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The Eocene Nisai Formation in the Kakarkhorasan Basin, West-Central Pakistan

Ahmad Raza Yasin[1] and Muhammad Ashraf[1]

ABSTRACT

In the Kakarkhorasan Basin, the Nisai Formation overlies a lava sequence, and shows facies such as unroofing conglomerate, deltaic clastics, red gypsiferous shale and sandstone, bioturbated lagoonal carbonates, skeletal build up carbonates, basinal shales, and carbonate turbidites.

The Muslim Bagh uplift created shallow marine environment that was covered partly by a lava flow. The Nisai carbonate and clastic sediments were deposited there over the lava. The Nisai carbonate shelf was fringed by a clastic shoreline. Basinwards there were submarine carbonate turbidites fans.

INTRODUCTION

The Kakarkhorasan (KK) Basin lies in west-central Pakistan (Figure 1). The basin has been differently named as Kakarkhorasan flysch basin (Kazmi and Rana, 1982), Khojak flysch belt (Farah et al., 1984), Pishin flysch segment (Bannert et al., 1992), Pishin flysch trough (Bannert and Raza, 1992), and Katwaz flysch basin (Jadoon, 1992).

Pakistani sedimentary basins are; the Indus Basin, the Axial Belt, and the rear troughs (Hunting Survey Corporation, 1960; Shah, 1977). The Indus Basin borders the Indo-Pakistani Craton northwestward followed by the axial belt and the belt of rear troughs. Based on stratigraphy, Hunting Survey Corporation (1960) called the Axial Belt a pre-orogenic geanticline that formed near the end of Early Jurassic. It controlled the nearby sedimentation after that. North of Quetta, the Axial Belt turns from north-south to east-west. The KK Basin is northward of the Axial Belt there.

The Indo-Pakistan detached from the Gondwanaland, drifted northward, and collided with the Eurasia by Eocene by subduction of the in-between Tethys sea-floor (Powell, 1979). From Late Palaeozoic to Cretaceous, Pakistan was an Atlantic-type, northwestern continental margin of the Indian sub-continent (Farah et al., 1984). The margin was deformed and uplifted due to the collision that started in Early Tertiary.

"In Maastrichtian, a flysch trough developed (the KK Basin) in the south of the Afghanistan Block" (Arthurton et al., 1982). This basin is underlain by the Tethys sea-floor of Mesozoic age and its sedimentary cover and it formed between Late Paleocene and Miocene times (Bannert and Raza, 1992). Further more they say the area may have been occupied earlier by shallow water sediments such as the Nisai Formation and by the Tethys sea-floor before the flysch sedimentation derived from the Afghanistan Block.

The Nisai Formation contains many sedimentary facies. The formation is very important as this represents the oldest unmetamorphosed sedimentary unit in the KK Basin. From the hydrocarbon view-point this formation is the only attractive target there. The formation is distributed widely along the southern margin of the KK Basin along and above the Muslim Bagh ophiolites where it is mainly a shallow water deposit. Various features and facies of the Nisai Formation are discussed to build a depositional model presented in this paper.

LOWER CONTACT OF THE NISAI FORMATION

The lower contact of the Nisai Formation is mostly with a lava horizon marking a sedimentary contact. The contact is marked by a bed that contains weathered and reworked lava clasts. On the Muslim Bagh ophiolites the contact may, at places, be with the ophiolites.

BASAL CLASTICS

At the base of the Nisai Formation clastic rocks are present. These clastic rocks are classified in three groups namely: (1) unroofing conglomerate, (2) coarsening up deltaic clastics, and (3) red gypsiferous shale and sandstone, which are described below.

[1]Geological & Reservoir Laboratories, Oil & Gas Development Corporation, I-9, Islamabad.

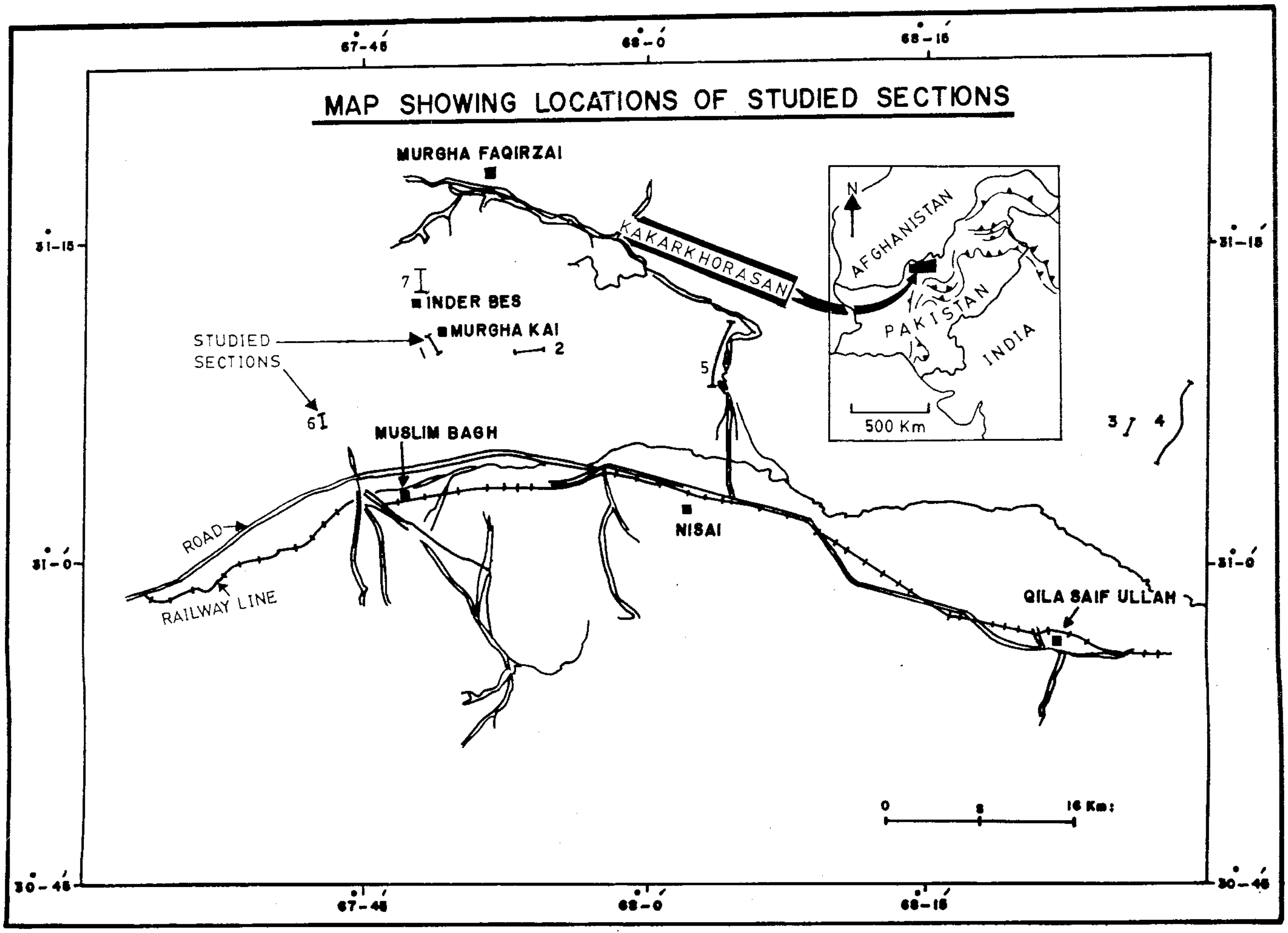

Figure 1- The insert map with the location of Kakarkhorasan Basin and the map of the Muslim Bagh area showing locations of the studied sections.

Unroofing Conglomerate

This conglomerate is well exposed northwest of the Muslim Bagh (Figure 2). It is clast supported consisting mainly of boulder to pebble size limestone clasts.

Starting from the base of the exposed succession, limestone clasts are mainly derived from the Cretaceous Parh Group rocks. Towards the top, the frequency of the Parh Group clasts decreases and that of the Triassic Alozai Group clasts increases. The clasts are associated to their sources based on their lithologial contrast as described by the Hunting Survey Corporation (1960).

A younging downward clast conglomerate suggests an unroofing sedimentary succession. There should be progressive uplift in an area; as the area will be uplifted the youngest rocks will be the first to be reworked. These reworked clasts will be deposited in a suitable area near the margin of the uplift. With time, older and older rocks were exposed and reworked. These clasts would go and be deposited on the top of the earlier deposits. Hence in the resulting deposit the clasts from the youngest reworked formation will be more common at the bottom and those of the older units would be more common towards the top.

The unroofing conglomerate succession also delimits the timing of the Muslim Bagh uplift. One would expect to find Eocene limestones at the very base of the deposit if the uplift was post-Eocene. The very base of the succession is not exposed at the studied locality northwest of the Muslim Bagh (Section 6, Figure 1). However, no Eocene limestone clast was found in the deposit, hence the uplift completely pre-dates the Eocene Nisai Formation. Also the deposit underlies the rocks that appear as equivalents of the Nisai Formation. If there would have been Paleocene carbonates in the uplifted terrain, then one should expect those clasts near the base of the deposit too. Such clasts were not seen which suggests that either the Paleocene carbonates did not form in the source area or the uplift pre-dates the Paleocene carbonates too. It is inferred that the area was subjected to tectonic uplift in post Parh Group times. Since the Parh Group is Cretaceous (Hunting Survey Corporation, 1960), hence the uplift is post Cretaceous.

The top of this conglomerate consists of well rounded and sorted vein quartz pebbles which appear a gravely beach deposit. This lithology is followed by sandstones which give way to carbonates upward.

Coarsening up Delta Cycles

The base of the Nisai Formation is marked by clastics that are well exposed at places (Section 2, Figure 1). These clastic sediments coarsen up in grain-size in cycles that are around 10 metres thick and consist of mainly shale with thin-bedded, very fine sandstone to siltstone at the base. The thin bedded sandstone or siltstone is ripple cross-laminated and shows current ripple form-sets. The shales are 0.3 to 0.4 metre thick with intervening siltstone beds that are 0.05 to 0.1 metre thick. Further up in the cycle the frequency of thin bedded sandstones increases and near the top of the cycle the rock is mainly cross bedded sandstone. One cycle is capped by a 2 metres thick sandstone bed. Near the top of the cycle there are also abundant reworked shell fragments.

These clastic rocks showing coarsening up grain size cycles were formed by prograding small deltas as one cycle is about 10 metres thick. These sediments underlie the Nisai carbonates.

Before the deposition of the Nisai Formation, the Muslim Bagh ophiolites area was being uplifted and it was supplying clastic sediments to the near by KK Basin as shown by unroofing conglomerate described above. Besides gravel, sand and mud may have been supplied that prograded in the KK Basin as small deltas.

Red Gypsiferous Shale and Sandstones

North of Qila Saif Ullah (Section 3, Figure 1) red shales and grey red sandstone underlie the Nisai carbonates (Figure 3). The moderate to very dark red shales contain thin flakes of gypsum. The sandstones are cross-bedded and show abundant upper flow regime plane laminations (Allen, 1984). The sandstone bodies appear as small stream channel deposits. There is abundant silicified wood in the sandstone. A 0.10m in diameter, silicified tree-trunk was recovered from a sandstone body. Mud cracks are also present in some muddy sandstones. These clastic rocks underlie the Nisai carbonates, which also contain silicified wood pieces.

These rocks possibly represent coastal plain deposits. Vegetation such as trees were growing on the uplifted terrain that were reworked and preserved as silicified wood. Tentative observations regarding palaeocurrents suggest the sandy sediments were derived from the south. The environment would have been hot and arid as suggested by the gypsum and red colour of these rocks. Lithologically, these sediments appear similar to the Eocene Kuldana Formation of the Kohat-Potwar Basin (Fatmi, 1973).

CARBONATES

Organic Build up Carbonates

There is a strong possibility that organic build ups were formed in the Nisai carbonates. Coral growth is abundant in some carbonates of the Nisai Formation (Section 2, Figure 1). Forams were, however, the most abundant calcareous organisms in these carbonates.

Nodular Carbonates

These carbonate sediments overlie the lava flow horizon with a sedimentary contact (Section 2, Figure 1) The weathered lava horizon is followed by the nodular carbonates. Benthic forams are very abundant. The nodule size varies vertically in a cyclic manner. Each cycle is several metres thick (Figure 4).

Bioturbated Muddy Carbonates

These Nisai carbonates contain abundant carbonate mud and are highly bioturbated showing abundant trace fossils on the bedding surfaces. There are thin to thick bedded carbonate mudstones, wackestones and packstones. Some packstone beds have channelled bases. These channels were shallow and may have been 0.2 to 0.4 metres deep. The facies style and the sedimentary features suggest that these sediments were deposited in lagoonal environments.

Such facies indicate that carbonate grainstones should have been deposited some where near the edge of this shallow carbonate platform. The carbonate grainstones may be accompanied with small organic build ups.

GREY SHALES

Grey shales are another important facies in the Nisai Formation (Section 2, Figure 1). The organic matter content looks fair visually. A shaly horizon was seen that was 15 metres thick (Figure 5).

CARBONATES TURBIDITES

This Nisai facies is well exposed along the track leading to Murgha Faqir Zai (Section 7, Figure 1). There the carbonate beds show reworked carbonate material. The carbonates are medium to thick bedded. The beds are very continuous as far as the limits of outcrops allow their observation. The beds are arranged vertically in bed thickening up cycles, which may be many tens of metres thick (Figure 6). These rocks are interpreted as carbonate turbidites. The bed thickening up carbonate cycles may represent lobes of submarine fans. The carbonate material was probably derived from the carbonate platform where shallow water Nisai carbonates were forming. Above a bed thickening up cycle there is another smaller coarsening up grain size cycle that ends with conglomerate (Figure 6). This conglomerate consists of vein quartz and limestone pebbles. This submarine fan may have been deposited at a low stand of relative sea-level.

COARSENING UP DELTA CYCLES OVER THE NISAI FORMATION

The top of the Nisai Formation is marked by clastic sediments (Section 5, Figure 1). These sediments are arranged into coarsening up grain-size cycles that are deltaic. These cycles consist of shale and thin siltstone beds near the base that gradually change up into sandstones. These sandstones are cross-bedded and

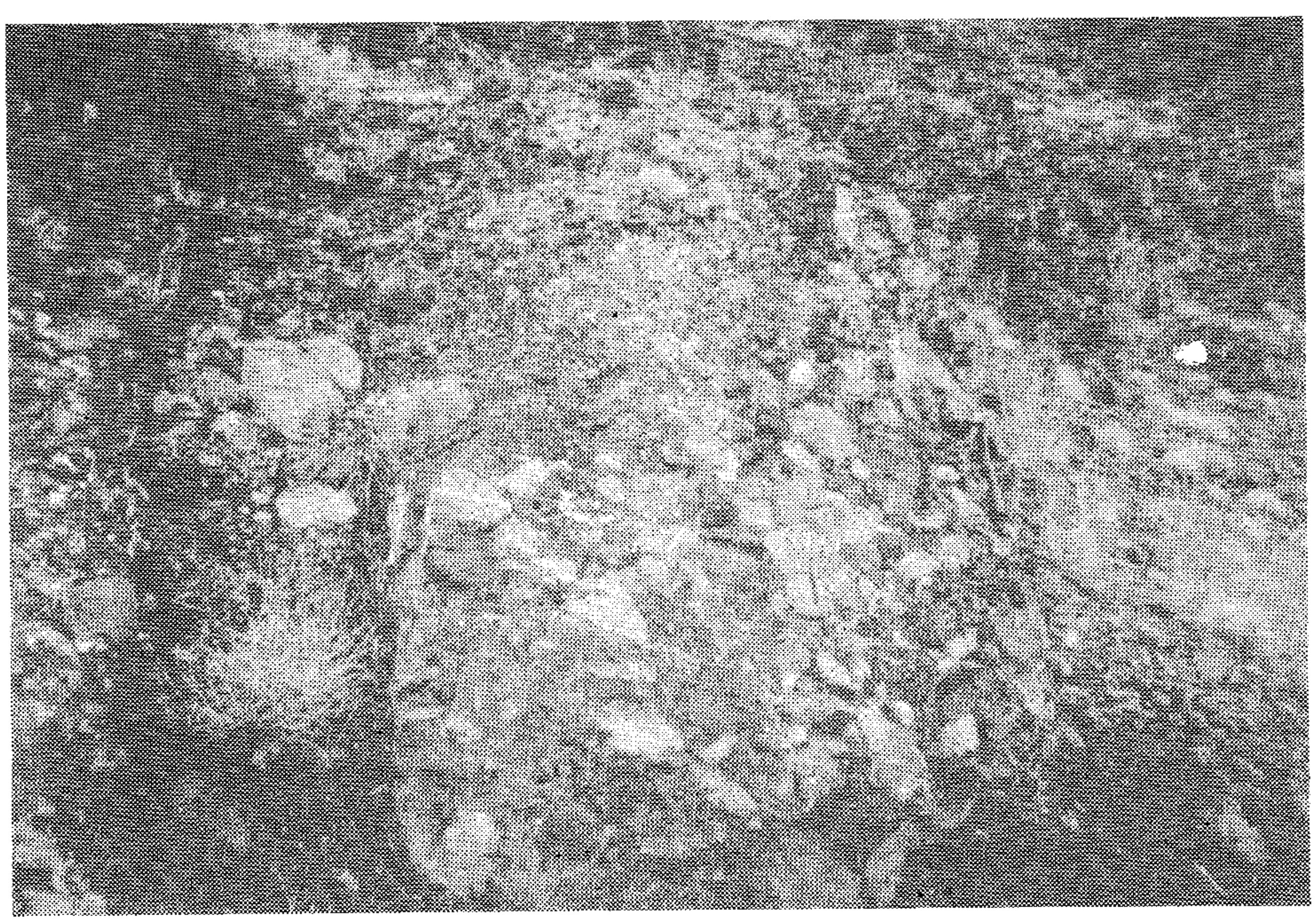

Figure 2- Unroofing conglomerate at section 6 in figure 1.

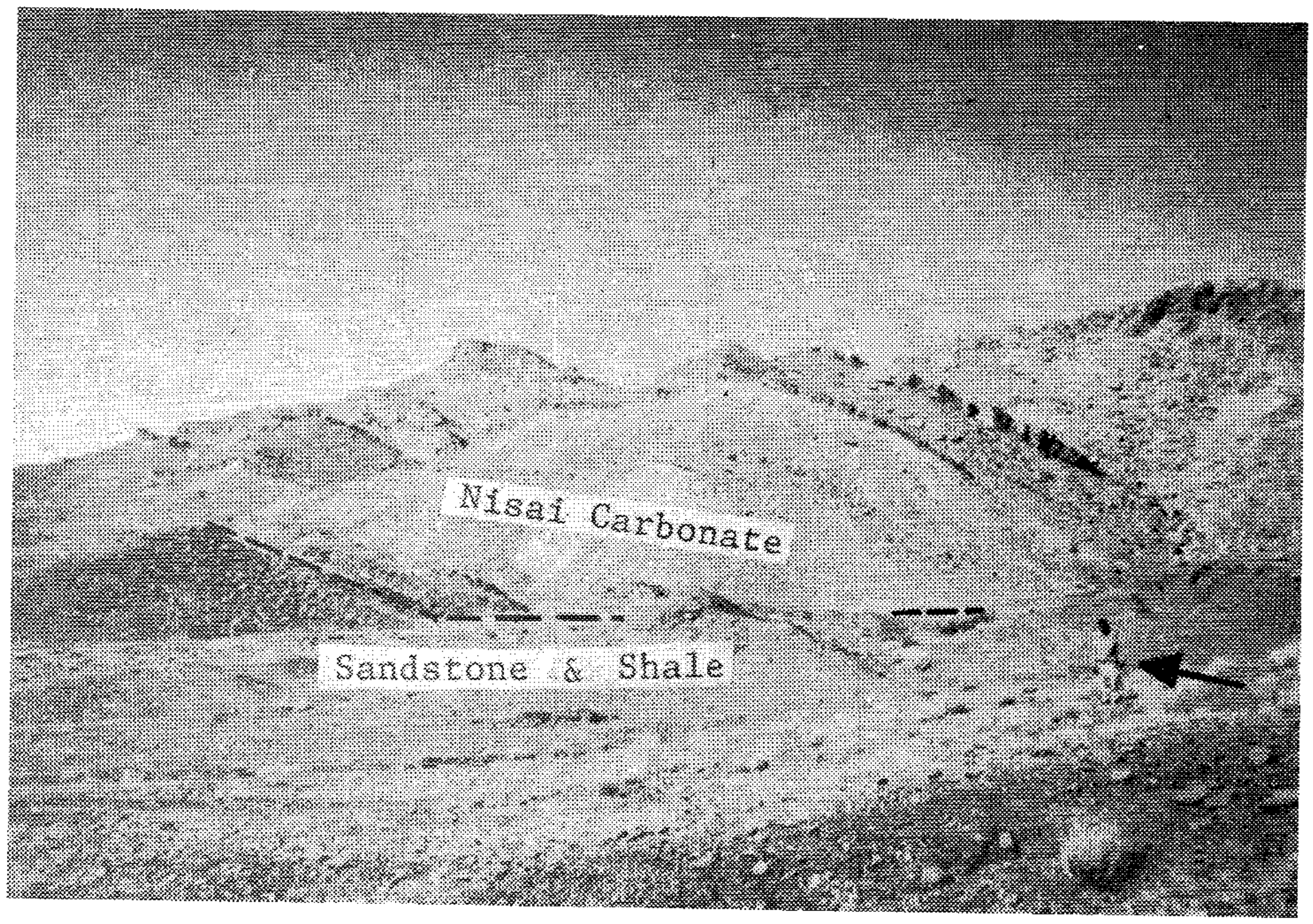

Figure 3- Sandy sequence underlies the Nisai carbonates at the section 3 (Figure 1) that contains abundant silicified wood and gypsum.

Figure 4- Nodular cyclical carbonate at the section 2 (Figure 1).

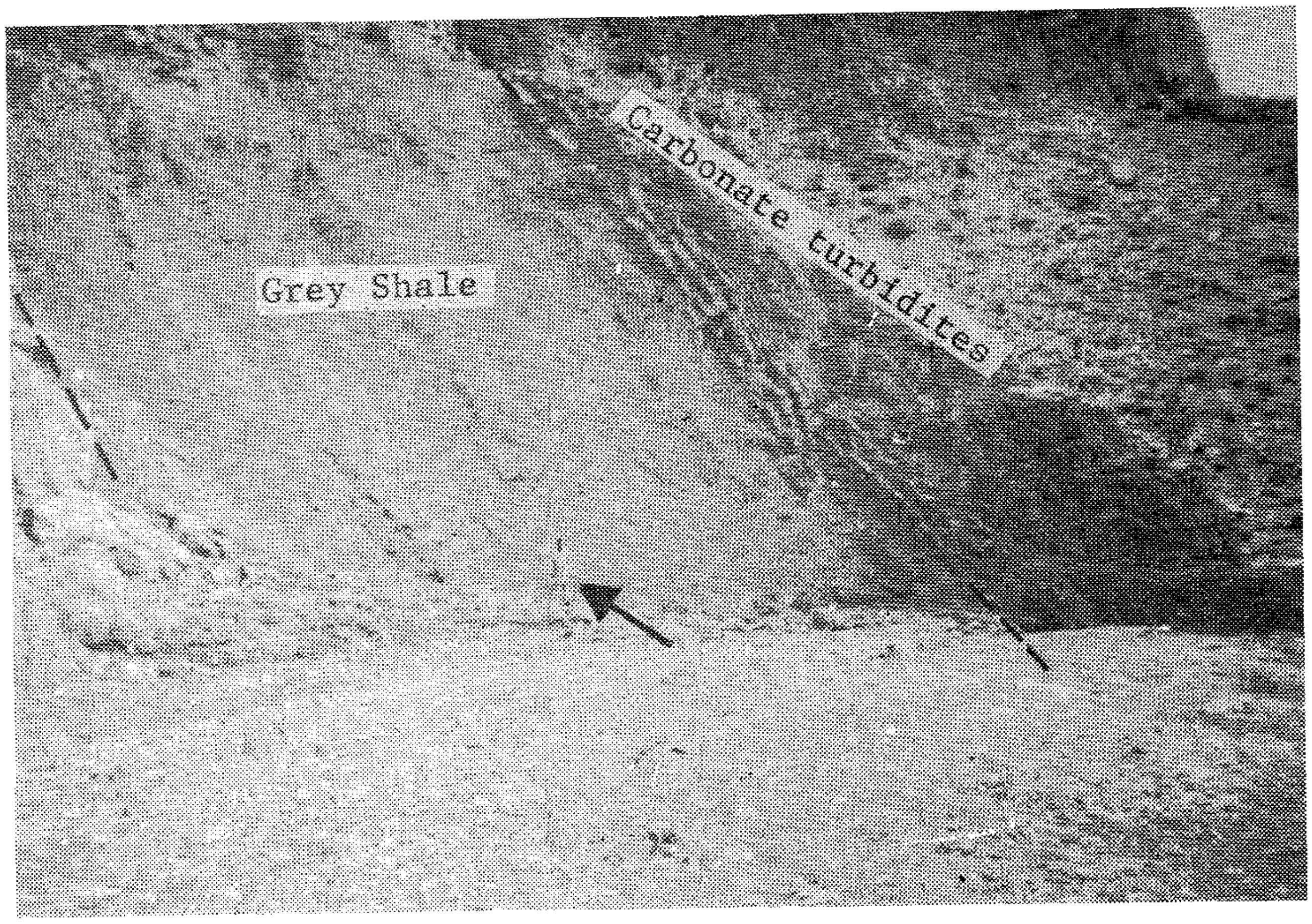

Figure 5- Grey shale below the Nisai carbonates at the section 2 (Figure 1).

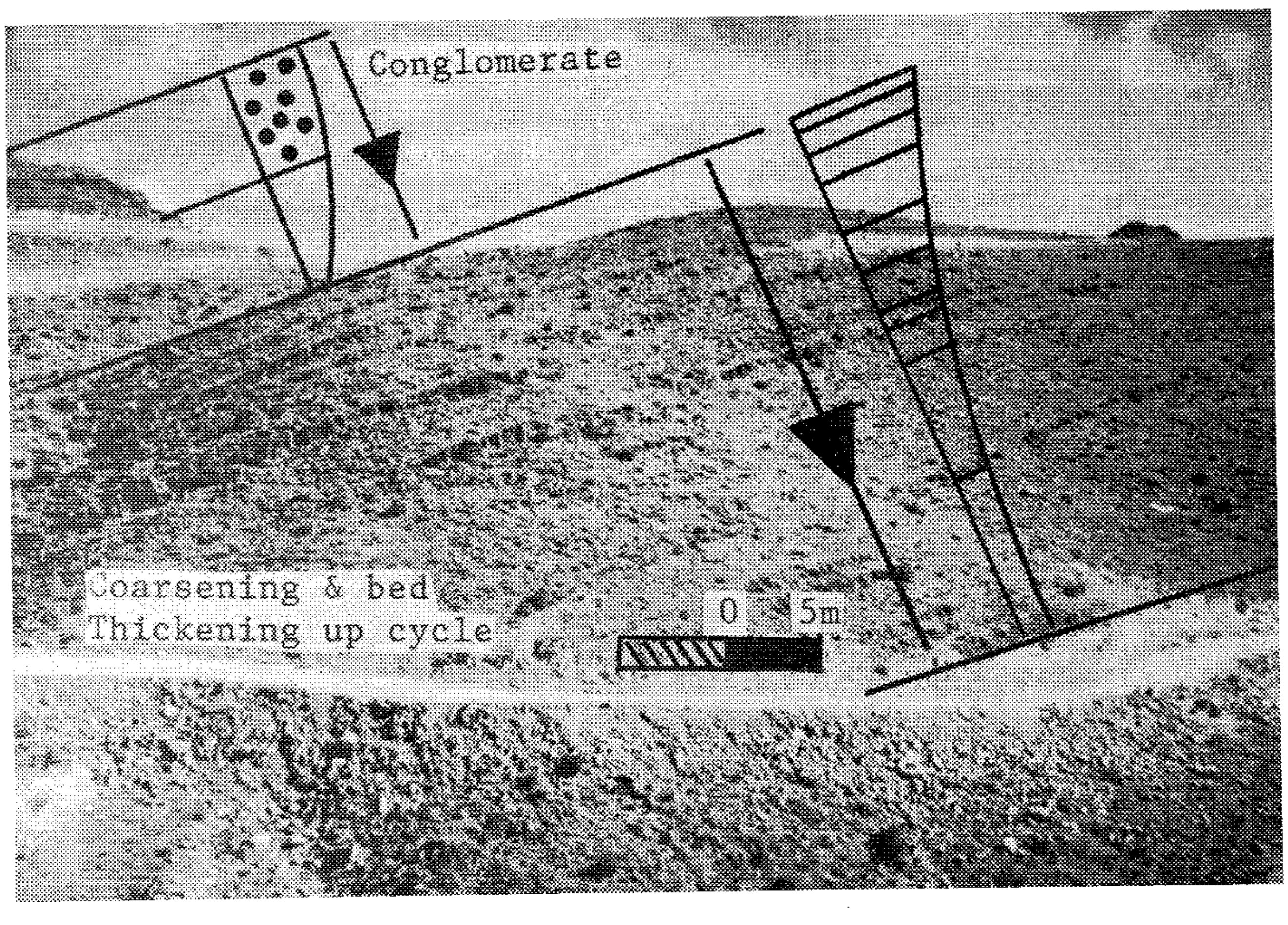

Figure 6- Carbonate turbidites at the section 7 (Figure 1). The rocks consist of one coarsening and bed thickening up cycle that ends with conglomerate in the top-left of the photo. Many beds show partial bouma sequences of sedimentary structures.

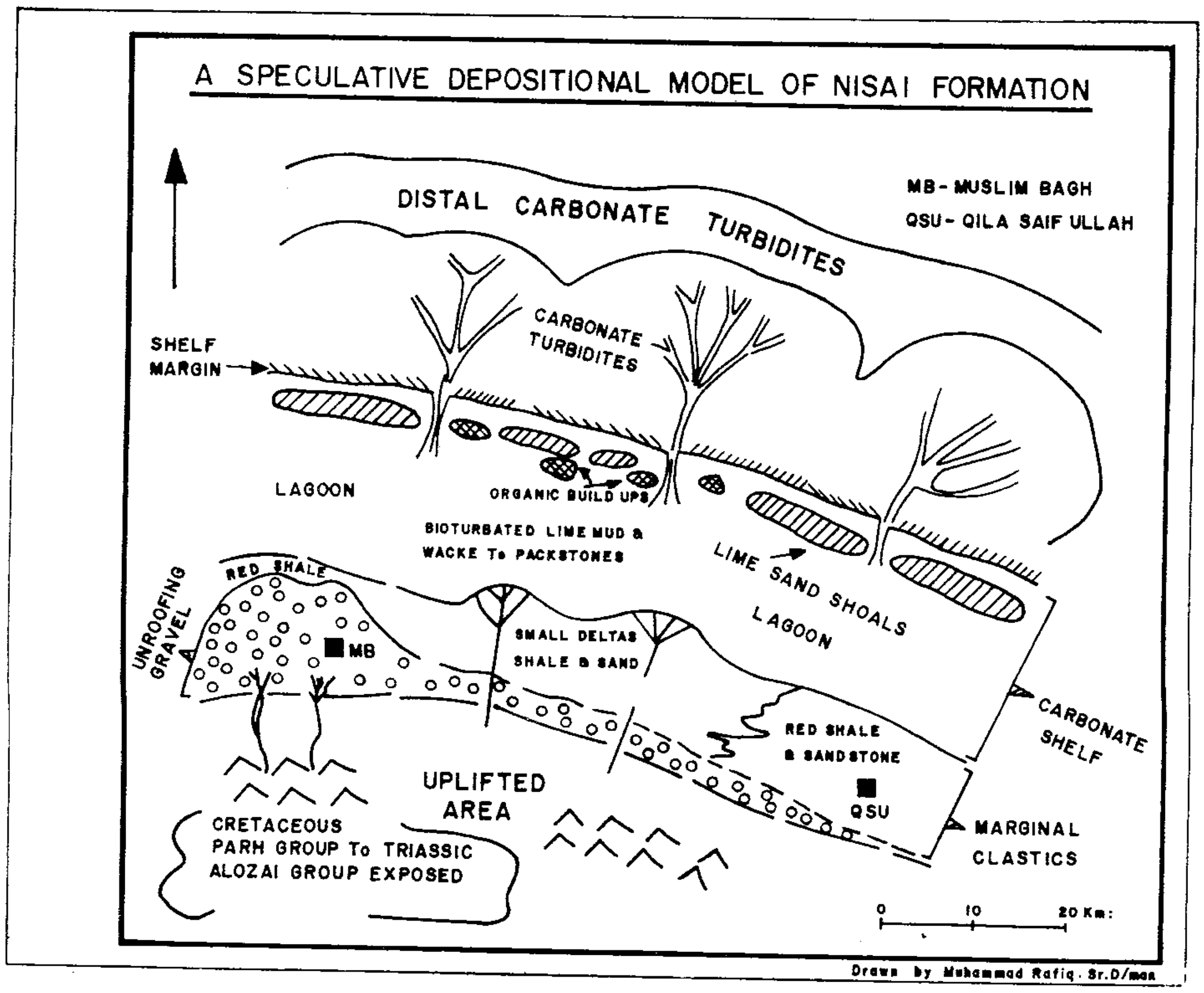

Figure 7- A speculative depositional model of the Nisai Formation that shows a clastic shoreline changing into carbonate platform and there are carbonate turbidites beyond the platform edge.

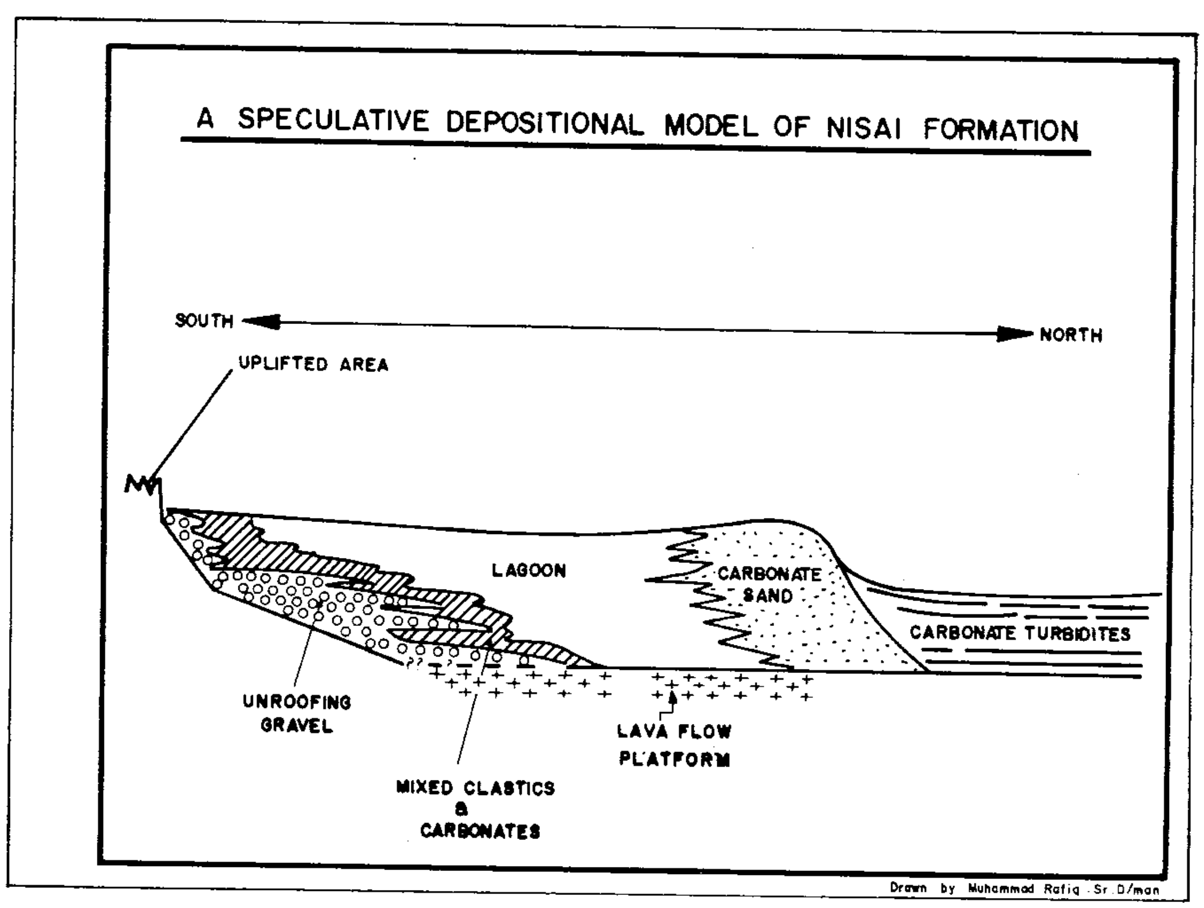

Figure 8- A speculative depositional model of the Nisai Formation in cross section. The model emphasizes on the clastic shoreline and the regressing, backstep geometry of the formation.

plane laminated. There are small shaly horizons in these sandstones as well. Some muddy sandstone beds show mud-cracks. These cycles are more than 10 metres thick and were formed by migration of small deltas.

DEPOSITIONAL MODEL OF THE NISAI FORMATION

A speculative model is presented based on observed sedimentary facies of the Nisai Formation. The model is presented as a sketch map and a schematic cross section (Figure 7, 8).

The sketch map (Figure 7) shows a clastic shoreline along the Muslim Bagh uplift that changes northward into a carbonate shelf. The gypsiferous red shales, sandstones with silicified wood, coarsening up delta clastics and gravel fans are supposed to mark this clastic shelf margin. The carbonate lagoonal facies lie further northward. There may be carbonate sand facies and carbonate organic build ups near the carbonate shelf margin. Further basinward beyond the shelf margin the carbonate turbidites were deposited. In the schematic cross-section (Figure 8) the carbonate facies are shown to prograde over the clastic shelf. It is seen today that clastic facies underlie the Nisai carbonates, hence in time, the carbonate deposition spread and covered the clastic sediments all over. It was probably controlled by relative sea-level change.

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