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GEOLOGIC MAPPING AND ECONOMIC RESERVES OF INDUSTRIAL MINERALS AND HYDROCARBON POTENTIAL ROCKS OF KHISOR RANGE: TRANS-INDUS RANGES, NORTH PAKISTAN

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ABSTRACT

The western Khisor Range segment of the Trans-Indus ranges is a south-vergent, east-west trending fold-thrust belt that protrudes southward into Himalayan foreland deep. The frontal flanks of range are characterized by east-west trending parallel to en echelon, plunging local anticlines and synclines structures. General structural style of folds has observed asymmetric to overturn and dominantly south vergent. The frontal outskirts of the study area is demarcated by a youngest partly emergent thrust fault named as Khisor Thrust. Outcrops projection to subsurface of the structural features suggests a thin-skinned tectonic mechanism for growth of the western Khisor Range where gliding surface for the frontal thrust sheet being located within the Cambrian rocks of Jhelum Group at a maximum depth of 4km. The structural evolution of the western Khisor Range is generally ascribed to southward directed thrust transferral system along the basal décollement being observed at base of the Cambrian Khewra Sandstone. Along this detachment horizon the Khewra Sandstone emplaced over the recent alluvium and boulder bed deposits. The Khisor Thrust fault bulldozed the forelimb of the Saiyiduwali Anticline and demarcates the north-western proximity of the Punjab Foredeep. The Khisor Thrust sheet is predominantly comprised of the shallow marine rocks of Paleozoic to Mesozoic, laterally extended along the range. The stratigraphic framework of the western Khisor Range is considerably related and correlative to the eastern Trans-Indus and Salt ranges. Cambrian strata of the western Khisor Range comprise of Jhelum Group where its apex is underlain by the Permian Nilawahan and Zaluch groups rocks, consists of the Sardhai and Amb formations. The Sardhai Formation observed 50m thick and consists of dark gray to blackish gray and black carbonaceous shale while the lower constituents of the Amb Formation contains of dark gray carbonaceous and calcareous shale up to 30m thick, constructs favourable setting for hydrocarbon potential of the area. Blending of structural style and stratigraphic framework of the western Khisor Range urges that the south-western foredeep in proximity of Saiyiduwali is significantly associated for the hydrocarbon research, as thick carbonaceous lithofacies of both formations are viable potential source rocks. This stratigraphic sequence along with relevant structural geometries suggests an important petroleum system comprised of potential source, reservoir and seal rocks for the oil and gas generation and accumulation.

Keywords: *Khisor, Marwat Range, minerals, industrial raw material, hydrocarbon potential source, limestone, sandstone, shale, silica sand, laterite, energy source minerals*

1. INTRODUCTION

The Trans-Indus extension of the Salt ranges is composed of the frontal ranges including the Surghar-Shinghar, Marwat-Khisor, Sheikh Budin Hills, Manzai and Bhittani ranges which form an

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"S" shaped double re-entrant and surrounds the Bannu Basin (Alam, I. 2008) (Figure 1). These ranges represent the western part of the northwestern Himalayan foreland fold-and-thrust belt that formed by progressive south-directed décollement-related thrusting of the sedimentary cover sequence of Indian Plate crust during the ongoing collision between India and Eurasia (Wells, 1984; Yeats and Hussain, 1987; Smith et al., 1994; Beck et al., 1995), deformation generally shifted southward with time. The southernmost and latest thrusting has occurred along the frontal thrust system bordering the Trans-Indus ranges (Khan et al., 1988), (Figure 2).

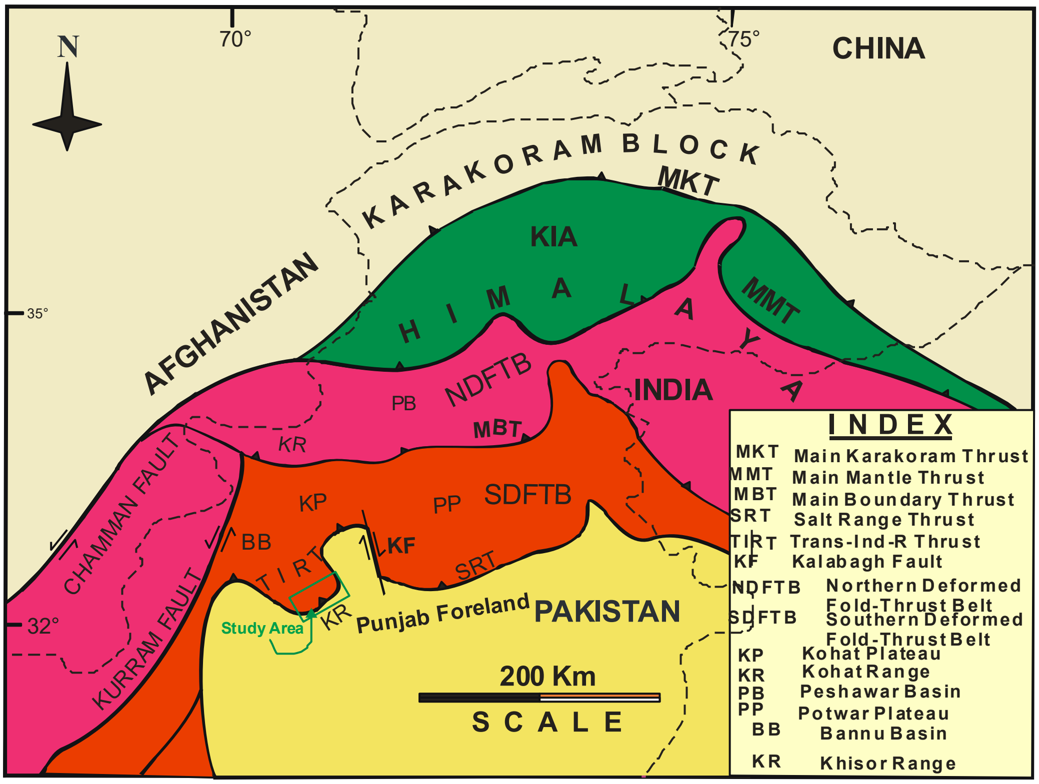

Figure 1. Tectonic map of the north Pakistan, showing the location of study area.

The study area covers about 500 square kilometers of the Khisor Range in the central part of the Trans-Indus ranges (TIR) (Fig. 2). The Khisor Range located among the geodetic coordinates as longitudes 70˚ 50′00″ to 71˚ 15′00″ E and latitudes 32˚ 10′00″ to 32˚ 30′00″ N to compartmentalize the area. Geographically the Khisor Range is marked by the Marwat Range in the north, D.I. Khan Plain in the south, Indus River in the southeast, and Bhittani Range to the northwest (Figure 2). Low to moderate relief ranging from 200m at the valley floor to 1300 m at the Kingriali peak characterizes this range (Alam, I., 2008). It stretches from Paniala in the west up to Dara Tang in the east (Fig. 2). The Marwat Range is an anticlinal feature largely covered by the Siwalik Group rocks. The Khisor Range that lies south of Marwat Range exposes the non-outcropping Cambrian to Triassic rocks underneath the Bannu Basin and Marwat Range at surface and is characterized by east to east-northeast structural trends. The structural style of the range includes parallel to en echelon fold trends detached at the base of Jhelum Group rocks of Cambrian age. The Cambrian to Plio-Pleistocene rocks of the Khisor Range are thrust southwards over the Punjab Foreland along the Khisor Thrust that is probably the western extension of the Salt Range Thrust (Gee, 1980). Cambrian

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to Triassic age shallow marine lithologies predominantly underlies the Khisor Range that is unconformably overlain by the Plio-Pleistocene Siwalik Group rocks (Fig. 3). The exposed stratigraphic sequence of the Khisor Range is broadly correlative with that of the Western Salt Range with the exception that rocks of the Rawalpindi Group (Miocene) are missing.

This area occupies an important geological position in understanding the structural evolution of the southernmost Himalayan frontal thrust system of North Pakistan. There are a lot of reserves of minerals commodities particularly in the western and central Khisor Range to be mined / quarried for Industrials raw minerals and construction materials.

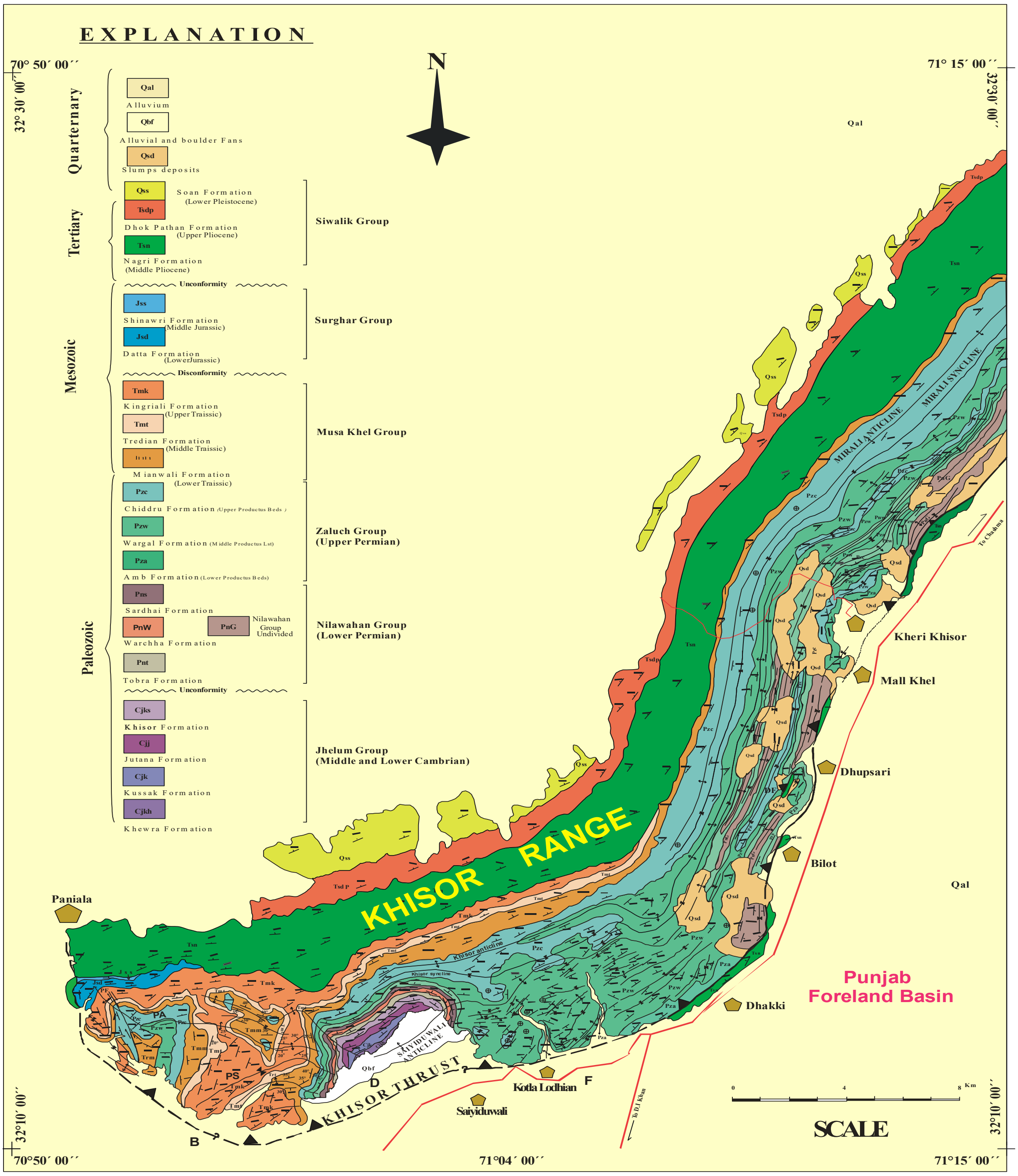

Figure 2. Geological map of the Khisor Range, Trans-Indus Ranges, north Pakistan

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2. HISTORICAL WORK

Detailed geological studies of the Bannu and Dera Ismail Khan areas were carried out by Hemphill and Kidwai (1973). They described the litho-stratigraphic units of the Marwat-Khisor ranges and parts of the Suleiman Range and the Waziristan area. Siddiqi, (1973) studied the silica sand deposits of the Khisor Range and Sheikh Budin Hills and estimated reserves of about 20 million tons. Hussain, (1973) concluded that about 31 million tons of silica sand was workable at a depth of 200 feet in the Marwat-Khisor ranges.

Blisniuk (1996) presented a regional structural outline of the Khisor Range while conducting paleo-magnetic studies of the Siwalik Group rocks. He interpreted that south verging thrusting and normal faulting are responsible for the tectonic evolution of the Khisor Range thrust front. Blisniuk et al., (1998), also noted that the area along the present day thrust front was affected by synorogenic normal faulting within the foreland basin before thrusting began.

Fold-thrust styles has been interpreted in the Marwat-Khisor ranges by Alam, I., et al.,(2005), on the basis of outcrop structural data and proposed that the structural form is thin-skinned involving décollement thrust-fold assemblages, kinematically interrelated to a provincial basal décollement being observed at the base of Jhelum Group rocks.

Ahmad et al., (2003) have tinted the petroleum prospectivity and structural interpretation of fraction the of the Bhittani and Northern Suleiman ranges.

3. METHODOLOGY

This field work is conducted in the Marwat -Khisor Ranges with the combination of detailed geological mapping to establish relation between the structure and stratigraphic framework of the area. We studied and measured the thickness of formations and noted structural variation along and across the structural trend of the range and in this association several field traverses have been made across the strike of the structural axis of the different anticlines and synclines and acquired structural outcrop data of the study area.

4. STRATIGRAPHIC SETTING

The stratigraphy of the area is well established from the outcrop exposures in both the Marwat-Khisor ranges and Sheikh Budin Hills. Fatmi et al, (1999) ~~has~~ studied the stratigraphy of the area and drawn two columnar sections. One section of the Cambrian, Permian and Triassic rocks of the western Khisor Range near Saiyiduwali and the other section of the Permian and Mesozoic rocks at Pungi Wand, Sheikh Budin Hills. The Saiyiduwali section revealed rocks exposed at the base is Jhelum Group and the top is marked by the Kingriali Formation of Triassic age. The Pungi wand section of Sheikh Budin Hills exposed the Wargal Limestone of Permian age at the base and Samana Suk Formation of Jurassic age at the apex. Oil well drilled in the Marwat Range disclosed the subsurface stratigraphic sequence of the study area. The stratigraphic sequence encountered in the well is comparable with the columnar section measured in the western Khisor Range by Fatmi et al, (1999), with the exception of Siwalik Group rocks being encountered in the Marwat Range. Stratigraphic profile of the surface outcrop along the Khisor frontal thrust sheet in the vicinity of Saiyiduwali and Paniala sections suggest that it is similar to the other parts of the range except the Jhelum Group rocks of Lower Cambrian age which exposed along the Saiyiduwali section (Alam, I., 2008). The Stratigraphic sequence of the Marwat-Khisor ranges and along the present day thrust

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front can be subdivided into three major, unconformity-bounded stratigraphic horizons, which are given from bottom to top as:

4.1 Precambrian Crystalline Basement rocks

These rocks are not exposed in the study area, but exposed towards the south and southeast of the Trans-Indus and Salt ranges in the form of Kirana Hills and Nagar Parker granite. The Nagar Parker is understood to encircle the northwestern fraction of the Indian Shield and describes the spreading out of Precambrian rocks of the Indian Peninsula. Kirana Hills exposes the Precambrian rocks of the Indian Shield about 100 km towards south of the Khisor Range near the Sargodha town.

4.2 Shallow Marine Cambrian, Permian and Mesozoic rocks

Cambrian rocks are well developed in the Salt and Khisor ranges. The pre-orogenic platform rocks of Permian age are located along the southern outskirts of the Kohat-Potwar Plateau. The Mesozoic sequence is also well developed in the southern perimeter of both the plateaus. The Permian system is well developed in the eastern portion; Mesozoic rocks have been mapped in the western portion and Cambrian sequence in the central portion of the Khisor Range.

4.3 Cenozoic, Late Tertiary i.e., Neogene to Quaternary

These syn-orogenic foreland basin sediments are coarse clastics dominantly conglomerate and molasse deposits are mapped along the back limb of Khisor Range of the study area i.e., the northern flank of the range is frequently composed of the clastic sediments of alternate beds of sandstone and argillaceous materials and the same lithology have been mapped at various locations in the frontal segments of the Khisor foothills.

5. ECONOMIC GEOLOGY

The Khisor Range fraction of the Trans-Indus Ranges (TIR) is important due to its diverse economic potential. This segment of the TIR is prosperous in varieties of industrial raw materials, construction materials and economic industrial minerals. As the Permian succession of the area comprised of a thick sequence of carbonates and mixed carbonate-siliciclastic rocks representing a wide variety of shallow marine to non-marine environments of deposition. The exposed stratigraphic sequence suggests an important petroleum system comprised of potential source, seal and reservoir rocks for oil and gas generation and accumulation. The carbonate host rocks are relatively abundant at various levels within the basin succession. These rocks commonly have enhanced secondary porosity and permeability, reveal tectonically induced fracture system along with primary diagenetically induced defects. Variation in the permeability of rocks is provided by vertical and lateral lithological changes. These are the valuable prerequisite in hand for the establishment of potential hydrocarbon reservoir in the region.

This range is thoroughly comprised of source of raw material for the manufacturing of Portland cement and variety of construction materials. Permian horizon is dominantly comprised of huge deposits of excellent quality of limestone, the most favorable limestone for this purpose are expected to be the Zaluch Group limestone (stratigraphic bar, Fig. 3). The upper part of the Amb and some middle parts of the Chhidru Formation may probably not be suitable for the manufacturing of Portland cement because they comprises siliceous fossils and cherts nodules

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along the stratigraphic section. This group includes rocks and minerals, which can be utilized as such or after some processing in various industries. Bountiful reserves of the industrial raw materials exist throughout the study area. Deposits of several industrial raw materials of great importance have been observed that include huge deposits of limestone, dolomite, sandstone, gypsum, silica sand, laterite, bentonite, shale, minor coal deposits and frontal boulder gravel nala beds.

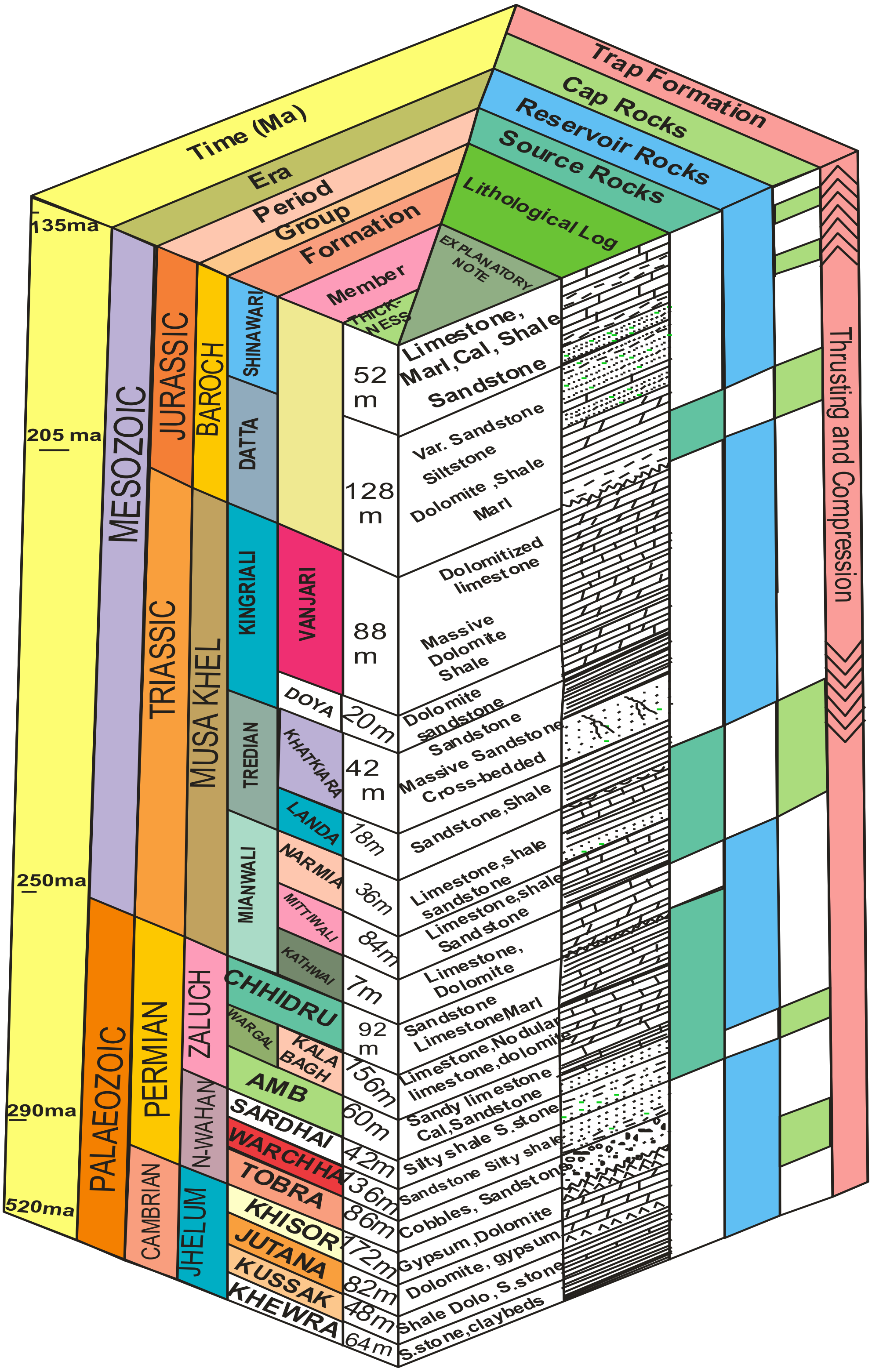

Figure 3:- Generalized stratigraphic bar and anticipated petroleum system of the Khisor Range

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5.1 Limestone and Dolomite

Limestone and dolomite is of great interest because of their economic worth. Huge deposits of limestone and dolomite have been mapped throughout the map extension. Limestone is by far the most abundant mineral commodity of the area. Major limestone deposits are associated with the Permian Zaluch Group rocks (Fig. 4, a, b, c) while dolomite reserves are found in the Kussak and Jutana formations of Cambrian and Kingriali Formation of Triassic age (Fig. 5, a, b, c). Dolomite is the near twin-sister rock to limestone. Like limestone, it typically forms in a marine environment but also as has a primary magnesium component. These can be used for building blocks, road bases, rip rap, and agricultural lime; cosmetics and other personal hygiene products; paints; glossy paper; caulking; medicines; fiberglass; roofing shingles; trap shoot targets; rubber hoses; window glass and auto windshields; and wall spackling.

Figure 4: a,) Thick bedded b) nodular and c) brecciated Limestone of Zaluch Group rocks

Figure 5: a) Whitish gray massive dolomite of Kussak, b) thick and horizontal bedded dolomite of Jutana and c) gently dipping dolomites of Kingriali Formation.

5.2 Gypsum

Economically viable gypsum deposits are mapped in the core of Saiyiduwali Anticline belonging to the Khisor and Jutana formations of Cambrian age. The thickness of these deposits is greater than 200 m in both the formations (Fig. 6, a, b). Gypsum is used for manufacturing the plaster and wall board; filler for medication, water treatment; and cake frosting.

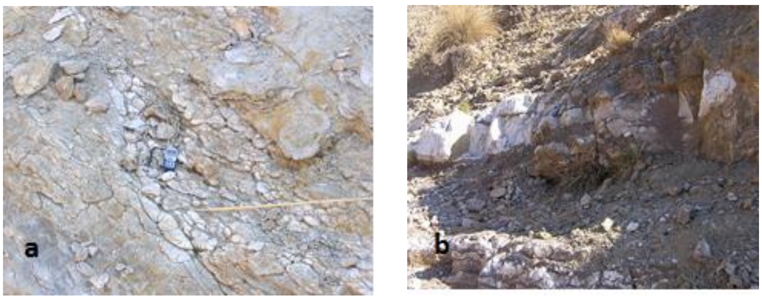

Figure 6: a) whitish gray thick bedded gypsum of Khisor Formation, b) interbedded gypsum with shale of Jutana Formation

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5.3 Silica Sand

The basal part of Jurassic Datta Formation southwest of Paniala village dominantly consists of silica sand (Fig.7 a, b, c). The bed of silica sand is about 20 m thick and is exposed for a length of 16 km from Paniala to Pezu (Siddiqi, 1973). Sieve analyses have shown that the sand size is medium to fine grained, suitable for glass making. Silica content varies between 76% to 97% and ferric oxide range from 0.67% to 4.5%. The sand is friable, thus easy to mine. Total reserves as estimated by Siddiqi (1973) are 20 million tones up to a workable dip of 30 m depth.

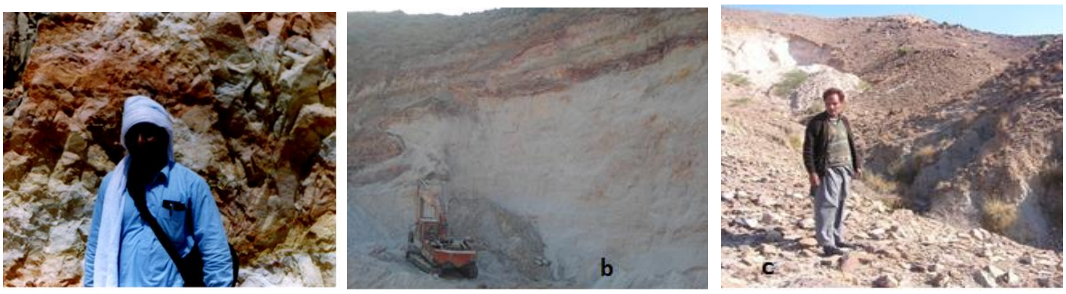

Figure 7, a, b, c: - Massive silicasand deposits of Datta Formation, southeast of Paniala Village.

5.4 Laterite

Mineable laterite beds are commonly associated with the Datta Formation southwest of Paniala village (Fig. 8, a, b). Laterite is a red, residual soil containing large amount of aluminum and ferric hydroxides, formed by the decomposition of several kinds of rocks. Laterite is being mined as Portland cement raw materials.

Figure 8, a, b: Economic laterite deposits at top of the Datta Formation southeast of Paniala Village.

5.5 Bentonite

Bentonite beds have been found in the lower middle part of the Nagri Formation through out the study area. Huge deposits are located east of the Paniala village along the back limb of the Paniala Anticline and south of Katta Khel village along the southern limb of Abdul Khel Syncline. Bentonite can be used in ghee industry, used in the drilling industry as drilling fluid/mud. Bentonite has the property of swelling into a gelatinous mass or disintegrating into a granular to fluffy aggregate. Bentonite, unlike ordinary shale and clay, commonly has a waxy translucence in thin chips.

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5.6 Sandstone

Thick to massive bedded sandstone bodies of significant interest have been mapped in the Saiyiduwali and Paniala sections of the western Khisor Range (Fig. 2) Khewra Sandstone of economic worth is located at the base of Jhelum Group rocks in Saiyiduwali Area. Massive deposits of Tredian Sandstone are mapped towards western terminus of the Khisor Range near Paniala Village (Fig. 2). Sandstone is the most generous deposit of the area and can be exploited for the construction of building, road, embankment and dam in the region. The same formations are considerably jointed and fractures might be considered as potential reservoir horizon for the accumulation of hydrocarbon.

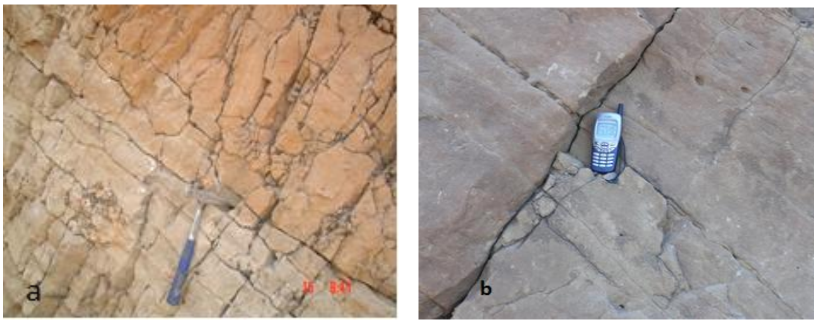

Figure 9: a,) Thick bedded Khewra Sandstone, b) Massive bedded Tredian Sandstone

5.7 Fireclay and Shale

Fireclay is a kind of clay capable of resisting intense heat, used for making firebricks, furnace linings, drain and decorative tiles; pottery; ceramics; and flue liners, cement, sports and hobby uses; and liners and caps for landfills, ponds, and oil and gas wells. It is commonly associated with the upper part of the Nagri Formation and in the lower parts of the Dhok Pathan Formation both in the Marwat-Khisor ranges. Laminated to thin bedded, dark gray to blackish gray to black carbonaceous shale of thickness 50m present in the Sardhai Formation making potential source horizon of hydrocarbon in the region as well(Fig.10, a, b). The Fireclay deposits are also seen at different places of thickness ranging from 1 to 4m in the Jurassic Datta Formation in Khisor Range near southwest of Paniala.

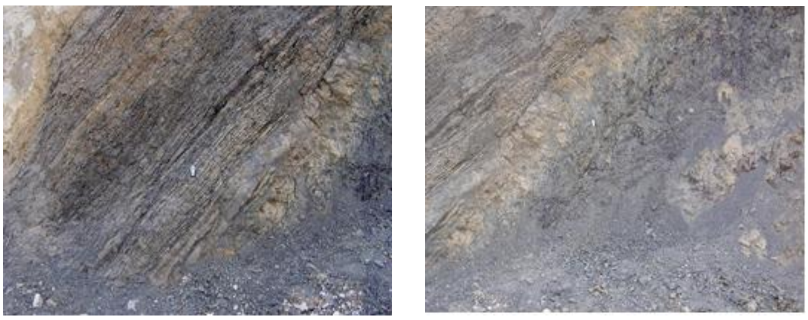

Figure 10 a, b: - Showing blackish shale along with interbedded sandstone beds in the Sardhai Formation

5.8 Coal Deposits

In the study area towards the northwestern terminus of the western Khisor Range some fair coal deposits are present southeast of Paniala Village in the Datta Formation of Jurassic. The outcrop of Datta Formation is confined to the northern limb of Paniala Anticline in the Gori Tang Nala. At this

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locality the coal beds is more than 01 m thick. Local coal mine along with mined out coal heap is located in the (Fig.11).

Figure 11:- Showing coal mine located southeast of Paniala Village.

5.9 Aggregates

Natural aggregates include sand, gravel, and crushed stone. Aggregates are composed of rock fragments that may be used in their natural state or after mechanical processing, such as crushing, washing, or sizing. Recycled aggregates could be used in crushed Portland cement concrete in civil structures and superstructures. It is also used in crushed asphalt pavement in road construction and resurfacing; general uses in building construction; mass concrete; concrete block and slabs; dams and backfill/bedding. In the study area all the major streams near south of Paniala, towards the frontal escarpment face of the Saiyiduwali Anticline, Bilot, Dhupsari and Mall Khel areas are filled with good quality of aggregates.

Figure 12:- Showing cobble, boulder gravels aggregated deposits in the nalas.

5.10 Uranium Potential Horizon

The older rocks including the Permian horizon of Nilawahan Group and Triassic sequence will be prospected for the occurrences of Uranium minerals as the depositional environments are suitable like fluviatile environment where uranium minerals are reported in the country. The following formations are appropriate for the occurrences of desired minerals.

5.10.1 Warchha Sandstone

The Warchha Sandstone of Permian is proposed for detailed foot radiometric survey and field rock sampling. This sandstone is exposed throughout the Khisor Range, particularly in the Saiyiduwali,

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Dhakki and Dhupsari areas. As the name represents, it is predominantly composed of fragile, soft medium to coarse-grained sandstone. The sandstone is massive and red to chocolate brown, and cross-bedded. The lower part of the sandstone is coarse while the upper part is fine and occasionally interbedded with shale. The mass of the sandstone body comprised of fine to coarse fragments of the pre-existing crystalline basement rocks and showing upward fining depositional environments of continental origin. The shale is soft, thin bedded and occasionally flaky, brownish to dark and partly chocolate brown. The formation is 136m thick in the Khisor Range (Fig. 13).

Figure 13: Photographs showing massive red to chocolate brown Warchha Sandstone.

5.*10.2) Triassic Tredian Sandstone*

The Tredian Formation is basically a non-marine horizon exposed towards the western Khisor Range. It is comprised of sandstone and shale. The sandstone is whitish gray to weathering gray, non-calcareous, soft, fine to coarse grained, micaceous, medium to thick-bedded, cross-bedded and shows different colors. The shale is gray to greenish gray, soft, laminated to very thin bedded (Fig. 14). It is 85m thick in the study area. The formation is environmentally suitable for the occurrences of radioactive minerals.

Figure 14. Photographs showing thick to massive bedded sandstone of Tredian Formation near Paniala.

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6. DISCUSSION

The mineral and power generating industry of the country is desired to be developed at the level of advance countries. There are potential prospects of minerals and raw material in the country and its current and future prospects and potentials seem encouraging. Pakistan has huge reserves of phosphate, glass sand/silica sand, building stones, oil shale, dolomite, travertine, rock salt, clays, and gypsum, in addition to a promising prospecting of metallic minerals such as copper, manganese, chromites, iron and gold. The reserves of radioactive minerals like uranium, thorium, and zircon are also present in the country. The Siwaliks sequence of the Khisor Range occupied the north and northeastern flank of the range could be exploited for the exploration of radioactive minerals like uranium.

The role of Geological Survey of Pakistan, Pakistan Minerals Development Corporation, Oil and Gas Development Company Limited, Federal Administrated Tribal Areas Development Authority and Pakistan Atomic Energy Commission is playing a vital role in the exploration and prospecting of ores and minerals commodities in the country, but it is necessary to be created a National Minerals Exploration and Extraction Operations Organization to execute the necessary measures for the exploration and mining of minerals throughout the country. So a committed setup with systematic and advance exploration approach which will undoubtedly lead to significant new discoveries and production is needed. The Khisor Range is the outer extension of the Trans-Indus ranges comprise of huge reserves of several valuable minerals and industrial rocks and raw materials of economic importance could be utilized in the construction and production industries of the country. The study area especially the western Khisor Range subdivision of the Trans-Indus ranges is a south-vergent; east-west oriented a prominent structural province facing to the southward into Himalayan foreland deep.

The range is characterized by east-west oriented, local to mega scale anticlines and synclines structures. Most of the fold structures are asymmetric to overturn and dominantly south facing. The frontal periphery of the Khisor Range is defined by a latest partially developed thrust fault named as Khisor Thrust. The structural development of the Khisor Range is commonly attributed to southward heading thrust transferral system along the basal detachment horizon located at the base of Cambrian Khewra Sandstone. Along this detachment horizon the Khewra Sandstone has been thrusted over the recent alluvium and boulder bed deposits. Major structures developed in the Khisor Range are associated to this thrust fault as fault-bend and fault propagation folds. These structures are more valuable for the construction of structural traps for the hydrocarbon accumulation perspective at the subsurface level.

The Khisor Thrust sheet is primarily comprised of the shallow marine rocks of Paleozoic to Mesozoic ages which are laterally extended along the range. The stratigraphic outline of the Khisor Range is considerably comprised of relative rock sources favourable to construct suitable setting for hydrocarbon potential and mineral and material for industrial use. The existing structural style and stratigraphic scaffolding of the Khisor Range support that this area is significantly related for the hydrocarbon research, as all the pre-requisites are available for the exploration of hydrocarbon. The stratigraphic sequence along with pertinent structural geometries suggests an imperative petroleum system comprised of potential source, reservoir and seal rocks for the oil and gas generation and accumulation. Thick formations of the valuable minerals/industrial material extended for more than 40 km along the range could be explore and utilized.

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7. CONCLUSIONS

The Khisor Range subdivision of the Trans-Indus ranges is comprised of imperative structures and stratigraphic horizons could a lot be contributed in prosperity of the nation. The strata comprised of the entire prerequisite essential for the accumulation of Oil and Gas including desired rocks and structures. The outcrop structural geometries are looking much promising to be constructed structural traps in the subsurface level for the accumulation of petroleum. So favourable structural setting along with suitable stratigraphic framework is in hand for hydrocarbon potential in the area.

The study area is thoroughly comprised of resource of raw material could be utilized for the manufacturing of Portland cement, ceramic industries and variety of construction projects for the construction of superstructures in the country. Huge and excellent quality reserves of limestone, is available in the Zaluch Group rocks. Thick to blocky bedded, substantial quantity of good quality of dolomite is available in the Jutana and Kingriali formations. Good quality silica sand, gypsum and coal is available in the Khisor Range. All the minerals and material of industrial use and they could be utilized as such or after some processing in various industries for manufacturing of products generates raw materials and minerals.

8. ACKNOWLEDGMENT

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