Pakistan Journal of Hydrocarbon Research
Vol.10, (1998). p.31-39, 11 Figs.

Diagenetic Aspects of the Nari Formation, Belab Nala & Kaura Sori Nala Sections, Sulaiman Province, Pakistan

Muneer Ahmed Memon[1]

ABSTRACT

Diagenesis of sandstones of the Nari Formation has been deduced from outcrop samples of Belab Nala & Kaura Sori Nala sections (Zindapir Anticlinorium, Sulaiman Province). Important diagenetic events are compaction & cementation. Effects of mechanical compaction are obvious & common as compared to chemical compaction evident by the severe deformation of carbonate rock fragments (CRFs) as well as shale rock fragments (SRFs). Silica, is present in insignificant quantity, is found to be the first cement whereas calcite, which is common, has been observed as late cement. Recrystallization and dolomitization are other diagenetic events registered during analysis. The results of present study reveal that sandstones of the Nari Formation could not have good reservoir potential for hydrocarbon in the studied area because of the ductile deformation of unstable lithoclasts and calcite cement which is main porosity occluding component.

INTRODUCTION

This study of the Nari Formation is a part of the project "Evaluation of Hydrocarbon Potential of Zindapir Anticlinorium" and has been carried out as a technical cooperation between Hydrocarbon Development Institute of Pakistan (HDIP), Institute of Geology & Paleontology, Philipps University (Marburg), Institute of Geology & Dynamics of the Lithosphere (IGDL), Goettingen University and Federal Institute for Geosciences & Natural Resources (BGR), Hannover.

The Nari Formation has widespread stratigraphic distribution throughout the Kirthar and Sulaiman Provinces as well as in parts of the Axial Belt. The Formation has considerable variations in thickness from place to place. According to Shah (1977), its thickness ranges from 150 m (at Chattarwata) to 300 m (at Mughal Kot) in the Sulaiman Province and 200 m (in Sor Range near Quetta) to 600 m (in Nal) in the Axial Belt. At its type locality (Gaj River in Kirthar Province), the Formation has a thickness of 1400 m (Shah, 1977). However, it attains a maximum thickness of about 1,820 m in Kirthar Province (Hunting Survey Corporation, 1961).

The Nari Formation crops out throughout the Zindapir Anticlinorium which is located on the eastern flank of the Sulaiman fold belt (Lat. 30° . 00' & 30° . 50' N: Long. 70° . 15' & 70° . 30" E). Most of the previous work done on Nari Formation was related to the stratigraphic aspects. As no extensive study had been done so far, the primary objective of this study was to carry out the sedimentary petrography, diagenesis and pore-space development and depositional environment of the Nari Formation exposed in the foothills of the Sulaiman Range (Zindapir Anticlinorium).

The geological investigations restricted to the Nari Formation were conducted by a team of Pakistani and German geologists from March 8, 1996 to March 29, 1996.

For this purpose, various stratigraphic sections were visited. Two sections i.e. Belab Nala & Kaura Sori Nala were selected, measured and sampled (Figure 1). A total of 38 rock specimen were collected from both investigated sections. Fifteen (15) sandstone samples were cut and thin sections were prepared and analyzed in detail by using polarized microscope. Microscopic analysis comprising diagenetic history and porosity occlusion of these sandstones has been presented in this paper.

DIAGENESIS

Sandstone diagenesis of the Nari Formation comprises two distinct features i.e. compaction and cementation.

Compaction

Compaction phenomenon has occurred in all analyzed sandstone samples of the Nari Formation, but it is not very much extensive. Majority of detrital grains have point to long contacts or in a few cases restricted to concavo-convex contacts (Figure 2). However, ductile deformation of soft lithoclasts such as carbonate rock fragments (CRFs) and shale rock fragments (SRFs), has been frequently observed in many sandstones of the Nari Formation. These CRFs and SRFs are generally soft thus more likely to be deformed (bent, broken or crushed) or embayed by harder grains (Figure 3,4,5). Likewise, flakes of muscovite are also bent and broken or fractured along weaker planes thus indicating compaction effects (Figure 4). In some cases, these soft CRFs and SRFs have been strongly deformed, as a consequence the exact estimation of lithic grains and matrix has become very difficult or almost impossible (Figure 6).

[1] Hydrocarbon Development Institute of Pakistan, Islamabad.

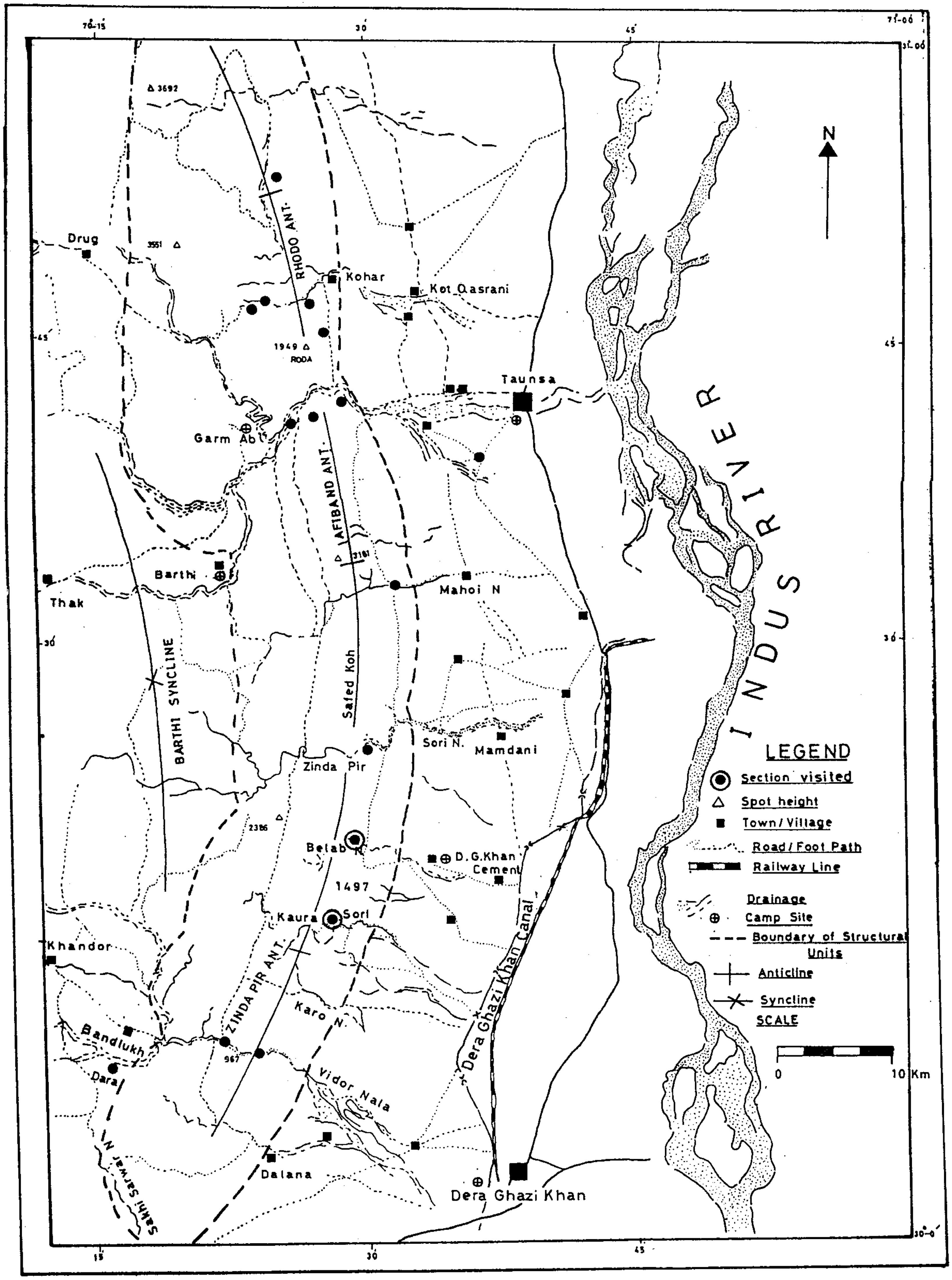

Figure 1- Location map of the investigated sections (After Iqbal & Helmcke, 1995).

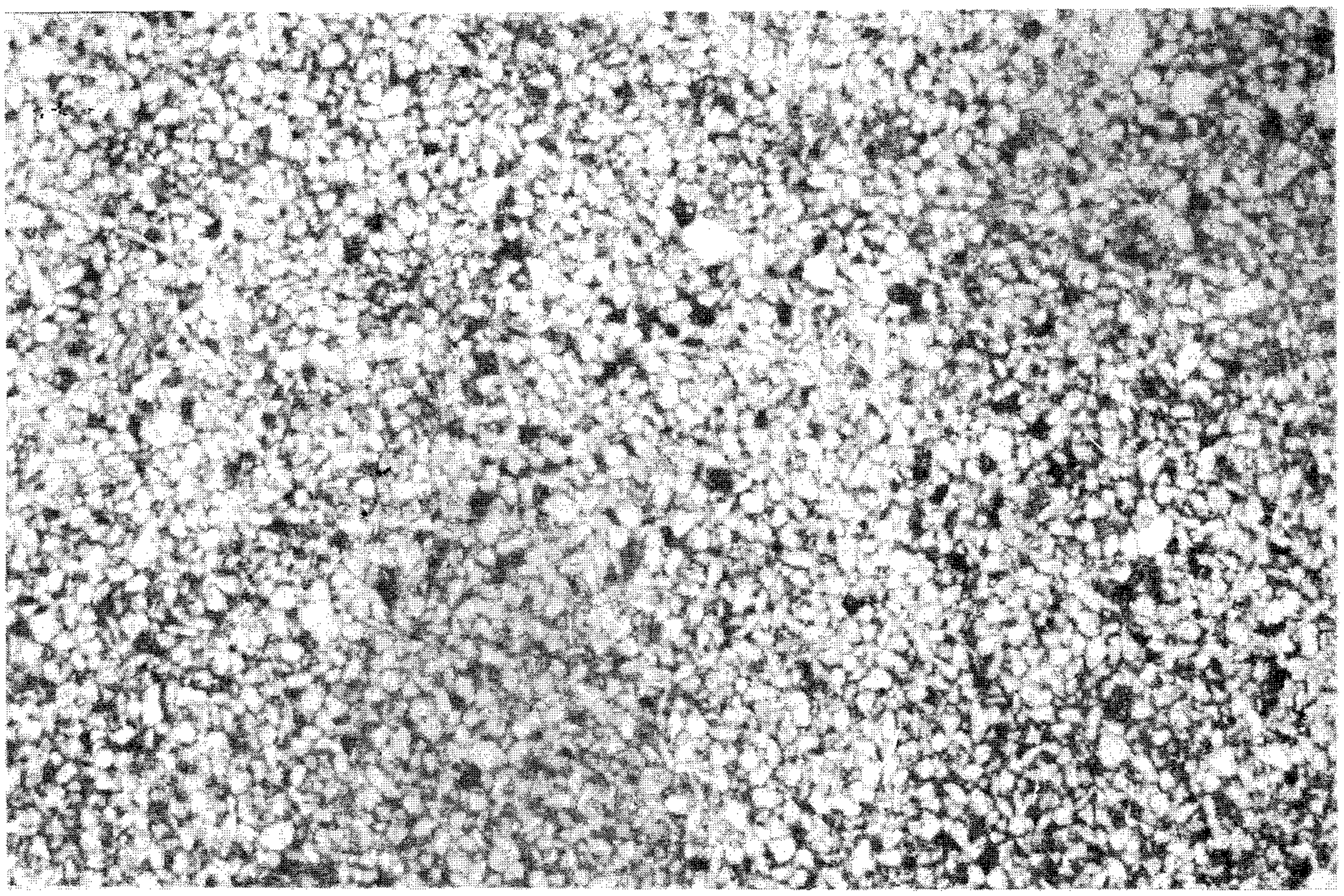

Figure 2- Typical view of very fine to fine-grained quartzarenite comprising the basal part of the Nari Formation(Sample No. 96.3.15-8, Belab Nala; magnification x25, PPL.

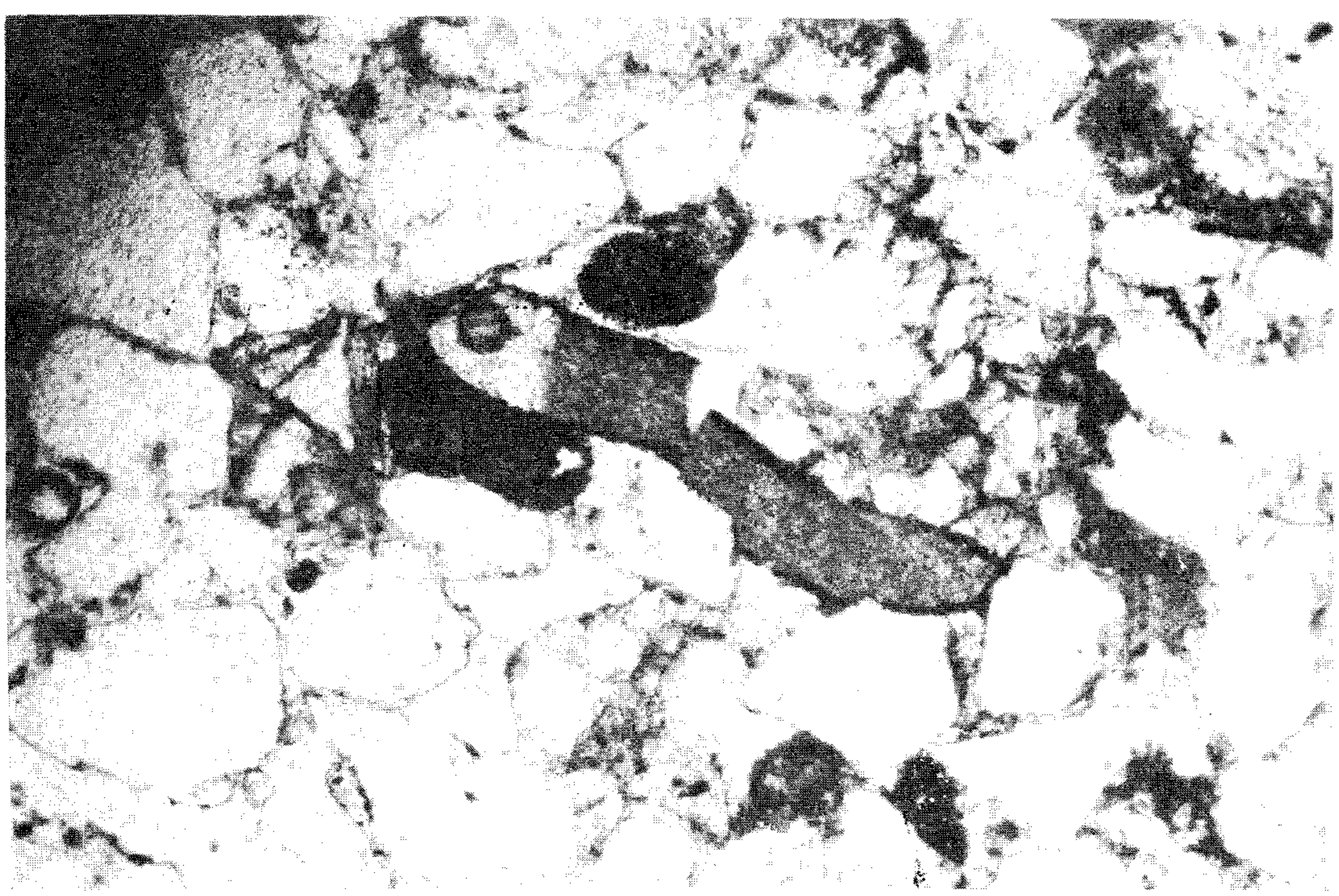

Figure 3- Micritic lithoclast, which has been deformed due to the overburden compaction(Sample No.96.3.15-15, Belab Nala; magnification x100, PPL).

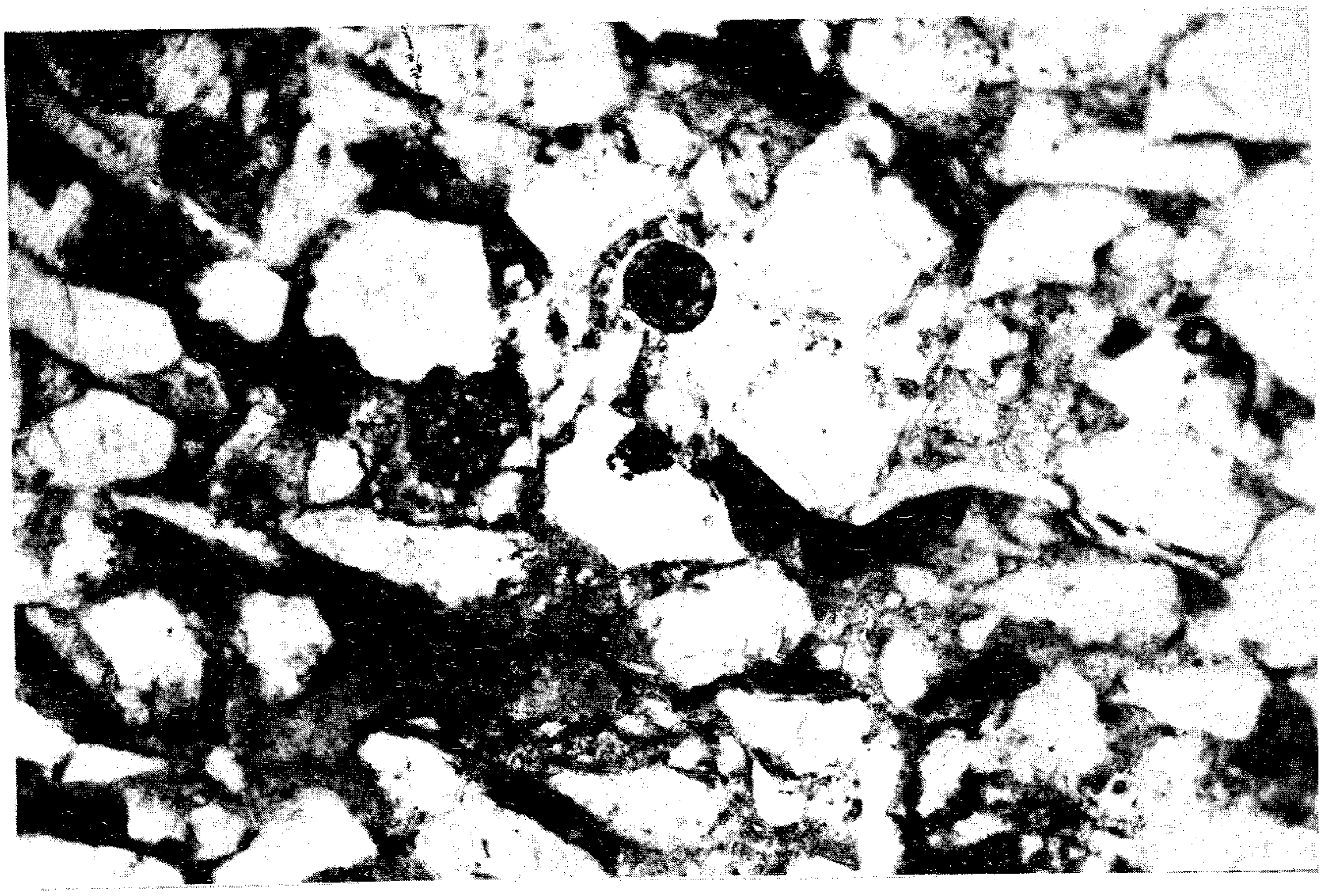

Figure 4- Bended & broken muscovite flake indicating compaction effects (Sample No. 96.3.15-16, Belab Nala; magnification x100, PPL).

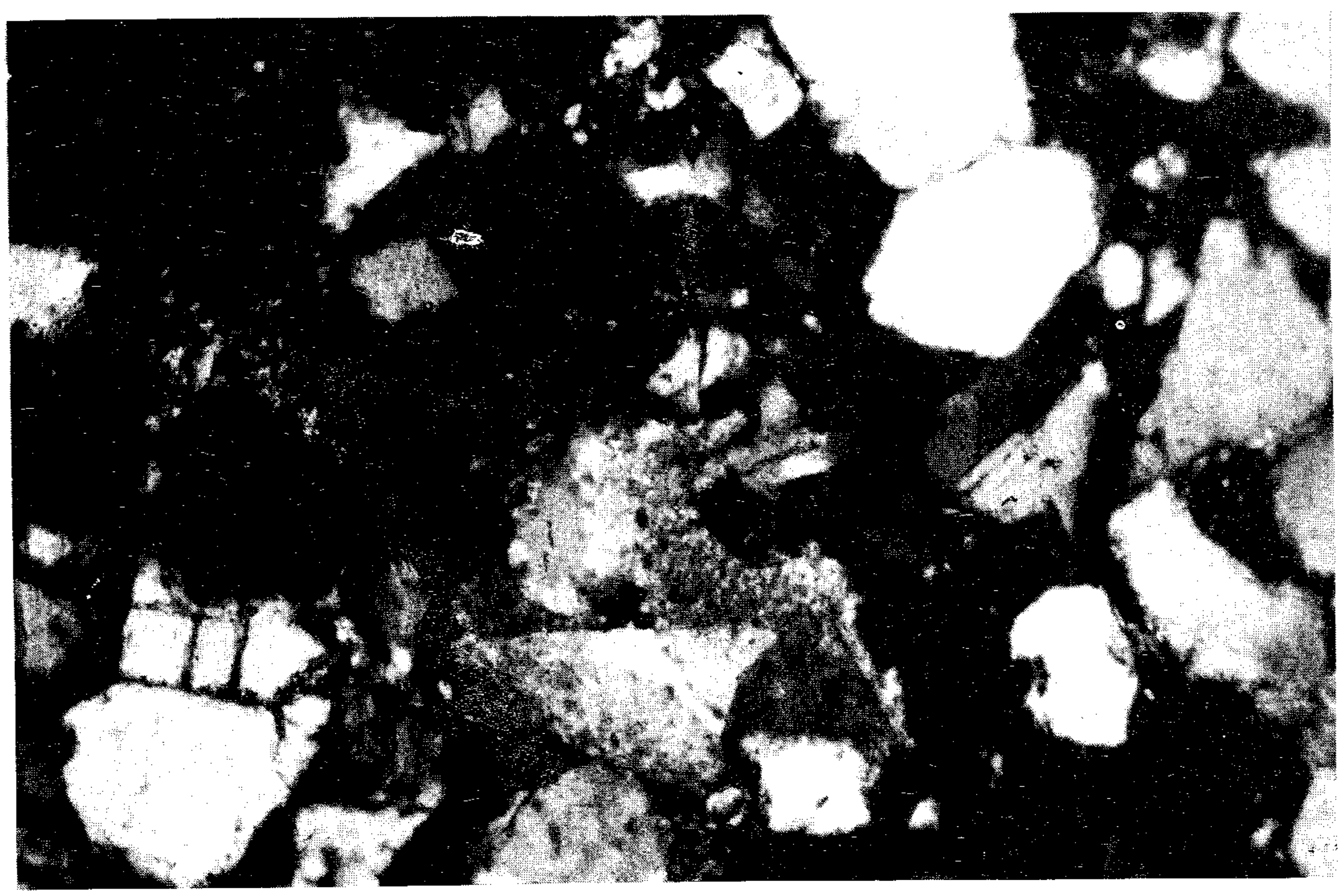

Figure 5- A soft micritic lithoclast is pressed into another micritic lithoclast due to compaction. Grain boundaries(long contacts) between quartz crystals give an indication that compaction was not strong but moderate(Sample No. 96.3.15-20, Belab Nala; magnification x100, XPL).

The lack of compaction effects such as strained or fractured quartz grains, sutured and interpenetrant grain boundaries resulting from pressure solution in sandstones of the Nari Formation is directly associated with the stratigraphic occurrence of rocks which is evident by the fact that these sediments have not undergone very deep burial.

Cementation

Two types of cements are recognized in sandstones of the Nari Formation i.e. silica and calcite.

Silica

Authigenic silica, typically formed as syntaxial overgrowth around the detrital quartz grains, is relatively common in white gray to white, very fine to fine-grained quartzarenitic sandstones (lower part of the Nari Formation) of both sections i.e. Belab Nala section and Kaura Sori Nala section. It has been rarely noticed in all other analyzed samples. Although, it occurs commonly in quartzarenitic facies of the Nari Formation, but does not constitute a significant pore-occluding cement. Sandstones having sublitharenitic composition, on the other hand, formation of secondary overgrowth around detrital quartz grains is followed by the calcite cement (Figure 7) which is a clear indication that quartz overgrowth was occurred earlier than calcite, most probably during early to intermediate stage of diagenesis.

Calcite

Calcite cement, occurred after the formation of secondary quartz overgrowth has been found in several sandstones (except for the lower most part in both sections) of the Nari Formation. Its abundance (upto 15%) has been observed in conglomeratic sandstone of Belab Nala section (Figure 7), where the detrital grains are frequently floating in a groundmass of calcite cement. In some cases, calcite seems to be a large single crystal as indicated by the uniform extinction and the consistency of orientation of twin lamellae (Figure 8). Such patches of calcite cement with floating detrital grains (poikilotopic texture) are quite common in the analyzed sandstone samples of both investigated sections of Belab Nala & Kaura Sori Nala.

Calcite, despite of filling the pore space, has also replaced the detrital grains either marginally or completely (Figure 9). Many detrital grains are severely corroded by calcite resulted in deep embayments. Similarly secondary quartz overgrowth is also noticed to be replaced by late calcite cement.

Recrystallization

In, sample No. 96.3.15-21, 22, 24, 25, 27 and sample No. 96.3.20-1, partial recrystallization within carbonate rock fragments (CRFs) has been noticed which also support a late diagenetic event (Figure 10).

Dolomitization

Rare occurrence of Dolomite in distinct morphology is also recognized. It is specially observed in a few carbonates rock fragments (CRFs). During late stage of diagenesis, these lithoclasts were subjected to dolomitization (Figure 11). Likewise, in sample No. 96.3.20-4, calcite cement is also partly dolomitized.

POROSITY OCCLUSION

Sandstones of the Nari Formation are devoid of effective porosity except the basal part having quartzarenitic composition (Figure 2). These fine-grained quartzarenitic sandstones are characterized by primary intergranular porosities of about 2.5% to 5% and having least amount of matrix with no calcite cement at all. In all other sandstone samples, no porosity either primary or secondary is observed owing to compaction and/or precipitation of late diagenetic calcite. The reservoir quality of the Nari Formation has been adversely effected by compaction as well as by late calcite cementation.

Compaction seems to be an important pore-occluding phenomenon in sandstones of the Nari Formation. The majority of labile components (CRFs & SRFs) appear to have been deformed during compaction and may have flowed into adjacent pores thus occluding porosity (Figure 6).

Minor amount of silica cement as quartz overgrowth, is also reported in quartzarenitic facies of both studied sections but has no significant effect on the reservoir quality of sandstones of the Formation.

Late diagenetic calcite observed as the dominant cement, is present in significant amounts in both investigated stratigraphic sections (Figure 9). After compaction, it is another major factor controlling reservoir quality of the Nari Formation. A major part of the primary intergranular porosity was occluded by the precipitation of late calcite cement which has resulted in the complete occlusion of porosity (Figure 9).

There are no evidences of framework grain dissolution which could have resulted in the development of secondary porosity.

CONCLUSIONS

1. The Nari Formation in the studied area is a poor reservoir for hydrocarbon accumulation.
2. Ductile deformation of unstable rock fragments (CRFs & SRFs) due to overburden compaction and significant amount of calcite cement are major factors controlling reservoir quality.
3. No secondary porosity has been observed which could have enhanced the reservoir quality.

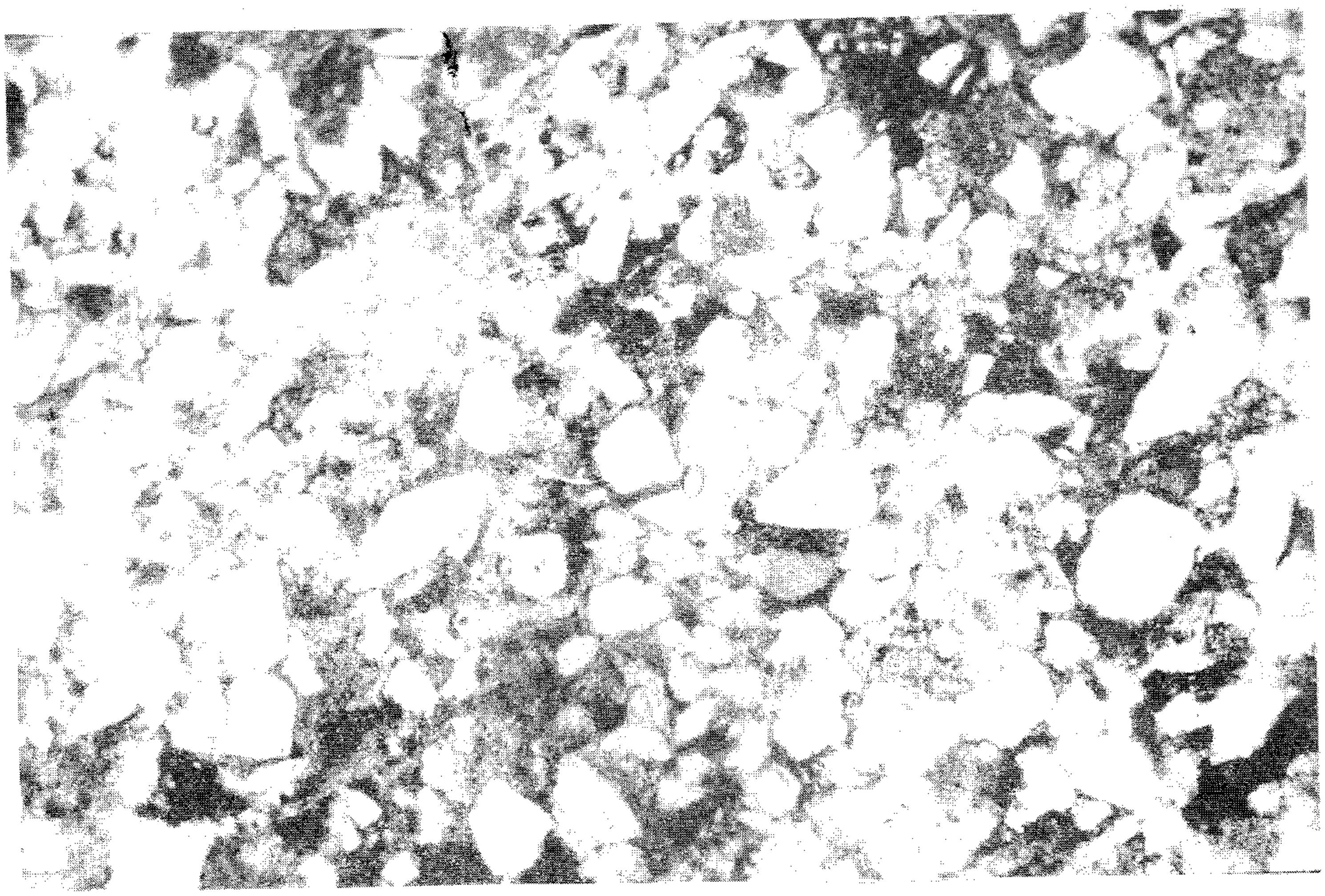

Figure 6- Typical view of the Nari Formation comprising middle & upper part. No porosity has been observed due to the squeezing of soft lithoclasts into pores. Glauconite can also be seen in the field of view(Sample No. 96.3.15-22, Belab Nala; magnification x63, PPL).

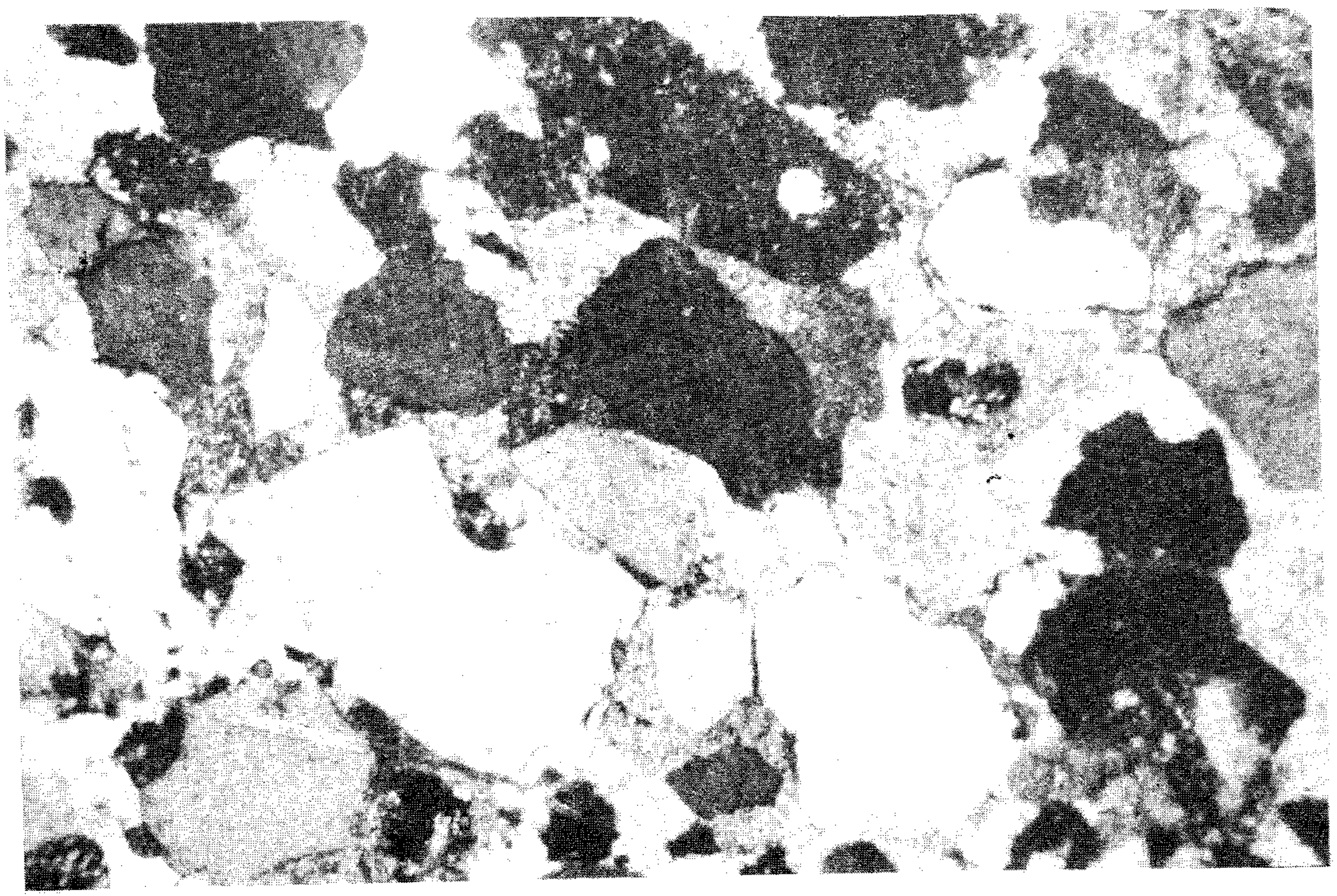

Figure 7- Detrital quartz grains with secondary euhedral quartz overgrowth followed by late calcite cement (Sample No. 96.3.15-27, Belab Nala; magnification x63, XPL).

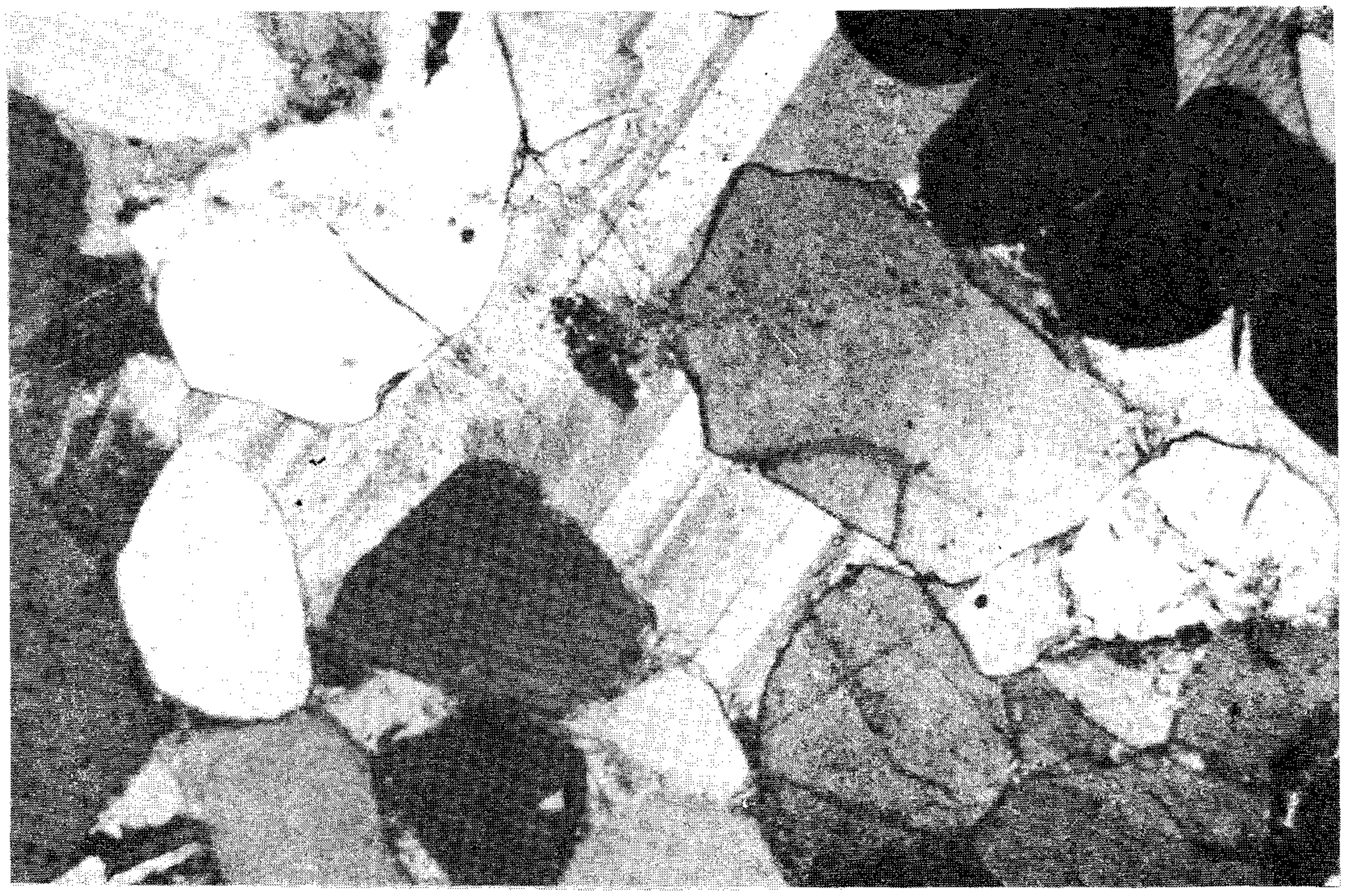

Figure 8- Detrital grains are floating in poikilotopic calcite cement. The consistency of orientation of twin lamellae & uniformity of extinction shows that the cement is a single crystal (Sample No. 96.3.20-1, Kaura Sori Nala; magnification x63, XPL).

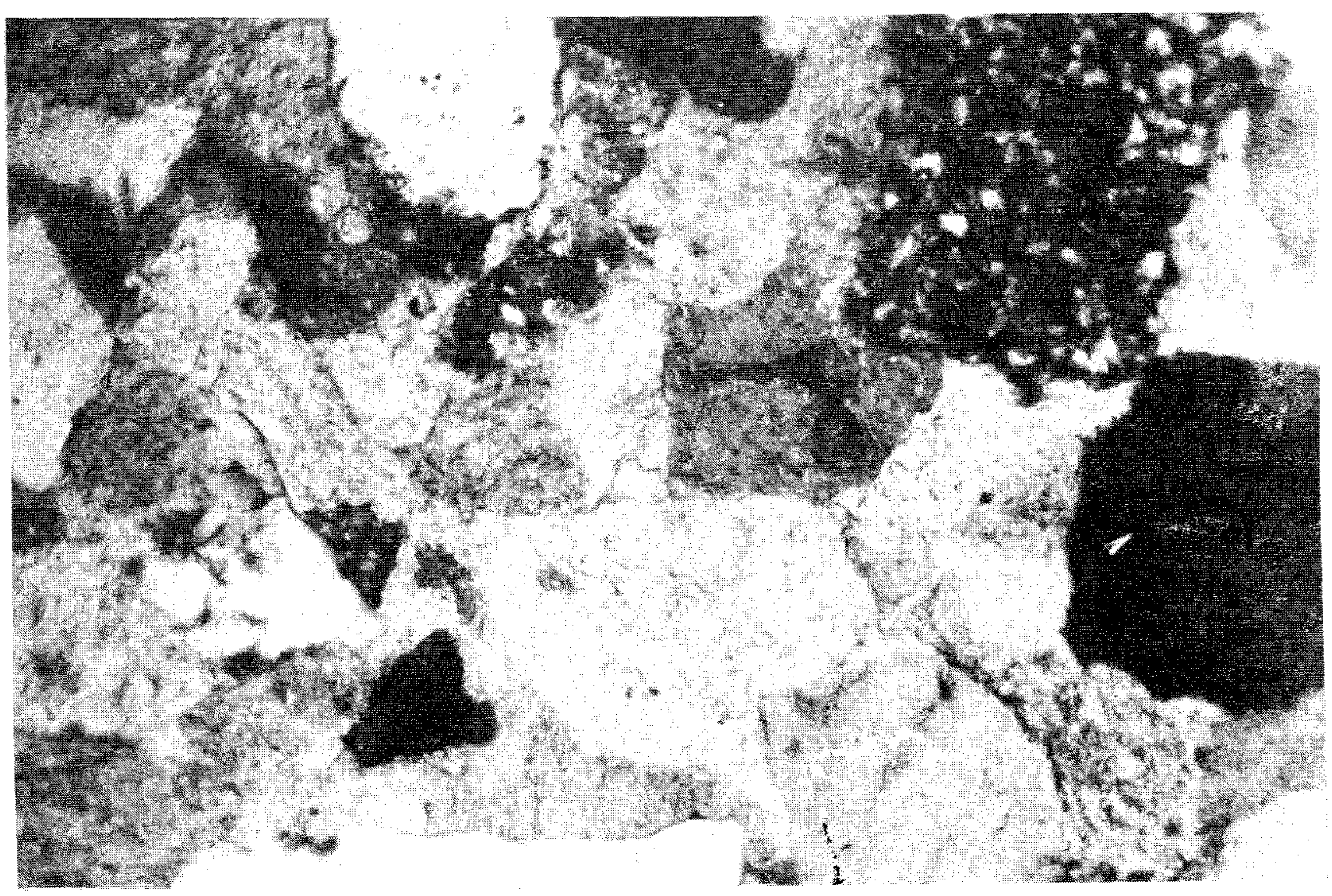

Figure 9- Detrital quartz grains are more or less completely replaced by late calcite. Abundance of late calcite cement has left no pore space open thus complete occlusion of porosity occurred (Sample No. 96.3.15-27, Belab Nala; magnification x100, XPL).

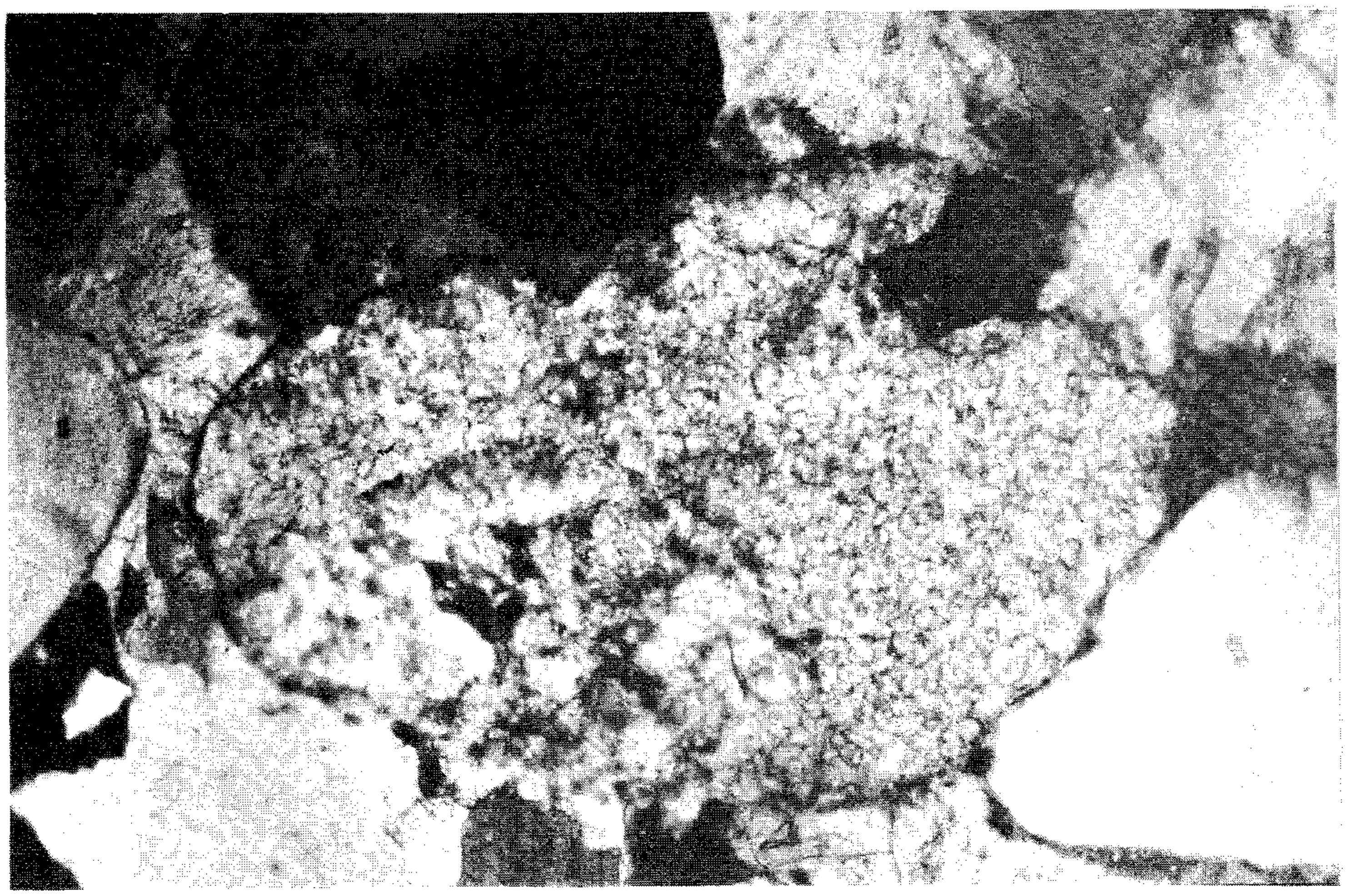

Figure 10- A micritic lithoclast is partially recrystallized. Note that its upper right corner is deeply embayed by quartz grain thus indicating moderate compaction effects(Sample No. 96.3.20-1, Kaura Sori Nala; magnification x100,XPL).

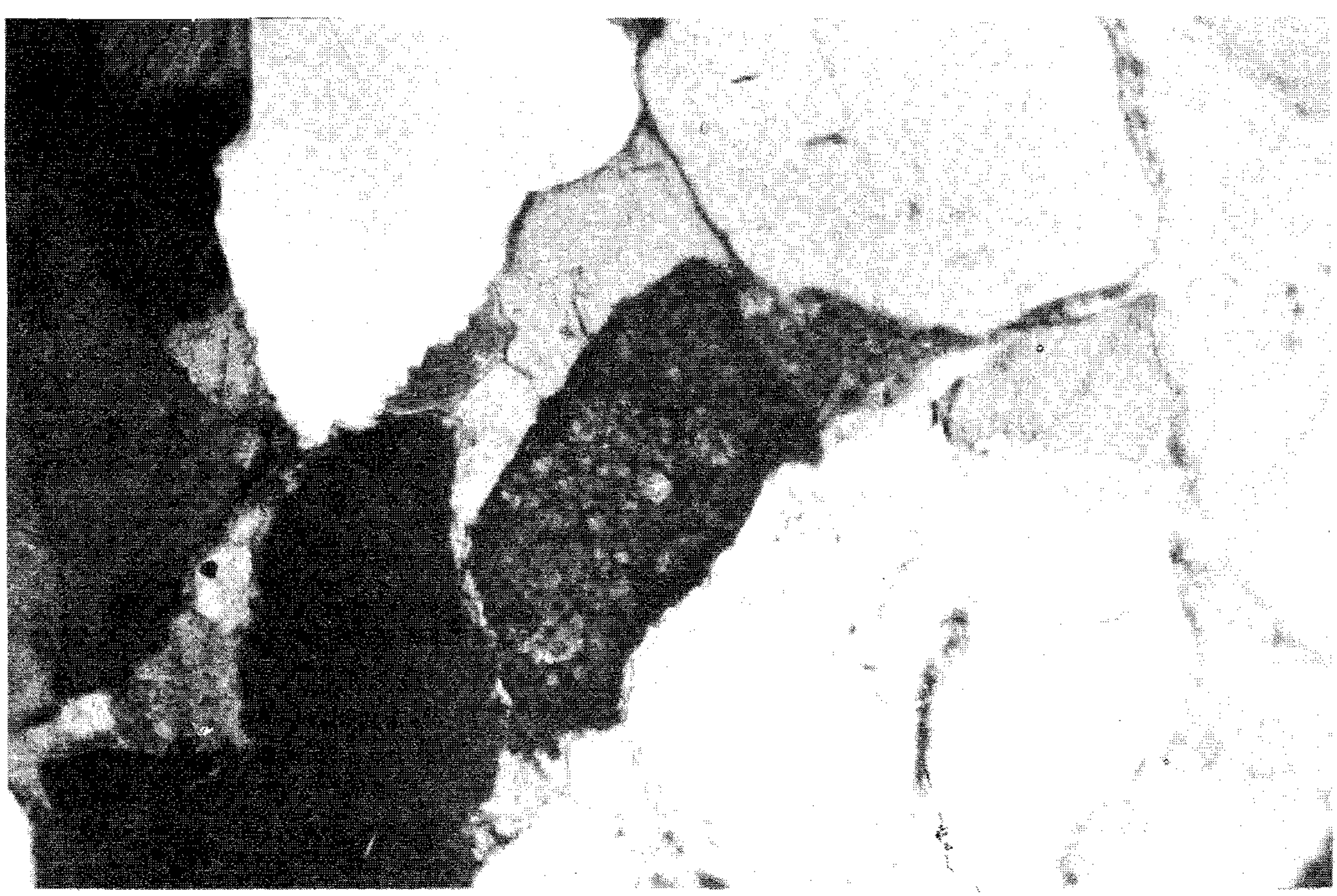

Figure 11- A micritic lithoclast at its initial stage of dolomitization(Sample No. 96.3.20-1, Kaura Sori Nala; magnification x100, XPL).

ACKNOWLEDGEMENTS

The author thankful to Mr. Hilal A. Raza, Director General of HDIP for his consent to publish this paper. Thanks are also paid to the Chief Geologist (HDIP), Mr. Riaz Ahmad for his encouragement. I am grateful to Mr. M. Iqbal (Senior Geologist) who provided technical assistance and cooperation during field investigation. Thanks are also extended to Mr. Dirk Radies & Mr. Bodo Dietrich (Philipps University, Marburg) for their cooperation during the field work. The author wishes to express great appreciation to Mr. Nazir Ahmad for typing the manuscript and to Mr. Afzal Asi for preparing thin sections for microscopic studies.

REFERENCES

Hunting Survey Corporation, 1961, Reconnaissance geology of part of West Pakistan (Colombo Plan Cooperative Project): Canada Govt., Toronto, 550p.

Iqbal, M. & D. Helmcke, 1995, Evolution of Zindapir anticlinorium, Pakistan. HDIP-IGDL internal field report.

Shah, S.M.I., 1977, Stratigraphy of Pakistan.- GSP Memoir, v. 12, 138 p.