STRATIGRAPHY AND PETROGRAPHY OF THE JUTANA DOLOMITE, KHEWRA GORGE KHEWRA , JEHLUM DISTRICT; PUNJAB: PAKISTAN.

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ABSTRACT

This paper presents a detailed study of the Jutana Dolomite, exposed in the Khewra Gorge, Salt Range; Pakistan. The work consists of detailed study of stratigraphy and petrogarphy of the Jutana Dolomite. Environments of deposition with reference to the above mentioned salient features are also elaborately discussed.

The Jutana Dolomite was deposited under calm, warm, shallow, and well-oxygenated marine environments. Nevertheless, a part of it was definitely deposited under slightly agitated conditions. Such episodes are indicated by occurrence of oolitic/pissolitic structures in strata exposed at several stratigraphic levels. On the basis of lithology, petrography, and sedimentary structures, the Jutana Dolomite is divisible into three distinct units. This division is particularly very sharp in the Khewra Gorge. The divisions, as recognized in the Khewra Gorge, in order of superposition are:

3. Upper Dolomite .. ..Thick bedded pure dolomite.
2. Middle Shale ....Bluish-gray, maroon, and purple shale.
1. Lower Dolomite........ ... ...Thin bedded, arenaceous, argillaceous, and with oolitic/pisolitic bands at several stratigraphic levels.

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The Middle Shale unit is fossiliferous and contains almost identical faunas as observed in the Middle shale member of the Khussak Formation. On the basis of these faunas, the Jutana Dolomite is assigned a Late Early Cambrian age and is correlated with the dolomite outcrops exposed in the Trans-Indus Ranges, i.e., Khisor Range(west of Indus-Saiduwali) and on the eastern side of the Nilawahan Ravine.

Petrographic studies revealed that the Jutana dolomite is dominantly composed of carbonates (dolomite/calcite), sandy-dolomite, and dolomitic/calcareous sandstones. The dominant minerals present other than carbonates are, quartz, micas, chlorite, and glauconite.

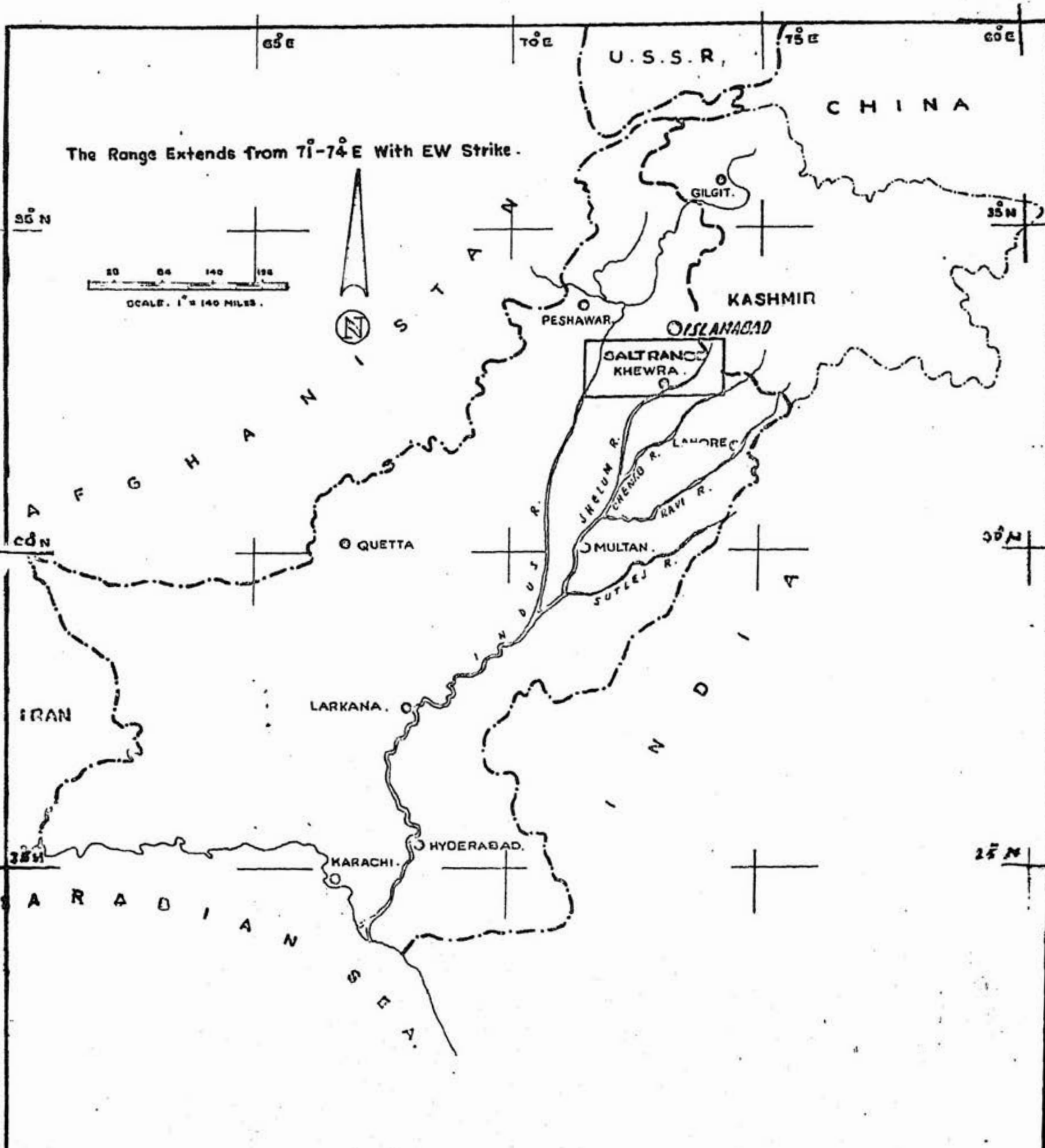
INTRODUCTION

Location and Accessibility

The world famous Punjab Salt Range is located between Latitudes 31°-33° N and Longitudes 71°-74° E (fig. 1) and the Khewra Gorge where the investigations were carried out is located just north of the town of Khewra, between Latitude 32°40'N and Longitude 70°.00' 30'' E. The outcrops of the Jutana Dolomite are exposed on the eastern and western sides of the Gorge, at a distance of about two and half miles from the Khewra Railway Station. The area is easily accessible by a fairweather route along the upstream direction. The Jutana Dolomite stands out sharply from the rest of formations because it forms vertical cliffs and steep escarpments. The creamish-gray and gray colours also sharply distinguish it from the dark gray to black colours of the underlying Khussak Formation, and maroon, purple, and reddish-brown colours of the overlying Baghanwala Formation.

Topography

The Salt Range as a whole, in which the Khewra Gorge is cut, is a flat-topped interlude between the majestic Himalayas in the north and the immense massive Indian Shield in the south. The Salt Range covers a distance of 200 Kms., with persistant East-West strike; the only exception being its abrupt swing in the west where indus separates it from the Trans-Indus Ranges. A change in the strike is also observed east of Baghanwala, where the range almost strikes North-South and then assumes a North-East trend. In Pakistan, Salt Range occupies and enjoys a great geological significance by not only containing salt and gypsum deposits, but also for demarcating the southern boundary of the Potwar Plateau. On the east it is delineated by the Jehlum River and in the west by the Indus River. It is



MAP SHOWING LOCATION OF KHEWRA IN SALT RANGE PAKISTAN seen to rise abruptly from the Punjab Plains in the south and subsequently underlain by the Siwaliks in the north. The average height of the range is 700 to 900 meters, however, the heighest point is reached at Sakessar Where the maximum height is 1525 meters. The entire range is highly folded and faulted and the block faulting is the most conspicuous structural feature of the range. The area of investigation lies in the Khewra Gorge which is a very narrow and swinging one. On either sides of this, the Jutana Dolomite is exposed in vertical cliffs formed by the strata which dip upstream and facilitate close observation and collection of specimens while one walks along the narrow stream.

STRATIGRAPHY

General Features

The Jutana Dolomite, formerly called as the Magnesian Sandstone (Wynne, 1878, and subsequent workers), indicates evidences of being deposited during late Early Cambrian or Early Middle Cambrian times. The formation as a whole shows lithological variation to some extent, and on the basis of this feature it can be divided into a Lower Dolomite and an Upper Dolomite. The two members being separated by a distinct and mapable maroon shale bed. Lower Dolomite which is gray in colour is abundantly arenaceous, and at places contains sandy intercalations. Many sandy intercalations can be noticed and majority of these are 1-2 cm thick. It contains abundant micas and glauconite whereas feldspars are present in minor amounts. Oolitic/pisolitic structures are common.

It is thin bedded; cross bedding, ripple marks, and penecontemporaneous deformational structures are commonly present. The presence of these structures suggests that the Lower Dolomite was deposited under shallow, warm, agitated and well oxidized marine environments.

The Middle Shale bed is bluish-gray and maroon in colour. It is thin bedded and comprises of siltstone, sandstone, and glauconitic sandstone with abundant argillaceous material. This shale bed is of great significance and indicates every evidence of being deposited under conditions during which the underlying Khussak Fomation was deposited. The same faunal content (as in the Khussak Formation) are noticed in this bed. It is because of this shale bed that the entire Jutana Dolomite has been assigned a late Early Cambrian or Early Middle Cambrian age. This shale bed is indicative of deposition under shallow, marine, and weakly oxidizing or euxenic environments.

The Upper Dolomite, which is thick bedded to massive, is cream coloured and contains negligible arenaceous material, except in the very basal part where glauconite-rich arenaceous bands of few inches thickness can be noticed. In the upper part it contains a thick spongy dolomite bed. Oolitic/pisolitic structure are almost absent, except in the glauconite-rich zone where these structures are present. A gastropod has been reported from this part of the Jutana Dolomite, nevertheless,it is almost unfossiliferous (Schindewolf and Seilacher, 1955).

Thus the Jutana Dolomite as a whole shows deposition under shallow, warm and oxidizing environments. The conditions were agitating during the deposition of a part of the Lower Dolomite, nevertheless, they were calm and quite. The calm and quite conditions of depositions are indicated by very thin laminae of shale, present at various stratigraphic levels.

The presence of various structures, characteristic of clastic sedimentary rocks, indicate that the carbonates were slightly transported and then reincorporated. Later on extensive dolomitization occurred which replaced original structure, leavıng behind ghost structures. The oolites/pisolites observed in the dolomite are replaced and are present as the ghost structures.

CAMBRIAN SYSTEM

Late Early Cambrian-Early Middle Cambrian

Jehlum Group

Jutana Dolomite

***Definition, Type Locality, and Regional Nomenclature*:**

The Magnesian Sandstone is the first informal name put forward by Fleming (1852). Wynne (1878) also used the same name. Warth (1891) published chemical analysis of a sample from this formation, showing that the rock is a dolomite. Noetling (1894) was the first to put forward the formal name based on the type locality, and called it the "Jutana Group". The subsequent workers, howevere, continued to use the name Magnesian Sandstons. Later Stratigraphic Code Committee of Pakistan formalized the name as the Jutana Dolomite (1973). Type locality of the formation is Jutana village (Latitude 32° 43'N and Longitude 73° 09'E), located in the eastern Salt Range, Jhelum District, Pakistan. The section exposed in Khewra Gorge can be used as a reference section. The formation constitutes the upper middle part of Jhelum Group.

Distribution: The outcrops of the Jutana Dolomite are prominently exposed in the eastern Salt Range, at Karangal, Diljaba, Chambel, Jogi Tilla ridges and Mount Choll area. Exposures of this formation are also present in the eastern side of Nilawahan, and at Saiduwali, in the south-eastern side of the Khisor Range. Subsurface drilling, recently carried out by Amoco., has revealed it's presence in Karampur well. When traced WNW from Khewra, the Tobra Formation lies successivly on the Lower Cambrian succession, and near Sakesar, the Jutana Dolomite is unconformably overlain by the former.

Lithology and thickness: On the basis of lithology, mineral composition, and stratification, the Jutana Dolomite can be divided into two main parts separated by a shale bed.

3. Upper Dolomite	Massive dolomite of light cream to gray colour, more thick bedded than the lower dolomite. Marked by abundant stylolite seams both horizontal and vertical.
2. Middle Shale	Dark bluish-gray and maroon in colour, finely laminated and friable.
1. Lower Dolomite	Massive arenaceous dolomite of light cream to gray colour.

Lower Dolomite: The Lower Dolomite is light cream to gray in colour, and is dominantly arenaceous, with pure dolomitic and calcareous sandstone intercalations at different stratigraphic levels. It is hard, massive, and well bedded (as compared with the upper dolomite). At places it is so thinly laminated that it becomes physically difficult to decipher various laminae. Very thin clay intercalations are also present. Ripple marks are noticed at many stratigraphic levels. Most of the ripple marks being the symmetrical ones, and majority of these have very small amplitude and wave length. Howevere, at one horizon the amplitude was measured to be 23 cms and the wave length as more than one meter. The presence of the ripple marks and light cream to gray colour are suggestive of shallow, warm and agitating environments of deposition.

Mineralogically three categories of dolomite have been distinguished; arenaceous dolomite, micaceous dolomite, and pure dolomite. The last category constitutes one third of the bulk. It is because of the abundance of the arenaceous content that the formation has been formerly called the Magnesian Sandstone, with a view that the rock is a sandstone with abundant magnesian matrix. This view has now been completely discarded, and it has been proved that the rock is a dolomite but contains abundant arenaceous material. Micaceous minerals are also fairly common throughout the thickness of the formation. Micas are present to a maximum extent of thirty percent in a bed just above the basal part of the formation. Wherever micas are present they show a prefered orientation, and are interlaminated with quartz or dolomite/calcite layers. These laminations are indicative of absence of any bottom movement of sediments and prevalence of calm conditions in the depositional basin. Abundance of dol_ omite/calcite is suggestive of the fact that the environments were warm and well oxygenated when the calcareous ooze was deposited. However, the oxygenated conditions did not prevail throughout the deposition of the Lower Dolomite, and at time were reducing or euxenic. This is indicated by the presence of glauconite in beds of the basal part of the formation.

Feldspars are present in traces in some of the samples, and are comparatively more common in the very basal part as compared to the upper part of the Lower Dolomite. Iron staining is fairly common throughout the Lower Dolomite.

Small pelletoid ghost structures are commonly present at many stratigraphic levels. These approximately range in size from 0.25 to 3 m.m. in diameter. Microscopic studies of these structures have not clearly revealed the presence of an internal structure. However, concentrations of thin films of iron oxide suggest that they posses some degree of concentric arrangements. Consequently these structures can be called as oolites or pisolites. These oolites/pisolites are so abundant in some layers that they constitute more than ninety percent of some thin sections

Such oolitic/pisolitic bands are fairly common in the Lower Dolomite at many stratigraphic levels. These structures are discussed in detail in petrographic studies of the Jutana Dolomites. The authors have suggested their origin to be the result of penecontemporaneous aggregation around the faecal excreta of the crawling/burrowing animals. These oolites/pisolites are, thus, also suggestive of warm and agitating conditions of deposition.

Average grain size of the Lower Dolomite ranges from very fine to fine, howevere, at places where recrystallization was extensive, medium grained dolomite/calcite was also noticed.

No definite fossil has been reported from the Lower Dolomite as yet, except the trace fossils, especially tracks and burrows made by trilobites especially Redlichia- described and analysed in detail by Schindewolf and Seilacher (1955). Thickness of the Lower Dolomite is about 23 meters in the measured section.

Middle Shale: The Lower Dolomite is succeeded by a thick dark bluish-gray and maroon coloured shale bed. The shale is interbedded with siltstone at the base, succeeded by glauconitic sandstone of 9.5-15 cms. thickness, overlain by maroon siltsone and sandstone. This shale bed is of great significance and bears features similar to those of the Khussak Formation. It is richly fossiliferous and contains same fossils as the Khussak Formation. Schindewolf and Seilacher (1955) have reported *Lingulella fuchsi*, *Batsfordia granulata*, and more rarely *Redlichia noetlngi*. Crawling tracks and burrows made by *Redlichia* have also been reported from the base of the Middle Shale bed. Because of very fine texture, a limited result reveals the shale to contains siltstone, sandstone, and glauconite. It is thus evident that this shale bed has a mineral composition and the faunal content similar to the Khussak Formation. It is bcause of this reason that it is considered to have been deposited under deep, marine, euxenic or weakly oxidizing environments, typical of the Khussak Formation. Such evironments might have been caused by the temporary regression of the sea and setting in of the stagnant condition. However, the sedimentation was very slow which resulted in the formation of glauconite. The Middle Shale bed plays an important role in assigning a definite age to the Jutana Dolomite.

The measured thickness of the Middle Shale bed is 3.04 meters.

Upper Dolomite: The Upper Dolomite is light cream to whitish in colour and is hard and massive. The bedding is very thick as compared to the Lower Dolomite. It contains lesser amounts of sandy and micaceous impurities. At about 32.92meters from the base, a glauconite rich bed occurs in this dolomite. The content of glauconite in the rock is about twenty percent. No detrital feldspar was recorded in any of the thin sections of the Upper Dolomite. Oolitic/pisolitic structures are present on a smaller scale as compared to the Lower Dolomite, nevertheless, bulk of the Upper Dolomite lacks in such structures. Absence of these structures can be attributed to the calm conditions of deposition, as compared to high energy environmental conditions of deposition of a part of the Lower Dolomite.

Slump bedding is noticed at one definite stratigraphic level in the section measured by the authors. Ripple marks and stratification are also the important syngenetic structures present in this part of the formation.

The Upper Dolomite is highly jointed and contains numerous seams of stylolites. Near the middle of the Upper Dolomite, brecciated structure is also noticed, in which matrix and fragments are composed of the same rock. The authers suggest it to be the indicative of penecontemporaneous deformation caused by the regional movements. A thick bed of spongy dolomite is noticed near the top of the Upper Dolomite.

A gastropod fossil *Pseudotheca* cf. *subrugosa* and species of trilobite genera-*Ptychoparia and Chittidilla*, have been reported from the Upper Dolomite (Shidewolf and Seilacher, 1955). Trace fossils, especially tracks and burrows of the trilobites, have been described by Schindewolf and Seilacher (1955).

Absence of oolites/pisolites, arenaceous material, and the glauconite, suggest that the Upper Dolomite was deposited under well oxygenated water environments.

The thickness of the Upper Dolomite measured by the authors is about 22.86 meters. The total thickness of the Jutana Dolomite measured in the Khewra Gorge, is 45 meters and 83 centimeters.

The detailed description of the section measured (from bottom to top of the formation) along the eastren side of the gorge is as follows:

	Meters	Centimeters
Calcareous sandstone, light gray, medium to fine grained, very thinly laminated, loosely cemented......	0	7.8
Arenaceous dolomite, gray, fine grained,		

recrystallized, oolitic / pisolitic, thick bedded, hard, massive	0	41
Arenaceous dolomite, gray, fine grained, recrystallized, thinly laminated, alternating laminae of sandy and carbonate minerals, hard, massive, oolitic/pisolitic, iron leaching distinct, micaceous minerals prominent, contains glauconite	0	36
Micaceous sandstone, gray, fine grained, profusely laminated, alternating laminae of quartz grains and micas, quartz grains are subangular to subrounded, slightlyhard, iron leaching, abundantly calcareous, loosely cemented	1	7
Arenaceous dolomite at the base and pure dolomite at the top, overall gray colour, fine grained matrix, coarsely recrystallized, oolitic/pisolitic, arenaceous dolomite contains abundant micas and alternating thin laminae of quartz grains and mica flakes, laminations vary in thickness, softer than upper part, dolomite is hard, massive and oolitic/pisolitic	0	46
Dolomite, gray, fine to medium grained recrystallized, profusely laminated, alternating laminae of quartz grains and carbonate minerals, laminations, pitch and swell at different distances, cross bedding, and microslumping also noticed at a few places, contains some quartz grains, hard, massive, and compact	1	

Dolomite, gray, medium grained, recrystallized, laminated, at places very thin sandy laminae are present which are softer and lighter in colour, contains traces of terrigenous minerals, hard, massive, and compact......	0	8
Arenaceous dolomite, light brown, fine grained, slightly recrystallized laminated, alternating, laminae of carbonate and terrigenous minerals, at places contains lenses of sandy material, one lense was measured 4 feet long and 10 inches thick, sandy material softer and gray, quartz grains are subrounded, upper part is hard, dolomitic	1	20
Dolomite, light brown on weathered surfaces, gray on fresh surfaces, medium grained, strongly recrystallized, coarse grained in oolitic / pisolitic structures, allochems embedded in fine grained matrix, iron leaching common but concentrated around the peripheries of the allochems, very fine quartz grains present only in the matrix, hard and comact...............................	0	51.5
Arenaceous dolomite, light gray, fine to medium grained, thinly laminated, arenaceous at the base and hard massive in the upper part quartz grains subangular, compact.................................		38.7

Dolomite, light gray, gray, and brownish, coarsely recrystallized, oolitic/pisolitic, allochems embedded in fine grained matrix, peripheries of oolites/pisolites marked by thin films of iron oxide, profusely laminated at the base and massive at the top, at one place there is ripple filling by arenaceous material, stylolitic seams parallel to bedding common, but abundant in the upper part, columnar jointing. worm burrows present, hard, and massive...	3	16
Arenaceous dolomite, gray, fine grained, laminated, alternating laminae of carbonate and arenaceous material, ripple lamination noticed, quatz grains subrounded, hard, and massive...	0	31
Dolomite, light gray, coarsely recrystallized, matrix fine grained, oolitic/pisolitic, thick bedded, hard, massive, near the base there is a lamina of quartz and micaceous minerals, stylolites parallel to bedding common, a few stylolites extend across the bedding, much jointed..............................	3	85
Arenaceous dolomite, light gray, fine grained, quartz grains subrounded profusely laminatend, cross bedding also noticed, stylolites present but not common, iron leaching common, hard, massive..............................	0	91

Arenaceous dolomite, light gray, fine grained, laminated, thick bedded, ripple lamination also present, a few laminae pinch out at some distance, iron leaching common, hard, massive, compact	1	1
Arenaceous dolomite, gray fine grained, thick bedded, cross bedded, ripple laminated, stylolites parallel and perpendicular to bedding are common, jointed, slightly hard	1	70
Arenaceous dolomite, gray, fine grained, thin bedded, cross bedded, ripple filling present, miniature slumping observed, micaceous minerals show prefered orientation, abundance of quartz grains, well cemented	1	10
Arenaceous dolomite, gray, fine grained, thick bedded, contains little quartz, cemented with calcareous material	0	91
Calcareous sandstone, light gray to dark gray, fine grained, laminated, thin bedded, lenticular units common, contains much micaceous minerals, a few intercalation of arenaceous dolomite, hard	1	45
Arenaceous dolomite at the base, and pure dolomite at the top, brown, fine to medium grained, oolitic/pisolitic, disturbed laminations, abundant iron leaching, a 6 inches thick unit indicates weathering surface and contains sand pebbles,		

basal part loosely cemented by calcareous material, upper part hard, massive	0	36
Siltstone, glauconitic sandstone, siltstone-sandstone, shale, bluish-gray and maroon, fine to medium grained, thinly bedded, friable, worm burrows present near the base..............	3	66
Micaceous sandstone (with abundant calcareous cement) at the base, and glauconitic dolomite (with abundant quartz grains) at the top, surface coated with metanterite, fresh surface gray to light brown, basal part is very fine grained and very thinly laminated, more than 100 laminae can be counted in one inch, upper part contains oolitic/pisolitic structures and is coarsely recrystallized, ripple lamination present, worm burrows present, glauconitic concentration in a layer of 8 inches thickness, glauconite rich zone contains miniature slump structure	2	74
Dolomite, basal part is brownish-gray, middle part is dark gray, and upper part is light gray, fine grained, thin bedded at the base, thick bedded and massive in the middle part, and again thin bedded at the top, cross bedding common, worm burrows present, penecontemporaneous slumping noticed, stylolitic seams parallel to bedding common, highly jointed near the		

top, contains small amounts of quartz and micas, iron leaching more prominant in upper part, hard, compact..................................	5	20
Dolomite, surface coated with metanterite, fresh surface is cream coloured, very fine grained, thick bedded, profusely cross bedded, contains little arenaceous material, hard, massive and compact......	0	91
Dolomite, cream coloured, fine to medium grained, recrystallized, thick bedded, irregular bedding, spongy in texture, autoclastic brecciated structures are common, stylolites parallel to bedding abundant, and perpendicular to bedding common, highly jointed, contains negligible arenaceous material, hard, compact, and massive...	11	89
Dolomite, cream coloured, fine grained, at places very coarsely recrystallized, laminated, thick bedded, contains no terrigenous material, hard and compact	0	91
Total thickness	45	83

Relation to Adjacent Formations:

The Jutana Dolomite conformably overlies the Khussak Formation. The contact is gradational but still a sharp contact can be placed at the base of a hard, massive and definitely dolomitic bed. Sharp contrast in colours also helps in the exact placement of the contact. The upper contact of the Lower Dolomite with Lower contact of Middle Shale bed is sharply marked by the colour differences from light gray to dark maroon. The contact

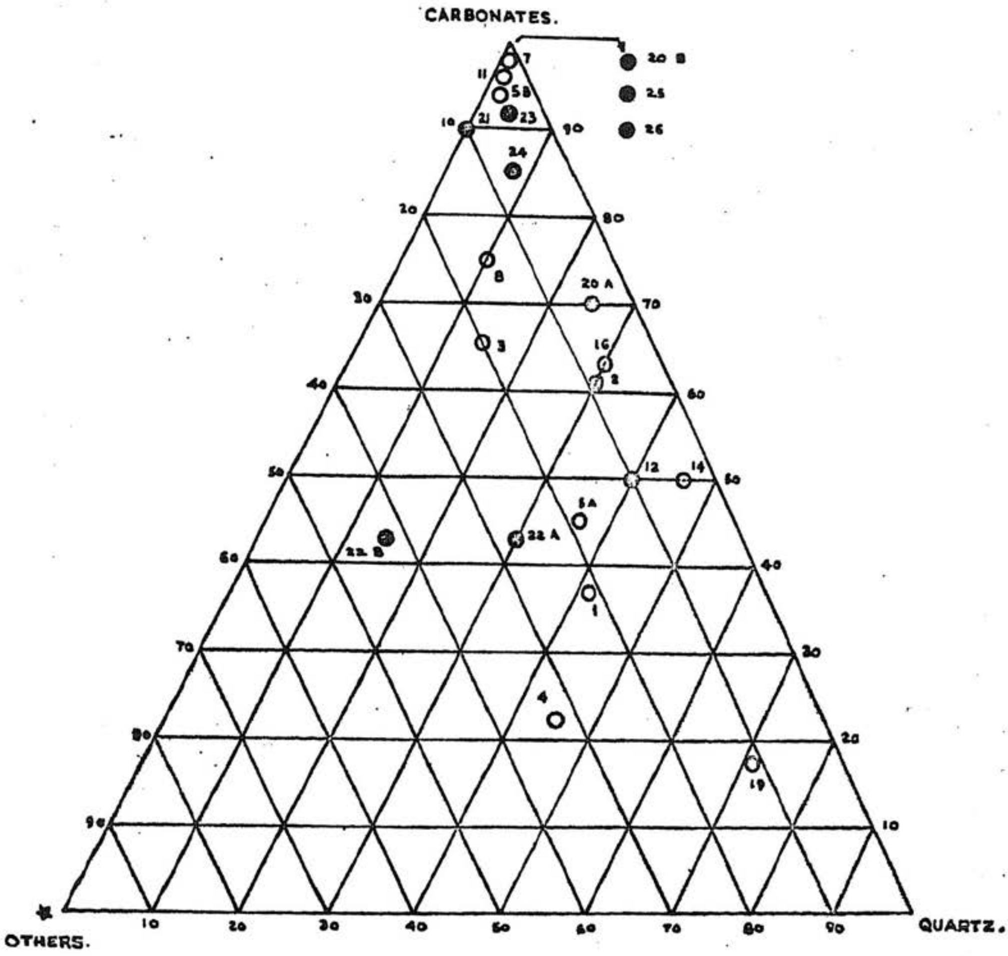


FIG. 1.

The Composition of Some Samples from the Jutana Dolomite, Khewra George, Salt Range.

* INCLUDE – MICA, GLAUCONITE, CHLORITE, FELDSPAR, OPAQUE MINERALS.

○ SAMPLES FROM THE LOWER HALF OF THE JUTANA DOLOMITE.

● SAMPLES FROM THE UPPER HALF OF THE JUTANA DOLOMITE.

is conformable, but indicates sudden deepening of the basin, increase in organic content, and the advent of reducing or euxenic environments. The euxenic environments, however, prevailed temporarily and ultimately gave way to oxygenated environments during the deposition of Upper Dolomite.

The Jutana Dolomite is conformably overlain by the Baghanwala Formation. The contact over here is also gradational but can be easily marked by a sharp contrast in colours. The Baghanwala Formation is characterized by deep rusty-red, maroon, bluish-gray, and olive coloured beds. The contact marks rapid shallowing of the basin of deposition dominated by highly oxidizing environments.

Age and Correlation: The Middle Shale bed in the Jutana Dolomite is abundantly fossiliferous. Schindewolf and Seilacher (1955) have reported the occurrence of *Ligulella fuchsi*, *Batsofordia granulata*, and *Redlichia noetlingi*. Opik (1956, 1958) has shown that the Genus *Redlichia* occurs in rocks of early Middle Cambrian age in Australia. He also suggests an Early Middle Cambrian age to rocks containing *Redlichia forresti*, a species closely similar to *R. noetlingi*.

Schindewolf and Seilacher (1955) have described in detail some trace fossils from the Lower Dolomite. They recorded tracks and burrows made by trilobites, especially *Redlicha*. They also recorded a gastropod, *Pseudotheca* cf. *subrugosa* and species of the trilobite genera *Ptychoparia* and *Chittidilia*. Earlier *Stenotheca* has been reported from the Jutana Dolomite.

On the basis of trilobite faunas found in the Jutana Dolomite, Schindewolf and Seilacher (1955) have assigned a late Early Cambrian to Early Middle Cambrian age to this formation. Teichert (1964) also agrees with Schindewolf and Seilacher, and the authors view also conform with the assigned age.

The Jutana Dolomite exposed in Khewra Gorge is correlated with the dolomite outcrops exposed in Khisor Range (west of Indus River) at Saiduwali, and on the eastern side of the Nilawahan Ravine.

PETROGRAPHY

Petrographic studies of twenty six thin sections reveal that the formation can be divided into two parts, separated by a shaley unit of bluish colour. This is recognizable in the field as well. The lower part is dominantly arenaceous while the upper part is mainly a pure dolomite rock. The dominant minerals of the Jutana Dolomite are carbonates and quartz in the lower part and carbonates in the upper part of the formation. Micas are markedly present in the lower part. Glauconite is present to the extent of five percent in the basal portion of the lower part, and to the extent of twenty percent at one level in the upper part. Glauconite also occurs as traces at a few more horizons. The lower part is thin bedded and shows abrupt variations in mineral composition, whereas the upper part is thickly bedded and is almost composed of carbonates.

Following Robert L. Folk (1965), the constituents of the Jutana Dolomite can be classified into i. terrigenous-minerals formed as a result of detrital processes and ii. chemical-minerals formed as a result of chemical processes. Chemically formed minerals can be further classified as A. allochemical- formed by chemical processes but deposited after slight transportation, and B. orthochemical-formed by chemical processes and deposited in situ. Petrographic studies indicate that quartz and micas are important terrigenous minerals, while carbonate minerals (dolomite/calcite) occur both as allochemical and orthochemical minerals.

Average grain size of the Jutana Dolomite ranges from very fine to fine. Sudden variations in grain size are common, which are indicative of fluctuations in the depositional environments and also varying susceptibility to recrystallization. Majority of the terrigenous minerals are angular and subangular, some are subrounded while a few are rounded. Terrigenous minerals are cemented by allochemical and orthochemical dolomite/calcite and appear as floating over a ground mass of these carbonate minerals. It can be said that calcite is dominating the very basal part while in the above lying part of the formation, dolomite is the most dominant mineral The calcite occurs as bleb-shaped grains in the lower part, while rhombic dolomite is dominant in the upper part. Carbonate minerals, in many thin sections, indicate rounded to subrounded faces suggesting transportation from a distance.

The carbonate minerals also show bimodal distribution of grain size and can be distinguished as i. small sparry, and ii. large sparry recrystallized grains. The small sparry carbonate minerals, which constitute the cementing material, show rounded out-lines and also occur as pore space filling, While large sparry recrystallized carbonate minerals consitute the main framework, which are embedded in a fine textured sparry matrix, and show evidences of replacement. The carbonate minerals also seem to be replacing quartz.

The most important textural feature of the Jutana Dolomite is the presence of ghost structure as observed in many slides. These structures appear to be the result of replacement of original material by dolomite/calcite. The boundaries of these structures are marked by a thin film of iron oxide, and centre, in most of the cases, is marked by fine grains of quartz. Such ghost structures have been variously called as pellets, granules, false oolites, pseudo-oolites, and so forth. Since the ghost structures present in this formation are lacking an internal structure, except slight concentric arrangement, their origin cannot be discussed with certain·ty.

Long (1953) has regarded all structureless carbonate clasts as mechanical in origin. Others believe them to be the result of penecontemporaneous aggregation (Illing, 1954). However, the most impressive and brief argument which can be made in their favoure, is that, the nucleous is a faecal excreta of pelagic animals which has been enlarged as a result of penecontemporaneous aggregation, under the rolling effect of slight current action. Presence of slight current action is also favoured by the subrounded carbonate grains. These aggregated pelletoid forms have, then, later been replaced by the carbonate minerals, as a result of recrystallization under the effect of meteoric water. Replacement, following the recrystallization, was so extensive that none of the original texture was left and a sort of ovoid mechanical clast resulted. A few rounded aggregates are surely of accretionary origin. This may be mainly due to the growth of algal heads of small size. Majority of the ovoid mechanical clasts are indicative of having some degree of concentric arrangement, noticed by thin iron oxide films, and range in size from 0.2-2.0 m.m. It is because of these facts that the authors assign them as oolites/pisolites.

Quartz is the most important detrital constituent of the Jutana Dolomite and ranges upto seventy one percent at different stratigraphic levels. The quartz grains vary from very fine to coarse grains. Most of them are subangular to subrounded, rarely they are rounded. Majority of the quartz grains are monocrystalline, while some polycrystalline quartz grains have also been noticed. A few grains of quartz show authigenesis.

Micaceous minerals are also present in the Jutana Dolomite. They are more prominant in the lower half and become scarce in the upper half. Biotite, present to an extent of eighteen percent in one sample, occurs as traces in many slides.

Muscovite is also prominant in the lower half but is almost negligible in the upper half. Biotite shows alteration to chlorite and glauconite in many slides. Micaceous minerals, in all slides, are oriented in a certain direction and are interlaminated with cabonate minerals. In some cases, grains and lamellae are very fine and as many as hundred can be counted in one inch. Micaceous minerals also show microfolding. Glauconite is concentrated in a few slides from the lower half of the section. In many cases it seems to be the alteration product of biotite. In one slide from the upper part, it is present to the extent of twenty percent. Over here it occurs in the form of large blebs and appears as being replaced by the carbonate minerals.

Plagiocalse, microcline, and orthoclase are also present in small amounts. Glaucophane has been traced in some of the slides also.

In cases where some argillaceous material is interlaminated, minture penecontemporaneous slumping is noticable. In many of the thin sections concentration of iron ore minerals is also noticable. Under plane polarized light the ore minerals in the Jutana Dolomite appear as opaque, dark, and brownish-gray in colour, suggesting the presence of hematite, magnetite, ilmenite, and leucoxene.

Table 1 shows the mineralogical composition of some of the samples collected from the Jutana Dolomite exposed in the Khewra Gorge. A look at the table shows that the Jutana Dolomite is primarily composed of carbonates (calcite/dolomite). The bulk of the samples fall within this category, whereas the others fall in the category of arenaceous dolomite (micaceous, quartzose, and glauconitic). There are only one or two samples which fall within the category of calcareous/dolomitic sandstones.

CONCLUSIONS

The Jutana Dolomite, which forms the basal part of the Upper Jehlum Group, is of Late Early Cambrian age. It has been deposited in a shallow basin under warm well-oxygenated, and calm marine environments. Slightly agitated conditions prevailed during the deposition of part of the Jutana

TABLE—1. Mineralogical composition (%) of the Jutana Dolomite Khewra Gorge, Salt Range

Slide No.	Carbonate.	Quartz.	Biotite.	Muscovite.	Glauconite.	Chlorite.	Plagioclase.	Microcline.	Glaucophane.	Orthoclase.	Ore minerals.	Nomenclature.
1	36	42	4	7	5	1	1	1	–	1	2	Calcareous Sandstone.
2	61	30	3	2	1	2	TRACE	TRACE	–	–	1	Arenaceous Dolomite.
3	65	15	8	1	4	5	TRACE	–	TRACE	TRACE	2	Arenaceous Dolomite.
4	22	45	18	8	2	4	TRACE	TRACE	–	TRACE	1	Micaceous Sandstone.
5. A.	45	36	10	4	1	2	–	–	–	–	2	Arenaceous Dolomite.
5. B.	95	2	TRACE	TRACE	2	–	–	–	–	–	1	Dolomite.
6	81	7	5	2	1	3	–	–	–	–	1	Dolomite.
7	91	1	TRACE	–	TRACE	–	–	–	–	–	TRACE	Dolomite.
8	75	10	5	3	1	5	TRACE	–	–	–	1	Arenaceous Dolomite.
9.	97	1	–	TRACE	TRACE	–	–	–	–	–	2	Dolomite.
10.	73	20	3	2	1	1	TRACE	–	–	TRACE	TRACE	Arenaceous Dolomite.
11.	97	2	TRACE	–	TRACE	–	–	–	–	–	1	Dolomite.
12.	50	40	3	2	1	2	TRACE	–	--	TRACE	2	Arenaceous Dolomite.
13.	98	1	TRACE	TRACE	TRACE	–	–	–	--	--	1	Dolomite.

TABLE—1. Continued

14.	50	41	3	2	1	1	TRACE	–	--	--	1	Arenaceous Dolomite.
15.	67	25	3	3	–	–	1	–	--	--	1	Arenaceous Dolomite.
16.	63	30	3	2	–	1	TRACE	–	--	--	1	Arenaceous Dolomite.
17.	55	40	1	–	–	1	1	–	--	--	2	Arenaceous Dolomite.
18.	75	20	2	1	–	TRACE	TRACE	–	--	--	2	Arenaceous Dolomite.
19.	18	71	4	4	–	–	1	TRACE	--	TRACE	2	Calcareous Sandstone.
20. A	70	25	1	1	–	–	1	–	--	--	2	Arenaceous Dolomite.
20. B	99	TRACE	TRACE	–	–	–	–	–	--	--	1	Dolomite.
21.	60	25	2	2	8	1	TRACE	--	--	TRACE	2	Shale.
22. A	43	30	10	5	–	10	–	--	--	--	2	Micaceous Sandstone.
22. B	46	15	8	TRACE	20	8	–	--	--	--	1	Arenaceous Glauconitic Dolomite.
23.	92	4	1	1	TRACE	1	TRACE	--	--	--	1	Dolomite.
24.	85	8	5	–	–	–	–	--	--	--	2	Dolomite.
25.	98	1	TRACE	–	–	–	–	--	--	--	1	Dolomite.
26.	99	TRACE	–	–	–	–	–	--	--	--	1	Dolomite.

Dolomite. Abundant fluctuations in the depositional environment are evident, which in turn have effected the lithology. On the basis of lithological variations, combined with the primary sedimentary structures, it is concluded that the Jutana Dolmite can be divided into three distinct units. This distinction is particularly very vivid and sharp in the Khewra Gorge. The three units differentiated are as follows:

iii.	Upper Dolomite	Mainly pure dolomite, thick-bedded, deposited under warm, shallow, calm and well-oxygenated marine environments.
ii.	Middle Shale	Bluish-gray, maroon, friable shale containing fossils similar to those found in the underlying Khussak Formation, Deposited under comparatively deep marine euxenic or at least weakly oxidizing environments. Glauconite occurs associated with organic remains.
i.	Lower Dolomite	Abundantly arenaceous and argillaceous, thin bedded, deposited under warm, shallow, calm, well-oxygenated marine environments. A part of it was deposited under slightly agitated conditions (such levels are marked by oolitic/pisolitic structures). Indications of prevalence of occasional euxenic or slightly reducing environments are provided by the occurrence of glauconite. It is also possible that some of the glauconite may have been derived from the underlying Khussak Formation which is abundantly glauconitic.

The Jutana Dolomite, excluding the Middle shale Unit, comprises mainly of carbonate (dolomite), sandy or arenaceous dolomite and argillaceous sandstone Glauconite is always present in all the samples studied in thin sections under microscope. Only one sample falls within the category of protoquartzite.

The Jutana Dolomite has undergone recrystallization which has resulted in the obliteration and in some cases complete destruction of original textural and structural features. Ghost textures and structures after original such features are the only relics left. The two members of the Jutana Dolomite are very poor in the faunas. It is the Middle Shale Unite which contains faunas almost similar to those found in the underlying Khussak Formation.

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