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Petroleum Resource Appraisal of Lower Goru Play, Badin Block, Lower Indus Basin, Pakistan

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ABSTRACT

Badin Block is a concession area granted to Union Texas Pakistan (UTP). The petroleum resource appraisal of the lower Goru play of Badin Block has been carried out through the "Discovery Process Model" of a software developed by John R. Lacey International Ltd. in association with Prass Consultants of Canada. The Early Cretaceous Lower Goru sandstones are the main oil and gas producing reservoir rocks of this block. These sandstones can be divided into five discrete sand bodies; however, the uppermost and the lowermost sands of the sequence are often considered the primary reservoirs.

Exploration in the Lower Indus Basin started in 1939 and the first discovery of oil, in the Badin Block, was made by UTP Group in May, 1981 at Khaskeli. Until December, 1992, UTP has discovered 31 oil and gas fields in Badin Block, and the recoverable reserves of these 31 oil and gas pools provide the basis for the estimation of recoverable reserves of oil and gas of the whole Badin Block.

The analysis shows that about 31% of the total recoverable oil reserves i.e. 35.5 mm bbl still remain to be discovered out of the additional 105 expected pools in the play. Similarly, it has been estimated that about 47% of the total recoverable gas reserves i.e. 520.5 Bcf still remain to be discovered out of the additional 124 expected pools.

INTRODUCTION

Badin Block is a concession area granted to Union Texas Pakistan. This concession block is located in the Lower Indus basin which is a sub-basin of larger Indus Basin of Pakistan (see location map, Figure1). The area is a relatively small entity which extends approximately between lat. 24° and 25° 60' N, and from long. 68 ° and 69° 45' E.

The petroleum resources appraisal of the lower Goru play of Badin Block has been carried out through the "Discovery Process Model" of the software PRASS1 (PETROLEUM RESOURCES APPRAISAL SYSTEM SOFTWARE), developed by John R. Lacey International Ltd. in association with PRASS Consultants, based in Calgary, Alberta, Canada.

The stratigraphy and Petroleum geology of the Lower Indus Basin has been described by many authors including Williams (1959), Rahman (1973), Shah (1977), Quadri and Shuaib (1986), Malik et al. (1988), Raza et al. (1990), kemal (1991), Kemal et al. (1991) and Hussain et al. (1991). Indus Basin is a part of the Indian Lithospheric Plate which broke up from the Lower hemisphere supercontinent of Gondwanaland and drifted northward, and eventually collided during Cenozoic with the Eurasian Plates. Indus Basin sedimentation began during the late Precambrian and continued on into the Cambrian, which is followed by a lengthy Late Cambrian to Late Carboniferous period of basinwide emergence and erosion. Subsidence and sedimentation resumed during Permian time. It is evident that deposition in Lower Indus Basin has been relatively continuous since the Permian (Hussain et al., 1991).

The oldest rocks encountered in the Badin Block are Chiltan Formation of Upper Jurassic age. Lower Goru sandstones of the Early Cretaceous age provide the reservoir; whereas, Sembar Formation, again of Early Cretaceous age, is the main source rock for oil and gas fields of the area.

EXPLORATION HISTORY

Exploration in the Lower Indus Basin started in 1939, when Burmah Oil Company drilled Drigh Road GID-1 well near Karachi. Second well was drilled on the Lakhra structure again by Burmah Oil Company in 1948. Exploration for oil and gas in the region accelerated, in fact, in 1955 onward. Aeromagnetic surveys were conducted by Standard Vacuum Oil Company (SVOC) in 1955, and by OGDC in 1962-63. Gravity surveys were carried out by SVOC in 1954-56, Sun Oil Company (SOC) in 1957-59, Pakistan Petroleum Ltd. (PPL) in 1949 and 1956-60, Pak Hunt Petroleum Ltd. in 1957-59, Tide-water Oil Company in 1959-60, OGDC in 1966-75, and Pakistan Texas Gulf in 1975.

Single-fold seismic surveys were conducted in different parts of the basin from 1955 to 1974 by SVOC, SOC, Tide-water, Hunt Oil, PPL, and OGDC. Detailed seismic surveys were conducted relatively recently by Union Texas and OGDC to confirm several leads picked by previous surveys.

In May 1981, UTP Group (comprised of Union Texas Pakistan, Occidental of Pakistan Inc., and OGDC) discovered oil at Khaskeli (located within the Badin Block). With this discovery, the Lower Indus Basin became the second largest oil-producing sub-basin of Pakistan, after Potwar. Uptill December 1992, UTP has discovered 31 oil and gas fields in the Badin Block (Figure 2), and the recoverable reserve data of these 31 oil and gas pools provide the basis for the current estimation of recoverable reserves of oil and gas of the whole Badin Block.

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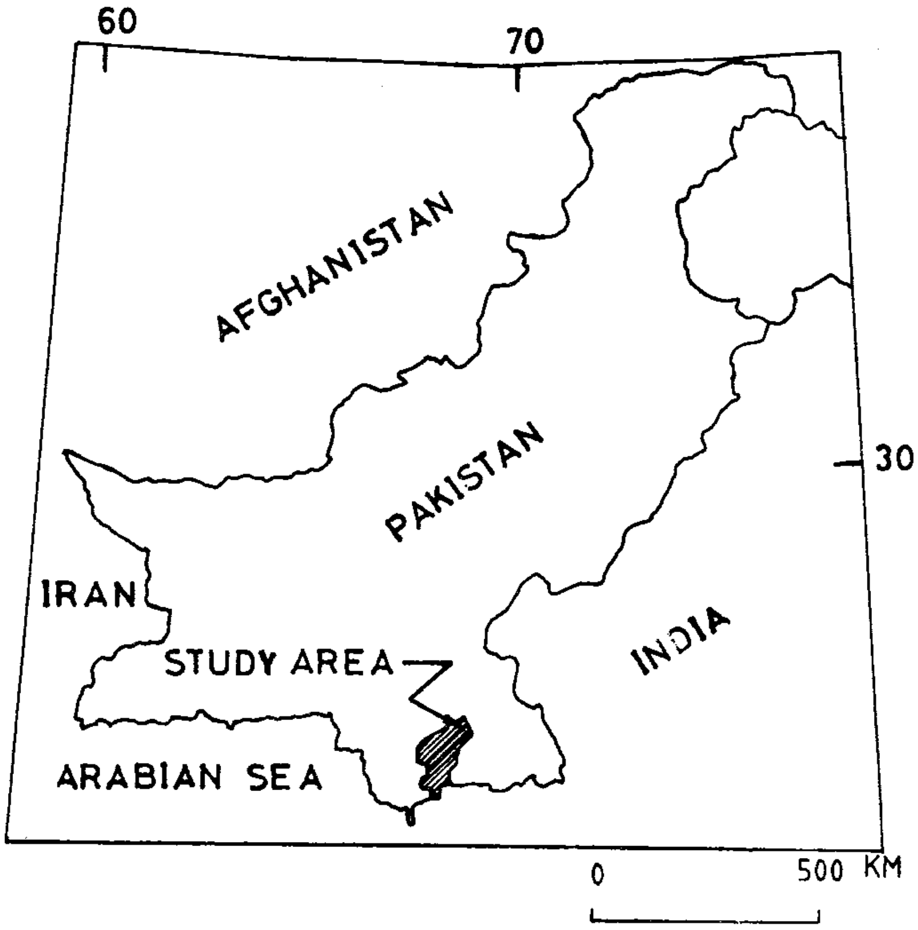

Figure 1- Location map of study area (Badin Block)

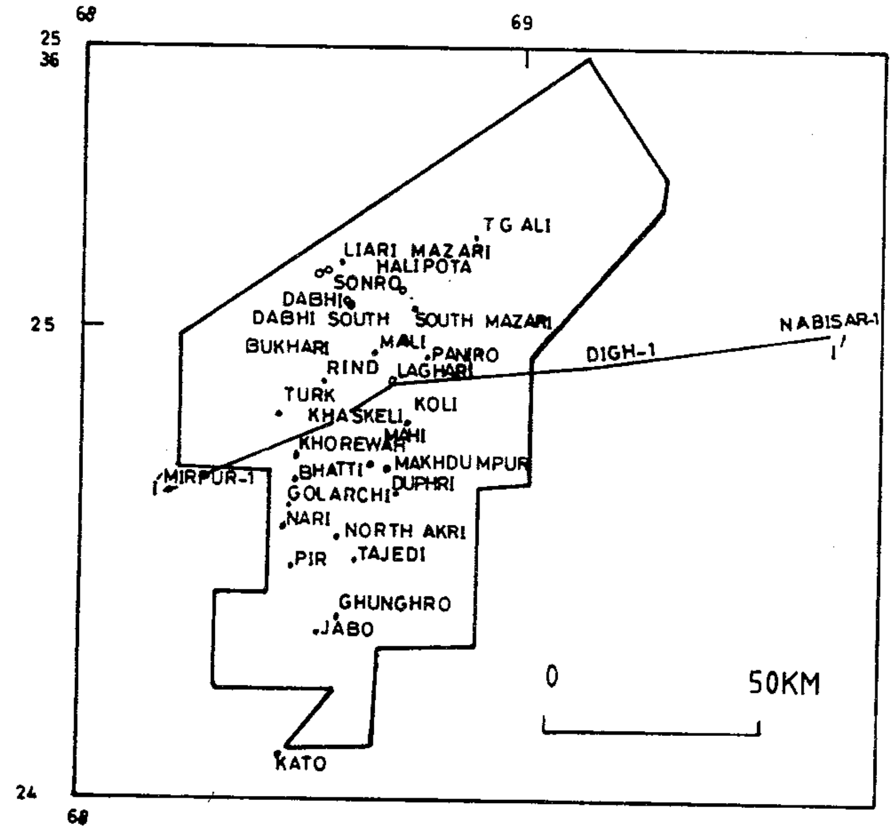

Figure 2-UTP Concession Area with well locations

STRUCTURAL STYLES AND PLAY TYPES

The extentional tectonism during the Cretaceous time created the tilted fault blocks over a wide area of the Eastern Lower Indus sub-basin. Seismic reflectors, representing Cretaceous and older layers, are broken by a system of faults with normal dip separation (Figure 3). The Cretaceous faults generally strike between N 30° W and N 50° W (Kemal et al., 1991). Commonly, the faults are arranged in en-echelon sets, aligned in zones that trend almost north-south. Fault-associated structural closures are responsible for trapping oil and gas in Lower Goru sandstones in the Badin Block. The tilted fault block traps were in existence at the time of hydrocarbon generation (Kemal, 1991). The underfilling of the structures can be attributed to upward leakage across the extensive network of small faults. Later wrenching have complicated the earlier extensional structures and redistributed the hydrocarbon (Kemal, 1991).

SOURCE POTENTIAL

The Early Cretaceous Sembar Formation basinal mudstones and the overlying basal Lower Goru prodelta shales appear to be the main oil source rocks in the central portion of the lower Indus basin (Malik et al,1988). They are also probably the main gas and condensate source rocks for the Badin Block and the adjacent areas. Extensive geochemical studies by both private and public sectors indicate that portions of Sembar Formation contain a total organic content upto 3.5%, with thermally mature type I and II (oil and gas prone) Kerogens (Quadri and Shuaib, 1986). Raza et al. (1990) have also stated that the Lower Goru Formation shales, exposed in the Kirthar Range, show good source rock potential (TOC: 1.72%, VR: 1.27%), and that portions of the upper Goru Formation can also act as a source rock unit (TOC: 2.55, VR: 1.51). In the Lower Indus Basin the oil and gas window of the Sembar Formation ranges from 82-132 degrees centigrade; whereas, gas/condensate window ranges from 132-260 degrees centigrade. At and around the Badin Block, the upper limit of the oil window occurs between 787 and 2362 meters. Its lower limit is expected between 2902 and 5118 meters (Quadri and Shuaib 1986).

RESERVOIR QUALITY

Lower Goru sandstones are the main hydrocarbon producing reservoir rocks at and around the Badin Block. These sandstones were formed as a result of erosion from the Indian shield during the late Early Cretaceous rifting episodes and redeposition of the sediments as a series of deltaic and barrier bar sands in both the Lower and Middle Indus basins, downdip to the west (Hussain et al., 1991). The depth to the top of the Lower Goru sandstones varies from less than 1,000 meters in the Khaskeli field to possibly more than 2,400 meters in the Thatta area in the north-west. The Lower Goru reaches its maximum thickness of 1,562 meters in the khaskeli field, from where its thickness decreases in all directions.

Lower Goru sandstones possess excellent reservoir qualities in the Badin Block, averaging 25%-30% porosity. Permeabilities of lower Goru sandstones often exceed 1 darcy in Badin Block (Quadri and Shuaib, 1986). Lower Goru

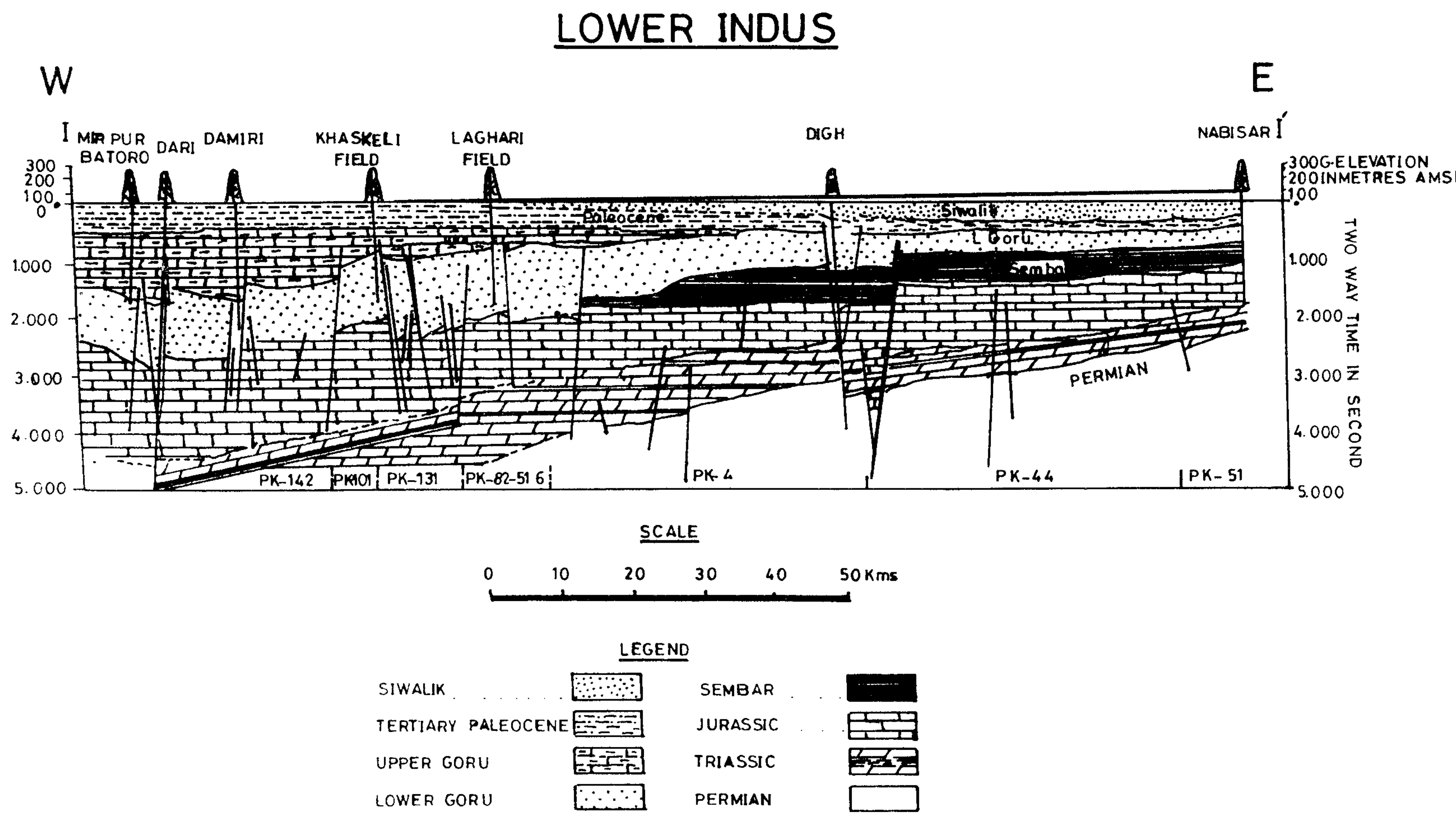

Figure 3- Structural cross section showing the extentional tectonic of Badin and adjoining area (Adapted from Kemal, 1991)

sandstones can often be broken into five discrete sand bodies, based on electric log characteristics in the Lower Indus Basin; however, the uppermost and lowermost sands of the sequence are often considered the primary reservoirs (Hussain et al., 1991).

METHODOLOGY

As mentioned earlier the current petroleum resource appraisal of the Lower Goru play of the Badin Block has been carried out through the PRASS1 package. PRASS1 provides two different approaches to the assessment of oil and gas resources at the play level: 1) Discovery Process Model- which is designed for evaluation of a play in which there is significant number of discoveries, and 2) Subjective Method- which is appropriate for conceptual and immature plays. In the use of either approach the fundamental objective is to determine two things- the parameters (mu and sigma square) of the underlying pool size distribution (a superpopulation) and an estimate of the total number of pools in a given play.

APPRAISAL OF PETROLEUM RESOURCE

In case of the Lower Goru play of the Badin Block, we carried out Discovery Process Model, as sufficient number of discoveries were available. This study is based on two important pieces of information regarding the oil and gas fields of Badin Block, i.e., 1) recoverable reserve data of individual pools and 2) discovery sequence. Based on these two pieces of information, we assessed the total oil and gas recoverable reserves of Lower Goru play of Badin Block as well as expected additional oil and gas pools and their respective sizes. Procedures of appraisal is the same for both the oil recoverable reserves as well as the gas recoverable reserves. The current appraisal of the oil recoverable reserves is based on the data of 30 pools (Table 1), whereas gas recoverable reserves on the data of 21 pools (Table 2). During the oil recoverable reserves appraisal following steps were taken:

1) Data pertaining to the recoverable oil reserve for individual pools and their dates of discoveries (Table 1) were fed to the computer.

2) Certain graphic modules, such as, log probability plot, discovery sequence plot, box plot, cumulative probability plot, and cross plot were constructed to examine the characteristics of the input data. This procedure is adopted, before starting the analytical procedure, to get a rough information about certain parameters. For example, the log probability plot is constructed to test whether input data for the appraisal approximates a log normal population or not. This is a very important step to be taken in the assessment of the petroleum resources of a play; because the observation, that the logarithms of pool sizes are normally distributed and can therefore be completely specified by the parameter mu and sigma square. These two parameters constitute a major assumption of PRASS1 methodology, as these are the standard descriptive parameters of a lognormal distribution which represent the mean and variance respectively of the log transform data. Lognormally distributed pools approximate a straight line when plotted on log-probability graph paper which provide a simple test for mixed population. Furthermore, values of mu and sigma square, estimated from such plots, can be used as preliminary parameters for running the early analytical modules.

4) Estimation of pool size distribution under Kaufman's Discovery Model was the first analytical module carried out to estimate the parameters of a pool size distribution using the Discovery Process Model. The parameters: mu, sigma square and expected total number of pools in the play were estimated through this module which represent a best fit or maximum log likelihood solution. Size and sequence of discoveries (in this case 30 fields) were used as input to the module, and following parameters are the output:

1) Total number of expected pools	:	135
2) Beta	:	0.70
3) Mu	:	-1.715
4) Sigma square	:	3.731
5) Log-likelihood	:	-88.0956

5) Based on the above noted parameters another analytical module i.e. MATCH (selection of final parameters by comparison of discoveries to prediction) was executed to match the discovered pools to a number of prediction scenarios. The output of MATCH gave the following parameters:

1) Mu	:	-1.900
2) Sigma square	:	3.200

6) Based on the results of MATCH another analytical module i.e. PSDR (pool size rank constrained by a discovery record) was run to further refine the results of MATCH. This gave the rank and sizes of the remaining pools in the play.

7) After removing the uncertainty through PSDR, final analytical module i.e. PPDR (play potential distribution constrained to a discovery record) was executed to assess the undiscovered play potential of the Lower Goru play. The output of PPDR shows that about 31% of the total recoverable oil reserves, i.e., 35.5 mm bbl still remain to be discovered out of additional 105 expected pools in the play. A summary of the oil recoverable reserves appraisal of Lower Goru play of Badin Block is as follows:

NUMBER OF POOLS

Discovered	Undiscovered	Total
30	105	135

RECOVERABLE RESERVES (mm bbl)

Discovered	Undiscovered	Total
77.3	35.5	112.8

Table 1. Recoverable reserves of 30 oil pools in Badin Block (source DGPC)

(Field)	(Recoverable Reserves) (mm bbl)	(Discovery Dates)
1. Khaskeli	8.196	070281
2. Laghari	20.261	092783
3. Golarchi	0.196	012884
4. Tajedi	0.464	051984
5. Dabhi	4.445	102384
6. Nari	0.399	013085
7. Turk	1.132	051285
8. Mazari	14.745	061285
9. Mazari South	10.902	063085
10.Sonro	0.950	080985
11.Bukhari	1.651	011086
12.Matli	0.311	031086
13.Dabhi South	0.100	042086
14.Jabo	0.100	061586
15.Makhdumpur	0.237	091486
16.Liari	5.429	102386
17.Halipota	0.432	121986
18.Ghungro	0.787	013188
19.Duphri	0.105	030988
20.Paniro	0.197	031289
21.Pir	0.100	031488
22.Khorewah	0.698	070988
23.Turk Deep	0.190	073088
24.Akri North	0.487	110488
25.Koli	0.179	060389
26.Kato	0.141	091089
27.Bhatti	0.617	110589
28.Rind	1.000	122789
29.Mahi	0.209	100192
30.Bari	2.531	110192

During the course of gas recoverable reserves appraisal, similar graphical and analytical steps were taken. The output of PPDR shows that about 47% of the total recoverable gas reserves i.e. 520.5 Bcf still remain to be discovered out of the additional 124 expected pools. A summary of gas recoverable reserves appraisal of the Lower Goru play in the Badin Block is as follow:

NUMBER OF POOLS

Discovered	Undiscovered	Total
21	124	145

RECOVERABLE RESERVES (Bcf)

Discovered	Undiscovered	Total
588.3	520.5	1108.8

Table 2. Recoverable reserves of 21 gas pools in Badin Block (source DGPC)

(Field)	(Recoverable Reserves) (Bcf)	(Discovery Dates)
1. Golarch	55.360	012884
2. Turk	113.560	051285
3. Mazari	10.550	061285
4. Sonro	17.840	080985
5. Bukhari	67.940	011086
6. Matli	55.550	031086
7. Dabhi South	3.720	042086
8. Jabo	2.800	061586
9. Makhdumpur	23.660	091486
10.Halipota	2.180	121986
11.Duphri	3.540	030988
12.Pir	1.420	031488
13.Khorewah	99.750	070988
14.Turk Deep	31.710	073088
15.Koli	14.830	060389
16.Tando Ghulam Ali	3.900	062489
17.Kato	4.740	091089
18.Bhatti	34.940	110589
19.Rind	1.500	122789
20.Mahi	13.080	100192
21.Nakurji	25.650	120192

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