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UPDATED STRATIGRAPHY AND MINERAL POTENTIAL OF SULAIMAN BASIN, PAKISTAN

M. Sadiq Malkani

Paleontology and Stratigraphy Branch, Geological Survey of Pakistan, Sariab Road, Quetta, Pakistan

Abstract

Sulaiman (Middle Indus) Basin represents Mesozoic and Cainozoic strata and have deposits of sedimentary minerals with radioactive and fuel minerals. The new coal deposits and showings, celestite, barite, fluorite, huge gypsum deposits, marble (limestone), silica sand, glauconitic and hematitic sandstone (iron and potash), clays, construction stone are being added here. Sulaiman Basin was previously ignored for updating of stratigraphy and economic mineral potential. Here most of known information on Sulaiman Basin is compiled and presented along with new economic deposits.

Keywords: Stratigraphy, Mineral deposits, Sulaiman Basin, Middle Indus Basin, Pakistan.

1. Introduction

The Indus Basin which is a part of Gondwanan lands (Southern Earth) is separated by an Axial Belt (Suture Zone) from the Balochistan and Northern areas of Tethyan and Laurasian domains (northern earth). The Indus Basin (situated in the North-western part of Indo-Pakistan subcontinent) is located in the central and eastern part of Pakistan and further subdivided in to upper (Kohat and Potwar), middle (Sulaiman) and Lower (Kirthar) basins. The rectangle shape Sulaiman Basin is the largest basin of main Indus Basin and consists of about 170 thousand Km^2 (more than 40% area of main Indus Basin), while the triangle shape Kirthar basin shows 120 thousand Km^2 and square shape Kohat and Potwar basin shows about 100 thousand Km^2. The Sulaiman Basin terminated in the south by the Khairpur-Jacobabad High line and in the north by Sargodha High line to Pezu, in the east by Indian Shield exposures and in the west by Axial Belt. The major tectonic zones of Sulaiman Basin are Sulaiman Foldbelt forming arc shape located in the west, Sulaiman Foredeep zone also arc shaped located just in front of Sulaiman Foldbelt, and Southern Punjab Monocline located in the eastern part. The subdivision of main Indus Basin in-to three basins is purely and mostly due to mostly different lithostratigraph nature. For example the difference in Eocene strata like Chamalang/Ghazij Group and Kahan Group of Sulaiman Basin is different than Laki and Kirthar formations of Kirthar Basin. In this way the Cretaceous Pab Formation was formed on different two basins which were bordered from the Khairpur and Jacob Abad High. The Kohat and Potwar Basin consists of Precambrian to Recent sedimentary rocks while the Sulaiman and Kirthar consist of the Jurassic to Recent strata. Axial Belt and its vicinity consist of mostly mélange of igneous, metamorphic and sedimentary rocks. The study area is located in the central part of Pakistan (Fig.1a). Previously, the Sulaiman Basin has received little attention, but this paper will add insights on updated stratigraphy and new mineral discoveries.

2. Materials and Methods

The materials belong to collected field data, during many field seasons like lithology, structure, stratigraphy and mineral commodities **(Figs. 1 and 2)**. The ages of the formations of Sulaiman Basin are determined by the vertebrates and invertebrates paleontologic studies, with the help of superposition and also from previous work. The methods applied here are many disciplines of purely geological description. Further, stratigraphic sections were measured for correlation and other related research.

3. Results and Discussion

Updated Stratigraphy of Sulaiman Basin of Pakistan

The stratigraphy of Sulaiman Basin is generally documented by Shah (2002; 2009), Fatmi (1977), Cheema *et al.*, (1977), Raza *et al.*, (2001) and Kazmi and Abbasi (2008). Some missing links were remained due to lack of field visits especially in the Loralai, Musa Khel, Khetran, Mari and Bugti hills which are fulfilled by the present research. Malkani along with other researchers have mapped many quadrangles such as 39B/11(Malkani, *et al.*,2001a,b,c), 39 B/15 (Malkani *et al.*, 1996), 39F/3 (Tariq *et al.*,1996), 39 F/4 (Malkani and Shahani, 2001), 39 F/7 (Malkani *et al.*, 1996),, 39 F/8 (Malkani *et al.*, 2010a), 39 F/12 (Malkani *et al.*,2010b), 39 F/13 (Malkani and Munir, 1997), 39 F/15 (Malkani *et al.*, 2007), 39 F/16 (Malkani and Munir, 1999), 39 G/4 (Malkani *et al.*, 2007), 39 G/5 (Malkani and Munir,

Email, malkanims@yahoo.com Ph. No. 081-9211032

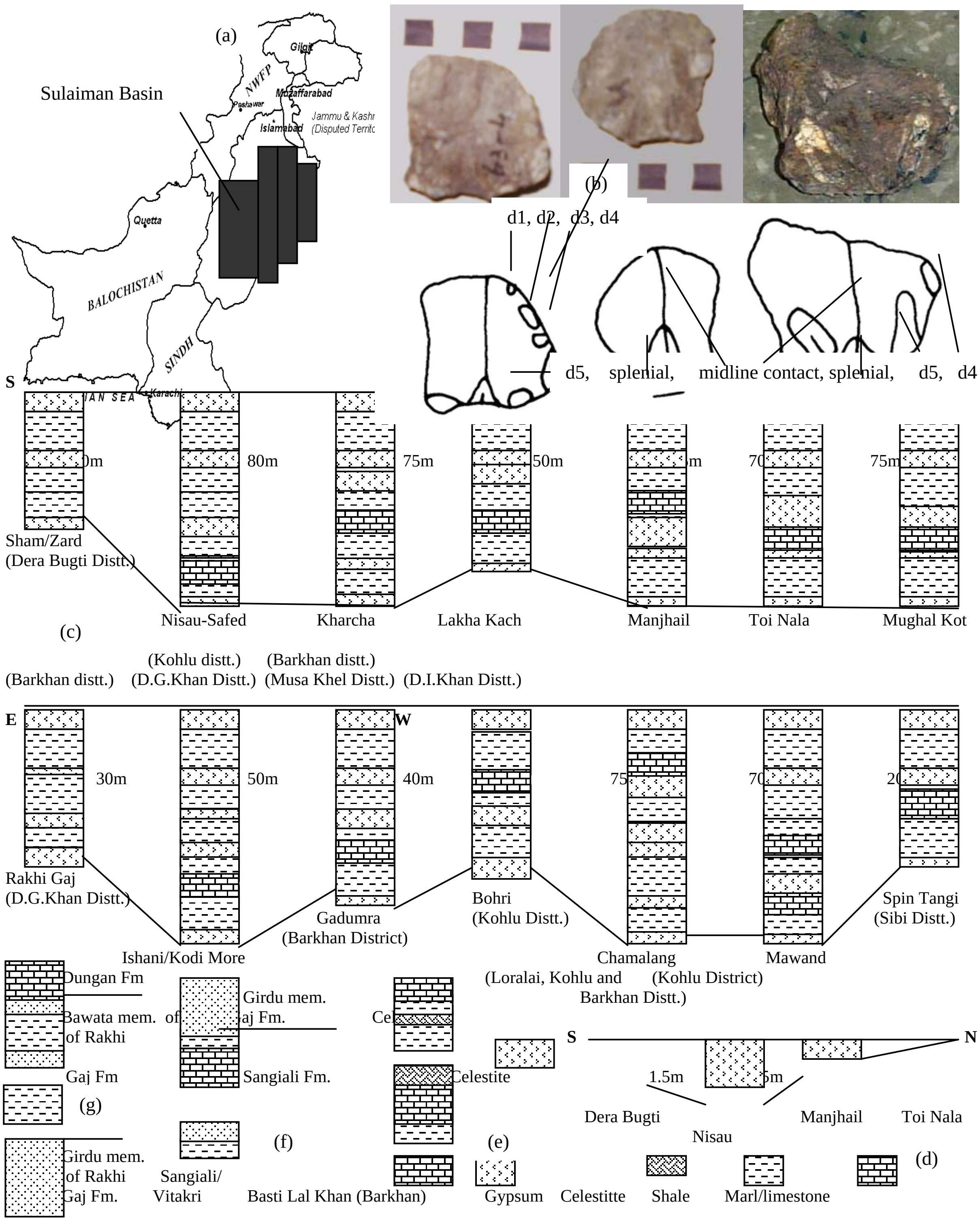

Fig. 1. (a) The black grey rectangles represent the Sulaiman Basin, Pakistan; (b) Specimen and line drawings of MSM-63-4 holotypic mandibles of *Sulaimanisuchus kinwai;* (c) Correlations of Baska Formation (host of enormous gypsum) of Sulaiman foldbelt, Pakistan. Upper sections show correlations south to north, and lower sections from east to west; (d) Smaller sections represents correlations of Domanda gypsum bed which is present only in southern Sulaiman foldbelt and absent in northern Sulaiman foldbelt; (e) Section of part of Drug Formation which is the host of Celestite deposits; (f) Sangiali Formation of Sangiali type area; (g) Girdu member (Gorge beds) and Bawata member of Fort Munro anticline.

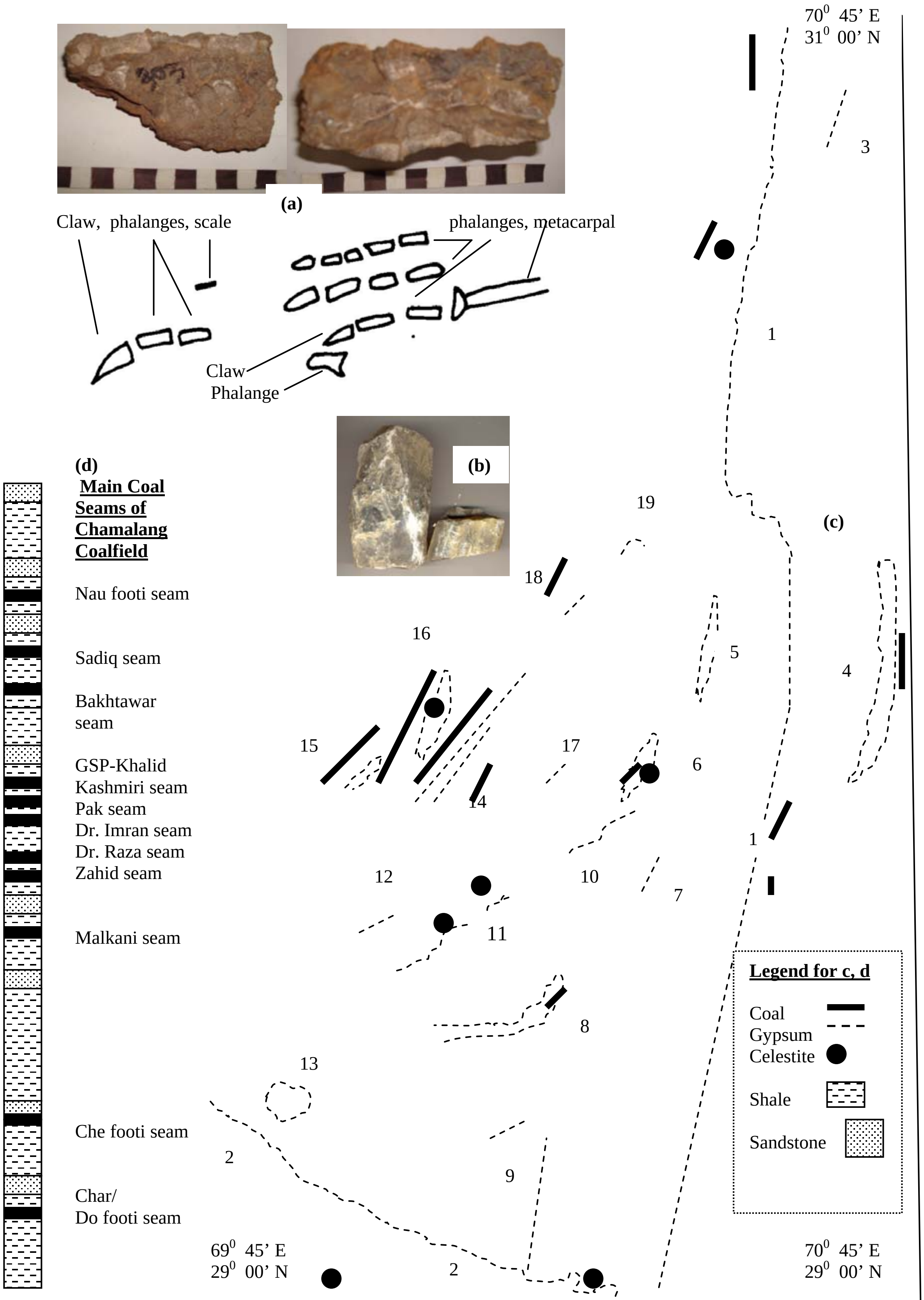

Fig. 2. (a) Specimen MSM-303-2 holotypic pes of *Vitakrisaurus saraiki* in two views with line drawings; (b) Celestite mineral (maximum 10 cm long); (c) Gypsum deposits of Baska Formation found from Sulaiman foldbelt. 1, Eastern Sulaiman gypsum belt. 2, Southern Sulaiman gypsum belt (Dera Bugti-Kahan-Khattan-Spin Tangi), 3, Domanda-western Drabin. 4, Zinda Pir. 5, Manjhail. 6, Lakha Kach (Rakhni). 7, Kharcha. 8, Nisau-Safed. 9, Janthali. 10, Ishani-Kodi More. 11, Gadumra-Chang Mari. 12. Bohri Kohlu. 13, Mawand. 14, Girsini-Bala Dhaka-Karher Buzdar. 15, Chamalang. 16, Bahlol. 17, Tumni Baghao. 18, Kingri. 19, Khan Mohd Kot, and new Coal and celestite findings; (d) Main Coal seams of Chamalang Coalfield.

1998b), 39 G/6 (Anwar and Malkani, 2001), 39 G/7 (Malkani and Dhanotr, 2007), 39 G/10 (Malkani and Zahid, 2001), 39 G/13 (Malkani *et al.*, 2010), 39 I/4 (Malkani *et al.*, 2007) which are unpublished so far.

The Sulaiman Basin consists of sedimentary rocks ranging in age from Jurassic to Recent. The different lithological units **(Table 1)** in ascending order are as follows.

Table-1: Stratigraphic sequence of Sulaiman (Middle Indus) Basin.

Age	Group	Formation	Lithology
Quaternary Rec and Subrec.		Surficial deposits	Gravel, sand, silt and clay
		----------------Angular Unconformity --------------------------------	
Pleistocene		Dada Formation	Conglomerate, sandstone and clays.
		---------------------Angular Unconformity ---	
T Pliocene	Vihowa	Chaudhwan Formation	Clays, conglomerate (cong) and sandstone
	Group	Litra Formation	Sandstone, clays and conglomerate
E Miocene		Vihowa Formation	Clays, sandstone and conglomerate
Oligocene		Chitarwata Formation	Clays, conglomerate and sandstone
R		Disconformity (Eocene-Oligocene boundary which represents major tectonic phase)	
	Kahan	Drazinda Formation	Shale with minor coquina.
T	Group	Pir Koh Formation	Limestone, marl and shale.
		Domanda Formation	Shale with minor coquina and gypsum.
I		Habib Rahi	Limestone, marl and shale.
	Eocene	Chamalang	Baska Formation Gypsum, shale with minor silty dolomite.
A	(Ghazij)	Drug Formation	Rubbly limestone and mudstone / shale.
	Group	Kingri Formation	Red muds/shale and grey to white sandstone
		Toi Formation	Sandstone, shale, rubbly limestone and coal.
R		Shaheed Ghat	Shale with minor marl /sandstone
Paleocene	Sangiali	Dungan Formation	Limestone, marl and shale
Y	Group	Rakhi Gaj Formation	Shale, mudstone, siltstone, sst. and limestone
		Sangiali Formation.	Brown limestone, glauconitic shale and sandst.
C		--------Disconformity (KTB)--------------------------------------	
R	Fort	Vitakri Formation	Two red mud units alternated with sandstone
	Munro	--------Disconformity (KTB)--------------------------------------	
	Group	Pab Formation	Sandstone (sst) with subordinate shale (sh)
E Late		Fort Munro Formation	Limestone, shale and coquina beds
T		Mughal Kot Formation	Shale, marl, sandstone, limestone and muds
A Early	Parh	Parh Formation	Limestone with minor marl and shale
C	Group	Goru Formation	Shale and marl with minor limestone
EOUS		Sembar Formation	Mainly shale with minor marl and mudstone
JURA- Late		--------Disconformity (JKB)--	
SSIC Middle	Sulaiman	Chiltan Formation	Mainly Limestone.
Early	Group	Loralai Fmormation	Limestone, marl and shale
		Spingwar Formation	Shale, marl and limest

Jurassic

Sulaiman Group: The term "Sulaiman limestone" was first used by Pinfold (1939), the type section in the gorge between Mughal Kot and Dhana Sar (lat. 31^0 26'N; long. 70^0 01'E) was formally described by Williams (1959), and later "Sulaiman Limestone Group" is used by the Geological Survey of Pakistan. The Alozai group was used by Shah (2009) for Spingwar and Loralai formations only on the suggestions of A.N Fatmi that the Alozai group is well exposed in the Quetta to Zhob. Malkani (2009f) used the term Sulaiman Group for the Spingwar, Loralai and Takatu/ Chiltan formations. The Sulaiman Group is adopted due to type locality of Alozai is located in Axial Belt and further Alozai consists of only Spingwar and Loralai formations, while Takatu Limestone is not developed in the Alozai type area. So considering the Alozai subgroup, here the Sulaiman Group is suggested which represents Spingwar, Loralai and Takatu (Chiltan) formations. Mesozoic rocks are mostly pericratonic marine shelf sloping westward from Indo-Pakistan Peninsula with some terrestrial strata. These sequence show igneous rocks in and near vicinity of Axial Belt.

Spingwar Formation: The Spingwar member of Shininab Formation was named by Williams (1959) and he designated the type section at Spingwar at the north of Zamari Tangi, about 35 km northwest of Loralai (lat. 30^0 32' 52''N; long. 68^0 19' 16''E). Stratigraphic committee (Shah, 2009) upgraded it to the formation level due to wide and thick exposures and clear cut differences among the under and overlying strata. It consists of grey to greenish grey shale, grey to whitish grey marl and limestone with some igneous sills especially in the vicinity of Axial Belt. It is mostly exposed near the Axial Belt. It is 665m in Zamari Tangi, 215m in the Mara Tangi, and 140m in the Tazi Kach sections (Shah, 2009). It is conformably contacted on the base with Triassic Wulgai Formation and upper contact with Loralai Limestone. It's Upper Triassic to Early Jurassic age is based fossils like ammonites, brachiopods, bivalves, crinoids, corals and shell fragments (Williams, 1959; Anwar, *et al.*,1991).

Loralai Formation: The Loralai member of Shininab Formation was named by Williams (1959) and he designated the type section in the Zamari Tangi in Loralai District (lat. 30^0 32’ 10’’N; long. 68^0 18’ 40’’E). Malkani *et al.*, (1996; Geological map of 39F/7) used first the term Loralai Formation. Stratigraphic Committee (Shah, 2009) formalized Loralai Formation. It represents mainly thin to medium bedded grey limestone with some grey shale and marl. It is mostly peak forming especially in the vicinity of Loralai, Mekhtar, Gadebar, Tor Thana, Anambar, etc. In these areas, the Chiltan Limestone is not developed, so here the age of Loralai Formation is extended to an upper level of deposition of Chiltan Limestone in Takht-e- Sulaiman, Ziarat and Takatu areas. Loralai Formation is 250m thick in the Zamari Tangi, 360m in the Mara Tangi, and 150m in the Tazi Kach (Khanozai area) sections (Shah, 2009), and in the Gadebar section it is more than 400m thick. Its lower contact with Spingwar Formation and upper contact with Takatu (Chiltan) Limestone is conformable. Where the Chiltan/Takatu is missing, its upper contact with Sembar Formation is disconformable and represented by J-K boundary. The Loralai formation is rich in radiolarian chert. The age assigned by Williams (1959) and Woodward (1959) is Early Jurassic but HSC (1961) have recorded Torcian fossils from its lower part. Some Torcian ammonites are also collected from Loralai and its vicinity areas. Its age ranges from Late Liassic to Bajocian (Early-Middle Jurassic).

Takatu (Chiltan) Limestone: Stratigraphic Committee (Shah, 2002; 2009) named the Takatu Formation after the Williams (1959). Its name was derived from the Takatu Range in the Northeast of Quetta. The type section is along Data Manda Nala, a small stream passing throughout the entire formation in very deep narrow gorge and enters the plain about 3km south of Bostan village (Lat. 30^0 20’N; Long. 67^0 03’E). The type locality of Chiltan is after the Chiltan Range (Lat. 30^0 01’ N; Long. 66^0 46’E). The famous name Chiltan limestone was introduced by Hunting Survey Corporation (1961) after the Chiltan Range southwest of Quetta. This term Chiltan Limestone is well known in all geoscientists. It is also valid in most of the Kirthar, Sulaiman and Axial belt areas. It consists of massive thick bedded limestone which forms prominent ranges and high peaks in the surrounding of Quetta, Ziarat and then in the Takht Sulaiman area, however in the vicinity of Loralai, the peak forming equilent is Loralai formation. This limestone is considered as biohermal or reefal. This formation is 800m thick in the type locality and 1100m in the Takht Sulaiman and in other areas varies from 600 to 1100m (Shah, 2009). The Mazar Drik Formation (~Dilband Formation) is less than 30 m and exposed only in the Loralai, Duki and Gadebar areas. It is considered a member of Takatu Formation by Shah (2009). It includes mostly the transitional and disconformable horizons representing Jurassic Cretaceous (J-K) boundary. This J-K boundary exposed in Duki, Loralai, Daman Ghar and Gadebar areas is represented by Mazar Drik light brown shale alternated with light grey fresh colour and light brown weathered colour limestone. The Dilband Formation which is about 20m thick in the type area was named by Abbas *et al.*, (1998) and designated three members like lower Jarositic clay member (light grey to brown), middle ironstone member (reddish), and upper green glauconitic shale member. The green glauconitic shale and light green to grey shale above just below the marly beds are remnants of Sember Formation, and lower two members of Dilband Formation represents the J-K boundary. The lower contact of Takatu (Chiltan) Limestone with Loralai Formation is conformable while upper contact with Dilband/Sembar Formation is disconformable. Arkell (1956) reported Late Bathonian ammonites from the lower part of Mazar Drik unit. So according to Fatmi (1969) and Arkell (1956) its age can be considered as Early Callovian to Late Bathonian (Middle Jurassic). Its stratigraphic position tells the age range from Middle Jurassic to Late Jurassic.

Cretaceous

Parh Group: The term Parh was first used by Blanford (1879) for rocks of Parh Range. The name was later applied by Vredenburg (1909) to a prominent white limestone in his Cretaceous succession. Williams (1959) redefined it as a limestone between the Goru and Mughal Kot formations. The type area lies in the Parh Range in the upper reaches of the Gaj River (lat. 26^0 54’ 45’’N; long. 67^0 05’ 45’’E). Goru and Parh formations are well exposed in the Goru and Parh ranges but the Sembar is well exposed in the Lakha Pir Charoh area just east of Parh Range. Parh Group represents Sember, Goru and Parh formations. Shah (2009) mentioned the Mona Jhal Group after the Fatmi *et al.*, (1996) from Mona Jhal Anticline, 13 km north of Khuzdar and it includes the Sembar, Goru, Parh and Mughal Kot. According to the author’s opinion the Mughal Kot Formation is arenaceous clastic in the Eastern Sulaiman and fit with the Fort Munro Group which is mostly clastic, except Fort Munro Limestone.

Sembar Formation: The term Sembar Formation was proposed by Williams (1959) to replace the term Belemnite beds of Oldham (1890). The type section is Sembar Pass (lat. 29^0 55’ 05’’N; long. 68^0 34’ 48’’E).

It represents three members in the Mekhtar and Murgha Kibzai area of Sulaiman Foldbelt like Sembar lower and upper shale members and middle member is named as Mekhtar member/Mekhtar sandstone member. The type locality of Mekhtar member is just south of Mekhtar town, near the Kareez (39F/7). This sandstone unit is about 100m thick. It is also found in the north of Mekhtar like Murgha Kibzai area. The shale is greenish grey and khaki, mostly calcareous, with rare glauconitic. The Mekhtar sandstone is Pab like white to grey, quartzose, thin to thick bedded and medium to coarse grained, mostly weathered as dark grey to black. The marl is grey to cream white, thin bedded and porcelaneous. Sembar Formation is estimated as about 1000m in the Loralai, Gadebar Range and Tor Thana areas. As lateral variation, this formation is relatively more and maximum thick in the Loralai, Tor Thana and Gadebar areas. It is being reduced in towards the Kirthar basin and axial belt regions and also toward the northern Sulaiman Foldbelt. It is 133m thick in the type locality and 262m in the Mughal Kot area (Shah, 2009). It is about 200m near the Lakha Pir of Charoh anticline in Zidi area in the east of Khuzdar town. Its lower contact with the Loralai/Chiltan/Dilband formations is disconformable and upper contact with Goru formation is transitional and conformable. The most of the fossils found belong to belemnite. Recently Malkani (2003c) has found dinosaurs (*Brohisaurus kirthari*) fossils from Sun Chaku (Karkh area) and Charoh (Zidi area) localities of Khuzdar district (Kirthar range) from the Dilband Formation (at the base of Sembar Formation). The age varies from latest Jurassic to Early Cretaceous.

Goru Formation: The term Goru Formation was introduced by Williams (1959). The type section is located near Goru village on the Nar river in the southern Kirthar Range (lat. 27^0 50’ 00’’N; long. 66^0 54’ 00’’E). It consists of alternations of about 3 thick marl units and two shale units. The shale is grey to khaki and calcareous. The marl is grey to cream white, thin bedded to thick bedded and porcelaneous. It is relatively reduced towards the axial belt regions. It is about 500m thick in the type area and also same in the Mekhtar area. It is being reduced towards axial belt near Quetta upto 60m thick. Its lower contact with Sembar Formation is transitional and conformable, and upper contact with Parh Limestone is marked by a marine maroon red beds which also show conformable contact, however some author have suggested the maroon beds are indicator of disconformity but in actual these are marine red beds. The most of the fossils found belong to belemnite. According to stratigraphic position, its age can be considered as Early Cretaceous.

Parh Limestone: It consists of mainly limestone with minor shale and marly beds. Limestone and marl is cream white to grey, thin to thick bedded and porcelaneous. The shale is grey, khaki and calcareous. It is 60-70m thick in Sulaiman Basin. As lateral variation, this formation is relatively more and maximum thick (about 300-400m) in Karkh, Kharzan and the type locality areas of Kirthar Foldbelt. Its lower contact with Goru Formation is conformable and upper contact with Mughal Kot Formation is also transitional and conformable represented by about 12m marly beds. The age of the Parh limestone is middle Cretaceous in the Sulaiman and Kirthar foldbelts, however it is maintained from middle Cretaceous to Late Cretaceous in the Axial Belt areas where the Fort Munro Group is not developed and also lower and middle Sangiali group is not developed. For example the Ziarat Laterite showing K-T boundary is contacted by Parh and Dungan formation

Fort Munro Group: The term Fort Munro Group was first time used by Malkani (2009f) for Mughal Kot, Fort Munro, Pab and Vitakri formations. Its type section is Rakhi Gaj and Girdu are in Toposheet 39 K/1. The lower contact of this group is also found in Shadani section in Toposheet 39 J/4.

Mughal Kot Formation: Williams (1959) named and designated the type section of the Mughal Kot Formation to be in the gorge 1-3 miles west of Mughal Kot post (lat. 31^0 26’ 52’’N; long. 70^0 02’ 58’’E). Its synonym is Nishpa formation. It has variable lithology like marly mudstone in the Rakhi Gaj area and its vicinity, alternation of shale, lenticular sandstone and limestone in the Tor Thana and Murgha Kibzai area, and alternations of shale with subordinate sandstone is common in all other areas of eastern Sulaiman Foldbelt. In the western Sulaiman like the vicinity of Loralai, the Fort Munro Group is represented by about 100m shale further reducing to axial belt, in the Ziarat laterite area, it is not developed. In the western vicinity of Ziarat, it is represented by shale and volcanics (Bibai Formation), and in the eastern vicinity of Quetta like Hana Lake and Sor Range areas it is represented by limestone with negligible shale. The shale is grey, khaki and calcareous and rarely noncalcareous. The sandstone is grey to white, quartzose to muddy, thin to thick bedded and medium to coarse grained, mostly weathered as dark grey to black. The marl and mudstone is grey to cream white. The Parh like limestone is creamy white, porcelaneous, thick bedded and lenticular observed in the Tor Thana area (39 F/3). It is estimated about 1200m in the Musa Khel and type locality area. Petroleum seep is reported in Toi River of Mughal Kot area, on the contact of Mughal Kot and Pab formations. As lateral variation, this formation is relatively more and maximum thick in the type locality and Musa Khel district. It is being reduced in towards the Kirthar basin and axial belt regions. It is mostly developed in shallow marine, prodeltaic and deltaic environments. Its lower contact with Parh Formation is transitional and conformable represented by marly beds well exposed in the Tor Thana and its vicinity areas, and upper contact with Fort Munro/Pab Formation is also transitional and conformable. Williams (1959) reported Maastrichtian fossils, while Marks (1962) reported Campanion to Early Maastrichtian fossils from Rakhi Nala (Sulaiman Foldbelt). According to its stratigraphic position in the Sulaiman and Kirthar foldbelts where Pab Formation is developed, its age is Early to Late Campanion

Fort Munro Formation: The name Fort Munro limestone member was introduced by Williams (1959) for the upper dominantly limestone unit of the Mughal Kot Formation and he designated the type section in the western flank of the Fort Munro anticline along the Fort Munro-Dera Ghazi Khan road (lat. 29^0 57’ 14’’N; long. 70^0 10’ 38’’E). Fatmi (1977) assigned it a separate formation status because of its distinct lithology and regional extent. It consists of grey to brown and thin to thick bedded limestone with minor greenish grey shale. It is 100m thick at type locality, 248m in subsurface at Dabbo Creek i,e due to dip it actual thickness may be 100-150m.. The lower contact with Mughal Kot Formation and upper contact with Pab Formation are transitional and conformable. According to Williams (1959), HSC (1961) and Marks (1962, its age may be late companion to Early Maastrichtian.

Pab Formation: The term Pab Sandstone was introduced by Vredenburg (1907) and the type section in the Pab Range (lat. 25^0 31’ 12’’N; long. 70^0 02’ 58’’E) was designated by Williams (1959). Malkani (2006d) divided the Pab Formation into three members like lower Dhaola member (Dhaola Nala, lat. 29^0 42’ 41’’N; long. 69^0 29’ 48’’E), middle as Kali member (Kali hills of Dhaola Range, lat. 29^0 42’ 41’’N; long. 69^0 29’ 42’’E) and upper Vitakri member). The best reference section for Dhaola member is Fort Munro area (lat. 29^0 57’ 14’’N; long. 70^0 10’ 38’’E) of D.G.Khan district, and for Kali member is Tor Thana area (lat. 30^0 12’ N; long. 69^0 11’E) of Loralai District. The Dhaola member (white quartzose sandstone with minor to moderate black weathering) represents the environments of proximal delta, near the coastline and consistent in the eastern Sulaiman Foldbelt. Kali member (shale and black weathering sandstone) represent middle and distal deltaic environments and mostly exposed in the western part of Sulaiman Foldbelt. Two members are not consistent every where in the Sulaiman basin. In the Dhaola and Chamalang sections, both Dhaola and Kali member are existed well. The thickness of Pab Formation is estimated 500m in the Fort Munro area. It is pinching toward north like Mughal Kot section (300m), and also toward south in the Khairpur- Jacob Abad high. This high separates the northern delta (Sulaiman Basin) from southern delta (Kirthar Basin). In the western Kirthar it is about 600m or more thick. It is not absent in Mari-Bugti Hills but shale proportion increases. The thickness of this formation is relatively less in the Mughal Kot and toward north and Axial Belt but uniform in the eastern Sulaiman Foldbelt. Its lower contact with Fort Munro or Mughal Kot Formation is transitional and conformable and upper contact with Vitakri or Rakhi Gaj Formation is disconformable. Recently, dinosaurs and crocodiles are found from Vitakri Formation (Previously upper member of Pab formation, for detail see in Vitakri Formation) According to dinosaur fossils and stratigraphic position, the age is considered as Middle to Late Maastrichtian.

Vitakri Formation: Malkani (2006d) introduced first time the upper member of Pab Formation as Vitakri member and Malkani (2009f) upgraded this member into Vitakri Formation (Type Vitakri area, lat. 29^0 41’ 19’’N; long. 69^0 23’ 02’’E) due to its distinct lithology, depositional environments and lateral extension. Vitakri village is about 30 Km in the south-southwest of Barkhan town. Vitakri Formation (15-35m, extended mostly in the eastern Sulaiman Fold and Thrust Belt) consist of alternated two units of red mud/clay (2-15m each unit) of over bank flood plain deposits and two quartzose sandstone units (2-15meach unit) with black weathering of meandering river system. Lower red mud horizon is based on Kali member or Dhaola member and capped by middle sandstone horizon of Vitakri Formation. The upper red mud horizon is based on middle sandstone horizon and capped by a resistant sandstone horizon. Its coeval strata (coal, carbonaceous shale and sandstone) represent the lacustrine and deltaic environment, and laterite represent the erosional disconformity. The sandstone is white to grey, thin to thick bedded and fine to coarse grained, quartzose, mostly weathered as dark grey to black. The shale is red, maroon, and greenish grey and calcareous to noncalcareous. The red muds of this disconformity and just below this are the host of latest Cretaceous dinosaurs in Pakistan. Vitakri Formation is regional extension in eastern Sulaiman Foldbelt and also Ziarat laterite is a part of Vitakri Formation. Vitakri Formation was the Park for the latest Cretaceous dinosaurs and crocodiles of Pakistan. Its lower and upper contact with Pab and Sangiali formations is disconformable. According to dinosaur fossils and stratigraphic position, the age is considered as latest Maastrichtian or latest Cretaceous.

Sulaiman Basin is famous for vertebrate paleontology like the biggest land mammals, walking whales, elephants, titanosaurians with head to tail and back to foot morphology, theropods with skull and post cranial morphology, and mesoeucrocodilian which is first diagnostic in Indo-Pakistan subcontinent. The first dinosaur fossils from Pakistan was collected by Malkani during early 2000 and reported first by Malkani and Anwar (2000) and Malkani *et al.,* (2001). The first dinosaur fossils from India were discovered in early nineteenth century but recently (since 2000 to until) Pakistan has produced about 3000 fossils of cranial, vertebral and appendicular elements of latest Cretaceous archosaurs, which were collected from the two red mud horizons alternated by two sandstone horizons of Vitakri Formation. Many hundreds significant holotypic and referred fossils which include *Khetranisaurus barkhani* (Malkani 2006b; 2009f), *Sulaimanisaurus gingerichi* (Malkani and Anwar 2000; 2006b, 2009f), and *Pakisaurus balochistani* (Malkani 2003b; 2006b; 2010a) of Pakisauridae (slender titanosaurians) and *Marisaurus jeffi* (Malkani 2003a,b; 2006b; 2008a; Wilson *et al.*, 2005), and *Balochisaurus malkani* (Malkani 2003b; 2006b; 2009f) of Balochisauridae (stocky titanosaurians) sauropods, *Vitakridrinda sulaimani* (Malkani 2006b,c; 2009f) of slender and large bodied (abelisaurian) theropod, and *Pabwehshi pakistanensis* (Wilson *et al.*, 2001; Malkani, 2007d) of carnivorous mesoeucrocodile were documented so far. The remains of body fossils from the Late Jurassic Sembar Formation of Kirthar basin represent *Brohisaurus kirthari* (Malkani, 2003c), possibly a titanosaurian sauropod. Further the trackways from the Middle Jurassic Samanasuk Limestone of Kohat and Potwar basin represent a group of wide gauge *Malakhelisaurus mianwali* (renamed due to previously engaged name of *Malasaurus*) titanosaurian sauropods and a narrow gauge running *Samanadrinda surgahri* abelisaurian theropod based on only ichnotypes (Malkani, 2007a, 2008f)). Further these vertebrates are also presented at many national and international conferences (2004a,b,c; 2006a; 2007b,c,e; 2008b,c,d,e; 2009a,b,c,d,e; 2010b,c).

Systematic Paleontology of *Vitakrisaurus saraiki* is Dinosauria Owen, 1842; Order Saurischia Seeley, 1888; Infraorder Theropoda; Vitakrisauria new taxon; Family Vitakrisauridae *and* Vitakrisaurinae new family and subfamily, and *Vitakrisaurus saraiki* new genus and species (honoring the Vitakri locality which is the host of *Vitakridrinda* and also *Vitakrisaurus*, and Saraiki language of Khetran tribe). The holotype specimen MSM-303-2 (Fig.2a), an isolated pes is collected from the Bor Kali Kakor locality. The specimen MSM-303-2 is collected from the latest Cretaceous Vitakri Formation of Sulaiman Basin, Pakistan. This specimen is found fragmentary just associated with the carcass of *Marisaurus* found from this locality. The foot seems to be birdlike tridactyl. The phalanges and unguals are robust. This foot/pes belongs to right hind limb. There are three preserved digits. The digit I has partial metatarsal with two phalanges and one claw. The digit II has preserved partial metatarsal and possible three phalanges and one claw. Some elements of digit III is preserved and have some impressions. The claw is three time long than its transverse width and also ventrodorsal height (Fig.2a). The length of *Pakisaurus* ungual is one and half time than width. In this way the length and width ratio is 3 in this theropod while in *Pakisaurus* (Pakisauridae, Sauropoda) is 1.5. The claw is 21 mm long with slightly concave in the ventral side. The thickness and width of claw is becoming less toward posteriorly and show a rounded asymmetrical recurved nature. The phalanges are also elongated having well developed expanded articular surfaces/condyle. The width of phalanges is about 7 mm while length is about 21 cm. Many smaller bone and phalanges are found just below the claw, which may show the gripping of bones in his claw or may be the bones of left pes of *Vitakrisaurus* or may belong to birds or other theropod.

Systematic Paleontology of *Sulaimanisuchus* is as follows: Crocodyliformes Hay 1930, Mesoeucrocodylia Whetstone and Whybrow 1983, Sulaimanisuchidae and Sulaimanisuchinae new family and subfamily, *Sulaimanisuchus kinwai* new genus and species (honoring the Sulaiman basin which is the host of fossils). The holotype specimen MSM-63-4 (Fig.1b), an isolated anterior portion of right and left mandibular rami fused at the symphysis (Fig.1b) is collected from the Kinwa Kali Kakor locality of Vitakri area. This specimen is collected from the latest Cretaceous Vitakri Formation of Sulaiman Basin, Pakistan. This specimen is found fragmentary. The preliminary aims of Malkani (2007d; 2009f) were to preserve and document the fossils so as to prevent from any mishappening of significant fossils and also to avoid new namings. Malkani (2007d) mentioned the possible similarity of MSM-63-4 with Pabwehshi. But now on detail study it shows many differences from *Pabwehshi*, so consequently the new genus and species are being assigned here. The teeth numbers and arrangements of this mandibular rami show the great differences from Pabwehshi. The mandibular rami consist of fused dentaries and splenials preserved from their posterior margin at the fifth alveolus forward. This mandible is D shaped arc with less shallow at the anterior part and more shallow or deep in the posterior part. Its transverse width is maximum at the position of d5 and become gradually decreasing toward anterior and abruptly decreasing towards posterior to d6. The first tooth is thin and peg like which is close to mid line. The second and third teeth are relatively thicker than d1. The fourth tooth is relatively enlarged and more thick and oval than d1, d2 and d3. The fifth tooth is also enlarged and thicker than d1, d2 and d3, and located close to splenial and midline relative to d4 and d3. Possible a diastema is existed between d4 and d5. The separation displacement of d1 and d2 is slightly more than the inter displacement between other teeth. The portion of splenial anterior to d6 is preserved. The splenial contacts the medial aspects of the dentary along its height from the base of the jaw ramus to the alveolar margin. The splenial extends medially to the midline and participates in the symphysis. The dentary portion of the mandibular symphysis extends from the back of the mid alveolus of d4 anteriorly, whereas the splenial makes up the portion from the back of the mid alveolus of d4 posteriorly. Only the first dentary tooth is rounded while remaining all preserved teeth are elliptical and compressed transversely (Fig.1b). The size difference is found in many teeth. The dorsal part of preserved dentary is mostly covered by matrix, however the ventral side is comparatively clean and show pitted surface. This pitted surface nature of *Sulaimanisuchus* is same as *Pabwehshi.* The left side of dentary of *Sulaimanisuchus* is compressed while right side is remained mostly safe. Further the *Sulaimanisuchus* and *Pabwehshi* are being arranged in the subfamily Sulaimanisuchinae and family Sulaimanisuchidae.

Paleocene

Sangiali Group: Malkani (2009f) introduced Sangiali Group representing Sangiali, Rakhi Gaj and Dungan formations. The type section (Sangiali village area, lat. 29^0 41’ 53’’N; long. 69^0 23’ 54’’E) is exposed just 1km south southeast of Village Sangiali. Sangiali Village is 4km north of Vitakri Village. Sangiali Village is about 26 Km in the south-southwest of Barkhan town. The best and easily approachable reference section (close to type locality of Kingri Formation) is about 5km in the northwest of Kingri town (39F/15). The Khadro Formation of Kirthar Foldbelt has much volcanics. In Sulaiman Range there are no volcanics but its green shale and sandstone may be glauconitic or may show some volcanic source. Further the dominant sandstone in Khadro can hurdle for identification of Rakhi Gaj formation. Further the upper sequence is again different from Ranikot group. It is about 30m thick in the type area (Fig.1f) and it is being reduced on every side from type locality area but existed in the eastern Sulaiman Foldbelt. Sangiali Formation and Group is suggested to remove the problems. Mesozoic in Sulaiman and Kirthar are closely resemble while Paleocene is different because the Bara and also part of Khadro formations were deposited by fluvial to deltaic while in the Sulaiman the deposition was marine and deltaic.

Sangiali Formation: Malkani (2009f) introduced first time the Sangiali Formation (due to its distinct lithology, depositional environments and lateral extension) with type section (Sangiali village area, lat. 29^0 41’ 53’’N; long. 69^0 23’ 54’’E) exposed just 1km south southeast of Village Sangiali. It is extensive in most part of eastern Sulaiman Foldbelt and consists of green shale and sandstone with resistant brown limestone (Fig.1f). The shale is found in the lowermost part, which is graded in to sandstone. The sandstone is capped by limestone. The shale is green and glauconitic and may be phosphate bearing. The sandstone is greenish grey to grey and white and thin to medium bedded. The limestone is brown, thin to thick bedded and bivalves bearing. Nautiloids are common in the type and just south in Vitakri area. Its lower contact with Vitakri Formation is disconformable and upper contact with Rakhi Gaj Formation is transitional and conformable. The Nautiloids and bivalves are common in this formation found from the Sangiali and Vitakri area. Eames (1952) reported Early Paleocene fossils from Rakhi Nala. So its age is considered as Early Paleocene.

Rakhi Gaj Formation: Williams (1959) introduced the lower Rakhi Gaj shales. The Rakhi Gaj formation is mentioned by Shah (2002). The Rakhi Gaj Formation is also used by the present author in many Geological maps. Upon the suggestions of S.M.Hussain of American Oil Company, the Stratigraphic Committee (Shah 2009) has adopted the name Girdu Member for the Gorge beds of Eames (1952). The Rakhi Gaj Nala is designated as the type section (Lat. 29^0 57’ 14’’ N; Long. 70^0 11’ 30’’ E). Here the Rakhi Gaj formation is divided into two members like lower Girdu member (Gorge beds) and upper Bawata members (Fig.1g). It is the middle formation of Sangiali Group and lower formation where Sangiali Formation is absent. The Girdu member is about 100m thick at type area (Lat. 29^0 57’ 27’’ N; Long. 70^0 04’ 40’’ E) where it consists of thick and resistant beds of sandstone with minor shale. The sandstone is grey, greenish grey, thin to thick bedded and fine to coarse grained, bivalve bearings, hematitic and glauconitic weathered as dark reddish grey to dark grey. Iron and potash from glauconitic and hematitic sandstone seems to be significant especially in the Fort Munro, Rakhi Gaj and its vicinity areas of eastern Sulaiman Foldbelt. The Bawata member named here to fill the missing link. This upper member can be named Rakhi Gaj member which lacks the well developed contact with Dungan Formation while Bawata locality has well developed contact with Dungan Formation. The Bawata member (Bawata as type section;

Lat. $30^0$00’ N; Long. $69^0$57’ 30’’ E) consists of mainly shale along with alternation of sandstone (Fig.1g) is about 200m thick. The Shale is common in the uppermost part. The shale is grey, khaki and calcareous. The sandstone is greenish grey to grey, bivalves and iron bearings. The shale and sandstone of Fort Munro area show green colour may due to glauconitic or igneous origin from volcanism of Deccan trap. The Girdu member is about 100m and Bawata member is about 200 m in its type areas. Both members are exposed in the eastern Sulaiman Foldbelt and its contact is transitional. The lower contact of Girdu member with Sangiali and upper contact of Bawata member with Dungan Formation is conformable. The lower contact of Rakhi Gaj Formation with Pab is disconformable where Vitakri and Sangiali formations are absent. Latif (1964) has reported pelagic foraminifera possibly from the Rakhi Gaj Formation of Rakhi Nala. Its age is considered as middle Paleocene due to stratigraphic positions.

Dungan Formation: The term Dungan limestone was introduced by Oldham (1890). Williams (1859) designated the type section to be near Harnai (lat. 30^0 08’ 38’’N; long. 67^0 59’ 33’’E) and renamed the unit Dungan Formation. It consists of limestone, shale and marl. The limestone is grey to buff, thin to medium bedded and conglomeratic. Shale is grey, khaki and calcareous. The marl is brown to grey, thin to medium bedded and fine grained. This formation is 50-400m maximum thick. Laterally this formational facies is more diverse, at places thick limestone deposits while at places minor limestone showings. The Sui main limestone is an upper part of Dungan limestone due to its variable behavior. It is thick in the Zinda Pir, Duki, Sanjawi, Harand, and also in Mughal Kot section but negligible as in Rakhi Gaj and Mekhtar areas. Petroleum showings are common in this formation especially in the Khatan area (Oldham 1890). Its lower contact with Bawata member of Rakhi Gaj Formation is conformable, however near the Axial Belt it has disconformity at the base, while the upper contact with Shaheed Ghat Formation is transitional and conformable. It has many mega forams. It age is considered as Late Paleocene, rarely exceeding to early Eocene. However it is maintained all Paleocene in the Ziarat area and the Axial belt areas where the Sangiali and Rakhi Gaj formations i.e. the lower and middle Sangiali group is not developed. For example the Ziarat Laterite showing K-T boundary is contacted by Parh and Dungan formation

Eocene

Mesozoic in Sulaiman and Kirthar are closely resemble while Tertiary is different because the southern Kirthar source was Indian shield, while the Sulaiman and northernmost Kirthar the source was hinterland like Afghanistan.

Chamalang Group: The term Chamalang Group was first used by Malkani (2010a). The term Ghazij was introduced by Oldham (1890). Williams (1959) proposed that the type section be at Spintangi (lat. 29^0 57’06’’N; long. $68^0$05’00’’E) and used the term Ghazij formation. It is upgraded as group by Shah, (2002). Chamalang **(**Ghazij) group represents Shaheed Ghat, Toi, Kingri and Baska formations. Drug and Kingri formations are not well developed in the Spintangi area, so the Malkani (2010a) suggests for the Chamalang Group where all the formations of Ghazij group are well developed along with new formation like Kingri Formation. The type section for Chamalang Group is Chamalang area (lat.$30^0$10’N; long.$69^0$25’ E).

Shaheed Ghat Formation: Sibghatullah Siddiqui, Jamiluddin, I.H. Qureshi and A.H. Kidwai (1965) (verbal communications with Sibghatullah Siddiqui and Jamiluddin) used the name Shaheed Ghat Formation for the upper Rakhi Gaj and green nodular shales of Eames (1952). The type locality is Shaheed Ghat, Zinda Pir area of Dera Ghazi Khan District (lat. 30^0 24’N; long. 70^0 28’E). It consists of mainly shale/mud with negligible silt and sandy beds. The shale is grey, greenish grey, khaki and calcareous. The shale is rarely intercalated with silty and sandy lenses. The thickness of this formation is estimated 500m. The thickness of this formation is relatively slightly less than the other exposures in eastern Sulaiman Basin. Its lower contact with Dungan and upper contact with Toi Formation in the coal bearing areas) or Drug Formation (when Toi and Kingri formations are absent especially in the easternmost and southeastern part of Sulaiman Basin) are conformable. Siddiqui *et al.*, (1965) and Hassan *et al.*, (2001) suggested early Early Eocene age.

Toi Formation: The Toi Formation has been formalized after S. M. Hussain of American Oil Company’s briefing and verbal communication before the stratigraphic Committee of Pakistan (Shah, 2002). The Shah (2002) mentioned the Mughal Kot type locality with wrong grid reference, while correct references seams to be (lat. 31^0 29’ N; long. 70^0 07’E). Its name is derived from the Toi River/Nala flowing near the Mughal Kot locality. It consists of sandstone, greenish grey to grey shale and white to light brown marl/rubbly limestone along with some coal. The sandstone is greenish grey to grey and thin to thick bedded. The shale is greenish grey, khaki and calcareous. The marl or limestone is white to light brown and rubbly. The coal is sub bituminous and have metallic luster. The thickness of Toi Formation is about 600m in the type area of Mughal Kot section.

The lower contact of Toi Formation with Shaheed Ghat Formation is conformable while the upper contact with Kingri formation is disconformable. Raza (2002) correlated the Kingri molasses with the Litra and Chaudhwan formations of Vihowa group, but in actual Kingri molasses represents Eocene Toi and Kingri formations of Chamalang Group. It has no correlation with Vihowa or Siwalik mollasse. Shah (2002, 2009) mentioned the wrong position of Toi Formation. It has many fossiliferous sandstone/ coquina beds especially in the Chamalang area. According to its stratigraphic position, its age can be considered as middle Early Eocene.

Kingri Formation: The tem Kingri Formation was first used by Malkani (2009f). The type of Kingri formation is the just northwest of Kingri town (lat. 30^0 28' N; long. 69^0 47'E). It consists of reds shale/mud with subordinate grey sandstone. The shale is mostly red and maroon and sandy and silty and calcareous. The sandstone is grey to light brown, thin to thick bedded. The thickness of this formation is estimated about 700m in the type section. It represents the flood plain or overbank fines along with channel sandstone. Its lower contact with Toi and upper contact with Drug Formation are disconformable. Gingerich, *et al.,* (2001) has also found a unique mammalian fauna from the Kingri/Toi formation of Gandhera (Kingri) area. According to its stratigraphic position, its age can be considered as middle Early Eocene.

Drug Formation: Sibghatullah Siddiqui, Jamiluddin, I.H. Qureshi and A.H. Kidwai (1965) (verbal communications with Sibghatullah Sidique and Jamiluddin), and Iqbal (1969) used the name Drug Formation for rubbly limestone of Eames (1952). The type section (lat. 30^0 49' 15''N; long. 70^0 12' 30''E) has been designated in Drug Tangi located about 3 km southeast of Drug village (Shah, 2002). The Shah (2002, 2009) mentioned the wrong order or position of Ghazij group formations like Toi and Drug formations. The actual position of Toi Formation is below the Drug Formation while Shah (2002, 2009) mentioned every where the Toi formation is above the Drug formation. It is confirmed in the north and southwest of Sulaiman province. It consists of limestone, marl and shale. The limestone and marl is chalky white to light brown and grey, rubbly and thin to thick bedded. The shale is grey, khaki and calcareous. The formation is maximum thick in the core of Sulaiman foldbelt like Baghao and Rar Khan Areas of Barkhan District and estimated about 200-300m thick. It is being reduced in all directions from these maximum thick areas. It is absent in the Axial Belt, Kirthar Foldbelt and also in Mughal Kot section of Sulaiman Foldbelt and further north. Its lower contact with Shaheed Ghat Formation in the easternmost and southeastern Sulaiman Foldbelt is transitional and conformable, and upper contact in the northeast, central and western Sulaiman Foldbelt is disconformable with the Kingri Formation, and in the eastern and southeastern Sulaiman Foldbelt the upper contact with Baska Formation is conformable and marked at the first bed of alabaster gypsum. The Drug limestone and shale is the host of celestite mineralization (Fig.1e) in Sulaiman Foldbelt. It has many fossiliferous sandstone/coquina beds especially in the Chamalang area. Siddiqui *et al.,* (1965) and its stratigraphic position tells its age as late Early Eocene.

Baska Formation: The name Baska shale is proposed by the Hemphill and Kidwai (1973) to replace the descriptive term “shale with alabaster” of Eames (1952). Hemphill and Kidwai (1973) designated the type section exposed about 2 km east-northeast of Baska village (lat. 31^0 29'N; long. 70^0 08'E). It consists of gypsum, shale, limestone, marl and rare siltstone. The gypsum is grey to grayish white, medium to thick bedded and massive. . Shale is grey, khaki and calcareous. The marl is cream white, thin to medium bedded and porcelaneous. The siltstone is greenish grey to grey and thin to medium bedded. Its thickness is estimated variable from 100m to 30m. As lateral variation, this formation is relatively more and maximum thick than the other exposures in the Chamalang, Nisau, Manjhail, Toi Nala, Toi River and Barkhan areas and minimum thick in the south eastern and southern Sulaiman located in the central core of Sulaiman Basin. Its lower contact with Drug Formation and upper contact with Habib Rahi Formation are conformable. It has many fossiliferous rubbly limestone beds especially in the Chamalang and Mughal Kot sections. According to its stratigraphic position, its age can be considered latest Early Eocene.

Kahan Group: The term Kahan group was first introduced by Khan (2009) in his Geological map of 39 G (1^0 sheet). The type section is here designated near the village of Kahan (lat. 39^0 17'N; long. 68^0 50'E). Kahan group consists of Habib Rahi, Domanda, Pirkoh and Drazinda formations which were previously members of Kirthar Formation. The stratigraphic committee of Pakistan (Shah (2002) has formalized these formations.

Habib Rahi Formation: Tainsh *et al.,* (1959) used the term Habib Rahi limestone. The reference section (lat. 39^0 37' 50''N; long. 70^0 14'E) was mentioned by Hemphill and Kidwai (1973). But the grid of type locality (lat. 29^0 06' 10''N; long. 69^0 02' 30'E) located in the Vicinity of Dera Bugti town in the southern limb of Pir Koh anticline is first time being reported here. It consists of limestone, shale and marl. The limestone and marl is cream white, thin to medium bedded and porcelaneous. The shale is grey, khaki and calcareous. Its thickness is estimated 70m in the Dera Bugti area with vertical changes as 38m limestones alternated with shale and marl, 30m shale, and upper 5m limestone. As lateral variation, this formation is relatively more and maximum thick in the Pirkoh area than the other exposures in Sulaiman Foldbelt. Its lower contact with Baska Formation and upper contact with Domanda Formation are transitional and conformable. Muller (2002) assigned NP 16 of Nannoplanktonic zone. Early Middle Eocene age is assigned to this formation. From the transition zone of Habib Rahi and Domanda formation, Gingerich et al. (2001) discovered the walking whale from Lakha Kach syncline of Rakhni area of Barkhan District, has solved the evolution of swimming whale from walking early Artiodactyla instead of Mesonychia, and also assigned the age of the transitional zone (which is host of *Rhodocetus balochistanensis* and *Articetus clavis*) or contact of Habib Rahi and Domanda Formation as 47 Ma. So the age of Habib Rahi Formation is Early Middle Eocene.

Domanda Formation: Hemphill and Kidwai (1973) used the term Drazinda shale member and designated the type section to be just west of Domanda Post and adjacent to the Zhob-D.I.Khan road (lat. 31^0 35' 30''N; long. 70^0 12'E). It consists of mainly shale/mud with one bed of gypsum. The shale is chocolate, khaki and calcareous. Massive gypsum with one bed (1-2m thick) has white to light grey colour. The thickness of this formation is estimated 90m in the Dear Bugti area which comprised of vertical variations as 55m shale, 1-2m gypsum bed, and upper 35m chocolate shale. The thickness of this formation is relatively less than the other exposures in northern Sulaiman Foldbelt. Its lower contact with Habib Rahi Formation and upper contact with Pirkoh Formation is transitional and conformable. Eames (1952) reported vertebrates and invertebrates and Gingerich *et al.,* (1979, 1994) collected also vertebrates. This formation yielded fishes (e.g. *Apogon*), Shark (*Galeocerdo latidens*), sea snake (*Pterosphenus*) and cetaceans (*Indocetus ramani, Rhodocetus kasrani*). The basal transitional part of Domanda formation is aged by Gingerich *et al.,* (2001) as 47 Ma. Its age is middle Middle Eocene.

Pirkoh Formation: White marl band of Eames (1952) has been referred Pir Koh Limestone by unpublished records of oil companies (Cheema, 1977). Pir Koh limestone member was used by Hemphill and Kidwai (1973). The Pirkoh anticline is designated as the type locality (lat. 29^0 07'N; long. 69^0 08'E). It consists of limestone, marl and shale. The limestone and marl is milky white to cream white, thin to thick bedded and porcelaneous. Shale is grey, khaki and calcareous. The formation thickness is estimated 130m in the Pirkoh section (39G/4) and 30m thick in the Nisau area (39G/6), decreasing toward north in the Sulaiman Foldbelt. Its lower contact with Domanda Formation and upper contact with Drazinda Formation is transitional and conformable. Afzal *et al.,* (1997) mentioned Middle Eocene on the basis of 3 age-diagnostic planktonic foraminifers zones from Thak and Domanda sections and Bartonian age from Thak and Rakhi Nala sections. Middle to late Middle Eocene age is assigned to this formation.

Drazinda Formation: Hemphill and Kidwai (1973) used the term Drazinda shale member and designated the type section to the east and northeast of Drazinda village (lat. 31^0 46'N; long. 70^0 09'E). It consists of mainly shale/muds, and marl. The shale is chocolate, khaki and calcareous. The marl is cream white, thin to thick bedded, massive and porcelaneous. The formation thickness is estimated 120m in the Pirkoh section and 140m thick in the Nisau area, increasing toward north in the Sulaiman Foldbelt. In Dera Bugti areas, the Drazinda Formation have three horizons of white marl (each horizon is about 20m thick) in the base, middle and upper parts, alternated by thick shale horizons. Its lower contact with Pirkoh Formation is conformable while upper contact with Chitarwata Formation is disconformable. Latif (1964), Samanta (1973) and Afzal et al. (1997) mentioned the age range from late Middle to Late Eocene.

Oligocene-Pliocene

Vihowa Group: The term "Vihowa Group" is first used by Malkani (2009f). Oligocene-Pliocene Vihowa group (type section is the Vihowa Rud in Toposheet 39 I/4,8;lat.$31^0$04'N;long.70^0 16'E) represents Chitarwata, Vihowa, Litra and Chaudhwan formations. The Suture zones are elevated on a great tectonic event occurred at the collision of Indo-Pak subcontinent and Asia. The mollasse facies started and different river systems may have deposited this group and also its equilent strata.

Chitarwata Formation: The Chitarwata Formation was first used by Hemphill and Kidwai (1973). The type section designated to be at Chitarwata Post (lat. 31^0 03'N; long. 70^0 14'E). It consists of sandstone, shale and conglomerate. The sandstone is white, *et al.,* varicolored, thin to thick bedded and fine to coarse grained, gritty, ferruginous, calcareous when muddy and slightly calcareous to noncalcareous and siliceous in silica sands. Some iron beds and silica sand are also found in the Dera Bugti area. The shale is maroon, red, khaki and calcareous and ferruginous. The conglomerate is thin to thick bedded and dominantly sandy and calcareous and ferruginous. On the base of Chitarwata Formation, about 30-100m thick resistant conglomeratic sandstone with some interbeds of silts and muds are mostly common in the Sulaiman Foldbelt. This unit is followed by a soft and easily erodable mostly red shale and varicoloured sandstone.

The lower part of Chitarwata Formation forms ridges and cliffs, and upper part forms slopes in most of the Sulaiman Foldbelt. Hemphill and Kidwai (1973) mentioned about 380m in the southeast of Domanda post and also estimated about 150m at Chitarwata post, Kaura and Litra nalas, they also mentioned the pinching towards North Waziristan. Its lower contact is disconformable as observed in the Gadumra section (39 G/5) of Barkhan district. Further Eames (1950, 1970) recognized an unconformity in the Rakhi Munh section. In parts of Bannu area, the lower contact with Eocene carbonate rocks is sharp and disconformable (Kazmi and Abbasi, 2008). Downing *et al.,* (1993) subdivided the formation in to three units like lower 156m thick unit of multicolored siltstone interbedded with sandstone. Its lower 19 m is highly limonitic siltstone. Middle unit which is 104m thick consists of medium to coarse grained, massive, multistoried, tabular and trough cross bedded sandstone. Iron concretions and wood fossils are found along some bedding planes. The upper unit is 153m thick fine sandstone with abundant mollusks, and sporadic bone fragments. The formation thickness is estimated 130m which comprising of 3-4m red mud, 1m basal conglomerate and 130m-alternated sandstone with shale and conglomerate.

Raza *et al.,* (2002) mentioned about 500m Chitarwata, 700m Vihowa, 1700m Litra and exposed basal 400m Chaudhwan formations in the Zinda Pir anticline area. Downing *et al.,* (1993) reported 410m Chitarwata, and 300m lower Vihowa formations at Dalana area of D. G. Khan district. They marked the upper contact of Chitarwata Formation just below the trough cross bedded sandstone of Vihowa formation in Dalana area. Downing *et al.,* (1993) reported coastal systems at Dalana area and they also suggested the facies associations of Chitarwata and Vihowa formations like a sequential shift in ascending order are of estuary, strand plain, tidal flat/tidal channel and fluvial environments. All the mollusks from the upper unit like Trigonia, Exogyra, and Turritella are interpreted as littoral or sublitoral marine (Kazmi and Abbasi, 2008). Pilgrim (1908, 1912) and Eames (1950,1970) reported basal marine facies in the Zin Range, where it varies from a two inch thick calcareous sandstone bed with Nummulites intermedius and Pecten substriatus between Khajuri and Shori nalas, to about a two feet thick hard limestone bed with Nummulites sp. in Dakko Nala. Pilgrim (1912) considered contemporaneous this zone with the upper Gaj. Raza and Meyer (1984) are of the view that the marine fauna was eroded from the underlying drazinda Formation and deposited in the overlying Chitarwata Formation and they also correlated it with Fatehjang Member of Murree Formation in the Potwar Plateau. Waheed and Wells (1992) interpreted it as fluvial in Chaudhwan and Rakhi Nala. The also mentioned the meandering features such as epsilon cross bedding, fining upward channelised sandstone bodies, point bar cross bedding and abundant overbank fines intercalated with crevasse splay deposits. Its lower contact with Drazinda Formation and upper contact with Vihowa Formation is disconformable.

The Chitarwata Formation is synonymous with Bugti bone beds or Bugti formation of Dera Bugti area. This formation is the host of continental vertebrates like *Balochitherium*, *Bugtitherium*, etc. Vickary (1846) first time reported the vertebrate fauna and land flora in Bugti areas. He reported bones of mastodon (a partial tusk of elephant), partial jaw of hippopotamus, broken jaws and various bones of crocodiles embedded in loosely cemented gravel with Paldina and cardium shells. He also mentioned that many cart loads of the bones could be collected from an acre of ground in the vicinity of Khumbi and Dera Bugti areas. Later Blanford (1879), Pilgrim (1908) and Cooper (1911,1923,1924a,b,c) collected and described fossils from these beds. This formation represents a unique blend of mammals of Asian affinity. It includes rhinocerotids and antharacotherids with few proboscideans, carnivores, chalicotheres, suids and crocodilians (Shah, 2002). Pilgrim (1908) found the genus ***Bugtitherium*** of Anthracotheridae (**Artiodactyla**) based on two fragments of two skulls which were identical and had portions of maxillaries and premaxillaries. He also attributed some isolated teeth to this genus. Coopper (1911) described the giant sized species *Paraceratherium (*synonymous ***Baluchitherium****/Indricotherium)* of *Hyracodontidae* (**Perisssodactyla**) from Churlands locality of Bugti hills. *Baluchitherium* is the largest land mammal known so far. It is larger than largest mammoth like *Mammuthus sungari.* Adult *Baluchitherium* are estimated to have been 5..5 m (18ft) tall at the shoulder, 12 m (39 feet) in length with tail and a maximum raised head height of about 8m (26 feet) and a skull length of 1.5m (4..9 feet) and total estimated weight about 20 tons. **Bugtilemur** (Marivaux, *et al.,* 2001) the cousin of primitive primates are also reported from Dera Bugti area. Metais *et al.,* (2006) reported the new remains of the enigmatic cetartiodactyl *Bugtitherium grandincisivum* Pilgrim 1908, from the upper Oligocene of the Bugti Hills. All these mammals lived in the green and lush landscape. The *Paraceratherium bugtiense* was based on moderately complete lower jaw with all lower teeth on each side of the mandible. In close proximity to *Paraceratherium* in the same Churlands locality, Cooper (1911) found the bones of greatest of all the rhinos (*Baluchitherium bugtiense*). His remarkable discovery was based on some neck vertebrae, foot and limb bones. Cooper (1924) also reported its cranial parts from Dera Bugti area. Later on, the discovery of a skull and a part of mandible in Mongolia were the basis of *Baluchitherium gravgeri*. Shah and Arif (1992) discovered 12 different faunal localities in Bugti hills, represents fragmentary postcranial remains of great rhinos. A partial skull with all cheek teeth in place and almost complete mandible of *Bugtitherium grandicisivum* was reprted by Shah and Arif (1992).

Eames (1970) compiled a list of 60 mammalian and 3 crocodilian species. Raza and Meyer (1984) listed about 63 mammalian species from Gendoi post and Chur Lando Nala. Some important genera a **(Table 2)**.

Table 2. Mammals from the Chitarwata Formation of Dera Bugti area (after Raza and Meyers 1984).

FOSSILS	Chur Lando	Kha-juri	Kum-bhi	Bugti hills
CREODONTA				
Hyainailouros bugtiensis			*x*	*x*
Megisttotherium ingens				*x*
CARNIVORA				
Amphyicyon shabazi	*x*		*x*	
A. cooperi			*x*	
Metarctos ? bugtiensis				*x*
PROBOSCIDEA				
Gomphotherium angustidens			*x*	*x*
Trilophodon pandionsis		*x*		
Bunolophodon angustidens (=T. cooperi)				*x*
Deinotherium pentapotamiae	*x*			*x*
D. sp.				*x*
RHINOCEROTIDAE				
Diceratherium shahbazi			*x*	
D.? naricum			*x*	
Aceratherium bugtiense	*x*		*x*	*x*
A. gajense			*x*	
A. blanfordi (=Teleoceros blanfordi)				*x*
A. abeli	*x*			
Chilotherium smithwoodwardi	*x*			
Ceratorhinus tagicus	*x*			
Brachypotherium fatehjangense	*x*			
Teleoceros fatehjangense	*x*			
Paraceratherium churlandense	*x*			
P. bugtiense	*x*			
Baluchitherium osborni	*x*			
AMYNODONTAE				
Cadurcotherium indicum			*x*	
CHALICOTHERIDAE				
Phyllotillon naricus			*x*	
Chalicotherium pilgrimi	*x*		*x*	

FOSSILS	Chur Lando	Kha-juri	Kum-bhi	Bugti hills
SUIDAE				
Listriodon affinis			*x*	
Xenochoerusjeffreysi			*x*	*x*
ANTHRACOTHERIDAE				
Anthracotherium bugtiense	*x*		*x*	*x*
A. punjabiense				*x*
A. silistrense				*x*
A. exiguum, A. adiposum				*x*
A. smithos				*x*
Brachyodus pilgrimi			*x*	
B. gandoiensis, B. giganteus				*x*
B. hypopotamoides			*x*	
B. platydens, B. strategus				*x*
B. africanus	*x*			
B. orientalis, B. indicus				*x*
B. strategus, B.barbonicoides			*x*	
Parabrachyodus obtusus				*x*
Ancodus ramsayi			*x*	
A. sp.				*x*
Hyoboops palaeindicus			*x*	
H. longidentatus	*x*		*x*	
H. minor			*x*	
H. naricus	*x*		*x*	
Gonotelma shahbazi	*x*		*x*	
G. major			*x*	
Telmatodon bugtiensis			*x*	*x*
T. orientale				*x*
Hemimeryx speciosus	*x*		*x*	
H. lydekkeri	*x*			
Gelasmodon gracilis	*x*			*x*
RUMINANTIA				
Prodremotherium ? beatrix				*Pishi Nala*
Gelocus ? gajensis	*x*			
G. indicus				*x*
Tragalus sivalensis				*x*
Progiraffa exigua				*Dakko Nala*

and species are *Metarctos bugtiensis*, *Amphicyon sp.*, *Deinotherium pentapotaamiae*, *Gomphotherium sp.*, *Paratherium bugtiense*, *Diceratherium shahbazi*, *Aceratherium gajense*, *Brachyodus giganteus*, and *B. africanus*. Shah and Arif (1992) discovered 12 different faunal localities in Bugti hills, represents fragmentary postcranial remains of great rhinos during 1985 and 1987. They also reported a partial skull with all cheek teeth in place and almost complete mandible of *Bugtitherium grandicisivum.* Raza *et al.,* (2002) reported the large mammalian fauna from Zinda Pir anticline Deinotherida (*Deintherium*), Gomphotheridae (*Hemimostodon*, *Gomphotherium*), Chalicotheridae (gneus and sp. indet.), Rhinocerotidae (genus and sp. indet.), Suidae (*Snaitherium*?) and Anthracotheridae (*Masritherium*). They also mentioned the family level similarities of these fauna with the overlying Vihowa/ Siwalik group but different at generic level. Downing *et al.,* (1993) and Flynn 2000) reported a major faunal turnover event in upper Chitarwata Formation circa 20 Ma. Shah and Arif (1992) reported the lenticular beds of volcanic ash just below the *Baluchitherium* host beds in the Chur Lando Nala observed by GSP party in 1985. The sample of tuff was processed by

Tabbut *et al.,* (1992) for absolute dating. They have dated using the external detector method of fission track dating on zircon grains which yielded a concordant age of 22.6 +_ 2.9 Ma for this formation. Based on faunal analysis and absolute dating, the age of this formation is considered as Late Oligocene to Early Miocene (Shah, 2002). In the Zinda Pir anticline, small mammals and magnetic polarity (Lindsay and Downs, 2000) suggests an early Miocene age. According to stratigraphic position, its age may range from Oligocene to Early Miocene.

Vihowa Formation: The Vihowa Formation was first used by Hemphill and Kidwai (1973). The type section designated to be Vihowa Rud (lat. 31^0 04'N; long. 70^0 16'E). It consists of shale, sandstone and conglomerate. Shale is red, maroon, khaki and calcareous and ferruginous. The sandstone is grey to white, thin to thick bedded and fine to coarse grained, gritty, calcareous when muddy and slightly calcareous to noncalcareous and siliceous in silica sands. The conglomerate is thin to thick bedded and dominantly sandy and calcareous and ferruginous. The white to light brown, thin to thick bedded and medium to coarse grained silica sands are also observed. Thin to thick iron muddy and sandy beds are also observed. The formation thickness is estimated 400-700m. It is about 700m thick in the type area and about 400m thick at Chaudhwan Zam area. The dominant rock type is red siltstone and mud in the type area while in the north at Chaudhwan Zam the red sandstone and muds are common. Hemphill and Kidwai (1973) reported mammalian bone fragments near Baddha village. La Touché (1893) also reported bones and teeth between Parwara and Landai villages in a somewhat pebbly band near the base of this formation.

Its lower contact with Chitarwata Formation and upper contact with Litra Formation is disconformable. This formation is rich in continental vertebrates. Waheed and Wells (1992) mentioned its fluvial origin with braided river system flowing toward SSW. The abundance of sand, large size of bed forms, and southward flow indicates a large longitudinal trunk river (Kazmi and Abbasi, 2008). The Downing *et al.,* (1993) mentioned advanced cricetids, rhizomyids, a ctenodactylid, the enigmatic rodent *Diatomys*, possibly a hedgehog (*erinaceid*), plus tree shrews *(tupaiid*) and a bat, and large mammals include gomphothere, deinothere, chalicothere, rhino, suid, anthracothere, tragulid and bowid fossils. Downing *et al.*, (1993) also mentioned the similarity of Vihowa Formation of Sulaiman Foldbelt with Kamlial formation of Potwar plateau. Raza *et al.,* (2002) reported large mammals like carnivore, Deinotheridae (*Deinotherium*), Gomphotheridae (*Gomphotherium*), Chalicotheridae, Rhinocerotidae, Suide (*Sanitherium* and *Listridon*), Anthracothridae (hyoboops), Traguliade (*Dorcatherium minimus*), Giraffidae (*Giraffokeryx*), and Bovidae (*Eotragus, Elachistocerus*). Raza *etal,* (2002) estimated the onset of Vihowa Formation at Burdigalion time (~18Ma) and they confirmed the latest early Miocene to Middle Miocene on the basis of *Eotrgus noyei, Listriodon sp., Giraffokeryx sp.* and *Hyoboops sp.*

Litra Formation: The Litra Formation was first used by Hemphill and Kidwai (1973). The type section designated to be Litra Nala (lat. 31^0 01'N; long. 70^0 25'E). It consists of sandstone with subordinate shale and conglomerate. The sandstone is grey, thin to thick bedded and massive, fine to coarse grained, gritty and calcareous. The shale is maroon, khaki and calcareous. The conglomerate is thin to thick bedded and dominantly sandy and calcareous. Its lower contact with Vihowa Formation and upper contact with Chaudhwan Formation is disconformable. This formation is the host of continental vertebrates. Raza *et al.,* (2002) reported large mammals such as Gomphotheriidae (*Gomphotherium sp., Choerolophodon corrugatos*) and Equidae like *Cormohipparion (sivalhippus) theobaldi* and *Hipparison sp*. from the middle part from Zinda Pir anticline, while the bovids, graffids and suids from the upper part of this formation. Raza *et al.,* (2002) mentioned three toed horse Hipparion at about 10.7 Ma from the lower 400m of Litra Formation, which show the co-occurrence of common chinji type suid Listriodon that becomes extinct at 10.3 Ma in Potwar. They placed the lower age of Litra formation at 11 Ma based on Hipparaion in the lower part of this formation. They also estimated the age of Litra Formation from 11 to 6 Ma i.e. Late Miocene.

Chaudhwan Formation: The Chaudhwan Formation was first used by Hemphill and Kidwai (1973). The type section designated to be in Chaudhwan Zam (lat. 31^0 37'N; long. 70^0 15'E). It consists of alternated mudstone/shale, sandstone and conglomerate. The mudstone/shale is maroon, khaki and calcareous. The sandstone is grey, brown, thin to thick bedded, fine to coarse grained, gritty and calcareous. The conglomerate is thin to thick bedded and dominantly sandy and calcareous. Thick conglomerate beds with some mud and sands cap the upper part of this formation. This cap is forming long belt in the eastern most boarder of Sulaiman Foldbelt. This cap is the contact of Sulaiman Foldbelt and Sulaiman Foredeep zone. The formation thickness is estimated 750-650m. Its lower contact with Litra Formation is disconformable while upper contact with Dada Formation is angular. This formation is the host of continental vertebrates' likely Bugti lemur, etc. According to stratigraphic position, its age may be Pliocene.

Pleistocene

Dada Formation: Its name is derived from Dada River (lat. 29^0 50'N; long. 68^0 03'E) south of Spintangi Railway station (HSC, 1961). It consists of conglomerate with subordinate shale and sandstone. The conglomerate is thin to thick bedded and dominantly sandy and calcareous. Thick conglomerate beds with some mud and sands cap the upper part of this formation. The mudstone/shale is maroon, white, khaki and calcareous. The sandstone is grey, brown, thin to thick bedded, fine to coarse grained, gritty and calcareous. Its lower contact with older formations and upper contact with younger alluvium are angular. According to stratigraphic position, its age may be Pleistocene.

Subrecent-Recent

Subrecent and Recent surficial deposits show the alluvial, colluvial and aeolian deposits.

4. Updated mineral potential of Sulaiman Basin of Pakistan

Ahmed (1969), Heron (1954), Raza and Iqbal (1977) Kazmi and Abbas (2001), Malkani (2004c) have described and compiled the minerals of Sulaiman Basin. Some new findings from Sulaiman Basin are being added here.

Coal: Coal resources are necessary due to increasing energy demand in Pakistan as a consequent of increase in population and some coal deposits of world show associated gold, silver, arsenic, selenium and zinc. Further uranium from North and South Dakota lignites have been also reported (Brownfield, 2005; Siddiqui, 2007). Working coal mines in Balochistan are Mach, Sor Range-Deghari, Narwar-Pir Ismail Ziarat, Khost-Shahrag-Harnai, and Duki, Chamalang-Bahlol coal fields with total reserves of about 196 million tons. The coal from Dureji in the southern Kirthar, Balgor in the southern Makran range, Badinzai and Kach from Sulaiman Foldbelt are reported but details are not provided by Kazmi and Abbas (2001). Here some new findings (Fig.2c) are added. Due to energy crises and demand, the discoveries of fuel resources are necessary for consistency. The new findings of coal are being presented here.

Chamalang coalfield: The present investigations show the coal mining in Chamalang coalfield is extended from Mari Bijar to Surghari, Lunda, Bala Dhaka, Nausham and Bahlol areas (Malkani, 2004e). There are maximum (more than 20) coal seams in Chamalang Coalfield with relevant to coalfield in Balochistan province while Duki Coalfield has about 17 coal seams. There are 11 main coal seams greater than 1foot thick are exposed in the Canteen area. The lower zone have Do/Char footi and Chey footi seams, the middle zone have Malkani, Zahid, Dr. Raza, Dr. Imran, Pak and GSP-Khalid Kashmiri coal seams, and the upper zone have Bakhtawar, Sadiq and Nau footi coal seams (Fig.2d). The Angoor Shela, Mari Bijar, Toba Qadri area have only three main coal seams like Do footi, Chey footi and upper Nau footi coal seams. In the Surgahri area the number and thickness of coal seams are being reduced. The Lunda area has only exposed upper Nau footi seam and remaining are in the subsurface. The Nausham area may have moderate and mineable thicknesses of coal. The Bahlol area shows thin exposures of coal. The present work has estimated total reserves upto 30 million tons of one feet or more thick coal seams of Chamalang coalfield, while the total reserves of six inches or more coal seams of Chamalang Coalfield (Mari Chamalang, Toba Qadri, Angoor Shela, Canteen, Anokai, Lower Surghari, upper Surghari, Goru, Lunda, Bahney Wali, Bala Dhaka, Nosham, Lomro, Belond and Bahlol areas) are about 100 million tons. The coal from the Khauri locality of Zidi area (Khuzdar District, Toi Nala (Musa Khel District), Miri Wah and Bibar Tak-Kali Chapri (Barkhan District) have been reported first time now.

Coal from the latest Cretaceous Vitakri Formation of Kingri area of Musa Khel district, Balochistan Province: Kingri coal (Musa Khel district) has been first time reported by Malkani (2004c) from Vitakri Formation. Before this, no any coal of Cretaceous age was reported in Pakistan. However Malkani (2004c) mentioned the age as Paleocene but the present work has positioned it on the K-T boundary or latest Cretaceous. Its moisture, volatile matter and fixed carbon are low while ash and sulphur are high. It's heating value BTU/Lb varies from 5508.32 to 5526.00 or Kcal/Kg varies from 3057.12 to 3066.93. Moisture varies from 1.64 to 1.95 %, ash from 55.04 to 55.22 %, volatile matter from 17.98 to 18.04 %, fixed carbon from 25.02 to 25.10 %, and total sulphur from 5.56 to 5.58 %. Analyses of these constituents and factors represent the rank of coal as lignite. The Kingri coal has high mud content with dull luster but its thickness seems to be relatively more. Reserves estimation of Kingri coal of Sulaiman Basin is tentative because no exploratory holes have been drilled to ascertain the size of coal seams at depth. However, total estimated reserves are about 2 million tons. Malkani (2006d) mentioned these coal beds are deposited by lagoon to crevasse splays lacustrine, while alternated sandstone horizons are formed by meandering river system. However the crevasse splays over flood is from the D.G.Khan-Vitakri paleoriver flowing generally east west. The coal coeval strata in the southern vicinity are Vitakri Formation consist of meandering river and overbank flood system which is the host of dinosaurs and associated vertebrates. In the northern far the

Paleocene Hangu coal can be considered its coeval strata and possibly the same depositional environments. This latest Cretaceous coal is very significant for economic but also for the research study like the impact paleofire, fusinite, and iridium anomaly.

Coal from Early Eocene Toi Formation of Toi Nala area of Musa Khel district, Balochistan Province: The present coal discoveries in Sulaiman Basin have extended the coal basin from Chamalang Bahlol toward east and north east. New deposits of coal from Toi Formation (Chamalang/Ghazij group) have been discovered from Toi Nala area of Musa Khel District, Balochistan Province. The thickness of coal horizons (sandstone, coal, carbonaceous shale) vary from 1m to 4m. The coal seams are layered with the sandstone and hard muds. The coal seem is about 30cm thick in the eastern part of Toi Nala like Pahlwan Kach area, while it is more thick in the western part like Jamal Din Esot area. In The Jamal Din Esot area, the coal exposures are found on the vicinity of both sides of Toi Nala. Toi Nala coal is different from Shirani and Chamalang coal. Mughal Kot delta is separate delta than Kingri and adjoining Balochistan delta. The source of wood and other organic materials was favorable for the deposition of coal in Balochistan. The source of wood and other organic materials was scarce and not favorable for the deposition of Toi coal in Shirani area, however some coal and carbonaceous seams are also observed. The lower and upper contacts of Toi Nala coal and its host sandstone and muds (about 5m thick) are found with marine limestone/marl and shale. Toi Nala coal is hard with a well developed metallic luster. Further this coal is relatively close to the Indus highway and utilizing industries. The analyses of surface coal samples represent moisture from 1.90 to 2.31 %, ash from 22.78 to 23.32%, volatile matter from 42.10 to 56.21%, fixed carbon from 32.80 to 43.79%, and total sulphur from 6.01 to 8.03%. It's heating value BTU/Lb or) is B.T.U./Lb vary from 9748.88-9979.61 or Kcal/Kg from 5410.63-5538.69. Analyses of these constituents and factors represent the rank of coal as sub-bituminous. The presence of high volatile matter in coal is good on one hand because it improves the burn ability of coal flame configuration. However, at the same time, it makes extremely difficult the storage, grinding and preparation of coal for firing the rotary kiln. Reserves estimation of Toi Nala coal of Sulaiman Basin is tentative because no exploratory holes have been drilled to ascertain the size of coal seams at depth and also in the strike extension. However, total estimated reserves are less than 1 million tons. Further some showings of the Toi Formation coal has been found from Tang Mirri Wah of Baghao, Warezai and Narhan areas of Hosri, Karahi, Thal (south of Duki), some areas in the vicinity of Alif Mir Janzai (Luni) areas of Duki, Khan Mohd Kot area of Musa Khel, some localities on the west of Ziarat, and Drug Formation coal from Tumni, Lundi Sar and some other areas of Baghao.

Coal from Early Eocene Toi Formation of Shirani area of Frontier Region D.I. Khan District, Khyber Pukhtoonkhwa Province: The Toi coal from Shirani area (Shin Manda, Khoara Khel, Ragha Sar and Mughal Kot) of Frontier Region D.I. Khan District and Zamaray area of Musa Khel District have been reported. The Khoara Khel locality has best exposures but thin coal seams and stringes. One mine is under operation in the Khoara Khel area and Mine worker reported the coal seam thickness is being increased upto 8 inches at inclined depth of about 200 feet. The Baska Formation has also coal lenses and pockets in the Khoara Khel and its vicinity areas. The coal from Domanda/Drazinda Formation in the boarder of Shirani and South Waziristan has been reported by local inhabitants. At this moment these localities are not economic show no production but in near future some localities may prove small economic deposits because of high demand in fuel energy resources.

Coal from Late Eocene Domanda Formation of Rakhni area (Barkhan district), and Nisau area (Kohlu district), Balochistan: The Mahoi (Lat. 30^0 32' 51''N; Long. 70^0 31' 13''E;39J/10) and Zain coal (Lat. 30^0 34' 52''N; Long. 70^0 30' 17''E; 39 J/6) of Zain BMP post area of Taunsa, and Rakhi Munh (Lat. 29^0 57' 55''N; long. 70^0 07' 12'' E) coal of District D.G.Khan where coal had been mined out to some extent but the mine is abandoned at present. The thickness of the coal seam at Rakhi Munh is about 0.3m and its chemical analysis shows 4.3% moisture, 23.52% ash, 37.32% volatile matter, 34.86 fixed carbon, 6.72 sulphur, and 9286 BTU value. The floor and roof rock of the Rakhi Munh coal are shale/claystone (Thangani *et al.*, 2006). The Mahoi and Zain abandoned coal mines in Late Eocene Domanda Formation are located near Zain BMP post and can be approached from D.G.Khan through Barthi via Chaukiwala located on Indus highway. Rakhi Munh coal is accessible from Rakhi Munh town which is situated on D.G.Khan-Loralai road. Nabi Bakhsh Thal Nala (Lat. 29^0 44' 56''N; long. 70^0 02' 38''E), Khan BMP post (Lat. 29^0 45' 10''N; long. 70^0 02' 48''E), and Upper Tuso (Lat. 29^0 49' 06''N; long. 70^0 03' 07''E) coal in Domanda Formation of Khan BMP area are located in Rajan Pur District (Abbas, et al., 2008). These sites can be approached via footwalk from Thul Haro. Thul Haro is 15 km toward south-southwest from Choti Bala town which is connected via metalled road to D.G.Khan. New coal horizon has been found from the Late Eocene Domanda Formation of Rakhni area of Barkhan District, and Nisau area of Kohlu district, Balochistan. The Domanda coal are found where the Toi and Kingri formations are absent in the eastern and southern Sulaiman Basin. Further this coal is found stratigraphically just below the coquina beds and gypsum bed. The thickness of new Late Eocene coal horizons (coal and papery carbonaceous shale) vary from 30cm to 2m. The coal seem is 30cm thick in the Rakhi Gaj area but it may extend and become thick toward west or northwest due to basin and source configuration. The Domanda shale is the host of this coal horizon. There is possibility of this coal in the Safed, Chitarwata, etc, areas. This coal horizon is new, if productive then it will be very useful due to its relative close location to Indus highway and utilizing industries. Reserves estimation of Lakha Kach coal of Sulaiman basin is tentative because no exploratory holes have been drilled to ascertain the size of coal seam at depth, however, total estimated reserves are about 1 million tons. If extended throughout of Lakha Kach syncline, then it may contain more than 5 million tons. Further the Coal from Drazinda Formation of Haft Gath (Zinda Pir area) of D.G.Khan (Lat. 30^0 25’ 00’’N; Long. 70^0 31’ 14’’ E; Zinda Pir area) coal is hosted by Late Eocene Drazinda Formation (Abbas, *et al.*, 2008). The Coal from lower Oligocene-Miocene Chitarwata Formation of Vahova group of Sulaiman Basin from the Khandor locality (Lat. 30^0 13’ 55’’N; Long. 70^0 12’ 47’’E) in Oligocene Chitarwata Formation is located near Khandor BMP post and can be approached from Sakhi Sarwar which is on the D.G.Khan-Loralai road (Abbas, *et al.*,2008). The coal lenses/showings in Oligocene-Miocene Chitarwata, Vihowa formations have been observed from Chitarwata area in Vihowa rud of Sulaiman Basin.. Some pitting and digging are tried but so far no economic potential are proved.

Discovery of Celestite deposits from Sulaiman Basin of Pakistan: New celestite deposits are found from Sulaiman Basin (Balochistan Province) of Pakistan. This is the third deposits in Pakistan and has great significance as the previous proved reserves of celestite in Pakistan like Thano Bula Khan (Sindh) and Daud Khel (Punjab) are going to be exhausted, shortly. Celestite, one of the fluxing materials used in metallurgy and due to small deposits in the country is in high demand in Pakistan. Strontium and strontium compounds are utilized in pyroelectrics, such as in tracer bullets, distress signal rockets and flares, military signal flares, transportation warning fuses, and fireworks. Other use include ceramics, chemicals, depilatories, caustic soda refining desulphurizing steel, dielectrics, greases, luminous paint, plastics and welding rod coatings. Strontium salts are also used in desaccharizing beet-sugar molasses, and as a purifying flux in metallurgy. Powdered celestite is used as filler in white pains, as a substitute for barite as rubber filler, and in oil drilling mud. The discovered new celestite localities (Fig.2c) are under the administrative control of Barkhan, Kohlu, Dera Bugti, Musa Khel and Loralai districts. The Barkhan (Gadumra and Lal Khan Village) celestite deposits are about 135 kilometres west of Dera Ghazi Khan. The Lakha Kach celestite deposits are about 105 kilometres west of Dera Ghazi Khan. The accessibility from D.G.Khan is mostly by motorable fair weather metalled road with some unmetalled track just near the deposits. The Sham celestite deposits are about 195 kilometres south-southwest of Dera Ghazi Khan town. The Sham celestite locality lies at half an hour ascending walk toward peak from Sham village (about 2 kilometers). The Pirkoh celestite locality is just 15 km north of Dera Bugti town. The Toi Nala celestite localities are about 90 kilometres west of Vihowa town of Dera Ghazi Khan District. The Chamalang and Bahlol celestite deposits are about 70 kilometres north of Kohlu town and about 80 kilometres northwest of Barkhan town. Most of these deposits can be approached through Indus highway at D.G.Khan. D.G.Khan has a railway station and about 1000 km from Karachi. Celestite deposits are found on the synclinal limb. Celestite deposits are found on the limb of many synclines. Relief of celestite localities of Sulaiman Range varies from about 500 to 1800 meters above mean sea level (AMSL). Its topography is rugged. Climate of the area is semi arid with warm summer up to maximum 45 degrees centigrade and mild winter rarely down to freezing point. Summer is commonly severe and hot in the Range. The quarrying for celestite can be done in all seasons. The present discoveries which are being described here are highly valuable in mineral wealth of Pakistan. The celestite deposits are found in the Early Eocene Drug Formation (Fig. 1e) and Late Eocene Domanda Formation. The mineral celestite is composed of strontium sulphate ($SrSO_4$). The celestite of Sulaiman Foldbelt is orthorhombic with tabular or prismatic, white, faint blue tinge (Fig.2b), translucent, pearly, cleavable and coarse fibrous, and with a specific gravity of about 3.9 and hardness about 3.5.

Two principal types of celestite deposits are found in the Sulaiman Basin. **Vein type** deposits are found mainly in the Gadumra and Lal Khan Village deposits (Fig. 1e) of Barkhan District, and Sham deposits of Dera Bugti District. This vein type deposits are found in the shale of uppermost portion of Drug Formation in the Gadumra and Lal Khan Village deposits of Barkhan District, and Sham deposits of Dera Bugti District, in the limestone of Drug Formation in the Lakha Kach syncline. The width of individual vein in Dadumra, Lal Khan Village and Sham localities is 10 centimeters, exposed length varies from 10 meters to 50 meters, and however it seems more extensive. A vein of celestite (~10cm) is found in the Drug Formation just below the Baska gypsum beds in the Sham, Lal Khan and Gadumra areas. Its extensions seem to be consistent with the host formation however it needs ground follow up. The contact of ore body and wall rock is sharp. **Disseminated crystals in limestone** are found in the upper part of Drug Formation (and also below the vein type deposits; Fig. 1e) in the Gadumra, Lal Khan Village and Lakha Kach localities. The dissemination of celestite in the limestone is less than 30 cm in Lal Khan and Lakha Kach village. The veins of celestite deposits are of varying lengths and widths while disseminated celestite crystals are found in the fracture zones, cracks, joints and cavities in limestone. The dissemination in the limestone of Drug Formation is due to replacement of the limestone (calcite). The celestite apparently formed from geodynamically hydrothermal (epithermal) solutions containing strontium sulphate. The genesis of mineralization might be due to geodynamics/ plate tectonic orogeny which is responsible for the epithermal (hydrothermal) solution created from host rocks or the upper disconformable contact that may contain anomalous strontium sulphate content, since igneous rocks are not exposed in the immediate vicinity. All the Celestite deposits are related to gypsum deposits because the celestite deposits of Drug Formation are located just below the Baska gypsum, and celestite occurrences of Domanda shale are located just below the Domanda gypsum bed. It is possible that sulphate is originated from gypsum deposits and strontium from hydrothermal solutions from host rocks or gypsum associated strata. Chemical analyses of two samples of celestite from Sham locality were analyzed by the Chemistry Lab. Geological Survey of Pakistan, Quetta. These results show SrO 38.50 to 39.21%, SO_3 42.64 to 42.96 %, BaO 7.63 to 7.99% and CaO 1.10 to 1.12%. Celestite contains small amounts of calcium and barium. Reserves estimation of Sulaiman basin localities is tentative because no exploratory holes have been drilled to ascertain the shape and size of ore bodies at depth. The ore bodies are scattered in the area and mostly covered by scree. However, estimated reserves of Lal Khan village is 2000 tons, Gadumra area is 2000 tons, Lakha Kach areas is 5,000 tons, Sham area of about 2000 tons, Toi Nala area of about 1000 tons, Chamalang and Bahlol area of about 1000 tons and Pirkoh area of about 100tons. Malkani (2004c) reported first time the celestite from Sulaiman Basin. Malkani (2002b) found celestite nodules in the Late Eocene Kirthar limestone and shale of Karkh area of Khuzdar district. Both discoveries are compelling for further exploration in Sulaiman and Kirthar basins.

Gypsum deposits from Sulaiman basin of Pakistan

The gypsum deposits reported by HSC (1961) are Spintangi (39 C/1), Nakus (34N/161), Dungan (39 C/5), Bala Dhaka (39 F/8), Bahlol (39 F/12), Mawand (39 C/10) and Mach (34 O/5,6, 10). Sheikh (1972) carried the evaluation of Spintangi gypsum deposits. Some new deposits are discovered by Malkani (2000). Further the new details are being provided here. The mineral gypsum is composed of hydrated calcium sulphate, $CaSO_4.2\ H_2O$. Gypsum is formed as a saline residue arising by the evaporation of enclosed basins of sea water. Alabaster is the mineral which is fine grained and compact snow white to light smoky white with low hardness (1.5-2) and also low specific gravity (2.2). Gypsite is gypsum mixed with sand and dirt. Gypsum is used as retarder in cement, as a fertilizer, as filler in various materials such as paper, crayons, paints, rubber, etc and in the manufacture of plaster of Paris for which purpose the mineral is heated to expel some of its water of crystallization and then ground up. Calcined gypsum is extensively employed in the building trade for the production of various types of plasters, sheets, and boards and for stucco work; it is also used as polishing beds, in the manufacture of plate glass, and as an adulterant of foods. Some local peoples used the gypsum blocks in the graveyards for beauty. Gypsum is hosted by the Early Eocene Baska Formation (Fig.1c,2c) of Chamalang Group and Late Eocene Domanda Formation (Fig.1d) of Kahan Group in the Sulaiman Basin of Pakistan. These beds are Baska gypsum are quite extensiv and thicknesses are variable. The Baska Formation consists of shale, gypsum beds, limestone, coquina and marl/siltstone. Domanda Formation consists of shale with one but extensive bed of gypsum (found only in southern Sulaiman Foldbelt) varying in thickness from 0.3m to 6m. The maximum thickness of Domanda gypsum bed is observed in Gadumra and Nisau-Vitakri areas occupying southern side of the Sulaiman Basin and minimum thickness is found in the Manjhail-Kharar Buzdar area of central Sulaiman Basin and then further north it is absent. Main environments of gypsum beds show platform type supratidal environments. Total reserves of about 675 million tons have been estimated at 21 localities of Sulaiman Foldbelt. Out of these over 350 million tons exist in Barkhan and Kohlu districts, 44.0 million tons in Dera Bugti District, 16 million tons in Sibi District, and small deposits i. e., less than 1 million tons in Musa Khel District of Balochistan, while the rest i.e., 244 million tons in D.G.Khan and Rajan Pur districts of Punjab, and 20 million tons exist in Shirani area of D.I.Khan Distr. (NWFP). Gypsum 95% and anhydrite 5% are inferred from the Chemical analyses of about 125 samples from different deposits. The quality of gypsum and anhydrite is good as impurities are less than 2%. There are 4 to 15 beds of gypsum in Baska Formation with cumulative thickness of 5m to 25m. The Baska gypsum deposits are being described here.

Lakha Kach (Rakhni, 39F/16) is located very close to the metalled road near Rakhni town, which is connected with D. G. Khan. Gypsum is found in a syncline with beds dipping 25 to 70^0. The syncline extends upto 20 km. Taking extension of gypsum as 30 km on both limbs of the syncline, cumulative width 15m and easily mineable depth 50m, the total reserves are 49.5 million tons. Chemical analyses show that CaO content varies from 29.44 to 33.65%, SO_3 from 44.65 to 47.78%, and H_2 O from 16.30 to 18.99%. **Kodi More-Nodo (39 F/16)** is located 20km west of Rakhni town, which is situated near the Loralai-D.G.Khan metalled road. Baska gypsum beds dips 25 to 55^0 in the Kodi More and 35 to 80^0 in the Nodo area. The deposit is thrusted and faulted. The Kodi More deposit is found in the footwall and Nodo deposit is found in the hanging wall. There are 5-7 beds of Baska gypsum. Taking 5km as extension, 15m width and 50m depth, the reserves are 8.2 million tons. Chemical analyses show that CaO content varies from 30.84 to 32.25%, SO_3 from 45.68 to 46.46%, and H_2 O from 16.33 to 19.38%. **Ishani (39 G/9)** is located 35km southwest of Rakhni town situated on Loralai-D.G.Khan metalled road. The towns close to the deposits are Rakhni and Barkhan which are connected with D.G.Khan by a metalled road. There are 5-7 beds of Baska gypsum having 20m cumulative thickness of gypsum. The dips of the beds vary from 50^0 to vertical. Taking 7km as extension, 20m width, and 50m depth, the reserves are 15.4 million tons. Chemical analyses show that CaO content varies from 30.84 to 32.25%, SO_3 from 45.50 to 46.79%, and H_2 O from 16.59 to 19.48%. **Khurcha gypsum deposits (39 G/9, 13)** is located 15km southwest of Rakhni town situated on Loralai-D.G.Khan metalled road. There are 9 beds of Baska gypsum having 25m aggregate thickness of gypsum. The dips of the beds vary from 50^0 to vertical. Taking 3km as extension, 25m width, and 50m depth, the reserves are 8.2 million tons. Chemical analyses show that CaO content varies from 28.4 to 32.24%, SO_3 from 44.32 to 46.07%, and H_2 O from 18.25 to 19.22%. **Gadumra-Chang Mari gypsum deposits (39 G/2, 5,6)** is located 15km west of Barkhan town. The area is accessible from Barkhan through dirt and shingle track. Barkhan is connected through D.G.Khan metalled road. Gypsum is found as beds varying in thickness from 1 to 3m in the Gadumra and adjacent area. There are 5 beds of Baska Formation. The dips of the beds vary from 50^0 to vertical. Taking 8km as extension, 8m width, and 50m depth, the reserves are 7.0 million tons. Chemical analyses show that CaO content varies from 31.89 to 32.24%, SO_3 from 45.72 to 46.71%, and H_2 O from 18.17 to 18.87%. **Nisau (Vitakri)-Safed gypsum deposits (39 G/6,2 and 39 C/14)** is located 35km SSW of Barkhan town and is accessible through a shingle track from Barkhan. Barkhan is the district headquarters and is connected with D.G.Khan and Loralai by metalled road. D.G.Khan town has railway link with major cities of the country. Gypsum is found as beds varying in thickness from 1 to 4m in thickness. The gypsum beds are folded in a syncline dipping at 25 to 60^0 but at places the beds are even vertical. There are 9 to 11 beds of gypsum in the Baska and one bed of gypsum in Domanda Formation. Taking strike extension of 50km, cumulative width 25m, down dip extension of 50m, the total reserves of gypsum in this locality are 137.5 million tons. Chemical analyses show that CaO content varies from 30.84 to 32.24%, SO_3 from 45.28 to 47.54%, and H_2 O from 18.04 to 19.66%. **Janthali gypsum deposits (39 G/7)** can be approached through Beakar, Philawagh and Pathar Nala area of Dera Bugti district and also assessable via Kahan. It is 60km NNE from Dera Bugti and 130 km SSW from Rakhni, connected via shingle and mud tracks. These deposits are found south of Vitakri. These deposits are faulted. There are 4-6 beds of gypsum having 10m aggregate thickness of gypsum. The dips of the beds vary from 10 to 30^0. Taking strike extension of 7km as extension, 10m width, and 50m depth, the reserves are 7.7 million tons. **Kahan-Khattan gypsum deposits (39 C/11,15)** is accessible from Sibi and Dera Bugti towns. Kahan is 70km NNW of Dera Bugti connected via shingle and mud fair weather track. Khattan is 60 km NE from Sibi connected fair weather mud and shingle track. Kahan-Khattan gypsum deposits are found in the strike of Harnai, Spin Tangi, Dera Bugti and some Rajan Pur deposits forming southern Sulaiman gypsum belt. Gypsum is found as beds varying in thickness from 1 to 5m in Baska and Domanda formations which are folded into a synclinal structure with beds dipping 25 to 60^0. The syncline extends upto 20km. Taking extension of gypsum as 30km on both limbs of the syncline, cumulative width 10m and depth 50m, the total reserves are 33 million tons. Chemical analyses show that CaO content varies from 31.54 to 32.24%, SO_3 from 46.02 to 46.50%, and H_2 O from 18.60 to 19.24%. **Dera Bugti gypsum deposits (39 G/4,3,7,8,11,12)** is accessible from Dera Bugti towns. Dera Bugti town is connected with Kashmor via Sui, and Sibi via Lahri. Its gypsum deposits are found in the strike of Harnai, Spin Tangi, Kahan areas deposits forming southern Sulaiman gypsum belt. Four beds of Baska gypsum with 5m cumulative thickness, and one bed of Domanda gypsum with 1-2m thick are found in the Dera Bugti gypsum deposits. Taking extension of gypsum as 50km as belt, cumulative width 5m and depth 50m, the total reserves are about 27.5 million tons. The chemical analysis of Domanda gypsum represents CaO 31.38%, SO_3 46.30%, SiO_2 0.32%, Al_2O_3 1.10%, H_2O 20.89 %, Fe_2O_3 and MgO are in traces. In all other deposits the Baska gypsums are analysed. **Mawand gypsum deposits (39 C/10,14)** is located 90km NNE of Sibi town. Jeepable track leading upto Mawand is very rough. Gypsum has been reported in Sibi District near Khattan (29^0 34': 68^0 43'). The gypsum bed is 2.5m thick at Khattan while at Mawand (29^0 39': 68^0 43') the gypsum attains a thickness of 12m. These deposits are associated with the limestone (Baska formation) of Eocene age (Gauhar, 1966). Mawand gypsum deposits are found in a Mawand syncline. These deposits seem to be large. Gypsum is found as beds varying in thickness from 1 to 5m in Eocene Baska Formation which are folded in a synclinal structure with beds dipping 5 to 60 degrees. The syncline extended upto 20km. Taking extension of gypsum beds as 25km on both limbs of the syncline, cumulative width 15m and depth 50m, the total reserves are 41.2 million tons. Chemical analyses show that CaO content varies from 31.95 to 32.25%, SO_3 from 45.40 to 46.77%, and H_2 O from 18.85 to 20.18%. **Bohri Kohlu gypsum deposits (39 G/1)** is located 20km south of Kohlu town. The area is accessible from Kohlu through dirt and shingle track. Gypsum is found as beds varying in thickness from 1 to 3m in the Eocene Baska Formation. The exposures are very small and discontinuous. The deposits are mostly covered by alluvium. The cumulative exposed thickness is 1 to 5m in Eocen Baska and 1m in the Eocene Domanda Formation. The deposits seem to be small. Taking extension of gypsum as 2km on both limbs of the syncline, cumulative width 5m and depth 50m, the total reserves are 1.1 million tons. Chemical analyses show that CaO content varies from 31.40 to 32.52%, SO_3 from 45.90 to 46.70%, and H_2 O from 18.60 to 19.77%. **Girsini-Bala Dhaka-Karher Buzdar gypsum deposits (39 G/5, 39F/8,11,12)** is located on the Kohlu-Duki partially metalled road. Bala Dhaka is located 30km north of Kohlu town. The area is accessible from Kohlu and Barkhan through dirt and shingle track. Karher is located 60km from Barkhan through a dirt and shingle track. Gypsum occurs as beds varying in thickness from 1 to 4 m which are folded in a synclinal structure with beds dipping from 20 to 60 degree. The synclinal structure is more than 30 km long and one one bed in the Eocene Domanda Formation. Gypsum exposures are discontinuous due to highly weathering nature. Taking 40km exposed length on both limbs, width 5m and depth 50m, the total reserves are 22 million tons. Chemical analyses show that CaO content varies from 30.84 to 32.25%, SO_3 from 45.96 to 47.33%, and H_2 O from 18.45 to 19.66%. **A Chamalang gypsum deposit (39 F/8) is** located 80km northwest of Barkhan town. The area is connected with Kohlu and Barkhan through dirt and shingle track. Gypsum is found as beds varying in thickness from 1 to 4m in the Eocene Baska Formation. There are 13 beds of gypsum. These beds are folded into a synclinal structure with dips ranges from 30 degrees to vertical. One bed of gypsum of Domanda Formation is also observed. Taking extension of gypsum as 5km on both limbs of the syncline, cumulative width 15m and depth 50m, the total reserves are 8.2 million tons. Chemical analyses show that CaO content varies from 31.04 to 32.53%, SO_3 from 41.43 to 47.09%, and H_2 O from 17.94 to 19.88%. **Bahlol gypsum deposits (39 F/8,12)** is located 90km northwest of Barkhan town. The Bahlol gypsum deposit started from 4.5km west of village of Bahlol and ended on the west of Bala Dhaka village. It has been previously reported as the Chamalang deposit (Ahmed, 1969). Reserves are estimated at 7 million tons upto a depth of 30m (Gauhar, 1966). It is very close to the metalled road near Rakhni town, which is connected with D.G.Khan. Gypsum is found as beds varying in thickness from 1 to 5m in the Eocene Baska Formation. There are 13 beds of gypsum which are folded into a synclinal structure with beds dipping 15 to 60 degrees. The syncline extends upto 20km. One bed of gypsum in Domanda Formation has also been observed in the core of syncline. Taking extension of gypsum as 10km on both limbs of the syncline, cumulative width 10m and depth 50m, the total reserves are 11 million tons. Chemical analyses show that CaO content varies from 31.61 to 32.24%, SO_3 from 45.96 to 46.47%, and H_2 O from 18.90 to 19.70%. **Baghao Tumni gypsum deposits (39 F/12)** is located close to the metalled road near northeast of Barkhan town, which is connected with D.G.Khan. Gypsum is found as beds varying in thickness from 1 to 5m are exposed in the Eocene Baska Formation in the western limb of Baghao syncline. These beds dip 25 to 60 degrees. The syncline extends upto 15 km but the exposures of gypsum are very small due to alluvium cover. So the exposed gypsum deposit is very small. Chemical analyses show that CaO content varies from 31.54 to 32.25%, SO_3 from 44.95 to 46.15%, and H_2 O from 19.27 to 19.67%. **Kingri-Khan Mohd Kot gypsum deposits (39 F/14,15)** are located at two sites. Kingri site is close to metalled road while the other Khan Mod site is 8km away from the road. Gypsum is found as beds varying in thickness from 1 to 6m in the Eocene Baska Formation. There are exposed 5 beds of gypsum hosted by Eocene Baska Formation. The composite thickness of gypsum beds is 8m. The exposures are very small. The reserves upto 50m depth are very small due to alluvium cover. **Spintangi gypsum deposits** is located 60km NNW of Sibi town and accessible through a railway line from Sibi to Harnai. The gypsum deposits of Spintangi area occur in Garhar and gypsum member of the Kirthar Formation. The exposures are along Garhar-Mian Zard ridge and run roughly parallel to Spintangi-Harnai railway line. Chemical analyses have revealed that gypsum is almost pure with less than 2% impurities. The reserves upto depth of 50m has been estimated 16 million tons (Shaikh,1972). **Sham and Phailawagh gypsum deposits (39 G/7, 8):** These deposits are located in the southeastern part of Sulaiman Foldbelt. These deposits are started from Mir Dost Zard to Sham and Kalchas. These deposits are also found near the village of Sham. These deposits can be approached from Harrand/Jampur/Rajan Pur. These deposits are also accessible from Dera Bugti town. Gypsum is found as beds varying in thickness from 1 to 5m. There are 4 beds of gypsum hosted by the Eocene Baska Formation. The composite thickness of gypsum beds is 8m. One bed of gypsum in Domanda Formation has also been observed. Taking extension of gypsum as 20km, cumulative width 8m and depth 50m, the total reserves are 17.6 million tons. The chemical analysis of Baska Gypsum indicates CaO 31.65 to 32.06%, SO_3 41.02 to 43.05%, $Fe_2 O_3$ 1.19 to 1.59, MgO 0.50, insoluble 0.80 to 3.22 %, and $H_2 O$ 20.24 to 21.16%. **Manjhail-Kharar Buzdar gypsum deposits (39 F/15,16 and 39 J/3)** is located 35 km north of Rakhni. It is also accessible from Taunsa by fair-weather track. It is 100km wsw of Taunsa Town. Gypsum is found as beds varying in thickness from 1 to 10m in the Eocene Baska Formation which is folded in to a synclinal structure. There are 10 beds of gypsum in the Eocene Baska Formation and only one bed (less than 1m) in the Domanda Formation. The dips of the beds range from 25 to 70 degrees. The cumulative thickness of Baska gypsum is 40m in the northeastern part of the deposit. Gypsum deposits exposures are discontinuous due to its easily weathering nature. Taking 30km length, 20m width and 50m depth, the total reserves are 66 million tons. Chemical analyses show that CaO content varies from 30.84 to 32.24%, SO_3 from 45.75 to 48.36%, and $H_2 O$ from 17.62 to 18.62% **Eastern Sulaiman gypsum belt** is located in the Rajan Pur, D.G.Khan, Taunsa, and D.I.Khan areas. It is also located on the eastern foot of Sulaiman range, only Zinda Pir gypsum deposits are found in easternmost part, only in the central part of range. Gypsum is found as beds varying in thickness from 1 to 5m in the Eocene Baska Formation. There are 5 to 7 beds of gypsum dipping 15 to 70 degrees. Only one bed of gypsum is found in the southern part of eastern belt. The cumulative thickness of gypsum is 10m. Gypsum exposures are discontinuous. Taking extension of gypsum as 100km, cumulative width 10m and depth 50m, the total reserves are 110 million tons. **Zinda Pir gypsum deposits (39 J/):** Zinda Pir is located 20km west from Shadan Lund Railway station and 35km southwest of Taunsa Sharief Town. Gypsum is found as beds varying in thickness from 1 to 5m in the Eocene Baska Formation. There are 5 to 7 beds of gypsum which are folded into an anticlinal structure with beds dipping 10 to 70 degrees. The syncline extends upto 40km. One bed of gypsum in Domanda Formation has also been reported in the limb of anticline. Taking extension of gypsum as 80km on both limbs of anticline, cumulative width 10m and depth 50m, the total reserves are 88 million tons.

Other resources: Malkani (2004c) also reported other mineralization like gypsum, iron, coal, barite and some other mineralization. Malkani and Tariq (2000; 2004) reported first time **small barite deposits** from Mekhtar and Murgha Kibzai areas of Loralai and Zhob districts. It occurred as large nodules arranged as parallel to bedding in Early Cretaceous Sembar shales. There are about eight beds of Barite, which are widely space in a 50m sequence of shale. The galena may be associated with this barite mineralization. **Fluorite** is being reported first time from Gadebar and Daman Ghar ranges of Loralai area occurring as veins in faults and fractures which are hosted by the Jurassic Loralai limestone. The fluorite represents many colour like pink, blue, light grey, green, light yellow, etc. The fluorite seems to be good for gemstone, acid preparation and metallurgical grades. After the first largest deposits of fluorite from Pakistan, the Malkani (2002; 2004d) and Malkani et al. (2007) discovered the second largest deposits (6750 tons) of fluorite from Mula-Zahri Range of Pakistan. The present deposits from Sulaiman Foldbelt may prove the third largest deposits of fluorite from Pakistan. So far no detail work like pitting or drilling to know the shape and size of ore rocks has been carried, however estimated reserves are about 1000 tons. **Ziarat Laterite** is reported by HSC (1961), extending from Kach to Sanjawi. It is found on the contact of Dungan and Parh limestones representing weathering and erosion in the Parh limestone (Malkani, 2006d). Ochre is a yellow, brown or reddish mixture of hematite, limonite and clay. The ochres are mostly suitable for pigment in the manufacture of paint. **Petroleum seeps** reported by HSC (1961) are Mughal Kot (39 I/3), Khattan (39 C/6), Gokurt (34 O/6), and Sanni (34 O/8). Further bituminous staining is also reported by them in the Sanjawi limestone (Dungan limestone) near the Road cut in between Sanjawi and Duki. Ahmad (1962) reported the bituminous residues known as Salajeet were found in some parts of the Pab Sandstone in the Khuzdar region. **Tor Ghundi Micropegmatite** is discovered by Malkani and Haq (1998a) from the Tor Ghundi Shabozai area of Loralai district. It consists of coarse biotite along with feldspar and some quartz. Sulaiman basin has no common igneous rocks. **Marble** is not found in this basin, however the limestone of Dungan is being well used as marble for the preparation of many types of tiles. It is found in the Kasa, Karu and Anambar (39F/3, 39B/11, 39 B/15) and many other areas of basin. **Calcite** is the principal constituent of limestone and there are huge deposits in the Sulaiman basin. Pure forms used in the manufacture of paint and plaster and for ornamental use, and Iceland spar-a clear variety used to a small extent in prisms to polarize light in microscope. Pure calcite is also found in many calcite veins in limestone of different age but Jurassic Gadebar range is also very significant. Various types of **Clay deposits** are found Ghazij, Kahan and Vihowa groups. **Radioactive minerals like p**rimary and secondary uranium mineralization are commonly existed in the Vihowa group and probably in other sandstone formations like Mughal Kot, Pab, Vitakri, Sangiali, and Rakhi Gaj formations. The Sandstone of Toi and Kingri formations have opposite source from northwest but can not be ignored. **Aluminous rocks** can be associated with Ziarat laterite, Vitakri formation and Vihowa group red beds. **Iron and Potash from** glauconitic and hematitic sandstone beds of Rakhi Gaj formation (Gorge beds) has anomalous iron (14-21%), deposit and probably potash. OCHRE/**iron** from Chitarwata, Rakhi Gaj, Vitakri, Drazinda formations and Vihowa group may be significant. **Travertine/Aragonite/onyx marble** is found in the vicinity of hot water springs area like Anambar, Mahiwal and Karu. The aragonite thin beds are also found in the Shaheed Ghat shale in the Rakhni and Sham, Kulchas, Phailawagh and other areas of Dera Bugti district and also in other parts of basin. **Silica Sands** is the principal constituent of glass. Requirements vary, but in general for glass sand call for a fine grain, at least 95 % of silica, a very low content of iron and not more than 4% of alumina. Lime, magnesia and alkalis are permissible. It is found mostly in the sandstone of Toi Formation and Vihowa group. In the Toi Formation it is found from Duki, Chamalang, Kingri and probably Shirani area, while from the Vihowa Group it is found in the Zinda Pir and Dera Bugti area. **Manganese** is related to volcanism. Lava is carrier of mineralized solutions. There is no common volcanism in the area, so manganese deposits are not found, however the iron nodules in the Tertiary shale formations have some anomalous zinc and manganese. **Building stones** like Limestone from Chiltan, Loralai, Parh, Mughal Kot, Fort Munro, Sangiali, Dungan, Drug, Habib Rahi and Pirkoh formations, sandstone from Sembar, Pab, Vitakri, Sangiali, Toi and Kingri formations and Vihowa group. Gravel and sand from Chaudhwan and Dada formations, Subrecent and recent surficial deposits are significant. **Cement Industry** raw materials are huge in this basin. The cement industry at Zinda Pir is working well. More than a dozen cement industries should be installed in the Dera Bugti, Barkhan, Kohlu, Loralai, Musa Khel, Rajan Pur, D.G.Khan and D.I.Khan districts to fulfill the requirement of country and earn foreign exchange through export for the development of Pakistan. The aggregate resources in the Sakhi Sarwar, Rakhi Munh, Rakhi Gaj, Sanghar and Vihowa areas significant for construction materials due to easy accessibility and other facilities. Further the Sulaiman Basin is the host of Petroleum and Uranium which show good economic potential. There are many streams where the dams can be constructed to increase the fresh water potential and also for the development of the area.

5. Conclusion

Sulaiman Basin represents Mesozoic and Cainozoic strata and have deposits of sedimentary minerals with radioactive and fuel minerals. Sulaiman Basin was previously ignored for updating of stratigraphy and economic mineral potential. Here revised with updated stratigraphic nonenclatures and economic mineral deposits are being presented. This paper will be helpful, handy and comprehensive for the students, geoscience’s researchers. mineral explorer and planners for the development of the area. The present discovered mineral deposits like gypsum, celestite, coal, barite, fluorite, ochre, Iron, marbles, cement raw materials etc will be really useful when the demand will increase or the previous reserves will be exhausted.

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