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DIAGENETIC STUDY AND POROSITY DEVELOPMENT WELL “IR” IN BATURAJA FORMATION SOUTH SUMATERA BASIN BASED ON PETROGRAPHY, CORE ANALYSES, AND PETROPHYSICAL CALCULATION

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ABSTRACT

South Sumatra Basin is an asymmetric basin located to the east of Barisan Mountains, to the north and west of the Lampung High, and to the south of Tigapuluh Mountains. Stratigraphy comprises Lahat, Talang akar, Baturaja, Gumai, Air Benakat, Muara Enim, and Kasai Formations. Baturaja Formation consists of Early Miocene carbonate buildups formed by clastic limestone and organic limestone (reef) deposited in shallow marine environment during marine transgression phase and it is divided into Upper and Lower Baturaja (BRF members).

The BRF limestone facies has been affected by some diagenetic processes such as cementation, replacement, dissolution, and compaction. The most common cementation agent is calcite commonly filling fossil chambers and some fractures, with minor pyrite (0-0.5%). Relatively significant replacement process has caused some matrix and unstable grain alteration or replacement commonly by calcite (8.00%-42.75%), with lesser micrite (3.50-12.50%) and rare dolomite (1.2%, only at depth 1534.0 m). Less significant compaction has affected this facies as evidenced particularly by the occurence of minor local stylolites and fracture grains.

Several core samples in BRF were collected for analyses including biostratigrapy ; permeability is fair to good (18-22 mD), visible porosity is generally poor to good (1.50-20.00%), represented by secondary vugs (7.50-18.50) and oversized-fracture (1.50-4.00) pore types. Oil in pores 2.09-2.80% and total water in pores 61.16-64.10%, grain density 2.735-2.759 gr/cc and comprising mud-wackestone facies. The range of observations may be related to heterogenity of the limestone facies. Biostratigraphic analyses revealed planktonic zone in N4 and nannoplankton zone in NN1 (inner-outer neritic).

Combination of wireline log and petrography data will used to define the porosity and assess the digenetic processes. Based on the understanding of reservoir character heterogenity on BRF, information about variation of porosity development and diagenetic level in carbonate reservoir can be achieved.

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INTRODUCTION

The ‘Well IR’ is located in southern part of South Sumatra Basin. South Sumatra Basin is one of a series of rift basin that presently occupy a back-arc position along the leading edge of Sundaland. It is one of the principal and most prolific oil producing basins in Indonesia. The objectives of this study were to determine framework grains composition and texture character and intepret diagenesis processess and their influence to improve visible porosity as well as reservoir quality of analyzed samples.

METHODOLOGY

This work integrated a wireline log suite and five sidewall cores from Baturaja Formation (Early Miocene) in well “IR” 1534-1595 meterd in depth. This study used petrographic observation to understand the porosity, mineralogy, carbonate particle distribution an dfacies in order to interpretate the depositional environment and diagenetic hystory.

REGIONAL GEOLOGY

The South Sumatra Basin is a NW-SE oriented Tertiary Back-arc Basin, delimited by Tiga Puluh Mountain Range to the NW and the Pre-Tertiary outcrops of Sundaland on Bangka and Lingga Islands in the northeast. The Barisan Mountain Range marks the southwestern limit, and the Lampung High forms the southeastern boundary of the basin. This basin is filled with more than 4000 meters of sediments. The South Sumatra Basin is generally composed of transgressive-regressive cycles of Tertiary sediments overlying an eroded basement. The general stratigraphy of South Sumatra Basin is one consisting of Tertiary Rocks unconformably overlying Pre-Tertiary basement.

Basement Pre-Tertiary rocks consist of metamorphic rocks (meta-sediment), granitic and ultrabasic igneous rocks, volcanic rocks aged range from Permo Carboniferous (248-354 Ma) to Mesozoic (Jurassic-Cretaceous, 170-110 Ma). Tertiary Rocks consist of Lemat Formation, Talang Akar Formation, Baturaja Formation, Telisa (Gumai) Formation, Air Benakat (Lower Palembang) Formation, Muara Enim (Middle Palembang) Formation, and Kasai (Upper Palembang) Formation. General stratigraphy of South Sumatra Basin can be seen in Figure 3.

PETROGRAPHIC ANALYSIS

Available raw data for this study consists of 5 SWC samples taken from depth interval 1534 m to 1595 m of ‘Well IR’. All samples analyzed with both thin section petrography and XRD (bulk&clay) analyses. The variety of analytical services perfomed on the samples are tabulated in Table 1.

These method were used to distinguish different carbonate minerals based on color resolution, and the result of staining are as follows :

Kind of minerals	Colour of minerals
Calcite	Pink
Ferroan calcite	Blue to mauve
Dolomite	Unstained
Ferroan dolomite (ankerite)	Turquoise blue

Point counting of thin section was carried out to determine grain composition and visual porosity percentages. The composition percentage of petrography analyses are presented in Table 2.

XRD analysis was conducted on all samples in order to determine quantitatively whole rock and clay mineralogy in terms of weight of the whole rock. Powder method utilized fully automatic PanAnalitical PW 6030 for whole rock mineralogy determination. Clay mineral analysis involved utrasonic diseggregation and centrifugation to isolate the clay fraction (<4 microns), followed by preparation of oriented clay mounts untreated and heated (360^o C) plus glycolated states. The XRD examination results are documented in Table 3.

CARBONATE FACIES ANALYSIS

Carbonate facies were interpretd from lithology, texture, sedimentary structures, composition and fossil content. Based on petrographic analysis of thin sections of cuttings and cores, the BRF in Well IR can be divided into five facies : Algae Wackestone-Packstone Facies, Coralin Wackestone-Packstone Facies, Echinoderm Wackestone-Packstone Facies, Mollusk Wackestone Facies, and Coralin Wackestone Facies.

Based on texture, composition and fossil content observed in these cabonate facies, it was determined that Well IR in BRF developed as no reefal buildup in low-moderate energy, low-moderate grain support, indicate the depositional environment was relatively deep (Longman, 1980).

CARBONATE DIAGENESIS

Based on petrographic analysis, the diagenetic processes observed in the BRF include:

Dissolution

Dissolution is the diagenetic process by which carbonate and evaporite minerals are dissolved and removed, thus creating and modifying pore space. The effect of this process on permeability depends upon the geometry and location of the resulting voids relative to the rock fabric. Dissolution can be fabric selective and can form moldic pores, a type of separate vug. In other cases, dissolution is not fabric selective and results in interconnected voids referred to here as touching vugs.

Dissolution occurred in carbonate rocks when the pore-fluid became undersaturated with respect to carbonate. Dissolution occured more intensively in Upper Baturaja Formation, producing secondary porosity as moldic and vuggy (Figure 9). Dissolution occurred as well in freshwater vadose or freshwater phreatic environments (Longman, 1980).

Cementation

Calcium carbonate cementation occludes pore space and reduces pore size. Calcite cements are composed of calcite, high-magnesium calcite, or aragonite when they are formed. However, high-magnesium calcite and aragonite are unstable minerals and are replaced by the stable form, calcite, with time and burial. Cementation starts soon after deposition. Indeed, clasts of cemented sediment, called intraclasts, are found redeposited in later sediment. Early cementation of sediments in shallow burial environment results from the circulation of large quantities of marine water through very permeable sediments such as grainstones and reef debris (Shinn 1969; James and Ginsburg 1979).

The driving force is tidal and wave energy characteristic of high-energy environments occupied by reefs and grainstone sediments. Marine cement typically precipitates evenly around the grains as fibrous or bladed cement and is referred to as isopachous cement. Large voids commonly found in carbonate reefs are often filled with large botryoidal fans of radiaxial marine carbonate cement.

Cementation by calcite continues as the sediment is buried (Heydari and Moore 1993). Cementation occurred in carbonate rocks when pore-fluids are supersaturated without kinetic factors hampering cement precipitation. This process requires a large volume of fresh or salt water to flow through the rocks. In stagnant water very little cementation occurs (Koesoemadinata, 1984). Mineralogy and cement fabric depend on pore-fluid composition, the speed of carbonate supply and precipitation, thus indicating a different diagenetic environment. Based on petrographic analyses, cement mineralogy comprises high Mg calcite, low Mg calcite, dolomite, and quartz, while cement types are blocky, syntaxial overgrowth, drusy, equant mosaic, micritic, fibrous and isopachous.

Neomorphism

Neomorphism (Folk, 1965) consists of inverse, recrystallization and coalescive neomorphism (aggrading/degrading neomorphism). Based on petrographic analyses, neomorphism caused micrite to change to microspar in most samples. This process occurred in early burial of freshwater phreatic and deep burial environments. Neomorphism observed in these samples are recrystallizations, mainly occurring in early burial in freshwater phreatic environments (Figure 7).

Compaction

Compaction effects are difficult to separate from cementation effects, but they both reduce pore-size and porosity. Compaction is both a physical and chemical process resulting from the increased overburden pressure due to burial. Textural effects include loss of porosity, reduction of pore-size, grain penetration, grain deformation, grain breaking, and fracturing. Compaction does not require the addition of material from an outside source, and it is a function of texture only. In addition, compaction is a source of energy to move fluids out of the sediment and into adjacent sediments, usually flowing upward.

Mechanical and chemical compaction occur in deep burial environments. Mechanical compaction results in grain fracture and porosity reduction by closer packing, and eventually grains may dissolve on a point contact to produce sutures and concaveconvex contacts. Chemical compaction produces stylolites and wispy seams, reducing bulk volume and porosity (Figure 6).

This limestone facies in the study samples have been affected by diagenetic processes such as cementation, replacement, dissolution and also compaction. The most common cementation agents are calcite, commonly filling fossil chambers and some fractures (1.00-7.00%; Plates 3,4 and 5) and minor pyrite (0-0.5%). Relatively significant replacement process has caused some matix and unstable grain alteration or replacement commonly by calcite (8.00-42.75%; i.e Plate 1 and Plate 2), with lesser micrite (3.5-12.5%) and rare dolomite (1.2%, only at depth 1534 m).

Dissolution of unstable grains (mainly skeletal grains) and carbonate mud matrix has caused the creation of most secondary, especially vuggy, porosity. Less significant compaction has affected this facies as evidenced particularly by the occurence of minor local stylolites (Plate 1 and 3) and fracture grains (Plate 4). The visible porosity estimated from thin-section petrography analysis is generally poor to good (1.5-20%, represented by secondary vuggy (7.5-18.5%; not identified at depths 1534 m and 1539 m) and oversized-fracture (1.5-4%; Plate 1) pore types. The pores commonly have poor to fair interconnectivity. However, routine core analyses results show good porosity (18.00-25.01%) and fair to good permeability (18-22 mD). The differences may be related to the abundance of microporosity in neomorphosed calcite crystals microspar (depths 1534 m and 1539 m).

RELATION OF PETROGRAPHY ANALYSIS AND DIAGENETIC POROSITY

Chronostratigraphically, BRF is divided into Upper Baturaja (1534 m to 1563 m) and Lower Baturaja (1563 m to 1595 m). Based on petrographic analyses, in BRF results of observed diagenetic processes are dissolution (Figures 8-9), neomorphism (Figures 6-10), and compaction (Figure 6). It was observed that dissolution can create pore space in reservoir rocks as vuggy or secondary porosity. On the other hand, neomorphism and compaction may reduce pore space and porosity in reservoir rocks. From petrophysical analyses, average porosity at depth 1534 m is 13.3%, at 1539 m is 12.1%, at 1557 m is 15.2%, at 1563 m is 17.4%, and at 1595 m is 7.9% (Figure 5).

CONCLUSION

From petrographic analyses to determine diagenetic processes that occured in samples at depth 1534 m to 1595 m, were compared with average porosity (ave PHIT) from petrophysical analyses that reservoir in BRF can be divided into two diagenetic processes. Dissolution occured at 1535-1565 m depth and compaction at 1570-1590 m depth. Based on study, reservoir at 1535-1565 m depth will be prospect zone to produce hydrocarbon in Well “IR”.

ACKNOWLEDGEMENTS

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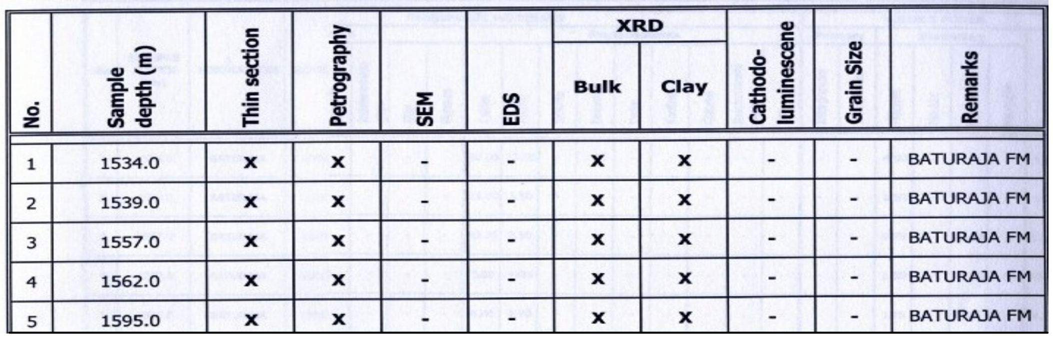
TABLE 1

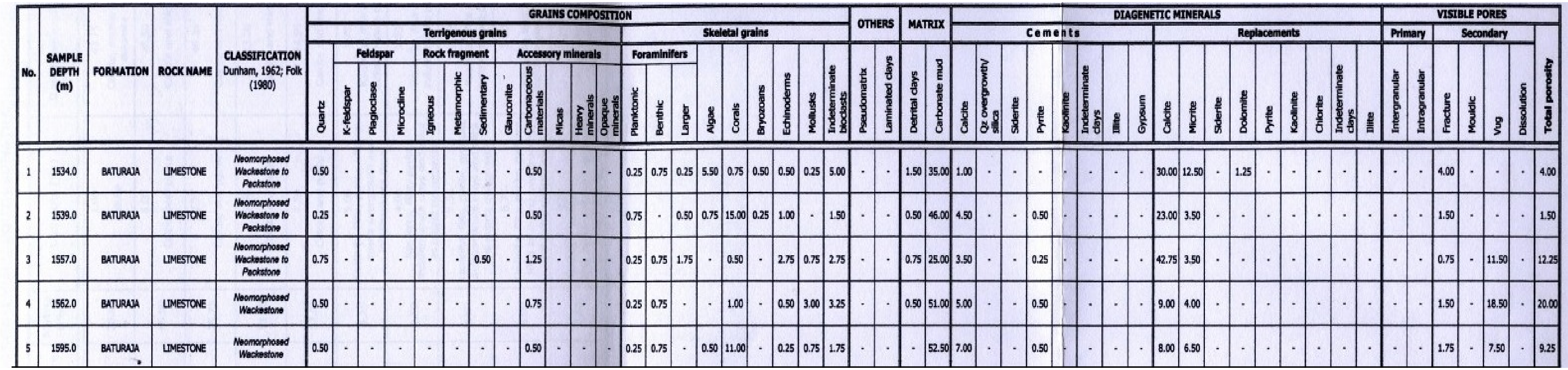
VARIERY OF SERVICES PERFOMED ON THE SAMPLES ANALYZED



No.	Sample depth (m)	Thin section	Petrography	SEM	EDS	XRD		Cathodo-luminescene	Grain Size	Remarks
						Bulk	Clay			
1	1534.0	x	x	-	-	x	x	-	-	BATURAJA FM
2	1539.0	x	x	-	-	x	x	-	-	BATURAJA FM
3	1557.0	x	x	-	-	x	x	-	-	BATURAJA FM
4	1562.0	x	x	-	-	x	x	-	-	BATURAJA FM
5	1595.0	x	x	-	-	x	x	-	-	BATURAJA FM

TABLE 2

COMPOSITION PERCENTAGES FROM PETROGRAPHIC ANALYSES



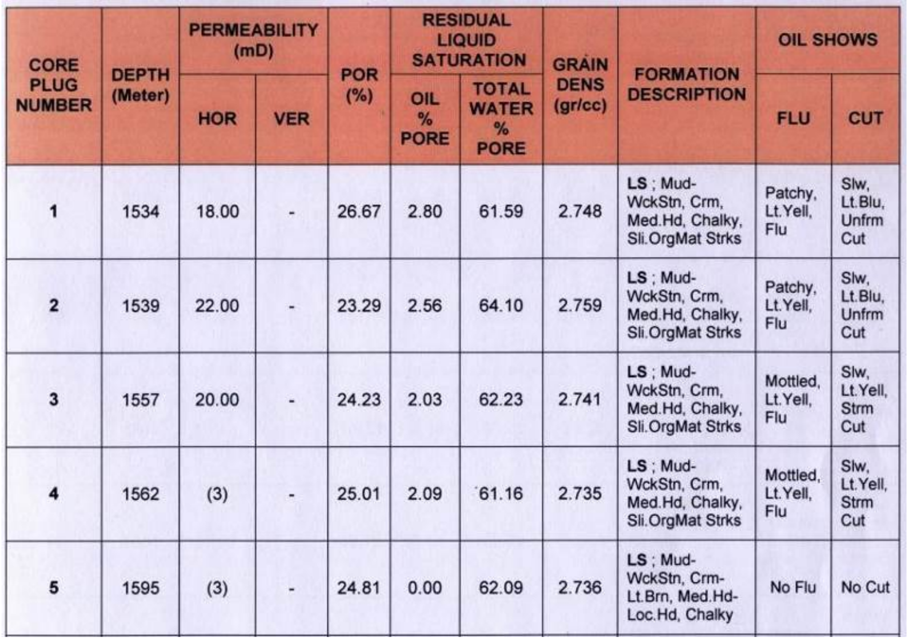
No.	SAMPLE DEPTH (m)	FORMATION	ROCK NAME	CLASSIFICATION Dunham, 1962; Folk (1980)	GRAINS COMPOSITION											
					Terrigenous grains											
						Feldspar			Rock fragment			Accessory minerals				
					Quartz	K-feldspar	Plagioclase	Microcline	Igneous	Metamorphic	Sedimentary	Glauconite	Carbonaceous materials	Micas	Heavy minerals	Opaque minerals
1	1534.0	BATURAJA	LIMESTONE	*Neomorphosed Wackestone to Packstone*	0.50	-	-	-	-	-	-	-	0.50	-	-	-
2	1539.0	BATURAJA	LIMESTONE	*Neomorphosed Wackestone to Packstone*	0.25	-	-	-	-	-	-	-	0.50	-	-	-
3	1557.0	BATURAJA	LIMESTONE	*Neomorphosed Wackestone to Packstone*	0.75	-	-	-	-	-	0.50	-	1.25	-	-	-
4	1562.0	BATURAJA	LIMESTONE	*Neomorphosed Wackestone*	0.50	-	-	-	-	-	-	-	0.75	-	-	-
5	1595.0	BATURAJA	LIMESTONE	*Neomorphosed Wackestone*	0.50	-	-	-	-	-	-	-	0.50	-	-	-

No.	GRAINS COMPOSITION									OTHERS		MATRIX	
	Skeletal grains												
	Foraminifers												
	Planktonic	Benthic	Larger	Algae	Corals	Bryozoans	Echinoderms	Mollusks	Indeterminate bioclasts	Pseudomatrix	Laminated clays	Detrital clays	Carbonate mud
1	0.25	0.75	0.25	5.50	0.75	0.50	0.50	0.25	5.00	-	-	1.50	35.00
2	0.75	-	0.50	0.75	15.00	0.25	1.00	-	1.50	-	-	0.50	46.00
3	0.25	0.75	1.75	-	0.50	-	2.75	0.75	2.75	-	-	0.75	25.00
4	0.25	0.75	-	-	1.00	-	0.50	3.00	3.25	-	-	0.50	51.00
5	0.25	0.75	-	0.50	11.00	-	0.25	0.75	1.75	-	-	-	52.50

No.	DIAGENETIC MINERALS																	VISIBLE PORES						
	Cements								Replacements									Primary		Secondary				Total porosity
	Calcite	Qz overgrowth/ silica	Siderite	Pyrite	Kaolinite	Indeterminate clays	Illite	Gypsum	Calcite	Micrite	Siderite	Dolomite	Pyrite	Kaolinite	Chlorite	Indeterminate clays	Illite	Intergranular	Intragranular	Fracture	Mouldic	Vug	Dissolution	
1	1.00	-	-	-	-	-	-	-	30.00	12.50	-	1.25	-	-	-	-	-	-	-	4.00	-	-	-	4.00
2	4.50	-	-	0.50	-	-	-	-	23.00	3.50	-	-	-	-	-	-	-	-	-	1.50	-	-	-	1.50
3	3.50	-	-	0.25	-	-	-	-	42.75	3.50	-	-	-	-	-	-	-	-	-	0.75	-	11.50	-	12.25
4	5.00	-	-	0.50	-	-	-	-	9.00	4.00	-	-	-	-	-	-	-	-	-	1.50	-	18.50	-	20.00
5	7.00	-	-	0.50	-	-	-	-	8.00	6.50	-	-	-	-	-	-	-	-	-	1.75	-	7.50	-	9.25

TABLE 3

CORE ANALYSES



CORE PLUG NUMBER	DEPTH (Meter)	PERMEABILITY (mD)		POR (%)	RESIDUAL LIQUID SATURATION		GRAIN DENS (gr/cc)	FORMATION DESCRIPTION	OIL SHOWS	
		HOR	VER		OIL % PORE	TOTAL WATER % PORE			FLU	CUT
1	1534	18.00	-	26.67	2.80	61.59	2.748	**LS** ; Mud-WckStn, Crm, Med.Hd, Chalky, Sli.OrgMat Strks	Patchy, Lt.Yell, Flu	Slw, Lt.Blu, Unfrm Cut
2	1539	22.00	-	23.29	2.56	64.10	2.759	**LS** ; Mud-WckStn, Crm, Med.Hd, Chalky, Sli.OrgMat Strks	Patchy, Lt.Yell, Flu	Slw, Lt.Blu, Unfrm Cut
3	1557	20.00	-	24.23	2.03	62.23	2.741	**LS** ; Mud-WckStn, Crm, Med.Hd, Chalky, Sli.OrgMat Strks	Mottled, Lt.Yell, Flu	Slw, Lt.Yell, Strm Cut
4	1562	(3)	-	25.01	2.09	61.16	2.735	**LS** ; Mud-WckStn, Crm, Med.Hd, Chalky, Sli.OrgMat Strks	Mottled, Lt.Yell, Flu	Slw, Lt.Yell, Strm Cut
5	1595	(3)	-	24.81	0.00	62.09	2.736	**LS** ; Mud-WckStn, Crm-Lt.Brn, Med.Hd-Loc.Hd, Chalky	No Flu	No Cut

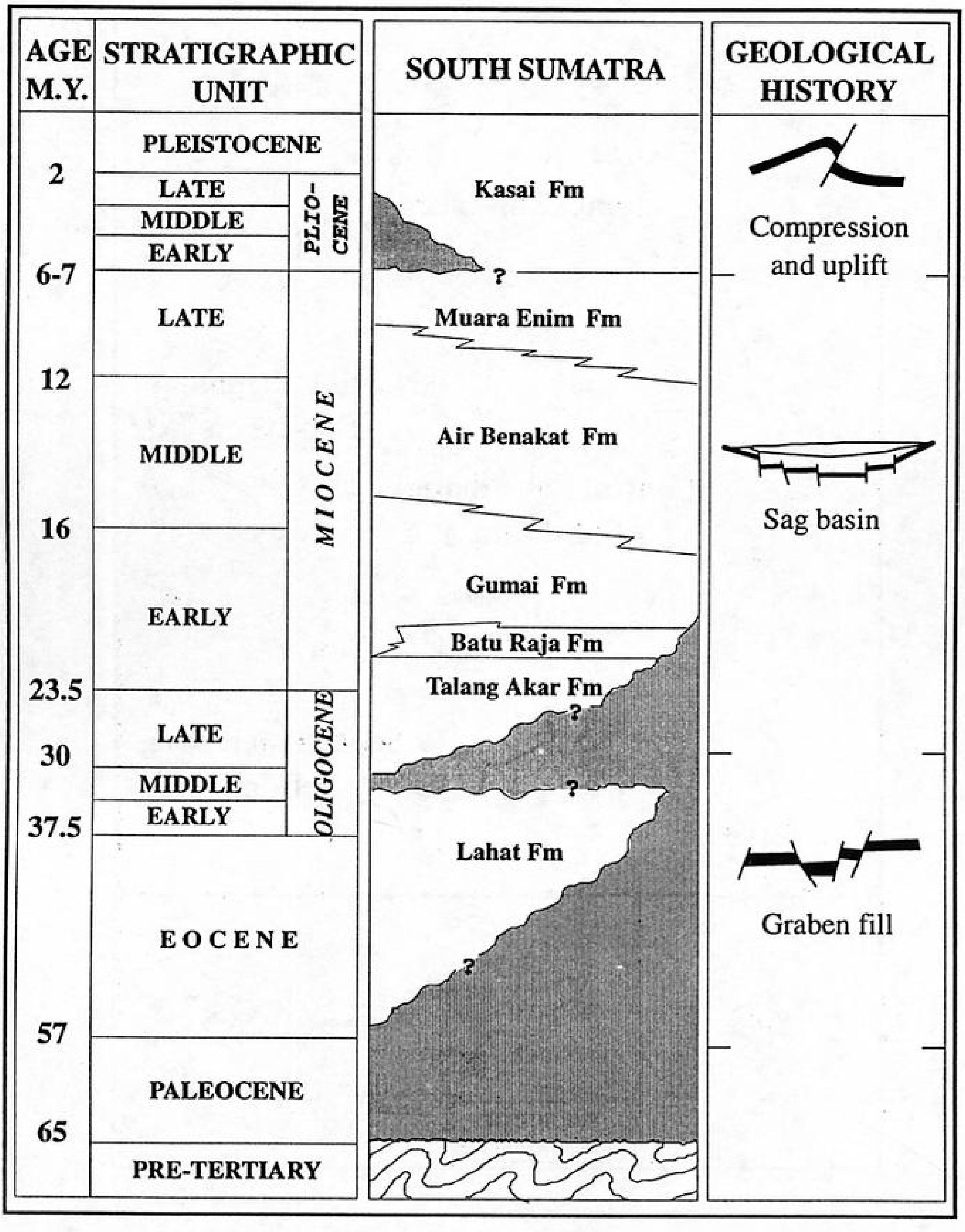


Figure 1 - Tectonic Evolution of South Sumatra

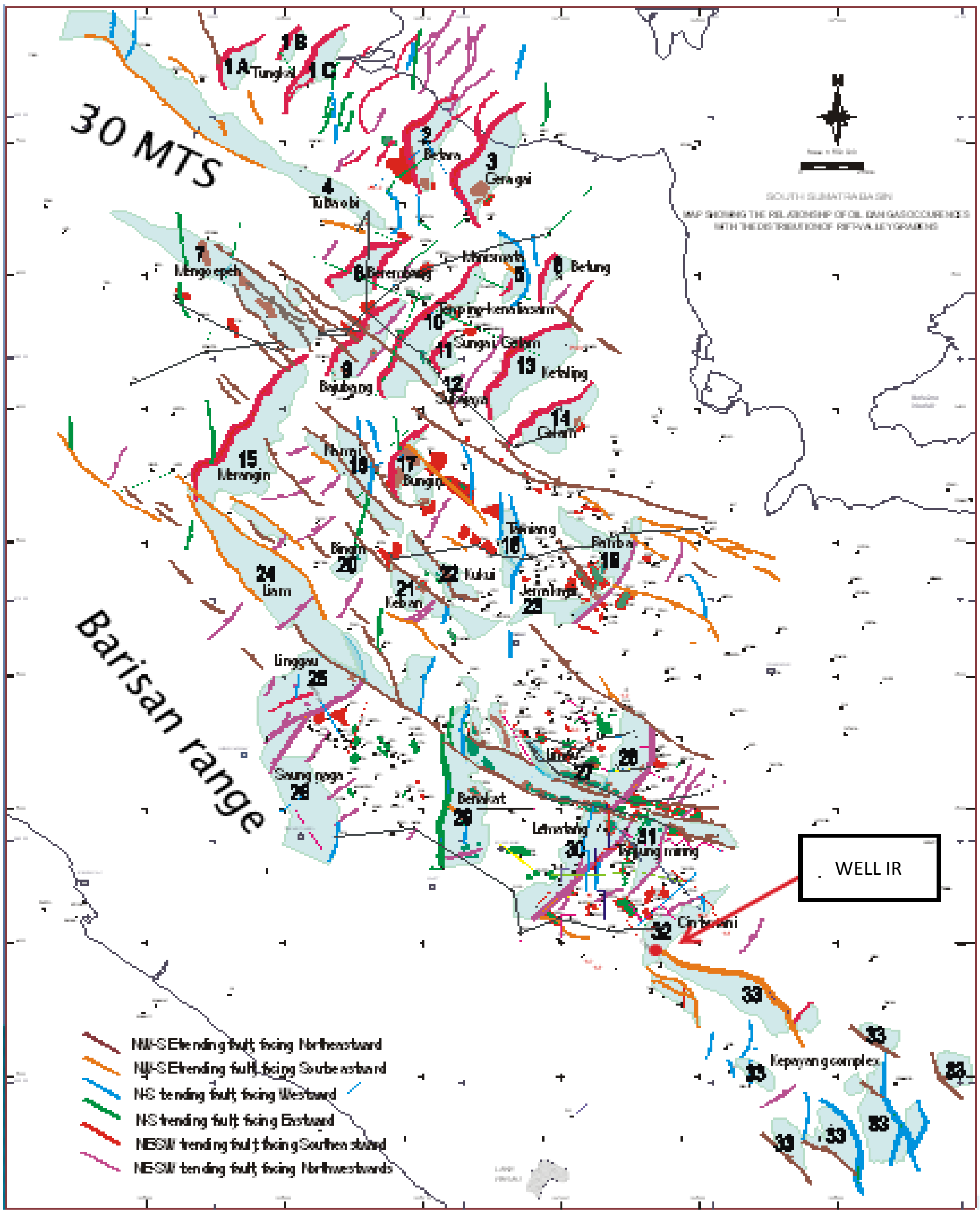


Figure 2 - Main structural trends South Sumatra Basin (Ryacudu, 2003)

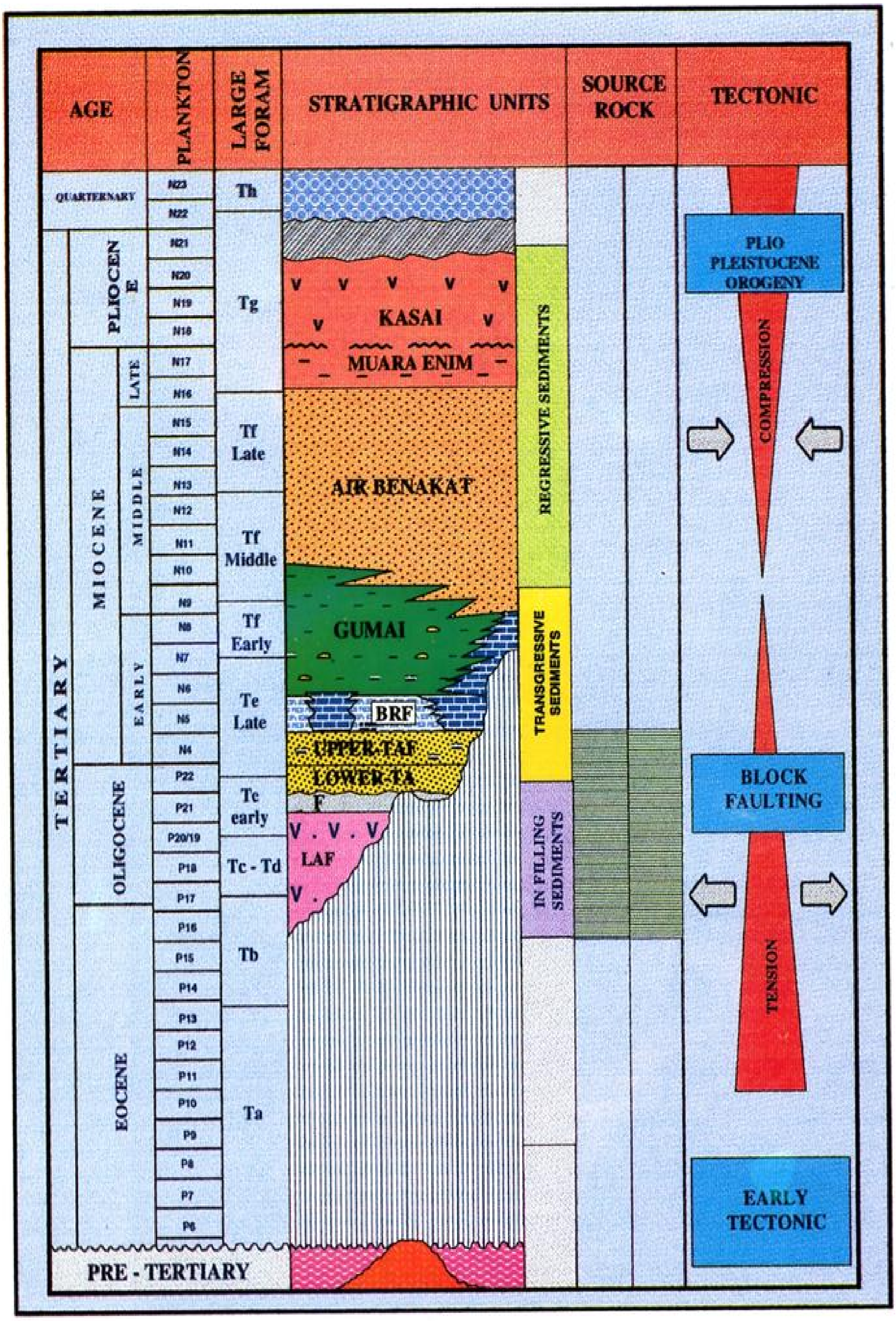
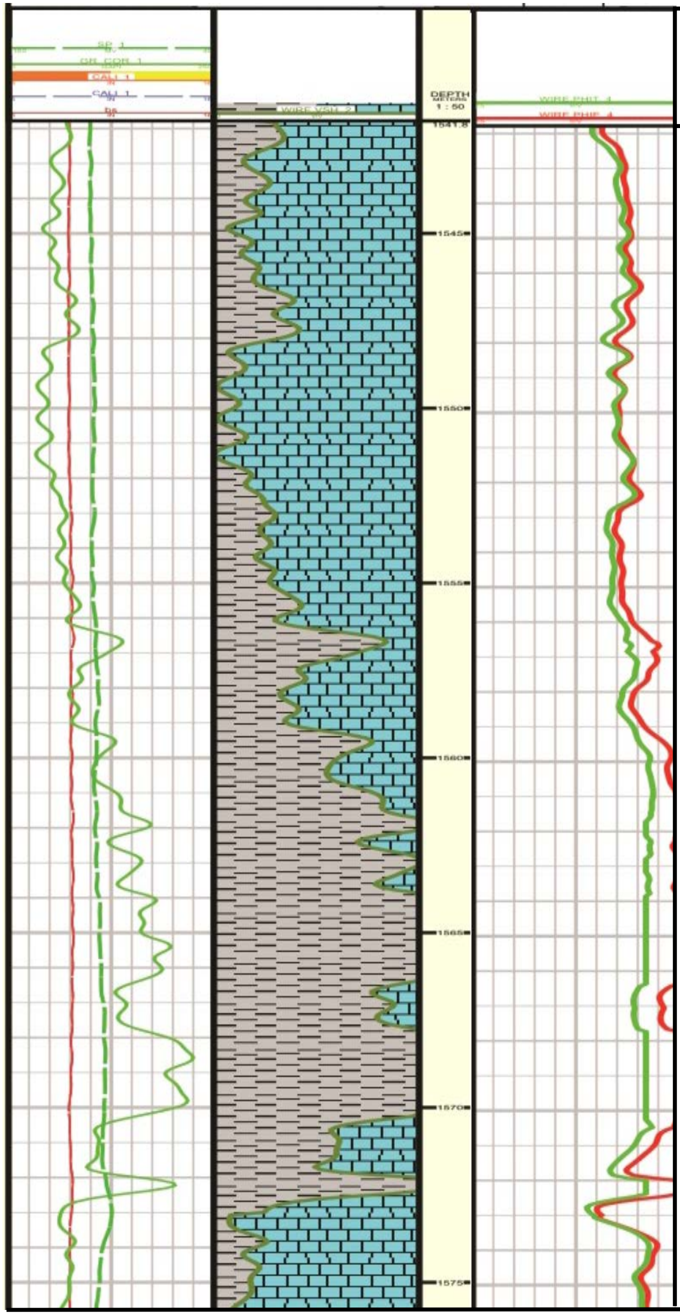
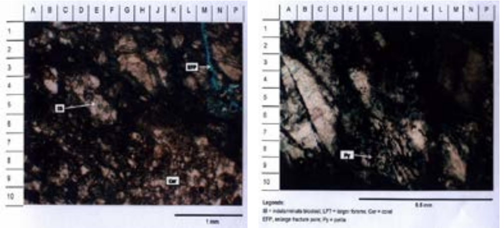
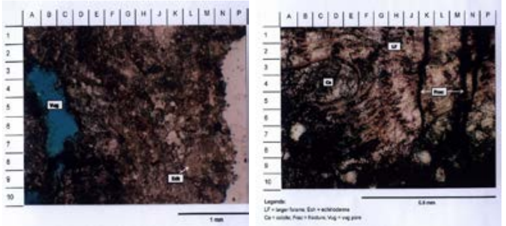
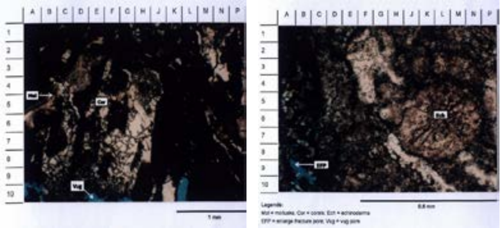


Figure 3 - Regional Stratigraphy of South Sumatra Basin



Depth (m)	Photos of Thin Section	Petrographic Description	PHIT
1541.8 1545 1550		Plate 2 at 1539 m, Neomorphosed Wackestone to Packestone, Enlarged Fracture Porosity (EFP), Skeletal Grain: Coral, Interdeminate Bioclast (Cor and IB), Pyrite and Calcite Cement (Py), 46% Carbonate Mud.	0,11-0,14
1555 1560		Plate 3 at 1557 m, Neomorphosed Wackestone to Packstone, Vug and Fracture Porosity (Vug and Frac), Echinoderms Skeletal Grain (Ech), Calcite Cement (Ca), 25% Carbonate Mud.	0,11-0,21
1565		Plate 4 at 1562 m, Neomorphosed Wackestone, Vug and Enlarged Fracture Porosity (Vug and EFP), Echinoderms, Corals and Mollusks Skeletal Grain (Ech, Cor, Mol), Calcite and Pyrite Cements, 51% Carbonate Mud.	0,17-0,20
1570 1575			

GR Log 〰 PHIT 〰

Figure 4.1 – Porosity development and petrophysical calculation of Well “IR” (1)

PHIE 〰

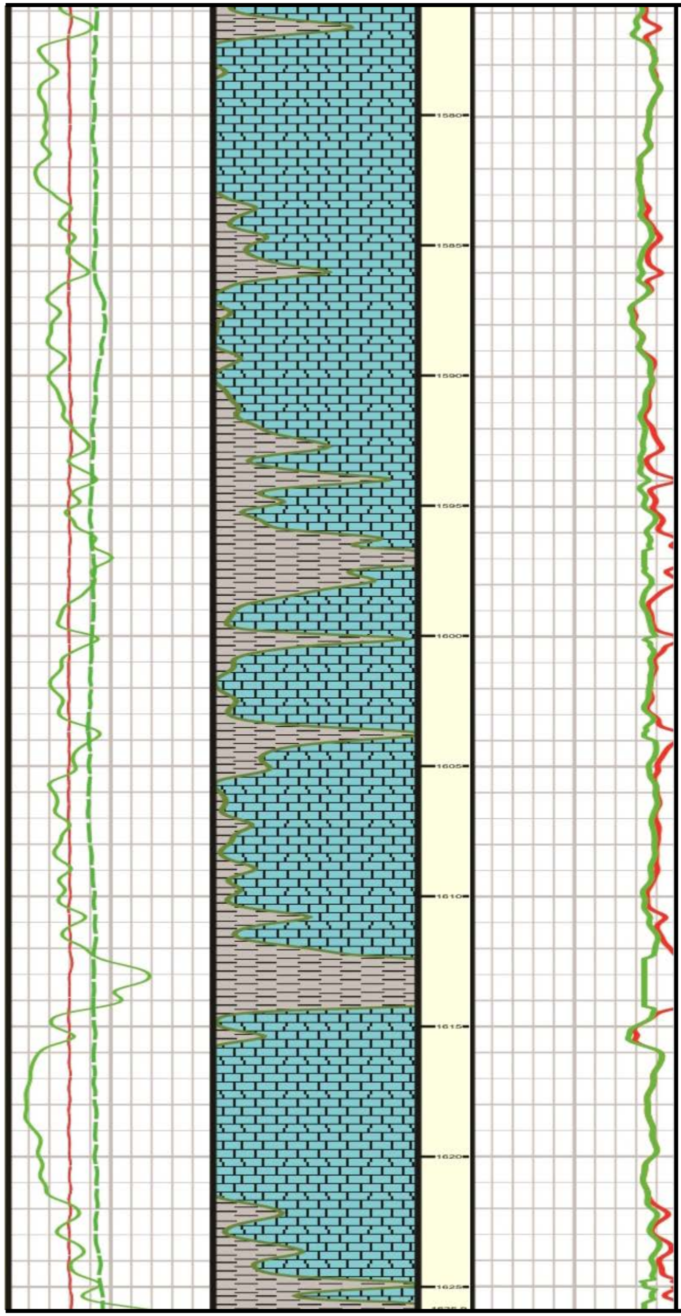
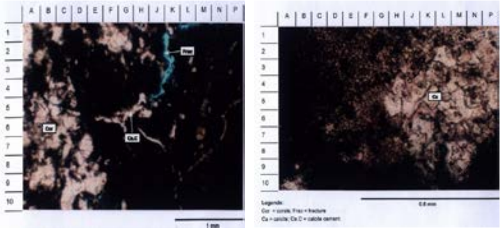
	1580 1585 1590 1595 1600 1605 1610 1615 1620 1625		Plate 5 at 1595 m, Neomorphosed Wackestone, Vug and Fracture Porosity (Frac), Corals Skeletal Grain (Cor), Calcite Cements (Ca.C), 52.5% Carbonate Mud	0,07-0,1

Figure 4.2 – Porosity development and petrophysical calculation of Well “IR” (2)

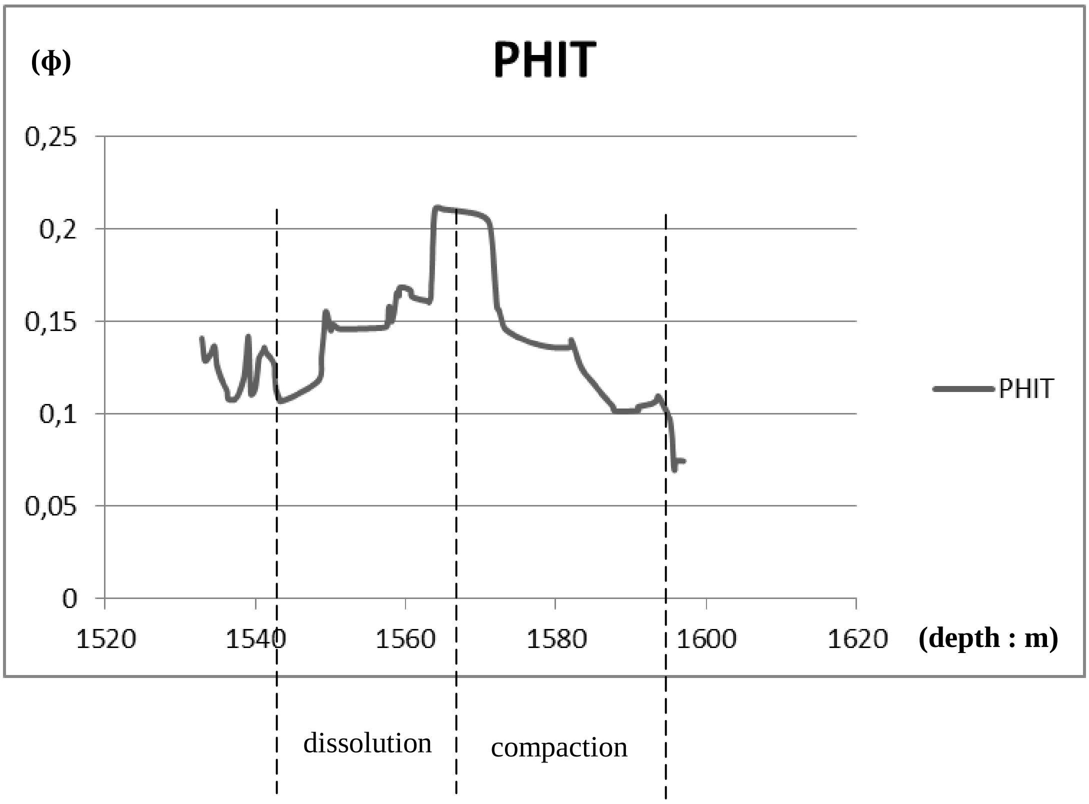


Figure 5 - PHIT Well IR based on petrophysical analysis

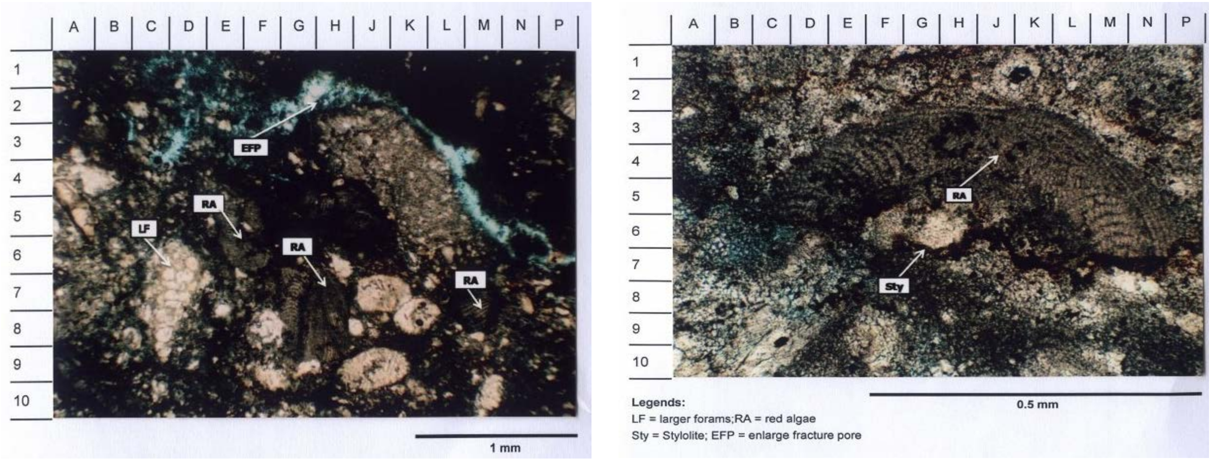


Figure 6 - Plate 1 at 1534 m, Neomorphosed Wackestone to Packstone, Enlarged Pore Fracture (EFP), Red Algae (RA), Stylolith (Sty), Calcite Cement, 35% Carbonate Mud.

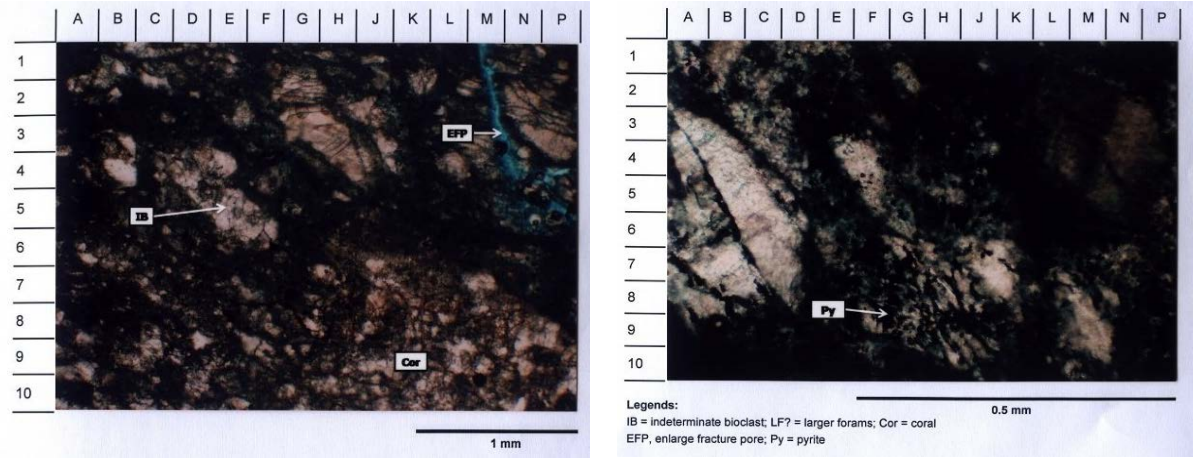


Figure 7 - Plate 2 at 1539 m, Neomorphosed Wackestone to Packestone, Enlarged Fracture Porosity (EFP), Skeletal Grain : Coral, Interdeminate Bioclast (Cor and IB), Pyrite and Calcite Cement (Py), 46% Carbonate Mud.

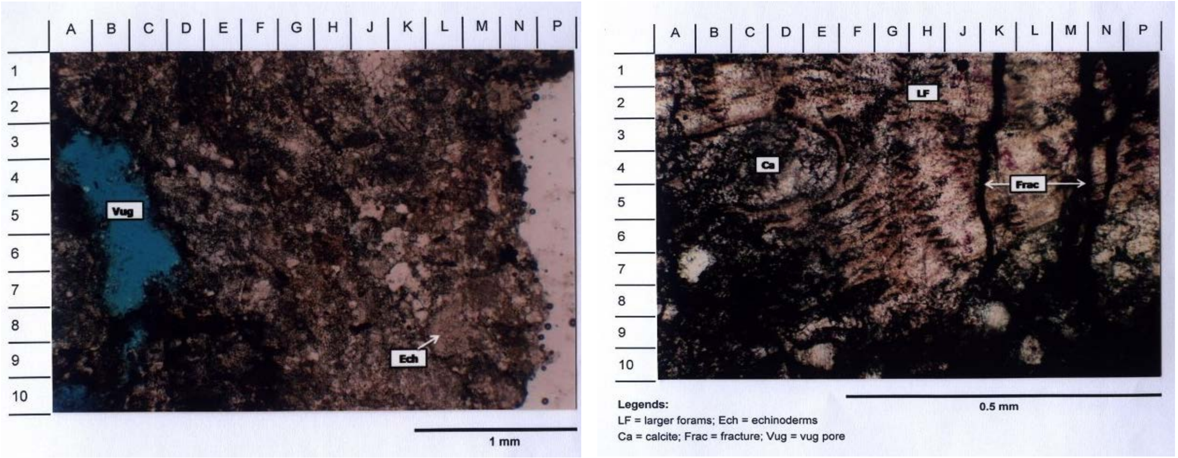


Figure 8 - Plate 3 at 1557 m, Neomorphosed Wackestone to Packstone, Vug and Fracture Porosity (Vug and Frac), Echinoderms Skeletal Grain (Ech), Calcite Cement (Ca), 25% Carbonate Mud.

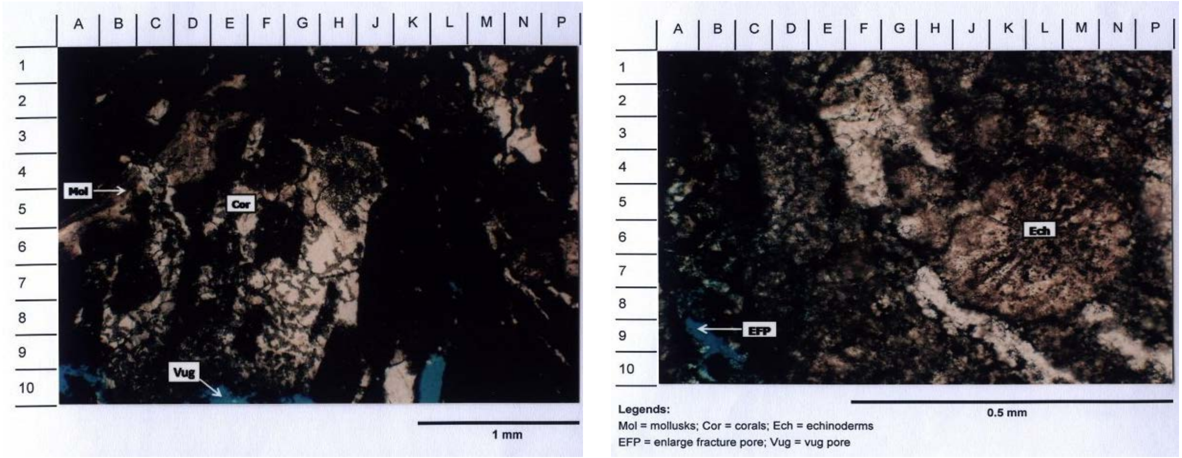


Figure 9 - Plate 4 at 1562 m, Neomorphosed Wackestone, Vug and Enlarged Fracture Porosity (Vug and EFP), Echinoderms, Corals and Mollusks Skeletal Grain (Ech, Cor, Mol), Calcite and Pyrite Cements, 51% Carbonate Mud.

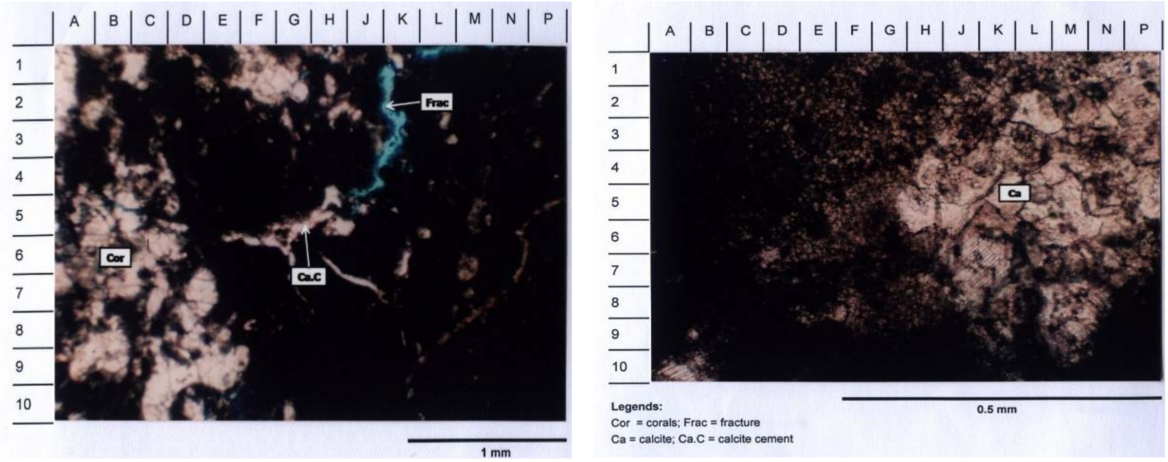


Figure 10 - Plate 5 at 1595 m, Neomorphosed Wackestone, Vug and Fracture Porosity (Frac), Corals Skeletal Grain (Cor), Calcite Cements (Ca.C), 52.5% Carbonate Mu