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

Muhammad Sadiq Malkani

Paleontology and Stratigraphy Branch, Geological Survey of Pakistan, Sariab Road, Quetta, Pakistan
E. mail, malkanims@yahoo.com Ph. No.92-0819211395

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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, chromite, 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.

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 corridor or Antarctica) before Late Jurassic or Early Cretaceous, and early seed radiation and common heredity show relatively high degree of similarity between Late Cretaceous fauna of Indo-Pakistan, Madagascar and South America, otherwise titanosaurian show cosmopolitan. Here most of known informations and newly field data collected by author on stratigraphy, mineral potential, 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 Pukhtun 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,2009f,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 (2010f) 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 reports 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 Siahan 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 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 **(Fig.1).** The methods applied here are many discipline of purely geological description.

2. MATERIAL AND METHODS

Stratigraphy of following different areas under the Balochistan province is being described here.

Updated Stratigraphy of Balochistan Basin, Pakistan

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

Chagai-Raskoh magmatic arc

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

Sinjrani Volcanic group: It consists of agglomerate, volcanic conglomerate, tuff and lava with subordinate shale, sandstone and limestone. It includes Basaltic-andesitic lava flows and volcaniclastics, 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 Pleistocene 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 Sinjrani volcanic group) is named for the village of Kuchaki (34 G/8) about 63 km southwest of Ahmad Wal (HSC, 1961). It consists of volcanic agglomerate, lava, tuff, with subordinate inpersistent limestone, tuffaceous shale and sandstone near the top of the assemblage. **Bunap complex** includes the obducted ophiolite mélange which includes gabbro, diorite and

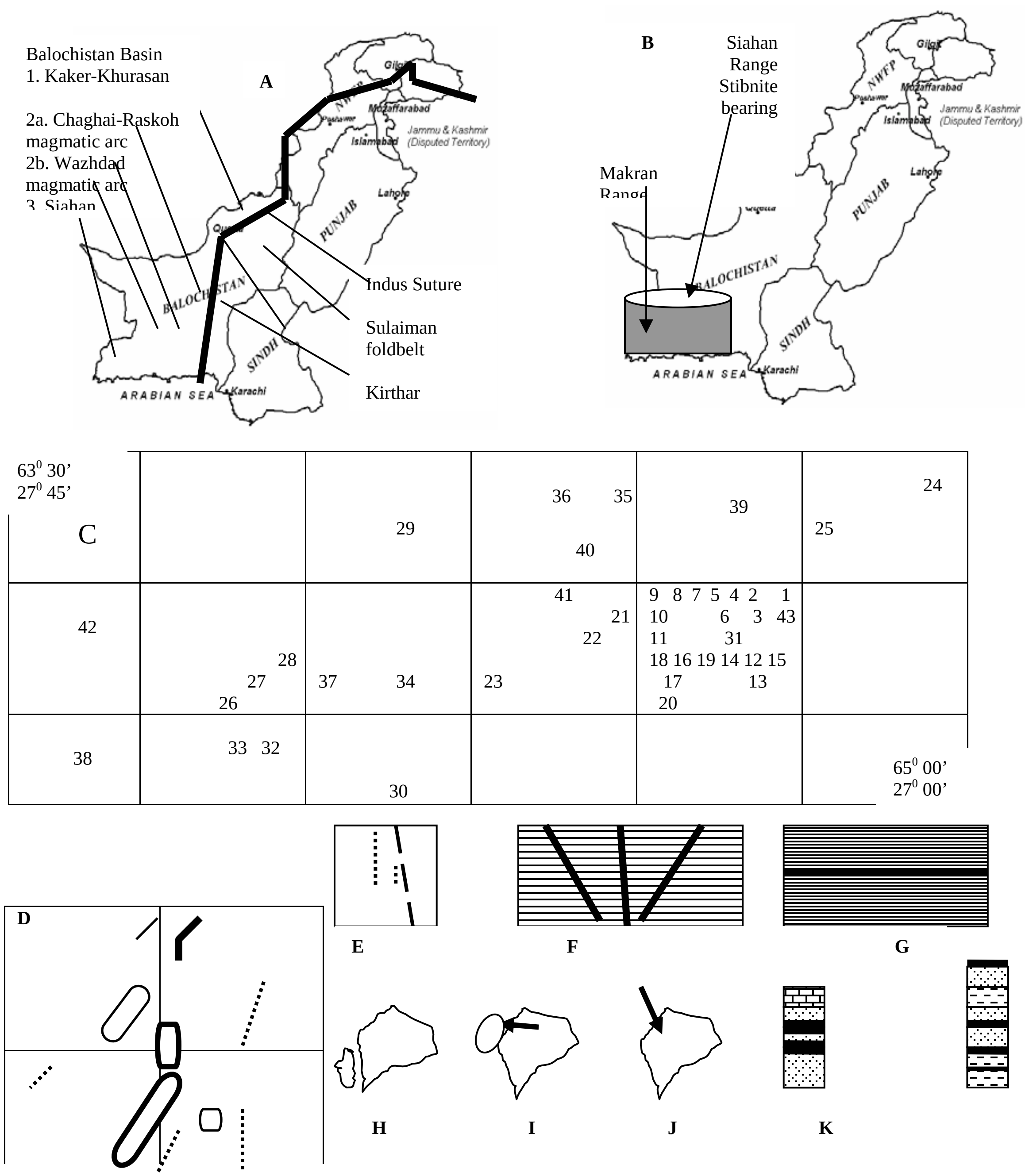

Fig. 1. (a) major parts of Balochistan Province are shown in the southwestern part of Pakistan; (b) the black grey rectangles represent the Makran Range of Balochistan basin, while white oval in the north represent Siahan Range which is the host of antimony mineral; (c) major mineral localities in Makran (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-Musa Kaur, 12-Kuchaki North, 13-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 Raidgi, 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 chromite) localities 39-Toe Koh, Washuk ophiolite-igneous rocks localities 40-Mazargati, 41-Johl, 42-Tank Zurati. Petroliferous and sulphurous 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-quarz-carbonate veins*;* (g) Jauder Thrust fault which are the host of stibnite-quartz-carbonate veins. Upper is the thrusted 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 lihtostratigraphic 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, normal diorite and biotite granite. Micropegmatitic quartz diorite is reported from Koh Naro. It is large batholiths that are invaded by Sinjrani volcanic group. The age is 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 in the middle and thick bedded to massive limestone at the top. The formation show great variation in lithology. The formation overlies unconformably the Chagai intrusion/Sinjrani volcanic group along the southern margin of the Chagai hills but in other areas has also a disconformable contact through the presence of basal conglomerate. The age is Late Cretaceous (Campanion-Maastrichtian) (HSC,1961).

Rakhshani formation: The name is derived from the tribal belt of Rakhshani at the eastern end of Dalbandin valley (HSC, 1961). It also includes the Juzzak formation, lower half of Gidar Dhor group and basal part of Pishi group of HSC (1961). It consists of intercalations of sandstone, shale, mudstone and limestone representing a turbidite sequence, and andesitic lava flows and volcaniclastics. Its age is Late Cretaceous to Paleocene

Nisai/Kharan/Robat limestone: It is medium to thick bedded foraminiferal and argillaceous limestone. Tanki sills consisting of mainly pyroxene diorite are located in the Robat limestone. It is Early Eocene. Kharan 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 syncline) which has been designated as the type locality (HSC, 1961). Its synonyms are Washap formation at Gwalishtap near the Pakistan-Iran boarder and the Amalaf formation. It consists of shale, siltstone, sandstone, marl and limestone with andesitic lava flows and volcaniclastics in the lower part. It is Middle to Late Eocene.

Shorkoh intrusions: Most of the intrusions are dykes or sills but a few small lenticular stocks have been found in the region of Robat and Saindak. These are hypabyssal and intermediate composition. The rocks are mainly diorite. The age is Late Eocene or later (HSC, 1961).

Pishi group/Dalbandin formation: It is named after the Pishi Rud lies in the Ras Koh Range south of Dalbandin. These rocks are found in between Gaukoh Hamun (30P/15) and Bunap (34H/5). The rocks of the group are thought to be also present in the Dalbandin synclinorium named as Dalbandin assemblage (HSC, 1961). It consists of shale, mudstone, soft sandstone and conglomerate. The clay is white, green, ochre and brown. A small amount of limestone in the lower part of assemblage contains Paleocene fossils. The Pishi and Dalbandin group are similar to Urak and Multana formations. The succession of sandstone and shale is similar to Nauroz formation but the limestone resembles the Kharan Limestone. The sandstone of the Pishi area is more gritty and thick than Dalbandin and Makran flysch indicating close to source and further does not show twofold subdivision like Murgha Faqirzai and Shaigalu in the north (Kaker-Khurasan), and Hoshab and Panjgur in the south (Makran). It is Early Miocene to middle Pliocene.

Buze Mashi Koh volcanic group consists of intercalations of andesitic-basaltic lava flows and volcaniclastics. It is Middle Miocene. **Koh-i-Sultan volcanic group** shows intercalations of dacitic-andesitic lava flows and volcaniclastics. It is Late Pliocene to Pleistocene. **Kamerod formation** is derived from Kamerod on the north margin of the Siahan range (31M/10). The lithology and description is same as Kech 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, Siahan shale, Wazhdad Volcaniclastic group, Zurati Formation, Washuk ophiolitic mélange, Hoshab shale, Panjgur and Kamerod formations. The detail is provided in the Makran and Siahan ranges.

Kakar-Khurasan (Back Arc) Basin

Kakar-Khurasan basin shows the Eocene Nisai formation and Khojak group consisting of Oligocene-Pliocene Murgha Faqirzai and Shaigalu formations and Pleistocene Bostan formation. 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 but the Cheema et al. 1977 redefined as Nisai formation for Nisai group, Nimargh limestone, Wad limestone, Wakabi limestone, Wakai limestone, Khude limestone, Kasria group, and upper parts of Jakker and Jhamburo 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 conglomerate. HSC (1961) subdivided in two units like thin (few lithologies) and thick (more diverse lithology) assemblages. The thick sequence is further subdivided in to three parts like lower dark limestone and pale grey shale, the middle largely shale with some limestone, marl and sandstone, the upper part contain thick member of limestone and sandstone with thin layer of shale and conglomerate. Thick assemblages are only found in the northern Balochistan Basin. The thin assemblages have a few exposures in northern and southern 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 comprises shale with minor sandstone and shelly 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 source of this formation is mostly Hinterland and partially Indus Suture. The tentative thickness ranges from 400-1200m. The lower contact with the Nisai formation and upper contact with Shaigalu formation seems to 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, brown and weathers light grey, brown, rusty with patches of black desert varnish on its surface. In the central and eastern part of Kaker Khurasan range the sandstone is more coarsely grained and thick bedded than western part. It shows the source from the Indus Suture, however the western part may have northern and northwestern source. Some sandstone is pebbly, red and maroon. Cross bedded and ripple marks are common. The shale is maroon, red ochre type, grey, greenish grey and calcareous. The red and maroon color is dominant in the Kaker Khurasan area while grey to greenish grey shale color is dominate in the southern Balochistan basin. It is 6000m thick in the northern Balochistan Basin, and 1000-2000m thick in the area between the Khwaja Amran Range and Jangal. This formation shows the continental (Molasse) conditions in the Kaker Khurasan range. Continental vertebrate bones of possibly rhinoceros, 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 iron beds from Kakar-Khurasan basin. The cranial and postcranial parts of large mammal likely Rhinoceroses, horses, crocodiles, etc are found from the terrestrial/continental Shaigalu sandstone (equalent of marine Panjgur formation in southern Balochistan) in the Shaigalu and

Qamar Din Karez area of Zhob district (toposheet no. 39 A/10,11,15; Verbal communication with Shahid Dhanotr and Latif ; Aziz ur Rahman Unar and Khawar Sohail in 2010). 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 uplift of the area.

Makran-Siahan Basin (Arc-trench gap), Wazhdad arc and Mashkel/Kharan (inter acr) 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 Panjgur formations), Miocene-Pliocene Talar group (Parkini, Talar and Chatti formations), Pliocene-Pleistocene Ormara, Jiwani and Kech formations, and subrecent and recent Makran extrusive muds and surficial and coastal deposits (Table 1).

Ispikan conglomerate: It is named after the village of Ispikan about 12 miles northeast of Mand (31 J/4; HSC, 1961). HSC (1961) mentioned only one exposure as an isolated hill on the north side of Kulbar Kaur, 2 miles northeast of Ispikan. The hill is about ½ mile long and 200-300 feet high and is mostly conglomerated. Its thickness may be few hundred meters only. The second exposure is marked by the present survey at the Dastak area 31 M/12 as a one small jumble mass. Conglomerate consists of pebbles of quartz, granite, andesite, and other igneous rocks. Matrix of conglomerate is chloritic (green). Pebbles are unsorted. Subrounded boulders of conglomerate range from few inches to 3 feet. Ispikan conglomerate shows the unstable depositional conditions created by the orogeny tectonism. Its lower contact with the thin bedded marl assigned to Parh series seems to be unconformable. Its upper contact is not clear but some remnants of Wakai limestone are found at the eastern end of the hill near Ispikan which show contact with Wakai formation. Age of Ispikan conglomerate is Paleocene determined by stratigraphic position between the Cretaceous and Eocene rocks, and some diagnostic fossils (HSC 1961).

Wakai limestone: It is named after Koh-i-Wakai in the valley of Tagrana Kaur (31 J/11; HSC, 1961). It is observed as a small exposure in the western part of Siahan range. Locality names are Dastak and Ali Sing (31 M/12), Growag (31 M/8), Machi Koh (31M/15), Waro and Boi (31M/16), Jaridak (35A/4), Gari Sing Patkin (35A/11, plate 3), Surk Kaur (35A/11), etc. It consists of limestone, marl and shale. Limestone is grey, brownish grey, blue grey, it weathers to brownish grey to grey. It is biosparitic to micritic, recrystallized, thin bedded to thick bedded, and massive locally, medium hard to hard and profusely fossiliferous. Limestone gives fetid small on hammering. The exposure of limestone is lenticular and bouldery type. Marl is maroon, laminated to thin bedded and medium hard, shale is maroon, bluish green, khaki, laminated to fissile, flaky, soft and calcareous to non calcareous. The lower contact of Wakai limestone is not exposed but seems to be with Ispikan conglomerate and the upper contact with the Siahan shale is abrupt and conformable. The fossils containing coelenterate, algae, nummulite, assilina, alveolina, and other smaller foraminifers are observed. The fossils are observed as conspicuous weathering color. The age of formation is Early Eocene to Middle Eocene (HSC, 1961). The formation is important for petroleum prospecting and source, if it has large subsurface extension.

Siahan group: It is named by the present author. It represents Siahan shale, Wazhdad volcaniclastic, Zurati and Washuk formations.

Siahan Formation: The name is after the Siahan Ranges (31 M/8; HSC, 1961). It comprises shale, slates, with siltstone and sandstone. It is light green, grey, brown and khaki, laminated, fissile, platy, flaky, and slightly calcareous to almost noncalcareous. It weathers grey, greenish to dark grey, brownish to reddish brown. The shale is medium hard to hard, it forms sharp ridges and saw teeth like weathering at the surface. Slates are grey to dark grey, black and weather in to grey to brown and light shining color. It is laminated to thin bedded, platy, hard, and noncalcareous to slightly calcareous. Shale metamorphosed to slates due to dynamic tectonic movements. It gives shining luster on sunlight reflection on slaty cleavage surface. The siltstone is grey to brown, laminated to thin bedded, medium hard and calcareous. It is interlayered in the shale and sandstone. The limestone is grey, grayish brown, thin to medium bedded, lenticular, medium hard to hard. It is mostly lense shape, observed in the shale, in some places it is shelly, and fossiliferous. The sandstone is greenish grey, grey, thin to thick bedded and massive locally, fine to medium grained, medium hard to hard and lenticular sandstone sills and dykes are rare in the Siahan shale. In some places the exposed undersurface has groove marks and upper surface has ripple marks. The possible paleocurrent direction seems to be North West to south east. It is very difficult to measure the thickness of Siahan Formation due to intense faultings (imbrications and strike slip faults) and foldings. However tentative thickness ranges from 1000 to 1500m in Siahan Range. The lower contact with Wakai limestone and the upper contact with the Zurati formation and Wazhdad volcaniclastic group are conformable. 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 Siahan 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 Siahan shale. Hafeez et al 1992 separated the Siahan shale and Panjgur 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 sills and dykes in shale are observed. It is fine to medium grained, hard, calcareous, and fractured due to 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 northwest to southeast. The shale is light green to grey, khaki, brown, and rarely maroon. It is laminated to fissile, platy, flaky, medium hard to 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 Wazhdad volcaniclastic formation and upper contact with the Hoshab shale is gradational and confirmable. 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 thrusted plane 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 quadrangle 31 M/11 areas. The observed rocks are granite, peridotite, bronze dunite, asbestos, (serpentine), soapstone (talc), and chromite. Its exposures are small, however in the southern vicinity, there is a wide alluvium cover 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.

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 comprises shale with minor siltstone and sandstone. The shale is grey, light grey to brown grey, laminated, splintery, 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, weathers in to black desert varnish color, thin bedded, and medium hard and calcareous. Ripple marks are observed on the sandstone of this formation, at some places the sandstone is grimy. This formation has no megafossils. 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 tentative thickness ranges from 1000 to 1500m in Siahan Range and 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 Siahan formation. According to stratigraphic position, its age is supposed to be Early Oligocene.

Panjgur formation: The name is after the Panjgur town (35 B/1; HSC, 1961). Panjgur formation is correlated with the Binga formation in the western vicinity of Panjgur, Shaigalu sandstone of Pishin-Zhob basin, Nauroz and Pishi group of Ras Koh Range. It consists of alternated sandstone and shale. Sandstone is light green to light grey to grey, fine to medium grained, thin to thick bedded, hard and calcareous. Black desert varnish weathering is common. Sedimentary structures such as groove and ripple marks are observed. Shale is light grey to grey, light green, brown and khaki. It is fissile, laminated, flaky, and splintery, soft to medium hard, slightly calcareous to noncalcareous. 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 hard and calcareous. Conglomerate consisting of pebble, cobble 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.

Talar group: It represents marine Parkani mudstone, Talar sandstone and Chatti mudstone. Talar group is named by present author due to well exposures of these formation and their contacts. The Hinglaj series of Vredenburg is considered here in this group. Talar group is well exposed in the South Makran.

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 Vredenburg (1909c, p.202, plate 10), and as "Lower mudstone stage" by Khan (1951). 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 Panjgur formation is abrupt and gradational and upper contact with the Talar formation is transitional. Large fossils are rare while Miocene microforms 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 Hinglaj 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 hard. 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 Gohrag-i-Daf (HSC, 1961; Map 4; 31K/2). Its lower contact with Parkini and Chatti formations is transitional but at places sharp. The fossils like gastropods (Mollusks) and lamellibranches are common. The microforms are Miocene age diagnostic (HSC 1961). The age of the formation is Late Miocene to Early Pliocene.

Chatti formation: It is after the locality of Chatti (31 K/3) about 17 miles north west of Gawader (HSC, 1961). These rocks were also included in the "Upper Mudstone" of Khan (1951). It is a part of Makran series paleontologically defined by Vredenburg (1909; p. 299-300). It consists of mostly mudstone which is interbedded with 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 unconformable. The fossils reported are lamellibrances, 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 Makran and Siahan ranges mostly in and around the valleys. It 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 colour, calcareous, soft, and friable with rare cross beddings. Gritty sandstone is grey, thin to thick bedded, soft to medium hard, calcareous and observed in the upper part of this formation. Mudstone facies is mottled dominantly creamy white, thick bedded, soft to medium hard, sticky and calcareous, tabular weathering is common on type locality section of Kamerod formation, and isolated hills are weathered into silt and clays representing clay balls earthy shape. Conglomerate is dark grey, extraformational, polymicritic and grain supported, dominant constituents of conglomerate are pebble with minor cobble. Dominant constituents are sandstone, shale, quartz, limestone with very rarely igneous rocks. Matrix is sandy and calcareous. It is mostly observed in the upper part of Kamerod formation. It is rarely cross bedded. Mudstone have low resistant on denudation but the conglomerate have high resistance grade than other members of this formation. It mostly forms cap shape on sandstone and mudstone of this formation. Components of this conglomerate are derived from the older formations. Conglomerate facies of this formation have three diagnostic properties from the other Quaternary gravel deposits (Qtg). First colour property like Kamerod formation have dark grey aggregate colour but the Qtg have light grey to greenish grey, and grey colours. Secondly Kamerod conglomerate have same dip as sandstone and mudstone of this formation while Qtg have angular contact. Thirdly Kamerod conglomerate is mostly grain supported and rarely matrix supported while Qtg is mostly matrix supported. The estimated thickness of this formation is 600m but may increase upto 1500m (HSC, 1961). The lower contact with Panjgur, Hoshab and Zurati formations or older formations is angular. It also has upper angular 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 "littoral concrete" (Blanford, 1872a, p.45), but has not been previously mapped (HSC, 1961). Rocks of Jiwani formation appear on all principal headlands and peninsulas 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 upto 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 limestone consists of shell fragments in a sandy hard calcareous matrix in 1-5 feet thick bed. The conglomerate contains rounded pebbles and cobbles of sandstone upto 8 inches long. On Ormara headland the pebbles include blue grey alveolina limestone and red jasper. The sandstone is medium to coarse grained, well sorted, cross bedded and has a calcareous cement. It is found only in the South Makran. It is 30m thick in the type area of Jiwani headland (HSC, 1961). The lower contact with Ormara formation is gradational and placed at the base of lower persistent bed of shelly conglomerate, 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 Pishin 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 about 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 serpentinized ultrabasic rocks like Muslim Bagh intrusions. The old muds are deeply gullied and pitted by the sheet flood or cloudburst 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 vents. It involves series of eruption and cone is formed from the drying of muds. The mud extruded from the vents is extremely fluid near its source and becomes more viscous as it flows, due to loss of water. The angle from horizontal is about 10-40^0. The simple cone like those of Chandragup (Map 5; 35G/14) are generally small ranging 10 to 400 feet, while the complex coalesced types of cones like Kandawari in the Haro Range (Map 6; 35K/2) rise above 1400 feet above the general terrain and have yielded tremendous quantities of mud from closely grouped vents. The **ridge** type of mud accumulation seems to have no connection with ventral vents or discrete points of eruption but appear as high, broad hill with steep sides and long and parallel with the regional structures. The angle from horizontal is about 40-70^0. Mud volcanoes associated with these ridges are small and widely spaced and apparently incidental to the mode of extrusion. Two largest mud ridges are over 20 miles long; one is located near the mouth of the Hingol River (Map 5; 35 G/11) and the other is 10 miles west of Bela (Map 11). Mud appear to be young and not folded, forming unconformity with older rocks. Extrusion of mud is closely related to faults which may provide the channel for extrusion. The materials of mud flows in the southern Makran are identical with those of the surrounding bed rocks such as Parkini mudstone and Talar sandstone and clearly derived from them. The derivation is also confirmed by the age assessments of fossils found in the mud of two volcanoes (HSC, 1961). At present small amounts of mud are being extruded but large quantities erupted during Makran earthquake of 1945. The result of this eruption, reported by Sondhi (1947) included the temporary appearance of islands off the coast (Map 4,5). Sondhi (1947) considered the islands to be mud volcanoes. According to some geologists, this eruption is indicator of petroleum. In the case of cone type, the gas is only reasonable source for the raising of fluid mud to vents 1400 feet above the terrain. In the case of ridge type, the steep sided hills and ridges were formed by wholesale upwelling of viscous mud along fault zones and related to tectonic pressure rather than upward movement of gas, although gas possibly contributed to the mobility of muds. The surface Character of temporary islands described by Sondhi as mud volcanoes are more in keeping with wholesale upwelling, fissuring and buckling of the sea floor than they are with cone type fluid eruption. The frozen earth waves on the island in Ormara west bay could only be due to compressive buckling (Sondhi, 1947). A submarine hill or mud shoal in the Gulf of Oman near the Iranian town of Jask was reported as a mud volcano (Stiffe, 1873). Small mud volcanoes which appeared immediately after the Quetta earth quake of 1935 had relatively brief period of activity and seemed to be due to violent readjustments of the ground water circulation in the epicentral region. One of the largest of these mud cones is about 10 miles southwest of Kalat at a point near the hills east of Surab road but it is not shown in map (HSC, 1961; Map 20; 34L/9). Its age is Pleistocene to Recent. Rutile is also present in these volcanoes.

Subrecent and Recent deposits: These are represented by Terrace gravel deposits, Fan gravel deposits, sand, silt and clay deposits (cultivated and noncultivated lands), Hamun deposits like Sand dunes (Seif/longitudinal and Barchann), and present channel deposits.

Depositional environments, geological history and geoevents of Makran-Siahan Basin

Makran-Siahan (arc-trench gap) basin shows structural features like complex (close) folds, imbricate (reverse) faults, strike slip faults, cuesta and hog back topography. General axes of folds and imbricate/reverse faults are E-W and NE-SW. The dips of synclines and anticlines of the Tertiary strata are greater than 50^0 in the north and less than 50^0 in the south. The major anticlines are located in the high area and synclines in the low area. The trends of the strike slip faults are mostly oblique to the bedding. The Pleistocene strata show dips less than 30^o which form open folds in and around the valleys. During Late Cretaceous Indo-Pakistan plate started journey, and connected with Balochistan basin, represented as Indus Suture. Due to northward movements of Indo-Pakistan subcontinent resulted as Chaman-Nal transform fault boundary just close to western belt of Indus Suture. Convergence of Indo-Pakistan plate with Asian plate affected the Arabian plate. In this way Arabian plate convergence and subduction in the Tethy came into existence and resulted in the form of Bazman volcanics in Iran, and Chagai, Raskoh and Wazhdad volcanics in Pakistan termed as Island arc. At present the convergence trench is located in off shore areas. The Kaker-Khurasan (back arc) basin show early flysch condition of Murgha Faqirzai shale and later molasse condition of Shaigalu formation with source in the east from Indus Suture. Makran and Siahan basin are located in the arc-trench gap, which represents accretionary wedge complex. The oldest formation Paleocene Ispikan conglomerate shows unstable marine conditions. The Early-Middle Eocene Wakai limestone show the reef marine condition, and Siahan shale facies show the marine condition, limestone lenses show the calcareous and reef and shallow marine environments for short time, thick sequences of sandstone show the turbidities current marine environments, and slates and quartzite are the post depositional dynamically metamorphosed products of shale and sandstone respectively. In the beginning of Late Eocene, the Wazhdad volcaniclastic group are deposited and it consist of tuff, agglomerate, breccias, tuffaceous sandstone and shale which show the volcaniclastic/pyroclastic marine sedimentary environments. During Late Eocene the sandstone, shale and siltstones sequence of Zurati formation are deposited in marine environment. Slates and quartzite of Zurati formation are dynamically metamorphosed by the convergence of Arabian plate and Iran-Afghan block of Eurasian plate. The Late Eocene or Early Oligocene Washuk ophiolitic rocks are observed in the faulted and thrusted zone of Washuk-Wazhdad-Zurati range (Wazhdad Island arc). Wazhdad Island arc is the third Island arc after Chagai and Raskoh in Pakistan. Washuk ophiolites have also faulted contact with Zurati formation of Late Eocene age and show the unstable obduction condition. During Early Oligocene the Hoshab shale is deposited 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 Siahan ranges have no evidence of deposition which show the uplift by tectonism 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 evaporation 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 fluviatile, eolian seif and barchan sand dunes (wind action), and hamun (lacustrine playa) deposits. Active mud volcanoes are also common due to overburden pressure and temperature in old muddy formations. As a whole five main geoevents of subduction of Arabian plate in Tethy are interpreted. First episode of tectonic activity occurred at the end of Early Eocene which changes the calcareous limy conditions (Wakai limestone) into flysch shale and sandstone conditions (Siahan shale, Zurati formation, Hoshab shale and Panjgur formation). Second episode of unstablity and emergence conditions occurred at the end of Middle Eocene which is deduced from volcanics of Wazhdad volcaniclastic group and obduction of Washuk ophiolite. Third phase of tectonic activity happened at the end of Oligocene, consequently the Siahan and northern Makran were uplifted. This is confirmed by the non deposition during Miocene and Pliocene period in this area. Fourth episode happened at the Early Pleistocene or end of Late Pliocene which is confirmed by the angular unconformity between the older strata (Eocene/Oligocene) and Pleistocene Kech/Kamerod formation. This phase is responsible for the foldings and faultings of older strata. Fifth phase of tectonic orogeny occurred at the end of Pleistocene which is confirmed by the angular unconformity between Kech/Kamerod (Pleistocene) and surficial (Subrecent and Recent) deposits. This phase is responsible for the open folding of Miocene-Pleistocene strata and intense (complex) foldings, and imbricate and strike slip faultings of Oligocene, Eocene and older strata. In some places the Subrecent and Recent surficial deposits show the fault alignment in aerial photographs and give some dip and other features show the rising and continuous movement of convergence plates.

Sedimentary structures and paleocurrent direction in Eocene-Oligocene of Makran basin

In the Eocene-Oligocene strata, the undersurface sedimentary structure commonly observed are groove marks, and load casts, and rarely observed are flute casts, upper surface sedimentary structures are ripple beddings. A general paleocurrent direction of Eocene-Oligocene strata of northwestern part of Makran basin was northwest to southeast, deduced from the vector sedimentary structures such as flute casts, and scalar sedimentary structures such as 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 Indus Suture (Axial Belt), Pakistan

The Indus Suture represents here the abducted ophiolitic complex with flysch deposition in the west represented by Balochistan basin, and mostly marine carbonate facies in the east represented by Sulaiman and Kirthar basins. Indus Suture complexes in the studied area are Bela volcanic group, Wad ophiolite complex, Muslimbagh ophiolite complex and Zhob ophiolite complex. These complexes include the ophiolitic mélanges and sedimentary Mesozoic and Cenozoic sedimentary sequences.

Bela volcanic group: It is 190km long and 20km wide, extending from Ornach in the north to Windar in the south. Volcanic rocks are subordinate in the north of Ornach 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. The lava flows are commonly pillowed and spilitic. 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, amygdules of calcite and microlites of feldspar are abundant. Interlayered sediments are shale, marl, 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).

Bela 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 compositions are diorite and gabbro. The gabbro is dark green rock spotted with large crystals of white feldspar which is kaolinized. Some types are pegmatitic and exhibit crystals upto 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.

Iridescent soapstone has been reported from Nal area.

Muslimbagh ophiolite complex: It consists of mainly serpentinized ultrabasic rocks that include saxonite, dunite and pyroxenite. It also consists of dolerite, gabbro, and diorite but these seem slightly later phase. The age is Late Cretaceous-Early Paleocene (Ahmed and Abbas, 79; HSC, 1961).

Geological formations associated with igneous rocks: The geological formations (Permian-Mesozoic) associated with igneous rocks are widely (10km) exposed in the Indus Suture zone as pericratonic shelf carbonates, neritic shales and volcanics occasionally intruded by magmatic 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 mélange, Zhob ophiolite, Zhob mélange, Bagh complex, Waziristan ophiolite mélange, Twin sister soda dolerite and Pir Umar basalts, and Triassic Khanozai group (Gwal and Wulgai formations, Jurassic Shirinab, Cretaceous Parh group (Sembar, Goru and Parh formations), Fort Munro group (Mughalkot or Bibai formation), and Paleocene Thar formation, Bad Kachu formation and Gidar Dhor group.

Updated Stratigraphy of Sulaiman Basin, Pakistan

Sulaiman basin shows the different updated lithological units in ascending order are; Triassic Khanozai group represents Gawal (shale, thin bedded limestone) and Wulgai (shale with medium bedded limestone)(Anwar, et al., 1993), Jurassic Sulaiman group represents Spingwar (shale, marl and limestone), Loralai (limestone with minor shale), and Chiltan (limestone) formations, Cretaceous Parh Group represents Sembar (shale), Goru (shale and marl), and Parh (limestone) formations, and Fort Munro group represents Mughal Kot (shale/mudstone, sandstone, marl and limestone), Fort Munro (limestone), Pab (sandstone with subordinate shale) and Vitakri formations. The Vitakri Formation (Malkani, 2009c) consists of two red muds horizons (which are the host of dinosaurs and fresh water crocodiles), each red mud horizon is followed by a 2-15m sandstone and each mud horizon is also 2-15m thick. The Vitakri Formation is aged as latest Cretaceous (70-65Ma). The Paleocene Sangiali group represents Sangiali (limestone, glauconitic sandstone and shale), Rakhi Gaj (Girdu member, glauconitic and hematitic sandstone; Bawata member, alternation of shale and sandstone), and Dungan (limestone and shale) formations; Eocene Chamalang (Ghazij) 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 and shale) formations, and Kahan 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, coal and volcanics) and Lakhra (limestone and shale) formations; Eocene Laki group represents Sohnari (lateritic clay and shale, yellow arenaceous limestone pockets, ochre and lignite seams) and Laki (shale, limestone, sandstone, lateritic clay and coal), Kirthar 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) group/ 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). The igneous rocks like Deccan trap basalts are found in the Early Paleocene Khadro formation in the Kirthar basin exposed in the Kirthar foldbelt and also encountered in the subsurface drill hole in the Kirthar monocline. The remains of body fossils from the Late Jurassic Sembar Formation of Kirthar basin represent *Brohisaurus kirthari* (Malkani, 2003c), possibly a titanosaurian sauropod.

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, 98t gneiss, 323t quartzite, 360t sulphur, 176t dolomite, 424t fluorite, 75t galena, 15,808t iron ore, 727,951t limestone, 70,740t marble (onyx), 267,312t 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, 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. 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 belts of Pakistan. Many important minerals including porphyry (Cu-Mo-Au), manto and vein type copper, stratiform and skarn type iron, volcanogenic gold-silver and sulphur, Kuroko type lead-zinc-silver-copper are intimately associated with the magmatic rocks of this arc (Siddiqui, 1996). The tholiitic 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 (29^0 33'N; 64^0 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 Sinjrani volcanic group. The host rock tonalite porphyry is centered by potassium silicate alteration and followed outwardly by quartz sericite and porphylitic 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 western stock. Average copper values in quartz sericite zone vary 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 rhyolite intrusives in which chalcocite is the main copper mineral and the other in volcanic breccia associated with gypsum, 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 (29^0 18'N; 61^0 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 siltstone, sandstone, and tuff of Amalaf 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 lean, patchy copper oxides zone with 0.4-0.5% copper is developed over the ore body. In this area 37 bore holes have established indicating reserves of 264mt averaging 0.388% copper at cut off grade 0.3%. The total reserves at Saindak comprised 412mt of ore containing average 0.38% copper and 0.3228gm/to of gold. At Saindak an open cast mine with infrastructure, crushing plant, concentrators and smelter has been developed and trial production of blister 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 550mt (Razique 2001) of averaging 0.4 to 0.6% copper and 0.2 to 0.5gm/ton of gold. According to BHP besides Rekodiq, Buzzi Mashi and western Ware Chah, other localities such as Parrah Koh, Borghar Koh, Koh Dalil, Koh Sultan 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 chalcocite blanket and hypogene zone. In this zone reserves of 70mt of ore with 0.85% copper are indicated. Chagai areas like Talaruk, Saindak, Rekodiq, Max. G. White, Koh-e-Dalil (Sam Koh), Mashki Chah, Darband Chah, Amuri, Yakmach, Kangord, Galtori, Omi, Ziarat Pir Sultan, Kabul Koh, Missi, Humai, Dasht Kain, Koh-i-Marani, Pakus nala, Nok Chah, Dalbandin, Amir Chah, Ziarat Malik Karkam, Bazgawanan, Kundi Balochap, Bandegan, Robat, Buzzi Mashi, Western War Chah porphyries, Parrah Koh, Bor Ghar Koh, Malaik Koh, Ting Daragun, Machi and Kirtaka (White, undated; HSC, 1961; Kazmi and Abbas, 2001) seem to be significant.

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, Mashki Chah, Durban Chah, Amir Chah, Chilghazi, Gorband, Kasanen Chapar, Kundi Balochap, Pachin Koh, Chigendik, Bandegan and Nok Chah areas (Ahmed, 1969). **Pachin Koh-Chigendik iron deposits** are located 88km and Chigendik 40 km NW of Nokundi town. It is comprised of magnetite and hematite. It is volcanogenic and occurs as intercalations with andesites of Sinjrani volcanics. The ore contains $Fe_2\ O_3$ 767-82%, SiO_2 9-22%, Al_2O_3 1.4-4.4% and CaO 1.2-2.2% (Asrarullah 1978; Kazmi and Abbas, 1991). There are 27 small magnetite-hematite bodies at this area. At Pachin Koh 62 holes, where as 29 holes in Chigendik drilled. The estimated ore reserves of Pachin Koh is 45mt and of Chigendik is 5mt of which 30mt are proved. The geological and geophysical investigations show that the deposit may be increased upto 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. **Chilghazi 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 sis found 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 magnetite 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 upto 7%), and phosphorous upto 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 proven and 0.90 probable). The low grade reserves with 25-30% iron are estimated 20mt (Schmitz 1968).

Tungsten: The tungsten ore has been recorded by Siddiqui et al. (1986) from Amalaf (29^0 18'N; 61^0 37'E) in Chagai district. The ore is found in pyroclastic rocks of Saindak formation intruded by quartz porphyry. The ore minerals are sheelite and tungstite associated with molybdenum and tin minerals. The mineralization is attributed to xenothermal alterations in the host rock.

Sulphur: Sulphur deposit is located in the Koh-i-Sultan volcano. Massive layers and lenses are interbedded with the Pleistocene volcanic ash. The ore contains 50% sulphur and reserves of 738,000 tons (Muslim, 1973b). Potential source of sulphur are Kohi-Dimak dome, desulphurization plants in the coalfields, sour gas (gas containing hydrogen sulphide in Natural gas, anhydrite and gypsum.

Marble: The marble (Ahmad W., 1965), various types of limestones and igneous rocks, mainly granite are found from Chagai area can be used for buildings, construction and Decorative stones

Others: Lead-zinc (Ahmed,1943) is reported from Saindak, Koh Marani, Dirang Kalat, Makki Chah (4km SE of Talaruk) and Ziarat Balanosh (100kn NE of Dalbandin). Manganese from Nushki (9km north of town), Barite from Chagai area (Koh Sultan), Barite from Chagai area (Koh Sultan), tourmaline from many sites Chagai area, Zinc from Makki Chah area is reported (Kazmi and Abbas, 2001).

3 RESULTS AND DISCUSSION

Mineral Potential of Raskoh magmatic arc

The Raskoh arc includes many minerals like Chromite, vermiculite, 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 Nag-Bunap and Rayo Nai valley within a distance of 3km, located 30km NW of Kharan 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.

Vermiculite: 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. Vermiculite deposits are reported from Doki River on the northern edge of the western Raskoh. It occurs in cliff 160m long, 140m wide and 40m high with reserves of 11 mt (Grundstoff-technik, 1993). The vermiculite contents vary from 5-20%. Exfoliation tests at 775^0 C resulted in tenfold increase in the particle size (Hussain, 1970). The average analyses includes 42% SiO_2, 13.16% $Fe_2\,O_3$, 119.05 % $Al_2\,O_3$, 1.38% TiO_2 and 10.75% $H_2\,O$ and 10.30% MgO (Bakr, 1965b).

Others: Manganese is reported from Sotkinoh hill (Ras Koh) (Kazmi and Abbas, 2001). The small deposit of gypsum (3.3m thick) is reported from the red shale of Eocene Gwalishtap 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, ochre, saline springs, and mud flows with methane-nitrogen gas are found. **Antimony** deposit like **t**he stibnite veins are hosted in Khojak group of Qila Abdullah which is 24 km NE of Qila Abdullah town, and smaller deposits in the Qila Viala area 40 km east of Qila Abdullah (LeMessurier, 1844; HSC, 1961; Klinger et al, undated; Ahmad, 1969; 1975). **Ocher** deposits are found in the Shaigalu sandstone of Kaker Khurasan area. Many **Saline springs** are found in the Qila Saifullah 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 Saif Ullah district (39 B/5,9; verbal communication Zahid Hussain).

Mineral Potential of Makran and Siahan ranges (and Wazhdad magmatic arc) of southern Balochistan Basin.

Malkani (2004c,f) reported first time some new findings of Makran and Siahan 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 M/8) show the homogenizing temperature upto 333^0 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 shale into slates and intense faulting and folding in Siahan range and north Makran. According to Shcheglov (1969), the antimony mineralization of Makran range is of epithermal origin. According to Sillitoe (1975), the circulation of connate fluids in the flysch succession during dynamo thermal metamorphism related directly to the faulting is proposed as an origin for the antimony deposits. Stibnite (antimony trisulphide, Sb_2S_3) is coated by yellowish 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 is calcite ($CaCO_3$). Quartz is 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 Siahan, 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 Siahan 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 found by Younas et al. (1995), Hussain, et al. (1995), Hafeez 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 35^0 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 (incline of 35 degree south) pits are observed. Quarry pits are less than 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. **Gokumb locality** (35 A/11: Fig.1c) is located at the southern slope of Koh Sabz and accessible from Basima, Nag and Panjgur. Antimony vein (18cm thick) is discontinuous lense shape. Host rock is Siahan 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 Siahan shale is observed in the strike slip fault trending northwest. In the southern and eastern vicinity the other Sb veins and stringers are also reported. **Siminj locality** (Fig.1c: 35A/4: Younas, et al. 1995) is accessible from Panjgur, Washuk and Palantak towns. The antimony vein is 10-12 cm thick and 30 meters long and occurred as lense and discontinuous nature. **Mir Baig Raidgi locality** (35M/15: Fig.1c) is accessible from Panjgur, Washuk and Palantak towns. This vein is reported in the strike slip fault on the northern slope of Koh Sabz ridge continuation. It is 10km from the Bibi Jan Ziarat (Langar). Siahan shale is the host rock. **Safed Gilanchi locality** (35M/15: Fig.1c) is accessible from Washuk and Panjgur in fair weather season. Exposures of antimony, gold, quartz carbonate vein and associated mineralization in the strike slip fault are exposed at south from Bibi Jan Ziarat village. It is found on the northern slope of Koh Sabz ridge continuation. Its accessibility is slightly easy. There is no major rise and fall. It is situated in the base of ridge continuation. Host rock is Siahan shale. **Machi Koh locality** (35M/15: Fig.1c) is accessible from Panjgur 85km toward north in fair weather. Machi Koh antimony, gold, silver and quartz carbonate vein and associated mineralization have reported on the northern slope of Koh Sabz range. It is located on the north of Machi Koh. It is observed in the south eastern top of Kunarain Kaur. It is 10km from Thal Waro area and approachable from Machi Kaur. The accessibility is difficult and have two hour foot walk with high water fall (upto 20 meters). The host rock is Siahan shale. **Palantak Koh locality** (35A/2: Fig.1e) is 1km on northwest from Palantak town. The antimony, gold, silver and quartz carbonate and iron oxide vein and associated mineralization have been found on the western part of Palantak Koh. Host rocks are Siahan and Panjgur formations. **Lidi locality** (35A/14: Fig.1c: Iqbal and Khan, 1995) is 10km east of Washuk town. The Sb-Au mineralization is also associated with discontinuous quartz carbonate vein. **Saghar locality** (35A/4; Fig.1e: Younas et al. 1995) is 20km toward north from Panjgur town. It is situated on the southern slope of Rakhshani range. Antimony is disseminated in the quartz carbonate vein. The vein is in discontinuous nature. **Miani locality** (35A/13; Fig.1e: Iqbal and Khan 1995) is 20km toward south west from Washuk town. It is found on the northern slope of mountain range. Au-Sb is associated with discontinuous lenticular quartz carbonate vein. **Other localities** of stibnite associated with gold and silver hosted by quartz carbonate veins in toposheet 35A/11 (Malkani and Rana 1995) are South Surmagi Patkin, North Surmagi Patkin, Haspi Patkin, Kulo Patkin, Hurain Patkin, Siagari, Kuchaki south, Ahmadab Kaur, Sor Jor Jauder, Mahmoodi Kaur, Kasig Kaur, Musa Kaur, Panir body east, Nagindap Damagi, Hashani Damagi, Hashani and Panir Body west.

Mercury 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,Ni,Co,Cu,Mn,Cd and Au. Mercury, silver, iron oxide, and other associated mineralization occur in the form of network of calcite veins, stringes 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 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, Sor Jor Jauder, and Hashani (35 A/11), Ahurag (31 M/12), Mazan Dastak (31 M/12), Palantak Koh (35 A/2), Sorgari and Siahgari (31 M/16), Sabz Village (35 A/12), 8km SW of Panjgur (35 B/1), Mazarap Malhan, Kurki, Saghar, Soro and Phud Kush (35 A/3,4,7,8), Baskroach (31 M/11), Hingol and many other areas. All of these areas have greater than 1km length and more than 200 meters thickness. Host rock of these iron oxidized zone are Siahan shale, Hoshab shale, Zurati formation, and Panjgur formation. All these iron oxidized zones have network of quartz carbonate veins and stringes, carbonate veins and veinlets. Malkani (2004c) has reported possible meteorite first time in Pakistan, represented by one iron ore body just like a big boulder with one or two minor boulders which are observed in the Soro and Phudkush area (Fig.1c) have no relation to host rocks and seems to be meteorites. It is a hematite with green weathered colour.

Quartz carbonate veins: Many quartz carbonate veins are observed in the iron oxidized zone. Au(gold)-Sb(antimony) mineralization are associated with quartz carbonate veins. Hg(mercury)-Ag(silver) of eastern Waro area (Fig.1c) is also associated with quartz carbonate veins network. Some quartz carbonate localities are Sor Jor Jauder, Hashani, Musa Kaur and Kasig Kaur, (35 A/11), Haibatan Koh (35 M/16), Siagari Shand long and thick quartz vein (35 A/11), Safed Gilanchi, Mir Baig Raidgi, Machi Koh and Dauda Top (35 M/15), Baskroach Koh and Tank Zurati (31 M/11) Ahurag, Mazan Dastak, Sarkini, Mustaki, Nalingar, and Darag Parag (31 M/12), Grawag (31 M/8), Palantak Koh and Baran Koh (35 A/2), Miani and Lidi (35

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 Siahan and Makran also have many quartz carbonate veins. **Siagari Shand quartz vein** (35A/11: Fig.1c) is located on the southern slope of the range. Its accessibility is difficult and can be made from Panjgur, Nag and Basima. Quartz vein is found in the imbricate fault trended east west. Quartz vein thickness is 2 meters with discontinuous length of more than 500 meters. Quartz is crystalline to cryptocrystalline. Elongated hexagonal quartz crystal upto 1cm are observed. The host rock is Siahan shale. Gold upto 0.458 ppm is recorded. **Eastern Waro locality** (35M/16: Fig.1c) is 6 km east from the western Waro locality. It consists of network of quartz vein and stringers and also have major ferruginous quartz carbonate vein trending northwest to southeast. On the west of this main vein the network of quartz veining are observed. Quartz of main vein is cryptocrystalline. Network of veining have subhedral quartz, however at the ending phase quartz are well developed which represent the late stage crystallization.

Pyrite mineralization: These mineralization are observed in the Durgi Kaur, Surap Kaur, and Wazhdad 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 found 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. **Wazhdad Kaur locality** (35A/6: Fig.1c) is 20 km far toward east from Palantak village and 70 km toward west from Washuk. Wazhdad Kaur pyrite/chalcopyrite mineralization is observed in the sandstone, shale, tuffaceous sandstone and shale of Zurati formation. It is found as nodules and flacks. **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 quartz 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 cm 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.

Ophiolitic rocks associated minerals: The ophiolitic and volcaniclastic rocks in the Wazhdad area and its vicinity show minor chromite, copper, soapstone and asbestos mineralizations (Malkani 2004c,f).

Sulphur: The **Jiwani** sulphur deposit (25^0 05'N; 71^0 47'E) are 20km NW of Jiwani and can be reached by boat from Jiwani but during the monsoon the best route is overland via Kuldan (Nagell, 1965). The sulphur deposit is nine inches thick discontinuous layer in dark grey clay near mud volcano. It is found within a few feet near the surface and some crystals are found in the overlying alluvial sand, cemented by gypsum, limonite and sulphur. The sulphur ranges from 43-56%. According to Ahmed (1962) the deposit is small. The **Ganz** sulphur deposit, about 1km to the west of town Ganz which is a small fishing village about 15km east of Jiwani, another similar deposit like Jiwani and also negligible deposit (Ahmed, 1969). The **Pimpishka** sulphur deposit (26^0 45'N; 63^0 43'E) is on the north side of salt playa at about 50km to the SW of Panjgur (Nagell, 1969). The deposit is near the road about 5km to the SW of small peak named Pimpishka. Oligocene sandstone has been intensely leached in an area of about 50 square feet, leaving quartz grains in a matrix of sulphur and gypsum. The sulphur ore contains less than 20% sulphur which fills fractures in the rocks near the spring. Origin is similar to Sanni sulphur. The **Karghari** sulphur deposit (25^0 27'N; 64^0 09'E) is near Golkurt on the Makran coast. Further sulphur deposit was also reported near **Khan Berar at** the southern end of Haro range about 5km from the sea coast near the Phor river (Nagell, 1965). Both sulphur and salts are associated with saline springs are found in the rocks of Miocene-Pliocene age (Kazmi and Abbas, 2001).

Bed rock and aggregate resources: The large reserves of bed rock resources like shale, slates, and sandstone, with negligible showings of limestone, the aggregate resources like gravel and sands are observed in the area. The sandstone of Zurati, Panjgur and Shaigalu formations, and limestone of Wakai and Jiwani formations though very rare but are significant for construction materials.

Water resources: Channel (stream) alluvium deposits, Quaternary gravel deposits and Pleistocene Kech/Kamerod/Jiwani formation, sandstone unit of Talar, Panjgur and Zurati formations play a significant role for ground water resources. Main tributaries of the reported area are of Rakhshan river, Mashkeil rud. Bibi Tank, Palantak Tak, Kurki, Mazarap, Greshag Kaur, Regintak, Kech, Hingol, Haro, etc. are ephemeral stream. Some hole are drilled and installed for domestic water supply in the Panjgur town. These holes are drilled on the banks of Rakhshan River. The water is fresh to slightly brackish. Here the water bearing rocks are stream channel, quaternary gravels and Kamerod/Kech conglomerate. In and vicinity of Panjgur town, the kareezes are the main source of cultivation, vegetation, and date farming. Kareezes are digged and pitted in the quaternary fan and terrace gravels and Kech formation. The water quality is slightly brackish to brackish. In the dispersed villages namely Grawag, Palantak, Nok Chah, etc, the artificial pitted wells, tributaries water and springs are source of water for domestic supply. Artificial holes are pitted in the alluvium and water table varies from 5metres to 50 meters. Rains are the main source for cultivations. One drilled (cased) hole are observed in Tank Zurati area (31 M/11) giving low pressure peizometric water (slightly brackish), may be completed by Asian development Bank (known by local inhabitants). Tank Zurati is best place for the construction of small dam on the Mashkel rud for the cultivation. More than 100 gorges are also suitable for smaller dam for water storage for cultivation and population which can play best for the development of the area. In short, these areas can be converted into cultivation and vegetation by efforts. In the Panjgur town the channel gravels give fresh water for domestic supply. The tubewells are observed on the both banks of Rakhshan river. Very low quality and quantity water is also available from the springs in mountainous areas. This low quantity and quality may be due to presence of shale and salts. The Makran is a mostly mountainous area which has some plains and semiplains areas inside where dam construction is necessary.

Others: Petroleum seep is reported near the boarder of Iran near to Grawag area called as Kwash seep (Clapp, 1939). Further two water springs (negligible quantity) coated by petroleum lustrous material was observed in the Gish Kaur Bulleda valley near the village of Koshk 31 n/3 district Turbat and in the Sor Jor Jauder area 35 A/11 district Kharan (Fig.1c). Mud volcanoes of cold muddy water also show anomalous gas like methane upto 74.5% and nitrogen upto 13.8% near Ormara (HSC, 1961). Many salts deposits and lakes are located in the vicinity of Makran coast and Hamun Mashkel area. Alum may also be associated with these salts.

Mineral potential of Indus Suture (Axial belt)

After the Chagai magmatic arc, the Indus Suture shows significant economic commodities.

Chromite: Chromite is first reported by Vredenburg (1901) and its mining was started in 1903 in the Khanozai area and extended to Muslimbagh in 1915 and in early twenties mining started in Sra Salwat area, 29 km south of Muslimbagh. The following deposits like Muslimbagh chromite (Qila Saifullah District) and Wad, Sonaro and Ornach chromite (Khuzdar District) are significant (Asrarullah,1960). **Muslimbagh area chromite (Qila Saifullah District)** extends from Gawal to Nisai a distance of about 100km. This region shows the best and largest deposits in Pakistan. Thrust blocks of various sizes are scattered in the Muslimbagh valley, however large outcrops are exposed near Muslimbagh and Khanozai areas. Two large bodies namely Saplai Tor Ghar and Jang Tor Ghar located south of Muslimbagh town, show a classic sequence of ultramafic tectonites, ultramafic and mafic cumulates, a dyke complex and a dolerite dyke swarm. Chromite occurs in the serpentinized dunites of ultramafic tectonites and cumulates in different forms and shapes. There are massive ore surrounded by banded ore, grape shot ores, banded deposits of disseminated ores, cigar-shaped ore bodies, dyke like ore bodies upto 100m long and thin wiggly, irregularly shaped bodies. The reserve in these types of ore bodies varies from 100-15,000 ton (Bilgrami, 1956,1987; Ahmad and Bilgrami 1987; Rossman and Abbas, 1970). The Muslimbagh chrome ores are aluminous chromite. The chrome of Jang Tor Ghar ore is of metallurgical grade. The Khanozai ore shows Cr_2O_3 49.3-52.6% and Cr:Fe ration 2.7-3.5:1, Jang Tor Ghar ore shows Cr_2O_3 48-57% and Cr:Fe ratio 3-3.7:1, Saplai Tor Ghar ore shows Cr_2O_3 44-52.5% and Cr:Fe ratio 3:1, and Nisai ore shows Cr_2O_3 39-49% and Cr:Fe ratio 2.1-2.6:1. The extension of present pittings shows much more reserves than above mentioned. **Zhob area chromite (Zhob District)** is close to Zhob town in the north. Thrust blocks of various sizes are found in the Zhob area. The Zhob chrome ores are aluminous chromite. Naweoba and Zizha (near Zhob town) is refractory grade while Jang Tor Ghar ore is metallurgical grade. The Naweoba and Zizha ore shows Cr_2O_3 36.7-46.5% and Cr:Fe ratio 2.9:1. Due to relatively less exposures, the deposit seems to be small. **Wad, Sonaro, Ornach chromite (Khuzdar District)** region contains the largest ophiolitic complex in Pakistan covers a long distance of about 320km. The Bela complex is mainly comprised of megamelanges, tectonically wedged in between the thrust sheets of Jurassic and Cretaceous sedimentary rocks (DeJong and Subhani, 1979). The ophiolites include fragments and blocks of peridotite, dunite, minor pyroxene, serpentinite, diabase, gabbro and lava flows. The Sonaro block extend over 116 sq kms and show a complete sequence of ultramafic tectonites at base and ranging upto pillow lavas and sediments at the top. The ophiolite contains lenticular or disseminated bodies of chromite. The main chromite deposits are near Sonaro, Baran Lak, Drakalo and Greshak area of Khuzdar, while Ahsan and Quraishi (1997) identified more than 15 pods. Open pit mining is in progress (Kazmi and Abbas, 2001).

Magnesite: There are several occurrences in the ophiolitic thrust belt showing small deposits or trivial showings. Magnesite from Nasai, Spin Tangi, Shabi Ghundi (Muslim Bagh), Tleri Mid Jan, Sra Salwat (Muslim Bagh), Zhizha, Loya Na Pani, Sinchi Md Khan (Wad) and Baran Lak (Bela) area are reported. The very small deposits like 60,000 tones of Magnesite (MgO 43.38-45.4%) of Spin Kan (30^0 47'N; 68^0 06'E) in serpentinized ultramafic rocks of Bagh ophiolitic thrust, 6,000 tones of magnesite (MgO 38.04-42.36%) deposit of Shabi Ghundi (30^0 48'N; 68^0 00'E) in serpentinized ultramafic rocks of Bagh ophiolitic thrust, very small deposits of magnesite of Tlerai Mohd Jan (30^0 53'N; 67^0 42'E) in serpentinized ultramafic rocks of Zhob ophiolitic thrust, very small deposits of magnesite of Zizha (31^0 3'N; 69^0 37'E) in serpentinized ultramafic rocks of Bagh ophiolitic thrust, very small deposit of magnesite (MgO 32.8%) of Kakru (27^0 43'N; 66^0 09'E) occurs as vein in serpentinized ultramafic rocks of Bela ophiolitic thrust, very small deposit of magnesite (MgO 32.84-44.56%) of Loya Na Pani (27^0 15'N; 66^0 20'E) occurs as vein in serpentinized ultramafic rocks of Bela ophiolitic thrust (Bashir 2008), 20,000 tones of magnesite (MgO 18.08%) of Baran Lak (26^0 59'N; 66^0 18'E) occurs as vein in serpentinized ultramafic rocks of Bela ophiolitic thrust, very small deposit of magnesite of Sinchi Bent (26^0 30'N; 26^0 21'E) occurs as vein in serpentinized ultramafic rocks of Bela ophiolitic thrust, 16,000 tones of magnesite (MgO 46.49%) of Sra Salwat (30^0 40'N; 67^0 53'E) occurs in Eocene dolomite unconformity overlying the Zhob ophiolites, very small deposit of magnesite of Nal (27^0 41'N; 66^0 11'E) occurs as replacement veins in limestone of Shirinab Formation of Bela ophiolitic thrust (Vloten, 1963; Kazmi and Abbas,2001). Bashir (2008) reported 1.23 million tons of magnesite from Khuzdar area, the localities with reserves in tons are Sonoro (582 tons), Godar (656t), Sokand Ghar (862t), Baran Luk south (8905t), Baran Lak (17390t), Baran Lak east (23375t), Baran Lak north (19728t), Chokri Ghor (25712t), Chrome mine (3836t), Pahar K. Bidrang south (3362), Pahar K. Bidrang (25935), Khushal east (2156t), Abui Ka Tang (133500t), Khushal west (9407t), Khushal central (14796t), Ustam Butt west (41454t), Ustam Butt east (43555t), Gangu (816000t), Karku (31970t), Lukh (1267t), Lukh north (2115t) and Bhanbhori Na Kund (840t).

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 deposited by hydrothermal solutions. The barite deposits of Balochistan 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 Shirinab, 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 (Ahsan and Khan, 1994). The Gunga 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 Kundi; Khuzdar area like Gunga, Shekran and Monar Talar have reported.

Platinum group elements (PGE)- Muslimbagh area: Platinum group elements (PGE) have been reported in the chromitites from the Muslimbagh ophiolites of Saplai 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, 303 The three samples from cumulate show ppb values of Os 41,13,6; Ir 35,24,7.7; Ru 100,55,9; Rh 16.8, 11.1, 4.5; Pt <5,<5,18; Pd 4,3,<2; Au 9.1, 7.4,1.3; Total PGE 202,111,47. CI-chondrite value of OS 514, Ir 540, Ru 690, Rh 200, Pt 1020, and Pd 545. Chondrite is a stony meteorite contains chondrule (small rounded bodies of olivine or enstatine) embedded in a fine grained matrix of pyroxene, olivine and nickel-iron (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 (Muslimbagh; Ahmad, 1969) and Wad Khuzdar.

Lead and Zinc: The major lead-zinc and barite deposits are discovered by GSP from the Las Bela-Khuzdar region (Azam et al. 1989; Ahsan 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 Shirinab Formation and are of sedimentary exhalative (Sedex) type. The deposits are found between major faults which have many subsidiary smaller faults. The Duddar deposit has multiphase mineralization and 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 preTertiary. 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; Ahsan 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 (Subhani and Durrazai, 1989; Ahsan and Khan, 1994

Manganese ore: Manganese deposits occur as marine, chemically precipitated sedimentary ores, as secondary enrichement deposits and as hydrothermal deposits. The deposits of manganese ore in Pakistan are associated with volcanic rocks in the ophiolitic thrust belt (Rizvi, 1951). In the Bela ophiolitic thrust belt, lenticular manganese ore bodies occur in ferruginous and siliceous horizons overlying basaltic pillow lavas. The most important localities are Kharari Nai (25^0 54'N; 66^0 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 (26^0 17'N; 66^0 33'E; 35J/11) 950,000 tons irregular veins and lenses ranges from 1-6 inches in thickness (Master 1960) of Mn 36% (Nasim 1996), Sanjro Dhoro (26^0 28'N; 66^0 26'E; 35J/7) 65,000 tons mineralization in discontinuous lenticular bodies having 0.5km strike length and 1-5metres thickness (Ahmad 1969) of Mn 15% (Nasim 1996), Bhampani Dhoro (26^0 11'N; 66^0 33'E; 35J/2) 5,800 tons the ore is square shape in an open pit (HSC, 1960) of Mn 41% (Nasim 1996), Gadani ridge (26^0 05'N; 66^0 34'E; Mn, 48%) and Dadi Dhoro (26^0 05'N; 66^0 37E; Mn, 35%). Most of the production comes from Las Bela region. Other localities are in Zhob area like Naweoba and Waltoi rud localities, Las Bela region like Kohan Jhal, Haji Khan Benty, Sanjro, Khabri, Siro and Khan Kheo localities.

Buildings, construction stones and Decorative stones: Large reserves of recrystallized limestone and marble are being used from the Indus Suture zone due to near road location to main industrial city Karachi. Large reserves of good quality gabbro are found in Muslimbagh- 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 Kanar mélanges 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, Boutecenne, 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 Shekran and Mona Talar, while Zhob region like Naweoba and Inzarki (Ahmad, 1969), minor **graphite** showings like stringes and lenses in Shirinab Formation from Sheikh Wasil area (29^0 55'N; 66^0 36'E) and in the west and northwest of Quetta (HSC, 1961), **soapstone** showings in the ophiolitic rocks from Zhob valley like Gach Inziakai, Shinghar hill, Zamankar nala (Walgai Oba) and Bahram Khel localities, the c**opper** from Sange Gar, Zizha, Shin Ghar and Otman near Jalat Killi of Zhob area, Nasai and Tor Ghar of Muslimbagh area and Ann Dhoro and Paha Dhoro of Las Bela area have been reported (Abbas, 1980b; Kazmi and Abbas, 2001), the **mercury** from Gunga and Duddar area, **Nickel** from Muslimbagh area, **Niobium** and **platinum** from Muslimbagh area, **phosphate** from Chapar area (WNW of Kalat), and **sulphur** deposit (29^0 06'N; 66^0 21'E) of Chapar near Manguchar about 25km NW of Kalat, large deposits of **dolomite** occurs in Jurassic Chiltan formation of Chiltan Range-Ziarat Nala (MgO 20%, CaO 32%, 250mt), quartz from Zhob and Las Bela and its vicinity areas, and jasper from 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, laterite/bauxite, ochre, barite, fluorite, petroleum seeps, marble, clays, iron, phosphate, travertine/aragonite/onyx marble, manganese, silica sands, building stones, cement raw materials, and nephlene 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 import of coal may be stopped or decreased. Further more thermal 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. At this moment only little mining are running slowly in the northern plunge (Sumat Ghar area) of Kingri anticline, and Aram area however 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 consequent of increase in population and some coal deposits of world show associated gold, silver, arsenic, selenium, uranium and zinc. Many coalfields of Pakistan are none developed. To develop these coalfields it is necessary to create the technology to use the mixed lignitic, subbituminos 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-Shahrag-Harnai, and Duki, Chamalang-Bahlol coal fields with total reserves of about 196 million tons. The present work has increased the coal reserves of Balochistan from 196mt to 408.4mt (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 coal (Dewal, Ghozeghar and Palwan/Betar of District Musakhel) and 1mt of Kingri-Shikar-Tor Shah Eocene coal (District Musakhel). In this way the reserves of Eocene Toi Formation coal of Balochistan are 327.4mt and latest Cretaceous coal of Balochistan are 81mt. The total of Eocene and latest Cretaceous coals 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 Sumat and Nath ghars, Aram, Nishpa, Tor Sari, Shiren, Sorbol, Nath and Khagoon areas of Musa Khel district; Coal from Early Eocene Toi Formation of Drug Tehsil region like Dewal, Ghoze Ghar, Miana, Tabai Khah, Takai, Alambadai, Palwan/Betar, etc (Toi Nala area) 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 carbonaceous shale in the Cretaceous strata of the Zhob area, and Cretaceous Sembar Formation of Chichlu (Mekhtar; Loralai District) area, Pab Formation in Vitakri (District Barkhan) and Mughalkot area, and Mughalkot Formation in the Toi Sar area (Musakhel District) have been found. **Chamalang Coalfields** show the coal which is extended from Mari Bijar to Surghari, Lunda, Bala Dhaka, Nausham and Bahlol areas (Malkani, 2004e; 2010g). This coalfields show Anokai syncline in the 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 Qadri-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 GSP has completed one drill hole (in 2009) upto depth of 775' 7'' 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 (lignitic 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 due to stoppage of drilling and lack of funds. There are maximum (more than 20) coal seams (lignitic 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 1foot thick are found in the Canteen area. The lower zone have Do/Char footi and Chey footi seams, the middle zone have Malkani, Zahid, Dr. Raza, Dr. Imran, Pak and GSP-Khalid Kashmiri coal seams, and the upper zone have Bakhtawar, Sadiq and Nau footi coal seams (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 seams that Char footi and Do footi are the name of same and one coal seam. In the northeastern part like Surgahri 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. The Bahlol area shows some thin exposures of coal. Malkani (2010g) has estimated total reserves upto 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 board, Canteen, Surghari (southwestern and 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-Nosham-Kali Chapri, etc) of six inch or more coal seams (lignitic 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 (2009f,2010g) from Toi Nala area of Musa Khel District. Coal from Early Eocene Toi Formation of Drug Tehsil region like Dewal, Ghoze Ghar, Miana, Tabai Khah, Takai and Alambadai (upper strike line) and Plawan/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, caped and roofed by sandstone/limestone beds dipping (20-35^0) eastward. The coal and hosted strata in the Alam Badai section is about 30m thick (Fig.1e,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 as like Chamalang coal. 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 total thickness, 0.4km depth, specific gravity (S.G.) generally about 1.2, the measured reserves of Toi Nala coalfield 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 10.8mt and hypothetical reserves beyond 5km depth may be more than 1mt (Table 3). The total estimated reserves are about 15.4mt. **Shirani coal** (F.R.D.I.Khan) is described by Malkani (2010g). It is located in the northeastern extremity of Toi coal basin. The northern part of Shirani area like the Khoara Khel and its close vicinity, show best exposures of 3 carbonaceous shale horizens in Toi Formation. The central horizon/coalseam may prove a 1 foot coal seam at depth. The southern part of Shirani area like Mughalkot, Nispura and Ragha Sar areas, show no best exposures of coal. **Kingri Coalfields** show Eocene coal (Coal in Toi Formation) and latest Cretaceous or K-T coal (Coal in Vitakri Formation). **Kingri Coalfields (K-T boundary coal)** are reported first time by Malkani (2004c) and followed by Malkani (2009f, 2010g) latest Cretaceous coal of Vitakri formation from Kingri area like Nath Ghar and Sumat Ghar (39 F/15,11) in the south, Nishpa (39 F/14,15), Tor Sari (39F/14,15), Aram and Shiren (39 F/14) in the central part and Manhi area like Surbol and Nath locality and Khagoon areas of Alu Khan Kach (Gharwandi;39 F/14) in the north (Fig.1d,k) and may be promising in Indur Pur and Sarin Lahar areas (Indur Pur anticline; 39F/15,14). There are two main coal horizons (which are time equalent to dinosaur red mud beds) alternated by sandstone horizons of latest Cretaceous or K-T boundary coal of Vitakri formation in these areas. Each horizon show 1-2 feet thick coal seam with low quality (mostly muddy coal with some metallic fine coal; probably lignite C to Subbituminous C) with low heating value probably 2000 to 10000 btu. At places the laterite and high sulphur is also associated with coal seams like Gharwandi (Nath) area and also northeastern Sumat Ghar. The brick makers do not like this coal due to its initial slow burning at the start, and after some times it burns fast which makes the brick khunger (partially solidified after melting and become hard). Further the **coal quality and low prices per ton** and also the **pinching and swelling nature of coal seams and faultings** are the reasons for the contractors which are not taking interest in mining activities, however its demands and suitable market can encourage the contractors to develop this coal. Estimation of reserves is purely tentative which is based on only some outcrops because no exploratory holes have been drilled to ascertain the ore bodies at depth. The lignitic/muddy coal seams (with minor metallic coal at subsurface) are mostly covered by thin scree and talus, and alluvium, however below this the coal seams may be expected. Taking 10km 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 10.8mt 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 2km 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 2.5mt. Total reserves of coal in the Gharwandi thrust (Alu 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 drillings and further exploration for confirmation. However the total deposits of lignitic coal may increase by confirmation of extension to Sharin and Indarpur 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 Coalfield**s (**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, Chamoz,Tor Shah etc. The coal seams strike is NE and dipping moderately toward SE and also NW due to anticlinal structure. This area also have one lignitic coal seam in Kingri formation such as in Gidar Doc, Shikar and Chamoz area, but here the Toi formation coal is significant for further exploration. The coal quality seems to be best like Chamalang coal. The tentative reserves of these lignitic to bituminous coals are likely 1mt (Table 3,4) based on only field observations. The **Narwel Coal area** (Lakhi area of Loralai district, Sari Dhaka/Dab Thana of Murgha Kibzai area of Zhob district, and Dab lahar area of Musakhel district) is also promising for further exploratory works due to well developed synclinal structure and Toi formation and some good quality coal exposures in its NE vicinity like Dab area (Musakhel district) and availability of road. Further some minor and some significant showings of coal of Early Eocene Toi Formation have been found in the Kingri, Chap, Gandhera, Dab, Shiren, Tor Shah, Alu Khan Kach (Gharwandi), Kot Khan Mohd, Tang Miri Wah (Baghao), Bibar Tak and Kali Chapri, etc. The present investigations by the present author show the extension of Eocene coal in the northern Sulaiman foldbelt (Fig.1d,e).

Celestite deposits: (Malkani 2010f) reported some new deposits of celestite in the Sulaiman Basin (Balochistan Province) of Pakistan. These are the third deposits in Pakistan 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 38.50 to 39.21%, SO_3 42.64 to 42.96 %, BaO 7.63 to 7.99% and CaO 1.10 to 1.12%. Celestite contains small amounts of calcium and barium. 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 Bahlol 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 Dhaka (39 F/8), Bahlol (39 F/12), Mawand (39 C/10) and Mach (34 O/5,6,10). Sheikh (1972) carried the evaluation of Spintangi gypsum deposits. Huge deposits of gypsum are discovered by Malkani (2000, 2010f) from Lakha Kach (Rakhni, 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), Janthali (39 G/7), Kahan-Khattan (39 C/11,15), Dera Bugti (39 G/4,3,7,8,11,12), Mawand (39 C/10,14), Bohri Kohlu (39 G/1), Girsini-Bala Dhaka-Karher (39 G/5, 39F/8,11,12), Chamalang (39 F/8), Bahlol (39 F/8,12), Baghao Tumni (39 F/12), Kingri-Kot Khan Mohd (39 F/14,15), Sham and 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 **50m** 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 Ghar, 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 (KP). 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 (0.3m-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 are about **26 billion tons** (1bt=1000mt) which are the **first largest deposit in Pakistan.** The breakup of total gypsum reserves of more significant localities are Lakha Kach or Rakhni 1bt, Ishani-Gadumra 1bt, Nisau-Safed 3bt, Kahan-Khatan 1bt, Dera Bugti 1bt, Mawand 1bt, Girsini-Bala Dhaka-Karher 1bt, Anokai (Bahlol and Chamalang) 1bt, Manjhail Kharar 3bt, Zinda Pir 3bt and Eastern Sulaiman belt (Rajan Pur to Waziristan) 10bt. Further the western Domanda syncline bifurcated the eastern Sulaiman gypsum belt in 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 hitted the metal road between Draban and Drazinda. This (Draban-Domanda) deposit is 15mt upto 50 m mineable depths, 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 deposits 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 Mekhtar (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 Khojakzai Kalai.

Bauxite, laterite, Fire clay and ochre: Very extensive deposits of Ziarat (30^0 23'N; 67^0 43'E), located in the disconformities between the Paleocene Dungan limestone and the Cretaceous Parh 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 apparently the largest laterite in Pakistan with reserves of about 100 mt. The laterite is reddish to maroon, hematitic and pisolitic with high specific gravity 3.1 to 3.4. Its iron content is quite high but 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% SiO_2, 34.4-51.7% Fe_2O_3, 18.62-32.48% Al_2O_3, 0.56-2.66% TiO_2 and 8.45-15.34% H_2O (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 Kasa and 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), Barkhan, Musa Khel, Kohlu and Dera Bugti. The ones most commonly used and which are mined in large quantities are marble (various types of limestones). Large reserves of recrystallized limestone and marble occur widely in the Sulaiman Basin. It provides slabs for tiles and wall facings. Several varieties of fossiliferous limestone with beautifully oriented designs of foraminifers, mollusk shells and calcite veins, ranging in shade from cream to fawn, light brown to shades of grey occur extensively in the Paleocene to Eocene sequences. The private sector exclusively deals with the production, processing and marketing of marble and other decorative stones. Travertine/Aragonite is found in the vicinity of hot water springs area like Anambar, Mahiwal and Karu. The aragonite thin beds are also found in the Shaheed Ghat shale in the Rakhni and Sham, Kulchas, Phailawagh and other areas of Dera Bugti district and also in other parts of basin. Building stones like Limestone from Chiltan, Loralai, Parh, Mughal Kot, Fort Munro, Sangiali, Dungan, Drug, Habib Rahi and Pirkoh formations, sandstone from Sembar, Pab, Vitakri, Sangiali, Toi and Kingri formations and Vihowa group. Gravel and sand from Chaudhwan and Dada formations, Subrecent and recent surficial deposits are significant.

Other Resources: Malkani and Tariq (2000; 2004) reported first time **small barite deposits** from Mekhtar and Murgha Kibzai areas of Loralai and Zhob districts. It occurred as large nodules arranged as parallel to bedding in Early Cretaceous Sembar shales. There are about eight beds of Barite, which are widely space in a 50m sequence of shale. Recently the present author discovered the barite mineralization in the lower part of Sembar shale from Pazha area of Surghar (Mauza Pramezai; 39 F/9) of Musa Khel district. However the barite nodules are commonly found in the Sembar shale. Pure **calcite** is also found in many calcite veins in limestone of different age. **Quartz** veins having white transparent to translucent quartz crystals are also found in the sandstone of Cretaceous Mughalkot formation in the Khagoon range (39 F/10) of Gharwandi (Alu Khan Kach) area. **Flint** from Tor Thana area (39F/3) show banded and wavy white and light blue colours which creates beauty for ornamental purposes. Various types of **Clay deposits** are found Fort Munro, Sangiali, Chamalang (Ghazij), Kahan and Vihowa groups. Large deposits of fire clay are expected from different coal bearing formations in Sulaiman Basin. The **Radioactive minerals like p**rimary and secondary uranium mineralization are commonly existed in the Vihowa group and probably in other sandstone formations like Mughal Kot, Pab, Vitakri, Sangiali, and Rakhi Gaj formations. The Sandstone of Toi and Kingri formations have opposite source from northwest but can not be ignored. The **Aluminous rocks** can be associated with Ziarat laterite, Vitakri formation and Vihowa group red beds. The **Iron and phosphate** from Rakhi Gaj formation (Gorge beds) has anomalous iron (14-21%) deposit, while phosphate from green and black shale and greenish grey sandstone of Mughalkot formation and green to greenish grey shale and greenish grey to red spotted and red wavy laminated sandstone of Rakhi Gaj (both Girdu and Bawata members) formation. **Silica Sands** is found mostly in the sandstone of Toi Formation and Vihowa group. In the Toi Formation it is found from Duki, Chamalang, Alu Khan Kach (Gharwandi), Kingri (Fig.1d) and probably Shirani area, while from the Vihowa Group it is found in the Zinda Pir and Dera Bugti area. **Manganese** is found anomalous in iron nodules. The iron nodules in the Cretaceous and Tertiary shale have some anomalous lead, zinc and manganese. **Pyrite** nodules are common in the shale of different ages. **Copper** mineral/azurite is also reported by local peoples in the Drug limestone of Rara Sham area. **Cement Industry** raw materials are huge in this basin. The cement industry at Zinda Pir is working well. More than a dozen cement industries should be installed in the Dera Bugti, Harand, Barkhan, Kohlu, Loralai, Musa Khel, Rajan Pur, D.G.Khan and D.I.Khan districts due to close existence of its raw material like limestone, gypsum and shale. Further its suitability will be strengthens by the close occurrence of raw materials which will be provided to industry by belts and not by trucks. It is a strong need to fulfill the cement requirement of country and earn foreign exchange through cement export for the development of Pakistan. **Phosphate** is reported from Rakhi Gorge (Sangiali and Rakhi Gaj Formations) and Mari-Bugti hills phosphatic nodules in Cretaceous Pab formation and also black and green shale and sandstone of Mughalkot formation of Gharwandi (Alu Khan Kach) areas (Fig.1d). Iridium anomalies can be found in the KT boundary laterite, muds and coal especially in the Gharwandi, Aram, Kingri, Vitakri, Fort Munro and other areas of Vitakri Formation. **Nephlene syenite** is a rock consisting of albite and microcline feldspar and nephlene. It is used in the manufacture of glass, ceramics, alkali carbonates, Portland cement and for extraction of aluminum. Jadoon and Baig (1991) reported Tor Ghar nephlene syenite. Malkani and Haq (1998) have reported it as a Tor Ghundi pegmatite (micropegmatite; intrusive) with deposit of feldspar and minor mica crystal (3-5cm) in the southwest of Kasa and south of Killi Shabozai. It is a circular pipe or plug type (1km in diameter) surrounded by Parh limestone and Sembar Shale. There are one another showing about 2km in the east in Sembar formation. Further the Sulaiman Basin is the host of petroleum and uranium which show good economic potential. **Petroleum seeps** reported by HSC (1961) are Mughal Kot (39 I/3), Khattan (39 C/6), Gokurt (34 O/6), and Sanni (34 O/8). Further bituminous staining is also reported by them in the Sanjawi limestone (Dungan limestone) near the Road cut in between Sanjawi and Duki. Further the present research show oil seeps in the black shale and greenish grey sandstone of Cretaceous Mughalkot formation in the Alu Khan Kach (Gharwandi area; 39 F/10) and Musa Khel area (39F/9) and Vitakri gas seeps (39G/6; Malkani, 2004). A small **sulphur** deposits (28^0 18'N; 68^0 26'E) reported near Jacobabad was investigated by Burmah Oil Company 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 (Daman) 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, Sori Lund, Mithwan, Kaha, Dera Bugti, Lahri, Tali and Nari (Sibi) areas.

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, Meting-Jhimpir, Jeruck-Ongar, Badin and Thar, which is one of the largest coalfields of world. However all these 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 the coal from Dureji in the southern Kirthar Foldbelt but details are not provided so far. Malkani (2010f) reported first time the coal of Khauri locality of Zidi area (Khuzdar District) and here the coal and carbonaceous shale is about 1 foot thick seam found in the Tertiary limestone, marl 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 Kolpur railway station. The ore is found as J/K boundary with low to gentle dips. The iron horizon is 1-7m thick with an average value of 2m. Mineralogically it consists of hematite with calcite, quartz and chlorite. It contains 35-48% iron. The estimated 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, simple mineralogy and acceptable grade, it is considered better than 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 beneficiation. Chemical analyses of iron ore represents Fe 45.7-48.03%, FeO 2.30-2.95%, SiO_2 13.7- 14.6%, CaO 2.23-2.4%, MgO 1.6-2.2%, MnO 0.09-0.11%, Al_2O_3 5.30-6.04%, TiO_2 20.32-0.35%, 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 and to save the export fundings. In Sindh lateritric clay and ochre, pockets of limonite and ochre are found in Eocene Sohnari Formation at Lakhra, Meting and Makli hills (Abbas *et al.*, 1998).

Witherite: It is a barium carbonate with 4.3 specific gravity. It occurs as gangue minerals with galena and barite. It is a source of barium salts and also used for pottery industry. Due to high specific gravity, it can be used for drilling industry. A deposit of witherite has recently been discovered a few kilometers west of Deghari in Balochistan. It occurs in veins and lenses in the Jurassic Chiltan limestone and mineralization extends for about 1 km (Sispal Kella, verbal communication with Kazmi and Abbas, 2001).

Fluorite: The attraction of mineral specimen as distinct from a facetted 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 (29^0 30'N; 66^0 55'E) fluorite mines in Kalat Division. In the vicinity of Dilband, the fluorite is reported from Pad Maran, Chah Bali and Dobranzel (Isplinji) areas (Bakr, 1965a; Mohsin and Sarwar, 1980). **Sulphur:** Sanni (south of Dhadhar) and Koh-i-Sultan (near Nokkundi) in Balochistan is the main sulphur localities. Sanni deposit is located in the foothills of Kirthar Range in the south of Dhadhar town. The Sanni deposit (28^0 02'N; 67^0 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 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 deposit (26^0 16'N; 67^0 57'E) was described by Vicary (1847) around the vicinity of hot spring near the town of Laki (Nagell, 1965). Gokurt sulphur deposit (29^0 33'N; 67^0 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 Sunni 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 Gaj Nalas are urgent demand due to population increase and also having barren areas for water utilization. Ahmad (1962) reported the bituminous residues known as Salajeet were found in some parts of the Pab Sandstone in the Khuzdar region

Geological History and Paleobiogeography 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 Wulgai 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 Sulaiman 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), Sembar, 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 clastic Mughal Kot (mudstone), carbonate Fort Munro (limestone) and clastic Pab (sandstone with shale) formation, and continental Vitakri 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 geanticline 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/Bibai formation also indicating collision. The Paleocene Sangiali group show marine clastic shale and sandstone, and carbonate limestone of Sangiali Formation, marine clastic sandstone and shale of Rakhi Gaj Formation, and marine carbonate Dungan limestone. The Early Eocene Chamalang (Ghazij) Group show marine shelf shale with some clastic marine sandstone of Shaheed 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 evaporitic 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 Chitarwata, Vihowa, Litra and Chaudhwan formations. The Pleistocene Dada Formation show fluvial conglomerate, sandstone and mudstone. The Subrecent and Recent are 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 boarder line of middle and lower Indus basin. After this J/K boundary the sea again transgressed and covered this highland. At K/T boundary the sea was regressed from the Fort Munro (D.G.Khan)-Vitakri (Barkhan)-Ziarat east west belt and formed the highland with terrestrial environments of Vitakri formation Fort

Munro-Vitakri region represent the Late Cretaceous Park of Pakistan which has preserved the latest Cretaceous dinosaurs from Pakistan. These J/K and K/T disconformities suggest for high lands in the northwestern part of Indo-Pakistan subcontinent, otherwise marine environments were dominant.

Paleobiogeography can be deduced from geological and palontaological data. Some time the geological data is sufficient, some time paleotological data is added. However the geological data by their very nature hold priority over paleontological data or vice versa. During Late Cretaceous (220 Ma) the lands united as Pangea. The breakup of Pangaea started in Middle Jurassic (170 Ma) while the breakup of Gondwana started in Late Jurassic (160 Ma). Indo-Pakistan subcontinent has a peak attraction for paleobiogeography due to its present contact with Laurasia (northern hemisphere) while its past is attached with Gondwana (southern hemisphere). Due to its long journey of about 6000-8000 km in a great period of about 80-100 million years, it remained as island but not Peninsula, and its sediment and fauna have experienced many paloeclimates/environments. The Chagai magmatism started during Cretaceous, representing Indo-Pakistan were close to it and creating stress. Further in the Early Eocene, the Indus Suture zone (Axial belt) was well geanticlines, served as separation or boundary between Balochistan basin of Tethys sea (Laurasia) and Indus basin of Indo-Pakistan subcontinent of Gondwana. The pre Eocene clastics source of Sulaiman and Kirthar basins was in the Indo-Pakistan shield (east; Fig.1i) but at the start of Early Eocene, the source of clastic material was shifted in the north or northwest (Hinterland, Asia: Fig.1j). The shifting of source rocks of clastic materials of Early Eocene Chamalang group of Sulaiman and northwestern part of Kirthar foldbelts from east (Fig.1i; Indo-Pakistan shield) to north or northwest or west (Fig.1j; Zhob to Afghan Hinterland area, Asia) shows the contact of Indo-Pakistan plate with Asia. This shows the Indo-Pakistan subcontinent contacted with Asia during Latest Cretaceous. This collision raised the Hinterland areas probably from 75 Ma to 55 Ma, especially in the north or northwest of Zhob to Afghan area which were the source of Eocene clastics. This was the first main orogeny. The second orogeny occurred in the latest Eocene or Early Oligocene (33-35 Ma) which is responsible for the rising of Himalaya which was the clastic source of Potwar group (Siwalik group) in Kohat and Potwar basin, Vihowa group in Sulaiman basin, and Manchar group in Kirthar basin. In the Oligocene the Tethys Sea was permanently regressed from the upper and middle Indus basins, however southward of Jacobabad high the sea remained in the Oligocene and regressed in the Miocene and later further southward. The second orogeny occurred after the 20 million years of first orogeny. In this way the first orogeny also needs 20 million years (75-55 Ma) for rising of Hinterland (Zhob-Afghan block) to supply the clastic materials. Wilson (2010) mentioned 6000km migration of Indo-Pakistan plate which may require 100 million years for connection with Asia. The connection of Indo-Pakistan with Asian plate in Paleocene is confirmed on the basis that the source of Eocene clastic deposits of Sulaiman and northwestern Kirthar basins of Indo-Pakistan plate was north and northwest in the Hinterland, instead of previous from east i.e. Indo-Pakistan shield. Taking average time of travel 100million year, the Indo-Pakistan plate started journey in the middle Jurassic (100 million years+75Ma=175Ma). So there were no chances of connection with Madagascar during Late Jurassic (Fig.1h) or atleast during Early Cretaceous. Probably during late Jurassic, and most probably during Early Cretaceous to middle Late Cretaceous Indo-Pakistan was as an island. Further some sediments of Jurassic (Spingwar formation) and Cretaceous (Sembar, Parh and Mughal Kot formations) of Sulaiman basin show igneous activity representing hot spots and emergency conditions during travel. During Early Paleocene, the volcanisms in Khadro formation of lower Indus basin show source from Decan trap and Pakistani dinosaurs became extinct just before these volcanic deposits. The hypothesis by Smith et al. (1994), Sampson et al., (1998: Africa-First model), Hay et al. (1999) and Sereno et al. (2004: pan Gondwana model) can not support the present model of isolation of Indo-Pakistan as island during most of the Cretaceous. mentioned the uplift of upper Indus Basin at K/T boundary which supports the present model.

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 and first reported by Sleeman (1844). 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 Anembalemba member of Maevarano Formation and its implication for paleobiogeography were reported by The first dinosaur fossil from Pakistan was collected by M.S. Malkani in early 2000 from the latest Cretaceous strata of Barkhan district, Balochistan and first reported by Malkani and Anwar (2000). So far Pakistan has produced about 3000 fossils (some articulated, some associated and some isolated) of cranial, vertebral and appendicular elements of latest Cretaceous four family level taxa of archosaurs which were collected from the two red mud horizons (alternated by two sandstone horizons) of Vitakri Formation. Vitakri Formation is of fluvial origin (sandstone units by meandering stream, and two red mud units by flood overbank deposits) deposited in arid -semiarid paleoclimates with repetitive flood events. These two red mud horizons (each 2-15m thick) served to entomb and preserve massive quantities of vertebrates' skeletal materials. India has produced well the Early Jurassic *Barapasaurus* and eggs clutches of Late Cretaceous dinosaurs but Pakistan has produced well developed and well preserved fossils of the latest Cretaceous titanosaurs, theropods and mesoeucrocodiles, and trackways of Middle Jurassic herbivorous titanosaurian herds confronted by a running carnivorous theropod. According to 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 so far endemic characters of Pakistani titanosaurs. Many hundreds significant holotypic and referred fossils which include *Khetranisaurus barkhani* (Malkani 2006b; 2009f), *Sulaimanisaurus gingerichi* (Malkani and Anwar 2000; 2006b, 2009f), and *Pakisaurus balochistani* (Malkani 2003b; 2006b; 2010a) of herbivorous Pakisauridae (slender titanosaurians) and *Marisaurus* of herbivorous Balochisauridae (stocky titanosaurians) sauropods, *Vitakridrinda sulaimani* and *Vitakrisaurus saraiki* (Malkani 2006b,c; 2009f; 2010g;2011a) of slender and large bodied carnivorous Vitakrisauridae theropod, and *Pabwehshi pakistanensis* (Wilson et al. 2001; Malkani, 2007d) *and Sulaimanisuchus kinwai* (Malkani, 2010g) of carnivorous Sulaimanisuchidae mesoeucrocodile were documented so far. Further the trackways from the Middle Jurassic Samanasuk Limestone of Kohat and Potwar basin represent a group of wide gauge *Malakhelisaurus mianwali* (renamed due to previously engaged name of *Malasaurus*) titanosaurian sauropods and a narrow gauge running *Samanadrinda surgahri* abelisaurian theropod based on only ichnotypes (Malkani, 2007a,2008f, 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 Domanda formations of Lakha Kach syncline (Rakhni) 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 *Balochitherium*, *Bugtitherium*, etc. The Vihowa and Litra formations are also rich in continental vertebrates.

The Gondwanan and Laurasian vertebrates show Pangean 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 consequences for the geographic distribution and subsequent 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 clades 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, noasaurid abelisauroids were small bodied counterparts to their large bodied cousins, the abelisaurids, in a manner parallel to small bodied maniraptorian coelurosaurs 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 fenistra, 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 *Vitakridrinda* is also different than theropods of Madgascar 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 latest Cretaceous Balochisauridae show endemic characters. The latest Cretaceous Pakistani fauna is slightly less provincial 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 Early Cretaceous, and early seed radiation and common heredity show relatively high degree of similarity between Late Cretaceous fauna of Indo-Pakistan, Madagascar and South America. In this way titanosaurians show cosmopolitan due to common seed radiation and heredity due to united continents as Pangea (Late Triassic; 220 Ma) and also at the breakup of Pangea (Middle Jurassic; 170 Ma).

With the fragmentation of Gondwana, which is generally agreed 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 Kingri formations) in the central, north and west of Sulaiman basin and northern Kirthar 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 Gondwanan landmasses to be fully isolated prior to the Albian/Cenomanion boundary, and other Gondwanan landmasses remained relatively cosmopolitan until the later 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

Age	Chagai-Raskoh Magmatic arc	Kaker-Khurasan flysch basin		Makran-Siahan Accretionary Basin
Quaternary Recent				Makran Mudvolcanoes
And Subrecent	Surficial deposits	Surficial deposits		Surficial deposits
Pleistocene	Koh Sultan volcanic group/	Bostan formation		Jiwani/Kech/Kamerod formation
	Kamerod formation		Talar	Chatti mudstone
T Pliocene	Buze Mashi volcanic group		group	Talar sandstone
Miocene	Pishi/Dalbandin formation	Shaigalu		Parkini mudstone
E Khojak	formation	Turbat		Panjgur formation
group	Murgha Faqirzai	group		Hoshab shale
R Oligocene	Amalaf formation	shale		Washuk ophiolite complex
T			Siahan	Zurati formation
I			Group	Wazhdad Volcaniclastic form A
	Saindak formation/Robat/			Siahan shale
R Eocene	Nisai/Kharan/Robat limestone	Nisai limestone		Wakai limestone
Y Paleocene	Rakhshani/Juzzak formation			Ispikan formation
	Humai formation			
	Chagai Intrusion, Bunap complex			
CRETACEOUS	Sinjrani/Kuchaki volcanic group			

Table 2. Mineral localities of Balochistan Province, Pakistan

Metallogenic zone	Economic Minerals/Commodities
Chagai magmatic arc	Copper, Gold, Silver, Iron, Tungsten, Lead, Zinc, Sulphur, Tourmaline, Manganese, Barite, Marble, Bed rock, Aggregate and water resources, Building, construction and decorative stones.
Raskoh magmatic arc	Chromite, Vermiculite, Manganese, gypsum, copper.
Kaker Khurasan basin	Antimony, Ochre, Saline springs, Mudvolcanoes gas.
Wazhdad magmatic arc	Chromite, copper,
Makran-Siahan	Antimony, Gold, Silver, Mercury, Iron, Ochre, Quartz, pyrite, Coal, Sulphur, Rock salt, Petroleum seep, accretionary prism Mudvolcanoes Methane-Nitrogen seep.
Indus Suture (Axial belt)	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.
Sulaiman Basin	Coal, Gypsum, Celestite, Sulphur, Laterite/Bauxite, Ochre, Barite, Fluorite, Marble, Clays, Quartz and flint, Iron, Phosphate, Manganese, Silica sands, Cement raw materials, Micropegmatite (Nephlene syenite), Building, construction and decorative stones. Petroleum seep.
Kirthar Basin	Coal, Iron, Fluorite, Sulphur, Building stones, Decorative stones, Marble, Celestite, Building, construction and decorative stones.

Table 3. Coal Reserves of Balochistan (million tones). Coal seams cumulative thickness ranges and status as developed and Non-developed.

Coalfield	**Coal seams (meter)**	**Status**	**Measured**	**Indicated**	**Inferred**	**Hypothetical**	**Total**
BALOCHISTAN							
Chamalang	0.2-2.5	Dev.	6	12	72	10	100
Kingri (K-T coal)	0.5-2.5	Dev.	3.9	7.8	35	34.	81
Kingri-Shikar-Tor Shah (Eocene)	0..2-2.0	Non-Dev.	1-	-	-	-	1
Toi Nala (Ghoze Ghar)	0.3-2.0	Non-Dev.	1.2	2.4	10.8	1	15.4
Khost-Sharig-Harnai	0.3-2.3	Dev.	13	-	63	-	76
Sor Range-Sinjidi-Deghari	0.3-1.3	Dev.	15	-	19	16	50
Duki	0.2-2.3	Dev.	14	11	25	-	50
Mach-Abegum	0.6-1.3	Dev.	9	-	14	-	23
Pir Ismail Ziarat	0.4-0.7	Dev.	2	2	8	-	12
Subtotal			**65.1**	**35.2**	**246.8**	**61.3**	**408.4**

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

Coalfield	**Moisture**	**Volatile Matter**	**Fixed Carbon**	**Ash**	**Total Sulphur**	**Heating (BTU/lb)**	**Rank (ASTM)**
Chamalang	2.46-4.58	12.66-41.71	7.96-50.05	6.25-74.80	3.44-6.93	2193-13569	LigC to hvBb
Kingri (K-T coal)	1.64	18.4	25.1	55.2	5.58	2000-10,000?	LigC to SubC?
Kingri –Shikar-Tor Shah (Eocene)	interpreted same as Chamalang						
Toi Nala (Ghoze Ghar)	1.8-1.9	42.3-42.9	32.1-32.9	22.8-23.1	5.8-6.1	9,790-12,000?	SubC to hvCb?
Khost-Sharig-Harnai	1.7-11.2	9.3-45.3	25.5-43.8	9.3-34.0	3.5-9.5	9,637-15,499	SubC to hvCb
Sor Range-Sinjidi-Deghari	3.9-18.9	20.7-37.5	41.0-50.8	4.9-17.2	0.6-5.5	11,245-13,900	SubA to hvBb
Duki	3.5.11.5	32.0-50.0	28.0-42.0	5.0-38.0	4.0-6.0	10,131-14,164	SubB to hvAb
Mach-Abegum	7.1-12.0	34.2-43.0	32.4-41.5	9.6-20.3	3.2-7.4	11,110-12,937	SubA to hvCb
Pir Ismail Ziarat	6.3-13.2	34.6-41.0	19.3-42.5	0.3-37.5	3.2-7.4	10,131-14,164	SubB to hvAb

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