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Litho-Statistical Study of Both the Jurassic and Cretaceous Type Sections in Saudi Arabia

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ABSTRACT. Litho-statistical study of both the Jurassic and the Cretaceous Formations' type sections suggests optimum lithological combinations of reservoir and cap rocks for possible oil accumulations in the Arab, Wasia, and Biyadh Formations. The Hith Formation is by far the best cap rock. Massive source rocks can exist in formations such as the Dhruma, Tuwaiq Mountain, Hanifa, and Sulaiy, if they contain sufficient amounts of organic matter and are geochemically mature. Both the statistics of the producing reservoirs and the geochemical analysis of the source in the region support the above conclusions.

Introduction

In order that a formation can become an important source, reservoir or cap rock for a petroleum accumulation, it must have a set of physical, chemical, and geological characters which help to generate, migrate, trap or cap hydrocarbons. Such characters can be expressed in terms of organic content and maturity, capillary pressure, porosity, permeability, ... etc., and are either directly or indirectly related to the basic lithological characteristics of the formation such as composition and thickness.

Knowing such lithologic characteristics may not, however, guarantee a good source, reservoir or cap rock, but may provide a clue to the possibility of having it. Comparison of such possibilities in different areas would be valuable in assessing exploration prospects in the region.

In this paper, data of lithology and thickness of the Jurassic and Cretaceous formations at the type localities as defined by Powers *et al.* (1966) are statistically analysed in the light of source, reservoir or cap rock capacity. However, because of lithofacies differences between the subsurface succession in the Eastern Province, where most oil pools occur, and the outcrop sections in the Central Province, where most type localities except that of the Arab Formation exist, some of the present statistical interpretations may not be valid.

Therefore, it is strongly recommended, here, to study the subsurface Jurassic-Cretaceous succession in the Eastern Province, to understand the statistical relationships with the occurrence of oil there. Such analysis could not be tackled here because of the unavailability of data due to its confidential nature.

Consequently, the interpretations, presented hereafter in this paper, are considered to be tentative and may change greatly with changing data. Nevertheless, the approach used in this paper is believed to have great potentials for future applications.

The following tentative guidelines were employed for interpreting the litho-statistical data.

1. For Source Rocks

A typical source rock is defined as a fine-grained rock which has generated and expelled hydrocarbons in sufficient amounts. Consequently, the evaluation of source rock depends on the organic carbon content (0.4% or more), the type of the organic carbon, the thermal maturity and the expulsion efficiency.

Ayres *et al.* (1982) mentioned that organic rich carbonate rocks in the Middle Jurassic and Early Crataceous subsurface successions of Saudi Arabia have an average organic carbon content of 3 to 5% (Fig. 1). However, in order to generate significant amounts of hydrocarbons, source rocks must also satisfy a minimum thickness which is arbitrarily considered, here, to be 4m, and must have sufficient amounts of organic matter and enough maturity.

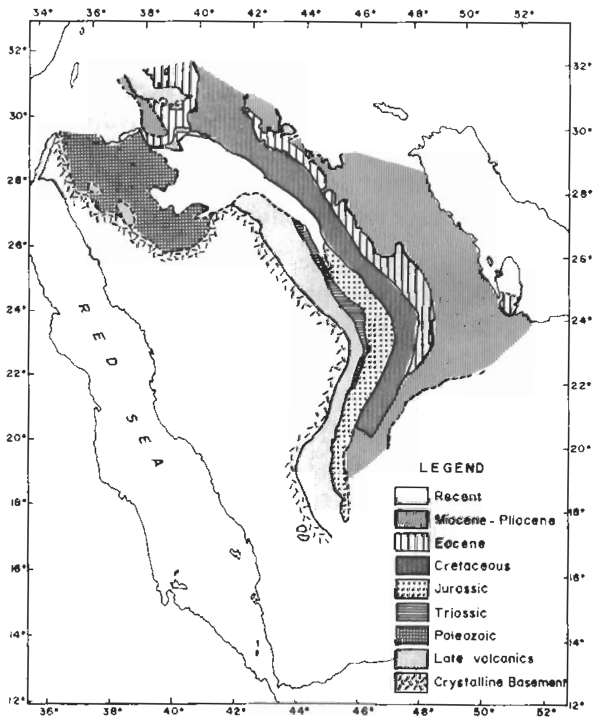

FIG. 1. Location map showing study area (after Powers *et al.* 1966).

2. For Reservoir Rocks

A reservoir is a hydrocarbon container which has relatively continuous porous media in a developed trap. It can be composed of calcarenites, fractured carbonates, sandstones, fissured crystalline rocks, ... etc. Two major types of reservoirs have been described in northeastern Saudi Arabia: calcarenites associated with dolomites, and sandstones.

The result of a preliminary study of the Arab Formation, the most important reservoir in Arabia, suggests that thinly interbedded (<1m) calcarenite, dolomite and aphanitic limestone can constitute a good reservoir. For sandstones, however, thick and homogeneous reservoirs may be suitable for trapping large amounts of oil.

3. For Seal or Cap Rocks

A seal is an impermeable layer which completely covers the reservoir and forms a vertical discontinuity against upward hydrocarbon migration.

In Saudi Arabia, thick evaporites are the main seal. Shales also can act as a seal.

A. Interpretation of Source, Reservoir, and Sealing Rocks in the Type Sections of the Jurassic Formations in Saudi Arabia

Firstly, using the type locality data by Powers *et al.* (1966), beds of one of the six lithologies (limestones, calcarenite, dolomite, anhydrite, sandstone and shale) were grouped according to their thicknessess (0.5-1, 1-2, 2-4, 4-8m and so on). Secondly, percentage of each lithology which belongs to each thickness interval was computed and plotted in a graphical form (*e.g.* Fig. 2).

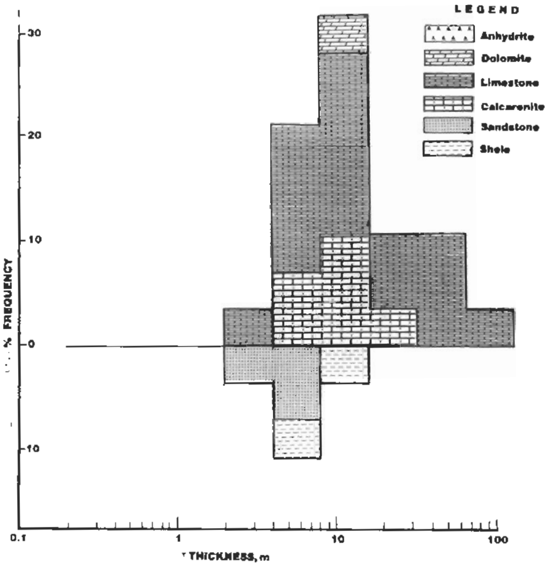

FIG. 2. Lithological frequency plot for the type Tuwaiq Mountain Formation.

To begin our discussions, a typical source (Tuwaiq Mountain Formation), a typical reservoir (Arab), and a typical seal (Hith) will first be described. Explanations for the other Jurassic formation will follow.

1. Typical Source Rock

From the geochemical point of view (*cf.* Ayres *et al.* 1982), the Tuwaiq Mountain limestone is considered as a typical source rock. The litho-statistics shows the best occurrence of frequency values of the aphanitic limestones within the effective thickness intervals (Fig. 2). The frequency value of 3.57% occurs within the thickness interval of 2-4m, whereas the values of 14.28, 17.85, 7.14, 10.71 and 3.57% exist in the effective thickness intervals of 4-8, 8-16, 16-32, 32-64 and 64-128m, respectively. These clearly indicate that the chances for being a reservoir and/or a sealing rock seem to be poor in the Tuwaiq Mountain Limestone outcrops, while the picture may be completely different in the subsurface of the Eastern Province.

2. Typical Reservoir Rocks

The Arab Formation, which has thin and cyclic calcarenite beds associated with both dolomites and aphanitic limestone beds, is believed to be the typical reservoir in the region (Fig. 3). It has a very high calcarenite frequency value of 48.5% which occurs in the thickness interval of 0.5-1m. Other thickness intervals of 1-2 and 2-4m have a frequency value of 4.85%. Dolomite also occurs within the thickness intervals of 0.5-1, and 1-2m with frequency values of 4.85 and 2.91%, respectively (Fig. 3) and the reader is referred to Aramco Staff (1959) for more discussion of the Arab reservoir. The anhydrite content of the Arab Formation shows frequency values of 3.88, 0.97, 1.94, and 0.97% within the thickness intervals of 0.5-1, 1-2, 2-4, 4-8 and 8-16m, respectively (Fig. 3).

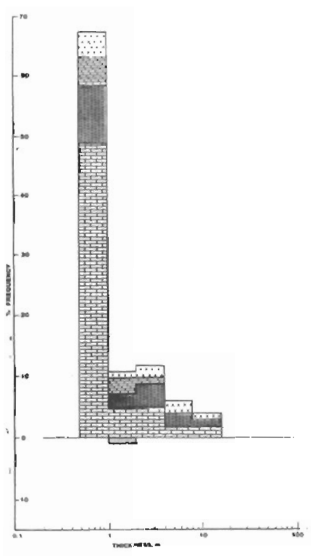

FIG. 3. Lithological frequency plot for the type Arab Formation. Refer to Fig. 2 for legend.

3. *Typical Sealing Rocks*

The Hith Formation (which consists of massive and compact anhydrite with occasional intercalating layers of fine-grained pure limestones) is considered here as a typical seal. The anhydrite of this formation has the highest frequency value among the Jurassic and Cretaceous formations of central Arabia (66.6%). This value occurs within the thickness interval of 2-4m (Fig. 4). The aphanitic and pure limestone has a frequency value of 33.3% within the thickness interval of 8-16m.

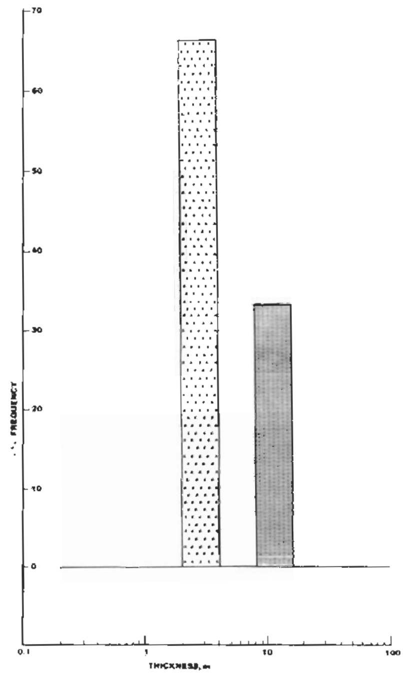

FIG. 4. Lithological frequency plot for the type Hith Formation. Refer to Fig. 2 for legend.

4. *Other Jurassic Formations*

The Jurassic sedimentary sequence in Saudi Arabia consists of the Marrat, Dhruma, Tuwaiq, Hanifa, Jubaila, Arab, and Hith Formations (from base to top). Out of these formations, the Tuwaiq Mountain, Arab, and Hith formations have been described above. Explanations for the other formations will follow:

Marrat Formation (Fig. 5).

a) Potential as Source Rocks

The Marrat Formation has aphanitic limestone frequency values of 5.9, 7.4 and 4.5% for the thickness intervals of 0.5-1, 1-2 and 2-4m, whereas effective thickness intervals of 4-8, 8-16 and 16-32m have frequency values of 5.5, 4.5 and 2.9%, respectively (Fig. 5). The shales have frequency values of 1.49, 1.49 and 4.48% for the thickness intervals of 0.5-1, 1-2 and 2-4m, respectively, whereas thickness intervals of 4-8, 8-16 and 32-64m have frequency values of 11.94, 7.46 and 1.49, respectively.

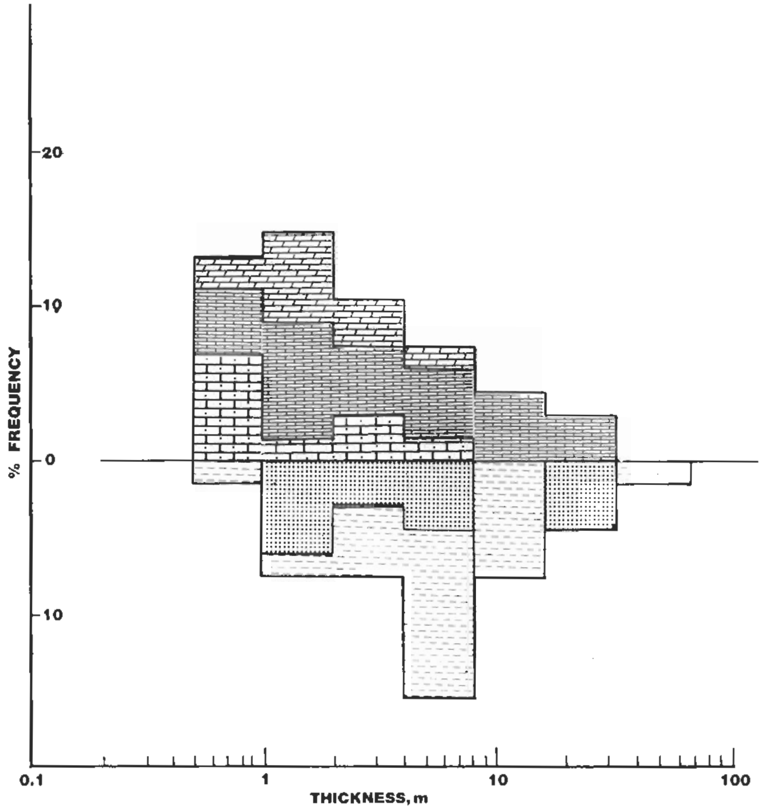

FIG. 5. Lithological frequency plot for the type Marrat Formation. Refer to Fig. 2 for legend.

The interpretation of the frequency values within the effective thickness intervals suggests that the Marrat Formation has a good chance to be a source rock if it is mature and with sufficient organic matter, particularly within the shales which have high frequency values (11.94%).

b) Potential Reservoir Rocks

The calcarenites of the Marrat Formation have frequency values of 5.97, 1.49, 2.98 and 1.49% for the thickness intervals of 0.5-1, 1-2, 2-4 and 4-8m, respectively, whereas dolomites also occur in the same thickness intervals with frequency values of 1.49, 5.97, 2.98 and 1.48%, respectively (Fig. 5). The frequency values of sandstones within the thickness intervals of 1-2, 2-4, 4-8, and 16-32m are 5.97, 2.98, 4.48 and 4.48%, respectively (Fig. 5). The low frequency values of both calcarenites and sandstones suggest that the Marrat Formation has a relatively poor chance to be a reservoir rock for significant amount of hydrocarbons.

c) Potential as Sealing Rocks

Although intercalating, shales may be a possible seal, anhydrites are completely absent within the Marrat Formation, which suggests that there is hardly any chance for the formation to be a good seal.

Dhruma Formation (Fig. 6)

a) Potential as Source Rocks

The Dhruma lithological frequency plot shows that the fine-grained limestones have frequency values of 4.49, 5.3 and 4.9% for the thickness intervals 0.5-1, 1-2 and 2-4m, respectively, while the effective beds which have thickness intervals of 4-8, 8-16, 16-32 and 32-64m have frequency values of 4, 3.67, 2.45 and 1.63%, respectively (Fig. 6). The shales have frequency values of 2.45, 5.71 and 5.3% for the thickness intervals of 0.5-1, 1-2 and 2-4m, and effective thickness intervals of 4-8, 8-16, 16-32, 32-64 and 64-128m have frequency values of 5.3, 4.49, 4.08, 2.45 and 0.4%, respectively (Fig. 6). The frequency values of limestones and shales within the effectiveness thickness intervals suggest that the Dhruma Formation has a good chance to be a source rock.

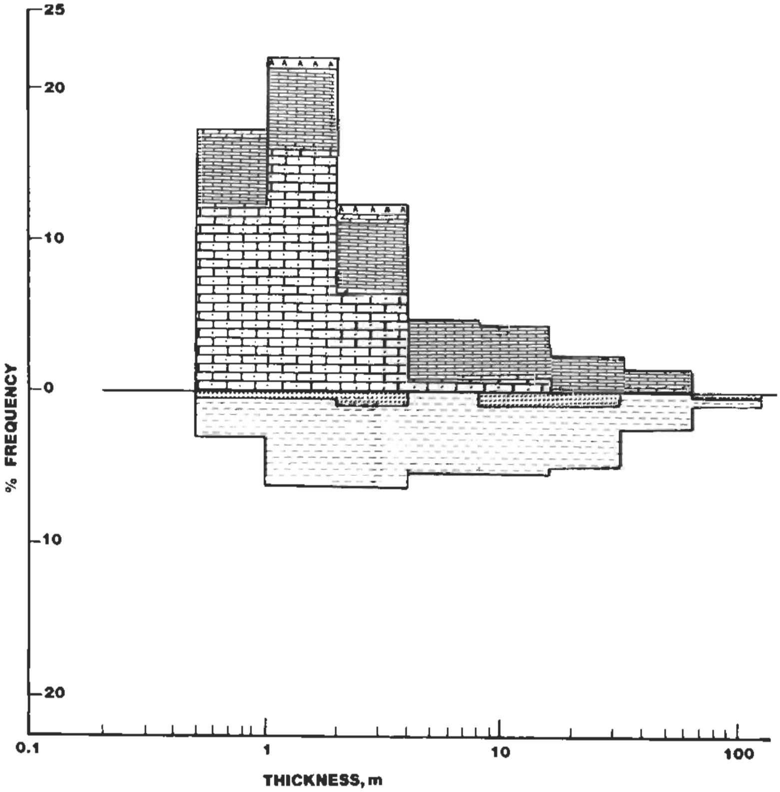

FIG. 6. Lithological frequency plot for the type Dhruma Formation. Refer to Fig. 2 for legend.

b) Potential as Reservoir Rocks

The frequency values of the Dhruma calcarenites occur within the thickness intervals of 0.5-1, 1-2, 2-4m and have values of 12.65, 16-32 and 6.53%, respectively, whereas sandstones have very low frequency values (Fig. 6). This suggests that the Dhruma type section has a little chance to be a reservoir, but not a good one.

c) Potential as Sealing Rocks

The anhydrite frequency values in the Dhruma Formation show very low values of 0.8% for the two thickness intervals 1-2 and 2-4m (Fig. 6). This indicates that there is virtually no chance for the type Dhruma to be a good seal, although shale intercalations may act as good seals.

Hanifa Formation (Fig. 7)

a) Potential as Source Rocks

The frequency plot of the Hanifa section shows aphanitic limestone frequency values of 5.26 and 10.32 for both the thickness intervals of 1-2 and 2-4m, respectively, while the effective thickness intervals of 4-8, 16-32 and 32-64m have frequency values of 5.26, 21.04 (highest value) and 5.26%, respectively (Fig. 7). Shales occur in both the thickness intervals of 4-8 and 8-16m with a common frequency value of 5.26% (Fig. 7). These can suggest that the type Hanifa has a very good chance to be a source rock.

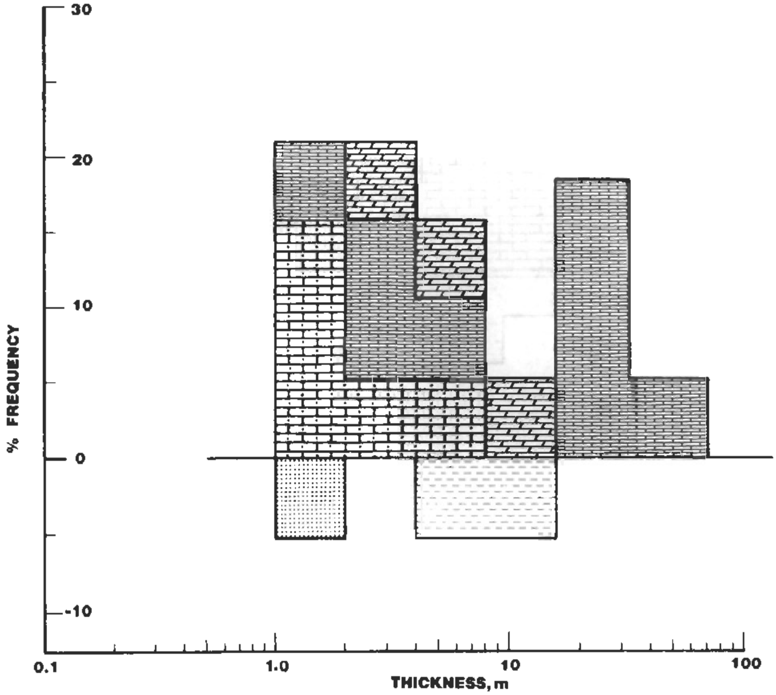

FIG. 7. Lithological frequency plot for the type Hanifa Formation. Refer to Fig. 2 for legend.

b) Potential as Reservoir Rocks

The calcarenites with the thickness interval of 1-2m has the highest value of 15.78%, whereas thickness intervals of 2-4 and 4-8m have a frequency value of 5.26% for both (Fig. 7). Dolomites have a frequency value of 5.26% for the thickness intervals 4-8 and 8-16m. The sandstone frequency value of 5.26% occurs within the thickness interval of 1-2m (Fig. 7). These data can suggest that the type Hanifa Formation has a good chance to act as a reservoir.

c) Potential as Sealing Rocks

No anhydrites were recorded within the type Hanifa Formation to form a good seal, but intercalating shales may have some minor sealing capacities.

Jubaila Formation (Fig. 8)

a) Potential as Source Rocks

Aphanitic limestones have frequency values of 4% for the thickness interval of 2-4m, whereas the effective thickness intervals of 4-8, 8-16, 16-32 and 32-64m have frequency values of 16, 8, 4 and 4%, respectively (Fig. 8). These values suggest that the type Jubaila Formation has a very good chance to be a source rock from the litho-statistical standpoint.

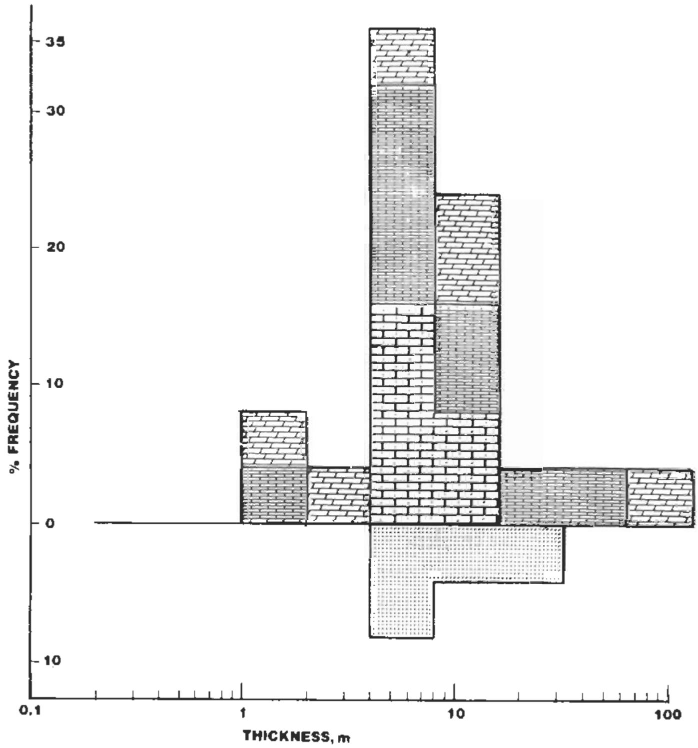

FIG. 8. Lithological frequency plot for the type Jubaila Formation. Refer to Fig. 2 for legend.

b) Potential as Reservoir Rocks

The frequency % of the Jubaila calcarenites have values of 16 and 8% for the thickness intervals of 4-8 and 8-16m, whereas dolomites have values of 4, 4, 4 and 8% for the thickness intervals of 1-2, 2-4, 4-8 and 8-16m, respectively (Fig. 8). On the other hand, sandstones have frequency values of 8, 4, and 4% for the thickness intervals of 4-8, 8-16 and 16-32m, respectively (Fig. 8). The calcarenites mostly occur within the thicker beds (>2m), whereas dolomites exist in the thinnest ones. These data can suggest that the type Jubaila has a good chance to act as a reservoir rock.

c) Potential as Sealing Rocks

Anhydrites and shales are both absent in the type Jubaila Formation which suggest that the formation has no significant seal rocks.

5. Summary for Jurassic Formations

The type Tuwaiq Mountain formation is considered a typical source rock, whereas the Marrat, Dhruma, Hanifa and Jubaila Formations have very good chances to be source rocks from purely litho-statistical standpoint. The type Arab Formation, which consists of thin and cyclic calcarenite beds, is believed to be the best reservoir in the Jurassic succession. Both the Hanifa and the Jubaila Formations in addition to the Marrat and the Dhruma Formations also have good reservoir potentials.

For sealing potentials, the type Hith anhydrite is considered to be the best in the Jurassic succession, and the type Arab also has relatively good sealing zones. Other Jurassic Formations have no chances to act as good seals, except for the shales in both the Marrat and the Dhruma Formations.

B. Interpretation of Source, Reservoir, and Sealing Rocks in the Type Sections of the Cretaceous Formations in Saudi Arabia

For each of the Sulaiy, Yammama, Buwaib, Biyadh, Wasia and Aruma Formations, the description of source, reservoir and seal potentials is as follows.

1. Sulaiy Formation (Fig. 9)

a) Potential as Source Rocks

The frequency plot of the type Sulaiy Formation has an aphanitic limestone frequency value of 5.26% for the thickness interval of 2-4m, whereas the effective thickness intervals of 4-8, 8-16 and 32-64m, have frequency values of 21, 15.78 and 15.78%, respectively (Fig. 9). This suggests that the type Sulaiy has the best chance to be a source rock if it is mature.

b) Potential as Reservoir Rocks

The calcarenites have frequency value of 10.52% for the thickness interval of 1-2m, whereas values of 10.52, 5.26, 10.52 and 5.26% occur within the thickness inter-

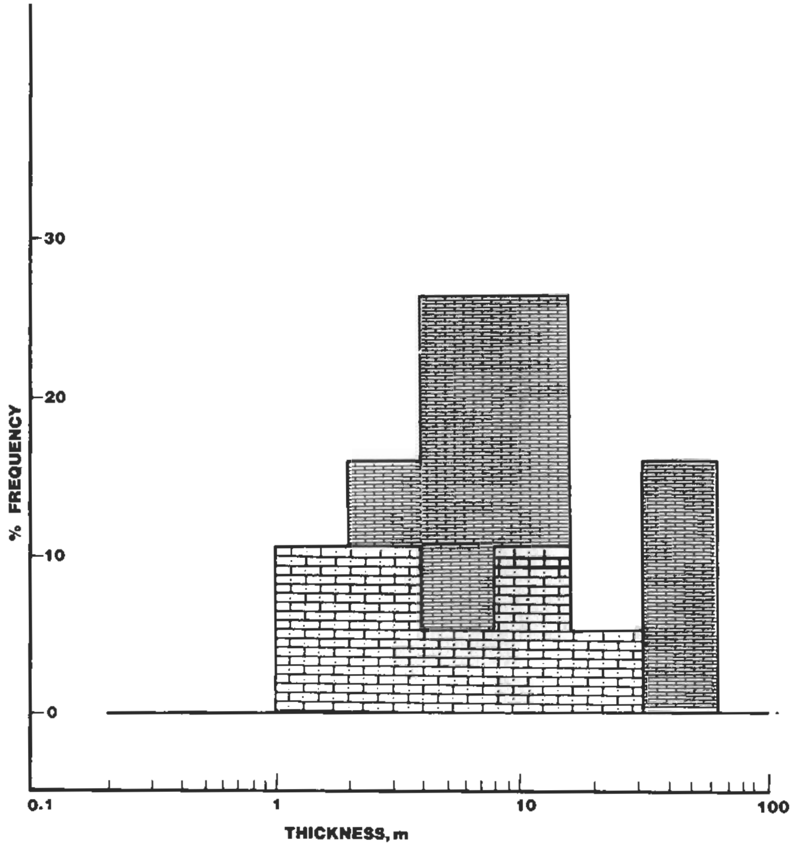

FIG. 9. Lithological frequency plot for the type Sulaiy Formation. Refer to Fig. 2 for legend.

vals of 2-4, 4-8, 8-16 and 16-32m, respectively (Fig. 9). This suggests that the type Sulaiy has a chance to be a reservoir, but only for a relatively limited amount of hydrocarbons.

c) Potential as Sealing Rocks

No anhydrites or shales are reported within the type Sulaiy Formation (Fig. 9), and this means that there seems to be no chance for this formation to be an effective seal.

2. Yamama Formation (Fig. 10)

a) Potential as Source Rocks

Aphanitic limestones have frequency values of 4.76, 19 and 9.52% within the thickness of 0.5-1, 1-2 and 2-4m (Fig. 10). The occurrence of the limestone frequency within the thinner beds (<4m) suggests that the type Yamama Formation has a poor chance to be a source rock.

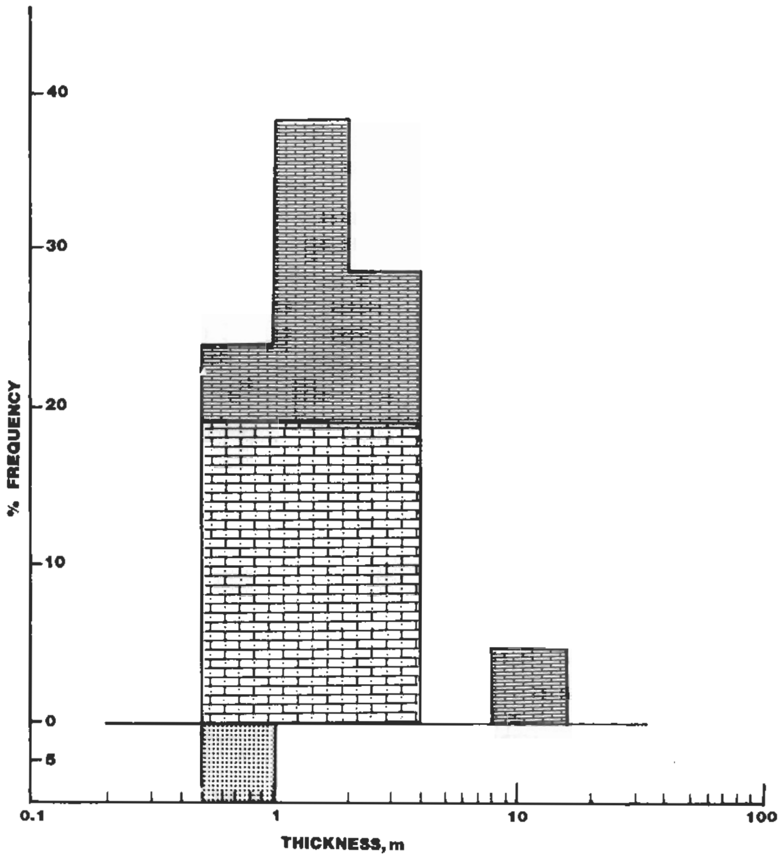

FIG. 10. Lithological frequency plot for the type Yamama Formation. Refer to Fig. 2 for legend.

b) Potential as Reservoir Rocks

The high frequency values of the calcarenites occur within the thickness intervals of 0.5-1, 1-2 and 2-4m (19% for each thickness interval, Fig. 10). The sandstone frequency value of 4.76% occurs in the thickness interval of 8-16m. The abundance of calcarenites within the thinnest beds suggests that the type Yamama Formation has a very good chance to be a reservoir rock.

c) Potential as Sealing Rocks

Both anhydrite and shales are completely absent in the type Yamama Formation (Fig. 10), which indicates that there is no effective seal within this type section.

3. Buwaib Formation (Fig. 11)

a) Potential as Source Rocks

Aphanitic limestone frequency have values of 18.75, 6.25 and 6.25% within the thickness intervals of 0.5-1, 1-2 and 2-4m, whereas the frequency value of 6.25% occurs within the effective thickness intervals of both 8-16 and 16-32m (Fig. 11). The shales have the frequency value of 6.25% for the thickness interval of 4-8m. These values suggest that the type Buwaib Formation has a good chance to be a source rock, if it contains a sufficient amount of organic matter and is mature enough.

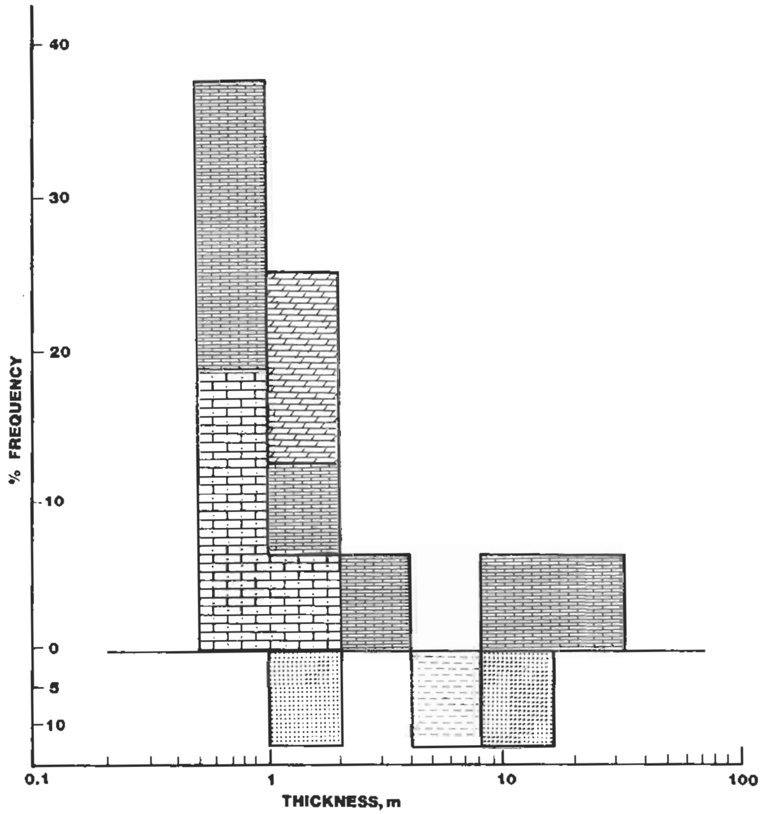

FIG. 11. Lithological frequency plot for the type Buwaib Formation. Refer to Fig. 2 for legend.

b) Potential as Reservoir Rocks

The calcarenite frequency values of 18.75 and 6.25% occur within the thickness intervals of 0.5-1 and 1-2m, respectively, whereas dolomite has a frequency value of 12.5% within the thickness interval of 1-2m (Fig. 11). Sandstones have the frequency value of 6.25% for both the thickness intervals of 1-2 and 8-16m. The existence of both calcarenites and dolomites within the thinnest intervals, in addition to the presence of sandstones can suggest that the type Buwaib has a good chance to be a reservoir, but the small thickness of the type section (about 18m) may be too thin for a calcarenite reservoir.

c) Potential as Sealing Rocks

There are no anhydrite beds within the type Buwaib, but only one shale bed exists which may act as a possible seal.

4. Biyadh Formation (Fig. 12)

a) Potential as Source Rocks

The frequency plot of the Biyadh Formation has the aphanitic limestone frequency value of 2.86% for the thickness interval of 0.5-1m (Fig. 12). The shales have frequency values of 5.71 and 8.57% for the thickness intervals of 0.5-1 and 2-4m, respectively, whereas effective thickness intervals of 8-16, 16-32 and 32-64m have frequency values of 2.86, 5.71 and 8.57%, respectively (Fig. 12). This suggest that the type Biyadh Formation may have the chance to be a source rock, if it contains the proper amount of organic matter and is properly mature.

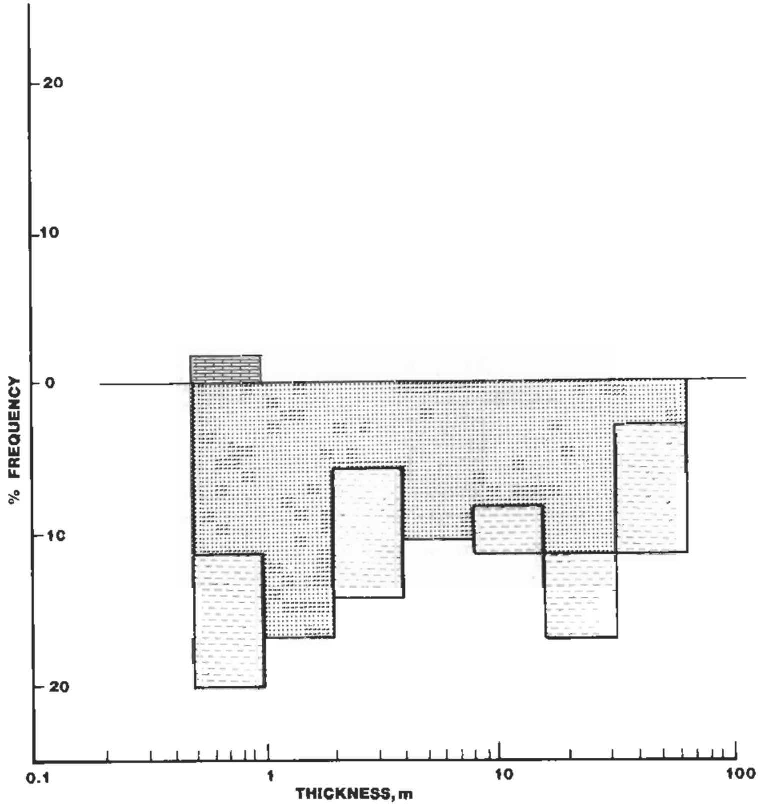

FIG. 12. Lithological frequency plot for the type Biyadh Formation. Refer to Fig. 2 for legend.

b) Potential as Reservoir Rocks

The type Biyadh Formation has sandstones representing the reservoir rocks with the frequency values of 11.43, 17.14 (the highest value), 5.71, 11.46, 5.71, 11.42 and 2.86% within the thickness intervals of 0.5-1, 1-2,2-4, 4-8, 8-16, 16-32 and 32-64m, respectively (Fig. 12). This suggests that the type Biyadh Formation has a very good chance to be a reservoir.

c) Potential as Sealing Rocks

Anhydrite is completely absent within the type Biyadh Formation, but intercalating shale beds can act as minor seals (Fig. 12).

5. Wasia Formation (Fig. 13)

a) Potential as Source Rocks

The type Wasia Formation frequency plot has a shale frequency values of 11.11% for the three thickness intervals 4-8, 8-16 and 32-64m (Fig. 13). This can suggest that the Wasia has a chance to be a source rock, in areas with sufficient organic content and maturation.

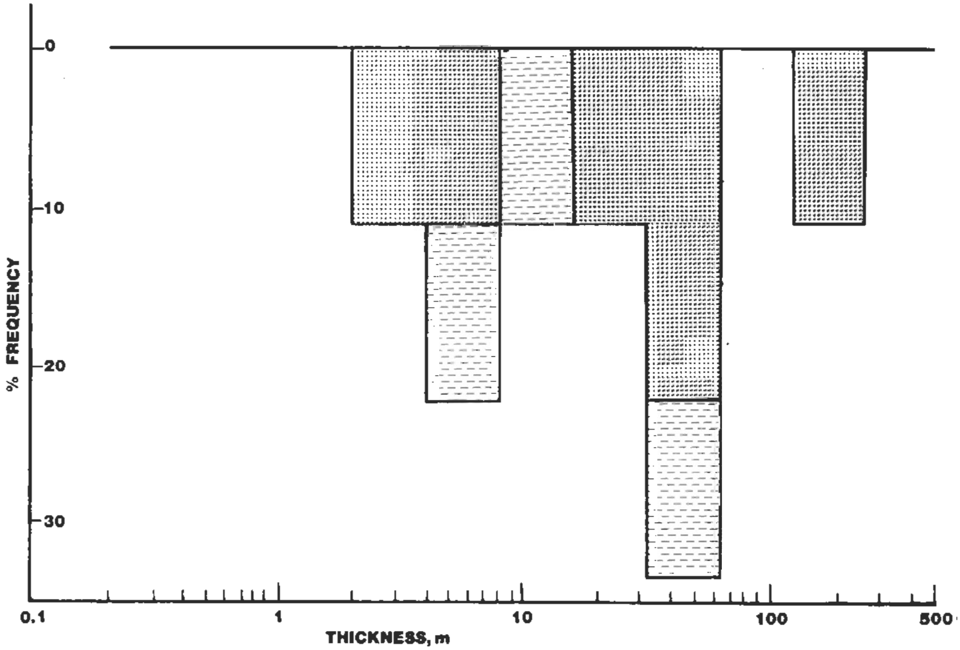

FIG. 13. Lithological frequency plot for the type Wasia Formation. Refer to Fig. 2 for legend.

b) Potential as Reservoir Rocks

Sandstones in the type Wasia are the only reservoir potential. Frequency value of 22.22% within the thickness interval of 32-64m, have been recorded, whereas other sandstones occur in the thickness intervals of 2-4, 4-8, 16-32 and 128-256m with frequency values of 11% for each interval (Fig. 13). These sandstone frequency values suggest that the type Wasia Formation has a very good chance to be a good reservoir.

c) Potential as Sealing Rocks

No anhydrites are recorded within the type Wasia Formation, but intercalating shales may suggest a possible seal (Fig. 13).

6. Aruma Formation (Fig. 14)

a) Potential as Source Rocks

An aphanitic limestone frequency value of 6.25% has been recorded for the three thickness intervals 0.5-1, 1-2 and 2-4m, whereas the effective thickness intervals of 4-8 and 32-64m have a frequency value of 6.25% for each interval (Fig. 14). Shales occur within the thickness interval of 2-4m with the frequency value of 12.5%, whereas in the effective thickness intervals of 4-8 and 8-16m, it has a frequency value of 6.25% (Fig. 14). The frequency values of both aphanitic limestones and shales can suggest that the Aruma Formation has a limited chance to be a hydrocarbon source rock, if proper burial is attained and a sufficient amount of organic matter exists.

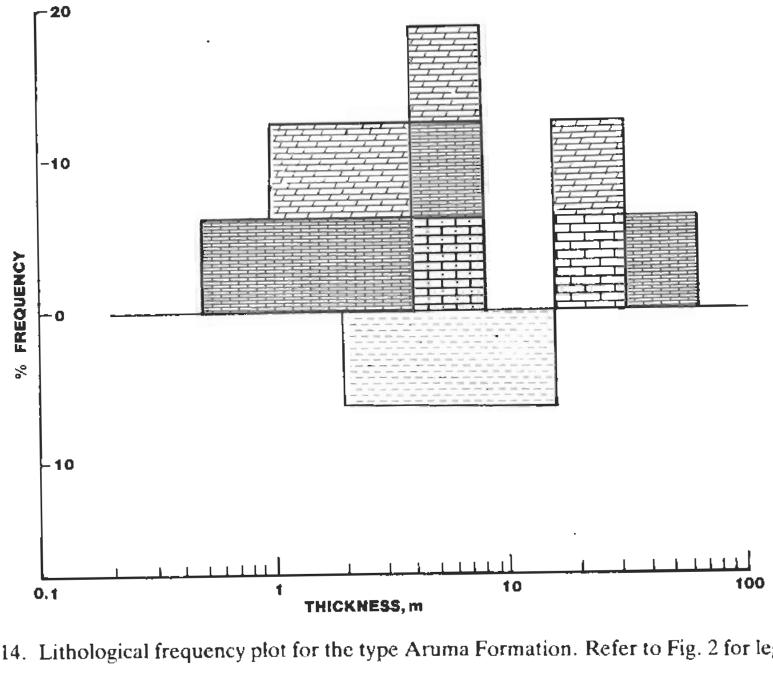

FIG. 14. Lithological frequency plot for the type Aruma Formation. Refer to Fig. 2 for legend.

b) Potential as Reservoir Rocks

Calcarenites occur within the thickness intervals of 4-8 and 16-32 with the values of 6.25 and 12.5%, respectively (Fig. 14). Dolomites have a value of 6.25% for the thickness intervals of 1-2, 2-4, 4-8 and 16-32m (Fig. 14). Reservoir potentials in this formation are obviously good, particularly in the light of its greater thickness.

c) Potential as Sealing Rocks

The Aruma Formation also has no anhydrite, whereas shales may show a minor sealing capacity.

7. Summary for Cretaceous Formations

The types Sulaiy has the best chance to be a source rock within the Cretaceous sequence of central Saudi Arabia. Intercalating shales of both the Biyadh and the Wasia Formations also suggest good chances for source rocks, if sufficient organic matter and enough maturity are provided.

For reservoir potentials, the Wasia Sandstones have the best chance, followed by the Yamama Calcarenite and the Biyadh Sandstones. Anhydrite seals are completely absent in the Cretaceous succession, but intercalating shales may act as good seals.

C. Lithological Frequency Plot for the Total Thickness of the Type Jurassic Formations (Fig. 15)

a) Potential as Source Rocks

The frequency values of aphanitic limestones within the thickness intervals 0.5-1, 1-2 and 2-4m have values of 5, 4.6 and 4.6%, whereas the effective thickness intervals of 4-8, 8-16, 16-32, 32-64 and 64-128m have values of 4.6, 4.6, 2.2, 1.8 and 0.2%, respectively (Fig. 15). Shales have frequency values of 1.4, 3 and 3.2% for the thickness intervals of 0.5-1, 1-2 and 2-4m, whereas the value of 4.6, 3.6, 2, 1.4 and 0.2% occur within the thickness intervals of 4-8, 8-16, 16-32, 32-64 and 64-128m, respectively (Fig. 15). Such values can suggest that the total thickness of the type sections of the Jurassic formations have good chances to be source rocks, if they contain sufficient organic matter and are mature enough.

b) Potential as Reservoir Rocks

Calcarenites have the highest frequency value of about 17% within the thickness interval of 0.5-1m (Fig. 15). The other thickness intervals of 1-2 and 2-4m have values of 9.6 and 5.2%, whereas thickness intervals of 4-8, 8-16 and 16-32m have frequency values of 2.4, 2.8 and 0.7% (Fig. 15). Dolomites and sandstones have frequency values less than 2% for the thickness interval of 0.5 to 32m. The values of calcarenite can suggest that the type Jurassic sections have very good chances to be reservoirs.

c) Potential as Sealing Rocks

The frequency values of anhydrites occur within thickness intervals between 0.5 and 16m with the values of 0.8, 0.6, 1.2, 0.4 and 0.2% (Fig. 15), which suggests good chances for seal.

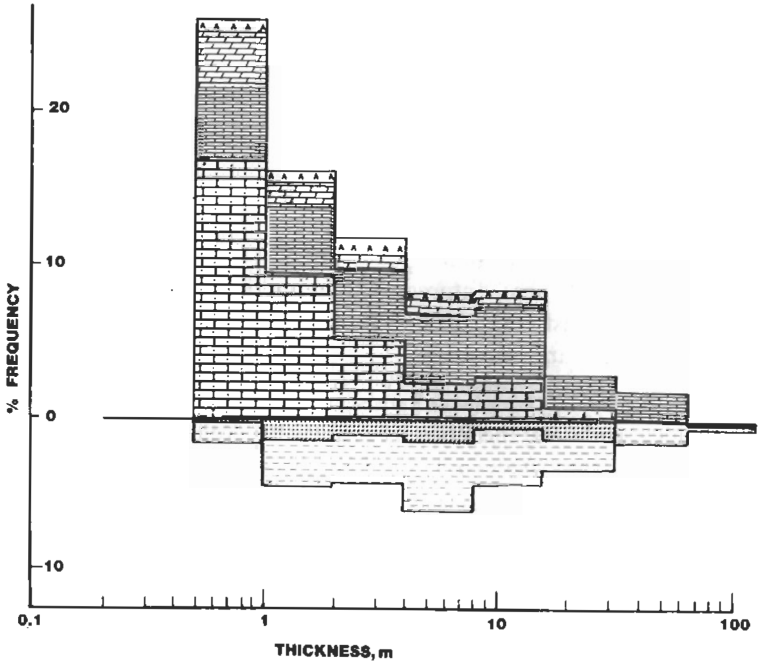

FIG. 15. Lithological frequency plot for the total Jurassic Formation type sections. Refer to Fig. 2 for legend.

D. Lithological Frequency Plot for the Total Thickness of the Type Cretaceous Formations (Fig. 16)

a) Potential as Source Rocks

Aphanitic limestones in the total thickness of the type Cretaceous Formations have frequency values of 5.17, 5.17 and 4.3% for the thickness intervals of 0.5-1, 1-2 and 2-4m, whereas the effective thickness intervals of 4-8, 8-16, 16-32 and 32-64m have values of 4.3, 3.45, 0.86 and 3.45%, respectively (Fig. 16). The frequency values of shales within the thickness intervals of 0.5-1 and 2-4m have values of 2.59 and 4.3%, while frequency values of 2.59, 3.45, 1.72 and 1.72% occur within the thickness intervals of 4-8, 8-16, 16-32 and 32-64m (Fig. 16). Both the limestone and shale frequency values can suggest that the type sections of the Cretaceous Formations have a good chance to be source rocks, provided that they contain sufficient amounts of organic matter that is mature enough.

b) Potential as Reservoir Rocks

Frequency values of calcarenites within the thickness intervals of 0.5-1, 1-2 and 2-4m are 6, 6 and 5.17%, respectively, whereas thickness intervals of 4-8, 8-16 and 16-32 have values of 1.72, 2.59 and 2.59%, respectively (Fig. 16). Sandstones have fre-

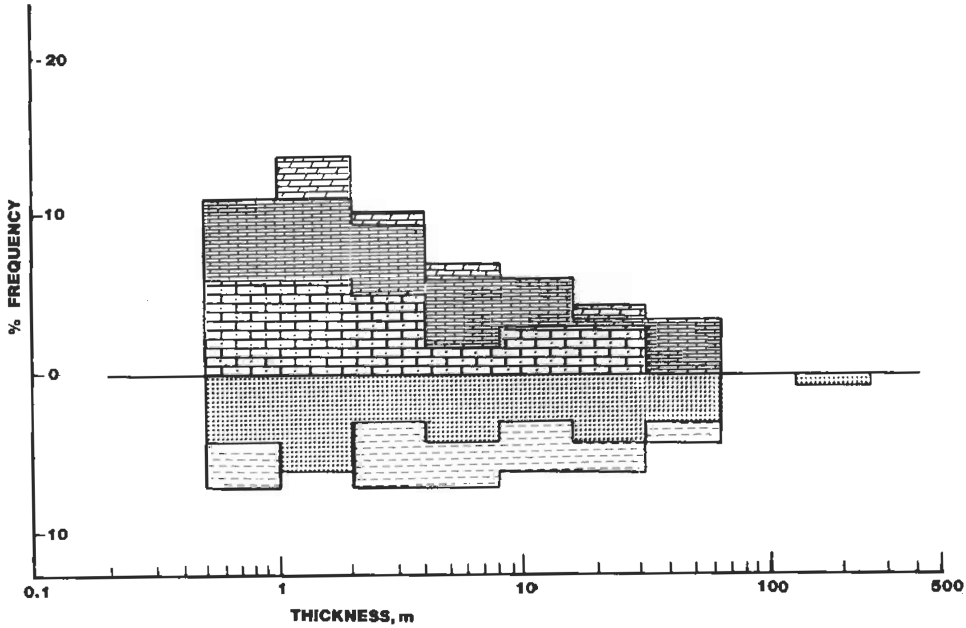

FIG. 16. Lithological frequency plot for the total Cretaceous Formation type sections. Refer to Fig. 2 for legend.

quency values of 4.3, 6, 2.59, 4.3, 2.59, 4.3 and 2.59% for the thickness intervals between 0.5 and 64m (Fig. 16). Both values suggest that the type sections of the Cretaceous Formations have good chances to be reservoirs.

c) Potential as Sealing Rocks

Anhydrite seal is completely absent within the type sections of the Cretaceous Formations, but intercalating shales may have possible seals (Fig. 16).

E. Cumulative Frequency Plots for Both the Jurassic and Cretaceous Type Sections (Fig. 17 and 18)

Litho-statistical data mentioned above were plotted on probability paper [Fig. 17 (Jurassic) and 18 (Cretaceous)]. The lines in each figure show the cumulative frequency plots of limestone, calcarenite, sandstone, shale, dolomite, anhydrite and the total lithology. Most of these lines show relatively straight trends, suggesting that the thickness distributions are nearly log-normal. Note that the thickness scale shown at the buttom of each figure is logarithmic.

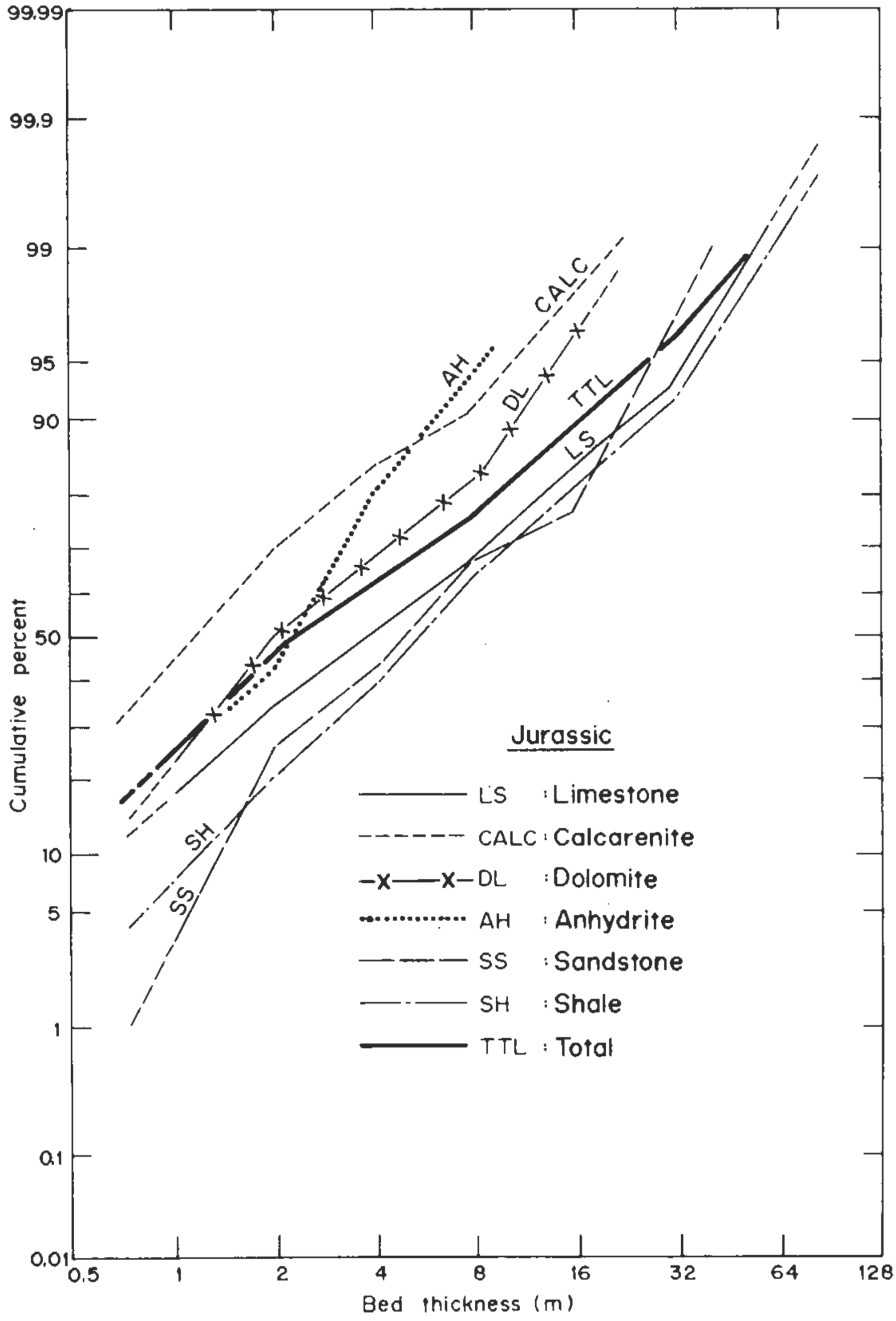

FIG. 17. Cumulative frequency plot for the total Jurassic Formation type sections.

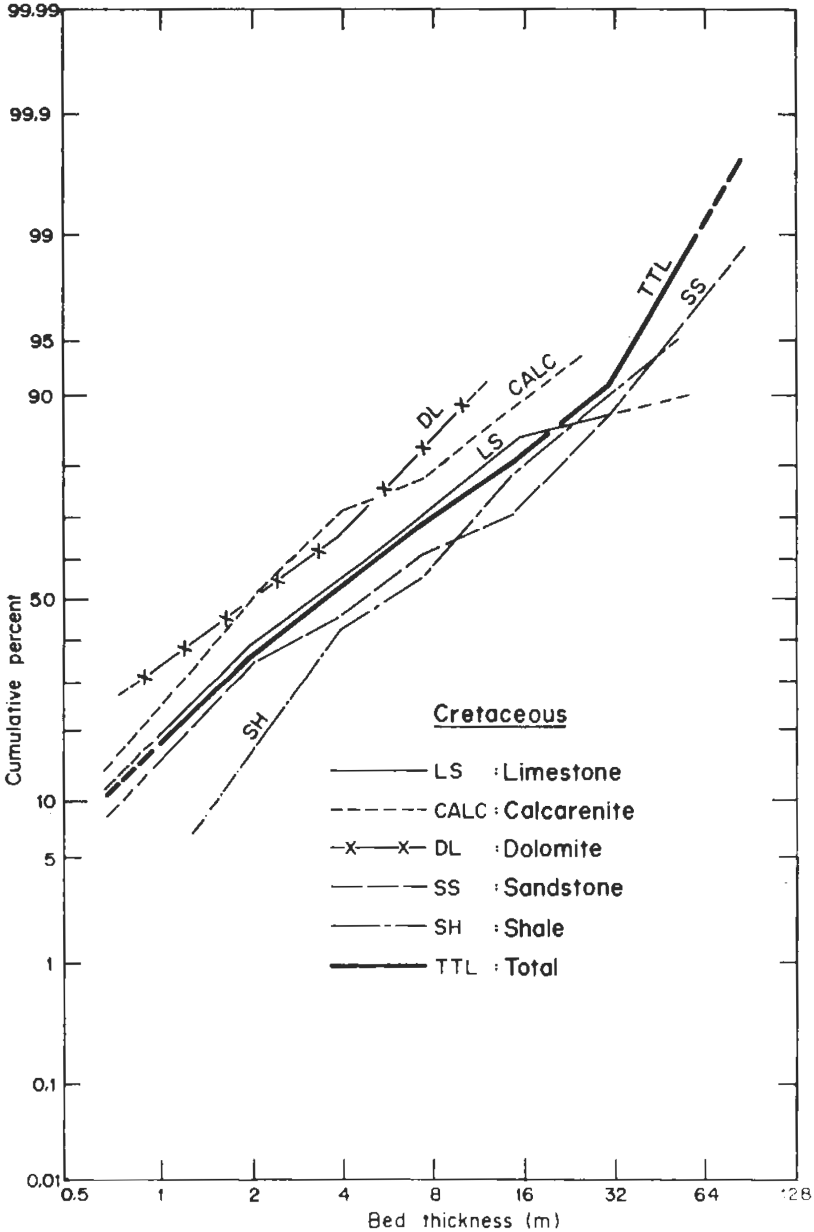

FIG. 18. Cumulative frequency plot for the total Cretaceous Formation type sections.

The median thickness value can be read at the 50 percentile point of the figures. The statistical minimum and maximum values may also be read at 16% (the median minus one standard deviation) and 84% (the median plus one standard deviation) points, respectively. The summary of these statistical values of both the Jurassic and Cretaceous formations is listed in Table 1. These values may have practical applications in the future in predicting the most likely, minimum, and maximum thicknesses of beds in the region when the Monte Carlo simulation program is applied.

TABLE 1. Statistical Summary for the Jurassic and the Cretaceous Formation type sections.

Rock Type	Minimum	Most likely*	Maximum
		Jurassic Formations	
Limestone	–	3.9	16.0
Calcarenite	–	1.2	4.0
Sandstone	1.7	5.2	19.8
Shale	1.7	6.0	19.8
Dolomite	–	2.0	11.0
Anhydrite	–	2.3	5.0
Total Jurassic	–	2.4	12.0
		Cretaceous Formations	
Limestone	0.7	3.3	16.0
Calcarenite	0.5	2.0	11.3
Sandstone	1.1	5.0	28.0
Shale	2.0	6.0	24.0
Dolomite	–	2.0	8.3
Total Cretaceous	0.8	3.6	18.5

Unit in Meter.

*Same as Median.

F. Correlation between Lithology and Oil Production in Saudi Arabia

Within the oil producing areas in Saudi Arabia, Ayres *et al.* (1982) evaluated source rock qualities of both the Jurassic and Cretaceous formations. These authors concluded that the fine-grained argillaceous limestones within each of the Dhruma, Tuwaiq, Hanifa and Jubaila Formations have a very high organic carbon content which suggests that these argillaceous limestone horizons could have been the main source rocks for the Jurassic oils.

The Sulaiy Formation was also identified as the main source rock for the Early Cretaceous oils. Litho-statistical analysis in the central part of Saudi Arabia agrees with the above conclusions.

The distribution of producing zones in eighteen oil fields in Saudi Arabia was studied and is shown in Fig. 19. The highest frequency percentage occurs in the Arab Formation with the value of 30.34% whereas the Jubaila, Hanifa and Dhruma Formations have frequency values of 19.56, 10.87 and 8.69%, respectively (Fig. 19). Within the Cretaceous formations, only the Wasia has a percentage value of 8.68%, whereas others have less than 5%. This indicates that the Arab Formation is the best reservoir and is followed by the Jubaila and the Hanifa Formations, respectively.

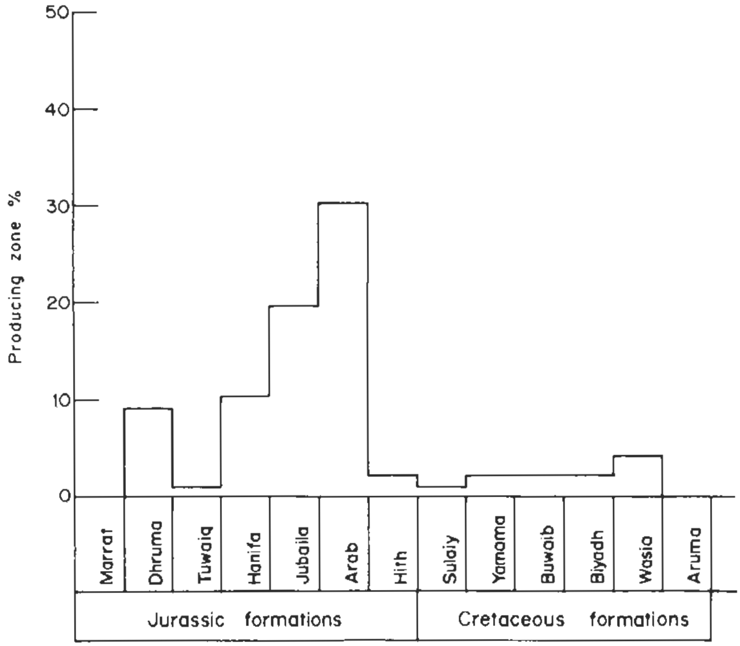

FIG. 19. Frequency plot for the most important producing zones in Saudi Arabia.

Both Wasia and Biyadh Formations have better chances to be reservoirs than both the Jubaila and the Hanifa limestones as indicated by the litho-statistical study.

Concluding Statement

As described in the Introduction, the source, reservoir or sealing capacity of a rock body can be controlled by a set of its physical, chemical and geological factors. Litho-statistical study may provide a possibility of interpretation. Such interpretation could be misleading if the areas of sampling and of production are not of identical litho-facies.

Therefore, the main purpose of this paper is to present the methods of analysis for potential future applications. It is strongly recommended to continue a similar research using better data in the future, in order to increase our understanding of source, reservoir, and cap rocks in this region.

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دراسة صخرية إحصائية للقطاعات النمطية لكلا العصرين الجوراسي والطباشيري في المملكة العربية السعودية

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أوعزت الدراسة الإحصائية لسِحَن مُتكونات القطاعات النموذجية لكل من العصر الجوراسي والطباشيري بالتوليفة والخلط الأمثل من صخور المكامن والغطاء لتجمعات الزيت المحتملة في مُتكونات العرب والوسيع والبياض .

ومتكون الهيث أفضل صخر غطاء على الإطلاق .

وصخور المصدر المصمتة يمكن أن توجد في متكونات مثل ضرمة ، جبل طويق ، حنيفة والسلي ، إذا مااحتوت على كميات كافية من المادة العضوية وكانت ناضجة جيوكيميائيا .

وكل من إحصائيات الخزانات (المكامن) المنتجة والتحليل الجيوكيميائي للمصدر في المنطقة يدعم ويؤكد الاستنتاجات السابقة .