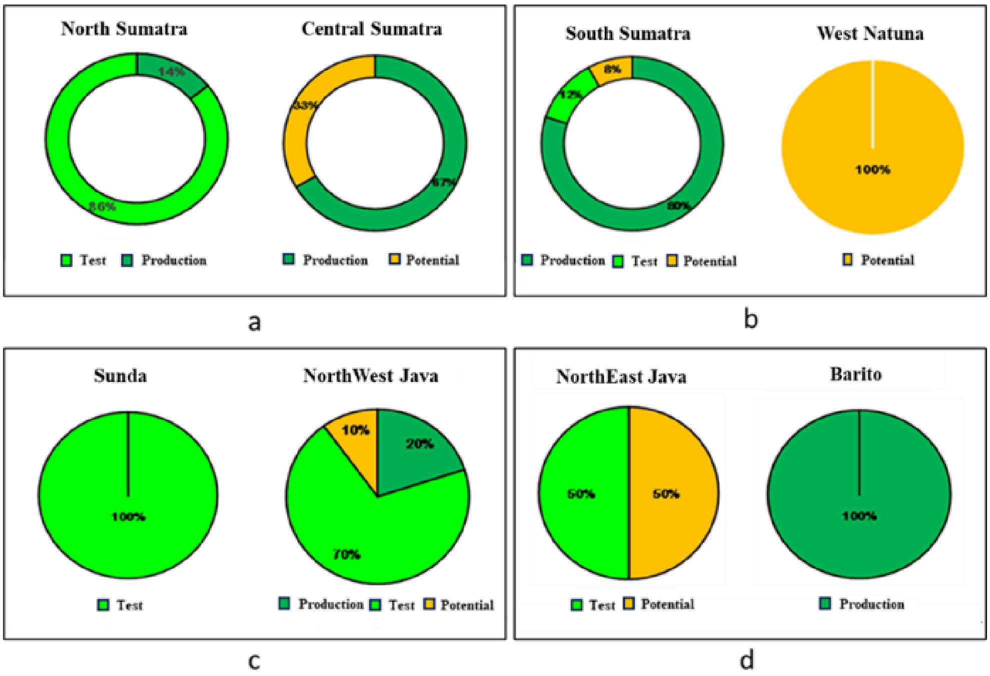

Fig 8: The Status of Basement Reservoir Potential

Next, the greatest potential status is in the Natuna West basin, as many prospects in this basin are drilled to basement. But this needs further proofs, although drilling data for some wells shows an interesting indication, but after being tested it did not produce good results. Figure 8a to Figure 8d show the distribution of the basement reservoir potential status of each basin.

Basement reservoirs in Indonesia in addition to consisting of crystalline and volcanic rocks also have a basic reservoir with weathering lithology from crystalline rocks (especially Granite) called granitic reservoirs.

Basically the basement reservoir is part of the natural fracture reservoir, because it is a crystalline rock that has no primary porosity and permeability. If any, the value is very small so it must have porosity and secondary permeability to be able to become a hydrocarbon reservoir. Secondary porosity and permeability in the rock base are usually produced from natural fractures.

Nelson, 2001, had divided natural fracture reservoirs into four main types - based on matrix characters which are then modified by Alan and Qingsun's, 2003 (Figure 9). In the new classification the difference between type II and type III mainly lies in the terminology of fracture porosity versus reservoir porosity compared to the terminology of permeability.

Based on existing data, basement rock reservoirs in Indonesia can generally be categorized in type II and III, only a few are included in categories I and IV. The basement reservoir type distribution in Indonesia can be seen in figure 10.

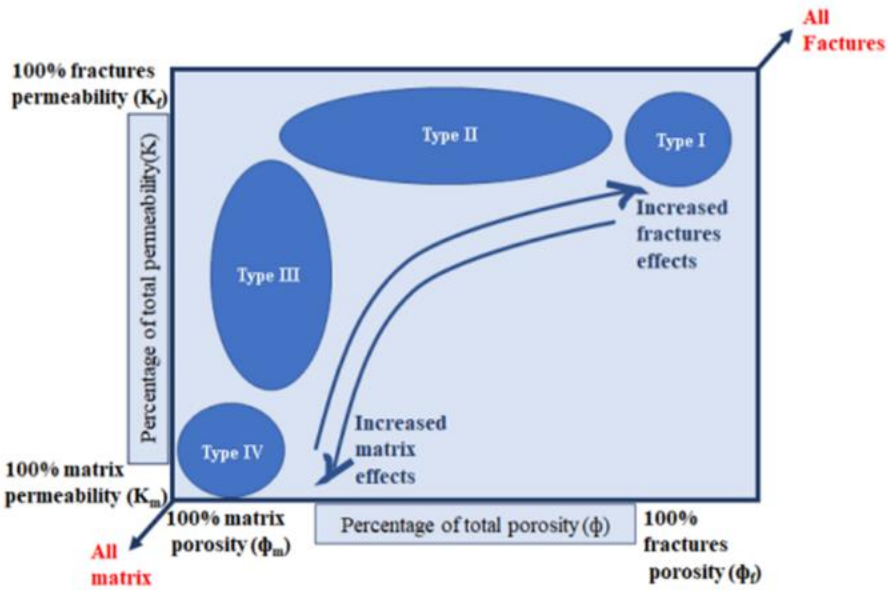

Fig 9: Classification of the naturally fractured reservoir based on percent of total permeability and porosity of the matrix and fractures (Deepshikha Singh, 2023)

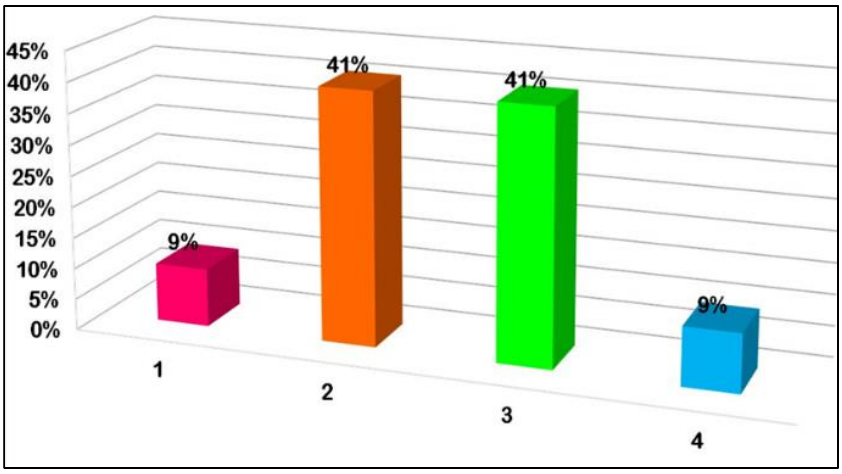

Fig 10: The Basement Reservoir Type Distribution in Indonesia

Regarding the fluid content, based on production results and tests carried out in wells drilled to the basement in Indonesia, the composition of the basement reservoir consists of 54 percent filled with gas, 38 percent containing oil and 8 percent containing water (Figure 11).Based on the results of production and tests carried out in wells drilled to the basement, the composition of the basement reservoir reservoir containing oil versus lithology consists of 30 percent oil in Granite rock and its variations, 33 percent are in various Metamorphic and Metasediment rocks and 37 percent are in various types of Volcanic rocks (Figure 12).

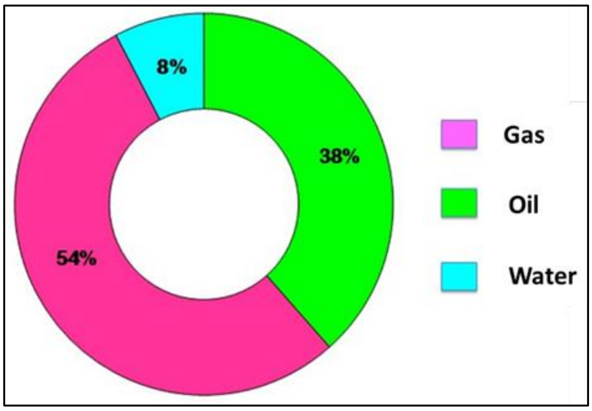

Fig11: Fluid Content in Basement Reservoir

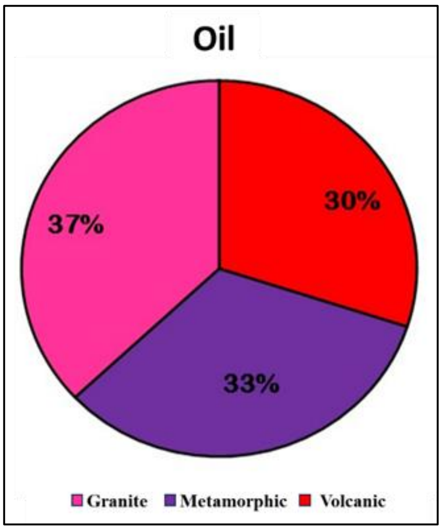

Fig 12: Oil Content in Basement Reservoir

The composition of the basement reservoir content containing gas versus lithology consists of 53 percent of gas in Granite rock and its variations, 40 percent are in various types of Metamorphic and Metasediment rocks and only 7 percent are in various types of Volcanic rocks (Figure 13). This discussion section provides a comprehensive analysis of the challenges, distribution, potential, and future prospects of basement reservoirs in Indonesia, with the aim of stimulating increased exploration and exploitation activities in this unique and valuable resource.

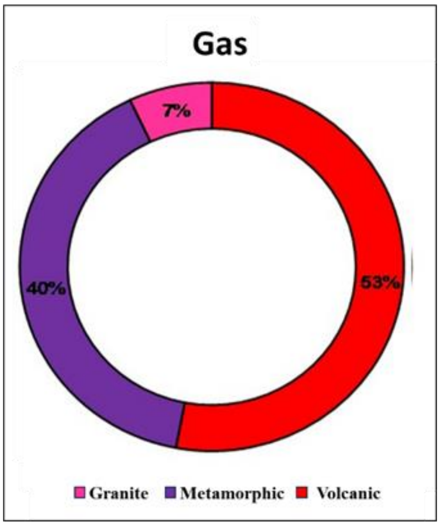

Fig 13: Gas Content in Basement Reservoir

4. Conclusion

1. The lack of information regarding reading materials, references and writings regarding the potential of bedrock reservoirs in Indonesia is the main reason the author wrote a paper entitled "Potential of Bedrock Reservoirs in Indonesia"
2. This is because subsurface data is only stored in each company's database, making it difficult for other companies to access it, even for companies with adjacent work areas, so the potential is not developed more widely.
3. There are around 70 (seventy) potential bedrock reservoirs spread across 9 basins which are included in the category of basins proven to produce hydrocarbons in 15 Production Companies operating in Indonesia
4. This potential is divided into 4 categories, namely

potential that has become a production field, proven from test results but has not yet been developed, potential based on subsurface analog data (logs, mud logs and indications of oil appearance) and potential that is still in the development stage. form prospects and concepts
5. It is hoped that this article can stimulate oil and gas exploration and exploitation activities in basement reservoirs in Indonesia

5. Acknowledgements
Thank you to Trisakti University management and SKK Migas management for making the data available.

6. References
1. Kamitsuji R, Yakoi S, Okajima T. Acid Stimulation of Onnagawa Tight Oil Formation in Ayukawa Field, Japan. SPE Unconventional Resources Conference and Exhibition-Asia Pacific; 2013 Nov 11-13; Brisbane, Australia, 2013.
2. Benyamin. Analysis of Source Rock and Hydrocarbon Filling Volcanic Reservoir in Indonesia. In: AAPG GTW Influence of Volcanism and Associated Magmatic Processes on Petroleum Systems; 2017 Mar 14-16; Oamaru, New Zealand, 2017.
3. Nurisman Syarif AM, Pahlevi MR, Annas AS. Basement Reservoir Play Concept and Its Potential in Western Indonesia. 36th, 2015 May.
4. Lyu Q, Wang W, Jiang Q, Yang H, Deng H, Zhu J, *et al*. Basement Reservoirs in China: Distribution and Factors Controlling Hydrocarbon Accumulation. Minerals. 2023; 13(8):1052.
5. Bawazer W, Lashin A, Kinawy MM. Characterization of a fractured basement reservoir using high-resolution 3D seismic and logging datasets: A case study of the Sab'atayn Basin, Yemen. PLOS ONE. 2018; 13(8):e0206079.
6. Risyad M, Suta IN, Haris A. Fault assessment for basement reservoir compartmentalization: Case study at Northeast Betara gas field, South Sumatra Basin. AIP Conference Proceedings. 2017; 1862:030186.
7. Department of the Interior U.S. Geological Survey. Field-Trip Guide to Columbia River Flood Basalts, Associated Rhyolites, and Diverse Post-Plume Volcanism in Eastern Oregon, U.S. Scientific Investigations Report 2017–5022–O, 2017.
8. Nanda N. Fractured-Basement Reservoirs. In: Seismic Data Interpretation and Evaluation for Hydrocarbon Exploration and Production. 2021, 293-304.
9. Permana BR. Fractured-Basement Reservoirs: An Overview. IPA, 2019. DOI:10.13140/RG.2.2.14259.58408.
10. Koning T. Global Accumulations of Oil & Gas in Fractured and Weathered Basement: Best Practices for Exploration & Production. Poster Presentation to the AAPG International Conference & Exhibition, 2014.
11. Pamurty PG, *et al*. Identification of Fractured Basement Reservoir in SWO Field, Salawati Basin, West Papua, Based on Seismic Data: A New Challenge and Opportunity for Hydrocarbon Exploration in Pre-Tertiary Basement. 32nd Annual Convention Proceedings, 2016.
12. Banks G, *et al*. Liverpool Land Basement High, Greenland: visualising inputs for fractured crystalline basement reservoir models. GEUS Bulletin, 2018. DOI: https://doi.org/10.34194/GEUSB-201943-02-04.
13. Hennings P, *et al*. Relationship Between Fractures, Fault Zones, Stress, and Reservoir Productivity in the Suban, gas field, Sumatra, Indonesia. AAPG Bulletin, 2012, 96(4).
14. Choudhary N, Singh D, Phirani J. Simulation and modeling of fractured reservoirs: an overview. In: Challenges and Recent Advances in Sustainable Oil and Gas Recovery and Transportation, 2023, 177-195.
15. Zou C. Volcanic Reservoirs; Petroleum Exploration. Elsevier Science, 2013.
16. Liu J, Wang P, Zhang Y, Bian W, Huang Y, Tang H, *et al*. Volcanic Rock-Hosted Natural Hydrocarbon Resources: A Review, 2012. Available from: https://www.intechopen.com/chapters/41663.