GeoConvention
Calgary • Canada • March 7-11 2016
OPTIMIZING RESOURCES

Lithofacies Attributes and Depositional Setting of the Middle Jurassic Samana Suk Formation, Potewar Basin, North Pakistan

Amjed Cheema[1] and Osman Salad Hersi[2]

1. ProGeo Labs, 2. Department of Geology, University of Regina

Summary

The Samana Suk Formation, Upper Indus Potewar Basin, is a Middle Jurassic carbonate unit dominated by well-agitated hydrodynamic lithofacies. The formation accumulated on an epicontinental carbonate platform located on the northwestern margin of the Indian continent after breaking away from the Afro-Arabian portion of Gondwanaland. Lithofacies attributes of the formation from three ourcrop sections, located along a 240-km transect, were studied in great detail. The formation is dominated by oolitic and bioclastic packstone, grainstone and rudstone lithofacies and moderate amount of bioclastic and oolitic mudstone to wackestone. Subordinate shale, marls and bioclastic sandstone intervals are also present. Lithofacies properties, their lateral extension and vertical stacking nature indicate that the formation was deposited in a gently-sloping carbonate ramp which has evolved to a distally-steepening shelf in its latest stages.

Introduction

Circum-Tethys Mesozoic carbonates are known for their prolific hydrocarbon content, particularly in the Middle East Arabian and Persian regions. Deposition of these rocks was continuous along the eastern shallow-marine margin of Arabia-East Africa–Madagascar-India block (i.e., the eastern margin of Gondwana, Fig. 1A). In Pakistan (the northeastern margin of the Indian plate), the Jurassic system is well developed throughout the Indus Basin of Pakistan (Fig. 1B) and consists both carbonate and siliciclastic successions. The Jurassic sediments of the Upper Indus Basin represent three-fold subdivision e.g. Datta Formation (mainly sandstone with subordinate shale), Shinawari Formation (limestone and shale) and Samana Suk Formation (predominantly limestone with subordinate shale/marl and sandstone). This sedimentary succession is bounded at the base and top by two regional unconformities (Fig. 1C). The overlying Chichali Formation is Cretaceous age and dominated by Shale with subordinate sandstone lithology.

The Middle Jurassic Samana Suk Formation has high hydrocarbon interest and is locally producing gas. Previous work has the scope of mapping and generalized lithologic attributes of the formation (Mertmann and Ahmad, 1994). Further details on the formation's lithologic attributes, stratigraphic lithofacies distributions (both vertically and laterally), diagenetic history and depositional environments are essential for better understanding of the reservoir properties of the formation. It is the scope of this work to document the sedimentologic properties and depositional setting of the formation in the upper Indus Basin (northern margin of the Potewar Basin). The formation was measured and sampled in detail from three localities (Fig. 1B); two in Hazara area (Sanghar Gali and Bagh sections) and one in Samana Range (Samana Section, the type section of the formation). Detailed sampling, field analysis, and petrographic and biostratigraphic investigation allowed the identification of the lithofacies attributes and depositional setting of the formation.

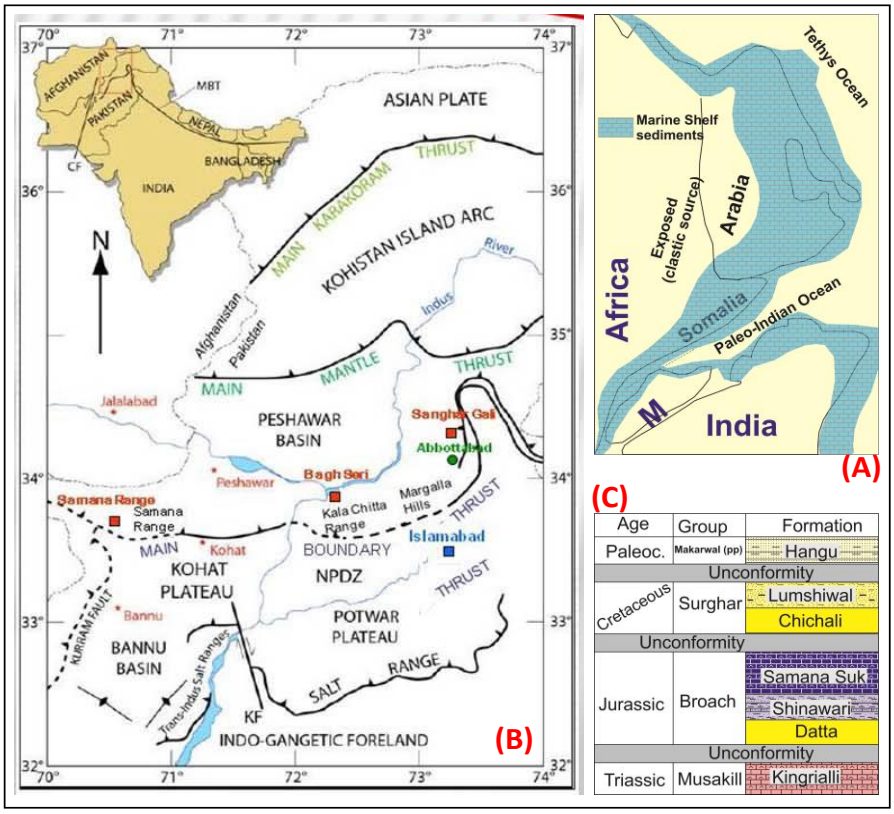

Figure-1: (A) Middle Jurassic paleogeographic reconstruction of eastern Gondwana. Southward extension of the Tethys Ocean and establishment of Paleo-Indian Ocean became a site of shallow marine carbonate production throughout the region (redrawn from Riccardi, 1991). (B) Location map of the study area. Three sections, (Sanghar Gali, Bagh and Samana sections) were studied in great detail during this study. (C) Stratigraphic chart showing the Triassic to Paleocene succession and intervening unconformities. The Samana Suk Formation forms the uppermost unit of the Broach Group; it is conformably underlain by the Shinawari Formation and unconformably overlain by the Early Cretaceous Chichali Formation.

Samana Suk Formation

Thickness, contacts and age

The Samana Suk Formation has its maximum thickness, 366 meters (Bagnotar section) in Hazara area (Shah, 1977). The formation has a conformable contact with Shinawari Formation and unconformably underlies the Chichali Formation. The Shinawari Formation consists of alternating gray to brownish gray, partly sandy and/or oolitic limestone, gray to dark gray, calcareous shale and white, brown or reddish, calcareous sandstone with cross bedding and ripple marks. Some ferruginous sandy and oolitic beds are present in the upper part of the formation. These upper beds are followed by the Samana Suk Formation with conformable contact. The Chichali Formation, which lies above the Samana Suk Formation, consists of medium-grained, greenish brown to yellowish brown glauconitic sandstone and greenish grey sandy to silty glauconitic shale. The formation is fairly fossiliferous and its age, based on biostratigraphic dating, spans between Bajocian to Callovian (Cheema, 2010).

Lithofacies properties

The detailed field and petrographic study of the formation led to the identification of the lithofacies units that constitute the formation. These lithofacies are grouped into five types: (i) mudstone to wackestone, (ii) packstone to grainstone, (iii) rudstone, (iv) marls and shales, and (v) bioclastic sandstone.

(i) Mudstone to wackestone: Gray to dark gray, thin to thick-bedded, well bioturbated to poorly-bioturbated, bioclastic, oolitic, intraclastic and/or peloidal mudstone to wackestone (Figure-2). Bioclastic content varies from place to place and includes gastropods and benthic foraminifera. Minor planktonic foraminifera and sponge spicules are locally present. The lithofacies locally contains sand and fine to medium crystalline dolomite patches, and thin, yellowish brown dolomudstone layers. Flaser bedding, planar laminations and dolomitized (*Thalassinoids*) burrows are present. The lithofacies accumulated in a low hydrodynamic environment that spans from deep shelf to shallow subtidal to supratidal mudflat.

(ii) Packstone to grainstone: This lithofacies is characterized by thin to thick beds, occasionally bioturbated, bioclastic, peloidal, intraclastic and oolitic packstone to grainstone (Figure-4). Small to large scale trough and tabular cross bedding, herringbone cross bedding, normal grading, and vertical to inclined burrows are present. The bioclasts include gastropods, bivalves, echinoids, and benthic foraminifera. Oncoids are locally present, as well. This facies is the most dominant one in the

formation. The sedimentary structures and textures of this facies suggest a moderate to high energy, shallow subtidal to intertidal on shoals and tidal channels.

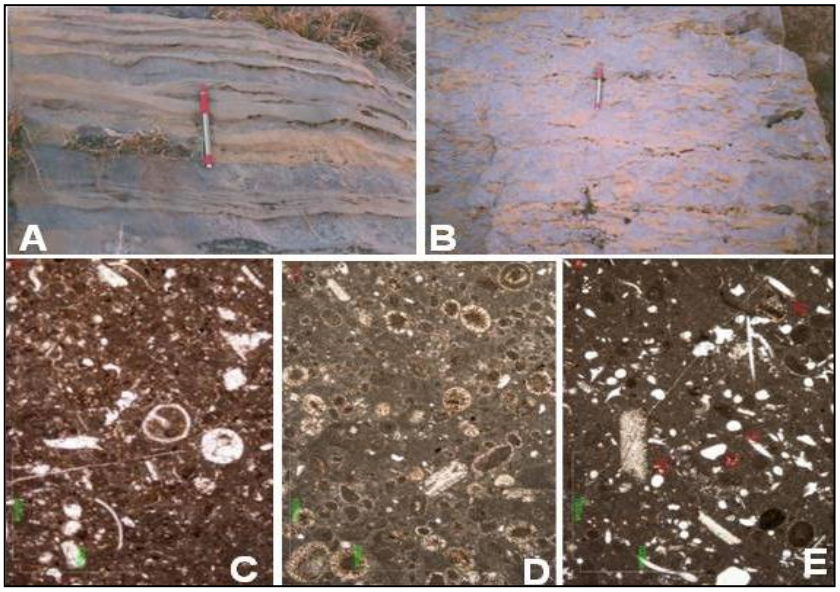

Figure-3: Field and microfacies slides of the mudstone to wackestone lithofacies. A) Medium to thin interbeds of bioclastic lime mud-/wackestone (grey) grading to buff-color dolomudstone layers. B) Thalassinoids burrows are common and filled by buff dolomudstone, Burrows are filled by dolomudstone. The microphotographs show bioclastic (c), oolitic (D) and sandy with sponge spicules (E) wackestones. Horizontal field of view is 2.2 mm for C, D & E. The marker in A & B is about 13 cm long.

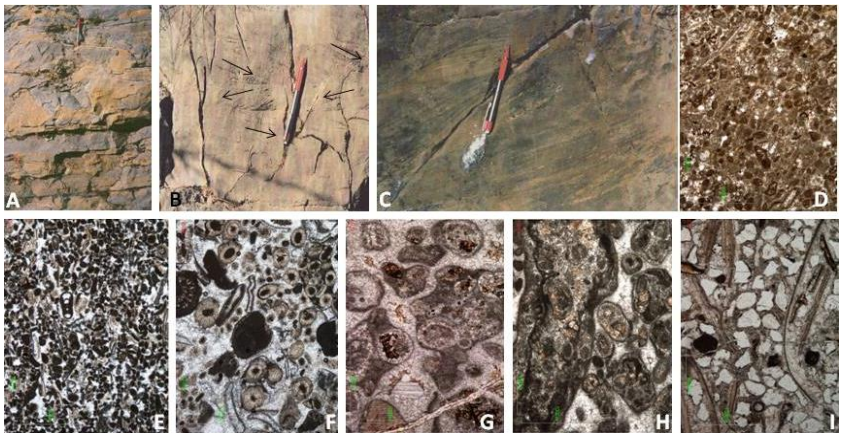

Figure-4 Field and microfacies views of the packstone, grainstone, rudstone and bioclastic sandstone lithofacies. A) Medium- to thickly-bedded, medium grey pack-/grainstone, B) bioclastic, intraclastic, oolitic grainstone to rudstone with herringbone x-bedding (arrows), C) oolitic grainstone with trough x-bedding, D) photomicrograph of oolitic, bioclastic packstone with some quartz grains, E) bioclastic, peloidal grainstone, F) bioclastic, oolitic grainstone, G & H) oolitic rudstone with grapestone lumps, I) bioclastic sandstone lithofacies. Horizontal field of view is ~2.2 mm for all microphotographs.

(iii) Rudstone lithofacies: This lithofacies is associated and very similar in most aspects to the grainstone lithofacies. The only difference is the grain size and type. The rudstone lithofacies is dominated by gravel-size fossil fragments and aggregate grains (Fig. 4F & G). The sedimentary structures are similar to those mentioned in the packstone-grainstone lithofacies (Fig. 4). The rudstone lithofacies was deposited in a highly-agitated environment of subtidal to intertidal environment.

(iv) Marls and shales: This lithofacies is volumetrically subordinate; it is light gray, thinly-bedded, highly bioturbated, poorly-cemented marls to calcareous shales. Bioclasts and peloids are present. This lithofacies mostly lies on rusty, brown surfaces that probably represent hardgrounds. It is interpreted as subtidal muddy facies and may indicate flooding events of the platform.

(v) Bioclastic sandstone: This lithofacies is characterized by thinly to medium-bedded sandstone dominated by quartz grains. Bivalve shells are commonly present in the lithofacies (Fig. 4I). The facies is volumetrically subordinate and occurs in few beds in the middle of the formation. It most likely represents a sea level drop. Further work on its significance in terms of sequence stratigraphic interpretation is in progress. The lithofacies is interpreted as high energy tidal channel deposits.

Depositional environment

The Samana Suk Formation is dominated by the bioclastic and oolitic packstone to grainstone lithofacies. Based on the lithologic attributes of the formation, as well as sedimentary structures, fossil content and relationship among the different lithofacies units, it is envisaged here that the formation was deposited in a shallow marine subtidal to intertidal environments defined by a gently inclined carbonate ramp/platform. The lithofacies relationship in the upper part of the formation also suggests that the depositional environment has probably evolved from simple ramp type platform to a distally-steepening platform. It has attained slightly rimed shape in a later stage (Fig. 5).

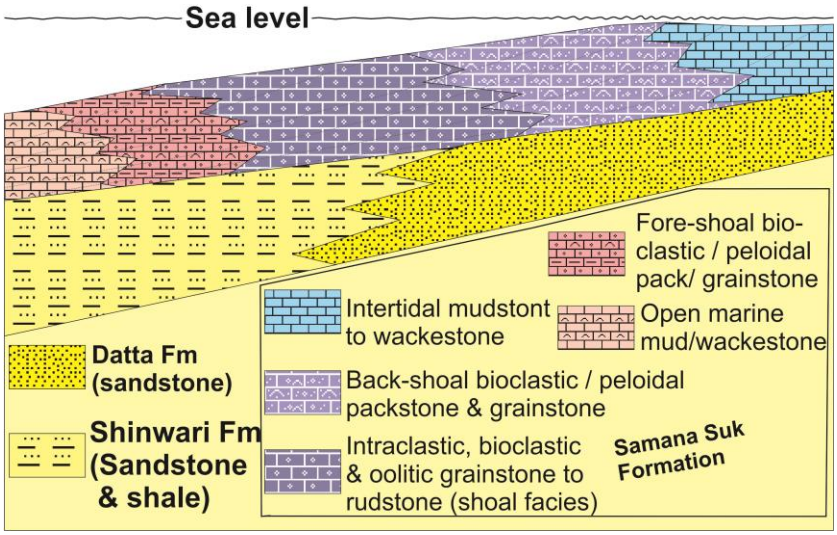

Figure-5: Simplified deposition model for the Samana Suk Formation. The formation accumulated in a carbonate ramp characterized by bioclastic and oolitic sand shoals (packstone, grainstone and rudstone lithofacies), subordinate semi-protected, back-shoal mudstone & wackestone and open shelf mudstone & wackestone lithofacies.

Conclusions

The Samana Suk Formation is dominated by bioclastic and oolitic packstone, grainstone and rudstone lithofacies. Poorly to fairly fossiliferous and oolitic mudstone to wackestone lithofacies are fairly present, as well. Subordinate marls, shales and bioclastic sandstone also occur in the formation. The fossil content of the formation indicates a Bajocian to Callovian age. The lithofacies units of the formation are arranged as recurring cycles of mud-dominated subtidal units succeeded by shallow subtidal to intertidal, high energy, bioclastic and oolitic packstone, grainstone and rudstone lithofacies. The formation was deposited in a gently-sloping ramp which later evolved in to a distally-steepening shelf.

Acknowledgements

We are highly thankful to Professor Dr. Muhammad Nawaz Chaudhary, University of the Punjab, Pakistan for his facilitation and support during this project. Practical help of Dr. Jamil Afzal (ProGeo Labs, Calgary) and Dr. H. Jurgan (Hanover, Germany) for different aspects of this study is well appreciated.

References

Cheema, A. H., 2010, Microfacies, Diagenesis and Depositional Environments of Samana Suk Formation (Middle Jurassic) Carbonates exposed in South East Hazara and Samana Range, Ph.D. Dissertation, University of the Punjab, Pakistan, 286 p.

Mertmann, D., and A. Ahmad, 1994, Shinawari and Samana Suk Formations of the Surghar and Salt Ranges, Pakistan: Facies and Depositional Environments: Zeitschrift der Deutschen Geologischen Gesellschaft,. Band 145, p.305-317.

Riccardi, A.C., 1991, Jurassic and Cretaceous marine connections between the southeast Pacific and Tethys. Paleogeography, Paleoclimatology, Paleoecology, 87: 155-189.

Shah, S. M. I., 1977, Stratigraphy of Pakistan: Geological Survey of Pakistan Memoirs 12, p. 1-138.