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GEOLOGY AND ECONOMIC SIGNIFICANCE OF TERTIARY ROCKS, KHORWARI SECTION, SURJAN ANTICLINE, THANO BULA KHAN, SINDH.

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Abstract

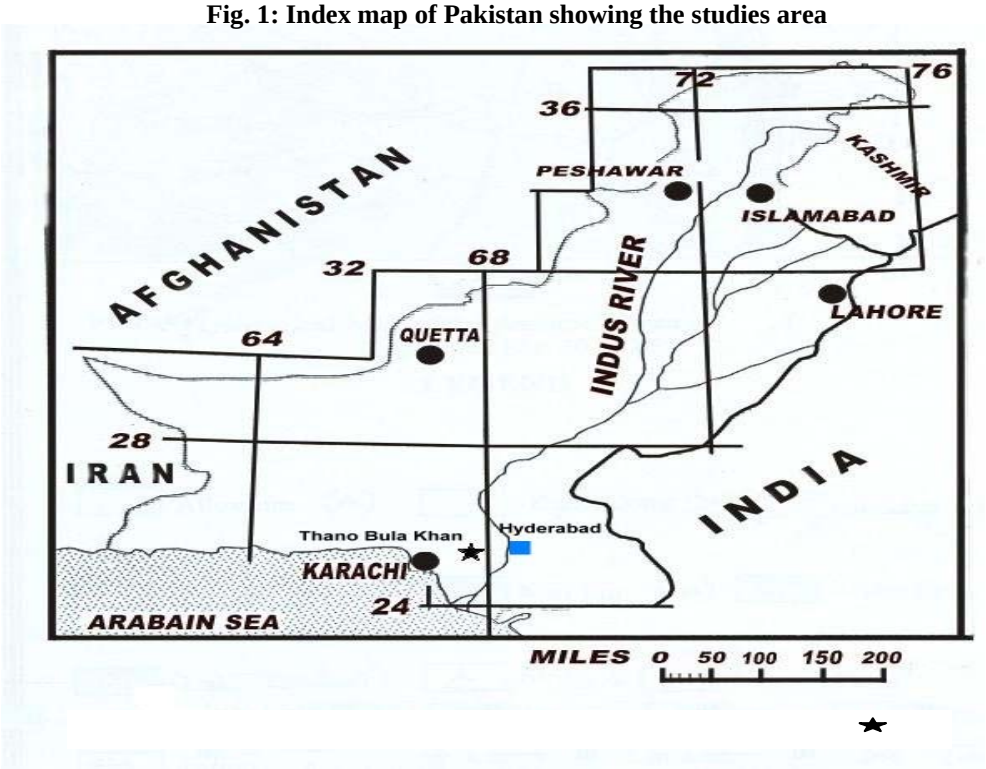
The Tertiary rocks ranging from Eocene (Laki Formation) to Pleistocene (Dada Conglomerate) in age are well exposed at the eastern flank of famous Surjan Anticline, district Jamshoro, Sindh, which in past remained focus for hydrocarbon exploration. In the present study, regional geology, including stratigraphy, structure, basinal division and tectonics of the studied area is discussed. While for the economic importance of the rocks both the flanks of the anticline were studied in detail. Stratigraphic studies were carried out on eastern flank. For achieving this target an ideal section at Khorwari Nala, from the core of anticline, was measured. The rocks are of mixed lithology of clastic and nonclastic, and shallow marine to non-marine origin. The clastic rocks are composed of shale, clay, sandstone and coarse grained sandstone while the nonclastic rocks are composed of limestone, dolomitic and arrenaceous-limestone. The possible lithological divisions on the basis of facies variations are also made. Two formations i.e. Gaj and Dada are already exposed around the Thano Bula Khan but are reported first time from the Khowari Section of the area. Preliminary hydrogeological studies were also conducted to ascertain surface and ground water conditions. Economic potential of minerals and rocks present in the area have also been discussed.

Keywords: Geology, Tertiary Rocks, Surjan Anticline, Sindh.

1. Introduction

The area of study lies 20 km southeast of Thano Bula Khan near the television boaster and at the eastern flank of Surjan Anticline in the Khorwari Nala named after a local Khor tree and is about 58 km southwest of Hyderabad and 118 km northeast of Karachi **(Fig. 1).**

Fig. 1: Index map of Pakistan showing the studies area



The area of research could be easily approached by the main road leading to Thano Bula Khan from Super Highway. Then four wheel drive vehicles can lead to the section in all favorable weathers. The ideal season for carrying out the geological work in the vicinity of Thano Bula Khan is recommended from November to March. Geologically the area of investigation lies in Survey of Pakistan, Toposheet No: 35 O/15, between Latitude 25° 19' 08'' to 25° 21' 39''N and Longitude 67° 51' 30'' to 67° 56' 56'' E **(Fig. 2).** The lithological units of various rock have common occurrence of mega-and micro-fossils. At places the rock units show much abundance of fossils and some times they become coquina. The ages of the formations in present area on basis of fossil have also been assigned by Hunting Survey Corporation, 1960 hereafter HSC, 1960. Six formations are exposed in the studied area. Laki Formation (early Eocene), Tiyon formation (middle Eocene), Nari formation (Oligocene), Gaj Formation (Miocene), Manchar Formation (upper Miocene) and Dada conglomerate (Pleistocene). The main purpose of this research work was to mark the lithological variations and contact relationship in existing formations and to prepare a detailed lithological columnar section. The two formations (Gaj Formation and Dada conglomerate) which are already exposed in the vicinity of Thano Bula Khan but are reported for the first time in this present work **(Fig. 4).**

Fig. 2. Geological map of the studied area a part of Topographic map No. 30 0/15

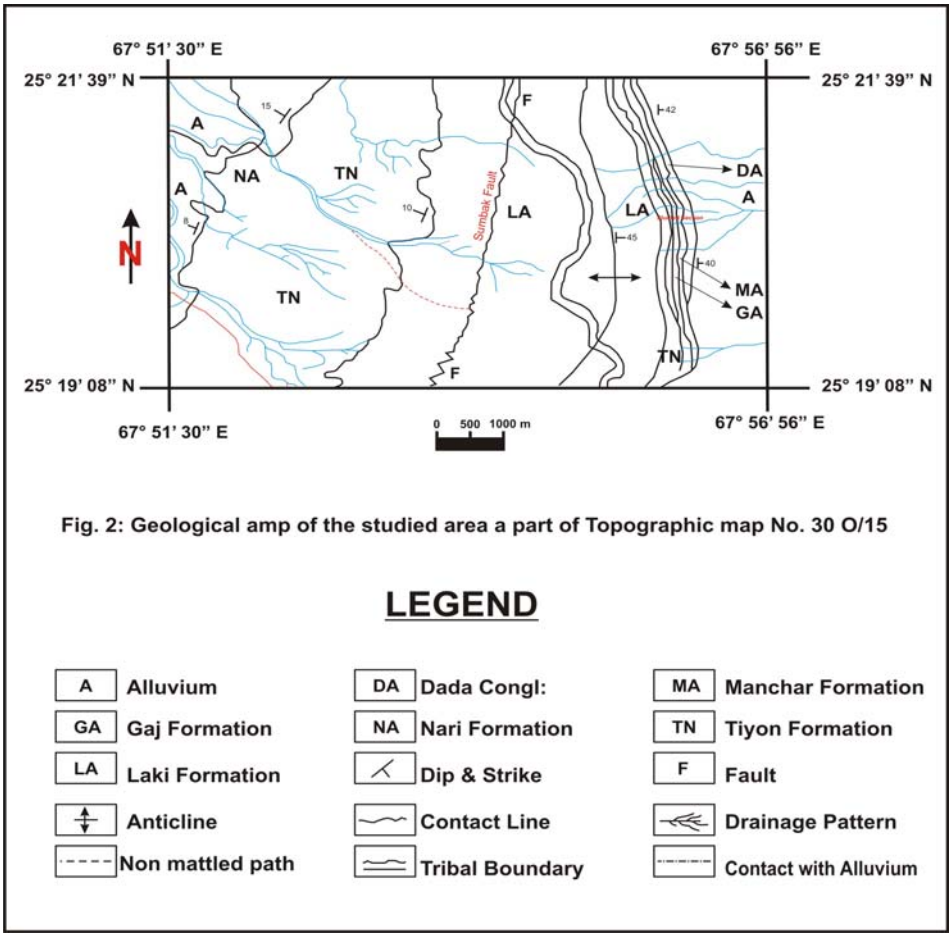
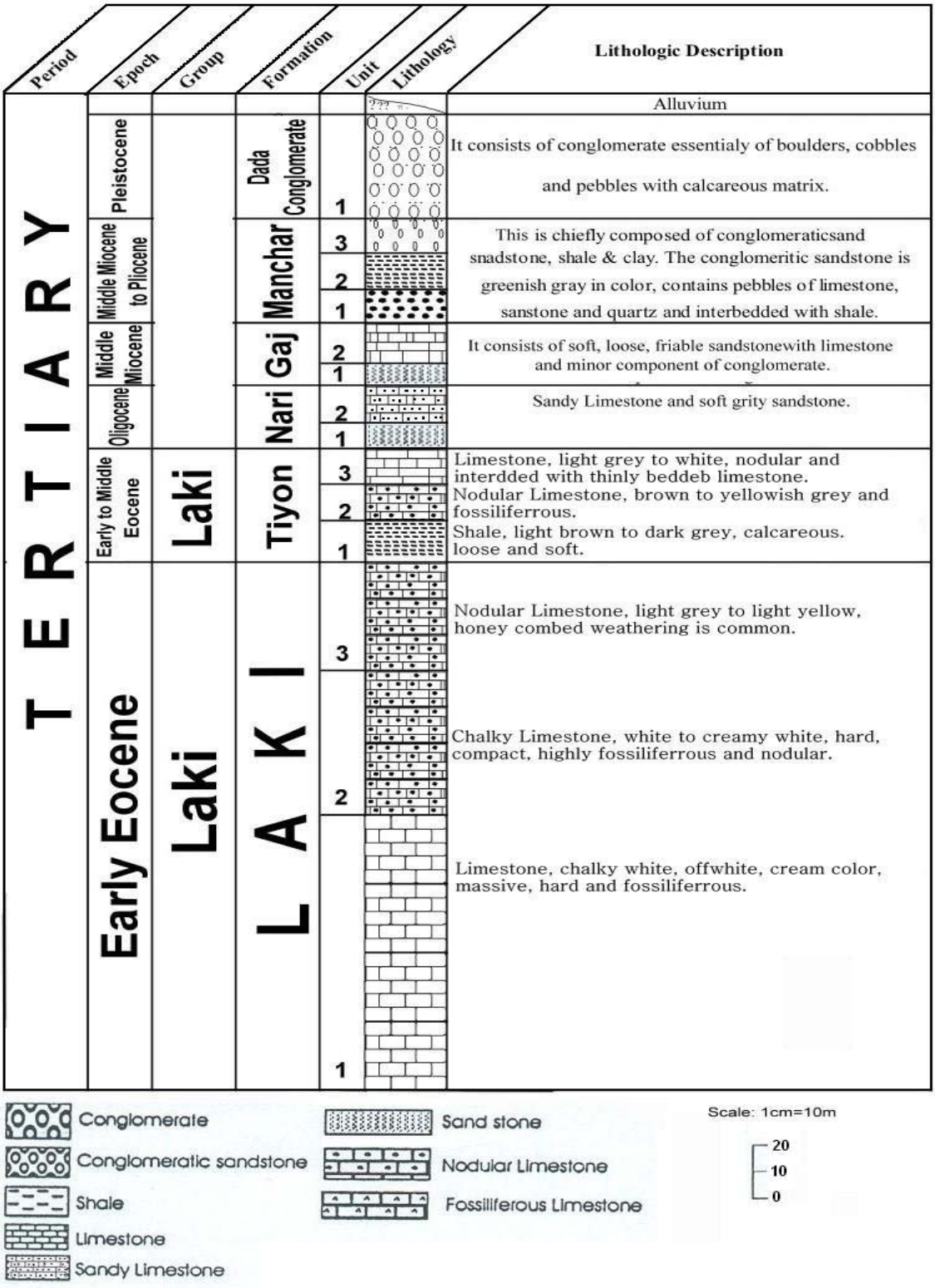


Fig. 4. Stratigraphic section showing the lithological divisions



Physiography

The study area has distinct physiographic unit namely the hill range of Surjan. The general topography of the area is that of alternate valleys and hills with their long axes in North-South direction. The Surjan Range in the east of Thano Bula Khan comprises of elongated hills located with-in Thano Bula Khan Valley. These hills reach a maximum height of about 393 meters. The hill ranges within the mapped area is fairly dissected by torrent channels. The eastern slope of Surjan Anticline is steeper as compared as to the western slope. In the studied area mainly onion type of erosion is common. The major drainage pattern of the area is radial and parallel type, controlled by structures and nature of the rock units exposed.

The area has arid climatic conditions characterized by high temperature, very low precipitation and less humidity. The average temperature in summer season is 90°F / 32°C and in winter season is 73°F / 23°C. The area receives average rainfall of 125 mm annually.

Wheat, Juwar, Bajra, Mustard and all types of vegetables are widely grown on the irrigated land. The habitation is generally confined to water resources.

Vegetation is not common due to scarcity of water, poor quality of soil and unfavorable climatic conditions. The following plants species are commonly found in the area.

S. No.	Local name	Botanical name
1.	Babur	*Acacia Arabica*
2.	Khor	*Acacia Senegal*
3.	Kandi	*Prosopis Specigera*
4.	Thuhar	*Euphorbia spp.*
5.	Jhangli Ber	*Zezyphers Namularia*
6.	Aku	*Calatiopis spp.*
7.	Khabar	*Cappris Aphyla*
8.	Nim	*Aristoda spp.*

2. Materials and Methods

The mapping was carried out directly on 1:50000 scale. The aerial photographs on 1: 40000 scale were used for mapping as well as detection of structure. The section measurements for the thickness control of formations in the studied area was carried out by three methods i.e. Jacobs Staff method, Slope distance method direct method was used for the measurement of thin layers. To get the good vertical columnar section offsets were also used during the measurements.

Tectonics

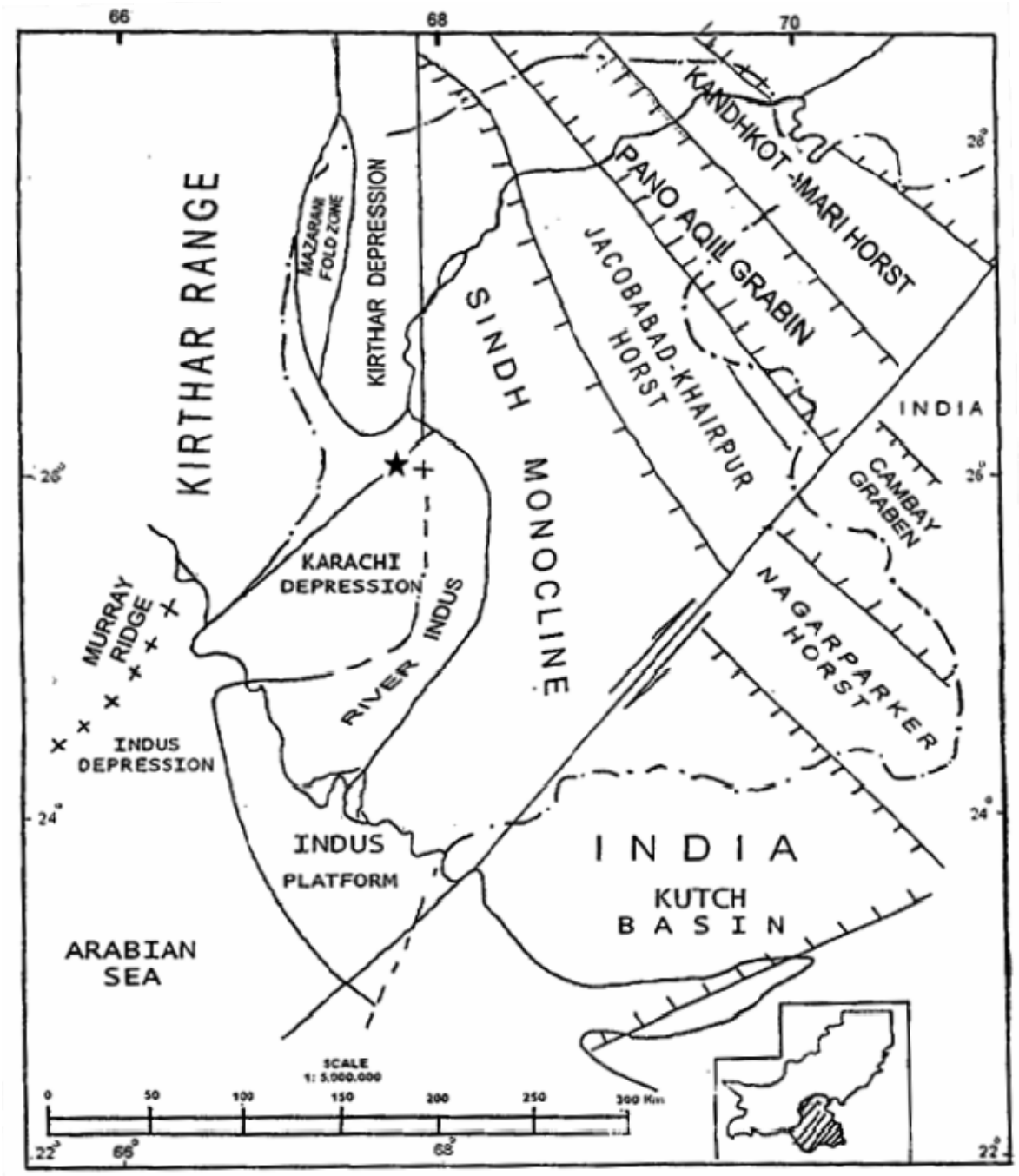
In global tectonic perspective, Pakistan is situated at junction of three lithosphere plates, the Indian plate, Arabian plate, and Eurasian plate (Kazmi and Jan, 1997). The Indus Basin is situated on the northwestern corner of the Indian plate. The Indian plate after separating from the African Plate during Jurassic-Early Cretaceous started drifting in the northeast direction and collided with Eurasian plate in Paleocene - Early Eocene. The collision is characterized by continent to continent collision, obduction and thrusting and is considered the proto type Alpine-Himalayan orogeny (Powell, 1979).

Pakistan comprises of two sedimentary basins, the Indus Basin and Balochistan Basin. These basins, are separated by a major fracture zone (axial belt), collectively occupy an area of about 8,28,000 sq. km (Shah, 1977). The Indus Basin is divided into large longitudinal oriented parallel tectonic features, which are further subdivided by sub-longitudinal basement highs and transverse uplift into smaller tectonic zones.

The main tectonic features of the Indus Basin are the plateform, and the fore-deep, which comprises depressions i.e. an inner fold zone and the outer fold zone. The platform, known as the Indian plateform, coincides with the present Indus plain and is subdivided into the Punjab monocline, Sukkur rift zone and Sindh monocline. Lower Indus basin, includes the Sukkur rift zone, Thar platform, Karachi trough, Kirthar fore deep, Kirthar fold belt and off shore Indus **(Fig. 3).**

During the Paleo-Pliocene times, Himalayan progeny (continental to continental collision between Indian and Eurasian plates) gave rise to the tectonic pulses generating compressional forces in northeastern direction, which folded the sedimentary layers and gave rise to the ranges in Sindh, including the Surjan Range which is an asymmetrical, doubly plunging anticline.

Fig. 3. Tectonic map of lower Indus Basin (after Raza *et al.*, 1990) showing the study area



Stratigraphy

The area is mainly composed of detrital and non-detrital rocks varying in age from Early Eocene to Pleistocene. The major constituent of the area is limestone, which represents the non-detrital type of origin whereas detrital sediments belong to shale and sandstone. In the reported area the formations dip steeply (40°– 45°) to eastern flank and dip gently (5°- 8°) to western flank. The general trend of the strike throughout the area is in northeast direction. The geological set up of the area from bottom to top is as under:

Formation	Age
• Dada conglomerate	Pleistocene
• Manchar Formation	Upper Miocene
• Gaj Formation	Miocene
• Nari Formation	Oligocene
• Tiyon formation	Middle Eocene
• Laki Formation	Lower Eocene

Laki Formation

The term Laki Formation was introduced by Cheema *et al*. (1977) for the Laki group of the (HSC, 1960) and the Laki series of Noetling (1905). Blanford (1876) included series of massive limestone containing *Alveolina spp.* fossils in the Kirthar and mapped it as a lower part of the Kirthar series. Vredenburg (1906) included the Laki Limestone and Meting shale in the Laki Series of Sindh. Nuttall (1925) subdivided the Laki series as under which is widely accepted; Laki limestone, Meting shale, Meting limestone, Basal Laki laterite.

Within the study area only the Laki limestone unit is widely exposed and is characterized by its nodularity. It consists of mostly limestone with minor amounts of marl and calcareous shale. The nodular limestone is mostly hard, compact and massive. The basal part of the Laki limestone unit is massive. On the basis of lithological variations this unit is further subdivided into following three units; Massive limestone, Chalky limestone, Nodular limestone.

The lower part of the Laki is the medium to massive bedded, hard and is highly fossiliferous. The occurrence of larger forams belonging to *Alveolina spp.* is abundant. At the bedding planes and fractures, calcite veins are commonly present. The middle unit of Laki limestone is chalky limestone, which is white, creamy weathers light grey, brownish white and dark grey in colour. It is medium bedded, hard, compact, fossiliferous. This unit also contains the abundant larger foraminifera in which *Alveolina oblonga*, *Numulites sp.* and *Assilina sp*. Besides this, *Gastropods* and *Bivalves* are also reported.

The upper unit is nodular limestone. The Nodules of this unit are ranging upto five inches diameter. Nodular limestone is light grey, light yellow in color. It weathers dark grey and yellowish brown. The Nodules are not hard. The Ferro-magnesium nodules are present at the contact of Laki and Tiyon formations. In some places limestone shows solution cavities and honeycombed weathering. The burrows in the limestone are also present. The thickness of this unit in the study area is about 229 meters. The base of the Laki Formation is not exposed but its upper contact is conformable with Tiyon formation.

The age of Laki Formation on the basis of fossils was assigned as Early Eocene. (Haque and Khan, 1956), (Haque, 1962), and HSC (1960) has reported mega as well as microfauna and Iqbal (1973). The present study also confirms the same age to the formation on the occurrence of the following selected species of fauna.

Larger Forams

Alveolina oblonga, Assilina granulosa. A. pustulosa., Lockhartia hunti var. pustulosa. Flosculina globosa , Operatorbitolites douvillei , Fasciolites oblanga , Linderina brugesi Dictyo conoides Vredenburgi.

Gastropods

Natica sp. indet , Certhium sp. indet , Conus sp. indet.

Lamellibranchia.

Area sp .indet , Chlamys senatoria.

Echinoidea

Ambly pygus subrolunds, Echinolampas numilitica.

Tiyon formation

The Tiyon formation was mapped as a part of Kirthar series by Vredenburg (1906), and

it has some paleontological and lithological similarities with Laki limestone unit. This unit (Nodular limestone of Tiyon formation) is separable from Lucky limestone having smaller nodules and possessing abundant occurrence of Bivalves. This part of Kirthar series of Vredenburg (1906) was mapped as a separate unit and named as Tiyon formation (HSC, 1960). This name was derived from the Tiyon Nai or stream which flows from the western flank of the Laki range, where a type section for the formation is designated. During the present research the type section was visited and it is noted that the name Tiyon is mis-spelled and mis-pronounced. Actually this name comes from Teyoon, a name of hindu person. The nai which flows through the western flank of Laki range and drains in a small tributaries known as a Teyoon Dhoro. It is designated as a type locality of Tiyon formation.

The Tiyon formation around Thano Bula Khan is not well exposed but at the Khorwari section it is well exposed on the both flanks of the Surjan Anticline. The maximum thickness at Teyoon Dhoro is 76 meters and it attains laterly a few meters and has been eroded on the eastern flank towards south. The Tiyon formation in the study area dips 35° SE. Generally striking north-south and south-east. The thickness of the Tiyon formation in this area is about 39 meters. The lower contact of Tiyon formation is conformable with underlying Laki Formation and its upper contact is unconformable with overlying Nari Formation.

The Tiyon formation in this locality is divisible on the basis of lithological variation into three units i.e. shale, nodular limestone and limestone. The shale is light brown in color, it weathers to brownish color. It is loose, and calcareous in nature. The limestone is white to creamy in colour, which weathers to brownish color. It is highly fossiliferous and full of larger forams.

The Lower unit of Tiyon is soft, nodular limestone interbedded with minor partings of calcareous clay and marl. In comparison to the Laki limestone the nodules of Tiyon formation are smaller. Some hard, compact beds with iron concretions are commonly present. The top unit of the formation is also nodular but it is more compact and hard. The mega fossil occurrence is less than that of the basal unit. It could be differed from other nodules of limestones by showing the rough surface nodules with orange yellow patches.

Early to middle Eocene age (Late Ypresian to Early Lutetian), on the basis of following different fossils (HSC, 1960), has been assigned to Tiyon formation.

Larger forams

Assilina davisi, A. spp., A. exponens, A. namillata, A. spinosa, A. granulose Alveolina sp., A. oblanga, A. ovicula, A. ovoidea

Gastropods

Turritella sp., Globularia sigaretina , Velates perversus

Lamllibranchia

Ortrea sp., Corbula (Bicorbula) subexarata., Venricardia sindensis.

Nari Formation

The "Nari series" of Blanford (1876), was named as Nari Formation by Williams (1959). He designated the type locality of it in the Gaj River, in the Kirthar Range, district Dadu, Sindh. Nari Formation is widely exposed in small outcrops around Thano Bula Khan which consists of predominantly crystalline limestone which is orange yellow to yellowish brown in color, thin to thick bedded and massive. Sandstone beds are also exposed which are cross bedded, medium to coarse grained and calcareous. In some places mega fossils (Mollusca) and gypsum partings are found. Beside this the calcareous shale together with thin bends of siltstone and argillaceous limestone containing fossils is also recorded.

In the study area the Nari Formation dips 50°-53° SE striking NE is very much restricted. It is exposed only from 5 to 8 meters and it consists of crystalline limestone, calcareous sandstone and shale. The limestone is sandy, yellowish buff, yellowish brownish or camel color. It weathers usually yellowish brown to dark brown showing some dark brown patches on the surface.

The sandstone bed is dark brown to greenish grey, but weathers rusty, yellowish

brown. It is fine to medium grained. The shale is khaki, yellow and dark in color. It is soft, fissile, sandy and gypsiferrous. In this area it overlies unconformably the Tiyon formation and is transitional with overlying Gaj Formation. The age of the formation (HSC, 1960) on the basis of different collection of larger foraminifers and mollusks is decided as Oligocene.

Larger Forams
Alveolina delicatissina., Amphistegina sp. Assilina spp. A. granulosa ,
Lepidocyclina dilatata.,Nummulites intermedium., N. Fichteli., N. vascus.
Lamellibranchia
Ostrea subangulata, Nucula sp.
Gastropods
Telescopium char pentieri.Notica sp.

Gaj Formation

The term Gaj series was first introduced by Blanford (1876, 1878, 1879) for sequence of shell and sandstone with subordinate limestone (Cheema *et al.,* 1977). Williams (1959) referred this series as Gaj Formation which is synonymous to lower and upper Gaj (Pascoe, 1963), estuarine passage beds, lower part of "Sibi group" and "Urak group" (H S C, 1960). The type section of the formation is chosen in the Gaj River, district Dadu, Sindh. At the type locality it consists of shale with subordinate sandstone and limestone. The shale is variegated, greenish grey and gypsiferous. The sandstone is brown, greenish grey, calcareous, ferruginous and cross bedded. The limestone is brown or yellowish white argillaceous and fossiliferous. In some places minor pebbly conglomeratic beds are also present.

The thickness of Gaj Formation in the study area is about six meters. It dips about 40° SE and striking NE. Here, it consists of sandstone, limestone and shale. The sandstone is greenish grey to olive grey. It is soft, loose, friable, fossiliferous calcareous and cross bedded. The limestone is mostly orange to yellowish brown in color and usually weathers brown or pale yellow. It contains ferruginous nodules. The limestone is white, creamy white in color and it weathers blackish white. It is medium to thin bedded and rough surfaced containing larger forams. The shale is greenish grey in color. Minor beds of clay and pebbly conglomerate are also present.

The upper contact of the Gaj Formation is conformable with Manchar Formation and its lower contact is transitional with Nari Formation. The age of the Formation on the basis of mega and micro fauna (HSC, 1960) has been decided from Early to middle Miocene

Larger Forams
Austrotrillinio sp. indet, Cyclocypeus sp. Dentalina sp. Gypsina sp. Lepidocyclina blanford., Operculina sp. Textularia sp.
Lamellibranchia
Ostrea subangulata, Dosinia sp.
Gastropods
Turritella., Cerithium sp. Globularia sp.
Echinoidea
Clypeasper depressus.

Manchar Formation

The Manchar/Manchhar Formation was named by Blanford (1876) after famous Manchar lake which is mentioned as the type section exposed in the west of Manchar lake near Sehwan, district Dadu, Sindh for proposed, "Manchar system" of Williams (1959).

The Manchar Formation is well exposed in Sindh and attains maximum thickness in Gaj River section where its thickness is about 1365 meters (HSC, 1960). The thickness of the formation decreases laterally and some times pinches out.

In the study area, the Manchar Formation dips 83° to 85° and striking NS direction. Sandstone facies predominates in the lower part of the formation whereas the shale becomes thicker in the upper part. It mainly consists of pebbly conglomerate, very coarse to coarse sandstone which becomes gritty at places, shale and subordinate marl. The conglomerate consists of rounded to sub-rounded pebble size. The pebbles mostly are of soft sandstone, limestone and quartz. The diameter of the pebble ranges from 1-5 cm. The sandstone is greenish grey to olive grey in color which weathers yellowish grey or greenish grey. It is medium to coarse grained and becomes gritty at some places. The shale is red,

brown or brick red in color. Weathering color is as same as fresh. It is soft, loose and inter bedded with sandstone. The thickness of the Manchar formation in this locality is about 39 meters. The upper contact of Manchar Formation with the overlying Dada conglomerate is gradational and its Lower contact with Gaj Formation is transitional.

Well preserved organic remains are common in the formation and well preserved fossilized mammals bones and teeth of mammals together with silicified trunks and their traces have been collected from the conglomeratic sand stone beds. According to the vertebrate fossil record (HSC, 1960) has given Middle Miocene to Pliocene age to this formation.

Characteristic Vertebrate fossils are as under:

Amphicyon sindiensis., Dinotherium sindiensislyd.. Crocodalus palaeimdicus., Khinocervos sivabensis., Mastodan latidens cliff., Hipparian punjabiensis lyd. Besides, the petrified wood fossils are commonly found in the studied area

Dada conglomerate

The name Dada conglomerate was introduced by HSC (1960) from the Dada River, south of spintangy railway station, Balochistan, for the upper part of the "Siwalik series" or "Manchar formation" of Blanford (1879). This formation is well exposed in the Gaj River, district Dadu, Sindh. It attains maximum thickness here as compared to other localities of lower Indus Basin. It was not reported previously in the study area. In the current study it is believed to be the lateral extension of the Dada conglomerate formation of the type locality. It dips about 40° striking NS. Mainly it consists of poorly sorted, sub rounded to rounded boulders, cobbles and pebbles with subordinate occurrence of very coarse grained sandstone. In the upper part of Dada conglomerate, brick red clay is present which gives it red hue. The cobbles and pebbles are up to 25 cm in diameter. They have probably been derived mostly from pre exposed formations i.e. Kirthar, Nari and Gaj formations. Thickness of Dada conglomerate in this section is about 35 meter. The lower contact of Dada conglomerate is conformable or gradational with the Manchar formation and its upper part is commonly covered with recent to sub-recent deposits. The Dada conglomerate does not contain any fossil, but on the basis of previous record (HSC, 1960), it is supposed to be Pleistocene in age.

Hydrogeology

Climate of the area is broadly classed as hot and arid. The studied area is a small part of Surjan structure which is also included in an arid region, hence the temperature remains high. Very low precipitation and less humidity prevails in the area, therefore the area is sparsely vegetated. Mean annual rainfall in the area is 150 mm with a variation of 25 mm. The rainfall period is very limited and mostly falls in summer season / monsoon from July to September. Both the intensity and volume in monsoon are high and can not be fully utilized. Due to un-certainty of rainfall, farmers normally use lesser input to reduce the risk of loss in the event of drought. Short periods of intensive rainfall in areas of catchments with large areas of bare rocks and high dips of mountain limbs result in high run-off from the ranges. Moreover, the steep gradient of beds of streams ensure that there is flow for fast and thus only a short period following rainfall providing little opportunity for infiltration of water into sediments / rocks of ranges. In flatter parts of the area, flow velocities of water are slower, therefore streams deposit sediments and lose water by infiltration into subsurface. This infiltrated water sustains aquifer in river alluvium, unconsolidated recent sediment and older limestone and sandstone formations.

Aquifers are mainly recharged by major *Nai/ Nalas / Dhoros*. All these *Dhoros* / tributaries are non-perennial, dry and originate from different mountains. The main agent of erosion appears to be rain water that washes soil down the steep slopes of the mountain. As a result of this, soil of the plain area are either poorly developed or entirely absent from the great majority of the area. There are the few springs in the area but they give out very small quantity of water. These springs give information about the presence of deep aquifers. Yield of the springs diminishes during dry season and with the advent of monsoon their yield increases almost every year.

There are no surface water resources to recharge aquifers, other than annual precipitation. Therefore, rainfall has only been considered the recharge to aquifers in the area. Due to non-availability of surface water, there is no other alternate than to exploit subsurface water to meet all water requirements of the area. Groundwater has remained main supply source of people for domestic and other purposes. Quality and quantity of groundwater varies from place to place. Generally, groundwater is of fair quality at shallow depth (<30m) and brackish-to-saline at deeper depth (>30m) in the area. Groundwater samples taken from three wells at a depth of about 15-20 m were found to be of fair quality with EC = 1500-1700 µS/cm , TDS = 990-1100 mg/l and pH = 7.3-7.5.

The run-off mostly is quick to leave the watershed/catchment areas and consequently stop a few hours after rainfall ceases. Water accumulates in natural surface water reservoirs which are mostly in depressions, and gradually infiltrate subsurface also. As the surface water is non-existent as far as rivers and streams are concerned; rainfall and run-off is the only source of recharge to groundwater aquifer system, from where it is pumped out and used for all purposes in the area. Main streams and channels are originating from hill ranges of Thano Bula Khan, dissecting the major structure of the hill ranges and eventually join the main tributaries which flow in north-south direction. At some places in the study area the streams flow in west to east direction also. All streams/channels are dry during most part of the year and flow for a little time during rainy season only. The rainfall and flowing streams/*Dhoros*/channels is only source to recharge aquifers through infiltration. Therefore, there is a possibility to detect fresh water aquifer/ formation along these *Nain /Dhoros* in the area.

There are some dug (open) wells, tube wells and ponds in low lying areas. Surface and ground water is non-existence in some parts of the area on the eastern side of Surjan Anticline and people are bound to travel far away from their houses in search of water for their basic needs. Shortage of safe drinking water is one of the key problem faced by local communities in the area. However, it is recommended that geophysical resistivity survey may be carried out to explore and exploit the fresh water reserves in the area. Water level decreases in dry / summer season, consequently affected the quality of groundwater. Some times drought season persist for couple of years and reduce quality and quantity of groundwater in the area. As there is no permanent source of recharge in the area, the quality and quantity of groundwater is also reduce with the high rate of withdrawal of water from tube wells / open wells.

Economic Geology

Economically the study area is not so promising for economic minerals/rocks. While for achieving this target both the sides of the flanks of the Surjan Anticline was thoroughly surveyed and some of the minerals and rocks are found and being used economically as discussed below.

Celestite

The minor deposits of celestite occur nine miles east of Thano Bula khan along the Surjan Sumbak fault plane. The enrichment is not uniform throughout the fault plane but it is found in veins, the thickness of the veins varies from the few inches at surface, to six feet at depth. The quarry has been abounded here due to depletion of the deposit. Minor mineralization zone of non economic significance also exist at places along this fault. The quantity of this deposit is of low grade and is less than Niamwari Dhoro mine. It is also present in little amount along the extension, Surjan-Sumbak fault in the area under present study.

Limestone

Limestone is present in almost all the major hill ranges in the studied area, it is dominantly in the Laki and Tiyon formations. On the eastern flank of Surjan Anticline, the laki limestone is hard, compact, massive and generally nodular in nature. It is locally used as a source lime. Limestone used in the Portland, cement factories as a flux stone, also used in the building and road construction. Tiyon formation is relatively loose generally thin to medium bedded limestone and is mainly used in the construction of roads. A good quality of Dimension stone belonging to limestone is found in Nari Formation.

Fullers Earth

The fullers Earth is found at the contact of Tiyon and Nari formations and in the depth of 21 meters in Tiyon formation. There are lot of promising areas and about 1 to 3 meter thick beds of fuller's earth are being mined and transported to Karachi.

3. Conclusions

1. Five formations Laki, Tiyon, Nari, Gaj, Manchar and Dada conglomerate are reported in the studied section. Among these Gaj is partly shallow marine and partly non marine where as Mancher is totally fluviatile and rest of the formations are marine.

2. Dada conglomerate is mapped as a separate unit.

3. Structurally the area belongs to famous Surjan plunging anticline attaining the maximum height of 1294 feet. In which chalky limestone unit is a prominent unit through out the axis and is useable for cement factory.

4. The Celestite mineral occurs along the Surjan-Sumbak fault zone which is transported to the local market.

5. The presence of Gaj Formation is also reported first time in present study in the studied section.

6. Three lithological formations, Laki Formation (limestone), Tiyon formation (shale, clay, limestone and marl) and Nari Formation (sandstone) in western flank of Surjan Anticline. In the eastern flank five formations are exposed, which are Laki, Tiyon, Nari, Gaj, Manchar formation with Dada Conglomerate ranging in age from Early Eocene to Pleistocene respectively. The oldest formation is Laki, where as the youngest one is Dada conglomerate on the eastern flank of the Surjan Anticline.

7. The thickness of the Laki and Tiyon formation in the mapped area is 754 ft and 127 ft respectively and the thickness of Nari Gaj, Manchar and Dada Conglomerate is 50, 20,128 and 225 feet respectively.

8. The Surjan-Sumbak fault is on the western flank of Surjan Anticline and runs parallel to the axis.

9. Surface water is non-existence in the area and groundwater is the only source to meet all requirements of life.

10. The quality of groundwater is fair at the shallower depth and brackish to saline at deeper depth in some parts of the area.

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