EXPLORATION PERFORMANCE IN SEDIMENTARY ZONES OF PAKISTAN

Hilal A. Raza, Riaz Ahmed, S. Manshoor Ali, Arshad M. Sheikh and Naseer A. Shafique

Abstract

Using exploratory drilling density (ft/mi^3) and the hydrocarbon discovery density (BOE/mi^3) as normalized measures of exploration performance, the status of exploration in the sedimentary zones of Pakistan has been highlighted.

The paper compares results of exploration in sedimentary zones of varying size with the help of normalised discovery functions. Statistics of exploration performance have also been surfaced through normalized drilling and discovery measures.

The study indicates that the exploration had been less intensive in larger zones as compared to smaller oil and/or gas rich zones.

Introduction

Exploration performance can be conveniently assessed by looking at the footage of the exploratory drilling and its outcome in the form of quantity of oil and gas discovered. These measures provide good analogues for any appraised area where an exploration compaign is planned.

Normalized measures of sedimentary volume are useful in overcoming the problem of comparing potential of appraised areas with analogues when the two have different dimensions. These measures are: (1) exploratory drilling density and (2) hydrocarbon discovery density.

Previously, the concepts of hydrocarbon discovery density and drilling density have been used for basin evaluations by workers like, Fohs (1948), Weeks (1949), Grender & Segers (1947), Grender & Rapoport (1979), Rapoport & Grender (1986) etc.

The hydrocarbon discovery density is the barrels of oil equivalent (BOE) discovered per cubic mile of sediment. From drilling density, which is the feet drilled per cubic mile of sediment, well density (w) can be estimated as number of wells per square mile by applying the relationship of Rapoport & Grender (1986) w=(H/h) d, where H=average thickness (in mile), h=average well depth (in feet).

The objective of the present study is to apply the above concepts to sedimentary zones of Pakistan for the purpose of assessing exploration performance in them. To achieve this, first the volumetric characteristics of the sedimentary zones are summarised and then these zones are compared using normalised drilling and hydrocarbon density measures.

Volumetric Characteristics of Sedimentary Zones of Pakistan

On the basis of geological similarities the sedimentary area of Pakistan can be divided into 24 zones (Figure 1). Table 1 shows the volumetric characteristics of these zones. In addition to the sedimentary volume, Table 1 also gives surface area, average depths (obtained by dividing volume by surface area) maximum depth, and number of fields discovered by the end of 1987. The tabulation also indicates "hydrocarbon rich zones".

From Table 1, it can be seen that the volume of the zones varies from about 4000 to 190000 mi^3 Figure 2 shows the logrithmic distribution of the sediment volume of these zones. The distribution is somewhat bell shaped and can be considered as normal distribution. About 25% of the sediments zone volume falls between 40000–80000 mi^3, with mean 496875 mi^3, however, the dispresion is quite wide.

The following points can also be noted from Table 1: (1) About 37.5% of all the zones are hydrocarbon rich, (2) About ½ of the smaller zones (less than 18000 mi^3) are barren whereas 2/3 of the larger zones are barren and (3). The average thickness of sediments of all zones generally increases with sediment volume (Figure 3).

Exploration Status of Sedimentary Zones

Data included in Table 2 forms the basis of comparison and correlation among the zones by using normalized measures of exploration performance. The normalized measures of exploration reduced about 70% indicate that some of the apparently hydrocarbon poor zones might possibly have yielded more hydrocarbons had their exploratory drilling densities been higher.

Normalized Discovery Functions

Volume-normalized measures of exploration performance describe discovery functions, which indicate the relationship between cumulative oil and gas discoveries and cumulative exploratory drilling for any particular area and depth zone.

Cumulative drilling and discoveries when translated into their normalized discovery functions for different areas are directly comparable on a point-by-point basis without any complication caused by difference in size of the areas. The superiority of normalized discovery functions over absolute ones is clearly brought out in Figures 4 and 5. Figure 4 (absolute measures) shows the total amount of hydrocarbon discovered against cumulative drilling for the zones B1 and A3 can not be compared. On the other hand Figure 5 (normalized discovery functions) clearly brings out that the intensity of exploration and hydrocarbon yield have a definite relationship. The ratio of maximum to minimum values of exploratory drilling and of discoveries is comparative on this figure. The exploratory drilling scale span in respect of the zones is 530991/4374=121 for the drilled footage and 36/0.432=83 for normalized drilling densities. The ratio of maximum to minimum discoveries is 0.79/0.07=11.28 in terms of actual BOE values but it decreases to about half i.e. 23.3/3.83=6.08 when normalized. Such reduction in over all scale span is indicative of the benefit of using the normalized measures of exploration for correlation among the zones.

Figure 6 represents a more clear picture of the advantage of this mehtod, it shows the relation of cumulative exploratory drilling densities and sedimentary volume. On the basis of this relation we can conclude that the drilling density decreases as the volume of sediment increases in the hydrocarbon ric zones, in other words smaller hydrocarbon rich zone are explored more than larger zones.

The other feature of the normalized method i the correlation between hydrocarbon richness an exploration intensity. This is shown by Figure where hydrocarbon discovery density for differen zones is plotted against drilling density. This figur also shows that as drilling density increases, discover density also increases.

Conclusions

Normalized drilling and discoveries measures ar an aid to comparative analysis. This type of explora tion statistics technique could lend new meaning t broad basin assessments and correlations whe combined with geological parameters.

Exploration results indicate that the sedimentary zones of Pakistan have been inadequately explored and merit more intensive drilling effort for bette yield of hydrocarbon. The general pattern of concen trated drilling in and around small pockets of produc ing areas has to be altered by diverting a part of th effort to less explored potential areas.

The results also show existence of example where hydrocarbon production is not comensurate with drilling effort (Zone A3) or where production is proportionate to drilling (Zone D1).

The study also prompts the need for probablistic modelling for future basin evaluations.

References

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Sedimentary Zones	Zone No	Hydro-carbon Rich	Sediment Volume (mi3)	Surface Area (mi2)	Average Depth (ft)	Maximum Depth (ft)	Number of Significant Fields
Punjab Monocline	A1	Yes	69313	26255	13944	27888	2
Khand Kot Mari Horst	A2a	Yes	3891	1853	10991	13780	2
Panno Aqil Graban	A 2b	NE PH	8340	2780	15584	22967	Nil
Jacobabad Khairpur Horst	A 2c	No	22395	8958	13124	26248	1
Sind Monocline	A3	Yes	33298	11892	14765	26248	20
Potwar Depression	B1	Yes	26409	8803	15585	24608	9
Kohat Depression	B2	IE PH	17931	4170	22967	32810	Nil.
Sulaiman Depression	B3	IE PH	67431	11429	31170	49215	Nil.
Sibi Depression	B4	No NE	10234	1931	27889	32810	Nil
Kirthar Depression	B5	No 1E	29662	4942	29529	32810	Nil
Karachi Depression	B6	Yes	11999	3243	19686	26248	3
Zindapir Inner Folded Zone	C1	Yes	7527	1158	34451	39372	2
Mari Bugti Inner Folded Zone	C2	Yes	33713	5714	31170	36091	5
Sanni Inner Folded Zone	C3	No	2867	541	27888	32810	Nil
Mazarani Inner Folded Zone	C4	No	4092	772	27888	32810	1
Sulaiman Outer Folded Zone	D1	IE PH	87570	20850	22147	31170	1
Kirthar Outer Folded Zone	D2	No	59242	21158	14765	19686	Nil
Pishin Depression	E	NE PA	40155	8031	26248	36091	Nil
Mashkhel Depression	F1	NE PA	49317	9305	27888	39372	Nil
Panjgur Accretionary Prism	F2	IE PA	189791	21815	45934	49215	Nil
Coastal Depression	F3	IE PH	96606	10734	47575	52496	Nil
Indus Offshore Platform	G1	IE PH	15573	4209	19686	26248	Nil
Indus Offshore Depression	G2	IE PA	64865	25946	13124	26248	Nil
Makran Offshore	G3	IE PA	92800	48842	9843	19686	Nil

Abbreviations: NE: No Exploration IE: Initial Exploration
PH: Potential High PA: Potential Average.

Table 1: Volumetric characteristics of sedimentary zones of Pakistan.

Sedimentary Zones	Zone No.	Hydro-carbon Rich		Sediment volume (mi3) (V)	Cumula-tive Explora-tory Footage (F)	Cumula-tive Discoveries (10^9 BOE) (D)	Cumula-tive Explora-tory Drilling Density (ft/mi^3) $d=5280\times\frac{N}{A}$	Cumula-tive Discovered Hydro-carbon Density 10^3 (BOE/mi^3) $Hd=\frac{D}{V}$
Punjab Monocline.	A1	Yes		69313	105376	–	2614	–
Khand Kot Mari Horst.	A2a	Yes		3891	17931	0.760	669	18.030
Panno Aqil Graban.	A 2b	NE	PH	8391	–	–	–	–
Jacobabad Khairpur Horst.	A 2c	No		22395	38601	0.172*	2.357	7.698
Sind Monocline.	A3	Yes		33298	530991	0.148	30.630	4.460
Potwar Depression.	B1	Yes		26409	483461	0.424	35.982	16.060
Kohat Depression.	B2	IE	PH	17931	57146	–	8.863	–
Sulaiman Depression.	B3	IE	PH	67431	30773	–	0.924	–
Sibi Depression.	B4	No	NE	10234	–	–	2.734	–
Kirthar Depression.	B5	No	1E	29652	36911	–	3.205	–
Karachi Depression.	B6	Yes		11999	93650	0.170	19.537	14.167
Zindapir Inner Folded Zone.	C1	Yes		7527	28548	0.159	22.790	21.123
Mari Bugti Inner Folded Zone.	C2	Yes		33713	65289	0.790*	7.390	23.300
Sanni Inner Folded Zone.	C3	No		2867	25375	–	19.500	–
Mazarani Inner Folded Zone.	C4	No		4092	10112	0.156	6.839	3.834
Sulaiman Outer Folded Zone.	D1	IE	PH	87570	29411	0.340	0.759	3.880
Kirthar Outer Folded Zone.	D2	No		59242	4374	–	0.499	–
Pishin Depression.	E	NE	PA	40155	–	–	–	–
Mashkhel Depression.	F1	NE	PA	49317	–	–	–	–
Panjgur Accretionary Prism.	F2	IE	PA	189791	10988	–	–	–
Coastal Depression.	F3	IE	PH	96606	37564	–	1.967	–
Indus Offshore Platform.	G1	IE	PH	15573	47391	–	–	–
Indus Offshore Depression.	G2	IE	PA	64865	40320	–	0.814	–
Makran Offshore	G3	IE	PA	92800	6585	–	0.432	–

Abbreviations: NE: No Exploration IE: Initial Exploration
PH: Potential High PA: Potential Average.

Table 2: Exploratory status of sedimentary zones. *Excluding giants

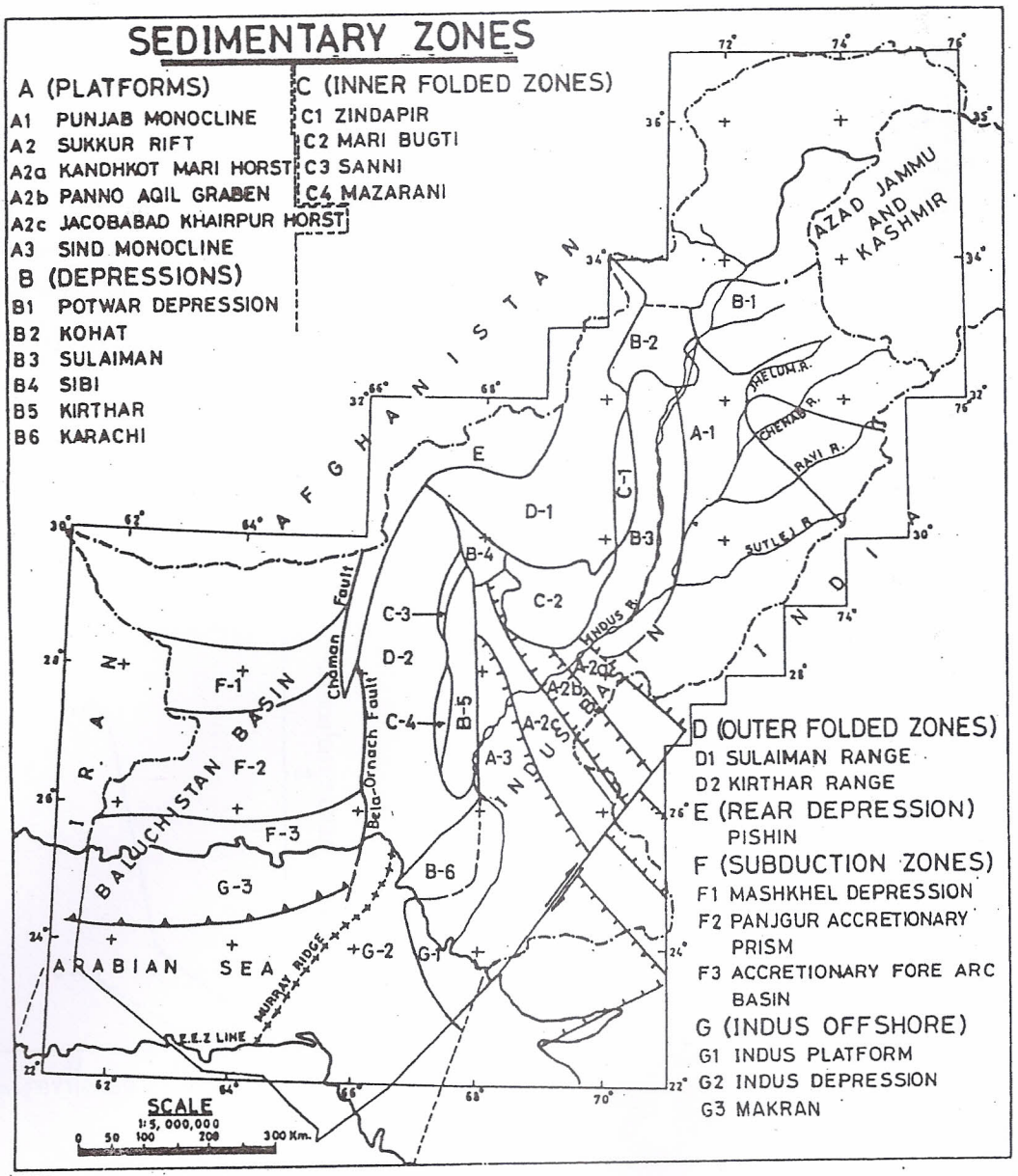

Figure 1. Location of sedimentary zones of Pakistan.

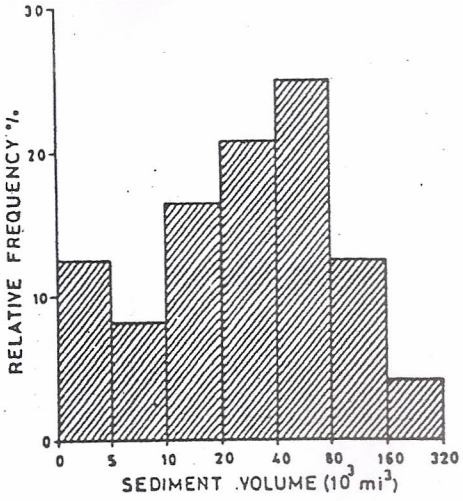

Figure 2. Frequency distribution of sediment volume.

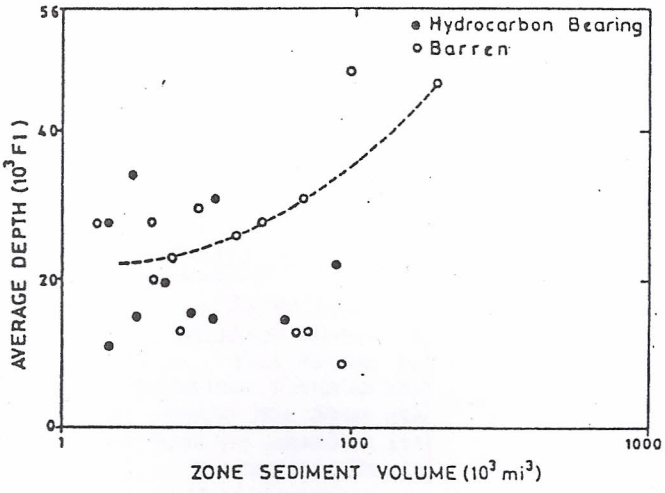

Figure 3. Correlation between average depth and volume of sedimentary zones.

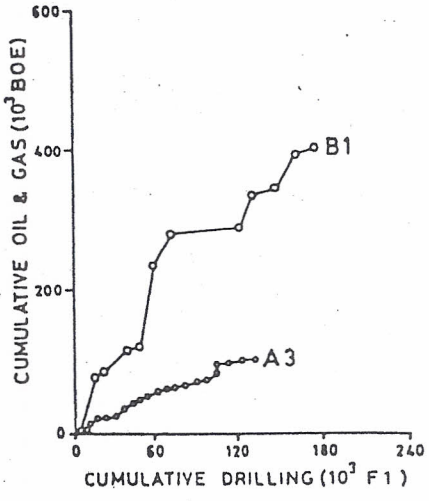

Figure 4. Comparison between Sind monocline (Zone A3) and Potwar depression (Zone B1) by absolute measures.

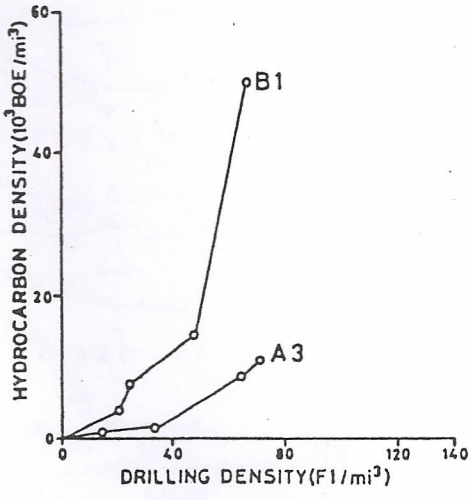

Figure 5. Comparison between Sind monocline (Zone A3) and Potwar depression (Zone B1) by normalized measures.

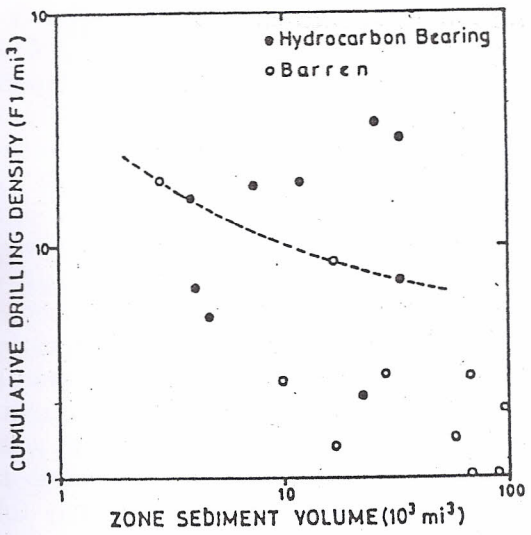

Figure 6. Correlation between drilling density and zone sediment volume.

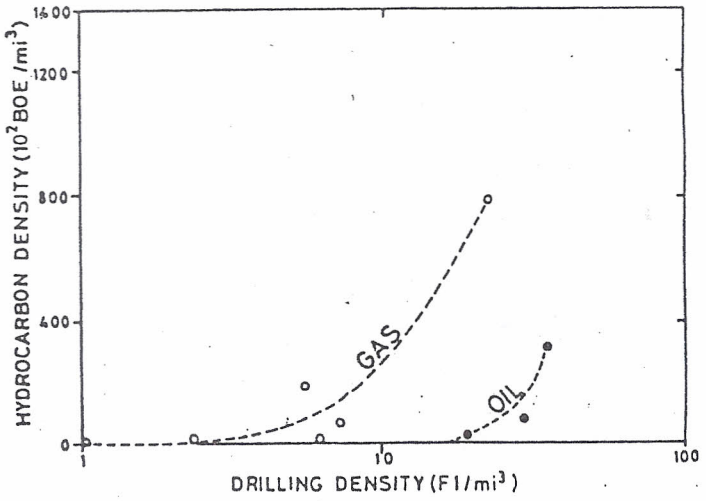

Figure 7. Correlation between drilling density and hydrobarbon density in different producing zones.