

Revised lithostratigraphy of the Pishin Belt, northwestern Pakistan

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Abstract

The Pishin Belt is divisible into six tectono-stratigraphic zones bounded by major thrusts and/or unconformities; each zone having its distinct lithostratigraphy. Muslim Bagh Ophiolite is the base and Zone-I of this belt. Zone-II comprises the Eocene Nisai Formation and Oligocene Khojak Formation. The newly proposed Miocene Dasht Murgha group comprises Zone-III, the Miocene-Pliocene Malthanai formation comprises Zone-IV, the Pleistocene Bostan Formation makes Zone-V, and the flat-laying Holocene deposits of the Zhob valley comprise Zone-VI. The role of tectonics on sedimentation and stratigraphy of the Pishin Belt is evident from composition of the Neogene succession, which contains clasts of Muslim Bagh Ophiolite, and Nisai and Khojak formations, reflecting uplift of the pre-Miocene succession that supplied detritus for the younger fluvial sediments of the Dasht Murgha group, Malthanai and Bostan formations. In general, the tectono-stratigraphic zones and their bounding thrusts within the Pishin Belt are progressively younger towards south and southeast. We propose that tectonic uplift and east-southeastward transport of hanging walls of the major thrusts caused subsidence of the footwalls, which provided accommodation for development of the younger fluvial systems in which the Dasht Murgha group, Malthanai formation, Bostan Formation and the flat-laying Holocene deposits of the Zhob valley were deposited respectively.

Keywords: Lithostratigraphy; Pishin Belt; Tectono-stratigraphic Zones; Younger fluvial systems

1. Introduction

The Khojak-Pishin Flysch Belt (Fig. 1) is the northeastern segment of the Makran-Khojak-Pishin Flysch Belt of Bender and Raza (1995). To the north of Quetta, the N-S trending Khojak-Pishin segment bends to the northeast around Quetta Syntaxis into the NE-SW trending Pishin Flysch Belt (Powell, 1979; Sarwar and DeJong, 1979). It is bounded in the west and northwest by the well-known Chaman Fault, which separates the belt from the Afghan Block of the Eurasian Plate (Lawrence et al., 1981; Jadoon and Khurshid, 1996), and in the east and southeast by the Zhob valley Thrust (Figs. 1 and 2). Structurally, it is a wide southeast convex belt comprising several thrust-bounding stratigraphic zones. The belt has been folded into tight narrow anticlines and broad synclines (Iqbal, 2004)

representing transpressional to compressional deformation styles from its western edge to the eastern limits. As a whole the belt has been translated to the southeast, along Zhob thrust, over the western passive margin of the Indian Plate (Lawrence and Yeats, 1979; Lawrence et al., 1981; Treloar and Izatt, 1993; Bender and Raza, 1995; Jadoon and Khurshid, 1996; Kazmi and Jan, 1997). We prefer to use the name Pishin Belt, as it also comprises sedimentary successions of shallow marine carbonates, as well as flysch and mollase-type sediments that range from Late Palaeocene to Holocene.

In this paper we propose a revised lithostratigraphy of the Pishin Belt based on our field observations as well as previously published literature. Bed thicknesses are categorized according to the classification scheme of Ingram (1954).

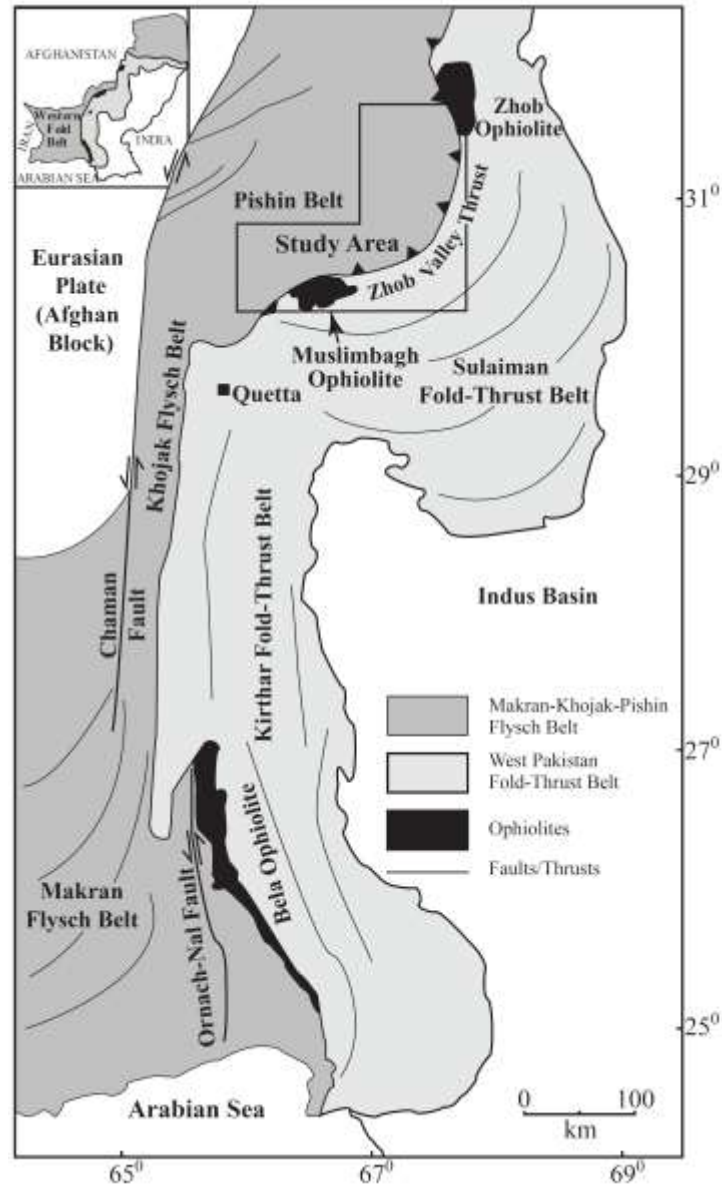


Fig. 1. Generalized geological map of the western part of Pakistan showing the position of Pishin Belt and study area.

2. Lithostratigraphy

The belt is subdivided into six tectono-stratigraphic zones bounded by major thrusts, which evolved in response to continued compressional tectonics (Fig. 2), each zone has its distinct lithostratigraphy (Table 1). The Muslim Bagh-Zhob Ophiolite and associated mélanges exposed along the northwestern margin of the Indian Plate marks the base and Zone-I of this belt. On top of the Muslim Bagh Ophiolite lies Zone-II, comprising the Eocene Nisai Formation (Hunting Survey Corporation, 1960; Cheema et

al., 1977) and the Oligocene-Early Miocene Khojak Formation (Bender and Raza, 1995). The Nisai Formation has a non-conformable contact with the underlying Muslim Bagh Ophiolite and is conformably overlain by the Khojak Formation. The newly proposed Early-Middle Miocene Dasht Murgha group, which is divided into the lower Khuzhobai formation, the middle Bahlol Nika formation and the upper Sra Khula formation, constitutes the Zone-III. The Dasht Murgha group overlies the Nisai Formation with angular unconformity. The Late Miocene-Pliocene Malthanai formation makes up Zone-IV. Its lower

and upper contacts with the Nisai Formation are thrust. The Pleistocene Bostan Formation (Hunting Survey Corporation, 1960) makes up Zone-V. Its contact with the Malthanai formation is also thrust. Further, the flat-laying Holocene Zhob Valley deposits comprise Zone-VI of the belt, which has thrust contact with the Pleistocene Bostan Formation.

2.1. Zone-I

2.1.1 Muslim Bagh Ophiolite

The Muslim Bagh Ophiolite is exposed in the

Zhob Valley northeast of Quetta (Figs. 1 and 2). It is part of Bela-Muslim Bagh-Zhob-Waziristan Ophiolite Belt at the northwestern margin of the Indian Plate (Siddiqui et al., 1996; Jadoon and Khurshid, 1996).

Vredenburg (1901) reported and mapped the Muslim Bagh Ophiolite for the first time. Hunting Survey Corporation (1960) prepared their reconnaissance map and Rossman et al. (1971) compiled their detailed map. More recently Khan et al. (2007b) carried out more precise mapping of the Muslim Bagh Ophiolite using remote sensing and GIS applications.

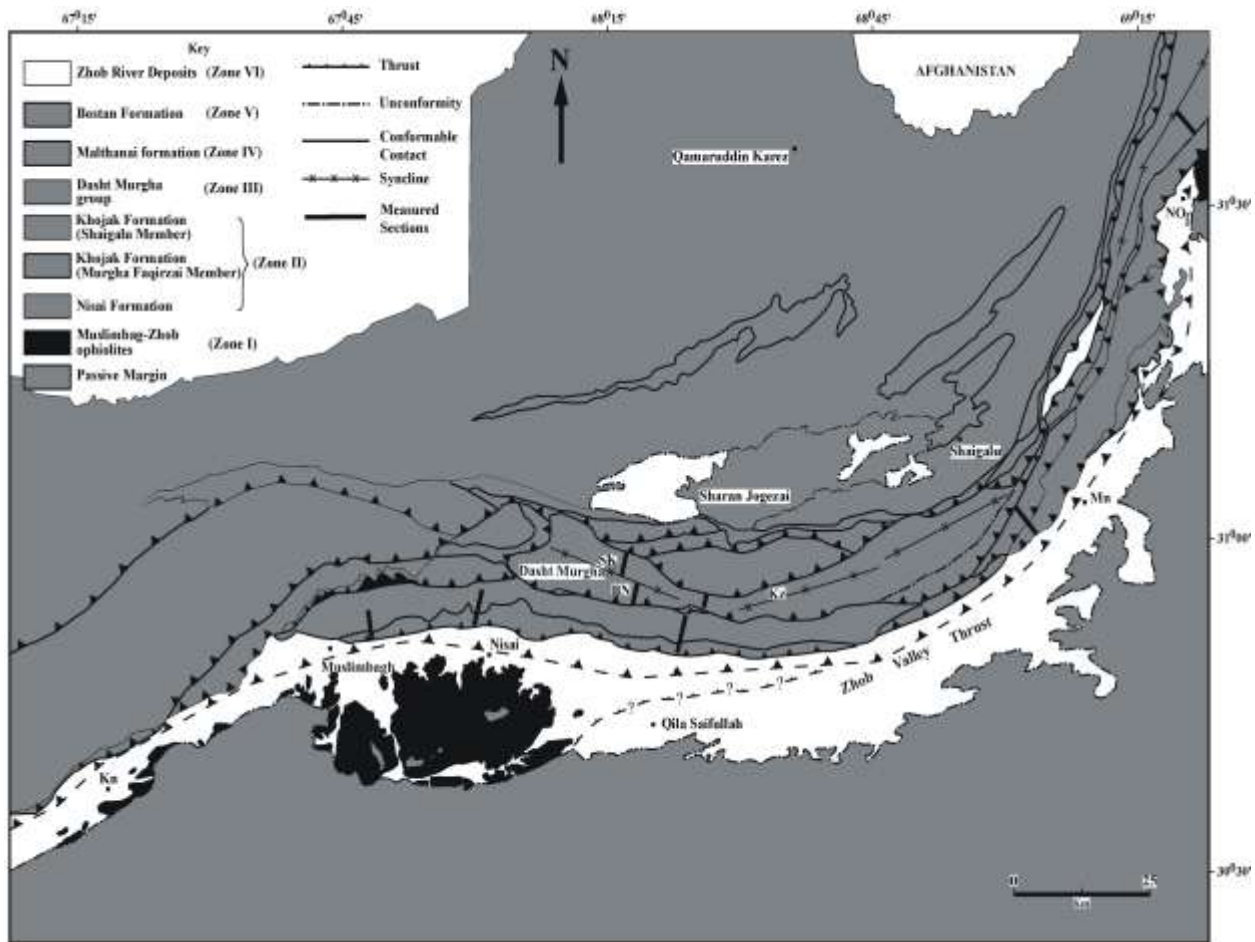


Fig. 2. Proposed geological map showing tectono-stratigraphic zones and lithostratigraphy of the study area (modified after the Hunting Survey Corporation, 1960). Abbreviations used are: BN (Bahlol Nika), Kn (Khanozai), Kz (Khuzhobai), Mn (Malthanai), No (Naweoba), SK (Sra Khula).

Table 1. Proposed tectono-stratigraphic zones and lithostratigraphy of the Pishin Belt and surrounding areas [(modified after the Hunting Survey Corporation (1960) and Cheema et al. (1977)].

Age	Group	Formation/Member	Lithology	Tectono-stratigraphic Zones
Holocene	-	Zhob River Deposits	Conglomerate, sandstone and shale / siltstone	Zone VI
		Thrust		
Pleistocene	-	Bostan Formation	Red colored shale/siltstone, conglomerate and sandstone	Zone V
		Thrust		
Late Miocene-Pliocene	-	*Malthanai Formation	Sandstone/conglomerate interbedded with red colored mudstone/siltstone	Zone IV
		Thrust		
Middle to Late Miocene	**Dasht Murgha Group	Sra Khula Formation Bahlol Nika Formation Khuzhobai Formation	Dark red Mudstone dominated cyclic alteration of mudstone, siltstone and sandstone Dominantly greyish green sandstone, with subordinate mudstone and occasional conglomerate Dominantly maroon mudstone with subordinate reddish brown sandstone	Zone III
		Thrust		
Oligocene – Early Miocene	-	Shaigalu Member Khojak Formation Murgha Faqirzai Member	Dominantly sandstone with subordinate shale Dominantly shale with subordinate sandstone	
Eocene	-	Nisai Formation	Highly fossiliferous to reefoid limestone interbedded with marl and shale and thick marine (fossiliferous) shale with occasional thin limestone horizons	Zone II
		Nonconfirmity		
Cretaceous	-	Muslim Bagh-Zhob Ophiolite	Mostly ultrabasic and basic igneous rocks	Zone I

*The name "Malthanai Formation" has been modified after the Multana Formation of Hunting Survey Corporation (1960).

**The name Dasht Murgha Group has been proposed by the author.

The Muslim Bagh Ophiolite is believed to be a relic of the oceanic floor of the Neo-Tethys, which was obducted onto the Indian Plate subsequent to closure of Neo-Tethys and collision of the Indian Plate with Afghan Block of the Eurasian Plate at the Cretaceous-Tertiary boundary or later in Paleocene-Early Eocene time

(Allemann, 1979; Sarwar, 1992; Ahmed, 1996; Gnos et al., 1996). The age of the emplacement of the Muslim Bagh Ophiolite has been determined as 65-70 Ma by $^{40}\text{Ar}/^{39}\text{Ar}$ dating (Mahmood et al., 1995). The ophiolite consists of an upper and a lower nappes; the upper nappe is composed of ultramafic rocks intruded by gabbro plutons and

dolerite dykes, whereas the lower nappe comprises pillow basalts and sediments underlain by mélangé of ophiolitic rocks and sediments (Khan et al., 2007a). The Muslim Bagh Ophiolite is non-conformably overlain by the Eocene Nisai Formation.

2.2. Zone-II

2.2.1. Nisai Formation

The name Nisai Group was proposed by Hunting Survey Corporation (1960) after the Nisai village for the “black nummulitic limestone” of Vredenburg (1904) and “older nummulitic beds” of Davies (1930). Cheema et al. (1977) redefined the unit as Nisai Formation. A section exposed 12 km north of the Nisai railway station was designated its type section, where it is 1200 m thick (Hunting Survey Corporation, 1960). The Nisai Formation is mainly exposed along the Zhob Valley Thrust, however, it is also widely exposed in the Sharan Jogazai area, west of the Dasht Murgha Syncline (Fig. 2).

The Nisai Formation comprises limestone, marl and shale with subordinate sandstone and conglomerate (Fig. 3a). The formation has been divided into lower, middle and upper parts at the type section (Kazmi and Abbasi, 2008). The Lower part contains dark grey to brownish grey argillaceous limestone and pale grey shale, which contains thin platy beds of white sandy siltstone. The middle part is dominantly shale with subordinate limestone, marl and sandstone. The shale is calcareous, sandy, fissile and pale grey to greenish grey in colour. The sandstone is greenish grey, fine grained and calcareous. The Upper part of the formation contains mainly limestone and sandstone with thin shale and conglomerate layers. The limestone is light grey to light brownish grey and highly fossiliferous. The conglomerate consists of poorly rounded pebbles and boulders of igneous rocks, marl, limestone and jasper.

Hunting Survey Corporation (1960) assigned an Early Eocene to Early Oligocene age to the Nisai Formation based on faunal assemblages. Allemann (1979) studied the oldest carbonate strata overlying the Muslim Bagh Ophiolite and suggested an Early to Middle Eocene age,

whereas Qayyum (1997) assigned a Late Palaeocene to Early Oligocene age on the basis of following foraminiferal assemblages:

Late Palaeocene: *Assilina dandotica*, *Discocyclina ranikotensis*, *Miscellanea stampi*, *Operculina subsalsa* and *Saudia labyrinthica*.

Early Eocene: *Lockhartia hunti* var. *pustulosa*, *Nummulites dolloto* and *Assilina granulosa* (*placentula*).

Early to Middle Eocene: *Assilina granulosa*, *A. granulosa* var. *spinosa*, *A. laminose*, *Nummulites atacicus/dolloti* and *Orbitolites complanatus*.

Early Oligocene: *Nummulites fichteli*.

The Nisai Formation has been deposited in shallow water carbonate platform environment, as well as in deep water slope and basin environments, as revealed by turbidite facies (Qayyum, 1997). The Nisai Formation is conformably overlain by the Khojak Formation.

2.2.2. Khojak Formation

The Khojak Formation, named after the historic Khojak Pass near the town of Chaman, was mapped as Khojak Shale by Vredenburg (1909). Hunting Survey Corporation (1960) divided the formation into a lower shale-dominant succession, the Murgha Faqirzi Member, and an upper sandstone-dominant succession, the Shaigalu Member. Qayyum et al. (1996, 1997a) retained the same classification for the lower shale-dominant succession and upper sandstone-dominant succession. We also prefer to use the same terminology for the upper and lower members. In the Chaman area thickness of the Khojak Formation exceeds 6300 meters.

2.2.2.1. Murgha Faqirzai Member

The Murgha Faqirzai Member is named after the Murgha Faqirzai village of Qila Saifullah District. The Rud Faqirzai section is proposed as the reference section for the Murgha Faqirzai Member, where it is 2000 m thick (Hunting Survey Corporation, 1960).

It is composed dominantly of shale or slate of greenish grey and olive grey colour, interbedded with sandstone, siltstone and occasional beds of shelly limestone. The Lower part of the member is composed of rhythmically interbedded greenish grey

and olive grey shales, sandstone/siltstone. The Middle part is dominated by siltstone, very fine grained sandstone, shale and mudstone. In the upper part shale intervals are very thick. Metamorphism of the sediments is common in the areas that are close to major thrusts, where the shale has been metamorphosed to slate and phyllite, and the sandstone is converted to quartzite and schist.

Hunting Survey Corporation (1960) has assigned it an Oligocene age on the basis of foraminifera. The Murgha Faqirzai Member rests conformably and transitionally on the Nisai Formation, whereas its upper contact with Shaigalu Member is also transitional.

2.2.2.2. *Shaigalu Member*

This member is named after the Shaigalu militia post situated about 50 km southwest of Zhob (Fig. 2) which is also the reference section for the Shaigalu Member (Hunting Survey Corporation, 1960).

The Shaigalu Member is dominantly composed of sandstone interbedded with minor proportion of shale. The sandstone is light grey to greenish grey medium to coarse grained and thick bedded, with some beds up to 10 m thick. Shale is pale green, flaky and calcareous. Qayyum et al. (1996) has divided this member into three parts at the Manzakai section, where it is 3, 950 m thick. The lower part is 661 m thick succession, composed of numerous thickening-up cycles of medium to thick bedded, flat to amalgamated and hummocky-cross bedded sandstone with laminated greenish grey siltstone and shale. The middle part is 698 m thick succession containing numerous fining-up cycles of trough- to planar-cross bedded sandstone interbedded with intensely bioturbated, greenish grey to chocolate brown siltstone and mudstone. The upper part is 591m thick sandstone succession which is thick to very thick bedded, cross bedded, ripple laminated and have scoured into multicoloured mudstone. The mudstone also contains lenses of sandstone, siltstone, rare coal beds and soil horizons.

According to Qayyum et al. (1996) the Shaigalu and Murgha Faqirzai members were deposited in a wave-modified fluvial-dominated delta system. On the basis of foraminiferal assemblages the Hunting

Survey Corporation (1960) assigned an Oligocene age to the Shaigalu Member. Its upper contact is not known in the study area.

2.3. *Zone III*

2.3.1. *Dasht Murgha group*

Because of its occurrence as thrust bound tectono-stratigraphic zone having distinct lithological characters we hereby introduce the name Dasht Murgha group for the beautifully exposed succession in the Dasht Murgha area (Fig. 2), which is hereby designated as its reference section. Previously it had been mapped as the Khojak Formation by the Hunting Survey Corporation (1960). Also successions of the Dasht Murgha group and the Bostan Formation were collectively mapped as a single Sharankar formation by Qayyum et al. (1997a, 2001), on the basis of Landsat Thematic Mapper (TM) imaging and limited field work in the Gardab Manda section, north of Qila Saifullah. We have now clearly differentiated among the Bostan Formation, Malthanai formation and Dasht Murgha group on the basis of our field observations near Muslim Bagh, Nisai, Qila Saifullah and Zhob, including the Gardab Manda section (Figs. 3 and 4; Table 1). We hereby define the Dasht Murgha group, as a distinct lithostratigraphic unit of group status, exposed in a very large and broad syncline that extend from the town of Muslim Bagh to Naweoba, near the town of Zhob, constituting a 130 miles long SE-convex belt on the hanging wall of the Khutkandai-Sur Kach Thrust. In the Naweoba area the group attains maximum thickness reaching up to 4800 meters. Age of the Dasht Murgha group is difficult to determine due to the absence of fossils. On the basis of its tectono-stratigraphic position, i.e. occurrence to the SW of Khojak Formation and overlying the Nisai Formation with angular unconformity, we believe that it may be Early to Middle Miocene. We hereby propose further subdivision of the group into the Khuzhobai, Bahlol Nika and Sra Khula formations on the basis of their distinct lithological characters, which are described below:

2.3.1.1. *Khuzhobai formation*

We have named the Khuzhobai formation after the well-known Khuzhobai spring (N 30° 54' E 68°

30') situated 25 km north of Qila Saifullah on Qila Saifullah-Sharan Jomezai road (Fig. 2, Table 1). The formation is 150 m thick, and we propose the Khuzhobai section as its reference section.

The formation is composed of cyclic successions of sandstone and mudstone (Fig. 3b), however, mudstone is dominant over sandstone and its intervals range from 3 to 30 meters in thickness. It is mostly brownish-red to maroon, however, thin horizons of greenish grey mudstone are also present. It becomes gypsiferous in the upper part of the formation. Sandstone is reddish brown to maroon and mostly fine grained, however, medium to very coarse grained and pebbly beds are also present. It is thin to thick bedded (10 cm to 3 m) and occurs either as thick bedded successions or as thin bedded sandstone-mudstone couplets. Sandstone beds mostly display parallel and cross stratification, however, beds display moderate to intense bioturbation. Beds mostly exhibit channel morphology, erosive bases, lateral accretion and amalgamation.

The formation is more pronounced and consistent towards east, however, it gradually pinches out towards west. The Lower contact of the Khuzhobai Formation is an angular unconformity with the Eocene Nisai Formation, whereas, upper contact with Bahlol Nika formation is transitional and conformable.

2.3.1.2. Bahlol Nika formation

We hereby propose the name Bahlol Nika formation after the Bahlol Nika Ziarat in Dasht Murgha area 30 km northwest of Qila Saifullah (Fig. 2). A stream section south of the Bahlol Nika Ziarat (N 30° 54' 30" E 68° 22' 03") is proposed as its reference section where it is well exposed and up to 1200 m thick.

The Bahlol Nika formation comprises thick succession dominantly of sandstone, with subordinate mudstone, siltstone and occasional conglomerate beds (Fig. 3c). The sandstone is mostly greyish green but subordinately reddish brown. It is mostly fine to medium grained but infrequently coarse to very coarse grained and pebbly. Sandstone is thin to thick bedded in the lower part gradually becoming thick to very thick

bedded (up to 9 m thick) in the upper part. Thick bedded sandstone beds are generally massive. Bioturbation is common and may be slight to intense. The succession displays sedimentary structures such as large scale trough-cross bedding, low-angle cross bedding and parallel lamination, ridges and furrows and iron concretions on top of the beds. Mudstone is greenish grey and maroon in colour and subordinate to sandstone. Mudstone intervals range from a few centimeters up to 20 meters. Occasionally pebbly conglomerate beds are also present within the mudstone or sandstone succession, which are poorly sorted, sub-angular to sub-rounded, clast-supported and their maximum clast size reaches up to 35 cm. The conglomerate contains rip-up clasts of the same formation as well as limestone and sandstone fragments of the older rocks.

Lower contact of the Bahlol Nika formation with the Khuzhobai formation and upper contact with the Sra Khula formation are both transitional and conformable.

2.3.1.3. Sra Khula formation

We hereby propose the name Sra Khula formation, after the village of Sra Khula (N 30° 56' 30" E 68° 18' 35"), in the Dasht Murgha area (Fig. 2, Table 1), where the formation is nicely exposed in the core of the Dasht Murgha Syncline and is up to 700 m thick. The Sra Khula formation is composed of cyclic alterations of mudstone, siltstone and sandstone (Fig. 3d), mudstone exceeds sandstone in proportion, individual mudstone intervals reach up to 165 m in thickness. Mudstone is mostly dark red to maroon. Sandstone is dark brownish grey to reddish brown, mostly coarse to very coarse grained to pebbly and gritty. Gritty beds mostly contain profusion of mud intraclasts. Sandstone occur either as thick lenticular and tabular beds or as thin to very thin, fine to very fine grained beds within the mudstones. Sandstone is medium to thick bedded, mostly having lenticular morphology and erosive bases. It is characterized by trough-cross bedding, low-angle cross bedding and parallel lamination. Thin bedded fine grained sandstone beds are often moderately to intensely bioturbated or even mottled. Less frequently lateritic beds are also present. The formation

transitionally and conformably overlies the Bahlol Nika formation.

2.4. Zone-IV

2.4.1. Malthanai formation

The authors propose the name Malthanai formation for the Multana Formation of Hunting Survey Corporation (1960), after the Malthanai village near its type section. "Malthanai" a Pashto word for a small business of salt cropping from brackish water springs, emerging along the contact of Nisai Formation with Malthanai

formation or Dasht Murgha group around the vicinities of Kazha Merzai, Gardab Manda, Malthanai Kili (near the type section) and Sur Kach areas. The name "Multana" introduced by Hunting Survey Corporation does not convey any relationship with the local geographic names and therefore is misleading. Hunting Survey Corporation (1960) correlated it with the Shaigalu and Murgha Faqirzai members of the Khojak Formation and considered it as a "conglomerate axial belt facies" of these members. The formation is 2500 m thick at its type section [Oblin Nala section, (N 31° 02' 15" E 69° 04' 41")].

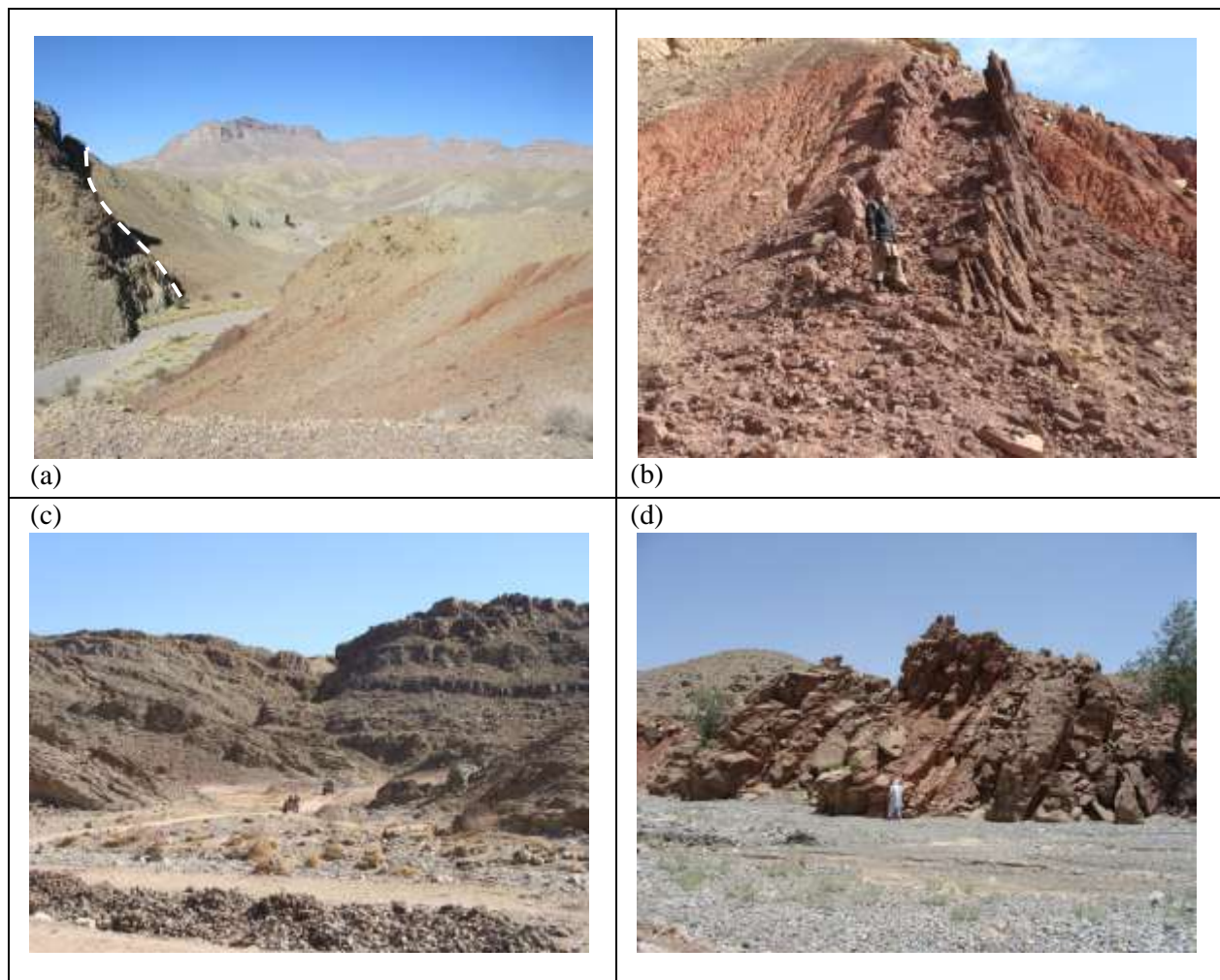


Fig. 3. Field photographs of the study area showing; (a) thrust contact (shown with dotted line) between the Nisai Formation (background) and Dasht Murgha group (foreground). Photograph was taken looking north, (b) cyclic succession of the sandstone and shale packages of the Khuzhobai formation. Photograph was taken looking east, (c) a distant view of the sandstone dominant Bahlol Nika formation. Photograph was taken looking south, (d) a view of reddish grey sandstone and shale packages of the Sra Khula formation. Photograph was taken looking northeast.

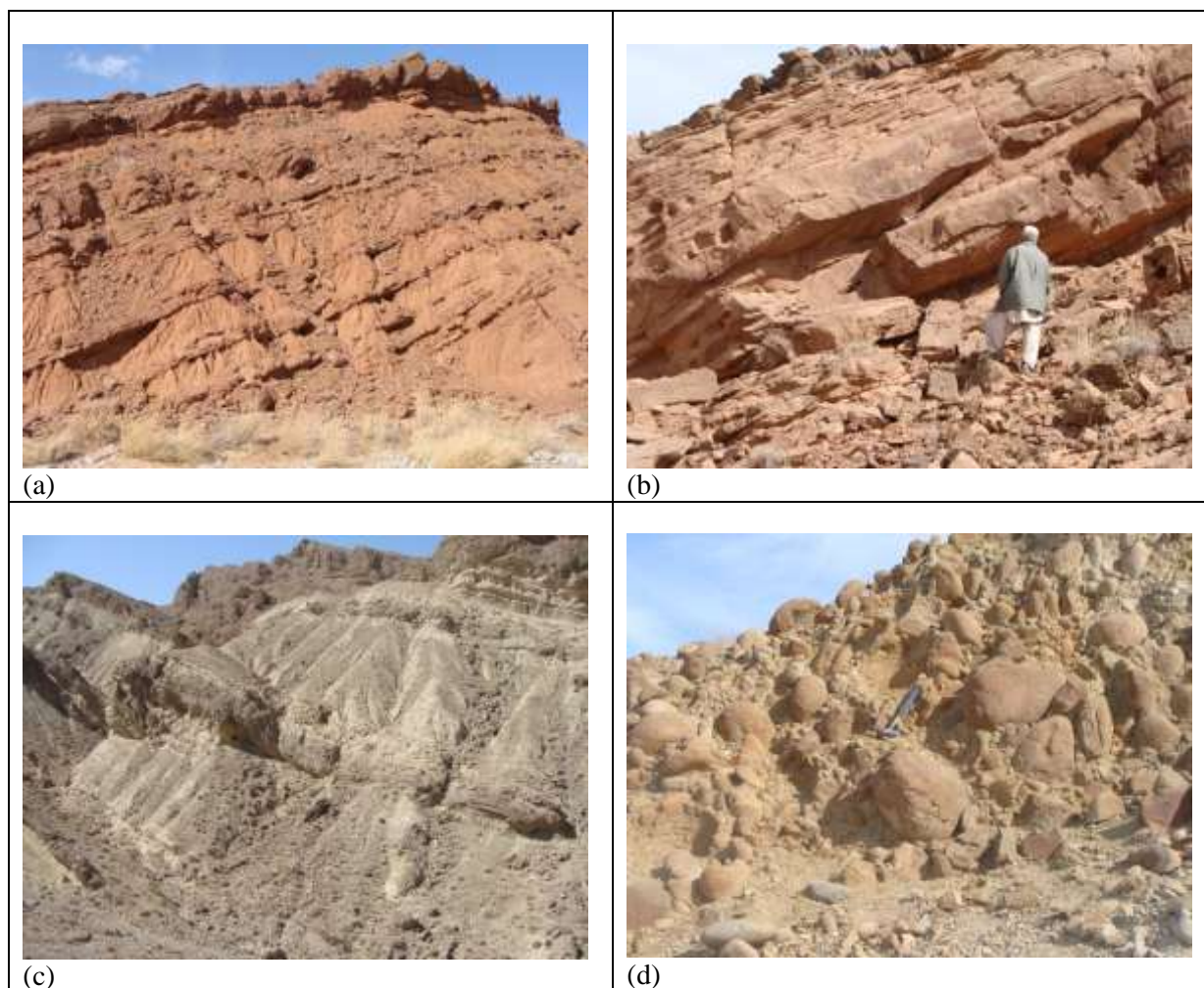


Fig. 4. Field photographs of the study area showing; (a) shale dominant packages interbedded with thin sandstone beds in the Malthanai formation. Photograph was taken looking northeast, cycle is 23 meters thick, (b) thick bedded sandstone with large size load casts at its base in the Malthanai formation. Photograph was taken looking northeast, (c) distant view of the conglomerate, sandstone and shale cycles within the Bostan Formation. Photograph was taken looking northwest. Cycle is 50 meters thick, (d) a close up view of the poorly sorted and well-rounded boulder conglomerate of the Bostan Formation. Photograph was taken looking northeast.

The formation comprises sandstone interbedded with siltstone, mudstone (Fig. 4a) and conglomerate. Ratio of the sandstone and mudstone/siltstone is roughly equal. Sandstone is mostly reddish grey, partly greenish grey, generally fine to very fine grained and medium to coarse grained in the lower and middle parts and very coarse to pebbly in upper part. Sandstone is very thin to very thick bedded (Figs. 4a and b), soft and friable. It occurs as medium to thick, lenticular beds and fine grained thinly bedded sandstone/siltstone–mudstone couplets. Amalgamation is common in thick beds which exhibit parallel lamination, cross bedding, ripple-cross lamination, and large ripples and dunes

on tops. Mudstone is massive and mostly reddish grey to maroon.

Pebbly sandstone and conglomerate beds are also present in upper part of the formation. Conglomerate contains abundant chert/jasper, subordinate limestone, sandstone, siltstone and mudstone intraclasts, and minor proportion of basic or ultrabasic fragments. In upper most part of the formation very thick bedded (up to 6 m thick) conglomerate beds appear, having maximum clast size of up to 50 cm. The cobbles and boulders are well rounded, moderately sorted and clast supported. They have erosive bases

having very large size load casts and longitudinal ridges and furrows at their bases. The framework grains comprise limestone fragments derived from the Nisai Formation and sandstone fragments of the Khojak Formation. Near the type section the Malthanai formation has thrust contact with the Pleistocene Bostan Formation, whereas lower contact is an angular unconformity with the Nisai Formation. Based on its tectono-stratigraphic position (Zone-IV), we envisage that it is younger than the Dasht Murgha group and may be of Late Miocene-Pliocene age.

2.5. Zone-V

2.5.1. Bostan Formation

The Bostan Formation has been named by the Hunting Survey Corporation (1960), after the village of Bostan, 30 km north of Quetta. The Pishin Lora (Pishin District) is designated as its type section. In the Zhob valley area the formation comprises cyclically interbedded packages of conglomerate, mudstone and sandstone (Fig. 4c) and reaches up to 1250 m in thickness at Gardab Manda section near Qila Saifullah.

In the type section the formation is dominantly red coloured mudstone with minor proportion of sandstone and conglomerate. However in the Zhob Valley conglomerate dominates over sandstone and mudstone. Conglomerate is very thick bedded and composed mostly of cobble- to boulder-size, and subordinately pebble size fragments (Fig. 4d). It is clast supported, having coarse sandstone matrix, well rounded, poorly sorted and showing pronounced imbrication. Conglomerate is composed of various types of rock fragments including basic igneous, ultramafic, metamorphic, sandstone and limestone varieties.

Sandstone and siltstone is often very soft and poorly lithified. Sandstone is light brownish grey and greenish grey, thick bedded, mostly medium to very coarse grained and in places pebbly to cobbly. Sandstone beds mostly display parallel-lamination, cross-bedding/lamination and bioturbation. Mudstone is massive, silty and light reddish to brownish grey and reddish brown.

The Bostan Formation has not yielded any age-diagnostic fossils, however, on the basis of its

stratigraphic position a Pleistocene age has been proposed (Cheema et al., 1977). Its contacts with the Malthanai formation and flat-lying Holocene deposits of the Zhob valley are thrust. We envisage that it overlies the older rock successions with an angular unconformity.

2.6. Zone-VI

2.6.1. Zhob valley deposits

The Zhob valley deposits are thick flat-lying Holocene deposits, covering wide area of the Zhob valley (Fig. 2). They are dominantly composed of mudstone interbedded with subordinate sandstone/siltstone and/or pebbly conglomerate. These deposits are very loose and friable. Due to its flat-lying and loose character, we envisage that they are of Holocene age.

3. Discussion

The Pishin Belt has evolved along the western-northwestern margin of the Indian Plate during its oblique collision with the Afghan and Kabul Blocks of the Eurasian Plate, 55 Ma before, around the Palaeocene-Eocene boundary (Searle et al., 1997; Khan and Srivastava, 2006). The Belt accommodates sedimentary succession, deposited in the Katawaz Basin, a south and southwestern extension of the remnant Neo-Tethys Ocean (Qayyum et al., 1997a, 1997b). The Late Palaeocene-Eocene Nisai Formation was deposited as shallow to deep marine limestone and shale succession during Late Palaeocene-Eocene times on top of the Muslim Bagh Ophiolite. We consider the Muslim Bagh-Zhob Ophiolite as our tectono-stratigraphic Zone-I, which is the base of the Pishin Belt. The Nisai Formation overlies the Muslim Bagh Ophiolite with non-conformity. The Late Eocene-Oligocene Khojak Formation, conformably overlying the Nisai Formation, represents a molasse-delta-fan continuum of the Palaeo-Indus River, which derived its siliciclastic detritus from the nascent Himalayas (Qayyum et al., 1997b; Carter et al., 2010). The Murgha Faqirzai Member of Khojak Formation represents a submarine fan facies, whereas the Shaigalu Member is composed of fluvial-dominated and wave modified deltaic facies (Qayyum et al., 1997a). We consider the Nisai and Khojak formations jointly to comprise our tectono-stratigraphic Zone-II.

Subsequent closure of the Katawaz Basin, towards the end of Early Miocene, caused to uplift and expose the Nisai and Khojak formations, which were deformed into NE-SW trending and E-SE verging folds (Qayyum et al., 1994). Due to the Chaman transform fault the western margin of Pishin Belt is dominantly transpressional, however, its deformational style gradually changes to compressional toward the east (Treloar and Izzat, 1993). Imbrication of the frontal parts of the thrust-wedges, through a series of emergent thrusts, built the topography along the eastern margin of the basin. The relative subsidence of footwalls to the SE of major thrusts subsequently provided accommodation for the fluvial succession of the Dasht Murgha group (our Zone-III). Continued compression caused uplifting and exposure of the older units, the Muslim Bagh Ophiolite (Zone-I) and Nisai and Khojak formations (Zone-II) that subsequently became the source terrains for the fluvial succession of the Dasht Murgha group (Zone-III), which was in turn uplifted by continued compression that provided accommodation for another fluvial succession of the Malthanai formation (Zone-IV). Further compression continued and caused uplifting and deformation of the Late Miocene-Pliocene Malthanai formation, providing space for deposition of fluvial succession of the Pleistocene Bostan Formation (Zone-V). Such relationships are evident from the major thrusts between these zones (Fig. 2). Active tectonism of the Pishin Belt is evident from the folding and thrusting of the Pleistocene Bostan Formation, which has been thrust over the flat-lying Holocene deposits of the Zhob valley (Zone-VI). Angular unconformity under the deformed succession of the Bostan Formation and flat-lying Holocene fluvial deposits of the Zhob valley suggests that deformation continued during the Pleistocene times and the area is still tectonically active. Recent movements along the Chaman transform fault and presence of the neotectonic features along the eastern margin of the Pishin Belt are the further evidences of the active tectonism in the area (Lawrence et al., 1992).

4. Conclusion

The Pishin Belt possesses distinct lithostratigraphy within six well defined thrust-unconformity-bounded tectono-stratigraphic zones.

Zone-I represents the Muslim Bagh-Zhob Ophiolite, whereas Zone-II comprises the marine to fluvio-deltaic successions of the Late Palaeocene-Early Miocene Nisai and Khojak formations. Zones-III, IV, V and VI are Middle Miocene-Holocene fluvial successions of Dasht Murgha group, Malthanai formation, Bostan Formation and flat-lying Holocene deposits of the Zhob valley respectively. These tectono-stratigraphic zones and their respective lithostratigraphic units developed in response to an amalgam of continued transpressional and compressional deformation along the western margin of the Indian Plate.

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