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Depositional Environments and Diagenetic History of the Lumshiwal Formation, Miranwal Nala Section, Surghar Range

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ABSTRACT

Cretaceous sediments of the Lumshiwal Formation in the Miranwal Nala section, Surghar Range are mainly composed of clastic deposits. The formation in the study area was deposited in a fluvial-dominated deltaic environment and there was continuous sedimentation from the base of the Lumshiwal Formation to the lower part of the Hangu Formation. The analyzed sandstone samples have been classified as quartzarenites with minimum 97% detrital quartz grains. The sediment-petrographic study indicates that the Lumshiwal Formation is not a good potential reservoir for hydrocarbon in the studied area.

INTRODUCTION

The studied section is located in the Kohat-Potwar Province (Lat. 32° 51' N : Long. 71° 09' E) (Figure 1). The formation has a wide distribution throughout the Kohat-Potwar Province. It is well-developed in the Surghar and Samana Ranges, Nizampur and Hazara but in the western Salt Range, it thins out and ultimately disappear to the east. The formation has its maximum thickness of 170 m (Samana Range), whereas it is about 96 m thick at its type locality (Miranwal Nala section) in the Surghar Range.

The prime objective of this study was to evaluate the depositional environments and diagenetic history of the Lumshiwal Formation. The study has been carried out as a part of the Pak-German Technical Cooperation Project between HDIP(Islamabad, Pakistan), BGR (Hannover, Germany) and Philipps University (Marburg, Germany). For this purpose, the type locality of the Lumshiwal Formation (Miranwal Nala section) was investigated, measured (bed by bed) and sampled by HDIP's geological party in November, 1993. This section was again investigated sedimentologically by the Pak-German field party in February, 1995 for further geological information. A sum of 32 outcrop samples were collected from the investigated section. Their petrographic analysis and sedimentologic interpretation were carried out at the Institute for Geology and Paleontology, Philipps University, Marburg (Germany).

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GEOLOGICAL SETTING

The studied section is located at the eastern margin of the Surghar Range (Trans Indus Salt Range), about 1 km N of famous Lumshiwal Nala and about 5.3 km W of Makarwal Town in Mianwali District (Punjab) (Figure 1). As a whole the study area is a part of Upper Indus Basin and tectonically related to the northwestern part of the northward driven Indian Plate (McKenzie & Sclater, 1971). The rocks from Jurassic (Samana Suk Formation) to Eocene (Sakesar Limestone) are well exposed in the studied section.

GEOLOGICAL INVESTIGATIONS

The formation is well exposed and covers an interval of about 96 m (Figure 2, 3). The Lumshiwal Formation has transitional contact (Memon, 1995) with the underlying Chichali Formation of Late Jurassic to Early Cretaceous age (Shah, 1977), whereas its upper contact is disconformable with the overlying Hangu Formation of Early Paleocene age (Shah, 1977). However, according to our investigations, the Lumshiwal Formation has also transitional contact with the overlying Hangu Formation. The Lumshiwal Formation can be divided into three distinct parts:

The lower part consists of shale with a bed of marl. The shale is greenish gray (near base), gray, brownish gray to brown, maroon, friable, soft, silty/sandy, ferruginous, glauconitic, gypsiferous and splintery. Sulphur nodules (?) are common while sparse belemnites and rare other fossils are also observed (Figure 4). The marl bed has thickness of about 15 cm and is reddish brown to maroon, silty/sandy, hard, calcareous, ferruginous and glauconitic.

The middle part of the formation consists of very fine to medium-grained sandstone with occasional conglomeratic beds. The sandstone is light gray, friable, soft, argillaceous, slightly ferruginous, glauconitic and contained organic matter in the form of tiny phytoclasts. Bioturbation is common. Likewise, argillaceous material is concentrated in the form of wispy clay laminae (Pettijohn et al., 1987) and is the most prominent feature of this part (Figure 5). The conglomerates are more or less nodular/concretionary (phosphorites ?) beds which are pink to reddish brown, soft to hard, calcareous and ferruginous (Figure 6). The thickness of individual conglomeratic beds is about 20-60 cm.

The upper part consists entirely of sandstone. It is white to light gray, medium to coarse-grained, friable to soft, thick-bedded and cliff-forming. Trough cross-bedding is the characteristic feature of the upper part (Figure 7). Diagenetic quartzose/ferruginous quartzose nodules commonly occur

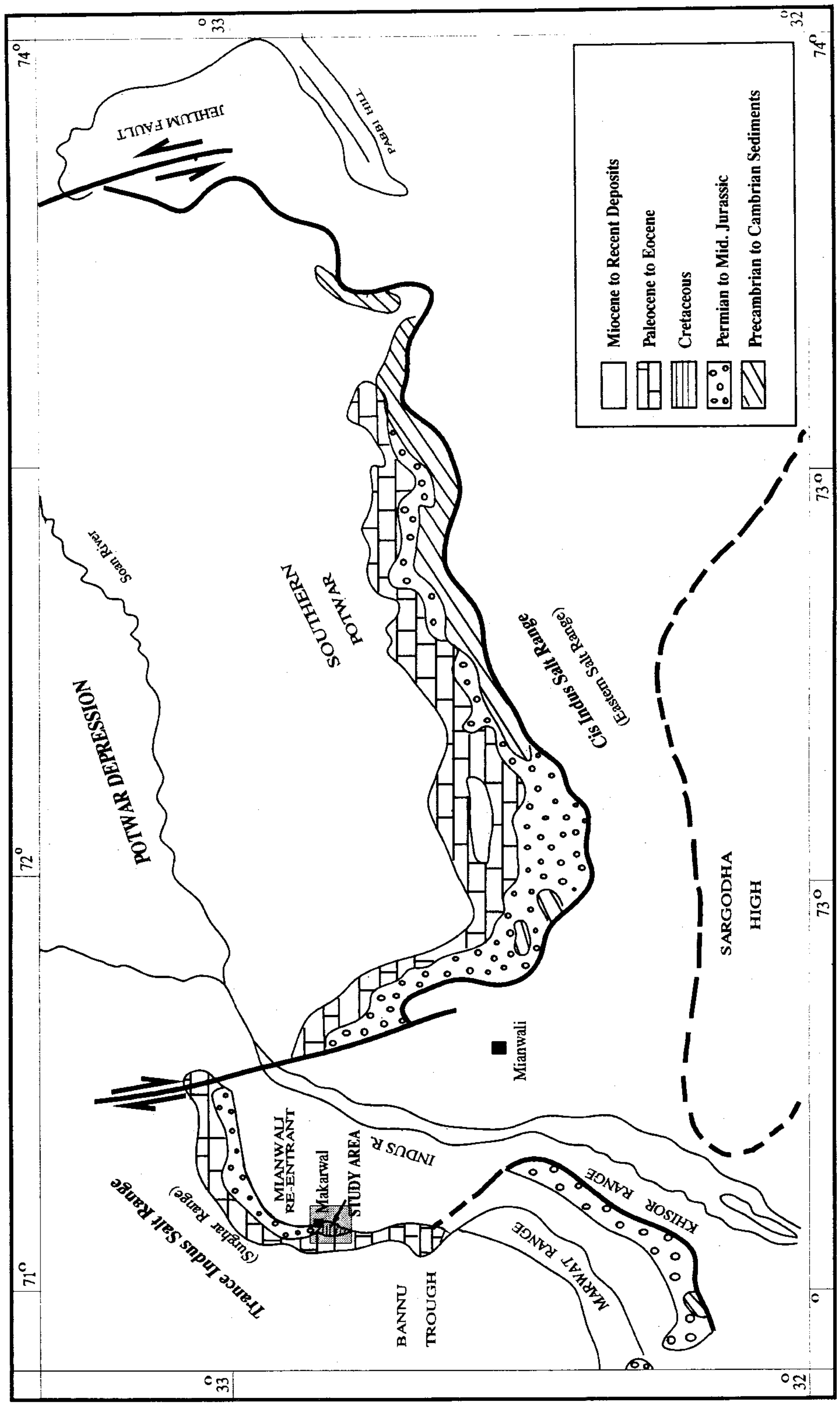

Figure 1- Location map of the investigated section of the Lumshiwal Formation (Miranwal Nala, Surghar Range) (Modified after Kemal, 1991).

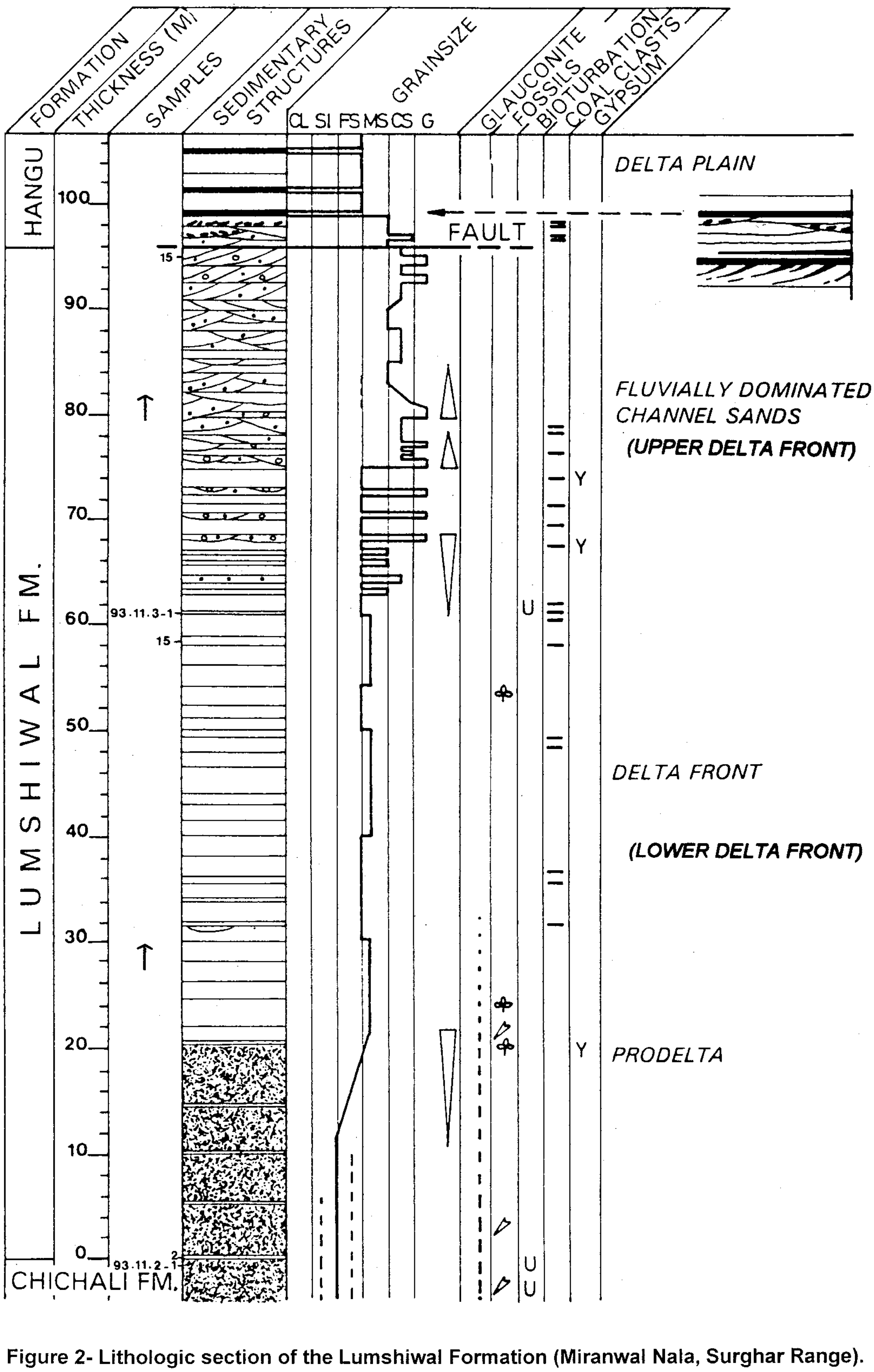

Figure 2- Lithologic section of the Lumshiwal Formation (Miranwal Nala, Surghar Range).

Figure 3- General stratigraphic view of the Miranwal Nala, Surghar Range.

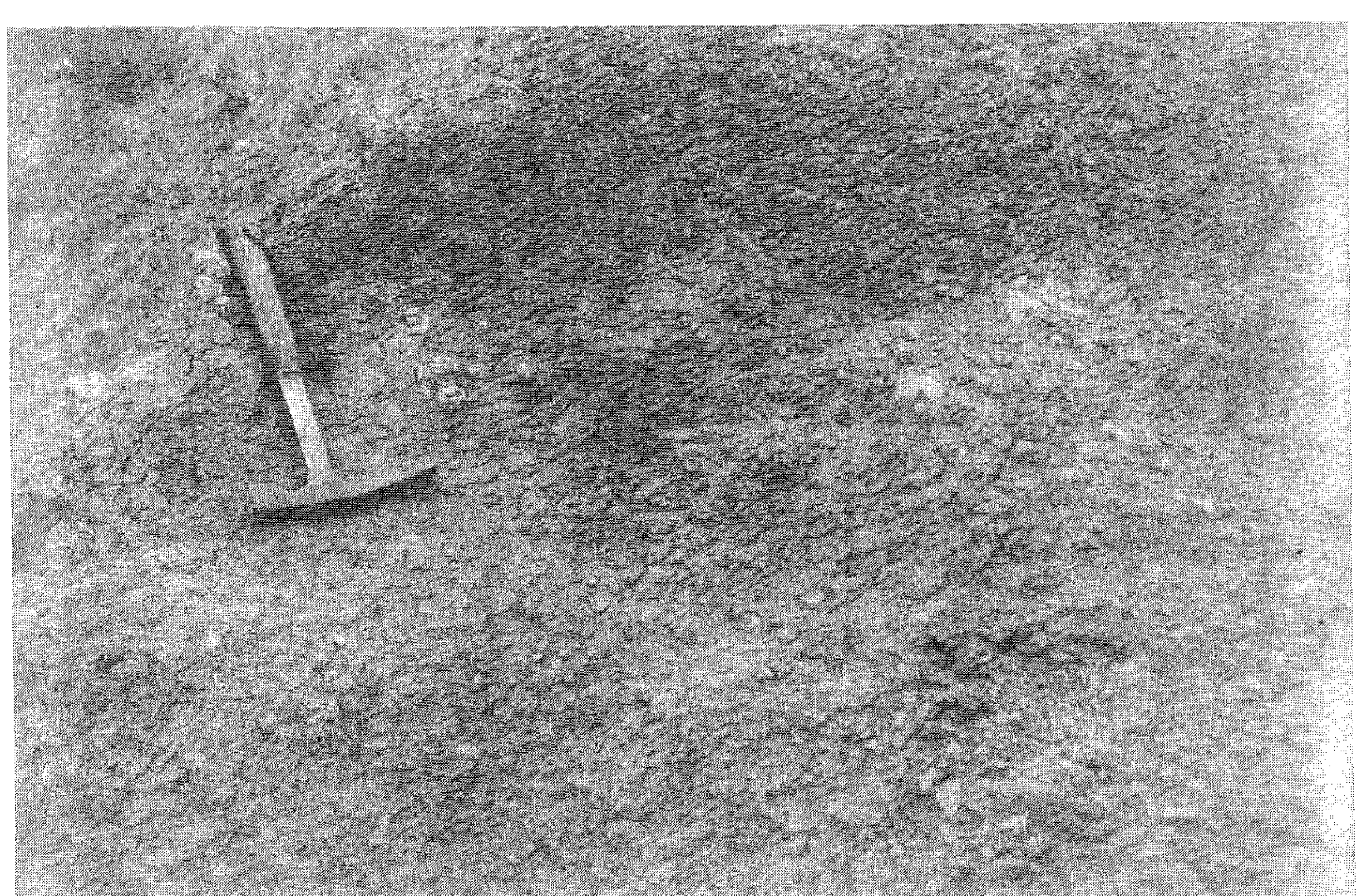

Figure 4- Sulphur nodules (?) & belemnites in the pro-deltaic shales of the Lumshiwal Formation.

Figure 5- Bioturbated fine-grained argillaceous sandstone of the lower delta slope/lower delta front with high content of organic matter & wispy clay laminae.

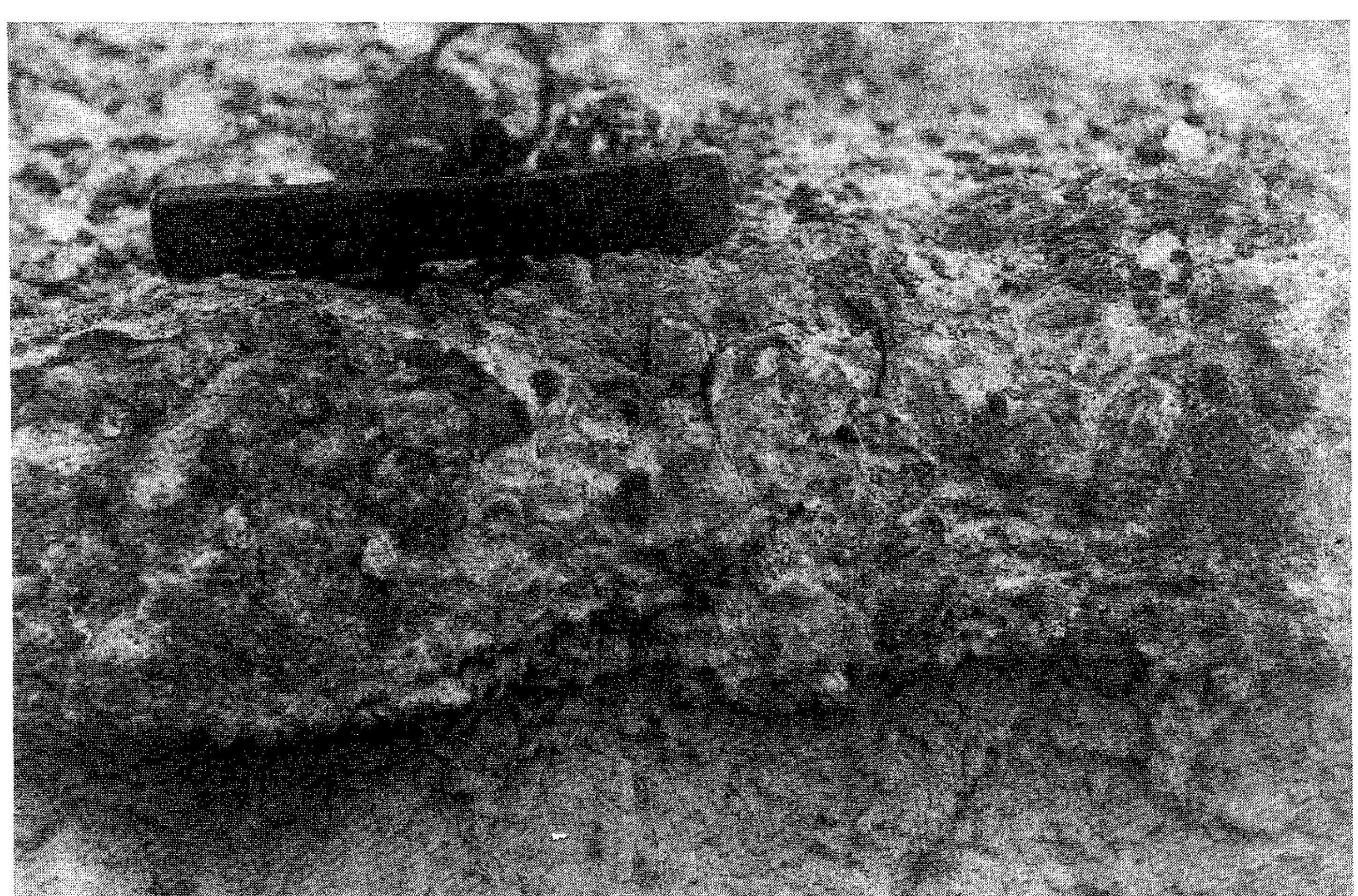

Figure 6- Interbedded conglomerate with nodules/concretions (phosphorites?) in the lower delta slope facies of the Lumshiwal Formation.

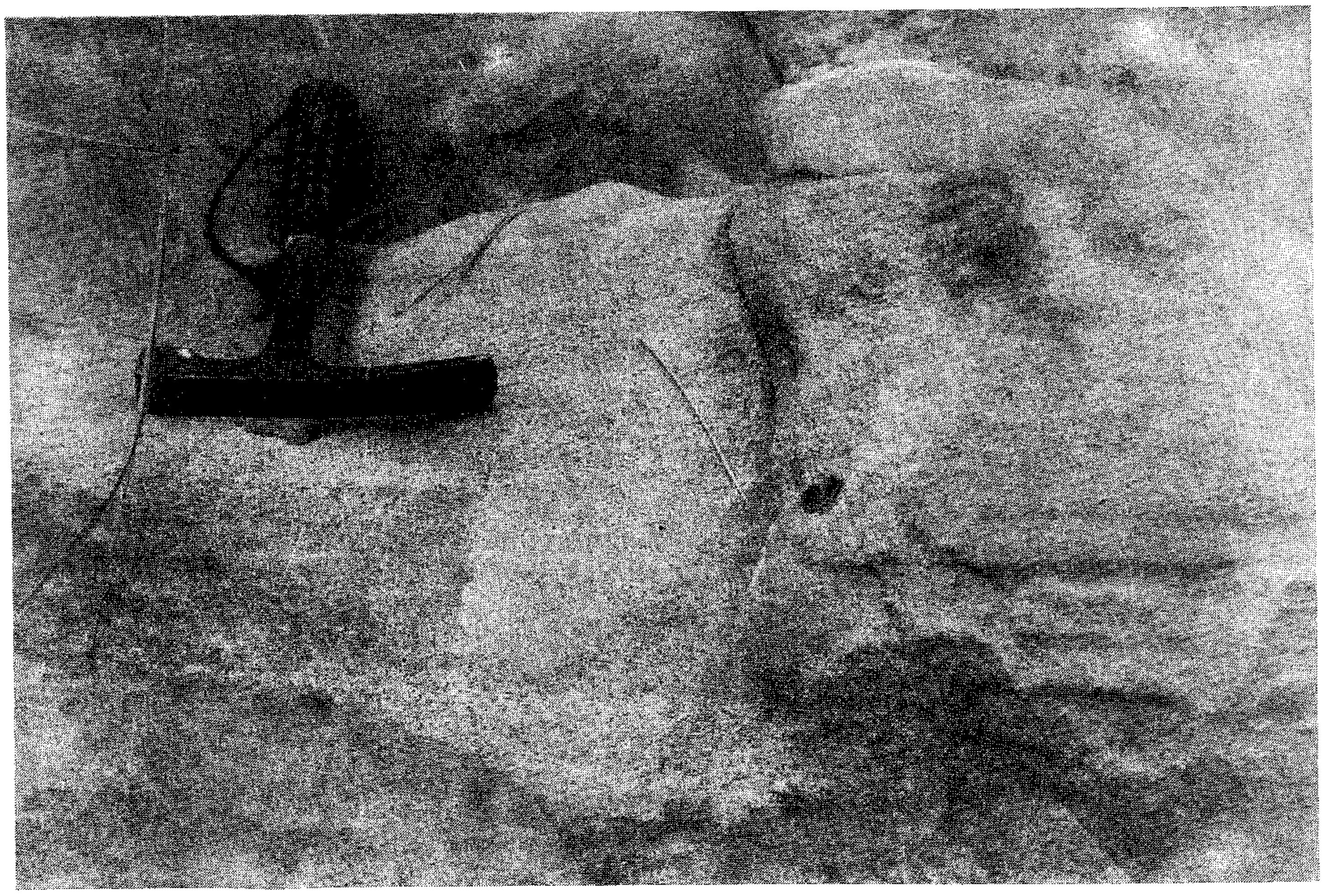

Figure 7- Trough cross-bedding in coarse-grained channel sands of the upper delta slope facies.

(Figure 8). Rare amount of irregularly distributed carbonaceous matter is also observed. Some of the cross-bedded sandstones are also contained coal clasts (Figure 8). At the top of Lumshiwal Formation, coal beds of Hangu Formation (?) are exposed (Figure 9). The formation overall shows a coarsening upward trend (Figure 2).

PETROGRAPHY

Sandstones of the Lumshiwal Formation are very fine to coarse-grained, angular to rounded, poorly to well-sorted and texturally immature to mature. Commonly, they have 97 to 100% quartz and upto 3% feldspar. For the total section, monocrystalline quartz is dominant with rare polycrystalline quartz. Amongst feldspar, plagioclase and orthoclase are more common than microcline. Muscovite, glauconite, tourmaline, zircon, rutile and opaque iron-oxide minerals are present in traces.

Cements are calcite, calcium sulfate (gypsum), silica and iron oxide. Calcite appears as major cement (Figure 10), especially in conglomeratic sandstones. It ranges between 2.5 to 15%. A minor amount of dolomite, as small rhombic crystals of authigenic origin, also occurs (Figure 11, 12). Gypsum is the second common cement which occurs as fracture-fillings (Figure 13) and varies from 1 to 10%. Silica cement is present as an overgrowth on quartz crystals. It occurs in very small amounts. Iron oxide is present in significant quantity i.e. 2.5 to 10%. Matrix is common in the lower part and ranges between 2 to 15%.

Depending on the detrital composition, sandstones of the Lumshiwal Formation have been classified as quartzarenites by using triangle nomenclature of McBride (1964).

ENVIRONMENTS OF DEPOSITION

The Lumshiwal Formation, at its type locality, exhibits the typical characteristic features of fluvial-dominated deltaic environment. The formation on the basis of lithology can be divided into three parts, each of them represents a particular subenvironment (Figure 2). The formation, at its lower part, consists of glauconitic shales with a bed of marl/lime mud. Belemnites (Figure 4) and other marine fauna are also observed. This part is considered to be deposited in a marine pro-deltaic environment. In the pro-delta area, because of low energy, suspended load of river was settled down over the pre-existing sediments of the Chichali Formation. As the delta prograded towards the shore, fine sand and clay together with relatively high amount of organic matter such as plant remains were deposited over the pro-deltaic sediments. Bioturbation and wispy clay laminae are prominent features (Figure 5). This part of delta is termed as lower delta slope or lower delta front and the sediments are known as lower delta slope or lower delta front facies (Figure 2). The delta slope sediments were further overlained by coarse sand. Large scale trough cross-bedding is a characteristic feature of these sandstones

Figure 8- Coarse-grained trough cross-bedded channel sands with diagenetic quartzose/ferruginous quartzose nodules and coal lenses.

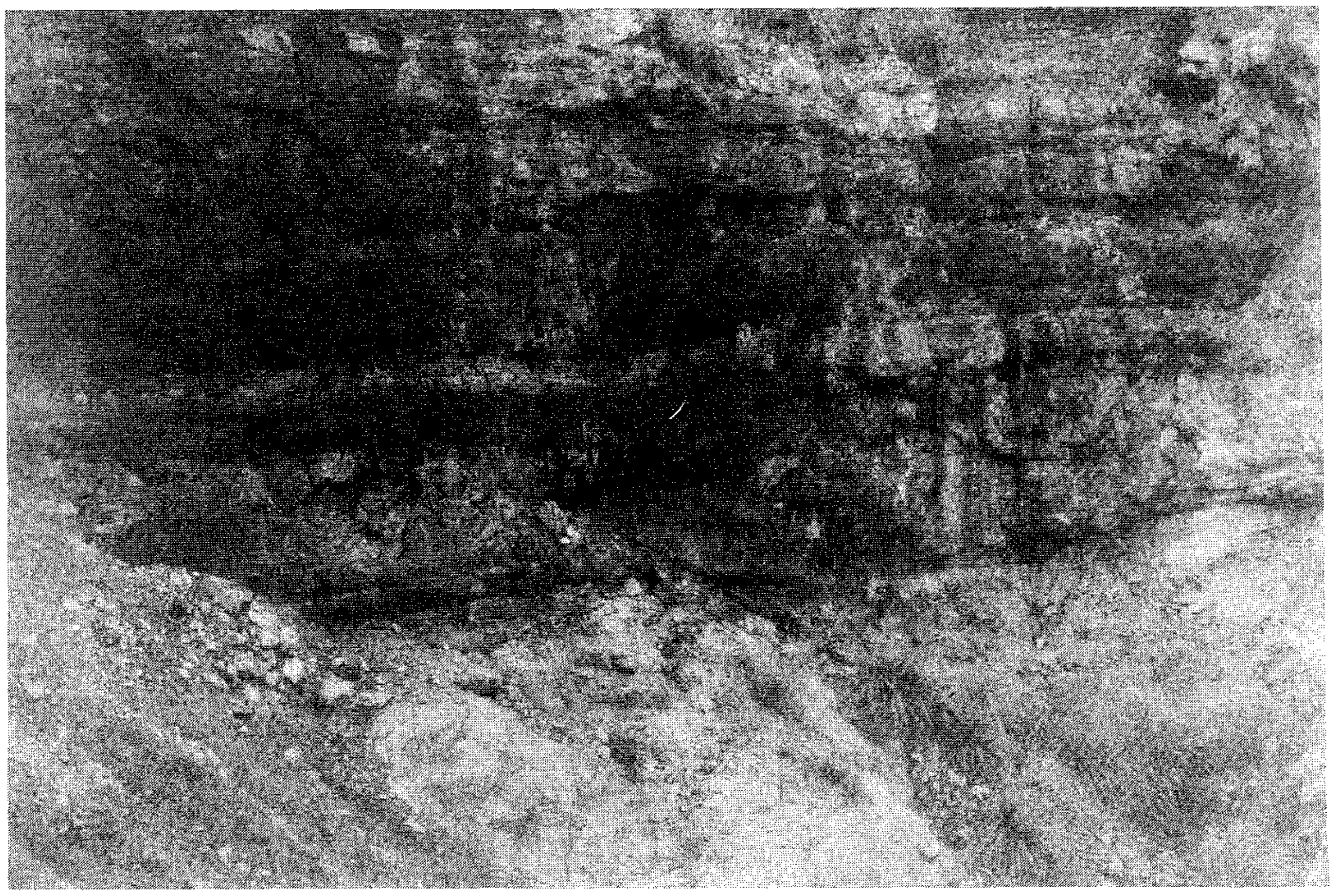

Figure 9- Coarse-grained channel sands of Lumshiwal Formation are overlained by coal beds of Hangu Formation (?).

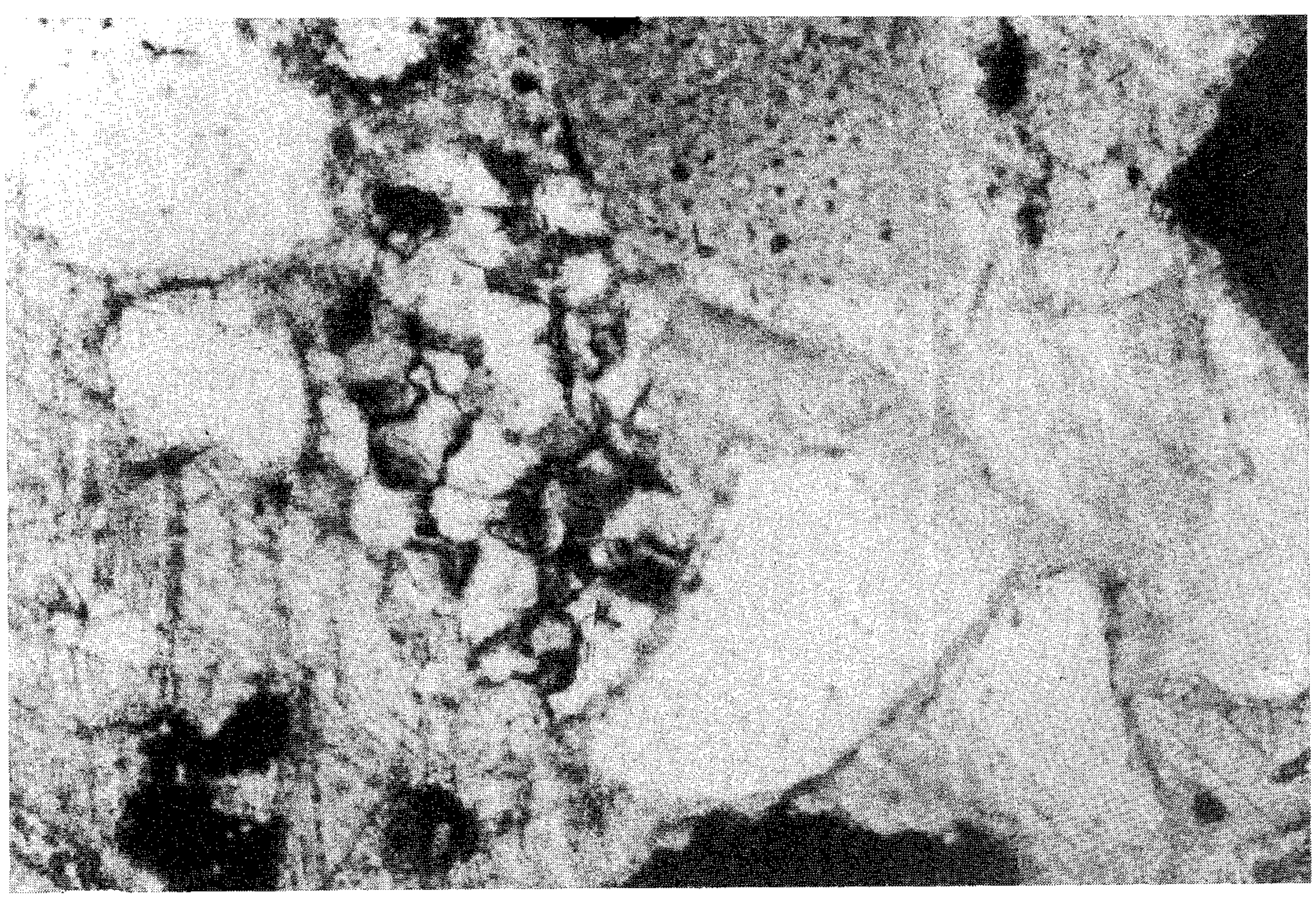

Figure 10- A high grade metamorphic polycrystalline quartz marginally replaced by calcite cement (poikilotopic texture) through its weaker planes. Total loss of primary porosity by late calcite cement can be seen very well (Sample No. 93.11.2-15, magnification x 160, XPL).

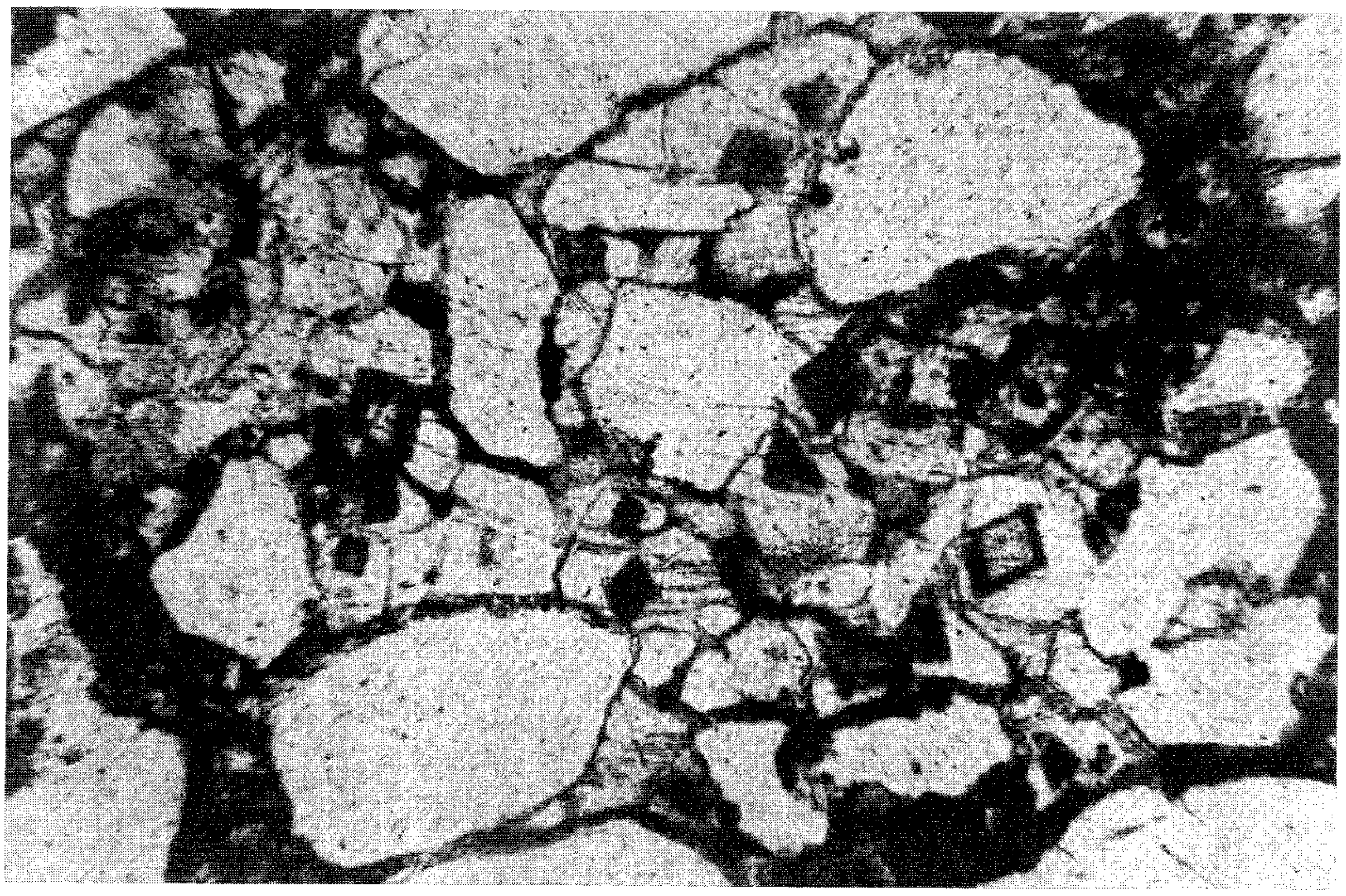

Figure 11- Well-developed authigenic dolomite rhombs formed due to the replacement of calcite (Sample No. 93.11.2-13, magnification x 160, PPL).

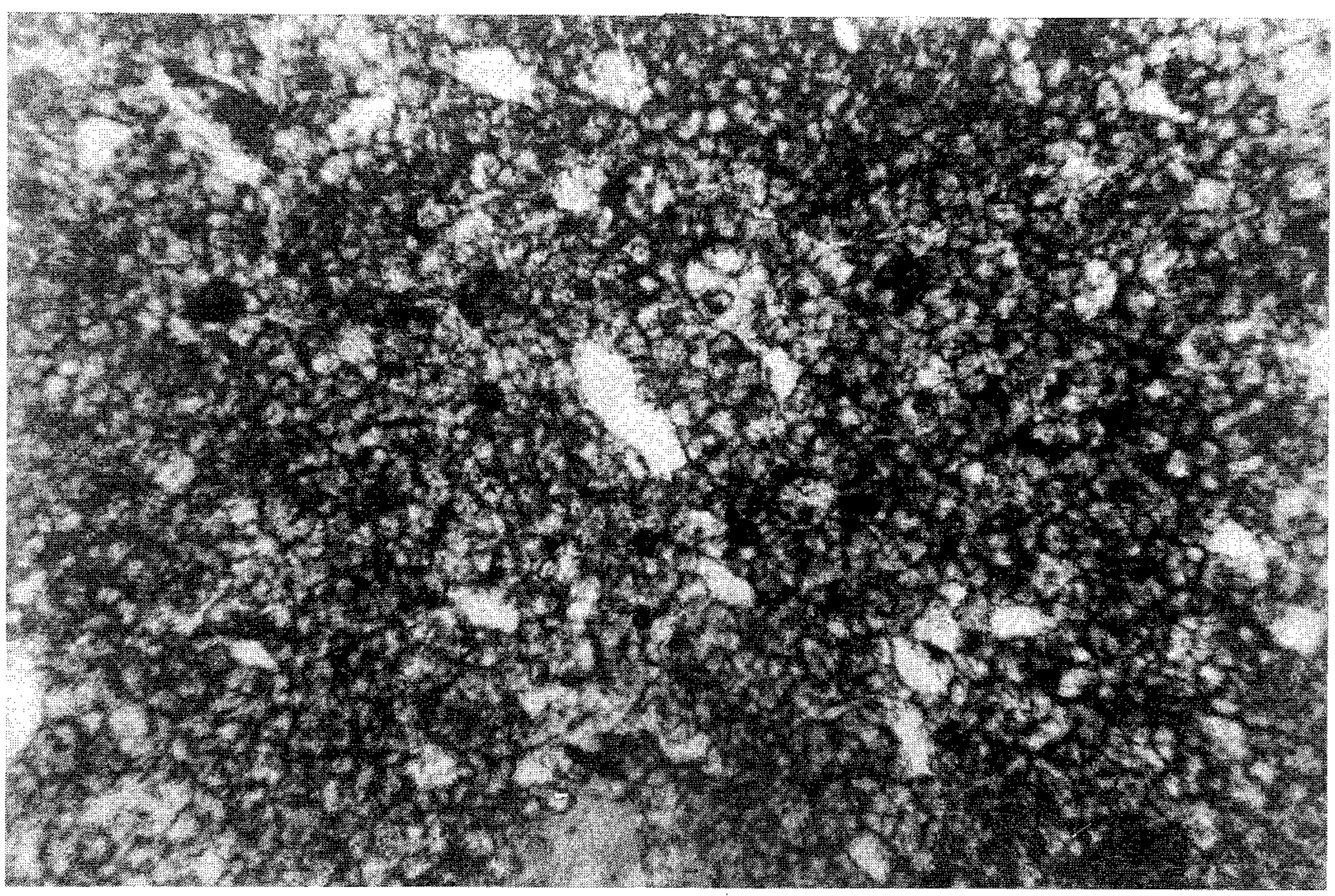

Figure 12- Authigenic dolomite formed due to the wholesale dolomitization of marl/lime mud (Sample No. 93.11.2-4, magnification x 160, PPL).

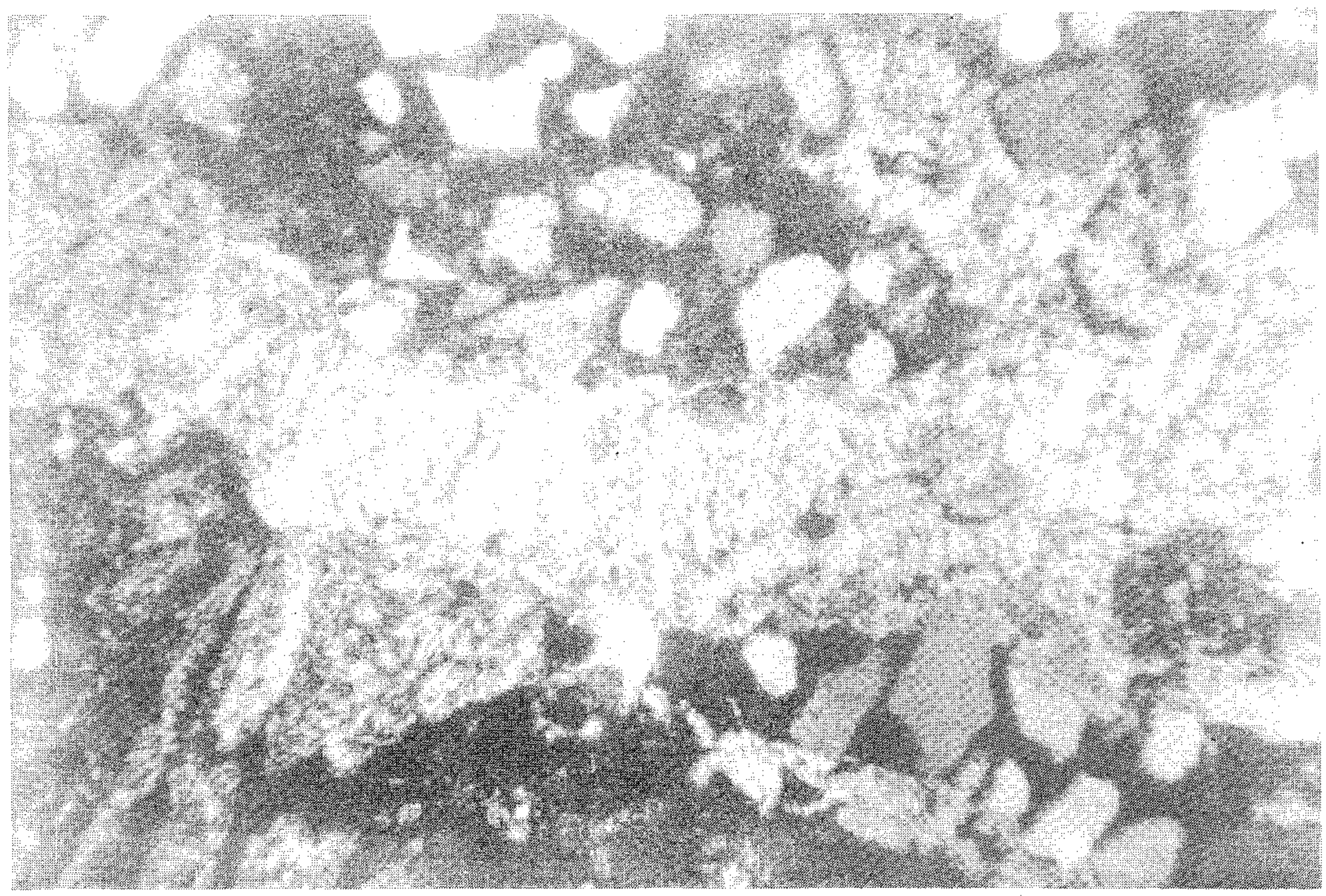

Figure 13- Fracture filled by calcium sulfate (gypsum) enclosing detrital quartz grains. Note that secondary fractured porosity has been completely occluded due to gypsum cement (Sample No. 93.11.2-13, magnification x 25, XPL).

(Figure 7). According to Reineck & Singh (1986), the most common sedimentary structure found in channel sands of delta slope is trough cross-bedding. This indicates the current dominated part of pro-delta and was deposited near the mouth of river. At the distributory channel mouth, current velocities were decreased due to the mixing of river water with the sea water, which resulted in the deposition of its bedload, mainly consisting of sand. These sediments are called as upper delta slop or upper delta front facies (Figure 2). Occasional occurrence of conglomeratic beds (Figure 6) within delta front may be the result of high velocity currents produced during extreme floods and the coarser material carried by currents, deposited as layers. The vertical cross-section of the Lumshiwal Formation thus clearly shows a coarsening-upward or shallowing upward sequence which is a most prominent feature of the deltas.

DIAGENESIS

Important diagenetic events involve compaction, silica cementation, iron-oxide cementation, late calcite cementation, replacement, dolomitization, dissolution and recrystallization of calcite and gypsum cementation.

Compaction

Effects of compaction have been noticed in all sandstone samples, but are not very extensive. Most of the detrital grains have point or long contacts and are compacted only by grain slippage and rotation. However, some detrital grains have concavo-convex contacts thus indicating moderate compaction.

Silica cementation

Silica cement, typically occurs as secondary overgrowth around the detrital grains. It is volumetrically minor and does not act as significant pore-occluding cement.

Iron-oxide cementation

The precipitation of iron-oxide was occurred most probably after the precipitation of silica cement. It is mainly present as pore-fillings, enveloping or staining the detrital grains, filling the microfractures within detrital grains and as pigments.

Late calcite cementation

It is very common in conglomeratic sandstones. Detrital grains are often floating in calcite cement thus forming a poikilotopic texture (Figure 10). In these sediments, the precipitation of late calcite is noticed as a displacive cement. The earlier formed iron-oxide cement, due to the displacive precipitation of calcite, is removed from its original sites and disbursed irregularly throughout the calcite cement. According to Dapples (1979), in such cases, later calcite cement becomes the principal lithifying agent but the former iron-oxide imparts its colour to the rock.

Replacement

Replacement, either marginal or complete, is commonly noticed. Detrital grains are often corroded and etched at their margins. Likewise, plagioclase and polycrystalline quartz are more commonly attacked by late calcite. These effects are well-observed along their weaker planes or cleavage system (Figure 10). Many detrital grains are completely replaced by late calcite and only the traces of such grains are left.

Dolomitization

Dolomite, formed due to the replacement of calcite, is well observed. Typically, it occurs as more or less euhedral rhombs indicating authigenic origin (Figure 11). In some of the analyzed thin sections, it occurs as aggregates. Such aggregates can be seen very well in the lower part of the formation where the original marl bed/lime mud, during late diagenesis, was subjected to wholesale dolomitization (Figure 12). Scanning electron microscope (SEM) analysis indicates that these dolomite rhombs are rich in iron but poor in magnesium.

Dissolution and recrystallization of calcite

This phenomenon is very clear in sandstones of the Miranwal Nala section. Due to chemical compaction, sediments were subjected to deformation. As a result, calcite cement was also subjected to dissolution. This effect is very prominent around the detrital grains where a rim of very late calcium sulfate cement (gypsum) has been developed followed by late calcite cement. The rim cementation by calcium sulfate cement clearly indicates that due to chemical compaction, calcite was dissolved and the space left by calcite was occupied by later cement i.e. gypsum. After a certain period, recrystallization of calcite occurred. As a result of recrystallization, microfractures within the detrital grains produced by chemical compaction, were filled by calcite.

Gypsum cementation

Gypsum is also found as cement in sandstones of the Lumshiwal Formation. Its precipitation is observed within the fractures (Figure 13). Typically, it has been observed as poikilotopic masses enclosing detrital grains and as rim cement. Some detrital grains, which were fractured have been noticed cemented by gypsum. It is also observed as replacing the detrital grains. Occurrence of gypsum through fractures, could be related to the movement of pore-waters from underlying pyrite-rich marine deposits of Chichali Formation or through sulfur-rich deposits (?) (lower part) of the Lumshiwal Formation itself.

Porosity

Porosity has only been observed in the upper part of the Lumshiwal Formation (i.e. channel sands) which is of primary intergranular origin and varies from 2.5 to 5%. In these channel sands, a minor amount of silica as secondary overgrowth and authigenic clay matrix are also registered but have no significant effect on pore spaces.

In the lower part of the formation i.e. argillaceous sandstones, primary porosity was completely occluded by detrital clay matrix, iron-oxide and late calcite cement. Likewise, secondary fractured porosity was occluded due to the introduction of calcium sulfate (gypsum) cement.

In general, the Lumshiwal Formation at the type locality, does not reveal any significant development of effective primary or secondary porosity.

DISCUSSION

For a long time it has had been assumed that at the type locality (Miranwal Nala section), sediments of the Lumshiwal Formation were deposited in a continental environment except for the basal part which was taken as of marine origin. However, our sedimentologic investigations clearly show that the entire Lumshiwal Formation as well as basal part of the overlying Hangu Formation were deposited in a deltaic environment.

The major subenvironments are:

----Pro-delta marine shales, consisting of silty/sandy glauconitic clays with rare marine fauna (Chichali Formation grading into the basal part of the Lumshiwal Formation).

----Lower delta slope facies, built up by light gray fine-grained argillaceous sandstones with coal fragments and high content of organic matter.

----Upper delta slope and/or channel mouth bar facies. Trough cross-bedded, light gray medium to coarse-grained sandstones (quartzarenites).

----Delta plain deposits which include gray fine-grained sandstones with high content of coal fragments as well as coal deposits.

----Locally coal bearing layers grading into units of large foreset beds of sandstones.

Overall there is a distinct coarsening upward development which coincides with a shallowing upward tendency of the depositional environment. In terms of sequence stratigraphy, the formation is a deltaic parasequence.

The observations also conclude that the lowermost coal beds, which are thought to be the part of the Hangu Formation are part of the deltaic parasequence of the Lumshiwal Formation (Figure 9). However, there may be some discontinuity in the sedimentary record within the Hangu Formation which is thought to be of Paleocene age (Shah, 1977). From our preliminary observations, the opinion rises that the Hangu Formation is built up by several parasequences very similar to the Lumshiwal Formation, some of them also terminating with coal bearing sandstones.

Further investigations are needed to evaluate the sedimentary record especially here in the time span from uppermost Early Cretaceous to Paleocene. It is especially necessary to determine more accurately the age of the Hangu Formation. This touches the question whether any unconformity exists between the Lumshiwal Formation and the Hangu Formation. It is, therefore, strongly recommended that further research work should be done in different parts of the Kohat-Potwar Province.

CONCLUSIONS

1. The formation at its type locality (Miranwal Nala section) was deposited in a fluvial-dominated deltaic environment with shallowing upward facies distribution.
2. There was a continuous sedimentation from the upper part of the Chichali Formation through the Lumshiwal Formation to the lower coal beds of the Hangu Formation (?) without any major break.
3. The formation has a transitional contact with basal part of the overlying Hangu Formation. At this stage of investigations, it is not clear, whether the coal layers are of Paleocene age (Hangu Formation) or of Cretaceous age (Lumshiwal Formation).
4. The continuity or discontinuity of the profile above the coal seams on top of the Lumshiwal Formation is not yet known.
5. The overlying Hangu Formation of the Miranwal Nala section, although not yet carefully investigated, seems to consist of a repetitive series of facies developments very similar to the underlying Lumshiwal Formation (shallowing upward parasequences).
6. The deltaic environment of sandstones of the Lumshiwal Formation at the type locality giving the clue of its lateral facies changes which may prove good quality reservoir in other areas.
7. Due to poor porosity and permeability, the Lumshiwal Formation at its type locality is a poor reservoir for oil and gas accumulation.

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