UNCONVENTIONAL HYDROCARBONS IN LIBYA – A REVIEW

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الملخص

يعد الغاز الصخري والنفط الصخري وهيدرات الغاز وميثان طبقة الفحم وغاز الرمال الحبيس من الأنواع الرئيسية للهيدروكربونات غير التقليدية. وتشير الأبحاث الحديثة إلى أن هذه المصادر ستهيمن كمصدر للطاقة في المستقبل. المشكلة الرئيسية هي الأضرار البيئية أثناء الإنتاج. الهيدروكربونات غير التقليدية في ليبيا ممثلة بالغاز الصخري والنفط الصخري. بالمقارنة مع الاحتياطيات التقليدية، تمتلك ليبيا احتياطيات غير تقليدية أكبر بكثير. المناطق الرئيسية للهيدروكربونات غير التقليدية في ليبيا هي أحواض سرت وغدامس ومرزق. الهدف من هذا العمل هو مراجعة الأبحاث السابقة التي تتعلق بالغاز الصخري والنفط الصخري في ليبيا من أجل تقديم رؤية أكثر شمولية لهذه الموارد المستقبلية.

الكلمات المفتاحية: الغاز الصخري، النفط الصخري، حوض سرت، حوض غدامس، حوض مرزق، حوض بنغازي، ليبيا.

Abstract

Shale gas, shale oil, clathrates, coal bed methane and tight sands are the main types of unconventional hydrocarbons. Recent research indicates that these sources will dominate as a source of energy in the future. The main problem is the environmental damage during production. Unconventional hydrocarbons in Libya are represented by shale gas and shale oil. In comparison to conventional reserves, Libya possesses significantly more unconventional hydrocarbon reserves. The Sirte, Ghadames, and Murzuq basins are the primary areas of the unconventional hydrocarbons. Reviewing earlier research on shale gas and shale oil in Libya is the aim of this work in order to present a more holistic view of these future resources.

Keywords: Shale Gas, Shale Oil, Sirte Basin, Ghadames Basin, Murzuq Basin, Benghazi Basin, Libya.

1. Introduction

In 2011 the world began to enter the so-called Golden Gas Era in the USA. The USA has been able to develop technologies to produce oil and gas from unconventional sources such as shale oil, shale gas, tight sands, clathrates and coal bed methane (e.g., [1]; [2]; [3]; [4]; [5]). These contemporary technologies have transformed gas into oil and derived oil from coal. According to [6], in 2035, China, Australia, and USA will produce 62, 50, and 46% of their total gas output from shale gas, respectively. Moreover, [7] issued a new report, which showed that there are 41 countries have reserves of shale gas and shale oil. The most important reserves are found in Russia, Argentina, Mexico, Algeria, Libya, Canada, UK and Netherlands. In addition, the recoverable reserves of shale oil and shale gas in the world are estimated at 345 B bbl and 7201 Tcf [8].

Shale gas and shale oil are natural gas and crude oil generated within shale formations. Shale is usually characterized by low permeability which makes shale gas and shale oil trapped in it. The most important environmental challenge facing shale gas and shale oil extraction is the leakage of some greenhouse gases into the atmosphere. Recent studies have shown that CO_2 pollution will rise by 20% in 2035 [9].

Sedimentary basins in Libya are divided into: (1) Continental basins (Ghadames, Murzuq, Sirte, Kufra, and Cyrenaica); and (2) Offshore basins (Sabratah, Misratah and Benghazi basins, Fig. 1). In Libya, proven reserves of 48.4 B bbl of crude oil and 50 Tcf of natural gas were found in the conventional reservoirs [10]. These proven reserves exist in the Sirte, Murzuq, Ghadames, and Sabratah basins. Shale oil and shale gas constitute unconventional hydrocarbons in Libya. These unconventional sources are mainly found in the Sirte (the Sirte/Rachmat Shale (Late Cretaceous) and the Etel Shale (Late Cretaceous)), Ghadames (the Hot Shale Member of the Tanezzuft Formation (Early Silurian) and the Awaynat Wanin/Frasnian Shale (Late Devonian)), and Murzuq (the Hot Shale Member) basins [11]; [12]; [13]), with trace quantities in the Benghazi Basin (the Lower Shale Formation (Apollonia Shale, Early Eocene) and the Upper Shale Formation (Shahhat Shale, Early Oligocene)) [14]**;** [15]). Because of the conjectural and restricted nature of the available data,

The Kufra Basin is deliberated but not quantitatively evaluated [11]. Theses shales contain reserves of 613 B bbl of risked OIP (with 26.1 B bbl as the risked) and 942 Tcf of risked GIP (with 122 Tcf as the risked) [11]. The aforementioned indicates that Libya has substantially larger unconventional hydrocarbon reserves than conventional reserves (Figs. 2 and 3), but gas and oil production in Libya is only from the conventional reservoirs. The goal of this work is to review previous studies related to the unconventional hydrocarbons in Libya to provide a more comprehensive vision of these future sources.

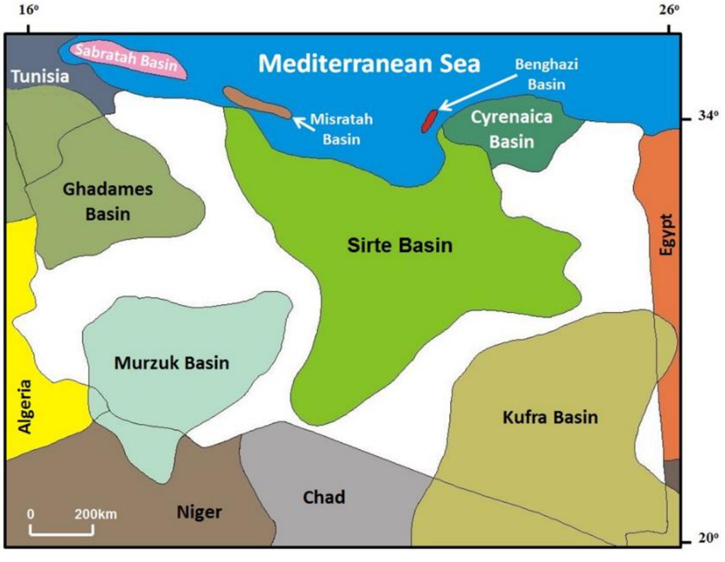

Fig. 1: Map presenting the sedimentary basins in Libya (after [13]).

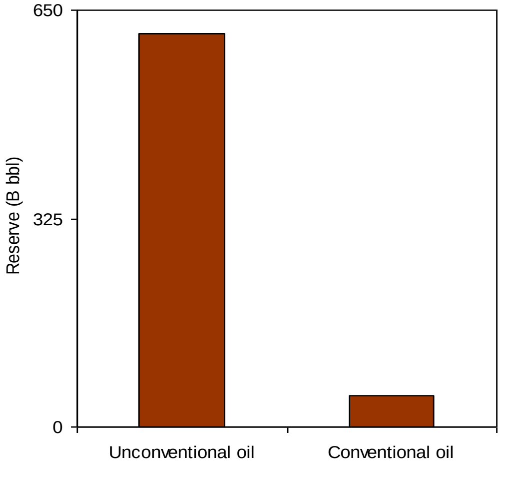

Fig. 2: Comparison between conventional and unconventional oil reserves in Libya.

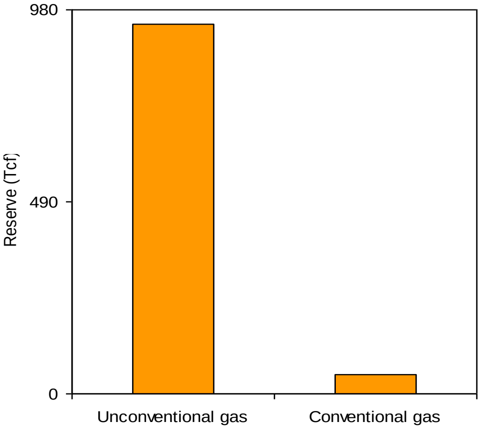

Fig. 3: Comparison between conventional and unconventional gas reserves in Libya.

2. Shale Oil

Shale oil in the Hot Shale Member was evaluated by [13] in wells D1-NC 174 and E1-NC 115 in the Murzuq Basin. They found that the member in well E1-NC 115 contains thick medium oils (Fig. 4).

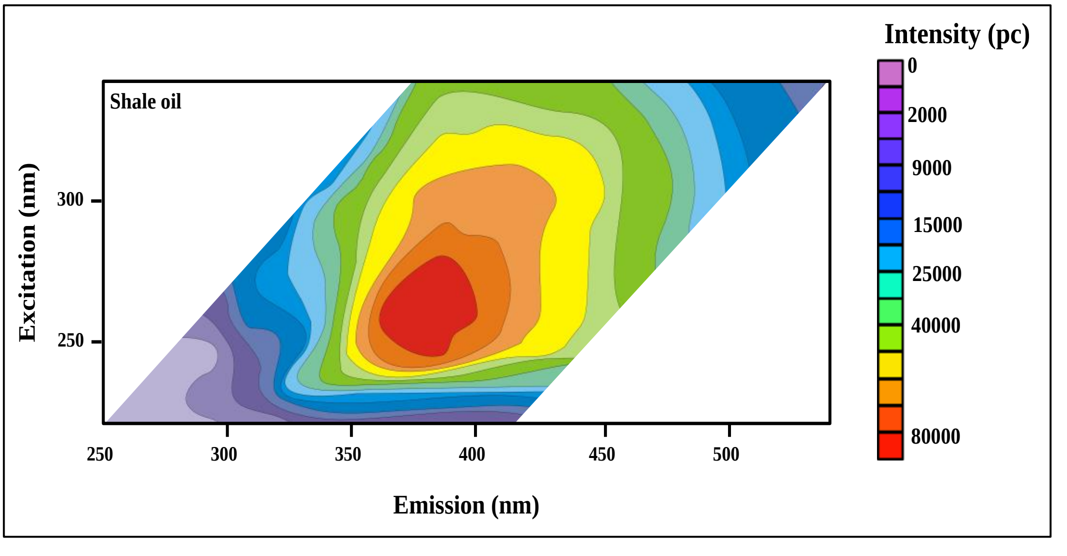

Fig. 4: Spectrograms of shale oil in the Hot Shale Member in well E1-NC 115 by TSF analysis (after [13]).

They also found that well D1-NC 174 is dominated by light oils (API gravity values range from 33.28° to 39.66°). As a feedstock for Libya's current conventional crude oil refineries, shale oil was assessed by [16]. The conclusions of this study are as follows: (1) It is possible to produce shale oil in the Murzuq basin and transport it to the Zawiya refinery for additional processing; (2) Shale oil is a new feedstock for product completing that can be processed using an existing crude oil refinery; (3) To reduce the cost of transportation, the produced shale oil can be moved via the network of pipes already in place; and (4) Since the quality of shale oil is comparable to that of conventional crude oil, it can also be used as feedstock in existing refineries with surface facilities.
The shale oil reserves in the Sirte, Ghadames and Murzuq basins are shown in Table 1.

Table 1: Shale oil reserves in the Ghadames, Murzuq and Sirte basins (after [11])

Basin	Reservoir	Oil phase	OIP concentration ($MMbbl/mi^2$)	Risked OIP (B bbl)	Risked recoverable (B bbl)
Ghadames	Hot Shale Member	Oil	12.0	98.8	4.94
		Condensate	3.1	5.1	0.26
	Awaynat Wanin/Frasnian Shale	Oil	31.3	24.6	1.23
		Condensate	7.0	1.3	0.06
Murzuq	Hot Shale Member	Oil	9.5	26.9	1.34
Srite	Sirte/Rachmat Shale	Oil	28.8	405.9	16.24
	Etel Shale	Condensate	6.3	50.5	2.02

Here is a brief explanation of the shale oil reserves: (1) Compared to the Murzuq Basin, the Hot Shale Member in the Ghadames Basin has greater reserves of shale oil (Fig. 5); (2) The Hot Shale Member in the Ghadames Basin has a larger reserve of shale oil than the Awaynat Wanin/Frasnian Shale (Fig. 6); (3) In the Sirte Basin, the shale oil reserves in the Sirte/Rachmat Shale are obviously high, while the Etel Shale's reserves are clearly low (Fig. 7); and (4) The Sirte/Rachmat Shale contains the highest reserves of shale oil in Libya (Fig. 8).

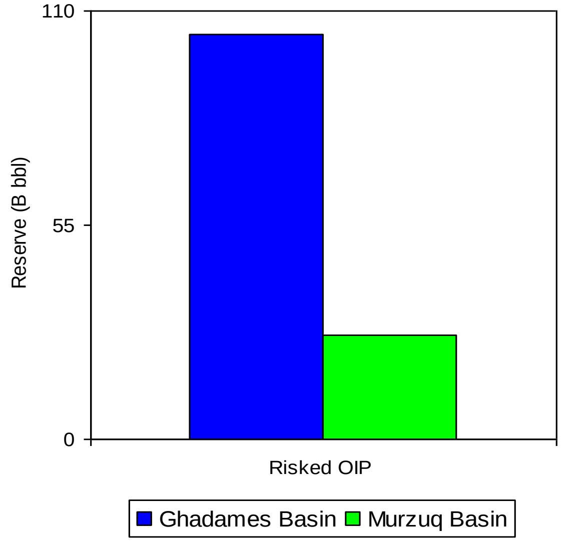

Fig. 5: Shale oil reserves in the Hot Shale Member in the Ghadames and Murzuq basins.

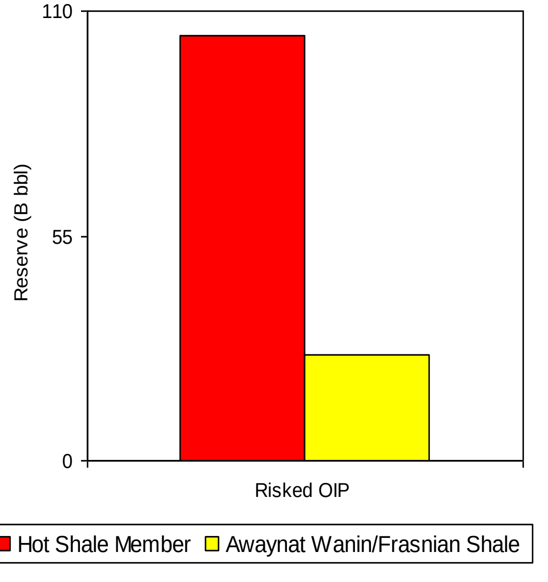

Fig. 6: Shale oil reserves in the Hot Shale Member and the Awaynat Wanin/Frasnian Shale in the Ghadames Basin.

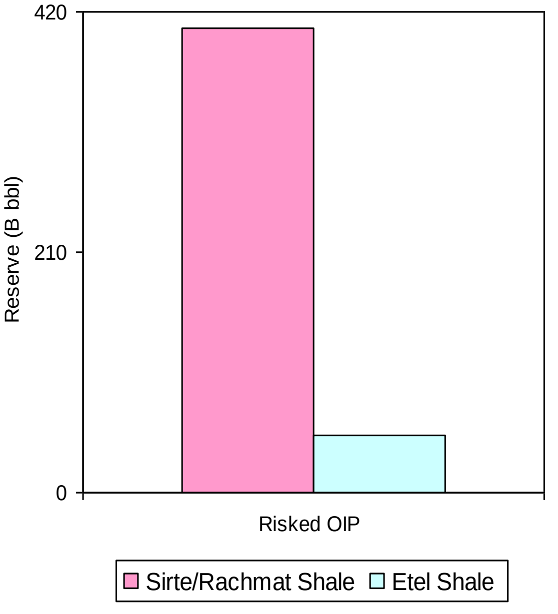

Fig. 7: Shale oil reserves in the Sirte/Rachmat Shale and the Etel Shale in the Sirte Basin.

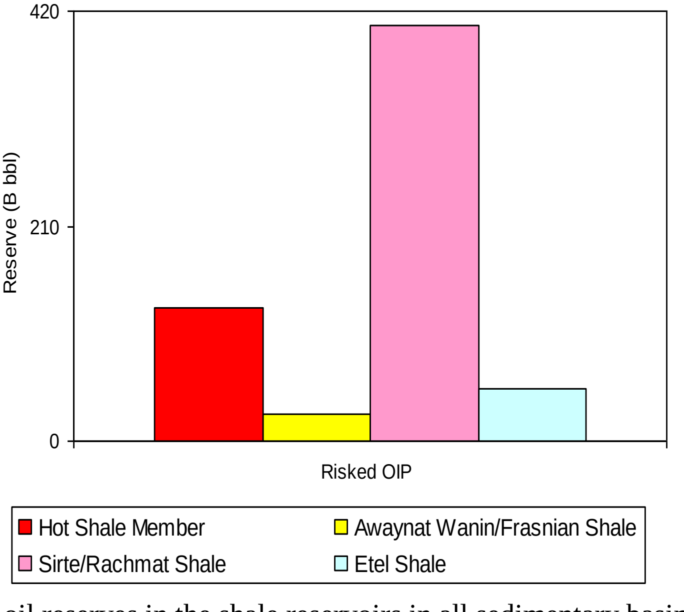

Fig. 8: Shale oil reserves in the shale reservoirs in all sedimentary basins in Libya.

3. Shale Gas

When compared to other shale gas basins in the world, the evaluation parameters (estimated basin area, shale play thickness, TRR, TOC, gas saturation, kerogen type, and SWOT analysis matrix) of the Ghadames basin yielded positive results that suggested the resource's potential for maintainable improvement in the future [17]. [13] revealed that adsorbed shale gas is dominant in the Hot Shale Member in well D1-NC 115 in the Murzuq Basin. In the Ghadames Basin, the maximum values of TEG and TRG are up to88 bcf/section and 96 bcf/km, respectively, with the present geological and geochemical characteristics, volumes, and dissemination of the dry gas sweet spot [18]. [15] estimated shale gas in the Benghazi Basin. Seven conclusions were reached: (1) Hydrocarbon gases are highly concentrated in the Apollonia Shale and the Shahhat Shale, while non-hydrocarbon gases are present in smaller amounts; (2) The hydrocarbon gases in the Apollonia Shale are primarily thermogenic, while those in the Shahhat Shale have mixed compositions; (3) Wet gas is prevailing in the shales; (4) The shales contain thermogenic CO_2; (5) Crustal origin is the main source of nitrogen and noble gases; (6) The gas content is very low (the highest value is 2.4 m^3/t); and (7) The Apollonia Shale and the Shahhat Shale contain adsorbed gas and free gas, respectively.

Table 2 displays the shale gas reserves in the Sirte, Ghadames and Murzuq basins.

Table 2: Shale gas reserves in the Ghadames, Murzuq and Sirte basins (after [11])

Basin	Reservoir	Gas phase	GIP concentration (Bcf/mi^2)	Risked GIP (Tcf)	Risked recoverable (Tcf)
Ghadames	Hot Shale Member	Associated gas	11.8	96.9	9.7
		Wet gas	43.4	72.7	14.5
		Dry gas	54.5	70.3	17.6
	Awaynat Wanin/Frasnian Shale	Associated gas	25.4	19.9	2.0
		Wet gas	79.8	14.8	3.0
		Dry gas	93.1	1.4	0.3
Murzuq	Hot Shale Member	Associated gas	6.5	18.6	1.9
Srite	Sirte/Rachmat Shale	Associated gas	24.8	349.8	28.0
	Etel Shale	Wet gas	37.4	297.9	44.7

Below is a brief discussion of shale gas reserves: (1) The Hot Shale Member in the Ghadames Basin has larger shale gas reserves than the Murzuq Basin (Fig. 9); (2) In the Ghadames Basin, the Awaynat Wanin/Frasnian Shale is lower in shale gas reserves than the Hot Shale Member (Fig. 10); (3) In the Sirte Basin, the reserves of shale gas in the Sirte/Rachmat Shale are slightly greater than those in the Etel Shale (Fig. 11); and (4) Libya's largest shale gas reserves are found in the Sirte/Rachmat Shale (Fig. 12).

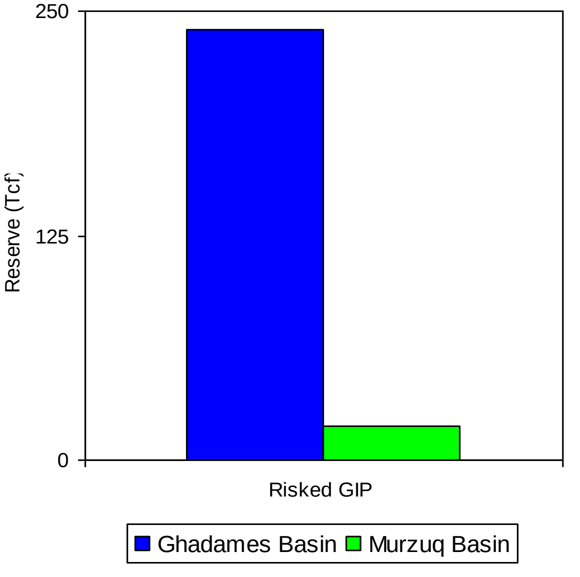

Fig. 9: Shale gas reserves in the Hot Shale Member in the Ghadames and Murzuq basins.

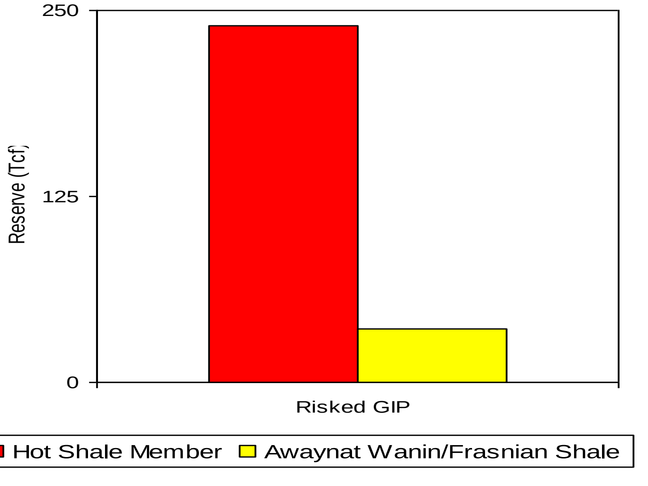

Fig. 10: Shale gas reserves in the Hot Shale Member and the Awaynat Wanin/Frasnian Shale in the Ghadames Basin.

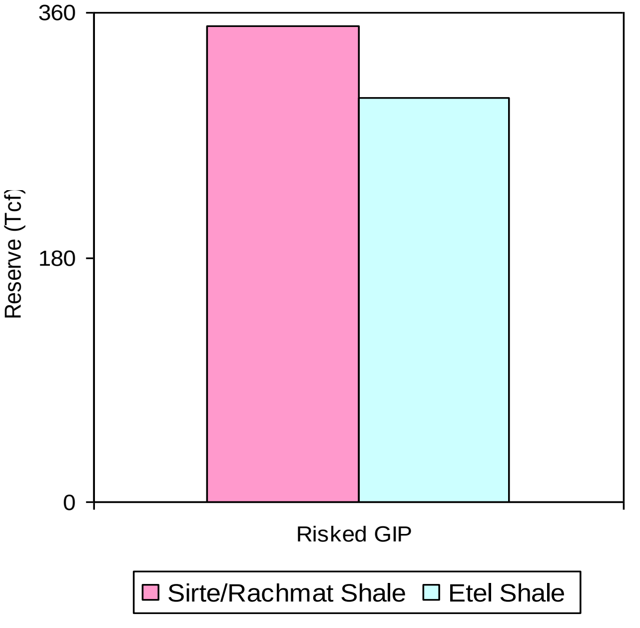

Fig. 11: Shale gas reserves in the Sirte/Rachmat Shale and the Etel Shale in the Sirte Basin.

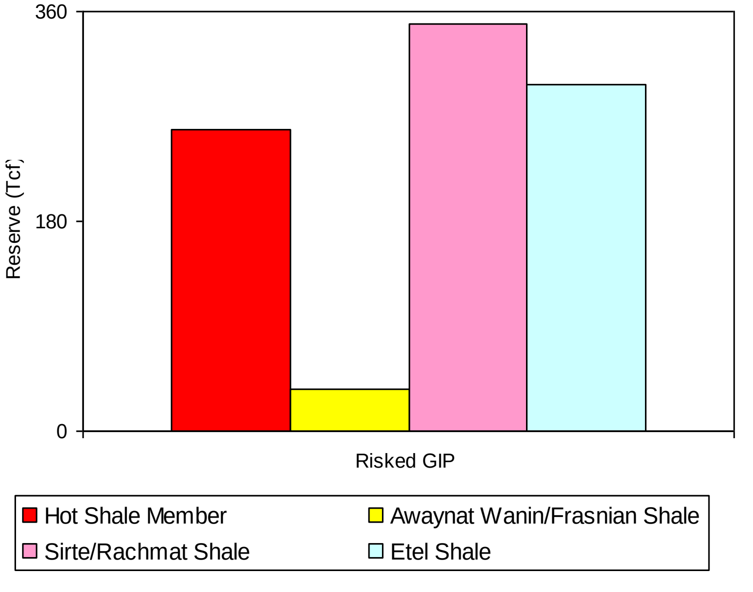

Fig. 12: Shale gas reserves in the shale reservoirs in all sedimentary basins in Libya.

4. Conclusions

According to recent studies, the main energy sources of the future will be the unconventional hydrocarbons. Shale gas and shale oil represent unconventional hydrocarbons in Libya. Libya possesses much more unconventional hydrocarbon reserves than conventional ones. The principal areas of unconventional hydrocarbons are the Ghadames, Murzuq and Sirte basins. In this work, recent research related to shale gas and shale oil in Libya was reviewed.

5. Recommendation

This review clarified the importance of shale gas and shale oil as a future source of energy in Libya, taking into account the environmental degradation.

6. Abbreviations

API = American Petroleum Institute
B bbl = billion barrels
Bcf = billion cubic feet
GIP = gas in-place
MMbbl = million barrels
m^3/t = cubic meter per ton
OIP = oil in-place
TEG = total expelled gas
Tcf = trillion cubic feet
TOC = total organic carbon
TRG = retained gas
TRR = technically recoverable reserve
TSF = total scanning fluorescence
SWOT = Weaknesses, threats, strengths and opportunities

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