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Stratigraphy, Mineral Potential, Geological History and Paleobiogeography of Balochistan Province, Pakistan

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Abstract: The Balochistan province represents Triassic to recent strata with different tectonometallic and sedimentary basins like Balochistan basin, part of Indus Suture (Axial Belt), Sulaiman (middle Indus) and Kirthar (lower Indus) basins. Indus Suture separates the Balochistan basin (part of Neotethys) in the west and Sulaiman and Kirthar (part of Indo-Pakistan subcontinent) in the east. Balochistan basin represents Cenozoic flysch, accretionary wedge complex and magmatic island arc system. Indus Suture includes the igneous, sedimentary and metamorphic mélanges. The Sulaiman and Kirthar basins consist of Triassic to recent strata. Balochistan is the richest mineral province of Pakistan. The Chagai-Raskoh magmatic arc and Indus Suture are the richest metallogenic zones in the Balochistan province and also in Pakistan, however the Sulaiman and Kirthar are trying to lead in sedimentary minerals. Balochistan province has large proven reserves of indigenous iron, copper (associated some gold, silver, molybdenum), lead, zinc, barite, chrome, coal, gypsum, limestone (marble), ochre, silica sand, etc. small deposits of antimony, asbestos, celestite, fluorite, magnesite, soapstone, sulphur, vermiculite, etc. Some commodities are being utilized and some are being exported but most of the commodities are waiting for their utilization and developments. Cement raw materials are common and also at one place, so the installation of more cement industries can help a great for the country economy by exporting. Further water resources are two much and water is going into sea after creating flood and loss in the agricultural lands and population, so smaller dams are necessary due to population increasing. The first and huge gypsum deposits of Pakistan are found in Sulaiman foldbelt of Balochistan but not utilizing. Coal production is 58% of country is from Balochistan.

2. MATERIAL AND METHODS

The methods applied here are many discipline of purely geological description. The materials belong to compiled data from previous work and also new field data collected by author during many field seasons about lithology, structure, stratigraphy, mineral commodities, geological history and paleobiogeography of Balochistan province with basinwise are being presented.

Keywords: Stratigraphy, Mineral deposits, Geological history, Paleobiogeography, Balochistan Basin, Indus Suture, Sulaiman Basin, Kirthar Basin, Balochistan Province, Pakistan.

1. INTRODUCTION

The Balochistan province includes the Balochistan Basin (Neotethys remnant), and part of Indus Suture (Axial Belt), Sulaiman (middle Indus) and Kirthar (lower Indus) basins of Indo-Pakistan subcontinent a Gondwana fragment (Fig.1). The Balochistan basin is separated from Kirthar basin in the southeast, and Sulaiman basin in the northeast by a suture zone called Indus Suture (western belt). The Indus Suture is a belt which is subdivided into northern belt (east-west general trend in northern areas; MMT), joined with western belt (north-south general trend in Balochistan and southwestern Khyber Pakhtun Khwa. The Indus Suture area show complex mélanges of sedimentary and igneous origin. The Balochistan Basin includes the accretionary wedge complex (arc-trench gap) exposed in the south, flysch and molasses (back arc) basin in the north, and Island arc like Chagai, Raskoh and Wazhdad in the centre. Gee (1949), Heron (1954), Ahmed (1969), Raza and Iqbal (1977), Kazmi and Abbas (2001) and Malkani (2000,2002,2004a,c,d,e,f,2010a,g) have mentioned some mineral discoveries of Balochistan Province. The stratigraphy of Pakistan as well as Balochistan is documented in 1977, 2002, 2008 and also 2009, but Malkani (2010) reported the revised and updated stratigraphy and some new findings of gypsum, celestite, coal, barite, fluorite, ochre, iron, marbles, limestone, cement raw materials etc from Sulaiman Basin. Geological Survey of Pak. carried the geological mapping and mineral investigations of Balochistan province. Many papers on 15° quadrangles were published but unfortunately maps remained unpublished so far. Further no any compilation reports on the stratigraphy and also on mineral potential of these areas were prepared. Previously the Balochistan province like Makran and Sianian ranges (Fig.1b), Sulaiman fold belt and northern Kirthar fold belt show missing link and also received little attention, but this paper will add insights on basin wise with revised and updated stratigraphy, mineral resources, geological history and paleobiogeography of the Balochistan Province.

The stratigraphy of Balochistan super basin (Table 1) is subdivided into many basin like Chagai-Raskoh magmatic arc, Wazhdad magmatic arc, Mashikel (Inter arcs basin), Kakar Khurasan (back arc marginal flysch and molasses basin) and Makran-Siahans (arc-trench gap) basin.

Chagai-Raskoh magmatic arc

The Chagai-Raskoh arc shows the Cretaceous to recent deposition.

Sinjran Volcanic group: It consists of agglomerate, volcanic conglomerate, tuff and lava with subordinate shale, sandstone and limestone. It includes Basaltic-andesitic lava flows and volcanioclastics, with minor shale, sandstone, siltstone, lenticular bodies of limestone and mudstone. It is Mid to Late Cretaceous (Aptian to Santonian). This group was invaded during Late Cretaceous to Paleocene by Chagai intrusions, represented by several phases including granite, adamellite, granodiorite, tonalite, diorite and gabbro. Its thickness is 900-1200m. The upper contact with Humai formation is generally conformable and lower contact is not exposed.

Kuchaki volcanic group (equivalent of Sinjran volcanic group) is named for the village of Kuchaki (34 G/B) about 63 km southwest of Ahmad Wali (HSC, 1961). It consists of volcanic agglomerate, lava, tuff, with subordinate interssent limestone, tuffaceous shale and sandstone near the top of the assemblage. Bunap complex includes the obducted ophiolite mélange which includes gabbro, diorite and
Fig. 1. (a) major parts of Balochistan Province are shown in the southwestern part of Pakistan; (b) the black grey rectangles represent the Makran Range of Balochistan basin, while white oval in the north represent Siahan Range which is the host of antimony mineral; (c) major mineral localities in Makran (and Siahan) basin. The stibnite-gold localities are 1-Jauder, 2-Mahmoodi, 3-Sor Jor Jauder, 4-Damagi Nagindap, 5-Hashani, 6-Damagi Hashani, 7-Ahmadap, 8-Panir Body East, 9-Panir Body West, 10-Kasig (northern slope), 11-Kuchaki North, 12-Kuchaki South, 14-Gokumb, 15-Siagari, 16-Surmagi North, 17-Surmagi South, 18-Huspi, 19-Hurain, 20-Kulo, 21-Gazin; 22-Aj Geiji, 23-Siminj, 24-Lidi, 25-Miani, 26-Machi Koh, 27-Mir Baig Raindi, 28-Safed Gilanchi, 29-Palantak, and 30-Saghar. Major quartz vein locality 31-Siagari Shand. Mercury-silver quartz vein networks 32-Eastern Waro. Mercury-silver ferruginous zone locality 33-Western Waro. Hematitic body (may be meteorite) 34-Soro and Phudkush. Pyrite localities 35-Sorap, 36-Wazhdad, and 37-Durgi. Coal and carbonaceous shale and sandstone locality 38-Ahurag. Washuk ophiolite (soapstone, malachite, asbestos and chrome) localities 39-Toe Koh, Washuk ophiolite-igneous rocks localities 40-Mazargati, 41-Johl, 42-Tank Kurati. Petrolieriferous and sulphuriferous water spring locality 43-Sor Jor Jauder. (d) Mineral map of toposheets 39 F/10,11,14,15; Two thick black ovals and one thick line show latest Cretaceous coal, two fine oval show silicasand bodies, fine dotted lines show Eocene Toi coal, thin single line show quartz crystal veins in Late Cretaceous Mughalkot sandstone and its vicinity show possible phosphate in black and green shales. (e) Mineral map of Toposheet 39 I/4; fine dotted lines show Eocene Toi coal, thick long dotted line show Eocene Baska gypsum deposits and huge limestone and shale (cement raw material). (f) strike slip faults which are the majority of antimony-quartz-carbonate veins; (g) Jauder Thrust fault which are the host of stibnite-quartz-carbonate veins. Upper is the thrustbed intraformational block. (h) show paleobiogeographic isolation between Indo-Pakistan and Madagascar during Late Jurassic; (i) arrow show eastward source of Sulaiman basin clastics from Indo-Pakistan shield upto Paleocene. (j) arrow show northward source of Early Eocene clastics of Sulaiman basin from Hinterland (Asia); (k) show lithologic section of coal and hosted sandstone and shale in Vitakri Formation of Kingri area (Legend. black lines=coal and carbonaceous shale; dotted blocks=sandstone with some shale alternations; line crossed= limestone). (m) show lithostratigraphic section of Toi Nala coal (Legend. black lines=coal and carbonaceous shale; dotted blocks=sandstone; long dots = shale).
serpentinite. The basic type contains pyroxene and amphibole. Its age is Late Cretaceous. *Chagai intrusions* include quartz hornblende diorite, tonalite and biotite granite. Migmatitic quartz diorite is reported from Koh Naro. It is large batholiths that are Late Cretaceous and later (HSC, 1961).

**Humai formation**: HSC (1961) introduced the term “Humai formation” from Koh Humai (hill of Kohi Sultan) in the eruptive zone for mixed lithology which included the 'Hippuritic limestone' of Vredenburg (1901). Conglomerate at the base, intercalations of shale, sandstone, siltstone and limestone represent a turbidite sequence, and andesitic lava flows and volcanioclastics. Its age is Late Cretaceous to Paleocene.

**Washuk ophiolitic mélange, Hoshab shale, Panjgur and Kamerod diorite**: The northern part of this basin show flysch deposition like Murgha Faqirzai shale and molasses deposition like Shaigalu sandstone, however the southern part like Pishin basin show both these formations as flysch deposition.

**Nisai/Kharan/Robat limestone**: Cretaceous to Paleocene basal part of Pishi group of HSC (1961). It consists of intercalations of mainly pyroxene diorite are located in the Robat limestone. It is Early Eocene. Humai limestone/Robat limestone is considered as synonym with Nisai formation. See more description in Nisai formation.

**Saindak formation**: The name is derived from Saindak Fort (a large fort and site of a hunting post) which has been designated as the type locality (HSC, 1961). Its synonyms are Washap formation at Gwalishap near the Pakistan-Iran boarder and the Amalaf formation. It consists of shale, siltstone, sandstone, marl and limestone with andesitic lava flows and volcanioclastics in the lower part. It is Middle to Late Eocene.

**Rakhashi formation**: The name is derived from the tribal belt of Rakshani at the eastern end of Dalbandin valley (HSC, 1961). It also includes the Juzzak formation, lower half of Gidar Dhor group and basalt part of Pishi group of HSC (1961). It consists of intercalations of sandstone, shale, mudstone and limestone representing a turbidite sandstone; 39E/4; HSC, 1961) seems to be a lateral facies of Shaigalu formation (name is derived from Multana/Multanai Kili west of Mina Kamari) which is an assemblage contains Paleocene fossils. The Pishi and Dalbandin group, Nimargh limestone, Wad lime stone, Wakai limestone, Khude limestone, Kasria group, and upper parts of Jalkeer and Jamburo groups of HSC (1961) of similar lithology. The section is exposed 12 km north of the Nisai Railway station and traversed by the road leading north from the Railway station, was designated as type section (39B/1) by HSC (1961). In the type section it consists of limestone, marl and shale with subordinate sandstone and siltstone. Tanki sills consisting of andesitic-basaltic lava flows and volcaniclastics. It is Early Eocene.

Kakar-Khurasan basin shows the Eocene Nisai formation and Khojak group consisting of Oligocene-Pliocene Murgha Faqirzai and Shaigalu formations. The northern part of this basin show flysch deposition like Murgha Faqirzai shale and molasses deposition like Shaigalu sandstone, however the southern part like Pishin basin show both these formations as flysch deposition.

**Nisai formation**: Hunting Survey Corporation (1961) proposed the name Nisai group for the black nummulitic limestone, conglomerate, etc. among which the Chakki gond and the Chakki flint. While the Chakki gond and the Chakki flint are mainly pyroxene diorite are located in the Robat limestone. It is Early Eocene. The name is derived from the village of Murgha and the village of Shaigalu in the north (Kaker-Khurasan), and the village of Panjgur in the south (Makran). It is Early Miocene to middle Pliocene.

**Balochistan basins and it is exposed mainly in the Axial Belt areas.**

**Khojak group**: It includes the Murgha Faqirzai and Shaigalu formations.

**Murgha Faqirzai formation**: It is named after the village of Murgha Faqirzai about 25 km north of Muslimbagh (34M/16; HSC, 1961). It is mapped by HSC (1961) in the northern and southern Balochistan Basin and also in Indus Suture. It is characterized by minor sandstone and yellow limestone. The shale is pale greenish grey and calcareous. Pencil cleavage is the typical feature of this shale observed in the metamorphosed area. The sandstone is green to grey, calcareous and ripple marked. Thin shelly limestone beds are found in the base and top for fossil collection source. The name of this formation is mostly Hinterland and partially Indus Suture. The tentative thickness ranges from 400-1200m. The lower contact with the Oligocene and upper contact with Shaigalu formation is transitional and conformable. According to stratigraphic position, its age is supposed to be Early-Middle Oligocene.

**Shaigalu formation**: It is named after the militia post of Shaigalu about 50km southwest of Zhob (39A/16). It consists of sandstone and shale but at places conglomerate and limestone. The sandstone is fine to coarse grained, gritty, thin to thick bedded, grey to greenish grey, iron-brown in the Kaker Khurasan area while grey to greenish grey, iron-brown in the northern Balochistan Basin, and 1000-2000m thick in the area from the Khwaja Amran Range and Jangal. This formation shows the continental (Molasse) conditions in the Kaker Khurasan range. Continental vertebrate bones of possibly rhinoceroses, horses, crocodiles, etc. are also found in the Kaker Khurasan areas. Multana formation (name is derived from Multana/Multanai Kili west of Mina Bazar railway station; conglomerate with subordinate shale and sandstone; 39E/4; HSC, 1961) seems to be a lateral facies of Shaigalu and have coarse materials due to close source. So this formation is here treated as Shaigalu formation. Further GSP teams have discovered some vertebrates and mineral showings like thin lenticular assemblages are only found in the northern Balochistan Basin. These assemblages have few exposures in northern Balochistan Basin and it is exposed mainly in the Axial Belt areas.

**Burhup formation**: It is named after the village of Shaigalu and the village of Panjgur in the north (Kaker-Khurasan), and the village of Panjgur in the south (Makran). It is Early Miocene to middle Pliocene. The name is derived from Saindak Fort (a large fort and site of a hunting post) which has been designated as the type locality (HSC, 1961). Its synonyms are Washap formation at Gwalishap near the Pakistan-Iran boarder and the Amalaf formation. It consists of shale, siltstone, sandstone, marl and limestone with andesitic lava flows and volcanioclastics in the lower part. It is Middle to Late Eocene.

**Buzi Masahi Koh volcanic group** consists of intercalations of andesitic-basaltic lava flows and volcanioclastics. It is Middle Miocene.

**Koh-i-Sultan volcanic group** shows intercalations of dacitic-andesitic lava flows and volcanioclastics. It is Late Miocene. Pencil cleavage is the typical feature of this shale observed in the metamorphosed area. The sandstone is green to grey, calcareous and ripple marked. Thin shelly limestone beds are found in the base and top for fossil collection source. The name of this formation is mostly Hinterland and partially Indus Suture. The tentative thickness ranges from 400-1200m. The lower contact with the Oligocene and upper contact with Shaigalu formation is transitional and conformable. According to stratigraphic position, its age is supposed to be Early-Middle Oligocene.

**Wazhdad magmatic arc** The Wazhdad arc show the Eocene Wakai limestone, Siahjan shale, Wazhdad Volcaniclastic group, Zurati Formation, Washuk ophiolitic mélange, Kamerod formation is derived from Kamerod on the north margin of the Siahjan range (31M/10). The lithology and description is same as Keh formation. **Sub recent and recent deposits** consist of unconsolidated gravel, sand, silt and clay.

**Wazhdad magmatic arc** The Wazhdad arc show the Eocene Wakai limestone, Siahjan shale, Wazhdad Volcaniclastic group, Zurati Formation, Washuk mélange, Kamerod formation is derived from Kamerod on the north margin of the Siahjan range (31M/10). The lithology and description is same as Keh formation. **Sub recent and recent deposits** consist of unconsolidated gravel, sand, silt and clay.
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Qamar Din Kareez area of Zhob district (toposheet no. 39 A/10,11,15; Verbal communication with Shahid Dhanotar and Latif; Aziz ur Rehman Khowar, Zhob, and Sohail H.Heidari, 1990). Further the stratigraphic position tells Late Oligocene to Pliocene.

**Bostan Formation:** It is named after the Village Bostan, 20km east of Kuchlak (HSC, 1961). It consists of clay, silt, sandstone and conglomerate. The clay and silt are red to maroon and brown. The sandstone and conglomerate are medium to thick bedded and mostly friable, and show upfolds of the area.

**Makran Basin (Arco-trench gap), Wazhdad arc and Mushkel/Kharan (inter arc basin)**

It represents Paleocene Ispikan, Eocene Nisai/Wakai, Siahan group (Siahan, Wazhdad volcaniclastic and Zurati formations), Oligocene Washuk ophiolite complex and Makran group (Hoshab and Pangir formations), Miocene-Pliocene Talar group (Parkini, Talar and Chatti formations), Pliocene-Pleistocene Ormara, Jiwani and Panjgur formations), Miocene-Pliocene Talar group (Parkini, Talar and Chatti formations), Pliocene-Pleistocene Ormara, Jiwani and Panjgur formations), Miocene-Pliocene Talar group (Parkini, Talar and Chatti formations), Pliocene-Pleistocene Ormara, Jiwani and Panjgur formations). According to (HSC1961) megafossils are rare in the shale and can not be thoroughly tested for microforaminifers, however some thin limestone beds yielded fossils which may be equalent to Wakai limestone. According to HSC (1961) and stratigraphic position the age is being assigned as middle Eocene.

**Wazhdad volcaniclastic group:** It is named after the Wazhdad Mountain (35 A/6) by the Malkani et al. 1995 for Wazhdad volcaniclastic group. The Wazhdad Range is located just west of Washuk and east of Palantak. As a formation it is treated here. These rocks are exposed in the Wazhdad Mountain (35 A/6) and may be extending upto 35 A/10. It consists of tuff, agglomerate, tuff breccias, tuffaceous sandstone and shale. These rocks are dark green color and weather in to dark grey to black color, hard and resistant, forming high peaks. The estimated thickness of this formation is 1200 to 1500m in the Wazhdad Range, the actual measurement is also difficult due to intense faultings and foldings. Their lower and upper contacts are faulted but seem to be conformable with the lower shiahan shale and upper Zurati formation. According to law of superposition the age of Wazhdad volcaniclastic group may be early to middle Late Eocene.

**Zurati formation:** The name is after the Zurati Koh and Tanke Zurati 31 M/11 by Hafeez et al, 1995. Hunting Survey Corporation 1961 gave the composite name as Panjgur and Siahahn shale. Hafeez et al 1992 separated the Siahahn shale and Pangir formation, but one unit arises complication exist in between these two formation. So it was named as Zurati formation. It comprises sandstone, shale, slates, and minor siltstone. Sandstone is conspicuous unit. It is thin to thick bedded but massive locally. Sandstone silts and dykes in shale are observed. It is fine to medium grained, hard, calcareous, and fractured by intense tectonic orogeny. Groove marking are present in the undersurface sedimentary structures of sandstone and ripple marks are the upper surface sedimentary structures. The generalized paleocurrent direction seems to be north west to southeast. The shale is light green to grey, khaki, brown, and rarely maroon. It is laminated to fissile, platy, flaky, medium to hard hard, and slightly calcareous. It is also metamorphosed to slates. The slates are grey to dark grey, laminated to thin bedded, medium hard to hard, platy, give shining luster on the reflection of sun light. Siltstone is light green to grey and brown, laminated to thin bedded, medium hard and calcareous. Limestone lenses are also observed rarely in the shale of this formation. Limestone is grey to brown, micritic and hard. It is very difficult to measure the thickness of Zurati Formation due to intense faultings and foldings. However estimated thickness ranges from 1000 to 1500m in Zurati Range west of Palantak town. The lower contact with the Hoshab formation and upper contact with the hoshab shale is gradational and conformable. Fossils are not observed but according to law of superposition, it seems to be middle to late Late Eocene age.

**Washuk ophiolite complex:** It is named by the Malkani et al 1995. These ophiolite (part of complete sequence) is exposed are occurred in the eastern part of Wazhdad mountain range. It is exposed on the southern side of Wazhdad mountain range at Mazargati (35 A/6), Jhal Kaur (35 A/7), and Toekoh (35 A/10) and also in Zurati quadangle 31 M/11 areas. The observed rocks are granite, peridotite, bronze dunite,
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Hoshab formation: It is named after the village of Hoshab in the Kech valley (31 N/16; HSC, 1961). HSC 1961 correlated it with the upper part of Murgha Faqirzai shale of north Zhob district. It contains tidal channels with minor siltstone and sandstone. The shale is grey, light grey to brown grey, laminated, siltstone, and pencil cleavage is common. Pencil cleavage is the typical feature of this shale observed in the Maropan area (35 A/6). The shale is slightly calcareous to non-calcareous and soft to medium hard. It forms sharp ridges, sawteeth and pencil like weathering is common on the surface. Siltstone is grey, thin bedded, medium hard and calcareous. Sandstone is grey to light grey, fine to medium grained, soft and friable with rare cross beddings. Gritty sandstone is thin to medium bedded, coarse grained, brown, earthy, thick bedded, fine to medium grained, soft to medium hard, slightly calcareous to non-calcareous. In some places it is metamorphosed in to slates. The slates are dark grey, laminated to thin bedded, and platy. Slaty cleavage of slates and splintery surface of shale give shining luster on sunlight reflection. It is interlayered with sandstone and siltstone. Siltstone is laminated to thin bedded, light grey to grey and brown, medium to very fine grained, calcareous. Conglomerate consists of pebble of quartz, chert, Jasper, sandstone with minor limestone and siltstone or fine grained sandstone and marl. It is estimated about 1000 to 1200m thick but its complete section is not found. The lower contact with the Talar formation is gradational and upper contact with the Ormara formation is angular. The fossils reported are lamellibranches, gastropods and foraminifers (HSC 1961). It is after the locality of Chatti (31 K/3) about 17 miles north west of Gwader (HSC, 1961). These rocks were also included in the “Upper Mudstone” of Khan (1951). It is a part of Makran series palaeontologically defined by Vredenburg (1909; p. 299). This formation consists of mostly mudstone which is estimated about 1000 to 1500m in the Shabzab area. Its paleocurrent direction of this formation is northwest. This formation is devoid of fossils. It is very difficult to measure the thickness of Hoshab Formation because lower part is contacted with the Zurati Formation but its upper portion is not exposed, in some places its upper part is well exposed but not lower part. However thickness of this formation ranges from 1000 to 500m in Siahn Range (HSC, 1961) or North Makran. The lower contact with the Zurati formation and upper contact with the Panjgur formation are conformable. According to HSC (1961) the Hoshab formation has no age guide fossils tested only one sample. Further (HSC 1961) correlated the Hoshab shale with the Murgha Faqirzai shale and upper part of Shani formation. According to stratigraphic position, its age is supposed to be Early Oligocene.

Panjgur formation: The name is after the Panjgur town (35 N/2; HSC, 1961). It is named by HSC (1961) after the Kech valley. It is named after the Parkini formation. Panjgur formation is correlated with the Binga formation in the western vicinity of Panjgur. Shaigalu sandstone of Pishin-Zhob basin, Nauroz and Pishhi group of Ras Koh Range are small, however in the southern vicinity, there is a wide alluvium covered with black mudstone which may yield more ophiolitic rocks in subsurface. The contact with the Zurati formation is faulted. Some phylite/schist is observed near the contact zone. The age may be Late Eocene or Early Oligocene.

Parkini formation: It is named after the Parkini Kaur, a tributary of the Hingol River (35 G/6). The rocks of the Parkini formation have been referred to as “Khojak shale” and “shale weathering to clays” by Khan (1951; p.202, plate 10), and as “Lower mudstone of Chatti” by Vredenburg (1909, p.300; HSC, 1961). The Parkini formation is considered as “Lower mudstone stage” by Vredenburg (1909, p.202, plate 10) and as “Lower mudstone of Panjgur” by HSC (1961). It consists of mostly poorly bedded mudstone with minor intercalations of siltstone or fine sandstone. Its estimated thickness ranges from 1000 to 1200m in the south Makran. The lower contact with the Parkini formation is abrupt and gradational and upper contact with the Talar formation is transitional. Large fossils are rare Miocene microfauna are prolifically abundant and can be obtained relatively easily from the mudstone, most of which disintegrates readily in warm water. According to microforms and stratigraphic position its age is Early Miocene.

Talar formation: It is named after the Talar gorge (31 K/10; HSC, 1961). It is considered equalent to Hinjal group of HSC (1961). It consists of sandstone, shale, mudstone and shelly limestone. The sandstone is mostly soft and crumbly and some is calcareous and calcareous. It is fine to coarse grained and greenish grey on fresh surfaces. The beds from 3-5 feet are common, however reached upto 20 feet at places. The shale is pale green, soft, and earthy. Its thickness approaches to about 4000m in the range south of Kohrag-ı-Daf (HSC, 1961; Map 4; 31K/2). Its lower contact with Parkini and Chatti formations is transitional but at places sharp. The fossils like Miocene microfauna are prolifically abundant and can be obtained easily from the mudstone, most of which disintegrates readily in warm water. According to microforms and stratigraphic position its age is Early Miocene.

Chatti formation: It is after the locality of Chatti (31 K/3) about 17 miles north west of Gwader (HSC, 1961). These rocks were also included in the “Upper Mudstone” of Khan (1951). It is a part of Makran series palaeontologically defined by Vredenburg (1909; p. 299). The formation consists of mostly mudstone which is estimated about 1000 to 1200m thick but its complete section is not found. The lower contact with the Talar formation is gradational and upper contact with the Ormara formation is angular. The fossils reported are lamellibranches, gastropods and foraminifers (HSC 1961). On the basis of these fossils and stratigraphic position its age is Pliocene (Vredenburg, 1909, p.300; HSC, 1961). The Ormara is the synonym of Chatti because Ormara is mapped in the eastern part of southern Makran coastal areas where Chatti formation is not mapped and distinction between Ormara and Chatti mudstone is also difficult in the western part also (HSC, 1961).

Kech formation: It is named by HSC (1961) after the Kech valley near Gish Kaur (Map 9; 31N/8) and Kech valley generally existed from Hoshab area to Turbat. It is also correlated with Kamerod partly Ormara formation. It is exposed in the Mcran and Siahn areas. The strata of Kech formation consists of conglomerate, mudstone and sandstone facies. It has following lithological variations. Fine to medium grained sandstone is creamy, white off, brown, earthy, thick bedded, fine to medium grained, soft to medium hard, sticky, calcareous and with tabular weathering. Coarse grained friable sandstone is thin to medium bedded, coarse grained, brown, earthy and calcareous, soft, and friable. Conglomerate consists of pebble of quartz, chert, Jasper, sandstone with minor limestone and igneous rocks in a sandy matrix are observed in Dastak, Suraf, and Sabzab area. The paleocurrent direction of this formation is northwest to southeast. Its estimated thickness ranges from 1000 to 1500m in the Panjgur area of North Makran. Its lower contact with Hoshab shale and upper contact with Kamerod/Kech formation is angular unconformable. It is correlated with the Shaigalu sandstone of the north Zhob district which also contains Oligocene vertebrate fossils. Panjgur formation is devoid of fossils in the Panjgur area, however, on the west of Panjgur near Iran Boarder, this formation has yielded Oligocene age diagnostic foraminifers. Further the stratigraphic position tells Middle to Late Oligocene.
increase up to 1500m (HSC, 1961). The lower contact with Panjigar, Hoshab and Zurati formations or older formations is angular. It also has upper contact with Subrecent and recent surficial deposits.

The age of the formation is Pleistocene.

Jiwani formation: It is named after the coastal village of Jiwani (31 G/12), where it is best exposed. It is synonymous with the “Sub-Recent shelly limestone” (Directory, p.12) and “lithal concrete” (Blanford, 1872a, p.45), but has not been previously mapped (HSC, 1961). Rocks of Jiwani formation appear on all principal headlands and promontories along the Makran coast as far east as Ras Malan; they also form the surface of Astola Island (31 O/16). The formation is restricted to the South Makran division of the arenaceous zone and has a thickness up to 100 feet in the type area of Jiwani headland (HSC, 1961). The formation is composed mainly of shelly limestone, sandstone, and conglomerate. The weathering colour is grayish brown or dark ferruginous brown but on fresh surfaces they are lighter. The lines are deeply gullied and pitted by the sheet flood or cloudburst and at places angular unconformable with Ormara, Parkini and Chatti formations. Its upper contact with the recent deposits or extrusive mud may be angular. The age may be Late Pleistocene to Subrecent.

Makran Mud volcanoes: This formation is common in coastal areas of Makran but also found in the Fishtin Zhob basin particularly near the Qila Saifullah area (HSC 1961). It consists of solidified silty and gritty muds. It is soft and friable. The fresh colour of mud is light grey and weathered as yellowish brown and pale greenish grey. It gives light green tone from a 200m or some more far. Angular chips of 1m are common. Fragments of oyster shells are also common. At Tor Deo Ghundai in the Zhob (Map no. 29; 39 A/4) the extruded mud resembles the Nisai group but contains large blocks of serpentinitized ultrabasic rocks like Muslim Bugh intrusions. The old mud is gullied and pitted by the sheet flood or cloudburst and type erosion while the young accumulation are less gullied and pitted. In general the mud appears in two forms like cones and ridges. The cones formed by one or more ventral veins. It involves series of eruption and cone is formed from the drying of muds. The mud extruded from the veins is extremely fluid near its source and becomes more viscous as it flows, due to loss of water. The angle from horizontal is about 10-40°. The simple cone like those of Chandragup are more viscous as it flows, due to loss of water. The angle from horizontal is about 10-40°. The simple cone like those of Chandragup may be angular. The age may be Late Pleistocene to Subrecent.

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contact with Zurati formation of Late Eocene age and show the unstable obduction condition. During Early Oligocene the Hoshab shale is uplifted in marine condition. After this period the basin is affected by tectonics. During middle to Late Oligocene the monotonous cyclic alternations of sandstone and shale sequence of Panjgur formation are deposited in turbidity currents marine and open marine sea conditions respectively. During Miocene and Pliocene the northern Makran and Sianah ranges have no evidence of deposition which show the uplift by tectonics and convergence of Arabian plate, however the southern Makran continue the deposition like Miocene Parkani mudstone and Talar sandstone, Pliocene Chatti mudstone. This uplift is confirmed by the angular unconformity between Pleistocene Kamerod formation and older formations. During Pleistocene the Kech/Kamerod/Gawader formation are deposited which show the lithology as mudstone, sandstone, and conglomerate of fluvial and lacustrine origin. Conglomerate deposited near the source, while the mudstone far from the source and sandstone in transitional stage. Existence of gypsum gives clue to the lacustrine vaporation or lagoonal environments. The Pleistocene Jiwani formation shows the coastal environments as by shelly lithology. After the deposition of Kech/Kamerod formation, further uplift took place and this evidence is confirmed by the angular unconformity in between the Kech/Kamerod formation and surficial subrecent and recent deposits. Subrecent and Recent deposits show the continental fluvial and desert. Ripple and groove marks are generally observed which show the rising and other features show the rising and continuous movement of convergence plates. Ripple and groove marks. However the source of the northeastern part of Makran basin seems to be both from northwestern and also from east/Indus Suture due to its close vicinity.

**Updated Stratigraphy of Sulaiman Basin, Pakistan**

Sulaiman basin shows the different updated lithological units in ascending order are; Triassic Khanozai group represents Sangi (shale, marl and limestone), Loralai (limestone with minor shale), and Chilwan (limestone) formations, Cretaceous Parh group represents Sampsar (shale, marl and limestone), Fort Munro (sandstone, marl and limestone), Par (limestone) formations, and Fort Munro group represents Dungan (shale/mudstone, sandstone, marl and limestone), Fort Munro (limestone), Pab (sandstone with subordinate shale) and Vitaki formations. These formations are conformable and each mud horizon is also 2-15m thick. The Vitaki Formation is aged as latest Cretaceous (70-65Ma). The Paleocene Sangi group represents Sangi (limestone, glauconitic sandstone and shale), Rakh Gaj (Girdu member, glauconitic and hematic sandstone; Bawata member, alternation of shale and sandstone), and Dungan (limestone and shale) formations. Eocene Chamalang (Ghazi) group represents Shaheed Ghat (shale), Toi (sandstone, shale, rubbly area are Bela volcanic group, Wad ophiolite complex, Muslimbah ophiolite complex and Zhob ophiolite complex. These complexes include the ophiolitic melanges and sedimentary Mesozoic and Cenozoic sedimentary sequences.

### Bela volcanic group

It is 190km long and 20km wide, extending from Ormarch in the north to Windar in the south. Volcanic rocks are subordinated in the north of Ormarch and dominate in the south. It consists of intermixed volcanic and sedimentary rocks. The volcanic rocks are mainly basalt, lava, coarse grained agglomerate and bedded tuff cone and the lava flows are commonly pillowed and split. Most of the weather reddish brown or green, but the more massive types weather black and are difficult to distinguish from intrusions (HSC, 1961). Rocks are altered and fractured filled with epidote and carbonate. Phenocrysts of augite with rims of chlorite are common, amygdalules of calcite and microfolds of feldspar are abundant. Interlayered sediments are shale, marm, limestone, conglomerate, and radiolarian chert. This group overlies the Windar group conformably (west of Mor range), and is overlain unconformably by the Oligocene Nal limestone (Northwest of Bela). The age is Cretaceous (HSC, 1961).

### Muslimbah ophiolite complex

It consists of mainly ultrabasic, basic, and intermediate compositions. Granitic rocks are rare. The true granite is in the form of conglomerate pebbles. The ultrabasic rocks are altered pyroxenite, serpentinized peridotite and amorphous and sheared serpentinite. The rocks of intermediate composition are diorite and gabbro. The gabbro is dark grey or green in color, and is feldspar with large crystals of white feldspar which is kaolinized. Some types are pegmatitic and exhibit crystals up to 4 inches across of biotite and pyroxene. A small body of the granodiorite located in the west of Porali river, 10km south of Wad. Concordant and discordant intrusions are found. Irregularly shaped soapstone has been reported from Nal area.

### Muslimbah ophiolite complex

The geological formations (Permain-Mesozoic) associated with igneous rocks are widely (10km) exposed in the Indus Suture zone as pericratonic shelf carbonates, neritic carbonates and volcanics occasionally intruded by mafic rocks and tectonically emplaced ophiolites and mélanges (Kazmi and Abassi, 2001) like Bela volcanics (Bela volcanic group/Porali agglomerates/Porali volcanic conglomerate), Bela ophiolite, Mor intrusives, Konar mélanges, Zhob ophiolite, Zhob mélanges, Bagh complex, Waziristan ophiolite mélanges, Twin sister soda dolerite and Pir Umar basalts, and Triassic Khanzai group (Gwad and Wulga formation). These formations are conformable and each mud horizon is also 2-15m thick. The Vitaki Formation is aged as latest Cretaceous (70-65Ma). The Paleocene Sangi group represents Sangi (limestone, glauconitic sandstone and shale), Rakh Gaj (Girdu member, glauconitic and hematic sandstone; Bawata member, alternation of shale and sandstone), and Dungan (limestone and shale) formations. Eocene Chamalang (Ghazi) group represents Shaheed Ghat (shale), Toi (sandstone, shale, rubbly...
limestone and coal), Kingri (red shale/mud, grey and white sandstone), Drug (rubbly limestone, marl and shale), and Baska (gypsum beds) formations and Khan group represents Habib Rahi (limestone, marl and shale), Domanda (shale with one bed of gypsum), Pir Koh (limestone, marl and shale) and Drazinda (shale with subordinate marl) formations, Oligocene-Pliocene Vihowa group represents Chitarwata (grey ferruginous sandstone, conglomerate and mud), Vihowa (red ferruginous shale/mud, sandstone and conglomerate), Litra (greenish grey sandstone with subordinate conglomerate and mud), and Chaudhwan (mud, conglomerate and sandstone) formations, and Pleistocene Dada (conglomerate with subordinate mud and sandstone) Formation which are concealed at places especially in the valleys and plain areas by the Subrecent and Recent fluvial, eolian and colluvial deposits (Malkani, 2009f; 2010g).

Updated Stratigraphy of Kirthar Basin, Pakistan

Kirthar basin shows mostly the same lithological units like Sulaiman basin during Mesozoic and Quaternary but vary in Tertiary strata such as; Paleocene Ranikot group represents Khadro (sandstone, shale, limestone and volcanics), Bara (sandstone with minor limestone, basalts and volcanics) and Lakhra (limestone and shale) formations; Eocene Laki group represents Sohnari (lateritic clay and sand, yellow arenaceous limestone pockets, ochre and lignite seams) and Laki (shale, limestone, sandstone, lateritic clay and coal) Formation. Kirthar basin group represents Kirthar (limestone, marl and shale) and Gorag (resistant and peak forming limestone with negligible shale and marl) formations and Oligocene Gaj group represents Nari (sandstone, shale, limestone) and Gaj (shale with subordinate sandstone and limestone) formations and Miocene-Pliocene Manchar (sandstone, conglomerate and mud) Formation. Vihowa group represents Chitarwata (grey ferruginous sandstone, conglomerate and mud), and Chaudhwan (mud, conglomerate and sandstone) formations, and Pleistocene Dada (conglomerate with subordinate mud and sandstone) Formation which are concealed at places especially in the valleys and plain areas by the Subrecent and Recent fluvial, eolian and colluvial deposits.

Mineral Potential of Balochistan Province, Pakistan

Islam et al., (2010) reported the production from Balochistan Province during 2007-08, 36, 583 tons (t) copper, 245t antimony, 49,268t barite, 331t basalt, 33,815t chromite, 25t clay, 2,325,220t coal, 291t granite, 259t rhyolite, 134t diorite, 183t gabbro, 2,431t serpentinite, 98 tgneiss, 323t quartzite, 360t sulphur, 170t dolomite, 424t fluorspar, 75t galena, 15,808t iron ore, 727,951t iron ore, 2,671,321t marble (ordinary), 790t magnesite, 1,385t manganese, 5,060t pumice and 1,306,764t shale. Mineral resources of Balochistan Province (Table 2.3,4) has large proven reserves of iron, copper (associated some gold, silver, molybdenum), lead, zinc, barite, chromite, coal, gypsum, limestone (marble), ochre, silica sand, etc, small deposits of antimony, asbesostes, celestite, fluorspar, magnesite, soapstone, sulphur, vermiculite, etc. Some commodities are being utilized and some are being exported but most of the commodities are waiting for their utilization and developments. Mineral potential of different areas under the Balochistan province are being described here.

Mineral Potential of Chagai magmatic arc

The Chagai arc is economically most important mountain belt of Pakistan. Many important minerals including porphyry (Cu-Mo), epithermal quartz vein type copper, Talaruk and vein type copper, and Kirthar type copper, volcanogenic gold-silver and sulphur. Kuroko type lead-zinc-silver-copper are intimately associated with the magmatic rocks of this arc (Siddiqui, 1996). The thiolitic and calc-alkaline magmatism in oceanic island arc was reported by Siddiqui (1996;2010) while before this it was considered as Andean type (continental) calc-alkaline magmatic belt.

**Copper**: The copper deposits and showings occur extensively at several localities in the Chagai magmatic arc (White, undated; HSC, 1961). Dasht Kain copper deposit is 35km NW of Chagai village (29°33'N; 64°29'E) is porphyry type copper prospect associated with two tonalite porphyry stocks. The stocks are intruded into a diorite cupola which is a part of a large batholith comprised of quartz monzonite and diorite. The batholith has intruded the Cretaceous Sinjran volcanic group. The host rock toalite porphyry is cemented by potassium silicate alteration and followed outwardly by quartz sericite and porphyritic alterations. There is a moderate to weak K zone and the hypogene mineralization has developed in two phases, the first phase produced pyrite, chalcopyrite, enargite and pyrhotite and the second one introduced magnetite, molybdenite and chalcopyrite (Siddiqui 1984). Three bore holes have been drilled in the copper stock. Average grade of copper varies from 0.1-0.17% and in the potassium silicate zone from 0.25 to 0.54%. The breccia pipe zone in the eastern stock contains surface values upto 4.5% copper but not drilled (Kazmi and Abbas, 2001). Talaruk copper deposit is 64km NW of Saindak in Chagai District. It is a massive Kuroko type deposit and mineralization is of submarine exhalative origin. The copper ore occurs in two zones, one in thylolitic intrusives in which chalcocite is the main copper mineral and the other in volcanic breccia associated with gypswn, with malachite as the main copper mineral. Six bore holes were drilled at this deposits and its copper content has been about 0.65% (Saigus 1977). Saindak copper deposit is located about 9.4km SE of Fort Saindak (29°18'N; 63°33'E) in Chagai district. The ore is hydrothermally altered and the mineralized zone is known as Saindak alteration zone (Sillitoe and Khan, 1977). It is developed in silstone, sandstone, and tuff of Kalser Formation. The mineralization is related two small patterns centered on three porphyry stocks of Mid-Miocene age and consequently there are three main ore bodies, the North, South and East ore bodies. The north ore body is developed along vein zones though oxide mineralization is also present in patches. Nineteen bore holes were drilled on this body and 19mt of ore averaging 0.498% copper (cut off grade 0.3%) has been proved. The south ore body lies 2km south of north ore body. Here the oxide zone is developed in patches. The ore is developed within a few meter of the surface and has been proved to a depth of 328m. 27 holes were drilled and reserves of 54mt of ore averaging 0.488% (cut off grade 0.3%) including 27 mt of 0.64% copper at cut off grade of 0.4% have been proved. Significant gold and molybdenum values are associated with this ore body. The east ore body is 1km SE of the south ore body. A low-grade chalcopyrite copper oxides zone with 0.4-0.5% copper is developed over the ore body. In this area 37 bore holes have been established indicating reserves of 264mt averaging 0.388% copper at cut off grade of 0.3%. The total reserves at Saindak comprised 412mt of ore containing average 0.38% copper and 0.322gm/to of gold. At Saindak an open cast mine with infrastructure, crushing plant, concentrators and smelter has been developed and trial production of bister copper has been done. It is planned to produce annually 15,800 tons of copper, 1.47 tons of gold and 2.76 tons of silver (Bizenjo, 1994). Other porphyry copper deposits in Chagai district were explored and evaluated by BHP. Their results suggest that the western part of the district has great potential for development of porphyry copper deposits. Based on the results of 80 test holes, it is estimated that this region has reserves of 350mt (Razique 2001) of averaging 0.4 to 0.6% copper and 0.2 to 0.5gm/to of gold. According to BHP besides Rekodiq, Buzzi Mashii and western Ware Chah, other localities such as Porra Koh, Bobhar Koh, Koh Dalil, Koh Sultan and Ting Daranga look promising and merit detailed exploration. Tethyan Copper Company has recently drilled 30 holes at Rackodiq (Koh Dalil) and has encountered a chalocite blanket and hypogene zone. In this zone reserves of 70mt of ore with 0.85% copper are indicated. Chagai areas like Talaruk, Saindak, Missi, Humai, Dasht Kain, Koh-i-Marani, Pakus nala, Nok Chah, and Ting Daragaun look promising and merit detailed exploration. Tethyan Copper Company has recently drilled 30 holes at Rackodiq (Koh Dalil) and has encountered a chalocite blanket and hypogene zone. In this zone reserves of 70mt of ore with 0.85% copper are indicated. Chagai areas like Talaruk, Saindak, Missi, Humai, Dasht Kain, Koh-i-Marani, Pakus nala, Nok Chah,
Mineral Potential of Raskoh magmatic arc deposits are also reported. Broken Hill Propriety (BHP) of Australia in number of porphyry copper deposits with gold and silver

Gold-Silver: The production of copper along with gold will be started soon from Saindak porphyry copper deposits. GSP has discovered a number of porphyry copper deposits with gold and silver mineralization (Ahmad, 1986). Telethermal vein type and skarn deposits are also reported. Broken Hill Propriety (BHP) of Australia in collaboration with BDA has discovered world class gold deposits.

Lake Resources (Australia) also explored copper and associated gold deposits and their alteration zones (Kazmi and Abbas, 2001).

Iron ore: Balochistan Basin show iron from Saindak, Maskhi Chah, Durban Chah, Amil Chah, Chighidrik, Gorbhand, Kasanen Chapar, Kundi Balochap, Pachin Koh, Chighidrik, Bandegan and Nok Koh areas (White, undated; HSC, 1961; Kazmi and Abbas, 1991). There are 27 small magnetite-hematite bodies at this area. Pachin Koh 62 holes, where an iron ore body is drilled. The estimated ore reserves of Pachin Koh is 45mt and of Chighidrik is 5mt of which 30mt are proved. The geological and geophysical investigations show that the deposit may be increased up to 100mt. Steel mills process this ore with 46% substitute of the imported ore. Hussain (1983) has suggested the ore is suitable for direct reduction plus electric arc furnace process combination. This process can produce steel billets at about 30% lower cast. Chighidrik iron deposits are located 52km NW of Dalbandin town. The area is underlain by Cretaceous Sinjrani volcanics, which are intruded by small bodies of diorite, quartz monzonite and granodiorite. The deposit sits in Sinjrani which forms asymmetrical gently dipping anticline. The iron ore is comprised of massive magnetite and layers of disseminated magnetite. The ore occurs at three horizons. The upper one near the top contains main deposits. The other two are 166 and 500m below the first one. The lower ore bodies are largely comprised of magnetic disseminations in volcanic rocks and are lean in their iron content (10-12%). The deposit has been drilled and indicates the main ore body contains iron 32-52% (average 45%), copper 0.1-1.96% (in one hole up to 7%), and phosphorous up to 0.1%. Some portion of the ore body contains upto 1 oz/ton of gold (Farooq and Rahman 1970; Ahmad, 1975). It has high grade ore with 3.36mt (2.46 proved and 0.90 probable). The average analyses includes 42% SiO₂, 13.16% Fe₂O₃, 119.05% Al₂O₃, 1.38% TiO₂ and 10.75% H₂O and 10.30% MgO (Bakr, 1965b).

Others: Manganese is reported from Sotkino hill (Ras Koh) (Kazmi and Abbas, 2001). The small deposit of gypsum (3.3m thick) is reported from the red shale of Qeshmian formation (HSC, 1961; Ahmad, 1975). Copper is reported from Tor Tangi of Ras Koh areas (White, undated). Various types of limestones and igneous rocks can be used for this construction and decorative stones.

Mineral Potential of Kaker-Khurasan (back arc) Basin Some economic minerals/commodities like antimony, ocher, saline springs, and mud flows with methane-nitrogen gas are found. Antimony deposit like the stibnite veins are hosted in Khojak group of Qila Abdullah which is 24 km NE of Qila Abdullah town, and Antimony mineralization. But the fluid inclusion study (homogenizing temperature upto 333°C, so it may be hypothermal. The Raskoh arc includes many minerals like Chromite, verniculite, manganese, copper etc.

Chromite: It is associated with ultramafic rocks as layered intrusions or as ophiolitic sequences. It occurs as extensive layer in layered intrusives while irregular and podiform/ lenses in dunite of ophiolitic rocks (Alpine type). Dunite occurs in the basal part of ophiolites i.e., in ultramafic tectonites and ultramafic cumulates (Kazmi and Abbas, 2001). Bunap and Rayo Ras Koh chromite (Kharan District) occurs in Nug-Bunap and Rayo Nai valley within a distance of 3km, located 30km NW of Khuran Kalat town. Chromite occurs as lenticular bodies or disseminations in the dunites. Nine small deposits with total reserves of 9,664 tons near Bunap and 7 deposits with reserves of 355 tons near Rayo Nai were reported by HSC (1960). These deposits have been mined out and exhausted (Ahmad, 1969) but still mining are continuing indicating more deposits.

Verniculite: It is mica like mineral that expands on heating to produce low density materials. It is used as light weight aggregate, thermal insulator, as a fertilizer carrier, soil conditioner in agriculture and as a filler and texturiser for plastics and rubber. It is not being used in Pakistan but can be exploited due to its availability. Verniculite deposits are reported from Doki River on the northern edge of the western Raskoh. It occurs in clift 160m long, 140m wide and 40m high with reserves of 11 mt (Grundstoff-technik, 1993). The average analyses includes 42% SiO₂, 13.16% Fe₂O₃, 119.05% Al₂O₃, 1.38% TiO₂ and 10.75% H₂O and 10.30% MgO (Bakr, 1965b).

Ocher: Ocher deposits are found in the Shaigal sandstone of Kaker Khurasan area. Many Saline springs are found in the Qila Safiullah area especially in the Nisai formation. Salt springs running and dry are reported from the red shale at the base of Nisai limestone and so far active mud volcano in the Spara Manda and its vicinity areas of Qila Safi Ullah district (39°B/5.9; communication Zahir Hussain).

Mineral Potential of Makran and Sibian ranges (and Wazhdad magmatic arc) of southern Balochistan Basin. Mankani (2004c,f) reported first time some new findings of Makran and Sibian ranges. The details are being provided here.

Antimony and associated gold and silver mineralizations: The stibnite in the Qila Abdullah is located in the back arc basin (northern Balochistan) and all other stibnite localities (show very small deposits) are found in the fore arc basin (Southern Balochistan) (Fig.1c). Presence of antimony mineral stibnite and chalcedonic (cryptocrystalline texture) quartz show the epithermal type of mineralization. But the fluid inclusion study (homogenizing temperature of some samples were analyzed by Rehan ul Haq Geoscience lab. Islamabad and show the possibility of mesothermal mineralization, only one sample of Grawag (31 M3) shows the homogenizing temperature upto 333°C, so it may be hypothermal. Antimony is found mostly in the strike slip faults (Fig.1f), except the Jauder locality where it is found in thrust fault (Fig.1g). The antimony mineralization originated due to dynamic (tectonic) activities and shearing in host rocks and deposited their lodes in the fractures, cavities, faults and gash fractures. This idea is proved by the metamorphism of slate into schist and intense faulting. Oche deposits are found in the Sibian range and north Makran. According to Shecheglov (1969), the antimony mineralization of Makran range is of epithermal origin. According to Sililtoc (1975), the circulation of conate fluids in the
flysch succession during dynamo thermal metamorphism related directly to the faulting is proposed as an origin for the antimony deposits. Antimony veining (Sb2S3) is coated by the accessory mineral like sulphur. Gold, silver and sulphur mineralization are also enriched in this zone. Stibnite is shining lead grey, fine grained to fibrous and blady, metallic, subconchoidal to irregular and hardness is low (2 to 3). Gold and silver mineralizations associated with stibnite have been detected by the chemical analyses. The gold found is fine grained and disseminated with the antimony mineral. The carbonate mineral in the veins (CaCO3) is a cryptocrystalline to crystalline, translucent to transparent, subconchoidal and have commonly box like texture. Stibnite occurs in the form of veins, stringers and lenses in the faults especially oblique strike slip faults, gash fractures and shear zone in the Sihan, Hoshab and Panjgur formations. The thickness of the stibnite varies from 2mm to 20cm. The stibnite vein is surrounded by quartz carbonate. Quartz is partially stained (maroon to red). Host rock or enclosing strata are also stained (brown, maroon to red) at the contact of antimony and quartz carbonate vein. Ferruginous alterations are also observed around the antimony vein. The thickness of the quartz carbonate vein varies from 2mm to 2metres. The nature and extent of quartz carbonate veins are discontinuous, lense shape, pinches and swells. Private and public sectors showed no interest for mining because of difficulties in access and also less thickness of stibnite vein. Some private sectors have started the mining at Jauder and Patkin but ended the work due to fair weather difficult accessibility, less thickness and discontinuous nature. The tentative estimated reserves of stibnite of known main localities of Sihan range are about 22500 tons, by taking total 500m length, 10cm thickness, 100m easy mineable depth and specific gravity about 4.5. The author discovered most of the following localities while some localities are followed by Younas et al. (1995), Hassanal et al. (1995), Haesa et al. (1995), Mustafa, et al. (1995) and Malkani et al. (1995). 

**Jauder locality** (35A/11: Fig.1c) is accessible from Washuk town and located on the northern slope of Koh Sabz Mountain range. Antimony-gold-silver is associated with the hanging wall of thrust fault 35° dipping toward south (Fig.1g). Vein is found in the sandstone unit of Panjgur formation. Antimony vein upto 20cm thick, discontinuous lense shape is observed. Now mining work is abandoned. Nearly 8 quarry (inclose of 35 degrees south) pits are observed. Quarry pits are located from 30 meters in depth but now they filled with scree/overburden. But the local inhabitant told that the antimony vein upto 30cm are recorded at the ending mining work. **Hurain locality** (35 A/11: Fig.1c) is accessible from Nag, Sabzab, and Panjgur town. Gold in this antimony veins are reported upto 8.81 ppm. This locality has many iron oxidize and quartz carbonate veins. **Kokumb locality** (35 A/11: Fig.1c) is found at the southern slope of Koh Sabz and located from Basima, Nag and Panjgur. Antimony vein (18cm thick) is discontinuous lense shape. Host rock is Sihan shale. Gold upto 1.7ppm is also found. **Kuchaki North locality** (35 A/11: Fig.1c) is located on the southern slope of Koh Sabz and accessible from Basima, Nag and Panjgur town. Antimony vein (10 cm thick) is discontinuous lense shape. Host rock is Sihan shale. Some calcite veins are also stained by yellowish brown to maroon iron colorations. In this area overturning of some beds and faults are observed. Mercury and silver mineralization is detected by the chemical analyses (Younas, et al. 1995).

**Iron oxidized zone:** Many iron oxidized zone are observed in the reported area (Fig.1c) like Waro (31 M/16), Jauder, Kasig, Musa Kaur, Dom Jauder, and Hashani (35 A/11), Ahurag (35 M/12), Mazaran Dastak (31 M/12), Palantak Koh (35 A/12), Dauda Top (35 M/12), Surmagi Patkin, North Surmagi Patkin, Haspi Patkin, Kulo Patkin, Hurain Patkin, Siagari, Kuchaki south, Ahmedabad Kaur, Sor Jor Jauder, Mahmooodi Kaur, Musa Kaur, Panir body east, Nangindap Damagi, Hashani Damagi, Hashani and Panir Body west. Merlin and silver mineralizations: Mercury and silver mineralization are reported in the western and eastern Waro area (35 M/16; Fig.1c). Western Waro area is divided into three zones like southern, central and northern zones. Thal Waro Hg-Ag and associated mineralization have been found on the western plunge of doubly plunging syncline. Its accessibility is easy and on the Panjgur-Palantak track. Chemical results show highly anomalous mercury, silver and iron while slight anomalous Pb,Zn,Co,Cu,Mn,Cd and Au. Mercury, silver, iron oxide, and other associated mineralization occur in the form of network of calci veins, stringers and lenses in the fracture zone in Panjgur formation. These veins and stringes pinches and swells. Thickness of stringes and lenses vary from 0.5cm to 15cm. Some calci veins are also stained by yellowish brown to maroon iron colorations. In this area overturning of some beds and faults are observed. Mercury and silver mineralization is detected by the chemical analyses (Younas, et al. 1995).
A/14), Sabzab (35 A/12) and Saghar, Mazarap and Kurki (35 A/3,4,7,8) and Surap (35 A/6). Other parts of Shian and Makran also have major disseminated sulphur deposits and Pleistocene Kech/Kamaro and Jiwan deposits. Sulphur ore contains less than 20% sulphur which fills fractures in the sandstone has been intensely leached in an area of about 50 square feet, leaving quartz grains in a matrix of sulphur and gypsum. The extension of these coal seams is not known. Coal and carbonaceous shale is also reported by HSC (1961) from the Hoshab/Balgor area. However Balochistan desert is also important for exploration of lagoonal and lacustrine coal.

Ophiolite rocks associated minerals: The ophiolitic and ultramafic rocks in the Washdah area and its vicinity show minor chalcopyrite, copper, soapstone and asbestos mineralizations (Malkani 2004.c.f).

Sulphur: The Jiwani sulphur deposit (25° 05’N; 71° 47’E) is 20km NW of Jiwani and can be reached by boat from Jiwani but during the monsoon the best route is overlain by Kuldan (Nagel, 1965). The sulphur deposit is nine inches thick and is 2 meters wide. The sulphur is mainly in the form of small nodules and flakes. It consists of network of quartz vein and stringers and also have major ferralugous quartz carbonate vein trending southwest to southeast. On the west of this main vein the network of quartz veinning are observed. Quartz of main vein is cryptocrystalline. Network of veinning have subhedral quartz, however at the ending phase quartz are well developed which resemble the quartz diapir around the sulphur deposit. The sulphur ranges from 43-56%.

Pyrite mineralization: These mineralization are observed in the Durgi Kaur, Surap Kaur, and Washdah Kaur, etc. Durgi Kaur locality (35A/3: Fig.1c) is 90 km toward north from the Panjgur and also accessible in fair weather. Durgi Kaur pyrite locality is also near the south-west of Palantak Tank. It is flow in the calcareous sandstone. This sandstone is greenish grey, thin to thick bedded, hard and calcareous. Pyrite and chalcopyrite is observed as nodules and flakes in the host rock. Host rock is Panjgur formation. Washdah Kaur locality (35A/6: Fig.1c) is 20 km far toward east from Palantak village and 70 km toward west from Washuk. Washdah Kaur pyrite/chalcopyrite mineralization is observed in the sandstone, shale, tuffaceous sandstone and shale of Zurati formation. It is found as nodules and flakes. Surap locality ((35A/6: Fig.1c) is 30 km toward east from Palantak village and 60 km toward west from Washuk. It is associated with iron oxide carbonate vein in the Surap strike slip fault. Host rock is Zurati formation. Pyrite is observed as nodules and flakes.

Coal, carbonaceous shale and carbonaceous sandstone: Coal, carbonaceous shale and carbonaceous sandstone are observed in the Ahurag area (31 M/12; Fig.1c.). It is 90 km northwest from Panjgur town. The thickness of coal and carbonaceous sandstone is 4 m on the eastern side of Ahurag Kaur. On the western side of Ahurag Kaur 3 further layers of coal, carbonaceous shale and carbonaceous sandstone are observed. The extension of these coal seams is not known. Coal and carbonaceous shale is also reported by HSC (1961) from the Hoshab/Balgor area. However Balochistan desert is also important for exploration of lagoonal and lacustrine coal.
tectonites and cumulates in different forms and shapes. There are massive ore surrounded by banded ore, grape shot ores, banded deposits, disseminated ores, and vein-like solutions. The deposits of massive ore bodies are found in the Zhob area. The chrome of Jang Tor Ghar ore is of metallurgical grade. The Naweoba and Zizha ore shows Cr₂O₃ 36.7-38.5% in area. The Zhob chrome ores are aluminous chromite. Naweoba and Zizha ore shows Cr₂O₃ 43.7-46.5% and Cr:Fe ratio 2.9:1. Due to relatively less exposures, the deposit seems to be small.  

**Barite:** It is being used for weighting agent in drilling mud. It is also used for barium chemicals, white pigment and in paper industry. It is also known for its association with ammonolite and barite deposits of the Bela ophiolitic thrust, very small deposits of magnesite of Sinchi Bent (26°07'N; 66°14'E) in serpentinized ultramafic rocks of Bela ophiolitic thrust (Vloten, 2008). The Barite deposits of the Beloachistan were discovered by Ahmad and Klinger (1967). These deposits extend from Khuzdar to Uthal (Jankovic, 1984, Azam et al., 1989; Jones and Shah, 1994). It is found in the Shirinah, Zidi and Windar formations (Triassic-Jurassic) forming bedded replacement or veins. The deposits of Gunga (near Khuzdar) and Duddar in Las Bela district have over 12 million tons of barite (Ahman and Khan, 1994). The Gunga barite deposit is being mined by joint venture of Balochistan Government and Pakistan Petroleum Ltd. Barite deposits are estimated about 30 mt. The production from these deposits meets the total requirement for drilling and barium based chemical plants. Further the nodules of barite are commonly found in the Cretaceous Sembar shale. Barite from Las Bela area like Naka Pabni, Gacheri, Dhoro, Siro Dhoro, Bankhari and Kundli; Khuzdar area like Gunga, Shekran and Monar Talar; Las Bela area like Gunga, Naka Pabni, Gacheri, Dhoro, Siro Dhoro, Bankhari and Kundli; Khuzdar area like Gunga, Shekran and Monar Talar have reported.  

**Platinum group elements (PGE)- Muslibagh area:** Platinum group elements (PGE) have been reported in the chromitites from the Muslibagh ophiolites of Sapli Tor Ghar. Preliminary study show the primary deposits but not economic and however there are chances of economic placer deposits (Nakagawa et al., 1996). The two samples from tectonite show ppb values of Os 24,36; Ir 30,45; Ru 85,130; Rh 10,13.3; Pt 35,33; Pd 15,46; Au 2.5, 7.4; Total PGE 179, 403 The three samples from cumulate show ppb values of Os 41,13; Ir 35,24,7.7; Ru 100,55,9; Rh 16,8, 11.1, 4.5; Pt 5,5,5,18; Pd 4,3,18; Au 9.1, 7.4,1.3; Total PGE 202,111,47. Cl-chondrite value of OS 514, 540, Ru 690, Rh 200, Pt 1020, and Pd 545. Chondrite is a stony meteorite contains chondrule (small rounded bodies of olivine or enstatite) embedded in a fine grained matrix of pyroxene, olivine and enstatite (Page et al. 1979).  

**Asbestos:** Small deposits and showing of chrysotile and tremolite asbestos are found in serpentines of the ophiolitic complex near Naweoba (Zhob; Ahmad, 1969), Taleri Mohd Jan (Muslibagh; Ahmad, 1969) and Wad Khuzdar.  

**Lead and Zinc:** The lead-zinc and barite deposits are discovered by GSP from the Las Bela-Khuzdar region (Azam et al. 1989; Ahman and Qureshi, 1997). The mineralization is found in the upper part of Lower Jurassic Shirinab Formation. Main deposits are Shekran, Ranj Laki, Malkhor (NW of Khuzdar), Mithi, Gunga, Surmai (SW of Khuzdar, and Duddar (SE of Bela). Gunga, Surmai and Duddar deposits have been explored and evaluated in detail. The Gunga and Duddar deposits occur in the upper part (Anjira member) of the Shirinah Formation and are of sedimentary exhalative (Sedex) type. The deposits are found between major faults which have many subsidiary smaller faults. The upper part of Shirinab Formation are of sedimentary exhalative (Sedex) type. The deposits are found between major faults which have many subsidiary smaller faults. The Shirinab Formation is folded and faulted, and has been subject to diagenetic and metamorphic overprinting of later phases on the earlier ones. At Duddar, the barite may be exhalative and formed on sea floor where as the sulphide mineralization is syndiagenetic and formed by displacement or replacement of the host siliceous fluids. Deformation of sulphide layering shows that ore was formed before early emplacement and there fore pre-Tertiary. Proved reserves of 6.38mt and inferred reserves 3.43mt with 11.34%Zinc and 2.01% lead have been established (Jones and Shah, 1994). The Gunga deposit, 11km SE of Khuzdar, is hosted by Early to Middle Jurassic Anjira Formation. The mineralization is stratiform, stratabound, open space filling type. The zone extends over a distance of 1200m and easily distinguished as silicic gossan. The gossan contains 3-4% Pb and Zn. The deposit was explored through 14 drill holes. The ore body contains over 6% Zn and 1.5% Pb, with proven reserves of 6.5mt, probable reserves of 3.0mt, and possible reserves of 3.3mt (Jankovic 1983; Ahman and Qureshi, 1997). The Surmai deposit is located 1km South of Gunga deposit and hosted by Loralai Formation and is of Mississippi valley type. It has been explored by GSP and JICA and reserves of 2.93mt of ore with average content of 6.5% have been established. This deposit also contains 10-20gm/tonne of Silver (15-20g/tonne).  

**Manganese ore:** Manganese deposits occur as marine, c hematized precipitated sedimentary ores, as secondary enrichment deposits and as hydrothermal deposits. The deposits of manganese ore in Pakistan
are associated with volcanic rocks in the ophiolite thrust belt (Rizvi, 1951). In the Bela ophiolite thrust belt, lenticular manganese ore bodies are running only little mineralized pillow lavas. The most important localities are Khairani Nai (25° 34' N; 66° 45' E; 35K/9) 34,000 tons of two separate pods of 70 and 7 square meters (Abbas 1980a) of Manganese 42% (Nasim 1996), Siro Dhoro (26° 17' N; 66° 33' E; 35J/11) 9,500,000 tons irregular veins and lenses ranges from 1-6 inches in thickness (Master 1960) of Mn 36% (Nasim 1996), Sanjoro Dhoro (26° 28' N; 66° 26' E; 35J/7) 65,000 tons minor showings of soapstone are found in the Shirinab formation of Chiltan Range-Ziarat Nala (MgO 20%, K2O 32%, 250mtons), quartz from Zhob and Las Bela area (Kazmi and Abbas, 2001) and minor showings of soapstone are found in the Shirinab formation of Khad Kucha area have been reported.

Mineral Potential of Sulaiman Basin

Sulaiman Basin include coal, gypsum, celestite, sulphur, latereite/bauxite, ochre, barite, fluorite, petroleum seeps, marble, clays, iron, phosphate, travertine/aragonite/onyx marble, manganese, silica sands, building stones, cement raw materials, and naphthenic syenite.

Coal: Share of coal in energy sector of Pakistan is increased from 6.5%(2003-04) to 7.6% (2008-09). Balochistan province is on the top for producing 58% coal of the country. Large deposits of coal are existed in Balochistan and also Pakistan but unluckily the Pakistan steel is importing coal 2.7mt to 5.9mt per year from 2003 to 2009. This funding can be saved and put on new possible technology if instead of direct burning may be stopped or fund decrease. Therefore in coal power plants should be installed to use indigenous coal reserves, to increase electrical power supply keeping in view of population increase. Chamalang, Lunda and Surghari are producing about 0.5mt coal per year, in this way to start the working and mining of Kingri and Toi Nala coalfield will be additive for the energy of country. But in this tunnel, the Frontier Corps (Balochistan) are trying to start mining in Kingri and Toi Nala coalfields (District Musakhel). Coal resources are necessary due to increasing energy demand in Pakistan as a consequence of increase in population and some coal deposits of world show associated gold, silver, arsenic, selenium, uranium and zinc. Many discontinuous lenstion in coalfields are none developed. To develop these coalfields it is necessary to create the technology to use the mixed lignitic, subbituminous and bituminous coal because majority of the reserves are lignitic in Pakistan. Working coal mines in Balochistan are Mach-Abe Gum, Sor Range-Deghari, Narwar-Pir Ismail Ziarat, Khost-Shahrar-Hamai, and Duki, Chamalang-Bahlol coal fields with total reserves of about 196 million tons. The present work has increased the coal reserves of the coal and carbonatite in the Cretaceous strata of the Zhob area, and Cretaceous Sembar Formation of Chichlu (Mekhtar; Lorali District) area, Pab Formation in Vitakri (District Barkhan) and Mughalkot area, and Mughalkot Formation in the Toi Sar area (Musakhel District) but details are not provided so far.

Manganese:

Manganese laterite/bauxite, ochre, barite, fluorite, petroleum seeps, marble, clays, iron, phosphate, travertine/aragonite/onyx marble, manganese, silica sands, building stones, cement raw materials, and naphthenic syenite are dominant productive mineral of Balochistan.

Other Resources:

Buildings, construction stones and Decorative stones: Large reserves of recrystallized limestone and marble are being used from the Indus Suturre zone due to near road location to main industrial city Karachi. Large reserves of good quality gabbro are found in Musammbagh- Nisai area. Dolerite dykes from several localities provide jet black slabs for tiles and wall facings. Several kinds of multicolored, exquisite brecciated rocks are mined from the Bela and Karan melanges in Bela-Khuzdar area. Several varieties of fossiliferous limestone with beautifully oriented designs of foraminifers, mollusk shells and quartz and calcite veins, ranging in shade from cream to fawn, light brown to shades of grey occur extensively in the Paleocene to Eocene sequences in Las Bela area. These are being mined and marketed under erotic trade names such as Golden, Trevera, Bouteenmee, Verona, Black and Red Zebra, Oceanic etc. The private sector exclusively deals with the production, processing and marketing of marble and other decorative stones (Kazmi and Abbas, 2001).

Others:

The iron ore from Las Bela-Khuzdar region like Shiker and Mona Talar, while Zhob region like Nawoeba and Inzakh (Abdul, 1969), minor graphite showings like stringes and lenses in Shirinab Formation from Sheikh Wasil area (29° 06' N; 66° 21'E) of Chapar near Manguchar show the coal which is extended from Mari Bijar to Chamalang (Table 3), due to increasing of Chamalang and associated coalfields from 6mt (previously) to 100mt (Malkani, 2010g; present work), along with addition of 81mt reserves of Kingri and associated coalfields (latest Cretaceous-KT boundary coal of Kingri, Aram and Gharwandi areas of District Musakhel), 15.4mt of Eocene Toi Nala coalfield (Dewal, Ghoozeghar and Palwan/Betar of District Musakhel) and 1mt of Kingri-Shikar-Tor Shah Eocene coal field (District Musakhel). In this way the resources of Eocene Toi Formation coal field of Balochistan are 327.4mt and latest Cretaceous coal of Balochistan are 81mt. The total of Eocene and latest Cretaceous coal of Balochistan Province are 408.4mt. Kazmi and Abbas (2001) reported the coal from Badinzai and Kach from Sulaiman Foldbelt but details are not provided so far. Malkani (2010g) mentioned some new findings of coal from Sulaiman Foldbelt like Coal from the latest Cretaceous Vitakri Formation of Kingri Tehsil region like Surob and Khagoon areas of Musa Khel district, Coal from Late Eocene Domanda Formation of Rakhni area (Barkhan district), and Nisau area (Kohlu district), and extension of Chamalang coalfields (Balochistan).Further the coal and carbonatite in the Cretaceous strata of the Zhob area, and Cretaceous Sembar Formation of Chichlu (Mekhtar; Lorali District) area, Pab Formation in Vitakri (District Barkhan) and Mughalkot area, and Mughalkot Formation in the Toi Sar area (Musakhel District) but details are not provided so far.

Chamalang Coalfields show the coal which is extended from Mari Bijar to Surghari, Lunda, Bala Dhaka, Nausham and Bahlol areas (Malkani, 2004, 2010g). This coalfield show the Anokai syncline from Gunga and Dargai area, southwest, then followed in the east by faulted (thrusted) Lunda anticline, Bahlol syncline and Nosham faulted anticline. Remaining subsurface in the Chuchandai syncline, the coal and its host Toi formation is again exposed in the Kali Chapri anticline. Further southeast, the Toi formation was not deposited. At present most of coal is being mined from the northwestern limb of Anokai syncline (Toba Qadir-Mari Bijar-Canteen area) with some coal from Surghari and Lunda area. Lunda area is also promising but the expected main coal seams are subsurface. The coal contractors are mining only good quality coal but not lignitic coal. Major problem in Chamalang coalfields is the deep faultings which can reduce the coal production and discourage the contractors. This problem can be solved by further drilling and detail exploration works. Recently GSB has completed one drill hole (in 2009) upto depth of 775 77' in the Canteen area and the other hole drilled (in 2010) upto 414' in Surghari area and closed due to lack of funding and severe flood. The drill hole in the Canteen area verified many coal seams (lignite to bituminous), and proved as productive, while the drill hole of Surghari area has proved a few coal seams (dominantly lignitic with few subbituminous thin layers) but not able to prove the main productive lower coal (bituminous) seams and seem to be lacking of funds. Therefore in the Toi formation (more than 20) coal seams (lignite to bituminous) in Canteen Yadgar area of 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 1 foot thick are found in the Canteen area. The lower zone have DoChar footi and Chey footi seams, the middle zone have Malkani, Zahid, Dr. Imran, Pahl and Borda area, and the upper zone have Bakhtawar, Sadig and Nau footi coal seams (Malkani, 2010g). 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. Chey footi and Char footi are being mined in Mari Bijar area and its vicinity while Nau footi, Chey footi and Do footi are being mined in Akram Bpard area. It seems that both footi and Do footi are the name of sandstone and one coal seam. In the northeastern part like Surghari area the number and thickness of coal seams are being reduced. In the southwestern part like Angoor Shela, Mari Bijar and Toba Qadri area, the numbers of seams are reduced than Canteen area. 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 (strike line). The Flawo and Betar (lower strike line) of coal Nala area (2010g) has estimated total reserves up to 30 million tons of one foot or more thick coal seams of Chamalang coalfield, while the total reserves of six inches or more coal seams are 100mt. The present reserve estimation is purely tentative and based on two drill hole by GSP, running mining data and also coal exposures. So the measured reserves (with high degree of assurance) of Toba Qadri, Mari Bijar, Angoor Shela, Akram Bpard, Canteen, Surghari (south central), Nosham and Lunda areas (from surface to 0.4 km depth) are 6mt, indicated reserves (with moderate degree of assurance) from 0.4km depth to 1.2km depth are 12mt, inferred reserves (with low degree of assurance) from 1.2km depth to 4.8km depth are 72mt and hypothetical reserves (undiscovered but possible geological extension) beyond 4.8km depth may be about 10mt. In this way total estimated reserves of Chamalang Coalfields (Mari Chamalang-Lunda-Surghari central), Nosham-Kali Chapri, etc) of six inch or more coal seams (lignite C to bituminous B; Table 4) are about 100 million tons but it needs further drilling and exploration for confirmation. Toi Nala (Ghoze Ghar-Dewal) Coalfield is first reported by Malkani (2004c) and followed by Malkani (2009, 2010g) from Toi Nala area of Musa Khel district. Coal from Early Eocene Toi Formation of Drug Teshil region like Dewal, Ghoze Ghar, Miana, Tabai Khah, Takai and Alaminadat (upper strike line) and Flawo and Betar (lower strike line) of Toi Nala area (Musa Khel district) are found. There are three main coal seams with five minor coal seams hosted by shale, capped and roofed by sandstone/limestone beds dipping (20-35°) eastward. The coal and hosted strata in the Alam Badai section is about 30th thick (Fig.1c,m). The lower main coal seam is more than one foot thick, the middle and upper main coal seams each about 9 inches or slightly less than one foot thick. The coal quality is good to excellent in the central part of Toi Nala. Estimation of reserves is purely tentative and roundabout which is based on only outcrop because no exploratory holes have been drilled to ascertain the ore bodies at depth. Taking 5km strike, 0.5m thickness and 0.4km depth, the measured reserves of Kingri anticline (Nath and Sumat Ghars) are 2.4mt, indicated reserves (from 0.4km depth to 1.2km depth) are 4.8mt, inferred reserves from 1.2km depth to 4.8km depth are 21.6mt and hypothetical reserves beyond 4.8km depth may be more than 21.2mt. Total reserves of coal in the Kingri anticline are about 50mt. Taking 5km strike, 0.5m thickness and 0.4km depth, the measured reserves of Aram anticline (Aram, Nishpa, Tor Sarai and Shiren) areas are 1.2mt, indicated reserves (from 0.4km depth to 1.2km depth) are 2.4mt, inferred reserves from 1.2km depth to 4.8km depth are 6mt and hypothetical reserves beyond 4.8km depth may be more than 10.6mt. Total reserves of coal in the Aram anticline are about 25mt. Taking 5km strike, 0.3m thickness and 0.4km depth, the measured reserves of Gharwandi area (Surbol, Nath and Khagoon) are round about 0.3mt, indicated reserves (from 0.4km depth to 1.2km depth) are 0.6mt, inferred reserves from 1.2km depth to 4.8km depth are 2.6mt and hypothetical reserves beyond 4.8km depth may be more than 10.6mt. Total reserves of coal in the Gharwandi thrust (Aul Khan Kach) are about 6mt. In this way all these three Kingri coalfields, the measured reserves are 3.9mt, indicated reserves are 7.8mt, inferred reserves are 35mt and hypothetical reserves are 34.3mt. The estimated total reserves of lignitic (and some subbituminous) coal from Kingri, Aram and Gharwandi coalfields are about 81mt (Table 3) but it needs further drilling and exploration for confirmation. As the chamalang coalfield is already well exposed, the deposits of lignitic coal may increase by confirmation of extension to Sharin and Indarapur areas, etc. The mineable reserves can be estimated of 60% of measured reserves. These deposits are subequal to Chamalang to Nosham deposits but Chamalang coal is better than Kingri coal. Kingri-Shikar-Tor Shah Coalfields (Early Eocene coal) is first time reported by Malkani (2010g). This coal is promising due to extensive and moderate thick exposures of carbonaceous shale along with some coals and availability of road. These areas are most significant for further exploration study and development. This promising coal from Early Eocene Toi Formation is observed in the Kingri area, on the vicinity of metal led road from Kingri to Kot Khan Mohd (Musakhel). It is an anticline with Shaheed Ghat formation in the core and Toi, Kingri and Drug formations in the flanks. This anticline is followed in the west by Tor Shah syncline and also in the east by Gandhera syncline. There are 5 main coal seams which are more than one foot thick carbonaceous shale and some associated coal. These coal exposures are started (in Shikar area) just 2km NE of Master Saleem house and about 5km NE of Kingri town and extending toward NE direction in the Gidar Shikai, Chamo, Tor Shah etc. The coal seams strike is NE and dipping moderately toward SE of anticlinal structure. This anticline is followed in the west by Tor Shah syncline and also in the lignitic coal seam in Kingri formation such as in Gidar Dok, Shikar and Chamo area, but here the Toi formation coal is significant for further exploration. The coal quality seems to be best like Chamalang
These are the third deposits in Pakistan and have great significance as celestite in the Sulaiman Basin (Balochistan Province) of Pakistan. The Sulaiman Foldbelt is orthorhombic cleavable and coarse fibrous, and with a specific gravity of about 3.9. The celestite of Sulaiman Foldbelt is orthorhombic and hardness about 3.5. These deposits are Vein type and disseminated crystals in limestone and have 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. The discovered new celestite localities are under the administrative control of Barkhan, Kohlu, Dera Bugti, Musa Khel and Loralai districts. The celestite of Sulaiman Foldbelt is orthorhombic with tabular or prismatic, white, faint blue tinge, translucent, pearly, cleavable and coarse fibrous, and with a specific gravity of about 3.9 and hardness about 3.5. These deposits are Vein type and disseminated crystals in limestone. Chemical analyses show SrO 38.5 to 39.21%, SO2 42.64 to 42.96%, BaO 7.63 to 7.99% and CaO 1.1 to 1.12%. Celestite contains small amounts of calcium and barium. Malkani (2010f) estimated the 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 Bahiil area of about 1000 tons and Pirkoh area of about 100 tons.

Gypsum: The gypsum has S.G. 2.2-2.3 and hardness 1.5-2. The gypsum deposits reported by HSC (1961) are Spintangi (39 C/1), Nakus (34N/161), Dungan (39 C/5), Bala Dhaika (39 F/8), Bahiil (39 F/12), Mawand (39 C/10) and Mach (34 O/5,6,10). Sheikh (1972) curried the evaluation of Spintangi gypsum deposits. Huge deposits of gypsum are discovered by Malkani (2000, 2010f) from Lakka Kach (Rakhi, 39F/16), Kodi More-Nodo (39 F/16), Ishani (39 G/9), Khurcha (39 G/9, 13), Gadumra-Chang Mari (39 G/2, 5, 6), Nisau (Vitakri)-Safed (39 G/6,2) and 39 C/14), Jahanthali (39 G/7), Kahan-Khattan (39 C/11,15), Dera Bugti (39 G/3,7,8,11,12), Mawand (39 C/10,14), Bohri Kohlu (39 G/1), Girsin-Bala-Dhaika-Karher (39 G/5, 39F/8,12), Chamalang (39 F/8), Bahiil (39 F/8,12), Bagho Tummi (39 F/8), grapes-Kot Khan Mohd (39 F/14,15), Kallh-Eshar-Kot Khan Mohd (39 F/14,15), Phailawagh (39 G/7,8), Manjhail-Kharar (39 F/15,16 & 39 J/3), Eastern Sulaiman gypsum belt (Rajan Pur, D.G.Khan, Musa Khel District, Taunsa, D.I.Khan and Waziristan areas), Zinda Pir anticline. Malkani (2010f) reported the total reserves upto 50mt easily mineable depth are about 675 million tons (mt) of 21 localities of Sulaiman Foldbelt. Out of these over 350mt exist in Barkhan and Kohlu districts, 44mt in Dera Bugti District, 16mt in Sibi District, and small deposits like 1mt in Kingri, 1mt in Chamoz Kot Khan Mohd, 40mt in Drug Tehsil areas (Drug, Barkoi, Karkana, Toi Nala, Pahlwan, Dewal, Ghoze Ghvar, Miana, Tabai Khah, Takai, Alambadai, etc of Musa Khel District of Balochistan, while the rest i.e., 200mt in D.G.Khan and Rajan Pur districts of Punjab, and 20mt exist in Shirani area of D.I.Khan District (KF). Malkani (2010f) mentioned the analyses of 125 samples from different localities of Sulaiman basin, however in general 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 in Sulaiman foldbelt while one bed (0.5m-6m) of gypsum in Domanda formation in only southern Sulaiman foldbelt. The present investigation show total estimated reserves (measured, indicated, inferred and hypothetical) of Sulaiman foldbelt is 26 billion tons (1.06 billion metric tons) which are the largest deposit in Pakistan. The breakup of total gypsum reserves of more significant localities are Lakha Kach or Rakhi 1bt, Ishani-Gadumra 1bt, Nisau-Safed 3bt, Kahan-Khatan 1bt, Dera Bugti 1bt, Mawand 1bt, Girsini-Bala-Dhaka-Karher 1bt, Anokai (Bahiil and Chamalang) 1bt, Manjhill Kharar 3bt, Zinda Pir 3bt and Eastern Sulaiman gypsum belt (Rajan Pur to Waziristan) 10bt. Further the western Domanda syncline bifurcated the eastern Sulaiman gypsum belt to two limbs. The western limb continues as eastern Sulaiman gypsum belt toward Waziristan in the south, toward Zamaray, Toi Nala and Barthi toward south. However the eastern limb is faulted and trends towards northeast and hited the metal road between Draban and Drazinda. This (Draban-Domanda) deposit is 15mt upto 50 m mineable depth, however the hypothetical reserves may approaches upto 1bt. The Domanda-Draban gypsum deposit is near the road and can easily be well developed.

Fluorite: Malkani (2010g) reported first time fluorite from Gadebar, Tor Thana and Daman Ghar ranges of Loralai area occurring as veins in faults and fractures, and replacement deposits near the fractures, which are hosted by the Jurassic Loralai limestone. The fluorite represents many colour like pink, blue, light grey, green, light yellow, etc. The pink fluorite is being exploited from Sande mine at Gadebar Range. The fluorite seems to be good for acid preparation, metallurgical grades and gemstones. After the first largest deposits of fluorite from Dilband and its vicinity areas of Kirthar foldbelt, the Malkani (2002; 2004d) and Malkani et al. (2007) discovered the second largest deposits (6750 tons) of fluorite from Mula-Zahri Range of Kirthar foldbelt, Malkani (2010f) discovered the third largest deposit of fluorite from Sulaiman Foldbelt. The present investigations by the author show that the Jurassic strata of Sulaiman foldbelt have possible largest deposits of the Pakistan. The fluorite shows impurities as calcite and quartz in the Sulaiman foldbelt. It is also interpreted that the Jurassic strata especially limestone of Kirthar and Sulaiman foldbelts and adjoining Indus Suture (Axial Belt) seems to be significant for further prospecting especially in the low dip strata. Now it is being mined from Loralai district area where tribal disputes are not found but most of the fluorite host area is in dispute and needs fruitful agreements between tribes to exploit fluorite. Mining is in progress in the Mehktr (Balao, Inde and Zhizhghi, Sande), Nahiwal (Chapar area) and Zarah (Watgam) areas. The estimated reserves are about 50000 tons. Fluorite is also reported from Zhob area like Khojazai Kalai.

Bauxite, laterite, Fire clay and ochre: Very extensive deposits of Ziarat (30° 23’N; 67° 43’E), located in the disconformities between the Paleocene Dungan limestone and the Cretaceous Parkh limestone. The laterite is exposed on both the limbs of several anticlines between Ziarat and Sanjawi about 30 kms. The laterite range in thickness from 0.5m to 5m. It also includes some resistant minerals like titanium, etc. This is apparent the largest laterite in Pakistan with reserves of less than 100 mt. The laterite is red brown in colour hematite laterite with high silica and titanium make it difficult to use as iron ore. However it has been mined for use in cement industries. The chemical analyses of Ziarat laterite include 7.7-21% SiO2, 34.4-51.7% Fe2O3, 18.62-32.48% Al2O3, 0.56-2.66% TiO2 and 8.45-15.34% H2O (Kazmi, 1955). K/T boundary in Sulaiman range is also very significant for lateritic and bauxitic materials. The lateritic beds found in Ziarat area Balochistan contains lenticular pockets of ochre, which is being used locally for paint making and other industries. These deposits are formed as residual soils on the erosional surfaces in the geological past. The base of Ranikot group in Sindh, Dungan formation in Balochistan, and at the base of Hangu Formation in Punjab contains lateritic horizons which can be used as ochre. The fire clay beds are associated with many coal horizons in the Sulaiman foldbelt. The possible Ochre/Iron/Fire clay from Chitarwata, Rakhi Gaj, Vitakri, Drazinda formations and Vihowa group of eastern Sulaiman Foldbelt seems to be significant.

Marble, construction stones and Decorative stones: A variety of exquisite decorative stones are found at several localities in Pakistan. Marble is not found in this basin, however the huge deposits (more than one billion ton) of Dungan limestone (white) in the Southwestern Karu areas is being well used as marble for the preparation of many types of tiles. It is found in the districts like Loralai (Kasa, Karu and Anambar area; 39F/3, 39B/11, 39 B/15; Malkani et al, 1997),

Stratigraphy, Mineral Potential, Geological History…
Pyrite found anomalous in iron nodules. The iron nodules in the Cretaceous sandstone of Toi Formation and Vitakri group. In the Toi Formation and Bawata members formation. spotted and red wavy laminated sandstone of Rakhi Gaj (both Girdu beds) has anomalous iron (14-21%) deposit, while phosphate from associated with Ziarat laterite, Vitakri formation and Vihowa group. It is found in the Zinda Pir and Dera Bugti area. probably Shirani area, while from the Vihowa Sandstone of Toi and Kingri formations have opposite source from Sulaiman Basin. The Chamalang (Ghazij), Kahan and Vihowa groups. Large deposits of Flint is also found in many calcite veins in limestone of different age. Travertine/Aragonite is found in the vicinity of hot water springs area parallel to bedding in Early Cretaceous Sembar shales. There are parts of basin. Building stones like from Chilmon, Loralai, Parh, Mughal Kot, Fort Munro, Sangiiali, Dungan, Drug, Habib Rahi and Sangiiali formation. The sandstone/azurite is also reported by local peoples in the Drug limestone and they concluded it is associated with Petroleum (Kazmi and Abbas, 2001). The thin bedded marl and limestone of Habib Rahi Formation of Chitarwata and Shadikhel Savi Ragha area (Toi Nala) show bituminous concentration and give burning in the fire. Water resources of the Sulaiman foldbelt are too much but needs its utilization. Sulaiman foldbelt have some valleys and plain areas inside, suitable for dam construction, and also fore deep (Damam) of Sulaiman foldbelt which have much barren areas, indicate for urgent dams construction. Further many suitable water dams should be constructed which are urgent needs due to congested and increasing population and large barren areas. The small dams should be constructed on Vihowa nala, Sanghar Nala, Sangiiali, Dungan, Drug, Dukan, Dera Bugti, Lahri, Tal and Nar (Khuz).

Mineral Potential of Kirthar Basin (Balochistan Province)

Kirthar Basin includes mineral commodities like Coal, Iron, Fluorite, Sulphur, Building stones, Decorative stones, Marble, Celestite, etc.

Coal: It occur in areas of Sonda, Lakhra, Thatta, Indus east, Badin, Metang-Jhimpir, Jeruk-Ongar, Badin and Thar, which is one of the largest coalfields of world. However all these identified coalfields are beyond the scope only Eocene coal of the Johan and Abe Gul areas, Paleocene coal from Dureji and Khauri areas. The coal of Johan is not being mined due to thin and discontinuous exposure and security reason. The coal of Abe Gul is on high peak and has very small extension. Kazmi and Abbas (2001) reported first time the coal of Khauri locality of Zidi area (Khuzdar District) and here the coal and carbonaceoussal is about 1 foot thick seam found in the Tertiary limestone, marble and shale. It is exposed near the road cut of Khuzdar to Karkh road.

Iron ore: Dilband iron ore found at J/K boundary in the Vicinity of Dilband and Johan area of Mastung, Kalat, and Bolan and Quetta districts, It is found between the Jurassic Chiltan limestone and Sembar Formation. It mostly represents and overlaps the Sembar Formation. Abbas et al 1998 has named it as Dilband Formation. Pakistan has large iron deposits occurring as ironstone and lateritic beds showing disconformities like Kirthar (lower Indus) foldbelt (Dilband). It is recently discovered by GSP with considerable economic significance. It is located on the Dilband area just NE of Johan Village. It is 70km from National Highway and 100km from Karachi railway station. The iron ore is found as a strong nodules with a width of 10cm to 1 meter in diameter with a width of 10cm to 1 meter in diameter. It is hard and resistant to weathering. The iron reserves are 200mt.
Due its large tonnage, low and gentle dips, favorable location (also close to Mach and Bibi Nani with belt loading), open cast mining, single working and acceptable grade, it is considered as one of other ores in Pakistan (Abbas et al., 1998; Kakepoto and Malkani 2001a,b). It comprises ironstone ore which is being mined in Europe, North America, Russia and China. The Pakistan Steel Mills have successfully blended 10% of raw Dilband ore with improved iron ores to produce sinter and pig iron. Laboratory scale experiments indicate that this ratio can be raised to 15% and possibly upto 70% after biochemical analyses of ore. The Agglomerated analyses showed 45.2, 48.03%, FeO 2.36-2.95%, SiO2 13.7-14.6%, CaO 2.23-2.42%, MgO 1.6-2.2%, MnO 0.09-0.11%, Al2O3 53.06-6.04%, TiO2 20.32-20.35%, P 0.24-0.34%, Cu 0.01-0.012%, S 0.12-0.19%, Zn 0.07%, LOI 4.5-7.45%. Pakistan Steel mill is started to use the iron of Dilband area but due to security it was abandoned. So necessary security arrangement may be provided to develop the Dilband iron ore for Pakistan Steel mill. Three audits were started and works on sulphur early in World War II promoted the Geological Survey of India to reopen the mine. Seven audits were started and works on sulphur formation at Sanni. Sulphur occurs as veins or as replacement of petroleum and sulphur. The mineralization extends for about 1 km (Sispal Kella, verbal communication with Kazmi and Abbas, 2001).

Fluorite: The attraction of mineral specimens as distinct from a faceted stone lies in its form and colour. Mineral specimens do not have to be of gem quality, though the gem crystals that escape cutting are admittedly most beautiful. In recent years a large and a flourishing market for good mineral specimen as collector’s items has developed world wide. Attractive violet fluorite crystals occur in the Koh-Dilband (29°30’S; 66°55’E) fluorite mines in Kalat Division. In the vicinity of Dilband, the fluorite is reported from Pad Maran, Chah Bali and Dobranzel (Ishquin) areas (Bakr, 1965a; Mohsin and Sarwar, 1980).

Sulphur: Sanni (south of Dhadhur) and Kohvi-Sultan (near NorMETE area) in Baluchistan is the main sulphur localities. Sanni deposit is located in the foothills of Kirthar Range in the south of Dhadhur town. The Sanni deposit (28°02’N; 67°27’E) is about 20km to the SW of Sanni Village. It is 60km west of Bellpat railway station and reached from there by a dirt road which passes through Bagh and Shoran. The mine was active to the prior to the visit of C. Massn in 1943. In 1888 the mine caught fire and collapsed. The shortage of sulphur early in World War II promoted the Geological Survey of India to reopen the mine. Seven audits were started and works abandoned at 1942 due to caving ground and poor ventilations. Three beds of sulphur totaling 20feet in thickness and containing from 32-68% sulphur were described by Krishnaswamy in 1941. Each bed is separated by 15feet of sandstone.  Cotter (1919) estimated an ore bed 68% sulphur were described by Krishnaswamy in 1941. Each bed is 11 feet thick and 1700,000 square feet in area and calculated 36,000 tons of ore allowing 25% for mining losses. An estimate (HSC, 1961) of 18,000 tons of reserves was based on an assumed extent of ore 200 feet from the face of the hill having thickness of 10 feet. The ore is controlled by competence of beds. The sulphur is confined to porous and brecciated zones, joints and bedding planes in soft argillaceous sandstone. The tar or Martha was noted in the lower working representing a genetic association of petroleum and sulphur. The hydrogen sulphide gas migrated and deposited by oxygen bearing water precipitated sulphur. The gypsum bearing Eocene limestone probably underlies the area. A gypsum layer 3-4feet thick overlies the sulphur formation at Sanni. Sulphur occurs as veins or as replacement of sandstone matrix in the Nari Formation. The ore contains 45% sulphur and the reserves are estimated at about 58,000 tons (Muslim, 1973a). Following minor showings of sulphur are also reported. Laki Sulphur (29°46’16”N; 67°57’E) is the main sulphur localities around the vicinity of hot spring near the town of Laki (Nagell, 1965). Gokurt sulphur deposit (29°33’N; 67°28’E) was reported by Tipper (1909) in the Bolan Pass in massive limestone of Late Cretaceous age. HSC (1961) shows the deposits in the Eocene limestone. It is 50km north of Sanni sulphur deposit.

Buildings, Construction and Decorative stones: Large reserves of recrystallized limestone and marble occur widely in the Kirthar range and now it is being used from the near road Kirthar range. Several varieties of fossiliferous limestone of Paleocene to Eocene sequences in various parts of Sindh are being mined and marketed under different names. During 1097-98 about 344,000 tones of marble was produced. The private sector exclusively deals with the production, processing and marketing of marble and other decorative stones.

Others: Phosphate from Pabni Dhora to Shah (Lasbela area) (Kazmi and Abbas, 2001) and celestite in Eocene Kirthar Formation of Karkh area (Malkani, 2010) have been reported. The Kirthar foldbelt have some valleys and plain areas inside, suitable for dam construction, and also fore deep (Daman) of Kirthar foldbelt which have much barren areas, indicate for urgent dams construction. The Dams on Mula and Dera Gaj Nalas are urgent demand due to population increase and also for water utilization. Ahmad (1962) reported the bituminous residues known as Salajeet were found in some parts of the Pab Sandstone in the Khudazar region.

Geological History and Palaeobiography of Sulaiman and Kirthar basins (western part of Indo-Pakistan subcontinent)

The Sulaiman basin show exposed rocks from Triassic to Recent. The Triassic Khanozai group (marine Waltagi and Gawal formations) includes the minor exposures in the contact of Sulaiman and Indus Suture. The Indus Suture is the western and northwestern boundary of Indo-Pakistan subcontinent with Tethys and Asia (Eurasia, Laurasia). The Jurassic Sulaiamun group includes Spingwar, Loralai/Anjira, and Chiltan/Zidi formations show marine shelf deposits. The Early Cretaceous Parh group consists of continental to marine ironstone and red shale of Dilband formation (J/K boundary), Sembhar, Goru and Parh formations show marine shelf, slope and also platform open sea deposits. The Late Cretaceous Fort Munro Group show uplift of the Indo-Pakistan shield and ultimate sea regression represented by marine and sea shore elastic Mughal Kot (mudstone), carbonate Fort Munro (limestone) and elastic Pab (sandstone with shale) formation, and continental Vitaki formation (latest Cretaceous and K/T boundary). The clastic source was in the east (Indo-Pakistan shield). During Late Cretaceous there is no or negligible deposition in the Western Indus Suture zone indicates geantline and high land, showing contact with Laurasia, which is further strengthen by the Cretaceous Chagai and Raskoh magmatism. Further volcanics of Indus Suture enters in the Early Cretaceous Parh group and Late Cretaceous Mughalkot/Bibi formation also indicating collision. The Paleocene Sangial group show marine clastic shale and sandstone, carbonate limestone and chert, sandstone and shale of Rakhi Gaj Formation, and marine carbonate Dungan limestone. The Early Eocene Chamalang (Ghazii) Group show marine shale with some clastic marine sandstone of Shaeheed Ghat Formation, deltaic sandstone, shale and marl of Toi Formation, continental fluvial sandstone and red mudstone of Kingri Formation, continental shale and sabkha type supratidal evaporite of Gypsum of Baska Formation, and marine marl, shale and limestone of Drug Formation. The Late Eocene Kahan Group show marine shale, marl and limestone of Habib Rahi, Domanda, Pirkoh and Drazinda formations. The Oligocene to Pliocene Vihowa Group shows mollase type (source from North/Himalaya) clastic mudstone, siltstone, sandstone and conglomerate of Chitarwa, Vihowa, Litra and Chaudhwan formations. The Pleistocene Dada Formation show fluvial conglomerate, mudstone and sandstone. The Subrecent and Recent is represented by fluvial surficial deposits. Triassic to Paleocene is mostly represented by marine strata except the J/K and K/T boundaries which represent disconformities. The J/K disconformity show major sea regression and uplift of the area forming Jacobabad-Dilband (Kalat District) highlands with southeast-northwest general trend, which is the border line of middle and lower Indus basin. After this again transgressed described by Vihowa Group. This is highland. At K/T boundary the sea was regressed from the Fort Munro (D.G.Khan)-Vitaki (Barkhan)-Ziarat east west belt and formed the highland with terrestrial environments of Vitaki formation. Fort
Muhammad Sadiq Malkani

The first dinosaur fossils from India were discovered in 1928 by Captain W.H. Sleeman from the Cretaceous sediments of Bara Simla hill near Jabalpur. Soon after the initial discovery of Titanosaurus from India and Patagonia, exploration in Mahajanga basin of Madagascar produced large bones including the first record of dermal armour (Deperet, 1896). The well preserved fossils from Madagascar in the latest Cretaceous 12m thick unit of Anembalanga member of Maevaran Formation and its implication for paleobiogeography were reported by Wilson (2010), “much of the latest Cretaceous fauna known from India is also present in Pakistan but there are fossil reptiles present in Pakistan that have not yet been recovered from India.” The trispinous distalmost caudal centra show pleurocoelous characters of Pakistan titanosaurians. Many hundreds significant holotypes and referred fossils which include Khetranisaurus bharhanki (Malkani 2006b; 2009f), Sulaimanisaurus gingersichi (Malkani and Anwar 2000; 2006b, 2009f), and Pakisaurus balochisthani (Malkani 2003b; 2006b; 2010a) of herbivorous Pakisauridae (slender titanosaurians) and Marisaurus of herbivorous Balochisauridae (stocky titanosaurians) sauropods, Vitakridinda sulaimani and Vitakasaurus saravi (Malkani 2006c; 2009f; 2010g; 2011a) of slender and large bodied carnivorous Vitakrisauridae theropod, and Pavbeshki pakistanensis (Wilson et al. 2001; Malkani, 2007d) and Sulaimanisuchus kinnai (Malkani, 2010g) of carnivorous Sulaimanisuchidae mesoeucrocodylids were documented so far. Further the trackways from the Middle Jurassic Sanasanskh Limestone of Kohat and Potwar basin represent a group of wide gauge Malakbelisaurus mianwali (renamed due to previously engaged name Malasaurus) titanosaurian sauropods and a narrow gauge running Samanandra suraghi abelisaurian theropod based on only ichnotypes (Malkani, 2007a,2008f, 2011b)). Further these vertebrates are also presented at many national and international conferences (2004a,b; 2006a, 2007b,c,e; 2008b,c,d,e; 2009a,b,c,d,e; 2010b,c,d,e,f; 2011a,b). Gingerich et al. (2001) discovered the walking whale from the transition zone of Habib Rahi and Donanda formations of Lakh Kach syncline (Rakhi) area of Barkhan District which has solved the evolution of swimming whale from walking early Artiodactyla instead of Mesonychia. The Chitarwata Formation is the host of continental vertebrates like Balochichthorium, Bagithorium, etc. The Vihowa and Litra formations are also rich in continental vertebrates.

The Gondwanan and Laurasian vertebrates show Pangaean heritage, but after separation during Jurassic both show fauna with distinct Characters. In this way Indo-Pakistan Subcontinent show Gondwanan heritage but after long migration and isolation from 160 Ma to 70 Ma, the continental vertebrates acquired distinct characters. The configuration of Gondwana changed dramatically during the Late Jurassic and Cretaceous as it broke apart into isolated landmasses. The dispersion of these landmasses undoubtedly had profound geographic distribution (for the geographic distribution model can not explain). The first land connection or dispersal model can not explain evolutionary trajectories of the resident terrestrial vertebrates’ fauna. Further Gondwana terrestrial fossil record on crocodyliforms, non avian dinosaurs and mammals are better than for most other vertebrate
The latest Cretaceous fauna of Pakistan do not show such highest degree of resemblance with Madagascar and South America as it should be if connected. Generally there is a community development in the world, at places some group is well developed and at places some other groups are developed. The dominance of some group in southern landmasses and some other groups in Laurasian landmasses are one of the tools for paleobiogeographic connections. In a number of ecosystems, noosaurid abelisauroids were small bodied counterparts to their large bodied cousins, the abelisaurids, in a manner parallel to small bodied maniraptorian coelurosaurians and large bodied tyranosaurids in many Late Cretaceous Laurasian ecosystems however in the present study it is strengthened by stratigraphy, geological history and tectonics data. The anteriorly orientation of antorbital fenestra, Chin in the anterior dentary rami, number of teeth, less dorsal slope/inclination of skull and wheel like armor bones of Rapetosaurus, and broad distal caudal vertebrae of Malagasy Texon B of Madagascar are different from Balochisauridae and Pakisauridae titanosaurian sauropods. The complex skull of Vitakridinda is also different than theropods of Madagascar and South America. However the Pakistani titanosaurs also show affinity with Nemegtosaurus, Quaesitosaurus and Alamosaurus etc of Laurasia. So far the trispinous distal caudal centrum and anteroposterior moderate/medium inclination of dorsal skull of late Cretaceous Balochisauridae show endemic characters. The latest Cretaceous Pakistani fauna is slightly different than previously associated Gondwana landmasses, while it is relatively more provincial than Laurasia and other regions of Gondwana. In this way the orogeny/tectonics, stratigraphy and fauna of Pakistan show isolation of Indo-Pakistan as island during probably Late Jurassic, or most probably Early Cretaceous to middle Late Cretaceous. Indo-Pakistan shows association with Madagascar and South America (via Antarctica) before Late Jurassic or Late Cretaceous. But present geological and paleontological studies agree to have commenced in earnest in the Late Triassic to Early Jurassic (Lawver et al., 1992; Torsvik et al., 2001; de Wit 2003; Wells, 2003) Madagascar, as part of “East Gondwana” (also including the Indo-Pakistan subcontinent, Antarctica, and Australia), began to separate from “West Gondwana” (South America and Africa) Initial rifting between the Indo-Pakistan-Madagascar block and Africa began during the Permo-Triassic, and seafloor spreading between the conjugate-rifted margin of southern Somalia, Kenya and Tanzania (Western Somali Basin) and northern Madagascar commenced by the late Middle Jurassic By the Late Jurassic (approximately 160 Ma; Fig.1h), in a narrow seaway separated the east coast of Africa from Madagascar and the rest of the East Gondwana block. When major faults or rifts occurred, these have many subsidiary faults or rifts. In this way the rifting between east and west Gondwana created both rift on the west and also in the east of Madagascar. Consequently Madagascar is separated from Africa and also Indo-Pakistan subcontinent is separated from Madagascar. Indo-Pakistan migrated toward northeast rapidly covering more than 6000km in about 80 million years, and contacted with Laurasia at Late Cretaceous about 75 Ma. From 75 to 55 Ma, the area of Hinterland in the north and northwest of Sulaiman basin, began to rise first and provided the clastic of Chamalang group (Shaheed Ghat, Toi and Kherah formation) in the central, north and west of Sulaiman basin and northern Kurthar basin. In the east and southeast of Sulaiman basin remained under sea and marine Drug formation was deposited, which were followed by wide evaporitic deposits (Baska gypsum). According to Krause et al. (2006) the Africa was the first of the major Gondwana landmasses to be fully isolated prior to the Albian/Cenomanian boundary, and other Gondwana landmasses remained relatively cosmopolitan until the last stages of the Late Cretaceous. But present geological and paleontological studies contradict this deduction and suggest for isolation of Indo-Pakistan subcontinent from Madagascar during Late Jurassic or atleast earliest Cretaceous.

### Table 1. Stratigraphic sequence of Balochistan Basin

<table>
<thead>
<tr>
<th>Age</th>
<th>Chagai-Raskoh Magmatic arc</th>
<th>Kaker-Khurasan flysch basin</th>
<th>Makran-Siyan accretionary Basin</th>
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<tbody>
<tr>
<td>Quaternary</td>
<td>Surficial deposits</td>
<td>Surficial deposits</td>
<td>Makran Mudvolcanoes</td>
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<tr>
<td>Recent</td>
<td>Koh Sultan volcanic group/ Kamerod formation</td>
<td>Bostan formation</td>
<td>Talar Chatti mudstone</td>
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<td>And Subrecent</td>
<td>Buzre Mashi volcanic group</td>
<td>Shaigalu</td>
<td>Talar sandstone</td>
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<td>Pleistocene</td>
<td>Pishi/Dalbandin formation</td>
<td>Turbat</td>
<td>Parkini mudstone</td>
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<td>T Pliocene</td>
<td>Murgha Faqirzai group</td>
<td>group</td>
<td>Sandian Zuriat formation</td>
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<td>Miocene</td>
<td>Amulaf formation</td>
<td></td>
<td>Group Wadhzad Volcaniclastic form A</td>
</tr>
<tr>
<td>E Khojak</td>
<td>Saindak formation/Robot/</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R Oligocene</td>
<td>Nisai/Kherah/Robot limestone</td>
<td>Nilai limestone</td>
<td>Sianah shale</td>
</tr>
<tr>
<td>T I Eocene</td>
<td>Rakshshani/Juzzak formation</td>
<td></td>
<td>Wakai limestone</td>
</tr>
<tr>
<td>Y Paleocene</td>
<td>Humai formation</td>
<td></td>
<td>Ishikan formation</td>
</tr>
<tr>
<td>CRETACEOUS</td>
<td>Chagai Intrusion, Bunup complex</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 2. Mineral localities of Balochistan Province, Pakistan

<table>
<thead>
<tr>
<th>Metallogenic zone</th>
<th>Economic Minerals/Commodities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chagai magmatic arc</td>
<td>Copper, Gold, Silver, Iron, Tungsten, Lead, Zinc, Sulphur, Tourmaline, Manganese, Barite, Marble, Bed rock, Aggregate and water resources, Building, construction and decorative stones.</td>
</tr>
<tr>
<td>Raskoh magmatic arc</td>
<td>Chrome, Vermiculite, Manganese, gypsum, copper.</td>
</tr>
<tr>
<td>Kaker Khurasan basin</td>
<td>Antimony, Ochre, Saline springs, Mudvolcanoes gas.</td>
</tr>
<tr>
<td>Wazhdad magmatic arc</td>
<td>Chrome, copper.</td>
</tr>
<tr>
<td>Indus Suture (Axial belt)</td>
<td>Chromite, Lead, Zinc, copper, Manganese, Fluorite, Barite, Iron, Platinum group elements (PGE), Asbestos, Witherite, Magnesite, Dolomite, Talc (Soapstone), Quartz, Graphite, Mercury, Nickel, Niobium, Phosphate, Building, construction and decorative stones.</td>
</tr>
<tr>
<td>Sulaiman Basin</td>
<td>Coal, Gypsum, Celestite, Sulphur, Laterite/Bauxite, Ochre, Barite, Fluorite, Marble, Clays, Quartz and Flint, Iron, Phosphate, Manganese, Silica sands, Cement raw materials, Micropegmaites (Nepheline syenites), Petroleum seep,</td>
</tr>
<tr>
<td>Kirthar Basin</td>
<td>Coal, Iron, Fluorite, Sulphur, Building stones, Decorative stones, Marble, Celestite, Building, construction and decorative stones.</td>
</tr>
</tbody>
</table>
Table 3. Coal Reserves of Balochistan (million tones). Coal seams cumulative thickness ranges and status as developed and Non-developed.

<table>
<thead>
<tr>
<th>Coalfield</th>
<th>Coal seams (meter)</th>
<th>Status</th>
<th>Measured</th>
<th>Indicated</th>
<th>Inferred</th>
<th>Hypothetical</th>
</tr>
</thead>
<tbody>
<tr>
<td>BALOCHISTAN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chamalang</td>
<td>0.2-2.5</td>
<td>Dev.</td>
<td>6</td>
<td>12</td>
<td>72</td>
<td>10</td>
</tr>
<tr>
<td>Kingri (K-T coal)</td>
<td>0.5-2.5</td>
<td>Dev.</td>
<td>3.9</td>
<td>7.8</td>
<td>35</td>
<td>34</td>
</tr>
<tr>
<td>Kingri-Shikar-Tor Shah (Eocene)</td>
<td>2.0-2.0</td>
<td>Non-Dev.</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Toi Nala (Ghooze Ghar)</td>
<td>0.3-2.0</td>
<td>Non-Dev.</td>
<td>1.2</td>
<td>2.4</td>
<td>10.8</td>
<td>1</td>
</tr>
<tr>
<td>Khosht-Sharig-Hamai</td>
<td>0.3-2.3</td>
<td>Dev.</td>
<td>13</td>
<td>-</td>
<td>63</td>
<td>-</td>
</tr>
<tr>
<td>Sor Range-Sanjudi-Deghari</td>
<td>0.3-1.3</td>
<td>Dev.</td>
<td>15</td>
<td>-</td>
<td>19</td>
<td>16</td>
</tr>
<tr>
<td>Duki</td>
<td>0.2-2.3</td>
<td>Dev.</td>
<td>14</td>
<td>11</td>
<td>25</td>
<td>-</td>
</tr>
<tr>
<td>Mach-Abegum</td>
<td>0.6-1.3</td>
<td>Dev.</td>
<td>9</td>
<td>-</td>
<td>14</td>
<td>-</td>
</tr>
<tr>
<td>Pir Ismail Ziarat</td>
<td>0.4-0.7</td>
<td>Dev.</td>
<td>2</td>
<td>2</td>
<td>8</td>
<td>-</td>
</tr>
</tbody>
</table>

Subtotal: 65.1 35.2 248 461.3 408.4

Table 4. Proximate analyses, Heating value and ranking of different coalfields of Balochistan Province.

<table>
<thead>
<tr>
<th>Coalfield</th>
<th>Moisture (%)</th>
<th>Volatile Matter (%)</th>
<th>Fixed Carbon (%)</th>
<th>Ash (%)</th>
<th>Total Sulphur (%)</th>
<th>Heating (BTU/lb)</th>
<th>Rank (ASTM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chamalang</td>
<td>1.64</td>
<td>84</td>
<td>25.1</td>
<td>55.2</td>
<td>5.58</td>
<td>2000-10,000?</td>
<td>LigC to hvBb</td>
</tr>
<tr>
<td>Khosht-Sharig-Hamai</td>
<td>1.712</td>
<td>9.3-45.3</td>
<td>25.4-34.8</td>
<td>9.3-34.0</td>
<td>3.5-9.5</td>
<td>9,637-15,499</td>
<td>SubC to hvCb</td>
</tr>
<tr>
<td>Sor Range-Sanjudi-Deghari</td>
<td>3.9-18.9</td>
<td>20.7-37.5</td>
<td>41.0-50.8</td>
<td>9.3-34.0</td>
<td>3.5-9.5</td>
<td>9,637-15,499</td>
<td>SubC to hvCb</td>
</tr>
<tr>
<td>Duki</td>
<td>3.5-11.5</td>
<td>32.0-50.0</td>
<td>28.4-20.0</td>
<td>5.0-38.0</td>
<td>4.0-6.0</td>
<td>10,131-14,164</td>
<td>SubB to hvAb</td>
</tr>
<tr>
<td>Mach-Abegum</td>
<td>7.1-12.0</td>
<td>34.2-43.0</td>
<td>7.96-50.05</td>
<td>6.25-74.80</td>
<td>3.44-6.93</td>
<td>2193-13,569</td>
<td>SubA to hvBb</td>
</tr>
<tr>
<td>Pir Ismail Ziarat</td>
<td>6.3-13.2</td>
<td>34.6-41.0</td>
<td>19.3-42.5</td>
<td>0.3-37.5</td>
<td>3.2-7.4</td>
<td>10,131-14,164</td>
<td>SubB to hvAb</td>
</tr>
</tbody>
</table>

Subtotal: 65.1 35.2 248 461.3 408.4

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