PETROLOGY AND PROVENANCE OF THE UPPER CRETACEOUS MUGHAL KOT FORMATION AND PAB SANDSTONE, WESTERN SULAIMAN THRUST AND FOLD BELT, PAKISTAN

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Abstract: *The Sulaiman Thrust and Fold Belt-Pakistan comprises of thick Mesozoic succession that was deposited at the northwestern passive margin of the Indo-Pakistan Plate within the Paleo-Tethys. The Mughal Kot Formation is mainly composed of mudstone with subordinate channeled sandstones and rare limestone. The Pab Sandstone is predominantly composed of sandstone with subordinate interbedded shale. The present study is based on data collected from the sandstone packages of Mughal Kot Formation from Mughal Kot and Siazgi sections, while the Pab Sandstone was studied from Mughal Kot and Gwal Haiderzai sections. In the Mughal Kot section, the Mughal Kot Formation is 650 m thick with six packages of channelized sandstone with thickness ranging from 4 to 45 m embedded within the thick mudstone. The petrology of these sandstones was studied and modal analysis carried out in order to classify and understand their detrital modes and provenance. The sandstone has been classified as sub-lithic arenite. The Q-F-L plot indicates a craton interior and recycled orogen. The detritus of sandstone of the Upper Cretaceous Mughal Kot Formation and the Pab Sandstone has been derived from the Indian Craton situated east-southeast of the study area.*

Keywords: Mughal Kot Formation, Pab Sandstone, Upper Cretaceous, sandstone packages, petrology, provenance

INTRODUCTION

The Sulaiman Thrust and Fold Belt-Pakistan contains thousands of meters thick Mesozoic succession (Fig. 1, and Table 1), which was deposited at the northwestern passive margin of the Indo-Pakistan Plate within the Paleo-Tethys. The succession was first mapped and its lithology was briefly described by the Hunting Survey Corporation (1961). Facies within the Mesozoic through Paleogene succession from northwest to southeast shows an overall general shift from deep to shallow marine reflecting basin evolution of the passive margin (Abbas and Ahmed, 1979).

The term "Mughal Kot Formation" was proposed by Williams (1959), to the strata between the Parh Limestone and the Pab Sandstone near the Mughal Kot village. The Hunting Survey Corporation (1960) did not identify it as a distinct entity, but included it within the lower part of their Pab Sandstone (Shah, 1977). A section exposed along the Zhob-Dera Ismail Khan Road (Lat: 31° 26' 52" N; Long: 70° 02' 58" E), west of the Mughal Kot Post, and an adjacent stream, (Toi Nala) has been designated as the type section of the Mughal Kot Formation by Williams (1959).

In the study area the Mughal Kot Formation is 650 m thick (Figs. 2a, 2b, 2c) and comprises dominantly claystone / mudstone and subordinately siltstone, limestone and sandstone (Fig. 3). Color of mudstone, shale and siltstone is grey to greenish grey, which weathers light grey to dark grey. Sandstone is fine to medium grained, well cemented and hard.

The term "Pab Sandstone" was introduced by Vredenburg (1908) from the Pab Range in the Kirthar Thrust and Fold Belt. Williams (1959), designated Sumalji Trail, west of Wirahab Nai (Lat: 25° 31' 12" N; Long: 67° 00' 19" E) across the Pab Range as its type section, where it is 490 m thick, though its thickness ranges from 204m (Mughal Kot) to 1000m (Pab Range). In the study area the Pab Sandstone consists of dominantly sandstones with subordinate inter bedded shale. The formation is 204m thick at Mughal Kot, 142m thick at Gwal Haidarzai, 48m thick at Siazgi and 7m thick at the Spera Ragha (Fig. 1).

The aim of this paper is to describe the sandstone petrology and provenance of the Upper Cretaceous Mughal Kot Formation and the Pab Sandstone by collecting data from the Mughal Kot, Gwal Haiderzai and Siazgi sections.

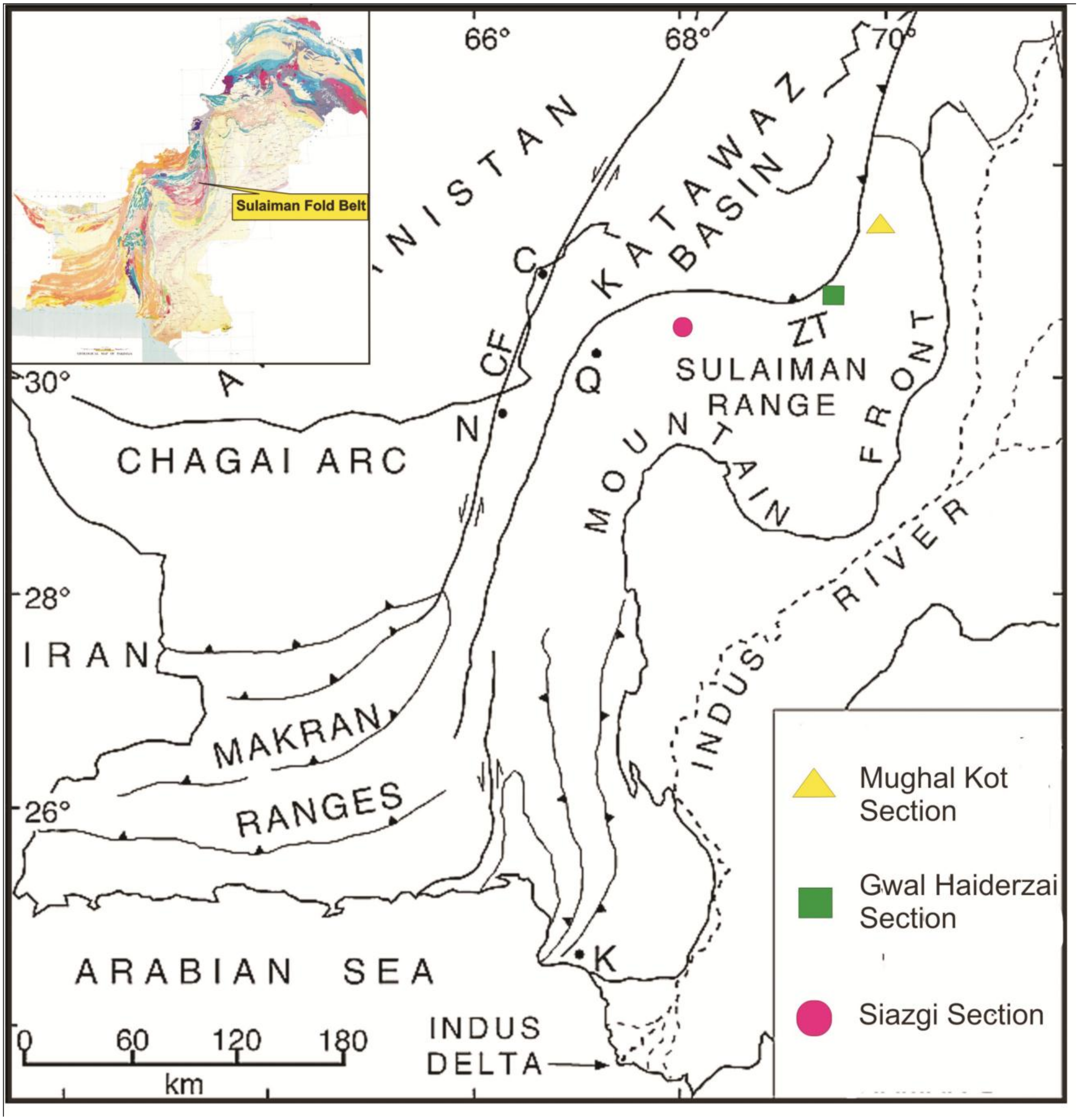


Fig. 1 Tectonic map of Pakistan showing location of the Mughal Kot, Gwal Haiderzai and Siazgi sections in the Thrust and Fold Belt.

Table 1. The Stratigraphic Succession of the Mughal Kot Area, Sulaiman Fold and Thrust Belt

Age	**Group**	**Formation**	**Lithology**
Eocene		Ghazij Formation	Yellowish to greenish grey shale interbedded with layers and lenses of claystone, mudstone, sandstone, limestone and conglomerate
Paleocene to Early Eocene		Dunghan Formation	Medium to thick bedded, massive and nodular limestone with subordinate marl and shale
Paleocene		Ranikot Formation	Very fine to fine-grained, light grey sandstone Interbedded with subordinate, grey arenaceous limestone and siltstone/shale
Upper Cretaceous (Middle to Upper Maastrichtian)		**Pab Sandstone**	Fine to medium grained quartzose sandstone and light brownish grey shale
Upper Cretaceous (Campanian to Early Maastrichtian)		Fort Munro Formation	Grey, argillaceous and highly fossilliferous limestone with minor calcareous shale.
Upper Cretaceous (Companion to Early Maastrichtian)		**Mughal Kot Formation**	Grey calcareous mudstone and shale with sandstone packages**.**
Middle Cretaceous (Barremian to Santomanian)	Parh Group	Parh Limestone	Bio-micritic limestone, medium to thick bedded and light grey to cream colored
Early Cretaceous		Goru Formation	Arenaceous limestone, light grey colored with occasional bio-micritic beds
Late Jurassic to Early Cretaceous (Neocomian)		Sembar Formation	Belemnitic shale of dark, brownish grey and light greenish grey color
Disconformity			
Middle Jurassic		Chiltan Limestone	Medium to thick bedded, light to medium grey colored limestone

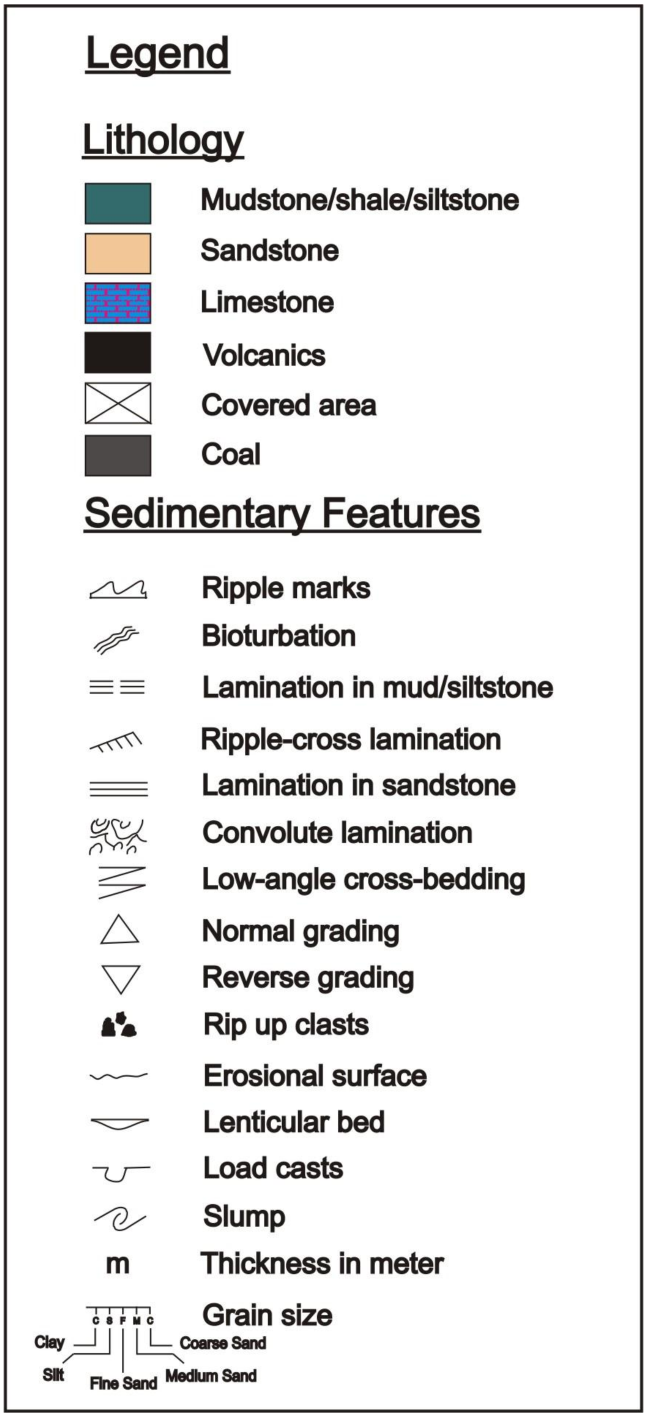


Fig. 2a Legend showing various geological features observed and shown in subsequent figures

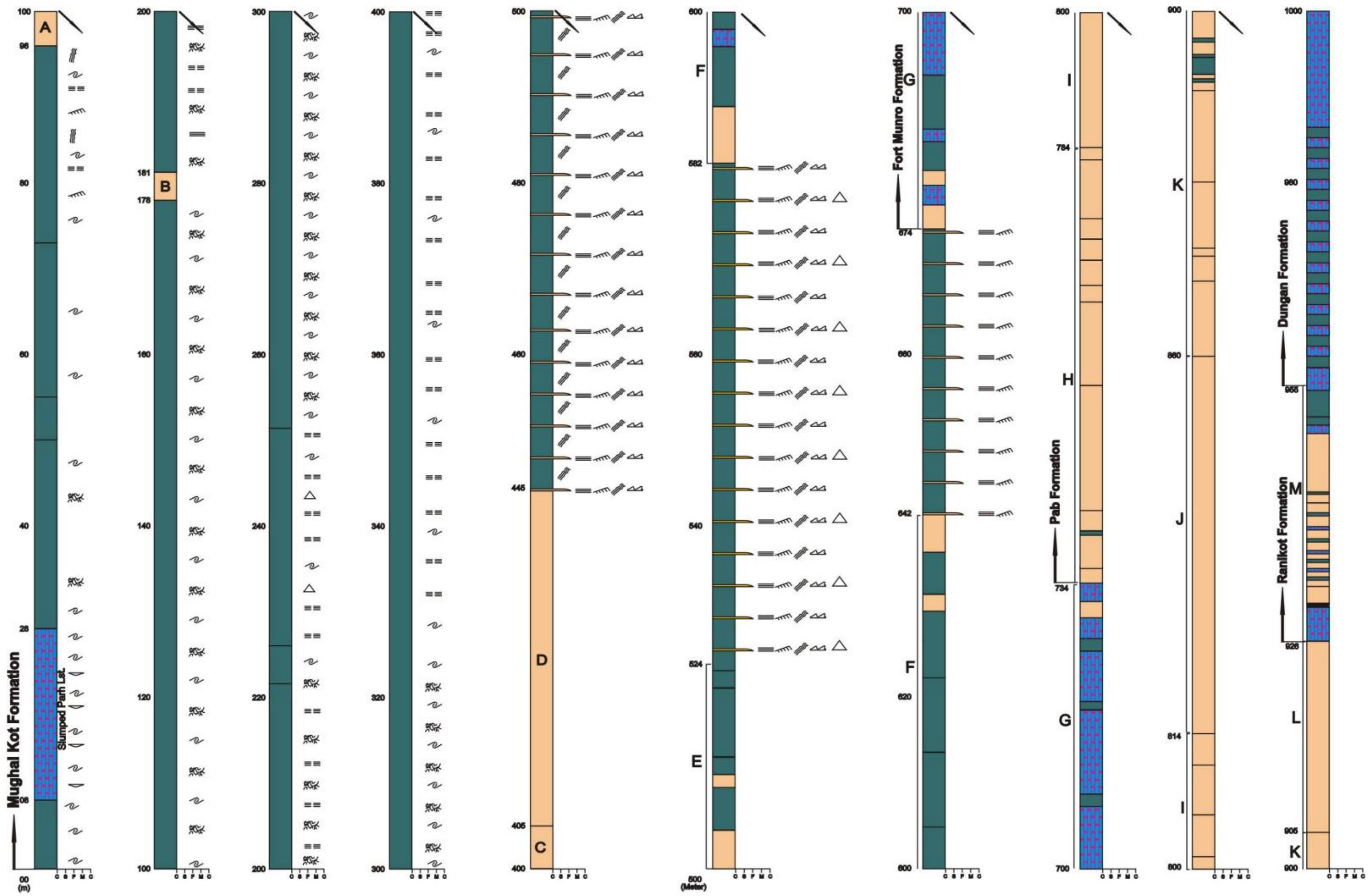


Fig. 2b Sedimentary logs (A, B, C, D, E, F, G, H, I, J, K and L) of the Mughal Kot Section, which have been enlarged in Figs. 2c, 2d and 2e.

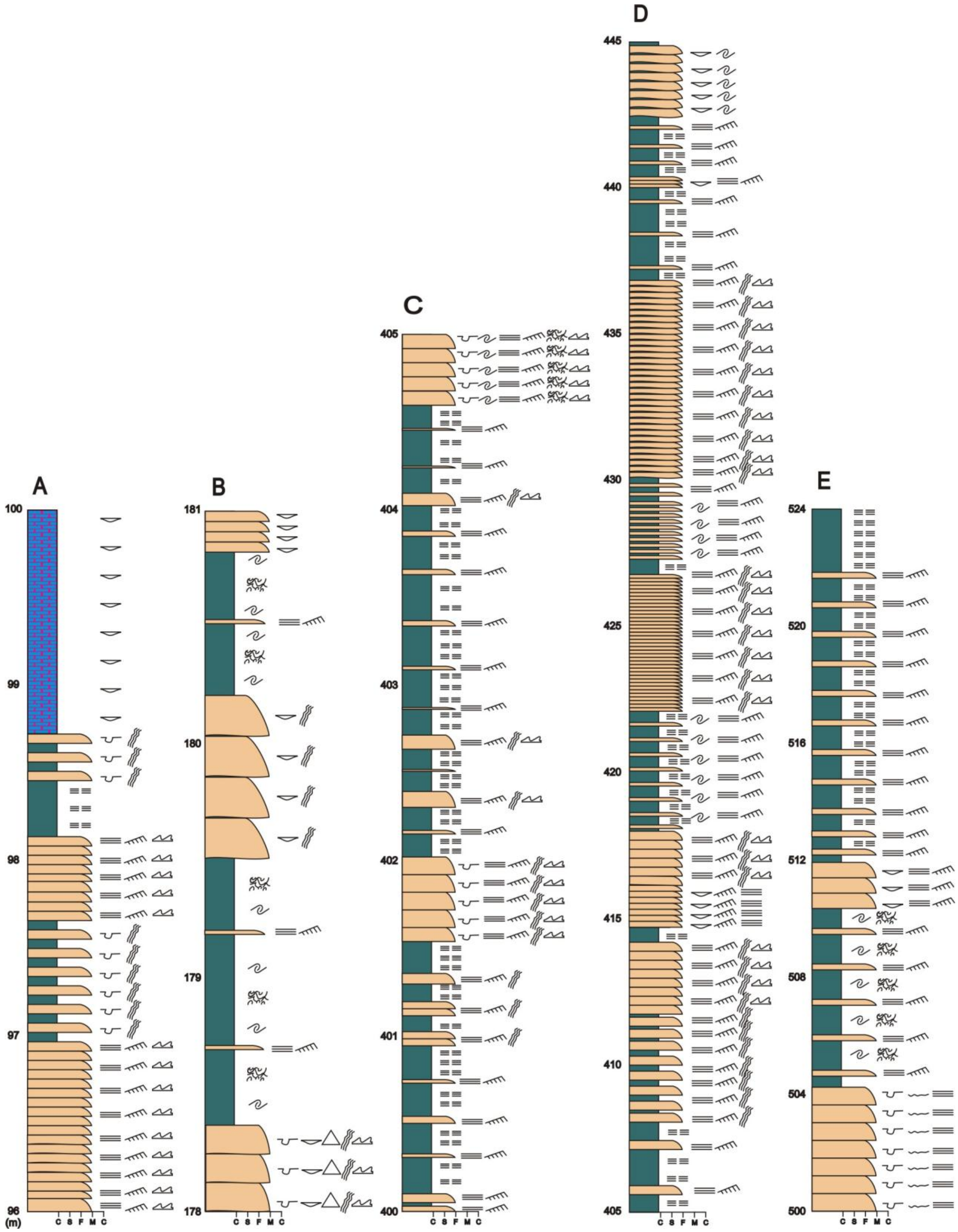


Fig. 2c (See Fig. 2a for symbols)

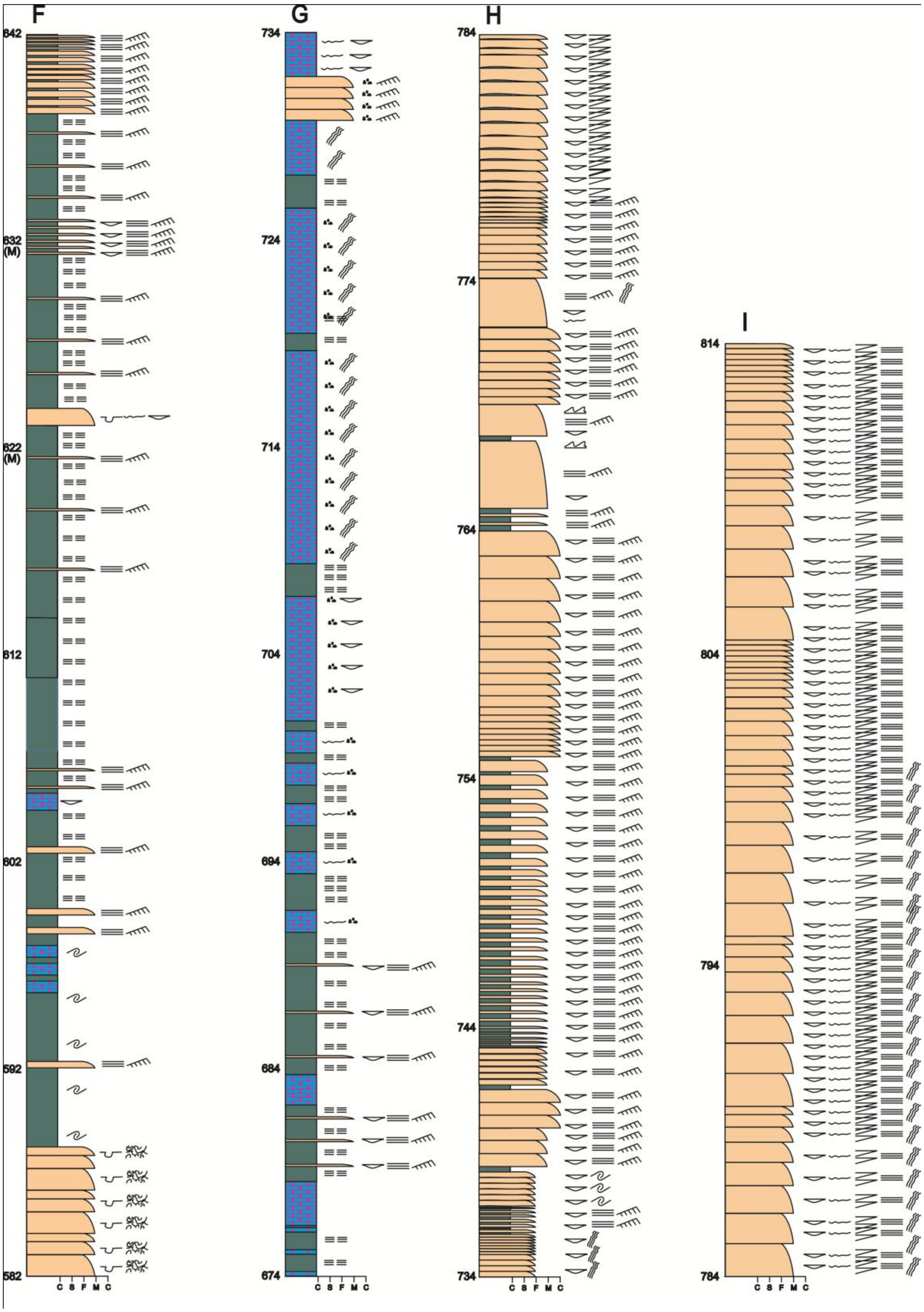
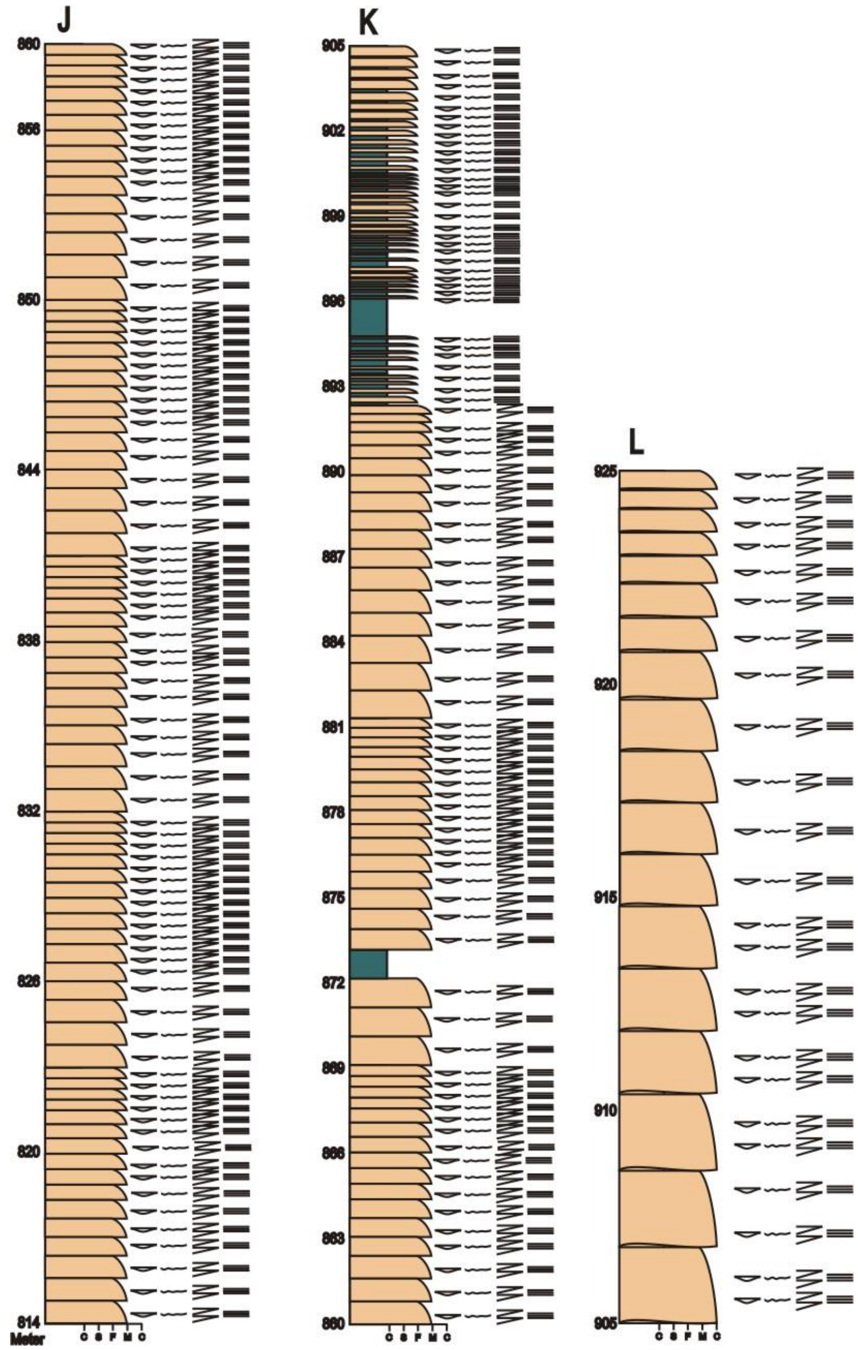


Fig. 2d (See Fig. 2a for symbols)



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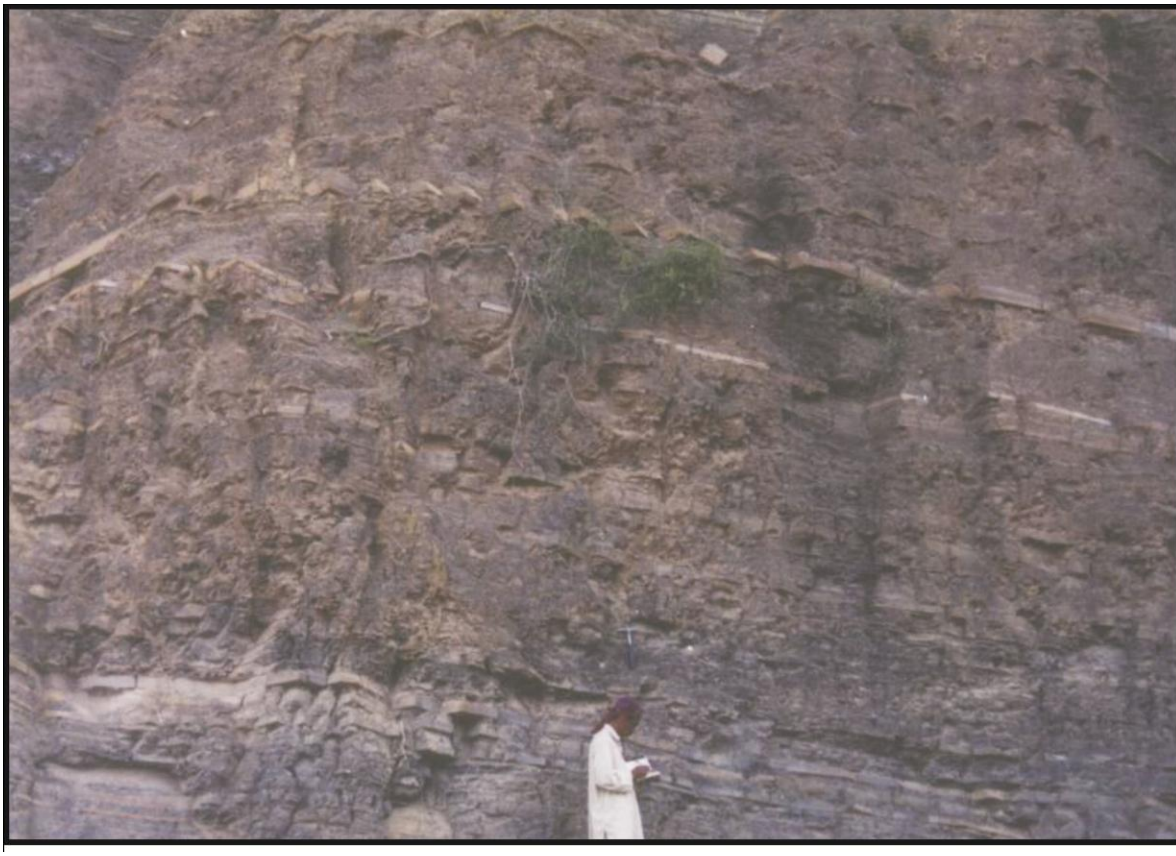

Fig. 3 Field photograph showing mudstone dominated sequence of the Mughal Kot Formation with beds of sandstones

GEOLOGICAL SETTING OF SULAIMAN THRUST AND FOLD BELT

The study area (Fig. 1) is located within the Western Sulaiman Thrust and Fold Belt (Bender and Raza, 1995, Bennert, *et al.*, 1992, Jadoon, 1991, Sarwar and Dejong, 1979 and Wadia, 1953). It includes sedimentary succession from Jurassic to Eocene age (Table 1), which was deposited on the northwestern margin of the Indo-Pakistan Plate. The succession reflects depositional environments and volcanic events before, during and after its collision with Eurasian Plate, (Bender and Raza, 1995, Jadoon, 1991, Otsuki, *et al.*, 1989, Tepponier, *et al.*, 1981 and Powell, 1979). The Paleozoic-Mesozoic succession was intensely deformed during the northward migration of Indo-Pakistan Plate and is now present in the region of the Sulaiman Thrust and Fold Belt with fragments of oceanic crust, island arcs and ophiolites.

Bender and Raza (1995) and Bennert, *et al*. (1992) have systematically subdivided the northwestern margin of Indo-Pakistan Plate into the Sulaiman and Kirthar blocks based on their structural style on satellite images. Also they have divided the region into tectonic-stratigraphic belts such as the West Pakistan Fold-Thrust Belt (Sulaiman and Kirthar Fold-Thrust Belt), the Bela-Waziristan Ophiolite Belt, the Makran-Khojak-Pishin Flysch Zone, the Indus Basin, the Tethyan Belt and Chaghi and Raskoh Belts.

The West Pakistan Fold and Thrust Belt and the associated syntaxial belts (Bender and Raza, 1995; Jadoon, 1991 and Powell, 1979), like the Sulaiman Lobe, are the most distinctive features of the geology of Pakistan, which developed during the collision process when the Indo-Pakistan Plate, also, underwent basement segmentation. The Sulaiman Lobe (Powell, 1979), about 250km wide, is a festoon-shaped belt. It has been established now that the West Pakistan Fold and Thrust Belt formed in the response to the collision of Indo-Pakistan continent with the Eurasia (Bender and Raza, 1995 and Powell, 1979). This thrust and fold belt consists of a thin-skinned wedge of material, as shallow seismicity is associated with it (Molnar and Powell, 1979, Seeber and Jacob, 1977 and Tepponier, 1975). It indicates that little of the underlying Indo-Pakistan Shield is deformed along with the cover sediments. It has been suggested by Bender and Raza, 1995, Bennert, *et al.*, 1992 and

Powell, 1979 that Pre-Cenozoic basement structures like basement faults and associated blocks, like the Kirthar, Sulaiman and Jehlum blocks, have controlled the shape of many of the younger ones.

The Bela-Waziristan Ophiolite (Asrarullah, *et al.*, 1979, Gansser, 1979, Alleman, 1979 and Abbas and Ahmad, 1979) shows fragments of oceanic crust abducted on to the Indo-Pakistan Plate during the Late Cretaceous, just before the Palaeocene. The classic concept of the Tethys (Deitz and Holden, 1970) is taken as a Mesozoic ocean that existed south of the Eurasian Plate. The closure of this ocean gave rise to the Alpine Himalayan Ranges (Sengor and Hsu, 1984, Sengor, 1981, Hsu and Benroulli, 1978). The India-Eurasia suture zone in the northern Pakistan is represented by the Kohistan succession of amphibolites, meta-gabbros and associated volcanics (Tahirkheli, *et al.*, 1979), which represents the crust of a classic alkaline island-arc. During suturing of India and Eurasia (the Hindukush-Karakoram blocks) the Kohistan Arc was abducted on to the Paleozoic cover of Indo-Pakistan Shield over the Main Mantle Thrust (MMT). Toward the south, the MMT separates the Kohistan Island Arc Complex from the Indo-Pakistan Plate, while to the north the Main Karakoram Thrust (MKT) separates the Kohistan Arc from rocks of the Eurasian Plate. The MMT and MKT are characterized by the outcrops of meta-volcanics and ophiolitic mélanges that record suturing of the arc to the Indo-Pakistan Plate in the south and the Eurasian Plate in the north.

The Sulaiman Thrust and Fold Belt, which includes the study area (Fig. 1), contains succession of sedimentary and volcanic rocks, which range from Triassic to Recent age, out of which we are focusing mainly on the petrography and provenance of the Upper Cretaceous Mughal Kot Formation and Pab Sandstone.

LITHOSTRATIGRAPHY

A detailed account of lithostrati-graphy of the Upper Cretaceous Mughal Kot Formation and Pab Sandstone is presented in the following lines:

Mughal Kot Formation

The Mughal Kot Formation is about 600m thick in the Siazgi area and comprises dominantly shale in the basal part with sandstone packages in the upper portion (Fig. 4). The basal 400 m thick portion consists of shale, which is brownish grey and grayish green in color, pelagic in nature and parallel laminated. This pelagic shale grades upward into silty shale in the upper 200 m thick portion, where it is interbedded with arenaceous limestone. This portion contains three sandstone packages too. The silty shale is of yellowish to greenish color and parallel laminated. The arenaceous limestone is of grey color, nodular with wavy upper surfaces and obvious parallel and cross-stratification. Also small shell fragments and intraclasts observed in almost all beds. The sandstone is yellowish grey, thin to thick bedded (5-60cm) and medium to coarse grained. The sandstone beds of every package are amalgamated and preserve well developed cross-bedding and parallel lamination. Cross bedding is of low to high angle (10-27o). Thickening upward trend is common feature of sandstone packages. The uppermost sandstone package contains mud intraclasts, bioturbation and very thin interbeds of silty shale.

Pab Sandstone

The Pab Sandstone of Mughal Kot Section is 204m thick (Figs. 2b, 2d and 2e) and consists of medium to thick bedded, off white, light grey color, medium to fine grained and quartz rich sandstone with subordinate shale. The shale is greenish grey to grayish and highly bioturbated .The sandstone contains mud clasts and intercalations of calcareous mud in the basal part. Parallel lamination, cross-lamination, erosive bases, beds amalgamation, channel morphology, truncation of the underlying strata and both fining and thinning upward trend are the common features of the formation. Few beds of thickening upward trend in the upper part of the formation have also been observed. The Pab Sandstone in the Mughal Kot Section can be divided into four facies: (1) Pro-delta facies, (2) Delta front sandstone facies, (3) Hummocky cross-stratified sandstones facies and (4) Sigmoidal cross-stratified sandstones facies.

The Pab Sandstone at the Gwal Haiderzai Section is 124 m thick (Fig. 5) which occurs at the top of the section. It dominantly comprises light grey sandstone (Fig. 6) with subordinate maroon shale and few limestone beds in the lower part. The sandstone is thin to thick bedded (10 to 160cm), light gray, medium to fine grained and amalgamated with wavy tops. Individual sandstone beds show slight grading, parallel, and cross-lamination, ripple marks at the top and flutes and load casts at the base (Fig. 7). Thickening upward trend is the common feature. The interbedded shale and marls are maroon, dark brown and reddish brown with widespread boiturbation however, parallel lamination has also been observed.

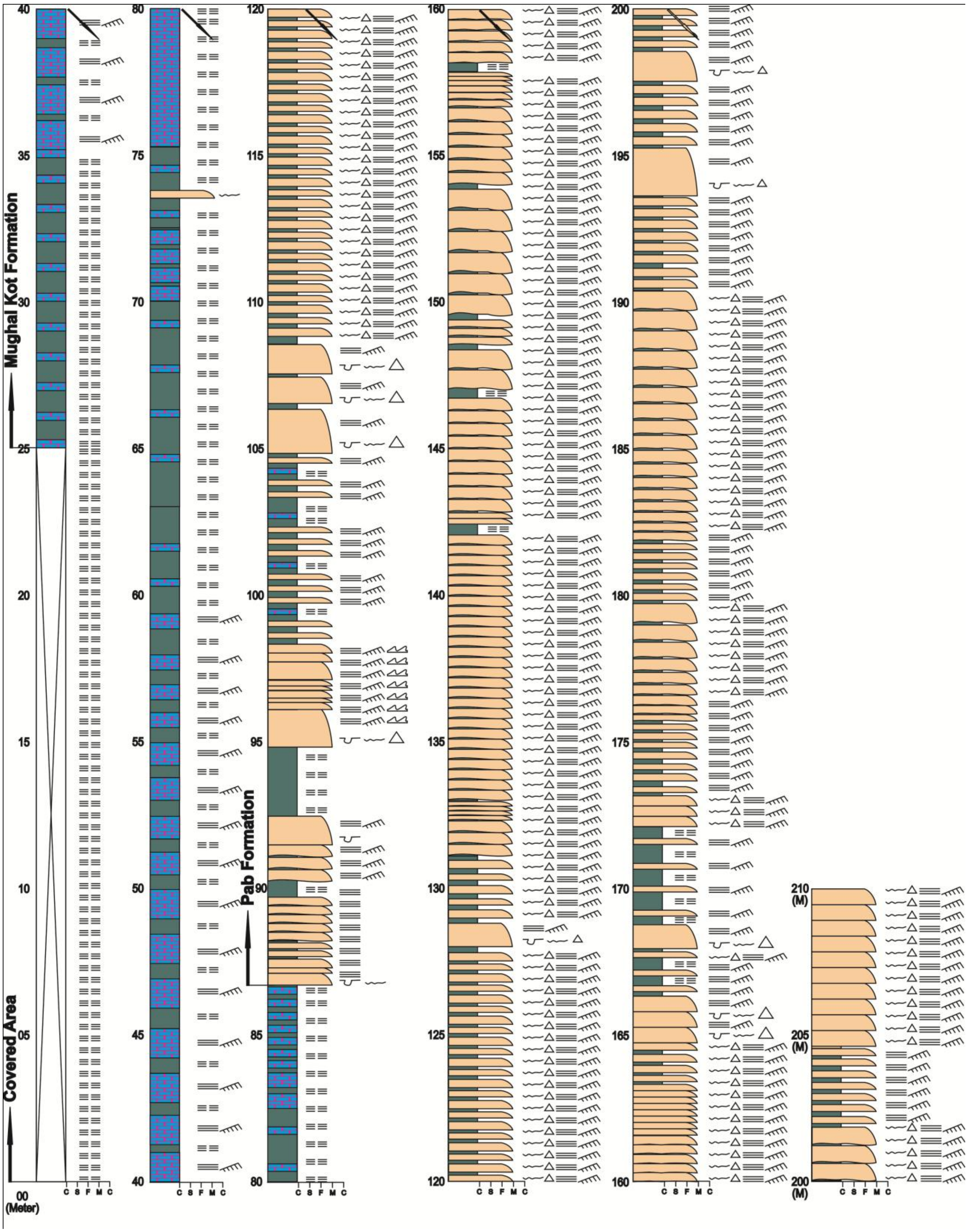

Fig. 4 Sedimentary logs of the Gwal Haiderzai Section (See Fig. 2a for symbols)

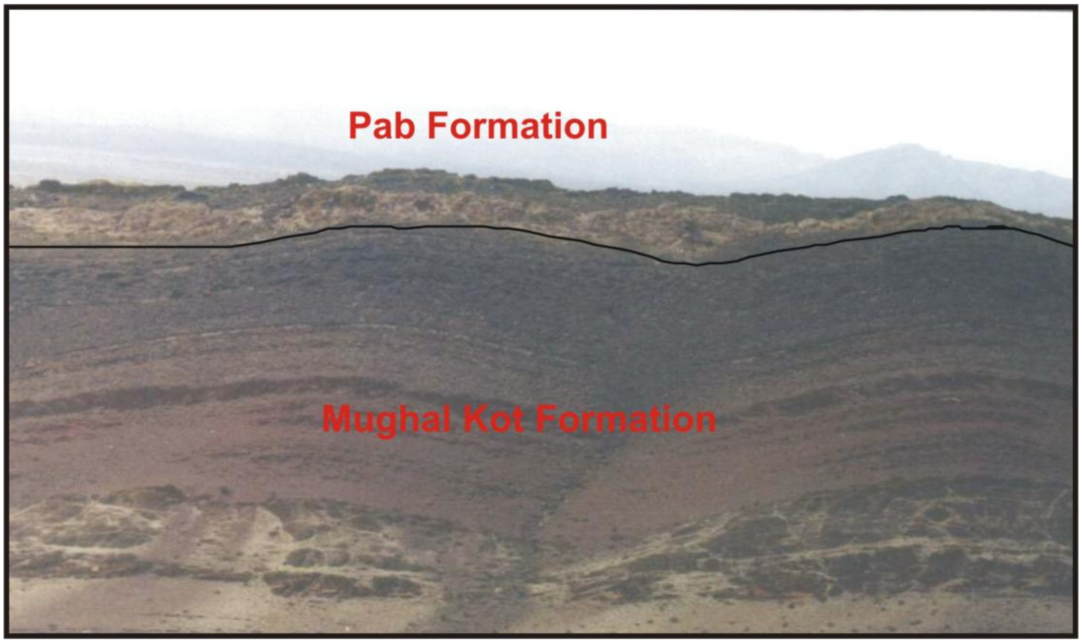

Fig. 5 Field photograph showing general view of the Upper Cretaceous Mughal Kot Formation (green and maroon) and Pab Sandstone at top (light gray) exposed at the Gwal Haiderzai Section and representing prodelta and delta sequence respectively.

Fig. 6 Field photograph showing the flute marks at the base of a thick sandstone bed of the Pab Sandstone indicating paleo-current direction 260^{o} towards west

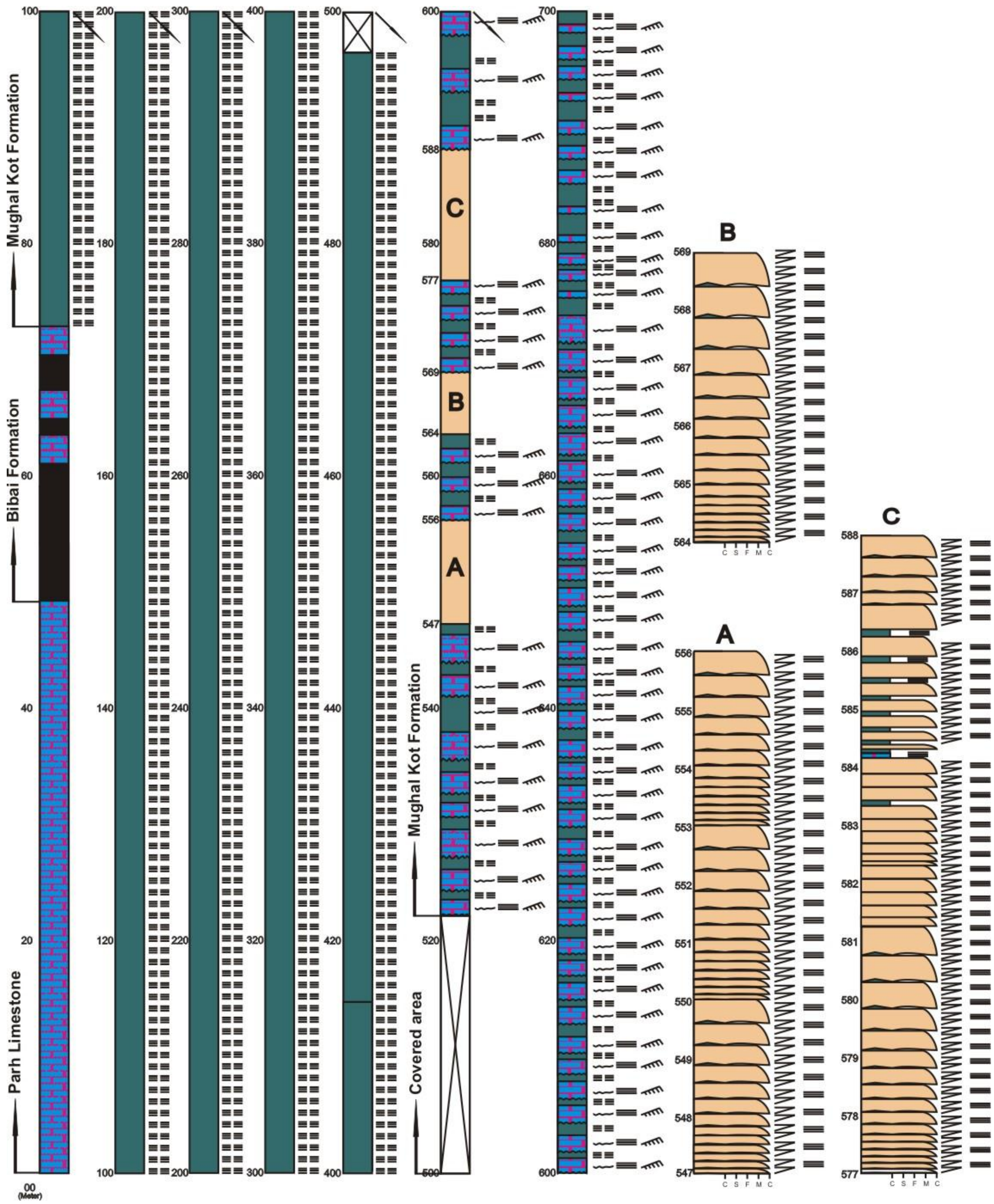

Fig. 7 Sedimentary logs (A, B and C) of the Siazgi Section along with their enlarged version (see Fig. 2a for symbols)

PETROGRAPHY

The petrographical and provenance studies of the sandstones were carried out in order to understand detritus modes and palaeo-climatic conditions of the source area. Composition of sandstones is controlled by characteristics of the source rocks that include composition, climate and topography of the source area. Detritus modes of sandstones provide information about tectonic setting of the basin of deposition and associated provenance.

Modal analyses of the sandstones were carried out for the purpose of classification and to understand provenance of the rocks. 500 points were counted in each thin section using Gazzi Dickinson Method to minimize the effect of grain size (Ingersol, *et al.*, 1984), which was converted into percentage (Table 2). Constituent minerals of sandstones were classified into mono-crystalline quartz, polycrystalline quartz, K-feldspar, plagioclase, rock fragments.

Mughal Kot Formation

The petrographic analyses of studied sections of the Mughal Kot Formation are narrated below:

Mughal Kot Section: Seven representative samples of sandstone were selected for petrographic study from the sandstone packages of Mughal Kot Formation. These sandstones are very fine to fine grained, sub-angular to sub-rounded, poor to well sorted in the lower packages, and fine to medium grained, sub-angular to sub-rounded and poorly to fairly sorted, in the upper packages. They are composed of monocrystalline and non-undulose quartz, very minor amount of K-Feldspar, plagioclase (Figs. 8A and 8B) and few iron oxide grains, fossil fragments, calcite fragments, siltstone fragments and dark green non-pleochroic heavy mineral-tourmaline (Figs. 8C and 8D). Cementing material is sparry calcite and iron oxide (Figs. 8E and 8F).

Siazgi Section: The sandstone of the Mughal Kot Formation is medium to coarse grained, fairly to well sorted, moderately to well rounded and well cemented. It is composed mainly of quartz grains with very minor proportion of k-feldspar, iron oxide grains and carbonate rock fragments. Quartz grains are mono-crystalline, having non-undulose extinction. Cementing material is sparry calcite and iron oxide. In some cases calcite is replacing quartz (Fig. 9A).

Pab Sandstone

The petrographic analyses of studied sections of the Pab Sandstone are described in the following:

Mughal Kot Section: Six representative samples of sandstone were selected for petrographic study from the Pab Sandstone. The Pab Sandstone is medium to coarse grained, in places fine to medium grained, poorly to fairly sorted, sub-angular to sub-rounded and grain supported. Minor proportion of k-feldspar and occasionally iron oxide grains observed. Quartz grains are mostly mono-crystalline and occasionally polycrystalline, having non-undulose extinction. Overgrowth quartz (Fig. 9B) and Quartzite (Fig. 9C) are also present in some rocks. Cementing material is quartz and sparry calcite.

Gwal Haiderzai Section: At this section the sandstone of the Pab Sandstone is fine to medium grained, fairy to well sorted, sub-angular to sub-rounded and grain supported to cement supported. It is composed mainly of quartz grains with minor proportion of k-feldspar (microcline) (Fig. 9D and 9E) and occasionally iron oxide grains and carbonate rock fragments. Quartz grains are mono-crystalline, having non-undulose extinction. Some rocks contain fragments of granite (Fig. 9F). Cementing material is iron oxide and sparry calcite.

Modal Analaysis and Classification of Studied Sandstones

Acquired results (Tables 2 and 3) were plotted on triangular diagrams (Figs. 10 and 11) after Dots (1964) and Folk (1980). It may clearly be seen that all samples of the Pab Sandstone of both the Mughal Kot Section and Gwal Haiderzai Section plot into the field of quartz arenite. Beside it three samples of Mughal Kot Formation of the Mughal Kot Section and one sample of Mughal Kot Formation of Siazgi Section, also, plotted into the field of quartz arenite. Although two samples of Mughal Kot Formation, three samples of Fort Munro Formation of Mughal Kot Section and one sample of Mughal Kot Formation of Mazu-Urghargai Ghar Section plotted into the fields of lithic and sub-lithic arenites.

DISCUSSION

The petrography of sandstones and detritus modes plotted in discrimination diagrams indicate derivation from craton interior and recycled orogen. The sandstones are classified as quartz arenites. The predominance of quartz in the sandstone indicates severe chemical weathering and possibly a long transport distance (Anani, 1999). The predominance of non-undulose mono-crystalline quartz over polycrystalline quartz suggests that the sandstone were derived from acidic plutonic igneous source (granite). The presence of tourmaline and zircon support the notion that sediments were derived from acidic igneous source. The paleocurrent direction towards NW indicates that sediments were derived from the Indian Basement located to east-southeast of study area. During Late Maastrichtian, the Indo-Pakistan Plate passed over a hot spot, thermally uplifting the area, which shed huge amount of sediments to the basin (Hedley, *et al.*, 2001).

DEPOSITIONAL HISTORY

The Sulaiman Thrust-Fold Belt was formed as the result of collision between the Indian Continent in the west and Eurasian Plate in the east and north. Before collision this mountain fold belt acted as passive margin till Late Eocene. The collision started in Early Eocene and completed in Pliocene to Pleistocene (Waheed and Well, 1992 and 1990). This margin was created when a fragment consists of India and Madagascar to the east was separated from the Africa to the west during Early Jurassic times. The margin experienced complex tectonic deformation since its formation. The depositional history of this passive margin starts from the Mid-Jurassic times when thick shallow limestones of the Shirinab Formation and the Chiltan Limestone (Shah, 1977) deposited. A regional disconformity and its time equivalent paraconformity (in the distal part of the basin) represented by laterite and omission surface respectively lies on the top of Jurassic Limestone. During Early Cretaceous pelagic sediments in form of black shales of the Sembar Formation followed by pelagic limestone, marls and shales of the Goru Formation were accumulated (Shah, 1977). Pelagic sedimentation continued with the deposition of thin bedded Parh Limestone of slope setting up to Early Campanian. In Early to Late Cretaceous the western margin of the Indo-Pakistan plate was separated from the Madagascar and Indo-Pakistani Plate started rapid moving towards north (Gnos, *et al.*, 1997 and Scotese, *et al.*, 1988). During this time the Indo-Pakistani passive margin was greatly affected by active normal faults. In the Sulaiman Fold Belt, the Late Cretaceous succession (Mughal Kot Formation, Fort Munro Formation and Pab Sandstone) was deposited in environments ranging from upper shelf to submarine slope. When the Indo-Pakistani Plate was passing over Reunion hot spot during Late Cretaceous, the Indo-Pakistan Shield area to the east was thermally uplifted and huge amount of sand-rich sediments were supplied to the basin and deposited as Mughal Kot, Fort Munro and Pab formation. This caused overall progradation in the basin and a regional disconformity was developed in the shelf area all along the margin. This is evident from the Ziarat laterites cropping out at the boundary of Parh Limestone and Palaeocene Dunghan Formation (Shah, 1977). Clastic materials supplied from the thermally uplifted shield area were deposited in tectonically controlled different setting.

In the southernmost part of the Kirthar Thrust and Fold Belt the Late Cretaceous sediments were deposited as turbidites in submarine fan systems (Khan, *et al.*, 2002), while in the northern part of the southern Kirthar Fold Belt (referred here as Khuzdar Basin) these sediments were deposited in shelf edge delta and clastic ramp setting. There is no clastic deposition (Mughal Kot and Pab sediments) in the northern Kirthar Fold Belt (from Khuzdar to Quetta). This is probably due to Paleo-Jacobabad High that did not allow accommodation for deposition. Mughal Kot and Pab sediments were deposited in the Sulaiman Fold Belt more or less in similar setting as observed in the Kirthar Fold Belt. It is thick in the eastern Sulaiman Fold Belt and thins out in the western Sulaiman Fold Belt. In the proximal parts (to the east), it is fluvial to shallow marine (Sultan and Gipson, 1995) while in the distal sequences (to the west) it shows characters of submarine slope and basin turbidites (Kassi, *et al.*, 2000). During the very Late Cretaceous hot spot related volcanic activity increased in the southern most vicinity of the margin that led to supply volcanic fragments of the basin and ended up with the detachment of Seychelles microplate from the Indo Pakistan Continent and formation of Deccan flood basalt. Supply of coarse clastic sediments to the basin was reduced during Palaeocene as a result of transgression and pelagic shales and limestones were deposited on the lower shelf to upper shelf setting (Ranikot and Dunghan formations).

Collision between Indo-Pakistan Plate and Eurasian Plate resulted in the uplifting of Himalayan Mountain Belt on the northern margin and Sulaiman and Kirthar Mountain Belts on the western margin. Compressional deformations continued till Pliocene to Pleistocene and were recorded in imbricate thrust sheets in the Sulaiman and Kirthar Thrust and Fold Belts.

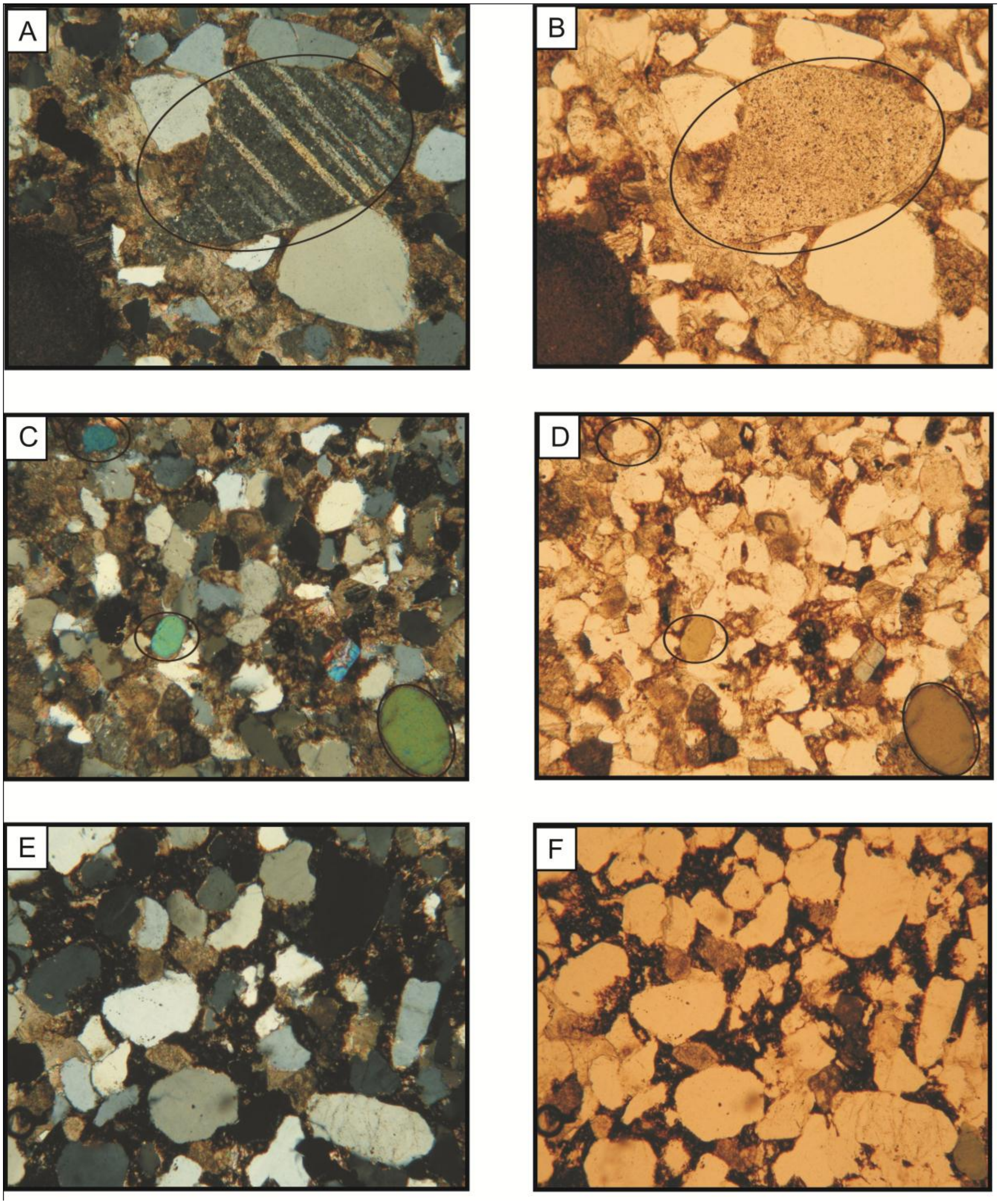

Fig. 8 **P**hotomicrographs of: **A**) Palgioclase(ellipsed). Magnification 10 × 10 × 06, under XN, **B)** Plagioclase (ellipsed). Magnification 10 × 10 × 06, PPL, **C)** Tourmaline (circled). Magnification 10 × 10 × 06, under XN, **D**) Tourmaline (circled). Magnifaction 10 × 10 × 06, under PPL, **E)** Iron Oxide, as cementing material among the quartz grains. Magnification 10 × 10 × 06, under XN and **F)** Iron Oxide, as cementing material among the quartz grains. Magnification 10 × 10 × 06, under PPL

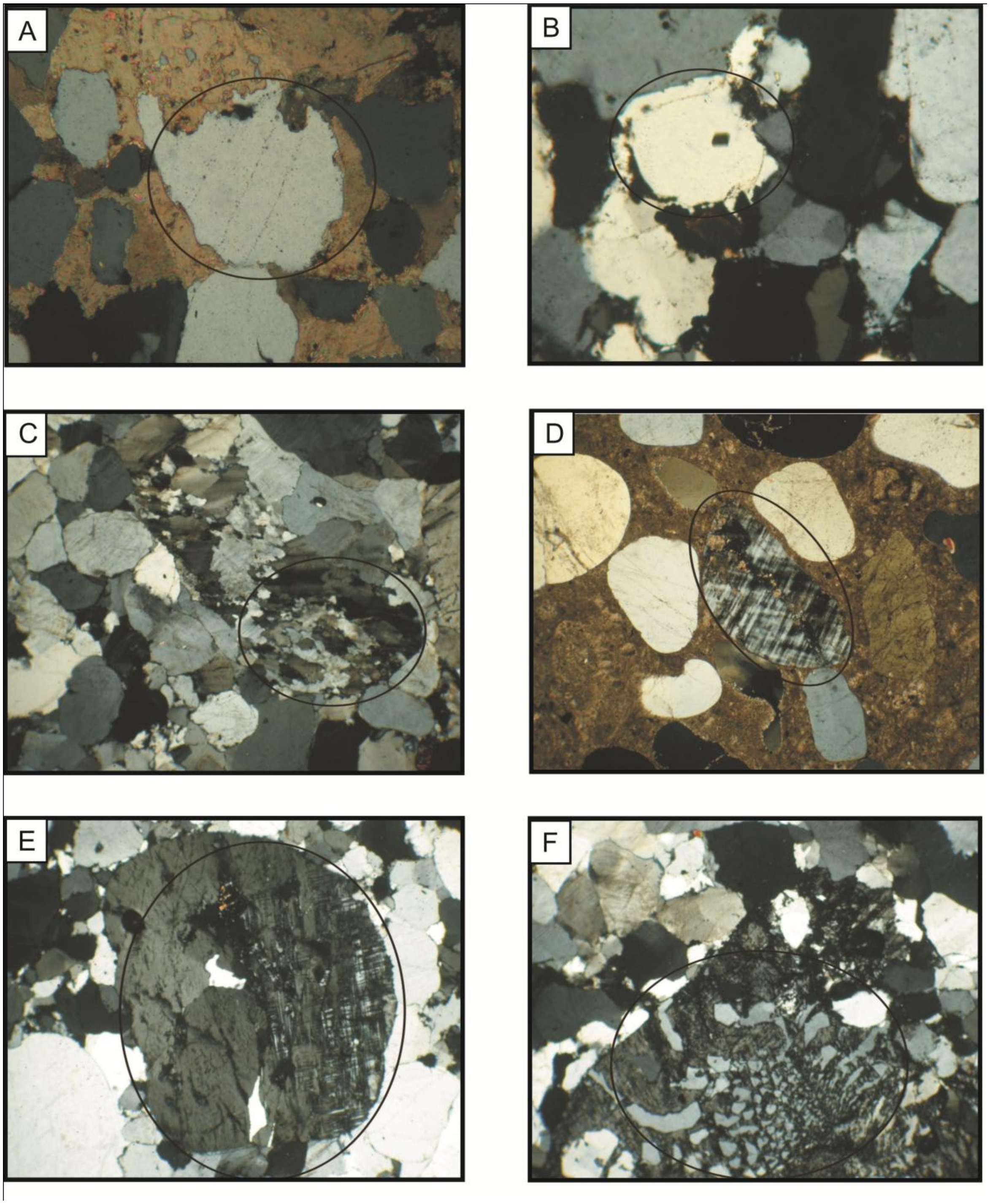

Fig. 9 Photomicrographs of: **A)** Corroded edges of quartz grain (circled). Magnifiction 10 × 10 × 12, under XN, **B)** Quartz overgrowths (circled). Magnification 10 × 10 × 12, under XN**, C)** Quartzite (circled). Magnification 10 × 04 × 06, under XN, **D)** Microcline (ellipsed). Magnification 10 × 04 × 06, under XN, **E)** Microcline (ellipsed). Magnification 10 × 04 × 06, under XN and **F)** Graphic granite fragment (ellipsed), surrounded by quartz grains. Magnification 10×04×06, XN

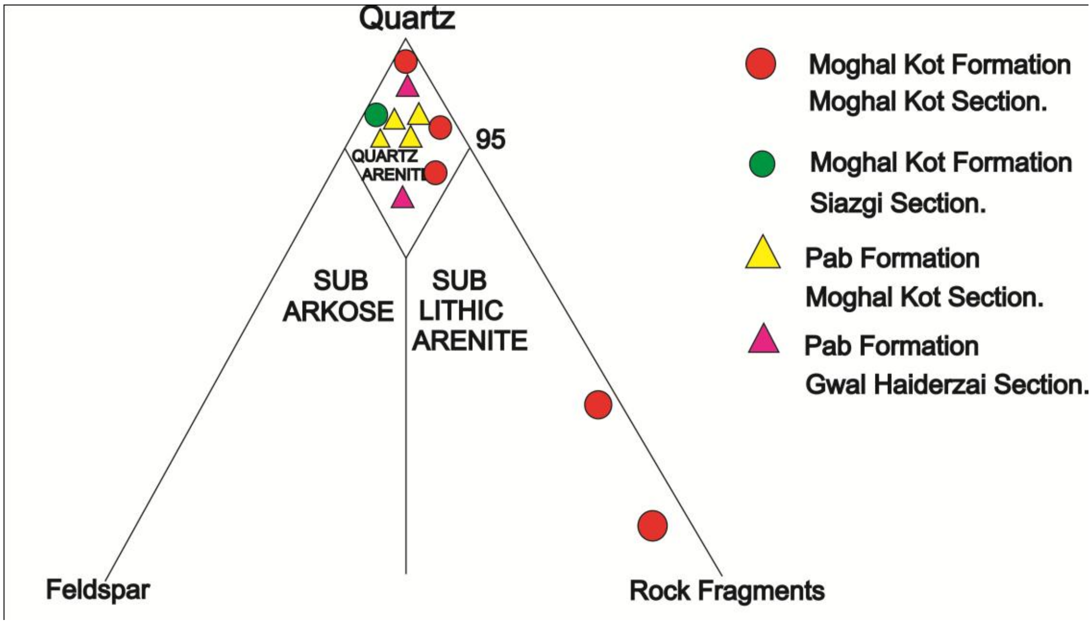

Fig. 10 Results of the model analyses plotted on to the triangular diagram of classification of sandstones (Modified after Dott, 1964). Upper parts show a close-up of the quartz arenite, sub-arkose and sub-lithic arenite fields.

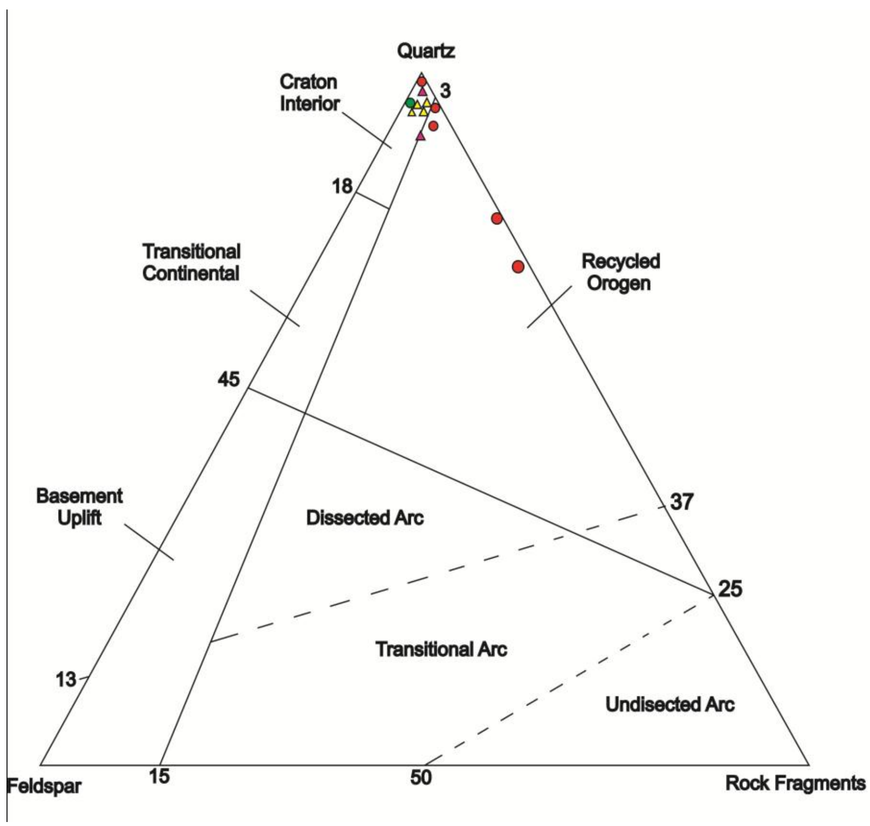

Fig. 11 QFL compositional diagram (modified after Dickinson and Suzek, 1979) of sandstones of the Mughal Kot Formation and the Pab Formation in the various sections of the study area. Note that all the samples plot in the fields of craton inteior and recycled orogen.

Table 2 Results of Point counting of the Sandstone of the Mughal Kot Formation and Pab Sandstone of the Study Area, Sulaiman Fold and Thrust Belt

CLASS	**Mughal Kot Type Section**																
	Mughal Kot Formation									**Pab Sandstone**							
	AFZ 15		**AFZ 17**		**AFZ 20**		**AFZ 21**	**AFZ 23**		**AFZ 32**		**AFZ 33**		**AFZ 34**		**AFZ 36**	
	No. of Counts	**% age**	**No. of Counts**	**% age**	**No. of Counts**	**% age**	**No. of Counts**	**No. of Counts**	**% age**	**No. of Counts**	**% age**	**No. of Counts**	**% age**	**No. of Counts**	**% age**	**No. of Counts**	**% age**
Quartz (m)	251	50.2	281	56.2	345	69.0	263	267	53.4	415	83.0	412	82.4	330	66.0	460	92.0
Quartz (p)	00	00.0	00	00.0	02	00.4	01	00	00.0	16	03.2	00	00.0	18	03.6	04	00.8
Feldspar	01	00.2	03	00.6	00	00.0	00	06	01.2	07	01.4	04	00.8	08	01.6	21	04.2
Calcite Cement	162	32.4	124	24.8	148	29.6	194	161	32.2	00	00.0	00	00.0	132	26.4	00	00.0
Quartz Cement	00	00.0	00	00.0	00	00.0	00	00	00.0	31	06.2	17	03.4	00	00.0	13	02.6
FeO Cement	27	05.4	00	00.0	04	00.8	31	54	10.8	23	04.6	66	13.2	09	01.8	02	00.4
R.F. Carbonate	53	10.6	76	15.2	00	00.0	05	04	00.8	00	00.0	00	00.0	02	00.4	00	00.0
R.F. Other	06	01.2	16	03.2	01	00.2	06	08	01.6	08	01.6	01	00.2	01	00.2	00	00.0
Matrix	00	00.0	00	00.0	00	00.0	00	00	00.0	00	00.0	00	00.0	00	00.0	00	00.0
Total	**500**	**100.0**	**500**	**100.0**	**500**	**100.0**	**500**	**500**	**100.0**	**500**	**100.0**	**500**	**100.0**	**500**	**100.0**	**500**	**100.0**

Table 2 continued……

CLASS	SIAZGI SECTION				GWAL HAIDERZAI SECTION					
	Pab Sandstone				Mughal Kot Formation					
	AFZ 54		AFZ 56		AFZ 65		AFZ 66		AFZ 67	
	No. of Counts	% age	No. of Counts	% age	No. of Counts	% age	No. of Counts	% age	No. of Counts	%age
Quartz (m)	403	80.6	350	70.0	308	61.6	127	5.4	95	19.0
Quartz (p)	02	00.4	00	00.0	00	00.0	00	00.0	00	00.0
Feldspar	05	01.0	19	03.8	04	00.8	02	00.4	01	00.2
Calcite Cement	72	14.4	88	17.6	152	30.4	09	01.8	14	02.8
Quartz Cement	00	00.0	00	00.0	00	00.0	00	00.0	00	00.0
FeO Cement	16	03.2	31	06.2	30	06.0	10	02.0	17	03.4
R.F. Carbonate	02	00.4	03	00.6	02	00.4	00	00.0	02	00.4
R.F. Other	00	00.0	09	01.8	04	00.8	352	70.4	371	74.2
Matrix	00	00.0	00	00.0	00	00.0	00	00.0	00	00.0
Total	**500**	**100.0**	**500**	**100.0**	**500**	**100.0**	**500**	**100.0**	**500**	**100.0**

Table 3. Recalculated Percentage Values of the QFL (Modified after Dott, 1964)

Sp. No.	Section	Formation	Quartz	Feldspar	Rock Fragments	Total
AFZ 15	MUGHAL KOT SECTION	Mughal Kot Formation	80.70	00.32	18.97	99.99
AFZ 17			74.73	00.79	24.46	99.98
AFZ 20			99.71	00.00	00.28	99.99
AFZ 21			96.00	00.00	04.00	100.0
AFZ 23			93.68	02.10	04.21	99.99
AFZ 32		Pab Sandstone	96.63	01.56	01.79	99.98
AFZ 33			98.80	00.95	00.23	99.98
AFZ 34			96.93	02.22	00.83	99.98
AFZ 36			95.67	04.32	00.00	99.99
AFZ 54	GWAL HAIDERZAI SECTION	Pab Sandstone	98.30	01.21	00.48	99.99
AFZ 56			91.86	04.98	03.14	99.98
AFZ 65	SIAZGI SECTION	Mughal Kot Formation	96.85	01.25	01.88	99.98
AFZ 66			26.40	00.41	73.18	99.99

CONCLUSIONS

Based on the discussions regarding field data and laboratory investigations the following conclusions are drawn:

- The Upper Cretaceous Succession (Mughal Kot Formation, Fort Munro Formation and Pab Sandstone) was deposited in deeper to shallow marine conditions, showing an east to west transition from fluvial-deltaic to slope facies dominated by hyperphycanal flows generated at the mouth of rivers during times of catastrophic floods, and influenced by episodic storm waves. It displays many of the features associated with a delta-fed clastic ramp.
- The Upper Cretaceous Succession was formed during a broadly regressive phase, marked by an overall shoaling trend. This is reflected in the thickening upwards cycles and also in the overall upwards increase of grain size, bed thickness, frequency of hummocky bedforms and low angle cross stratification.
- Paleo-flow, predominantly to the W and NW as evidenced by the flute casts present at the base of thick sandstone beds, together with sandstone petrography, suggests supply from the uplifting Indian basement to the east with input of carbonate from the shelf area.

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