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The Goru Formation and its Facies in Kirthar Sub-basin

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ABSTRACT

The Goru formation is described and subdivided into 6 facies on the basis of sedimentological study in Kirthar sub-basin. The study shows that reservoir properties of the formation improve in the eastern and southeastern parts of the study area where Facies I-III are developed i.e. sandstone lithology is dominating. These facies are hydrocarbon producers in the southern part, having porosities raning from 20 to 30 percent. The study further indicates some source rock potential in the Facies IV-V in southwestern part of the study area.

INTRODUCTION

This paper is based on the geological-sedimentological investigations conducted by Hydrocarbon Development Institute of Pakistan (HDIP) and Bundesanstalt fur Geowissenschaften und Rohstoffe (BGR) geologists in the Kirthar Range in 1987.

The area under investigation is bounded in the west by Bela-Ornach fault system, eastwards it reaches the Indian border, it extends northwards parallel to latitude 30° and to the present day offshore in the south (Figure 1).

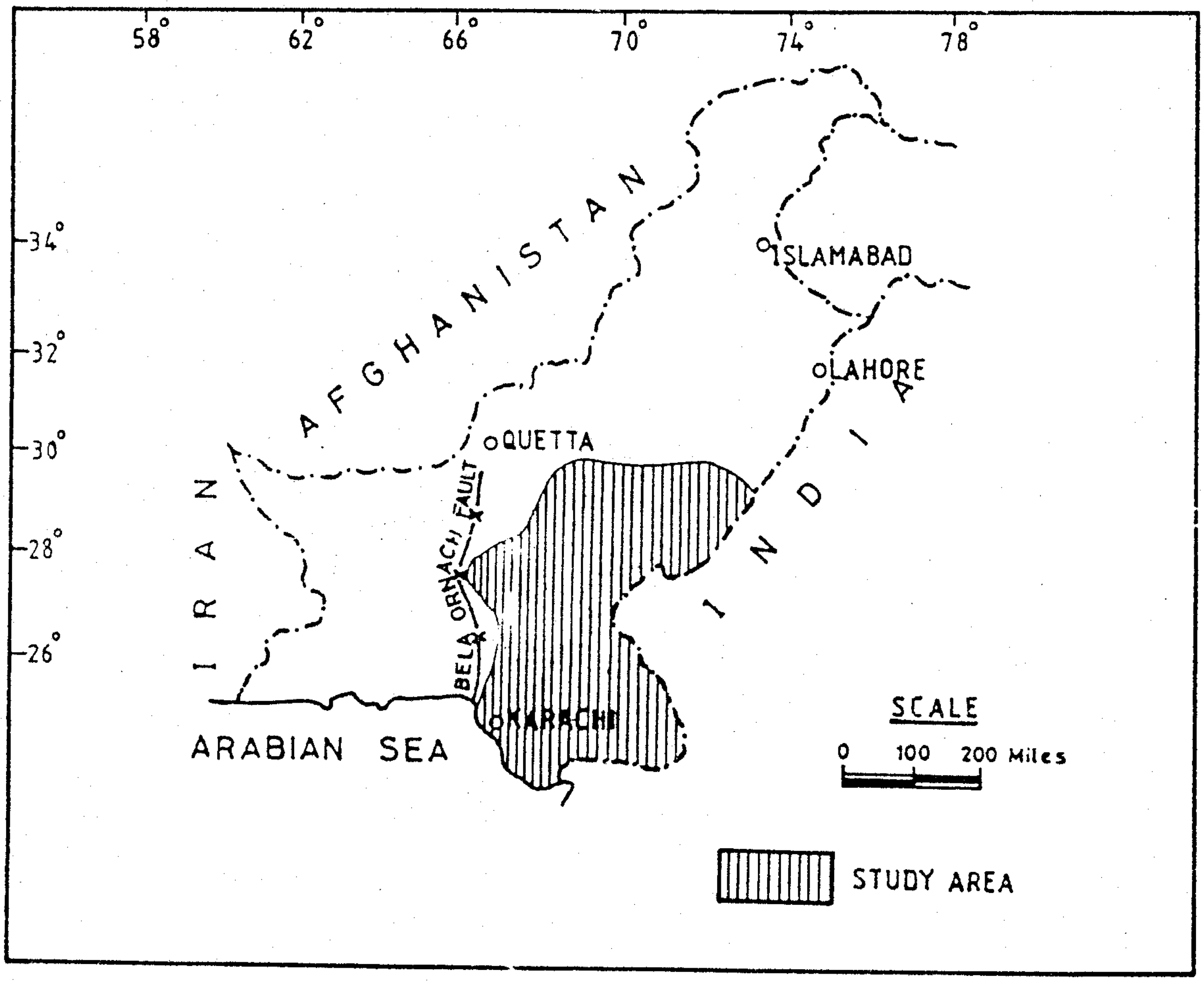

Figure 1—Index map of the study area.

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This article describes mainly the lithological aspect of the Goru formation, its lateral and vertical facies change and distribution in the area of study.

The exposed sedimentary sequence has been studied in several sections in the western part of the study area. In the extreme southeastern part of the area, well data was used for geological controls.

STRATIGRAPHIC SUCCESSION

The oldest rock unit in the area is the Shirinab formation and the youngest is the Gaj formation of Jurassic and Miocene age respectively. The general stratigraphy of the area is shown in Figure 2.

GORU FORMATION

Description

The name Goru formation was introduced by Williams (1959) for the upper part of Oldham's Beleminite beds (1892). The type section is located near Goru, a small village on the Nar River, a southern tributary of the Mula River in the central Kirthar Range (Lat. 27° 50' 00" N, Long. 66° 54' 00" E, topographic sheet no. 35, I-13).

The Goru formation at the type locality consists generally of interbedded limestone, shale and siltstone. The basal part is usually composed of very fine grained, thinly bedded and light to medium grey limestone with minor intercalations of shale. The interbedded shale and siltstone are grey, greenish grey, locally maroon, irregularly bedded splintery, hard and calcareous at places.

The limestone is dominant in the lower and upper parts of the formation, the increasing amount of limestone in the upper part with some dark spots takes the lithological characteristics of the overlying Parh limestone, however, it is interbedded with calcareous, silty shale or mudstone of similar colour.

The Goru formation is widely distributed in the study area. In the west the Goru formation consists mostly of shaly facies. It is 539m thick at the type locality but the thickness decreases to 60m near Quetta and in the subsurface a thickness of more than 2000m has been recorded.

The lower contact of the formation with the Sembar formation is conformable, but locally an unconformity has been observed in some sections in the west as in the Anjira River where the Goru formation directly overlies the Jurassic limestone and the Sembar lithology has not been developed. The contact between Goru and Sembar formations is placed on the appearance of frequent limestone beds. The contact with the Parh limestone is usually transitional and is placed at the last wide-spread and maroon coloured shale band, although this band migrates up and down-section somewhat and at times may be in Parh limestone.

The Goru formation is mainly of Early Cretaceous age, although in many areas its deposition started in the Late Jurassic and continued into the Late Cretaceous (Shah, 1977).

The Goru formation is exposed in the following sections in the area under study (Figure 3).

1. Anjira River
2. Arzanuk Nala
3. Bibi Nani Section
4. Ghat Jhal
5. Gaj-Kareiji Jhal
6. Gidar Dhor
7. Hatachi (Mula River)
8. Jakkher Dhora
9. Murad Khan Section
10. Wadh Section
11. Pabni Chowki
12. Akri Dhora
13. Samand Nala
14. Zawa.

Additional information is available from the following STANVAC profiles.

15. Koh-i-Maran
16. Tibbi River
17. Goru Section
18. Sundhi Nala
19. Mardan Nala
20. Moro River
21. Oosteri Nala

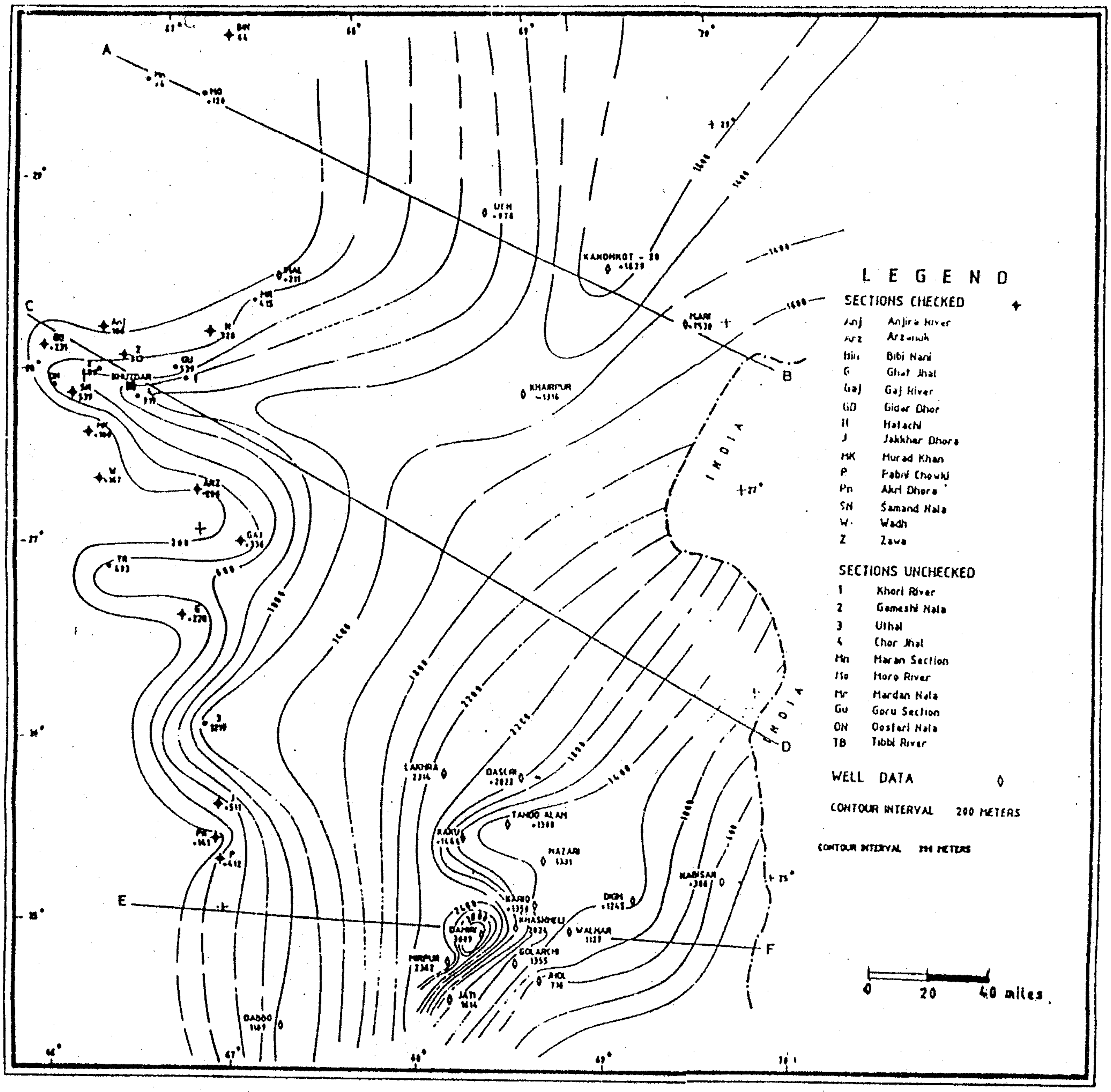
Distribution

The available geological information shows that from depositional point of view the Jurassic sequence of the lower Indus basin was followed by a thick succession of the Cretaceous sediments. Based on the results of geophysical investigations and drilling records, the source of the Cretaceous sediments was the Indian craton.

The given isopach map indicates that during the deposition of the Goru formation, the area around Damiri was a depocenter where more than 3000m thick clastic sediments were deposited (Figure 3), however, from this area the thickness decreases gradually in all directions and a thickness of 386m has been recorded at Nabisar well in the Thar slope on the east, 64m at Bibi Nani section on the north and about 100m at Murad Khan section on the west.

Period	Epoch		Formation		Lithology	Description
TERTIARY	PLIO PLEIST		SIWALIK GR.			Sandstone, Shale, Conglomerate. Continental out wash deposit 0 - 4618 m
TERTIARY	MIOCENE		GAJ Fm.			Shale, Sandstone, Limestone-gray-red variegated Sandstone and dirty gray detrial Limestone. Marine to non-marine 50 - 700 m
TERTIARY	OLIGIOCENE		NARI Fm.			Sandstone, Shale, Limestone - fine grained to Conglomeratic Sandstone interbedded with sandy limestone, Shale & calc. Sandstone. 150 - 1820 m
TERTIARY	EOCENE	LATE, MIDDLE	KIRTHAR Fm.			Limestone & Shale — Light colored generally hard massive but locally rubbly to nodular limestone interbedded Shale - 15 - 1270 m
TERTIARY	EOCENE	MIDDLE, EARLY	GHAZIJ Fm.			Shale, Sandstone, Limestone - gray to olive green silty shale with fine to coarse gra ned argillaceous Limestone in the lower part. mostly marine. 160 m
TERTIARY	PALEOCENE		DUNGHAN Fm.			Limestone, Shale, marl, Sandstone - dark gray to brown Limestone with olive shale black spots (bioturbation) 300 m
TERTIARY	PALEOCENE		KHADRO Fm.			Sandstone, Shale, Limestone - thin bedded fine Sandstone, Basalt, 67 - 180 m
CRETACEOUS		LATE	PAB SS			Sandstone - Light buff, brown, gray, locally quartzitic. Marine. 240 - 600 m
CRETACEOUS		LATE	FORT MUNRO			Limestone, gray to black, thick bedded, sandy in the upper part, argillaceous band in the lower part. marine. 90 - 248 m
CRETACEOUS		LATE	MOGHAL KOT			Limestone, Siltstone, Sandstone - gray Calcareous Siltstone scattered argillaceous Limestone band. marine. 160 - 900 m
CRETACEOUS		LATE	PARH Ls.			Limestone - Pale, gray, white, hard, porcellaneous, conchoidal fracture, well bedded, Marine. 268 - 600 m
CRETACEOUS		MIDDLE	GORU Fm.			Limestone & Shale_upper part inter-bedded Parh type Limestone and Calc. Siltstone & Shale Lower part gray, gray-green Siltstone with interbedded argillaceous Limestone and Sandstone. 60 - 3670 m
CRETACEOUS		EARLY	SEMBAR Fm.			Silty Shale, Limestone - dark olive-gray to black, silty fissile shale, nodular black siltstone, Sandy Limestone, beleminite common 133 - 262 m
JURASSIC		LATE	TAKATU Ls.			Limestone - gray to grayish brown, massive. 0 - 850 m
JURASSIC		MIDDLE	SHIRINAB Fm.	ANJIRA Member		Limestone - dark gray thinly bedded limestone thin shale interbeds. Marine. 100 - 400 m
JURASSIC		MIDDLE	SHIRINAB Fm.	LORALAI LS.		Limestone - dark gray to black, medium to thickly bedded with minor scattered thin Shale interbeds. Marine. 170 - 650 m
JURASSIC		EARLY	SHIRINAB Fm.	SPINGWAR Member		Limestone & Shale - dark gray to black, thickly bedded fine crystalline limestone & interbedded Shale or highly argillaceous limestone - Marine. 700 - 1900 m. Lower portions with sandstone intercalations.

Figure 2—Stratigraphic nomenclature of the study area (After Williams, 1959).



Fifure 3—Isopach map of the Goru formation

Facies Development

Resulting from the configuration of the basin as well as tectonic events the Goru formation displays remarkable variations in the lithofacies. Based on the aerial distribution and lithological features, the Goru formation may be divided into six facies. These facies are generally aligned in NE-SW directions (Figure 4).

Facies-I.— This facies of the Goru formation is confined to the southeastern portion of the area under

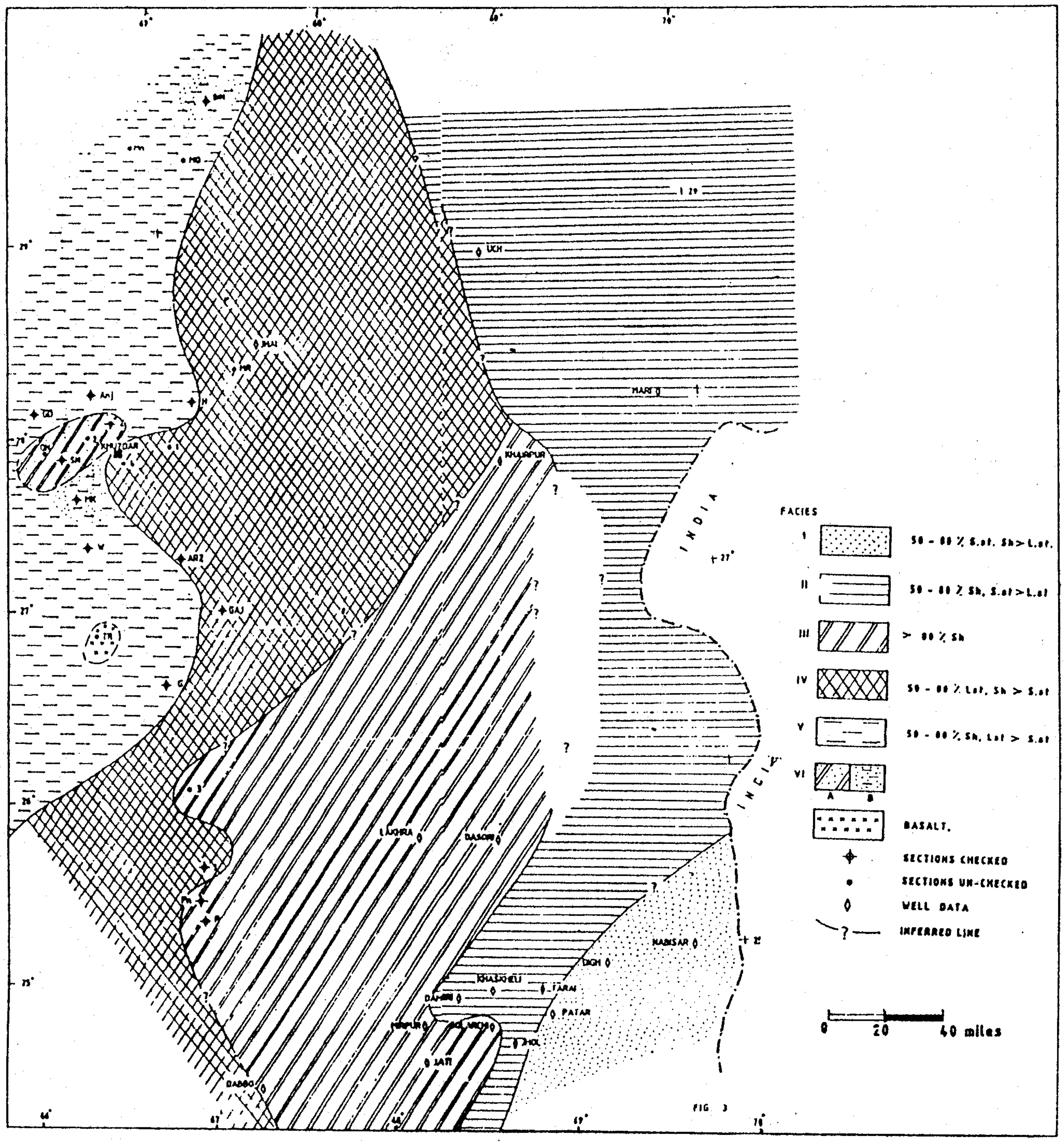


Figure 4—Lithofacies map of the Goru Formation.

investigation. It is almost exclusively represented by the Lower Goru formation and mainly consists of a regular alternation of sandstone and minor shale. Limestone appears to be merely a subordinate component of the lithology of this facies. The absence of the upper Goru formation in some wells on the east is obviously a result of erosion at that time.

Facies-II.— The Facies-II is located mainly in the eastern part of the surveyed area and borders of Facies-I on the southeast. Lithologically Facies-II is composed of grey shale (50-80%) with alternating sandstone and minor limestone beds. The influence of sandstone extends to Khairpur well in the north and Dabbo well in the south. This facies opens up northward and narrows down to offshore.

Facies-III.— This facies of the Goru formation lies in the lower half of the investigated area and extends to offshore in the south and Khairpur well in the northeast. Like facies I & II the geological information of this facies is available only from well data except in its western part where the Goru formation is exposed. Shale and siltstone are the most abundant rock types and composed of more than 80% of grey clastic facies with alternating minor sequences of limestone, concretions of iron carbonates, gypsum flakes, bioturbation on fresh surfaces and dark carbonaceous sediments having good organic carbon content are common in this facies. The lower contact of the Goru formation in the exposed strata is generally covered whereas the contact with the overlying Parh limestone is sharp and the latter is significantly reduced in that area.

Facies-IV.— The northern central portion of the area is occupied by this facies and the deposition took place in Kirthar depression and is aligned parallel to the Kirthar Range. Facies IV narrows down in the north and southwest. It is represented mainly by dark grey limestone sequence with alternating shale/siltstone sequences in the west and splits into a number of lobes which advance westward to Facies V. It becomes bituminous locally. Ammonites and Beleminites are common fossils.

Facies-V.— This facies is exposed in the western part of the surveyed area and runs in north-south direction. This facies includes dominantly shale/siltstone (50-80%) and intercalating limestone. The characteristic feature of this facies is abnormal variegated colouration of the sediments specially in central part of the area. However, in the northern part red and purple coloured sediments are predominant. Bioturbation and Ammonites are common. Generally the lower contact is covered, while the upper contact with the Parh limestone is transitional. Basalt occurrence has been reported in the western part of the area at Tibbi River section by STANVAC.

Facies-VI.— This unique facies of the Goru formation is locally developed in the north at Bibi Nani section, and in the southwest of Khuzdar. The facies consists of siltstone (80%) with intercalating limestone. Another feature of this facies is the occurence of thin layers of alternating, badly sorted, coarse-grained, calcareous sandstone with plant fragments and clay flakes. The colour of the sediments is generally variegated. Bioturbation, iron nodules and Ammonites are common in this facies, the latter are restricted to grey layers only. Generally the sections where the facies is exposed are disturbed and it overlies the Anjira member of the Jurassic whereas its contact with the overlying Parh limestone is transitional.

Facies Interpretation

In the light of facies distribution mentioned above, sandstone and siltstone are dominant lithological units of the Goru formation in southeastern and eastern parts of the area under investigation. These facies thin out towards the Indian craton.

In the Early Cretaceous time an extensive transgression took place and marine shallow water conditions prevailed during the deposition of the Sembar and Goru formations. The sediments are thicker in the west than in the east. The distribution of sediments and thickness variations indicate that the tectonic movements started at least in the Early Cretaceous and continued intermittently throughout the Cretaceous. The alternating shale and sandstone sequences in the southeastern part also reflect a cyclic deltaic deposition, however, sandstone diminishes in northwest direction. After the deposition of sandstone it appears that the whole basin had subsided and thick clastic sediments mainly shale and siltstone were deposited parallel to the platform and in the lower half of the surveyed area, specially in the area covered by Facies III. The occurence of Beleminites in a shaly sequence at Und Jhal, a tributary of the Gaj River, indicates that the influence of full marine environment was extended to that area.

However, dominant sequence of dark limestone with intercalating minor siltstone/shale and carbonaceous sediments in the area occupied by Facies IV indicate that deposition took place in a deep water environment, but comparatively at higher level than its contemporaneous southern facies. The depositional pattern thins out towards north. The area, occupied by Facies V and VI, runs generally north-south where the clastic influence again prevail and the Goru formation mainly consists of siltstone and intercalating limestone with abnormal variegated colouration of the sediments and also includes badly sorted, calcareous, coarse grained sandstone, Ammonites, plant fragments and clay flakes. These features indicate a nearby source of sediments, however, it is a question of academic research to find out the exact source, because the present Kithar Range did not exist in Cretaceous times.

The abnormal colour variations might have been caused by volcanic activities during deposition of the Cretaceous sediments. Nevertheless, there are also indications that some portions of the sediments could have been transported from a nearby source, whereas laterites could have existed during that time. Additionally, there is a chance of secondary oxidation after deposition.

Petroleum Aspects

The southern parts of the area occupied by Facies I, II and III are hydrocarbon rich. In most of the producing wells the production horizons are the Cretacteous sandstone of the Lower Goru formation ranging in porosity from 20 to 30%. The Lower Goru with interbedded sandstone and shale is confined primarily to the southern part of the Thar slope platform and adjoining offshore and is followed by the siltstone and shaly succession of the Upper Goru in the northwest whose reservoir potential is negligible, however, this thick shaly sequence may act as a good cap rock.

The main source rock in all these fields is considered to be the shaly part of the Sembar formation. The surface samples collected during the present field programme in the Kirthar Range, occasionally show good organic content in the Upper Goru formation. This indicates the Goru formation, at least partially, might have generated hydrocarbons.

CONCLUSIONS

The Goru formation is a proven reservoir of oil and gas in Badin area of Kirthar region, where oil and gas are found in some porous horizons of the formation. The present study has recognized six facies within this formation and has indicated that identification of these sedimentary facies can lead to new discoveries in the region and help in planning future exploration strategies.

Favourable reservoir facies (Facies I-III) are better developed in the eastern and southeastern parts, where more chances of finding oil and gas may exist. Facies IV-VI are shale dominating and provide seal to the underlying reservoir facies. Additionally, these facies are rich in organic matter and may act as source rocks.

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