Microfaunal Assemblage of the Sui Main Limestone from Sui Gas Field, Pakistan

Salma Rafi[1,*], S.H. Khursheed[2] and Syed Iqbal Mohsin[1]

[1]*Department of Geology, University of Karachi, Karachi, Pakistan*

[2]*NURICON Petroservices Pvt. Ltd. Karachi, Pakistan*

Abstract: Sui Main Limestone (SML) is the best reservoir in the Middle Indus Basin of Pakistan. It is an important reservoir that has produced gas for the last fifty (50) years and continues to produce 600 MMCF per day. The characteristic microfossil assemblages within the SML have been studied from fifty two thin sections of the reservoir rock from four Sui wells for understanding the reservoir architecture and quality.

There are two distinctive fossil assemblages within SML Formation. The major lower part (>300m) is a carbonate facies of massive fossiliferous limestone dominated by Nummulites along with Alveolina, Discocyclina and Miliolids. The upper part (20m) consists of argillaceous fossiliferous limestone interbedded with calcareous shale layers, making a transition to the overlying Ghazij shales. Assilina is the characteristic fossil with its associated assemblage.

Keywords: Sui main limestone, eocene (Ypresian), reservoir, sui gas field, microfauna, foramiifera, paleoenvironment.

INTRODUCTION

The Sui Main Limestone (Ypresian) is overlain by the shales of Shaheed Ghat Formation and underlain by the limestone of the Dunghan Formation (Paleocene) [1]. The Sui Main Limestone (SML) sequence comprises a thick carbonate overlain by muddy to grainy limestone with diverse skeletal assemblages [2], thin grainstones and muddy limestone with generally low diversity skeletal assemblages [3]. SML does not outcrop anywhere in Pakistan. This study is based on subsurface data acquire from Sui Gas field in collaboration with Pakistan Petroleum Ltd. (PPL). The author is thankful to the PPL and grateful to the sponsor Mr. Masood Abdali (Weatherford Pakistan).

MATERIAL AND METHODS

The core sample collections of SML from Sui field were carried out at PPL Core House, Karachi. Four Sui wells A-1, B-1, C-1 and C-3 were selected for this study located on north, center and south of Sui dome respectively (Figure **1**). Mega-scopic core studies have been carried out on four selected wells and samples were taken randomly from the length of the cores. Fifty two (52) samples from selected cores were taken for thin section preparation and were impregnated with blue dyed epoxy also. For determination of microfossil content binocular stereo-microscope (Olympus BX 51) has been used to study selected thin sections. Photomicrograph of microfossils were taken and presented with full labeling. The identified fossils are based on the classification proposed by Cushman and Moore [4, 5]. A total eight types of foraminifera are identified along with five other fossils associations. The quantity and percentage of the different large and small benthic foraminifera and other fossils were estimated visually and recorded on mirofaunal distribution sheet Table **1**. Method and procedure generally followed are those proposed by Cushman [4].

RESULTS

The important fossils groups are found in SML are foraminifera (large, small benthic foraminifera), calcareous algae, benthic sessile organisms (corals, bryozoans), and shell-bearing organisms with valves (brachiopods, mollusks and multi-plate shells (echinoderms). These groups and their major systematic units are studied in details Phylum, sub-phylum, class, order, sab-order, super-family, and family.

Foraminifera

(Protista- Sarcodina- Rhizopoda- Foraminiferida)

Nummulites

(Rotaliina- Rotaliacea-Nummulitidae)

Nummulites test are radial hyaline, biconvex, planispiral involute form that reveal V-shaped cavities in axial section [5]. In SML the axial sections of

*Address corresponding to this author at the Department of Geology, University of Karachi, Karachi, Pakistan; Tel: 0322-2756412; E-mails: salmar@uok.edu.pk; hasankhursheed@cyber.net.pk; drsimohsin@yahoo.com

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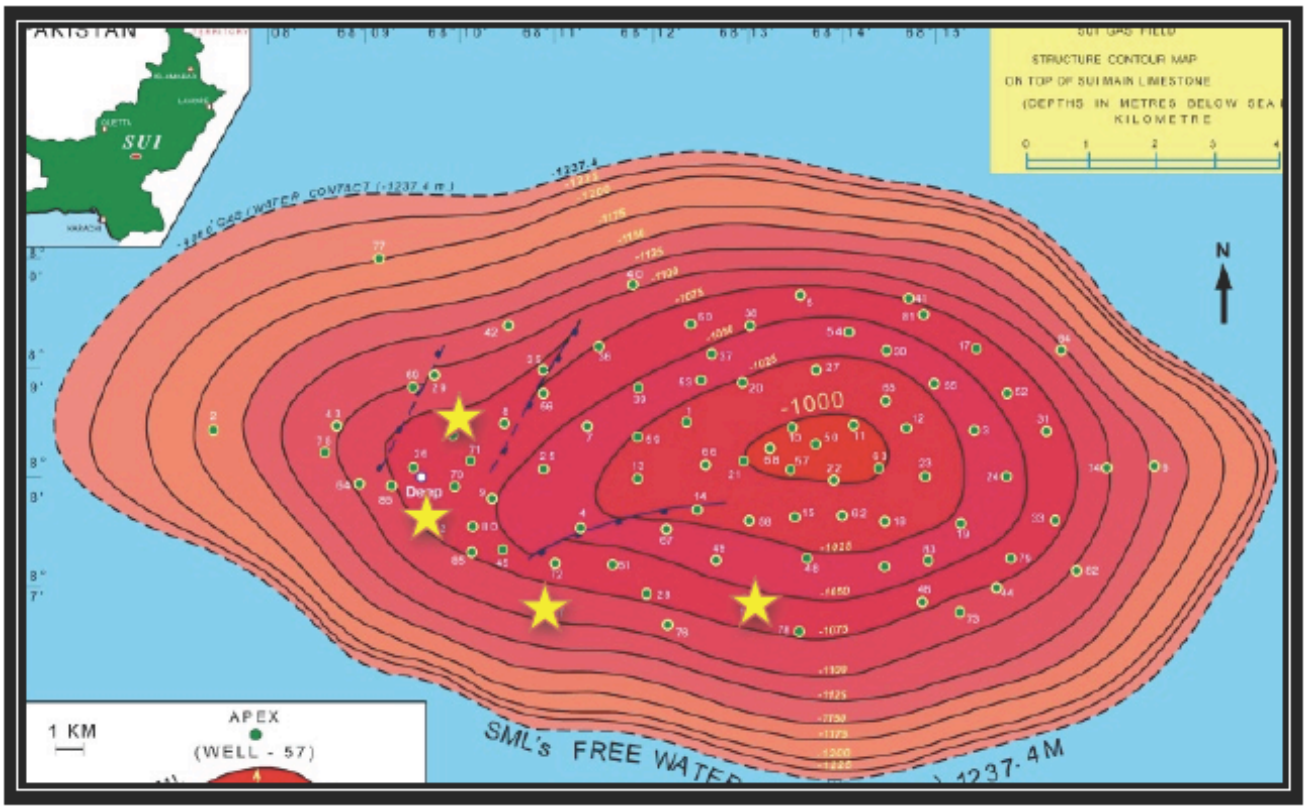

Figure 1: Depth contour map of Sui Main Limestone Formation showing the location of studied well (yellow stars) (adapted and updated from Siddiqui, 2004).

Nummulites are very easy to identify (Plate1: A). Nummulites are rotaliacean larger foraminifera widely used in correlating Eocene rocks [6]. Nummulites are very abundant in SML and form "Nummulites banks", Nummulites atacicus / mamilia group which are representative of early Eocene age are found abundant. They range from small to large, thick robust shelled. The big flat specimens lived near shore.

Assilina
(Rotaliina- Rotaliacea-Nummulitidae)

Assilina test are radial hyaline, biconvex, planispiral evolute form [5]. The V-shaped cavities in axial section and their lateral extensions are not present in Assilna [7]. The more lens shaped specimens lived in deeper water. Assilina are very abundant in upper parts of the studied sections of SML. The axial sections of the relatively big Assilina are very easy to recognize (Plate1: B).

Miliolina
(Miliolina- Miliolacea-Miliolidae)

The Milioline have imperforate calcareous test of porcelaneous appearance with a planispiral coiled proloculus [7]. They are relatively small and difficult to recognize in the thin sections. In the described section of SML they have a low abundance. Because of the difficulties in identifying the different species in this family, they are not further described (Plate1: C). Milioids are found in restricted marine environment and prefer to live in lagoons.

Alveolina
(Miliolina- Miliolacea-Alveolinidae)

Alveolinids are usually long and elongated and have imperforate test with a perforate proloculus [7]. Like the Miliolinids this family is not easily identified to the species level, only specie Alveolina oblanga was identified (Plate1: D).This family is relatively very abundant in the middle and lower sections of SML. Alveolinidae are abundant in reef and intertidal parts or in the open shoal part of carbonate platforms in an "open shoal" setting [7].

Orbitolites
(Miliolina- Miliolacea- Soritidae)

The specie Orbitiolites complanatus are found in few thin sections (Plate 1: E). These imperforate foraminifera are found mainly behind coastal barriers, in reefal settings [7] normally associated with Assilina and Miliolids.

Table 1: Microfaunal Distribution Chart

Formation	Well	Thin section	Foraminifera								Other Fossils				
			Ass	Dis	Num	Alv	Tex	Mil	Orb	Loc	Brc	Bry	Gas	Alg	Sk-Db
Top SML	Sui-C-3	C-3-01													
		C-3-02		©											
		C-3-03	©												
		C-3-04	©	©											
		C-3-05	α												
		C-3-06													
		C-3-07	α												
		C-3-08	α												
		C-3-09	©		©										
		C-3-10			α										
		C-3-11		©							Ғ	®	®		
		C-3-12			©	©									
		C-3-13			α	©									
		C-3-14													
		C-3-15		©	α	©	®				Ғ				
		C-3-16		©	α	©					Ғ				
		C-3-17			α										
		C-3-18		©	α										
		C-3-20			α										
		C-3-21			α	Ғ									
		C-3-22			α	©									Ғ
		C-3-23		Ғ	α										
		C-3-24			α					®					Ғ
		C-3-26			©										α
		C-3-28			©	©		Ғ	®						α
		C-3-29							®						α
		C-3-30			Ғ	Ғ		Ғ			®			Ғ	α
Well TD		C-3-31			©			Ғ						Ғ	α
Top SML	Sui-B-1	B-1-01				©					©				©
		B-1-03						©							©
		B-1-04			©	α				Ғ					©
		B-1-05			©										©
		B-1-07				α									©
		B-1-08				α									©
		B-1-10													©
Top SML	Sui-A-1	A-1-01				©					©				©
		A-1-03			©						©				©
		A-1-04			©					©	©				©
		A-1-05				©				©	©				©
		A-1-09			©	α				©	©				©
		A-1-10			α	α					©				©
		A-1-11			©	α					©				©
		A-1-13			©	α									©
		A-1-15			©	α			Ғ	Ғ					©
		A-1-16			©	α			Ғ						©
		A-1-19			Ғ	Ғ		©		©					©
		A-1-21				©		α	©						©
Top SML	Sui-C-1	C-1-01													
		C-1-03											Ғ		
		C-1-05				©		©					Ғ		
		C-1-07			Ғ	©		©					Ғ		
		C-1-09			Ғ	©		©					Ғ		

Ass: Assilina, Dis: Discocyclina, Num: Nummulites, Alv: Alveolina, Tex:Textuliriina, Mil: Miliolids, Orb: Orbitolites, Loc: Lockhartia, Brc: Brachiopod, Bry: Bryozoan, Gas: Gastropod, Alg: Algae, Sk-Db: Skeletal debris, α: Abundant, ©: Common, Ғ: Few, ®: Rare

Discocyclina
(Rotaliina- Orbitoidacea- Discocyclinidae)

These foraminifers are large, perforate [7] and lens shaped and have thin equatorial layer (Plate **1**: F). It is relatively abundant in upper parts of the SML studied sections. It is abundant in the open shoal and beginning of the slope in an “open shoal” setting of carbonate platforms. In a setting with reefs, Discocyclina is not very common but can also be present in the open shoal and beginning of the slope.

Lockartia
(Rotaliina- Rotaliacea-Rotaliidae)

Test conical to lenticular, trocospiral; chambers forming outer layer of cone, chamber walls curving

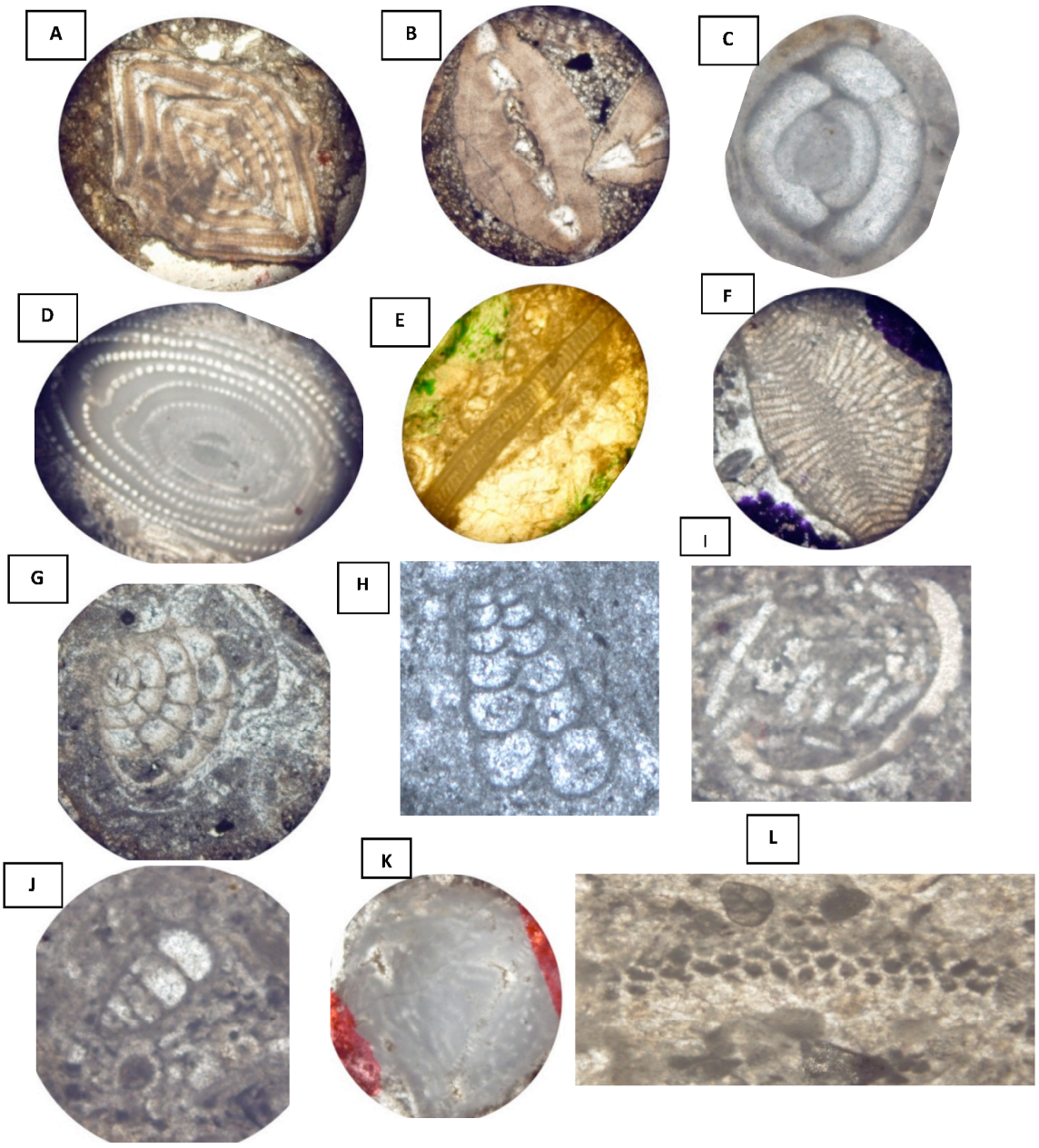

Plate 1: A: axial sections of Nummulite 40X, **B**: axial sections of Assilina 40X, **C**: Miliolid 100X, **D**: axial section of Alveolina 40X, **E**: Orbitolites 40X, **F**: axial sections of Discocyclina 40X, **G**: Lockhartia axial section, **H**: Textulariina, **I**: Brachiopods 40x, **J**: Gastropods, **K**: Algae 40X, **L**: Bryozoan 100X.

inward, wall calcareous, of laminated radially fibrous. Axial sections are found in thin sections (Plate **1**: G).

Textuliriina

(Textulariina- Lituolacea- Textulariidae)

Textulariina are large agglutinated orbitolinid foraminifera. It comprises important biostartigraphic markers and used for biozonations. The test consists of calcareous or non-calcareous particles cemented with mineral cement. The conical forms have uniserial stacks of low, saucer shaped chambers following an early trochospiral stage [8]. They are found in association with Miliolids. Textularina and other related agglutinated foraminifera are important members of the constructed and binder guild of Early Tertiary reefs [8] (Plate1: H).

Other Fossils

Brachiopods

Lots of thin shelled brachiopods are found in SML. It is difficult to identify the specific genera or specie because of shell recrystallization. The interior of shell is micritized and also filled by sparite crystals and usually form geopetal fabric (Plate1: I).

Gastropods

Few gastropods are also found. These are not further identified because of most of them only the inside cast or shell mold is preserved (Plate1: J).

Algae

Algae found abundant in the lower part of SML (Plate1: K) They range to relatively shallow, protected lagoonal environment to relatively warm shallow water behind reefs, were they are more abundant and contribute substantial amounts of calcareous material to the sediments [9].

Bryozoa

Fossil Bryozoa are most abundant in calcareous rocks such as limestone, calcareous shale and shaly marls, occur mainly in shelves and around coral reefs [9]. They are generally associated with benthic organisms such as brachiopods and mollusks as seen in SML (Plate1: L).

DISCUSSION

The recognition of environment-specialized genera or specie of fossil assemblages refines interpretation of paleoenvironment settings. Particular specie of benthonic foraminifera are known to have occupied particular time ranges, e.g. Nummulites atacicus/mamilia group which was present in the early Eocene to middle Eocene. Few facies specific fossils are highly dependent on the environment e.g. Nummulites Miscellena. Few forams are phylogenetically related e.g. Assilina dendotica which evolves into Assilina lamisoca that internally evolves into Assilina cancilitica. Assilina dendotica, is a Paleocene representative, Assilina lamisoca of lower Eocene and Assilina cancilitica representative of middle Eocene age [10]. Algae, brachiopods and gastropods are sensitive to ecological changes and have limited tolerance in response of environmental fluctuations, therefore helpful in precise paleoenvironmental interpretations.

Large benthonic foraminifera are helpful in reconstructing the paleoenvironment. In the setting of a carbonate platform, every specific depositional environment has its own fossil assemblage dependent on the place on the platform or slope. Due to changes in relative sea-level, carbonate production and accommodation space of these fossil assemblage tend to shift. Paleoenvironment could be recognized with the abundance of certain foraminifera and other bio-associations in thin section.

In a supposedly ‘open shoal’ carbonate platform setting, the Alveolina is mainly present on the open intertidal part of the platform. Nummulites, Assilina and Discocyclina are mostly present in the open shoal to the offshore part of the carbonate platform. These are Tertiary Foraminifera and are present in the entire studied section of early Eocene (Ypresian) age.

In general the imperforate foraminifera (i.e. Alveolina and Miliolids) indicate a near shore environment while the perforate foraminifera (i.e. Assilina and Nummulites) live in a deeper environment. If these two groups occur at the same time in the section then it is assumed that there was no barrier. If a barrier was present, both groups are not present together in the rock.

CONCLUSION

The upper part of SML consists of argillaceous fossiliferous limestone interbeded with thin calcareous shale layer. The fossil assemblages of Assilina together with Discocyclina form shaley interbedded carbonate. Low number of specimens observed might reflect low density of original population; thin wall and small size of tests suggest relatively deeper water conditions. These sediments were deposited in deep marine environment. In spite of low number of specimen the diversity of Assilina indicates the deep water ramp deposits. In addition few Nummulites and few Discocyclyna are also found. In this region, the scarcity, low diversity and small tests of Nummulites differentiate this assemblage from shallow water assemblage.

The lower massive fossiliferrous limestone dominated by large foraminifera i.e. Nummulites, represents shallow shelf deposits. Here “deepening up trend” is indicated by the existence of deeper marine ramp-slope sediments at top SML preceded by slope to shallow shelf sediments. The robust Nummulites, Alveolina, Milliolids, Discocyclina and rare Assilina give the evidence for shallower environment. Assilina and Discocyclina occur in relatively deep water environment while small Nummulites occur in shallow, inner shelf settings, often co-existing with Alveolina [11]. Gradual increasing number of bioclasts indicate relatively high energy environment within shelf sequences. The abundant small Nummulites formed in inner shelf

condition is proved by the occurrence of Algae in association with Miliolid and Orbitiolites demonstrated the restricted marine or lagoon environment.

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