EXTENSIVE CORE ANALYSIS DATA IMPROVED THE DESCRIPTION OF THE CARAPITA AND SAN JUAN RESERVOIRS IN EASTERN VENEZUELA.

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ABSTRACT

This paper presents a systematic methodology used to integrate core and log data for petrophysical evaluation of the highly heterogeneous Carapita and San Juan reservoirs in the Orocual Field. Conventional formation evaluation methods have previously been employed in these reservoirs with limited success. The reliability of the petrophysical data required for reservoir characterization and formation damage control has always been questionable. It was necessary to take advantage of the existence of a large core database and a new technique described in this paper to obtain more effective petrophysical evaluation and description of the reservoirs.

The method is based on the Hydraulic (Flow) units concept that combines the geological attributes of texture and mineralogy with petrophysical data to delineate the reservoirs into units with similar fluid flow characteristics. This zonation enabled the development of effective petrophysical models for the reservoir systems.

The systematic methodology described here includes the process of (1) building composite core and log databases for each reservoir, (2) hydraulic units zonation and verification and (3) petrophysical model development and predictions in uncored wells and intervals.

The existence and boundaries of the units were confirmed by mineralogical and textural attributes determined on core samples taken from each unit. Core samples from the same hydraulic units were shown to have similar mineralogical and pore throat attributes.

The present model is expected to provided better management strategies for these reservoirs and may be used for similar reservoirs.

INTRODUCTION

It is widely recognized that effective reservoir description requires detailed knowledge of the reservoir heterogeneity at both microscopic and megascopic levels. This knowledge base is typically enhanced by extensive core and log data acquisition. In this project, we took advantage of the available large core database. The core and log databases were organized and synthesized to facilitate a systematic linkage of the available geological, petrophysical and flow properties data. All ambient core data were stress - corrected, carefully edited and employed for hydraulic units zonation.

The hydraulic units methodology and applications have been published previously[1-5]. For the sake of clarity it suffices to simply state the Ebank's[6] definition of hydraulic units as "total reservoir rock volume within which geological and petrophysical properties that affect fluid flow are internally consistent and predictably different from the properties of other rock volumes".

For practical application of this technology, a parameter that quantifies geological attributes of the formation is defined and referred to as flow zone indicator[1](FZI). This parameter is typically obtained from core analysis data and can be estimated from log data.

In this study, deterministic and probabilistic models were developed with core derived FZI and normalized log data. The models enabled the estimation of FZI from wireline log signatures where core data were not available. The validity and robustness of the models were verified by comparing the wireline log- derived permeability with those measured on cores within the cored intervals. Results from the multiple well study showing very good agreements are presented in this paper. It is demonstrated that prudent application of large core analysis database improved the quality of the description of the Carapita and San Juan reservoirs for simulation and productivity enhancement studies.

BACKGROUND

The subject field was discovered in 1933, but, commercial production commenced only 20 years later, in 1953. Hydrocarbon bearing horizons of Oligocene and Paleocene/Cretaceous age, namely the Carapita and the San Juan Formation sands were discovered in December 1985 with the drilling of ORS-52 at a depth of 14,000 feet. The Carapita Formation sands are divided into two different members, separated by several hundred feet of shale. These members are currently subdivided into six fieldwide correlatable units.

The San Juan Formation Sands are currently divided into three members, named from top to bottom as Superior, Medio and Inferior. These members are subdivided into a total of eight litho-stratigraphic, field wide correlatable units. Production from the San Juan Formation originates from the two lower members only, the Inferior and the Medio.

A total of fourteen wells have been drilled into both the Carapita and San Juan Formations. Of these, cores were taken from four wells in the Carapita and four wells in the San Juan. The focus of this study was to provide petrophysical data required for effective reservoir description and simulation study.

EVALUATION PROCEDURE

The flow diagram for the systematic core/log integration is presented in Figure 1.

WireLine Log Data Pre-Processing

Wireline log data available in the Orocual Field database was acquired by three different Logging Service Companies over a period from 1985 through 1994. Logging suites run over both Carapita and San Juan intervals generally consisted of gamma ray, dual-induction resistivity, litho-density, compensated neutron, and acoustic logs.

To obtain a good core/log integration extensive depth adjustments and in some cases, borehole compensation editing were applied to the log data. Log data normalization was also performed to facilitate construction of multi-well databases for the deterministic and probabilistic modeling. This is required in order to eliminate all differences in the log signatures that are not direct function of reservoir properties.

Core Data Pre-Processing

The porosity and permeability were tabulated and the random errors associated with measurement were estimated by the root mean square technique[1,7]. All samples with coefficient of variance (given as Δ FZI / FZI) > 0.5 were considered unreliable for hydraulic units zonation[1] and were dropped out of the core database. The coefficient of variance is given as:

$$\frac{\Delta FZI}{FZI} = \pm 0.5\sqrt{\left(\frac{\Delta\phi}{\phi}\right)^2 \bullet \left(\frac{3-\phi}{1-\phi}\right)^2 + \left(\frac{\Delta k}{k}\right)^2} \quad ------(1)$$

Typically $\Delta\phi$ is taken as 0.5% if porosity is effective and 1% if total porosity is used. Random error in permeability measurement ($\Delta k/k$) is typically approximately 0.2.
Due to the lack of multiple stress data, a modified form of Stanley's two point stress[8] model was used to correct the permeability data to in-situ stress conditions of 4000 psi and 7000 psi for Carapita and San Juan. Generally stress sensitivity was not very significant in these reservoirs.

HYDRAULIC UNIT ZONATION

First Pass

For the delineation of the hydraulic units, Carapita and San Juan were treated as separate entities. This was done after initial data evaluation indicated that the rock qualities in both reservoirs were controlled by different geological phenomena. All the data that met the criteria given in Eq. 1 were assembled and the different parameters required for the hydraulic units identification were computed according to the following procedure;

1. Discrete values of flow zone indicators (FZI) were calculated using the following:

$$FZI = \frac{RQI}{\phi_z} \quad \text{----------------(2)}$$

$$RQI = 0.0314\sqrt{\frac{K}{\phi}} \quad \text{- - - ----- - (3)}$$

where

$$\Phi_z = \frac{\phi}{1 - \phi}$$

2. Histogram of the discrete FZI was constructed to determine the number of observable population based on the number of normal distributions.
3. Cluster analysis was performed using the numbers of units predicted from step # 2 to separate the samples into clusters.
4. Plots of RQI versus porosity group Φ_Z (log-log) and Permeability versus porosity (semi-log) were made for the different cluster groups.

Second Pass

Comparison of the first pass hydraulic units boundaries with the stratigraphic units boundaries on a well to well basis helped in the second pass to get a final delineation of the Carapita and San Juan respectively to seven and ten hydraulic units. The identity plots are given in Figures 2 and 3 for Carapita and San Juan, respectively. The descriptive statistics of the hydraulic units shown in Tables 1a and 1b indicate, that in each hydraulic unit, the differences between the mean and median FZIs are minimum that means that the rock properties can be averaged within these units with minimum errors. This is the normality test.

Hydraulic Units Verification

Geological Controls On Reservoir Quality - Petrographic

In order to assign some geological significance to the variation in flow properties from one unit to the other, the available petrographic descriptions for the sandstone reservoirs of Carapita and San Juan Formations were evaluated in the context of the hydraulic units zonation. As shown in Table 2, reservoir qualities of both formations are controlled by a combination of rock depositional texture and diagenesis.

Four samples were available for petrographic analyses in the Carapita, representing hydraulic units #1,# 2 and #7. From the petrographic description given in Table 2a, it may be inferred that pore size and pore throat size reduction appear to be a direct result of decreasing grain size with a concomitant increase in authigenic cements and clays in the Carapita. The observed variation in grain composition is likely to have had some control on resultant differences in diagenetic fabric and authigenic mineralogy.

Ten samples were available for the San Juan (Table 2b). Again, from the description given in Table 2, it may be concluded that both depositional and diagenetic processes have had an influence on the reservoir quality of these sands. Grain size ranges from medium to fine with a general decrease in grain size with increasing hydraulic unit #s. Sorting ranges from moderate to poor, with the medium grained sandstone (i.e., the lower HU #s) generally having poorer sorting characteristics. Clay matrix is uncommon in this suite of sandstone and detrital clay laminae were completely absent from all analyzed samples. Diagenesis appears to be the primary control on reservoir quality for the San Juan.

Engineering Control On Reservoir Quality - Verification of Hydraulic Units

The relationships between FZI and irreducible water (capillarity) and residual oil saturation (displacement) given by Figures 4 and 5 also indicate that the variation of the reservoir rock properties follows the same trend as the FZI(HU indicator).

CORE/LOG INTEGRATION : HYDRAULIC UNITS MODELING

Having delineated the reservoirs into hydraulic units, the core and log databases were combined for the purposes of core-log modeling and petrophysical analysis. The core data were depth shifted to match log depths in each well before recombining into a new multi-well database, one each for the Carapita and San Juan formations. These databases were then utilized for the construction of deterministic and probabilistic petrophysical models as follows.

Qv, Clay Bound Water & Effective Porosity Computation

Using the clay volume obtained from a correlation between FZI and MineralogTM data, total porosity (ϕ_t), average core measured grain densities (2.63 and 2.65 for the Carapita and San Juan respectively) along with values of core measured CEC, continuous depth variable values of Qv, clay bound water (C_{BW}) and effective porosity (ϕ_e) were derived using the procedure described by Hill, Shirley and Klein[9].

Water Saturation Computation

Electrical properties measurements made at in-situ stress on core plugs were used to determine cementation exponent (m*) and saturation exponent (n*) values, respectively, for utilization in a Waxman-Smits water saturation model. By comparing the electrical properties with the various hydraulic units, it was observed that the following average values are best for the Carapita Superior a=1.0, m* =2.05, n* 2.04, Carapita Inferior a=1.0, m*=2.05 and n*=2.35 and San Juan a=1.0, m*=2.0 and n*= 2.07. The computed water saturation results were validated against an independent computation of core analysis capillary pressure calibrated irreducible water saturation (Swir). Excellent agreement was seen in the highest quality reservoir intervals believed to be above the transition zone.

DETERMINISTIC MODELING FOR HYDRAULIC UNITS ZONATION

In order to extend the hydraulic units zonation and FZI computation from the cored wells/intervals to uncored wells/intervals, a non linear optimization model was developed each for Carapita and San Juan. The non linear optimization was performed using the Levenberg Marquard non linear optimization algorithm described by Ohen and Civan[10].

DETERMINISTIC MODEL

Model for Carapita

From rigorous rank correlation exercise, it was determined that a combination of core quality density porosity (ϕ), neutron and density porosity difference ($\Phi_{N\text{-}D}$) and gamma ray (GR) are best correlatable to the FZIs in Carapita. The final equation obtained from the non-linear optimization exercise is given as;

$$\mathrm{FZI} = \mathrm{EXP}\left[18.83\,\phi^{\,0.058} - \frac{0.085}{0.0052 - 1.6\,\Phi_{N\text{-}D}\ln(\mathrm{GR})^{-5.556}} \right] \text{ -------(4)}$$

Model for San Juan

Again from rank correlation exercise, it was determined that in San Juan, porosity (ϕ), deep resistivity (RT) and gamma ray (GR) best correlate with the FZIs. Equation for the deterministic prediction of FZI (HUs) in San Juan is given as;

$$\mathrm{FZI} = \left[\mathrm{EXP}\left((\ln(\mathrm{RT}))^{1.17}\phi^{0.53} - \frac{0.33}{2.043\ln(\mathrm{GR})^{-1.23} - 0.214)} \right) \right]^{1.55} \text{ ----(5)}$$

Model Validation

Shown in Figures 6 and 7 are the cross plot of model derived versus core derived FZIs. Considering that the prediction was made on composite, normalized, database of all cored intervals in the reservoirs, a correlation coefficient of 0.88 obtained in this work is considered very good. The validity of these results is further confirmed by the good match of the measured permeabilities and the results of probabilistic modeling discussed below .

PROBABILISTIC MODELING

Probabilistic modeling has been used in this work to estimate FZI and Permeabilities as comparison to the deterministic model. The software program which is part of the WDS package is called HORIZON and is based on a probabilistic implicit method which involves magnitude estimation. Detailed discussions of this technology and its applicability are presented by Tetzlaff and Anderson[11].

Deterministic versus Probabilistic Models

As in Figures 8a and 8b , the deterministic and probabilistic models approximate both the FZIs (HUs) and permeability very effectively. However, the deterministic model was preferred because (1)the deterministic model is more likely to provide better results in the uncored interval because of its ability to compute the unknown variable by using the full range of the input parameters (2) The deterministic model consists of equations rather than a "black box" and can therefore be used by Petrophysicist, engineers and geologists at any time.

PERMEABILITY ESTIMATION

The concept of the hydraulic units is based on the fact that the relationship between permeability and porosity is only valid within a unit of the reservoir with similar fluid flow characteristics referred to as hydraulic (flow) units. Therefore, the identification of hydraulic units and the knowledge of the characteristics flow zone indicators (FZI_C) is paramount in the development of the implicit relationship between permeability and porosity given as;

$$K = 1014\, FZI_C \, \frac{\phi^3}{(1.0 - \phi)^2} \qquad \text{----(6)}$$

The benefit of identifying hydraulic units lies in the ability to determine FZI_C that is the mean or median values of FZI obtained from frequency histogram of measured discrete FZIs and the descriptive statistics of the hydraulic units.

CENTRIFUGE IRREDUCIBLE WATER SATURATION

The aim of this modeling effort was to obtain continuous capillary pressure-calibrated log-derived irreducible water saturation values that can be compared to log computed in-situ water saturation. The following form of relationship[1] between Swir and FZI was used for a non linear optimization scheme;

$$S_{wir} = 1 - \frac{1}{a + bFZI^{-c}} \qquad \text{----(7)}$$

The results of the non-linear optimization show very good correlations between the measured and predicted (see Figures 4a and 4b) values.

GAS/OIL RESIDUAL OIL SATURATION UNDER GAS DRAINAGE

The aim of this modeling effort is to obtain a continuous S_{org} (See Figure 9a for Carapita and 9b for San Juan) values that may be used as an indication of the producibility of a given zone and make decision as to secondary recovery possibilities. The following functional form was optimized using core analysis relative permeability data.

$$f = K_{ro} - 1 + \frac{a}{b + S_g^{-c}} \approx 0.0 \qquad \text{--------(8)}$$

The Sorg obtained for each sample was correlated to FZI to obtain a model for as shown in Figure 7.

ADVANCED ROCK PROPERTIES AVERAGES

CAPILLARY PRESSURE AND GAS-OIL RELATIVE PERMEABILITY DATA

Relative permeability and capillary pressure data of samples with similar hydraulic unit were grouped together. Table 3 shows the importance of the hydraulic units zonation as a tool for sample selection to ensure full coverage of all the flow zones in advanced core analysis programs.

Reservoir Properties Averaging

As the hydraulic units' and stratigraphic units' boundaries do not coincide and average reservoir properties can be more effectively obtained by hydraulic units, hydraulic units thickness weighted averaged of the flow properties were provided to the simulation engineer.

VALIDATION WITH PRODUCTION DATA

Shown in Table 4 is a summary of the production tests by reservoir units and by well. Also included is an estimate of the total net producible reservoir in each zones. In all cases except Chl-4 and ORS-58 in Carapita, the production tests confirm the producibility predictions from petrophysical evaluation. Earlier study shows that the wells that do not conform were damaged during drilling and well Completions activities.

CONCLUSIONS AND RECOMMENDATION

- The hydraulic units concept has been used effectively to delineate and show the existence of seven and ten hydraulic units in the Carapita and San Juan reservoirs respectively. The technique helped to obtain better zonal averages of the rock properties data.
- The technique has been utilized to obtain reasonably accurate estimates of permeability in uncored interval based on wireline signature sand. It is considered adequate for permeability estimation in future wells as long as the wireline log curves are properly normalized.
- Reservoir quality based models for irreducible water and residual oil saturation have been developed to facilitate a quick assessment of completion potential of zones data derived from log only. These fluid saturation models are, however, based on limited capillary pressure and relative permeability data and therefore need to be updated.

NOMENCLATURE

Abbreviations

Chl	Chaguaramal
CP	Carapita
HU	Hydraulic Units
ORS	Orocual
RQI	Reservoir quality index (mm)
SJ	San Juan

Notations

ϕ	Porosity
$F_{N\text{-}D}$	Neutron and density porosity difference
GR	Gamma Ray,
h	Net sand thickness, ft
k	Absolute permeability, mD

k_{ro}	oil permeability , mD
k_a	Klinkenberg Permeability
K_{air}	Air permeability
m	Cementation factor
m*	Clay corrected cementation factor
n	Resistivity index
n*	Clay corrected resistivity index
Q_v	Cation exchange capacity (Meq/l),
RT	Deep induction resistivity
S_{org}	Residual oil saturation after gas drive

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REFERENCES

1. Amaefule, J.O. et al."Enhanced Reservoir Description: Using Core and Log Data to Identify Hydraulic (Flow) units and predict permeability in uncored Intervals/Wells", SPE 26436, 68th Annual SPE conference and exhibition, Houston, Texas, October 3rd - 6th, 1993.
2. Amaefule, J. O, Altunbay M, Henry Ohen, Kersey David and Lane Peter " A Hydraulic (Flow) Units-Based Approach for Predicting Formation Damage in Uncored interval/ Wells using core/log data.," Presented at the International Symposium on Formation Damage Control, 9-10 February, 1994.
3. Ohen Abuya Henry, Nnabuihe Larry and Ososanwo Dunni. " Laboratory Acid Effectiveness Evaluation is the Key to Productivity Improvement by Acidizing in the Clayey Agbada Formation of the Niger Delta," paper SPE 30101, presented at the SPE European Formation Damage Conference held in Hague, Netherlands, May 15-16, 1995.
4. Ohen . H.A., Austin Ajufo, and Federica Manni Curby " A Hydraulic (Flow) Unit Based Model For The Determination of Petrophysical Properties from NMR Relation Measurements," SPE 30626, 1995.
5. Udegbunam E.O., and Huff B.G : "Geological Characterization and 3-D Visualization of the Gas Storage Reservoir at Hillsboro Field, Montgomery County, IL," Paper SPE 29158, presented at the 1994 Eastern Regional meeting in Charleston WV, 8-10 November, 1994.
6. Ebanks W. J. Jr. " Integrated approach to reservoir description for engineering projects (abstract only) AAPG Abstract flow units concept.
7. Amaefule, J. O. " Stochastic Approach to Computation of Uncertainties in Petrophysical Properties," SCA-8907, 1989.
8. Jones, S.C : " Two-Point Determinations of Permeability and PV vs Net Confining Stress, " SPE Paper # 15380, 1986.
9. Juhasz ,I. " Normalized Qv - The Key to Shaly Sand Evaluation Using the Waxman-Smiths Equation in Absence of Core Data," SPWLA 22nd Annual Logging Symposium, Paper Z, June 23-26, 1981.
10. Ohen, Henry A. and Civan F; "Simulation of Formation damage in petroleum reservoirs," Paper SPE 19420, Advance Technology Series, April 1993, 27-35.
11. Tetzlaff, D.M, Rodriguez E. and Anderson, R.I : Estimating Facies and Petrophysical Parameters from Integrated Well data.

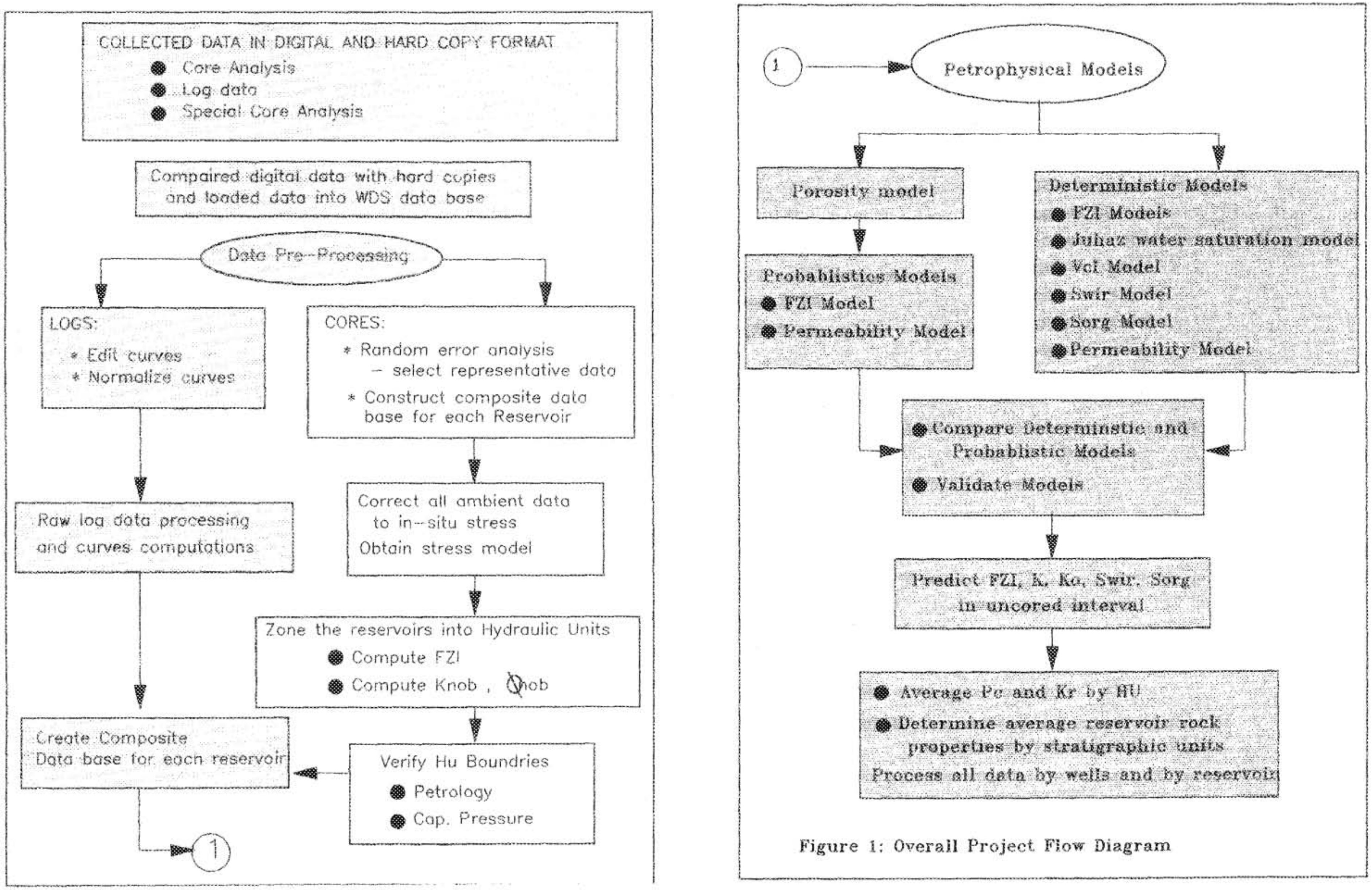


Figure 1: Overall Project Flow Diagram

Figure 2a : Hydraulic Units Zonation- Carapita

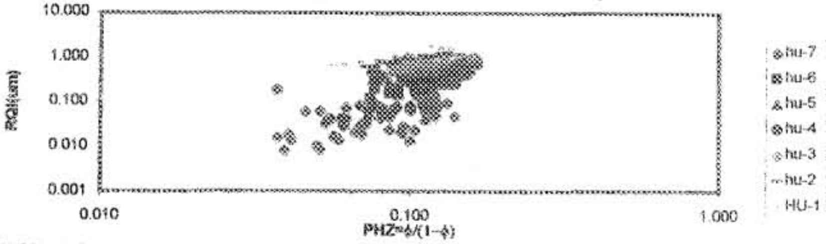


Figure 2b : Permeability - Porosity Relationship by HU - Carapita

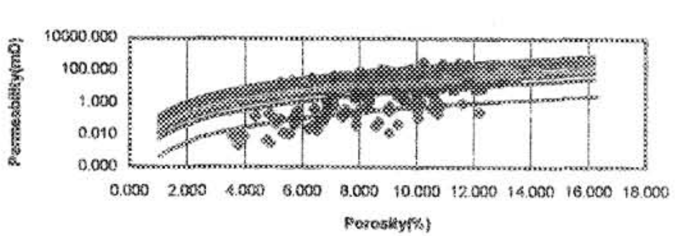


Figure 3a : Hydraulic Units Zonation -San Juan

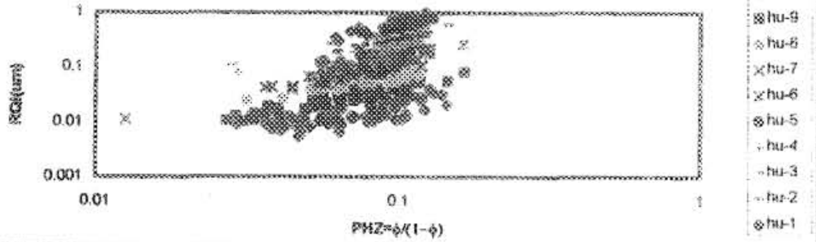


Figure 3b : Permeability-Porosity Relationship by HU - San Juan

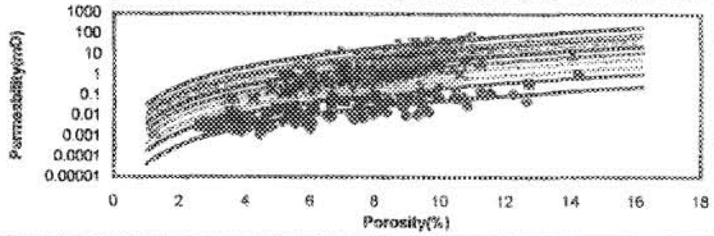


Figure 4 :S_{wir} Model From Capillary Pressure- Carapita

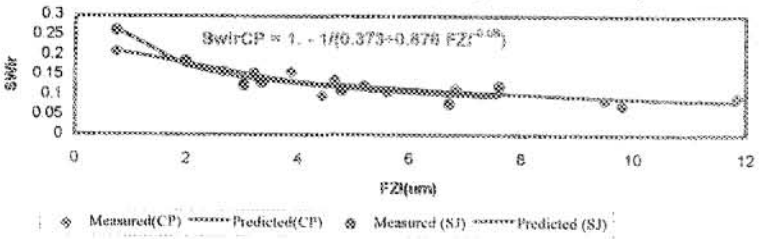


Figure 5: FZI-Residual oil to initial water Model

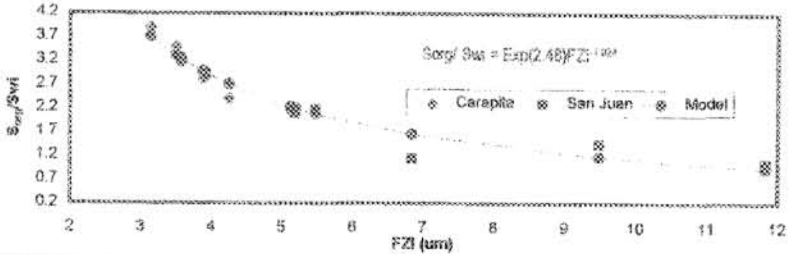


Figure 6 :Deterministic Wireline Log Predicted FZI - Carapita

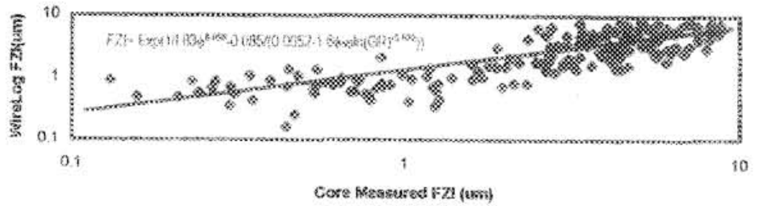
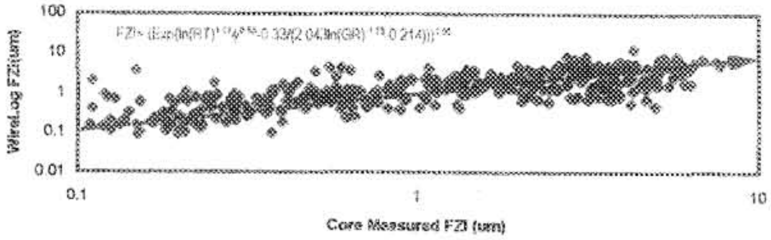


Figure 7 :Deterministic Wireline Log Predicted FZI -San Juan



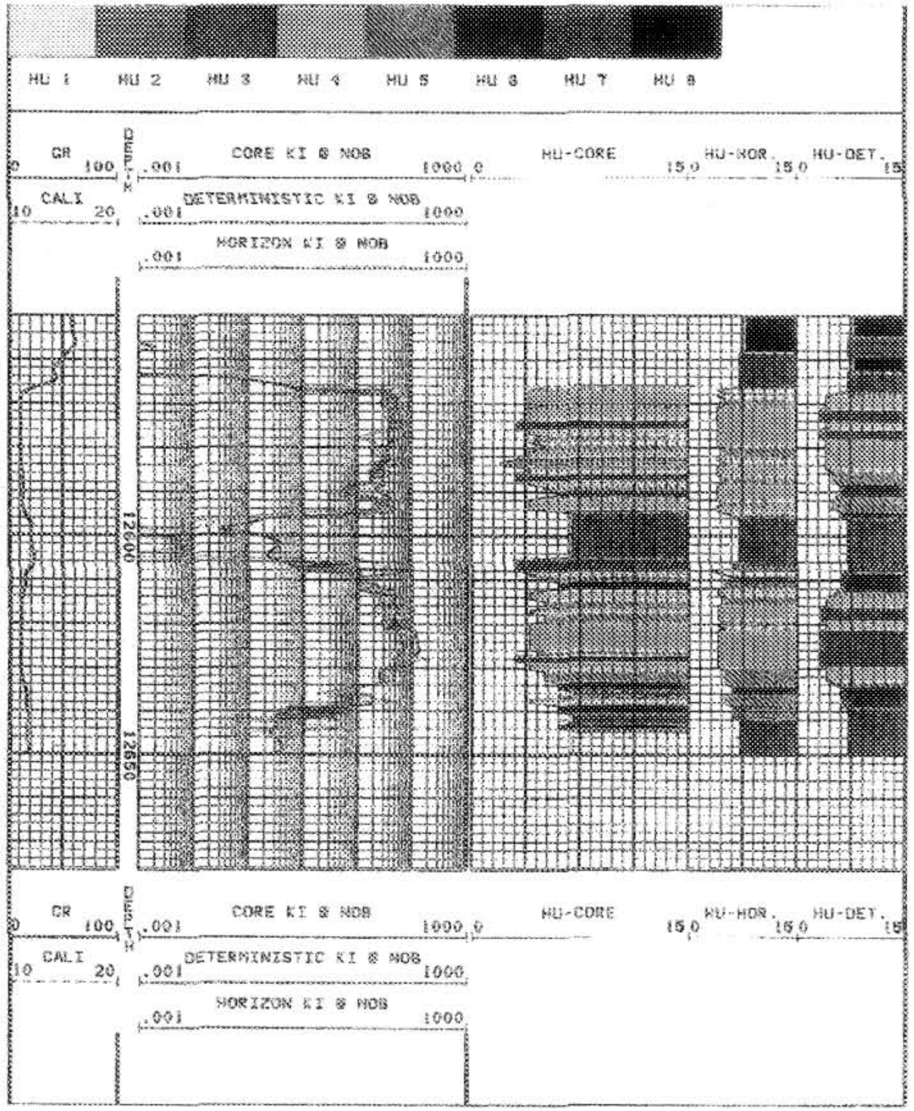


Figure 8a: Comparison Plot for the verification of Log derived HU (Carapita)

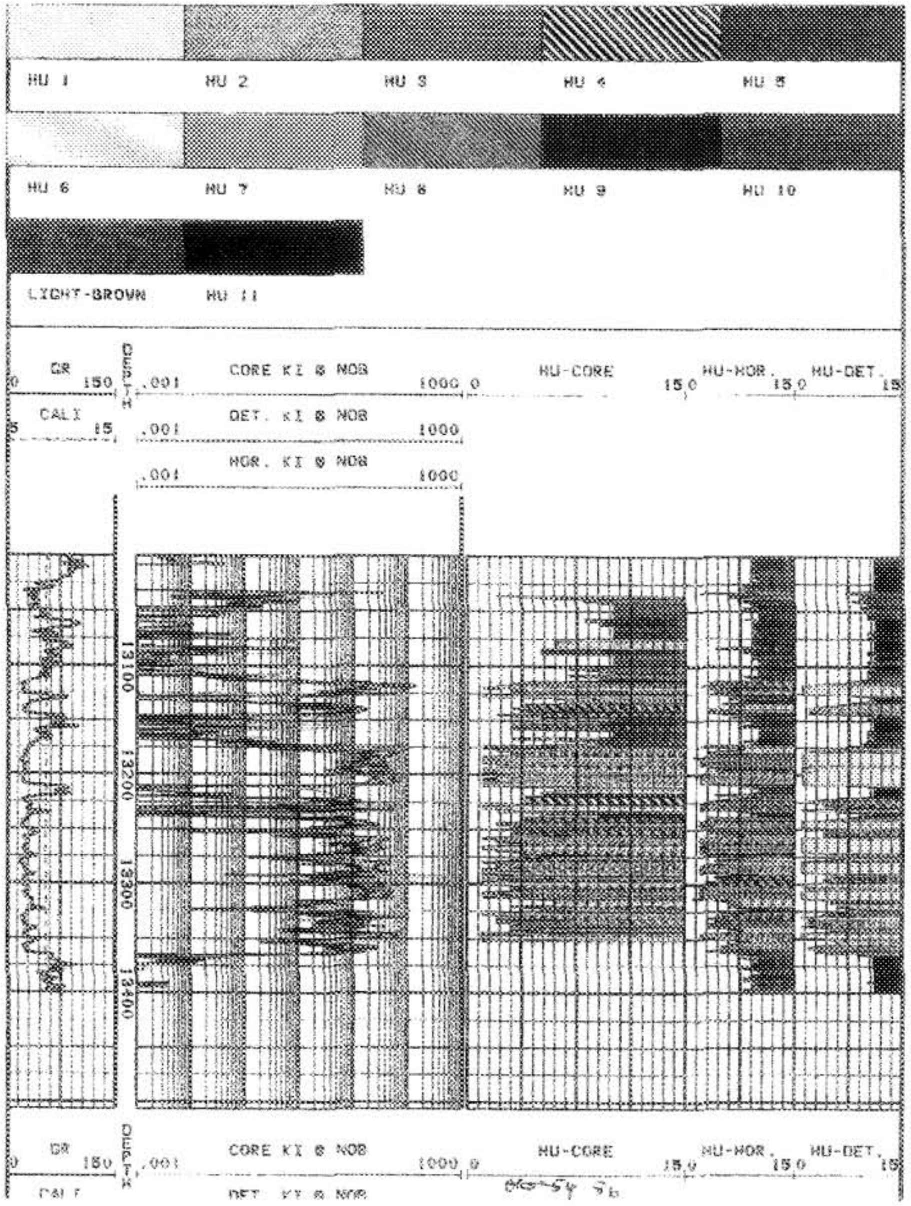


Figure 8b: Comparison Plot for the Verification of Log Derived HU (San Juan)

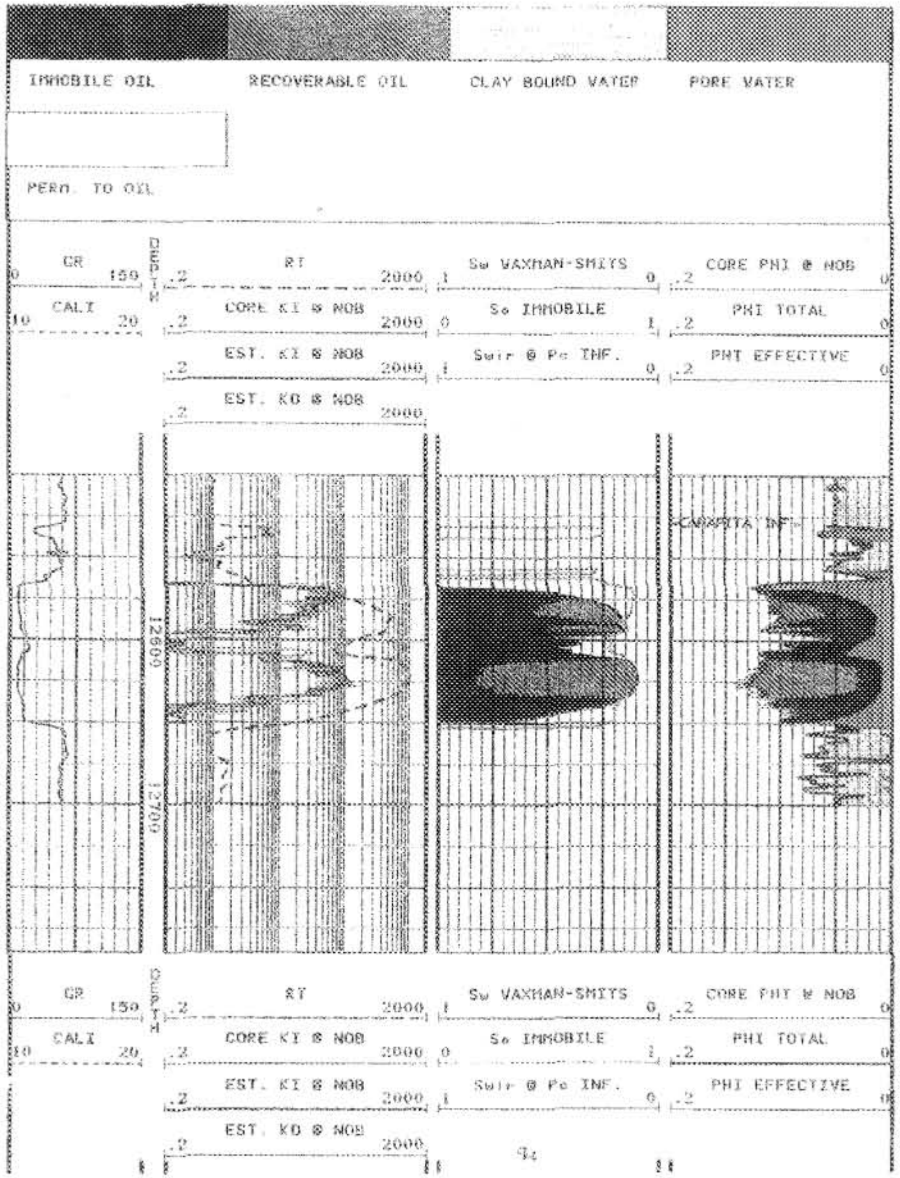


Figure 9a: Example of HU based model for the Estimation of Producible Reserves (Carapita)

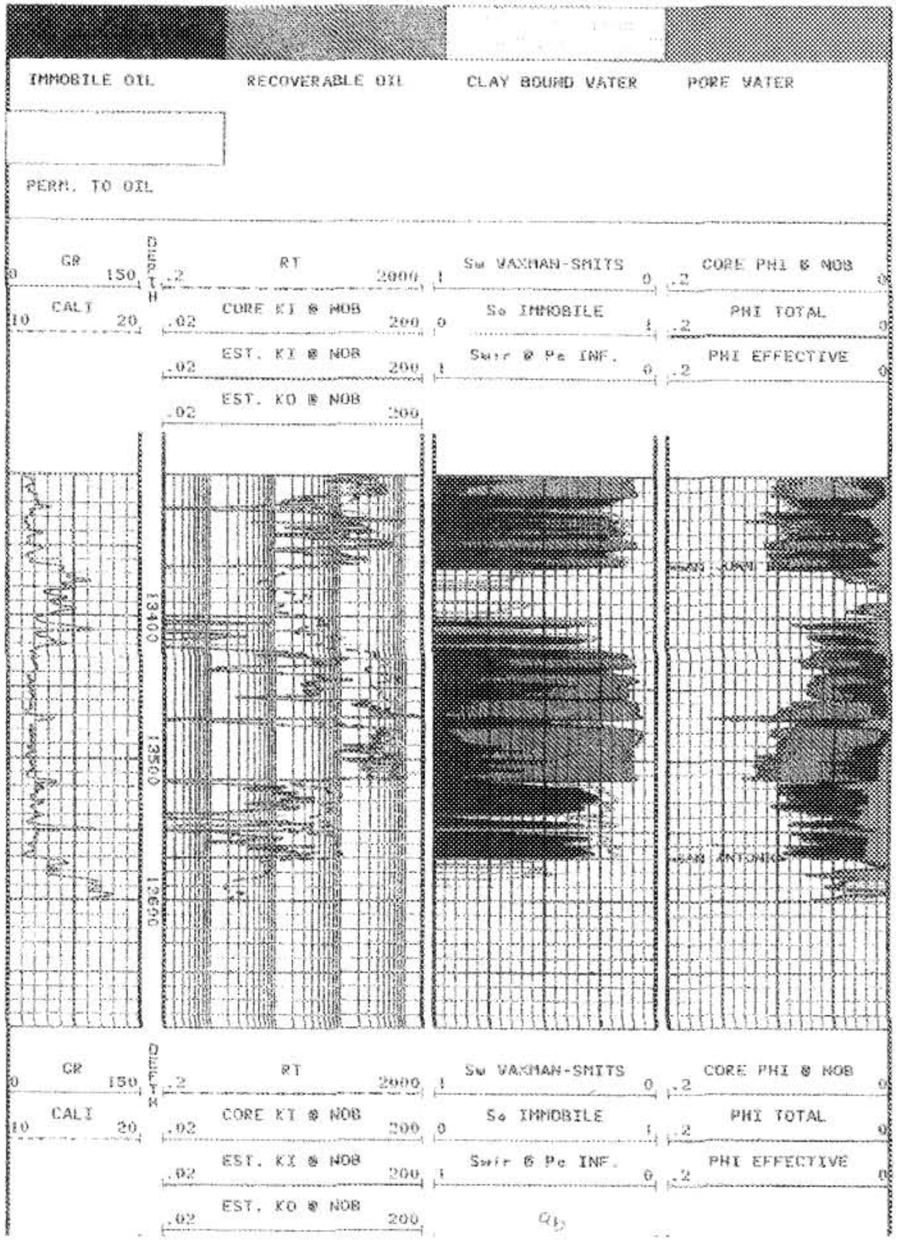


Figure 9b: Example of HU based model for the Estimation of Producible Reserves (San Juan)

Table 1 ;Descriptive Statistics of the FZIs (HUs)

A: CARAPITA

	HU-7	HU-6	HU-5	HU-4	HU-3	HU-2	HU-1
Mean	0.670	2.343	3.626	4.930	6.878	9.074	12.375
Median	0.645	2.365	3.609	4.873	6.927	8.956	11.855
SD	0.346	0.412	0.366	0.431	0.532	0.688	1.451
Minimum	0.128	1.594	3.016	4.291	5.966	8.074	10.986
Maximum	1.407	2.975	4.243	5.881	7.861	10.278	16.437
Count	61	45	47	55	41	20	13

B; SAN JUAN

	HU-10	**HU-9**	**HU-8**	**HU-7**	**HU-6**	**HU-5**	**HU-4**	**HU-3**	**HU-2**	**HU-1**
Mean	0.216	0.444	0.703	1.040	1.475	2.115	2.731	3.420	4.257	5.984
Median	0.221	0.444	0.687	1.042	1.421	2.114	2.744	3.408	4.231	5.762
SD	0.061	0.069	0.086	0.117	0.153	0.171	0.178	0.208	0.314	0.873
Minimum	0.105	0.331	0.576	0.877	1.266	1.807	2.467	3.105	3.850	4.941
Maximum	0.322	0.572	0.864	1.238	1.775	2.414	3.053	3.817	4.894	8.110
Count	75	61	38	38	43	43	54	62	40	55

Table 2 . Geological Interpretation of the Hydraulic Units

SAN JUAN FORMATION				
Well #	**Depth ft**	**FZI um**	**HU #**	**Description**
OR54	13072	0.167	10	Fine grained sandstone.Quartz and K-Feldspar Quartz overgrowth,pyrite cements, authigenic pore filling kaolinite, grain coating illite. Fair to poor intergranular porosity present. K reduced by detrital and authigenic clays. Sorting is moderate
OR54	13070	0.231	10	Fine grained dolomitic sandstone,Quartz K-feldspar, chert ferroan dolomite cements authigenic chlorite. Sorting is moderate
OR54	13123	0.465	9	Fine grained sandstone.Quartz and K-Feldspar minor Quartz overgrowth,pyrite cements, rare to minor authigenic kaolinite, illite and intergranular porosity. The flaky, laminated morphology of the clay indicaes detrital origin.
OR54	13162	1.770	6	Fine grained sandstone.Quartz metamorphic rock fragments. Abundant quartz overgrowth and minor dolomite cements rare authigenic kaolinite, illite. Fair, mostly small angular pores. Sorting is moderate
OR54	13318	2.021	5	Medium grained sandstone,Quartz and K-Feldspar Quartz overgrowth, isolated patches of authigenic clay. Cement is kaolinite. Good to fair partually ocluded intergranular porosity present. Sorting is poor.
OR54	13314	2.416	4	Medium grained sandstone,Quartz and K-Feldspar Quartz overgrowth, rare patches of authigenic clay Cement is kaolinite. Good to fair partially ocluded intergranular porosity present. Sorting is poor to moderate.
OR54	13242	2.531	4	Medium grained sandstone,Quartz and K-Feldspar Quartz overgrowth, no visible authigenic clay. Cement is kaolinite. Small, open intergranular porosity present. Moderate to well
OR54	13371	3.000	3	Sublitharenite,Quartz and K-Feldspar. Quartz overgrowth and kaolinite cement,pore filling kaolinite. Small, open intergranular pore space free of clay. Poor to moderate sorting
OR54	13366	3.827	2	Sublitharenite,Quartz and K-Feldspar. Quartz overgrowth and kaolinite cement,pore filling kaolinite. Small, open intergranular pore space free of clay. Poor to moderate sorting
OR54	13308	5.378	1	Medium grained sandstone.Quartz and K-Fedspar Quartz overgrowth, no visible authigenic clay. Fair intergranular porosity present. Sorting is poor.

CARAPITA FORMATION				
Well #	**Depth ft**	**FZI um**	**HU #**	**Description**
OR57	12318	0.850	7	Lower fine grained sandstone,Quartz, plagioclase and Chert and biotite. Quartz overgrowth,carbonate, authigenic chlorite and kaolinite. Very small intergranular pores are tight constricted by quartz overgrowth. Pores are not well interconnected. Sorting is well
OR57	12313	1.218	7	Very to fine grained sandstone,Quartz, plagioclase and K-feldspar. Quartz overgrowth,carbonate, chlorite cements Overgrowth from adjacent grain coalesce to form tight constriction of intergranular pores. Microporous authigenic clays exist. Sorting is moderate to well
OR57	12380	9.743	2	Lower coarse-grained sandstone nearly all quartz. Quartz overgrowth, no visible authigenic clay. Abundant intergranular pores are moderately. connected. Improved reservoir quality is grain size controlled. Sorting is moderate.
OR57	12361	11.987	1	Medium to coarse-grained sandstone nearly all quartz. Quartz overgrowth, traces of chert, kaolinite and chlorite Abundant intergranular pores are moderately connected. Improved reservoir quality is grain size controlled. Permeability reduction is due to scales of residual dead hydrocarbon. Sorting is moderate

Table 3: Averaged Relative Permeability and Cap. Pressures-Carapita

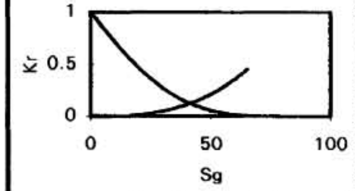
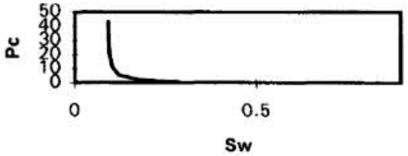
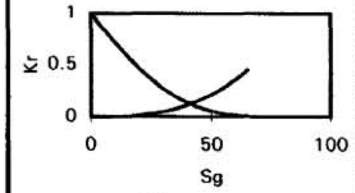
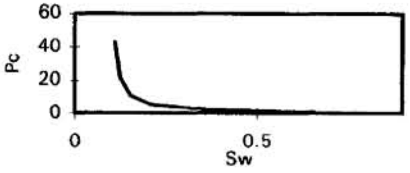
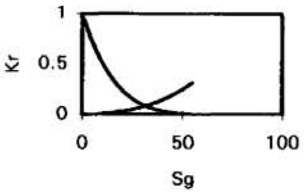
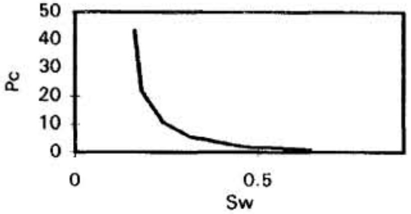
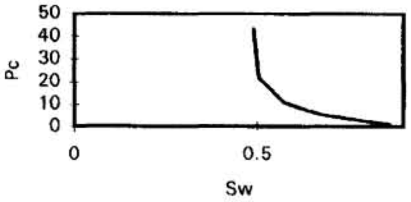
HU	FZI Range	Relative Permeability	Capillary Pressure
1	10 9-16 4		
2	81-103		
3	596-786		
4	42959		
5	302-423		
6	1 59-2.98		
7	0128-15		

Table 4: Summary of Production Tests Results

Reservoir	Wells	Sand Bottom(ft)	Sand Top(ft)	Thickness ft	Hp ft	BOPD	BWPD	MCFPD	Net Prod. feet
Carapita Superior	CHL-2X	13078	12894	184		1548	6.2	1561	26
	CHL-3	13556	13451	105	40	750	6.8	592	13
	CHL-4	12757	12661	96	44	-	-	-	13
	ORS-52	11538	11460	78		615	0.6	55	6
	ORS-57	12400	12304	96		1817	1.8	2170	8
	ORS-58	12274	12106	168	43	0	0.0	0	0
	ORS-59	11790	11770	20		1310	1.3	2310	14
Carapita Inferior	CHL-2X	13487	13376	111		2771	8.3	2793	35
	CHL-3	14010	13961	49	49	181	0.4	138	30
	CHL-4	13146	13094	52	45	-	-	-	49
	ORS-52	12048	11972	76		727	1.5	1074	15
	ORS-57			0		1329	1.3	1357	29
	ORS-58	12648	12566	82	70	0	0.0	0	40
	ORS-59	12192	12090	102		150	0.0	270	4
San Juan Superior	ORS-52	13625	13420	205		641	6.5	3878	28
	ORS-53	13942	13729	213		751	27.2	4438	5
San Juan Medio	ORS-52	13785	13642	143		787	7.9	4584	31
	ORS-53	14166	14002	164		669	38.2	3700	50
	ORS-54	13364	13221	143		840	8.5	5516	89
	ORS-55	14084	13990	94	72		0.0		65
	ORS-56	12950	12834	116		503	1.5	4490	46
San Juan Inferior	CHL-4	15380	15070	310	138				0
	ORS-52	14026	13850	176		556	166.1	2833	19
	ORS-53	14402	14228	174					0
	ORS-54	13570	13424	146		905	4.5	4220	78
	ORS-55	14200	14124	76	76				0
	ORS-56	13158	12996	162		671	28.0	4892	19
	ORS-58	14398	14256	142	86	886	2.7	1899	1125