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PROVENANCE STUDIES OF MIOCENE-PLIOCENE NAGRI FORMATION EXPOSED AT KANATI AREA, DISTRICT KHUSHAB, PUNJAB, PAKISTAN

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ABSTRACT

The Siwalik sediments are widely distributed in foreland areas of Pakistan, India, Nepal and Bhutan. In Pakistan they are composed of four formations (Chinji Formation, Nagri Formation, Dhok Pathan Formation, Soan Formation) These post tectonic deposits contain vast phylogenetic trends of modern vertebrate species especially dating back to Miocene-Pliocene. Our study encompasses the Miocene-Pliocene Nagri Formation exposed at Kanati Section, District Khushab. The purpose of the study is to establish depositional modal based of Lithofacies and Petrographical studies. The Nagri Formation in the Kanati Section is 47 m thick and predominantly contains sandstone, silt and clay with sub-ordinate conglomerates. Four Lithofacies were established. These are Conglomerate Facies (N1) interpreted as channel floor deposits, Sandstone Facies with cross beds and extraclasts (N2), where extraclasts were deposited by the lateral movement of channel, Siltstone and Claystone/Mudstone Facies (N3) which were interpreted as crevasse splay deposits, and Clay Facies (N4) interpreted as flood channel deposits. The clay exposed here was mostly brick red in color showing oxidizing conditions due to subaerial exposure. Spheroidal weathering was quite common in sandstone. Petrographic analysis for sandstone thin sections revealed mostly moderate amount of quartz (59.53%), lithic fragments (39.9%) with minimal amount of feldspar (0.55%). The petrographic results for Nagri sandstone were plotted on a QFL diagram from where it was interpreted as belonging to Lithic Arenites. The provenance of this sandstone was established to be of Recycled Orogen based on the studies.

KEYWORDS

Nagri Formation, Lithofacies, Provenance, Foreland basin.

1. INTRODUCTION

Siwaliks rocks are formed at the foothills of Himalayas, ranging from the Potwar and Sulaiman Range (Punjab), the Kirthar Range (Sindh), Waziristan (KPK) and many small and scattered areas in Baluchistan [1]. Siwaliks comprise of a width of about 6-90 km and cover an area of about 2000 km and are located in Pakistan, India, Nepal and Bhutan [2]. However, the cover in only Pakistan and India is estimated to be 6080 m [3]. Ulak pointed out that the Siwaliks are bounded by the Main Boundary Thrust (MBT) in the North and the Himalayan Frontal Fault (HFT) in the South [4]. The Group was deposited as a result of tectonics related to the Himalayan orogeny in the form of mollase type sediments formed in foredeep south of the Himalayas [5]. The Siwaliks are located at an altitude of about 300 m-1200 m above sea level [6]. These are comprised of a belt that is about 13 km wide [7]. The Siwaliks form an important part of the Salt Ranges. In the Salt Ranges the Siwaliks have been known of ages as young as 400,000 years and are overlain by an angular unconformity that is composed of Quaternary Fanglomerates [8].

1.1 Objectives of the Study

The objectives of this study are to carry out provenance studies using outcrop of well exposed Nagri formation in Kanati area, Central Salt Range, Pakistan (Figure 1) which include detailed interpretation of Lithofacies in the field along with petrographic studies of sandstone samples under polarizing microscope. This study will help in finding the overall architecture of the past when these formations are deposited.

2. METHODOLOGY

Detailed field work was carried out to measure a 47m thick bed of Nagri formation exposed in Kanati Garden. The beds were measured by means of Jacob's staff and measuring tape. Facies were observed, and the photographs of sedimentary structures were taken. oriented samples were collected from the field for petrographic analysis in the laboratory. Photomicrographs were taken for sandstone samples chosen for study. Three grains were identified Quartz, feldspar and lithic fragments which were then used to plot the classification and provenance of sandstone based on a QFL diagram. The classification scheme used was that of Pettijohn, and for provenance the samples were plotted on a QFL diagram [9,10].

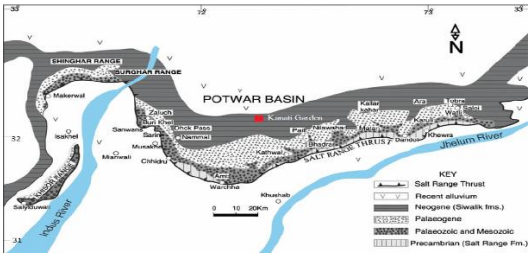

Figure 1: Showing structural map of Salt Range. The Square shows the location of study area [11].

3. REGIONAL TECTONIC SETTINGS

The collision of the Indian and Eurasian continental plates around 25 to 30 million years ago generated the Himalayan Foreland Basin in Pakistan, India and Nepal. The foreland areas are the low areas with respect to main land, so the proper river system have been created in these areas. The river system shed their sediment load in the low lands which created the siwalik mollasse deposits. Main Boundary Thrust (MBT) limits the width of this basin in its northern tectonic boundary, overridden by low grade Pre-Tertiary met sediments of the Lesser Himalayas. The Lesser Himalayas are in turn overridden by Main Central Thrust (MCT) [2]. The Neogene tectonism of the Himalaya together with monsoon precipitations on the subcontinent had caused the development of the Siwalik Foreland Basin on its southern front [12]. The extension of the Siwaliks is from the Potwar Plateau in the Northwest to Brahmaputra in Northeast covering a total length of about 2400 km, and a width of about 20-25 km. This basin is filled with the world's most comprehensive clastic sediments. The Siwaliks thin southwards from the folded regions of the Lesser Himalayas [13].

4. RESULTS AND DISCUSSION

4.1 Lithofacies

Four Lithofacies were identified for Nagri Formation in our study area. The Nagri Formation from the studied locality is interpreted as Conglomeratic facies (N1), Sandstone with cross beds and extra clasts (N2), Siltstone and Claystone facies (N3) and Clay facies (N4).
The N1 facies represent channel floor deposits derived from phenomena like crevasse splay. N2 facies represent cross stratification with extra clast material derived from conglomeratic sequence, N3 facies which may be crevasse fill deposits, and N4 facies dominantly clay facies which show oxygenated and rapid subaerial exposure. Details of the Lithofacies are given below

4.1.1 Conglomeratic Facies (N1)

These facies have been interpreted as channel floor deposits with intense amount of sedimentation and with poorly sorted intra and extra clasts [14,15]. The fragments are subangular which means that they have been reworked very little by water. May have resulted from a collapse of cohesive bank sediments into nearby channels [15]. Coarse channel floor deposits are largely gravels that accompany the deeper part of the channel where most of the finer material has been removed [16,17]. Larger clasts were as much as 8cm in size.

4.1.2 Sandstone Facies with cross lamination and extraclasts (N2)

Presence of cross stratification, as well as the lateral persistence of sandstone sheets is interpreted as a deposit of sand dominated braided fluvial system which are usually developed in higher areas and have abundance of coarser material [18]. In braided streams new channels form because banks are not especially very strong. The intraformational extraclasts are probably derived from sides of channel during lateral movement of the channel [18,19].

4.1.3 Siltstone/Mudstone facies (N3)

Encountered at the base of a massive clay bed. Interpreted as crevasse splay deposits. The ripple marks point out the migrating river channel. The clay lenses so found are intraformational. The reddish color of Siltstone and Mudstone Facies points out to good drainage and highly oxidizing conditions [19]. Laminated Mudstone Facies point out to low velocity floods with suspended load [20]. Ripple marks and planer stratification were deposited as a result of migrating ripple dunes [21].

4.1.4 Clay Facies (N4)

The Clay Facies observed are mostly red colored. The massive 3.3 m bed deposits above the Claystone Facies were deposited as flood channel deposits. Clay Facies are mostly red in color which means that they were deposited and exposed to subariel conditions pointing out to a highly oxygenated environment where abundant oxidation resulted in brick red colored clays [22].

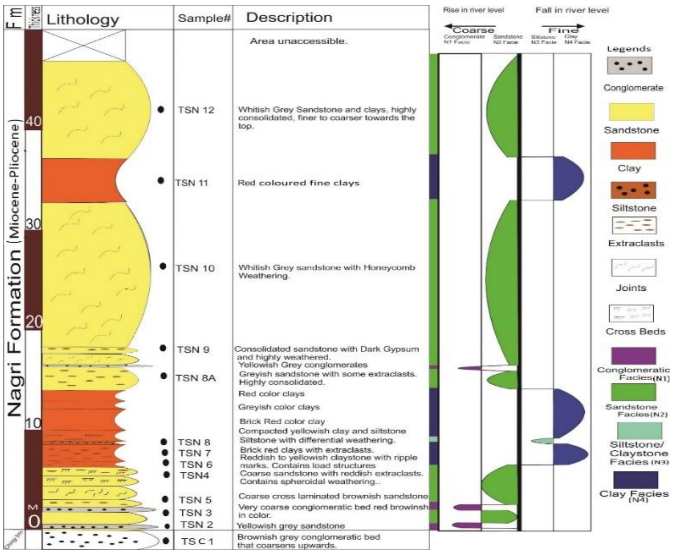

Figure 2: Lithostratigraphic log of the measured section of Nagri Formation from Kanati Section along with periodic fluctuations in the river system. Four facies were noted in the study area, Conglomeratic Facies (N1) (purple), Sandstone Facies (N2) (green), Siltstone and Claystone/Mudstone Facies (N3) (Blue Green) and Clay Facies (N4) (Dark blue).

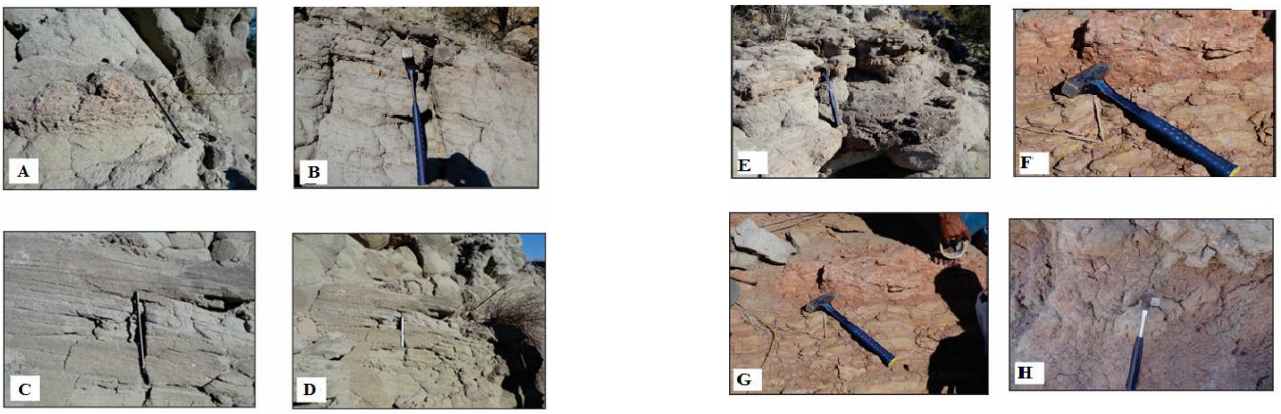

Figure 3: Photographs of Lithofacies exposed in our study area. (A) A thin conglomeratic bed (N1 facies) sandwiched inside a massive of sandstone; (B) Sandstone with extraclasts (N2 facies); (C) and (D) Cross laminated sandstone (N2 facies); (E) Sandstone with extraclasts (N2 facies); (F) and (G) Red colored Mudstone facies (N3 facie); (H) Red Clays (N4 facies).

4.2 Petrography

Petrographic analysis could only be done for three samples chosen from the study area due to non-competence of the lithology. The three samples chosen for this analysis were relatively competent. Petrographic analysis for three samples under study revealed abundant quartz grains with very little or no Feldspar in a few samples. Based on maturity the quartz grains are considered immature due to their angular nature. Feldspar encountered in a few thin sections showed only 0.55% percent of the total amount of minerals in the rocks.

On the basis of modal composition, the Nagri Formation falls in the category of Lithic Arenites. This has been assumed due to the presence of less than 15 % fine matrix and about 60% quartz encountered, along with significant number of lithic fragments. The petrographic samples under study were named TSN 5, TSN 8A and TSN 8B, where TSN stands for "Tertiary Siwaliks Nagri".

4.2.1 TSN 5

Petrographic analysis of this sample revealed abundant quartz and the dominant grain was in fact quartz. The matrix supporting this quartz was clay. The quartz is derived from fluvial conditions. Quartz grains observed were non-fractured, which shows that quartz was unaffected by pressure conditions during burial in digenetic processes. Since the quartz grains are angular in nature i.e. very less rounded, this means that quartz was derived from a place nearby. Feldspar was very little, about 1.4 % feldspar constituted in this slide. The very little percentage of feldspar shows that either the source rock was present in a nearby place, or the feldspar may have been eroded due to instability. Point count showed an average thirty quartz grains per unit area.

4.2.2 TSN 8A

The dominant mineral is quartz, in this particular thin section we encountered about 56 % quartz and with very less roundness. The quartz was immature due to its angularity of grains, and cementing material or finer matrix was clay. Feldspar was very little, about 0.36% feldspar was observed in eight views, i.e. only one Feldspar grain was observed. Mica was considerably in higher amount in this thin section than in TSN 5 and TSN 8B. Nine grains of Mica were observed due to their birefringence patterns and their plate appearances, which constituted about 3.2% of the material present in this thin section. About 26 % lithic fragments were observed, together with 13 % finer matrix.

4.2.3 TSN 8B

TSN 8B had higher proportions of quartz and lithic fragments than TSN 5 and TSN 8A. The quartz was mainly Monocrystalline, and fragments of quartz were extremely abundant in one view. About 47 % quartz was present in this thin section, together with 42 % lithic fragments. Mica also constituted about 0.84 % for this thin section. No feldspar was observed.

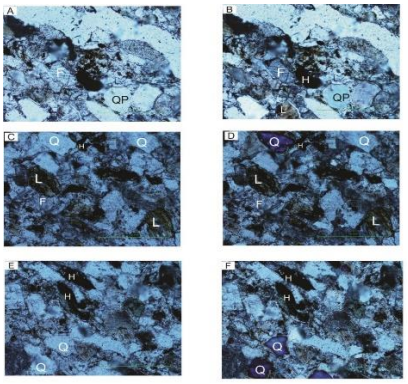

Figure 4: Photomicrograph of sample TSN 5. (A) Plane light view showing Polycrystalline Quartz (Qp); Plagioclase Feldspar (F). (B) Cross light view of "A", Polycrystalline Quartz (Qp); Feldspar (F); Heavy Mineral (H); Lithic Fragment (L). (C) and (D) Plane and cross light views respectively. (E) and (F) Plane and cross light views respectively, Heavy mineral (H) and Quartz (Q).

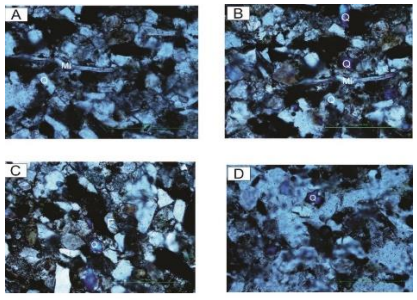

Figure 5: Photomicrographs of TSN 8A. (A) and (B) Plane light and cross light views respectively, Quartz (Q); Mica (Mi). (C) Feldspar (F); Quartz (Q). (D) Mainly Quartz has been observed in this view.

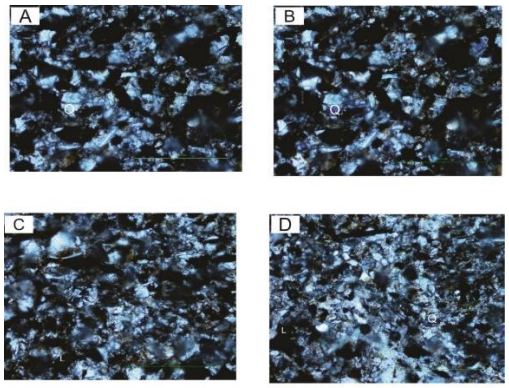

Figure 6: Photomicrographs of TSN 8B. (A) and (B) Plane light and cross light views respectively. Quartz has been mostly observed in this view. (C) and (D) plane and cross light views respectively. Proportionally a higher amount of Quartz has been observed in this thin section.

Table 1: Cumulative results of point counting of the sandstone of Nagri Formation of Kanati Area, Central Salt Range.

KANATI AREA					
Nagri Formation					
CLASS	**TSN 5**	**TSN 8A**	**TSN 8B**	**Total**	**Percentage**
Quartz	158	154	225	537	59.53
Feldspar	4	1	0	5	0.55
Lithic fragments	69	82	209	360	39.9
	231	**237**	**434**	**902**	**100.00**

5. INTERPRETATION OF PROVENANCE

Sedimentary provenance, nature of sedimentary processes and kind of dispersal path are three major important characters for sandstone compositions, and the key relationships between provenance and type of basin in which sandstone is deposited is governed by Plate Tectonics [10]. Sands derived from Recycled Orogens are rich in quartz and lithic fragments, and are derived from Subduction Complexes, Foreland Uplifts and Collisional Orogenic processes [10].

The sandstone of Nagri Formation was derived from Foreland Uplift provenance, one of the three categories in Recycled Orogens as described by some author [10]. This is because the quartz so calculated in our examples (Table 1) is moderately high when the average of all the data for quartz is taken. Quartz is approximately 60 % which points out moderately high amount. Feldspar is strikingly low, only 0.55 %. With both moderately high amount of quartz and low amount of feldspar, the Provenance of Nagri Formation is from a Collisional Foreland Uplift.

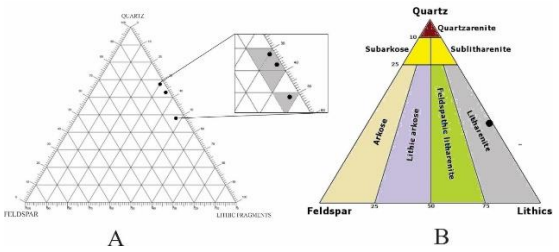

Figure 7: The position for studied samples have been plotted on the Triangular diagram of classification of sandstones. (B) Category of plotted Nagri Formation sandstone from Study Area. The sandstone so plotted falls in the category of Litharenites (rock fragments >25%) [9,23].

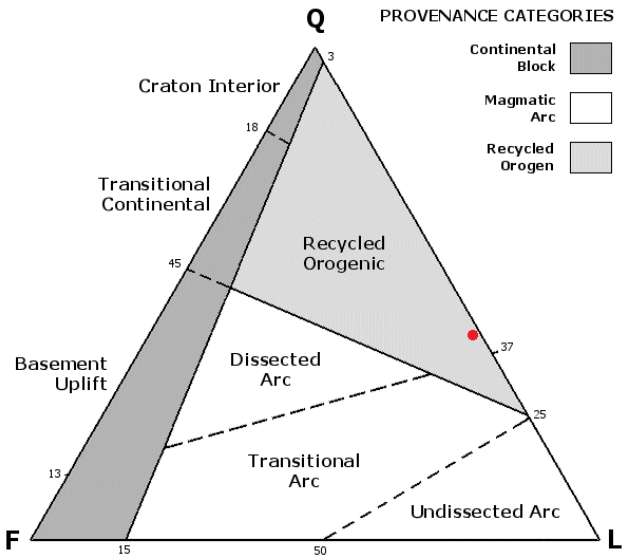

Figure 8: QFL compositional diagram for Nagri Formation sandstone obtained from study area. Samples plotted in this diagram point out its provenance from Recycled Orogen [10].

6. CONCLUSIONS

As a result of extensive field work and laboratory analysis, the following conclusion about the provenance studies can be drawn:

- Nagri formation is composed of four Lithofacies 1) N1 conglomeratic facies, 2) N2 sandstone facies with extraclasts, 3) N3 siltstone and claystone facies and 4) N4 clay facies. The higher amount of coarser material in our studied section (i.e. sandstone) is present in the study area points out to braided rather than meandering stream system was present at the time of deposition of the formation.
- The facies N3 and N4 is having brick red colour which shows that the conditions at the time of the deposition of the formation were more oxidizing than reducing.
- As a result of petrographic studies it is concluded that sandstone of Nagri Formation belongs to the category of Lithic Arenites, due to the presence of about on average 59.53% quartz and 39.9% lithic fragments. Feldspar was strikingly low only 0.55%. The reason for its very low percentage is its instability as feldspar becomes easily eroded.
- The provenance of Nagri sandstone concluded from the study area is as recycled orogeny produced as a result of load shed by the river system originating from the high hills of Himalayas. The sands from recycled orogens have a higher amount of quartz and lithic (rock) fragments.

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