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Petrology of the Kolhan Limestone

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ABSTRACT

The Kolhan Limestone Member is a unit which is highly variable in thickness and other features. It overlies the basal Sandstone with a gradational contact and is on its turn overlain by the phyllitic Shale Member again with a highly transitional boundary. This Member is impersistent and tapers out at a number of places. Its overall maximum thickness of nearly 65 ft. is attained only near Jhinkpani where the rocks are utilized for the manufacture of cement by the Associated Cement Company, Ltd. Towards the south the limestone are very much less developed and become uneconomic to support a cement industry.

INTRODUCTION

The Kolhan Limestone Member is a unit which is highly variable in thickness and other features. It overlies the basal Sandstone with a gradational contact and is in its turn overlain by the phyllitic Shale Member again with a highly transitional boundary. This Member is impersistent and tapers out at a number of places. Its overall maximum thickness of nearly 65 ft. is attained only near Jhinkpani where the rocks are utilized for the manufacture of cement by the Associated Cement Company, Ltd. Towards the south the limestone are very much less developed and become uneconomic to support a cement industry.

A detailed account of the mineral composition and texture of these Limestones is presented in the following pages, which is based on a systematic study of about one hundred thin sections of specimens collected from different parts of the outcrop. Etched thin sections gave additional information.

Mineral composition and texture.

The complexity of the mineral composition and texture of carbonate sediments and rocks is well brought out in some of the recent discussions and in the symposia on these materials held in quick succession in the present decade.

Composition and texture are the basic rock properties whose variation is used to differentiate carbonate rock types. The various compositional and textural terms used to describe carbonate rocks have been used with somewhat different connotations by different workers and it is, therefore, desirable to give first the exact sense in which the various terms have been used in the present study.

Recrystallization -"If calcite of one-grain size, morphology or orientation replaces a previous type of calcite, the change most properly should be termed "Recrystallization". A change of high Mg calcite to low Mg calcite would be an example. Some sedimentologists also use the term "Orthocrystallization" for spontaneous Recrystallization that takes place essentially at surface temperatures and surface to somewhat higher lithostatic pressures, whereas "metacrystallization" is due to elevated temperatures and/or directive stress. The latter process is not of any significance in the Kolhan Limestones which are all unmetamorphosed.

Neomorphism - A new comprehensive term is introduced by Folk (1965) for all transformations between one mineral and itself or a polymorph – whether inversion or recrystallization. An example is the alteration of a carbonate mud (unknown if originally aragonite or calcite) to 2-micron calcite forming lithographic limestone (micrite). Micrite forms a significant constituent in many of the limestone studied here.

Replacement -“Substitution of one mineral species for another by essentially simultaneous selective solution of the host mineral and precipitation of an intruding mineral; usually considered a metasomatic process. The replacing crystals are in most instances larger than the original crystals”. Conversion of calcite to dolomite, of limestone to anhydrite (gypsum), certification and calcification of dolomite are some examples of replacement. The Kolhan Micrite - This term is applied to “lithified accumulations of subtranslucent calcium carbonate crystals of diverse origin having a maximum grain size of 8 phi and averaging 1.5 to 2.5 microns (Folk, 1964)” as quoted in Todd (1966, p.331). It is an abbreviation of microcrystalline calcite (Folk, 1959 b).

Microspar - A product of recrystallization (neomorphism) of carbonate mud averaging 5-10 microns, called coarser “mud” by many workers. Both ordinary micrite and microspar form subequant rounded to polyhedral blocks with slightly curved to plane faces (Folk, 1965).

Pseudospar - Another name for coarser neomorphic calcite, coarser than 30 micron which differs from microspar in many cases to true pore-filling sparry calcite (Folk, 1965). Hence it is called pseudospar.

Sparite - Calcite with an average crystal size of 6.0 phi (15.6 microns) or greater and optically clear. Largely a pore and void filling cement but also a product of ortho-crystallization.

Terrigenous components - “Land-derived mineral and rock fragments, termed detrital by many workers”.

The extreme variability in the constituent composition (micrite, microspar, spar, terrigenous components, etc.) of the limestones in thin sections is a characteristic feature of these rocks. Allochemical components of both carbonate and non-carbonate types are extremely poorly represented so that intraclasts including intraplasts or phenoplasts, colloclast; grapestone, oolites including pseudo-oolites and pellets of any type are practically absent. Fossils of any description, whether of sedimentary organism or non-sedentary fossils including algal pisolites do not occur, although some very doubtful occurrences are suspected. Noncarbonate allochems which include glauconite pellets, phosphate nodules, organic material and others are also completely absent. In view of the absence of allochemical constituents, the term matrix used in the sense of a continuous component which lithifies and encloses the grains has lost much of its significance and can be equated with micrite without any injustice to carbonate petrology. Terrigenous components such as detrital quartz, feldspar, chlorite, and epidote are extremely rare. However, opaque detritals such as iron and manganese oxides are fairly well represented in certain sections and the same holds true for clay-slit components intimately admixed with micrite. Ferrimuscovite and sericite flakes are mostly associated with these components.

From the above brief general petrographic account, it would, at first sight, appear that the Kolhan Limestones have a comparatively simple petrographic composition. Limestones have a comparatively simple petrographic composition. However this apparently simple mineralogy is not valid as will be attested by the details of the petrography discussed below, but the limestones are affected by a complex series of diagenetic changes whose effects have been far-reaching in promoting mineralogical and textural alterations of these rocks. However, dolomitization which is a common diagenetic process encountered in limestones of all ages is conspicuously absent, a fact whose significance will be discussed later.

Although recrystallization is a universal feature of the micrite-sparite limestone, there occur towards the base certain thin horizons in immediate contact with the underlying calcareous sandstone, samples from which in thin sections show a marked deviation from the recrystallized types referred to above. This sporadic occurrence is a coarse calcilutite (size 4-6 phi) alternating with fine to medium calcarenite with grains of apparently detrital calcite ranging between 1 to 4 phi. The detrital grains are mostly angular to subangular. The alternating coarse and fine layers represent bedding features which are also corroborated by occurrence of similar angular to subangular detrital quartz grains, coarser in the calcarenite and finer in the calcilutite. A fine micro cross lamination marked by hematitic laminae is often observed which is however at times broken and distorted during the recrystallization of the calcite grains. A distinct alignment parallel thereto testify also to the detrital character of the calcite. A little patchy occurrence of micrite is occasionally observed. These thin layers of lithocalcarenites alternating with calcisiltites and calcilutites represent products of mechanically deposited detrital components, structures like cross-bedding as well scour and fill similar to those displayed by shallow water arenites. The paucity of a crystalline cement together with the low degree of sorting and rounding may suggest that the interstitial fine material was not winnowed out by current activity in the shallow water. The little amount of this cement might have been produced by recrystallization of the fine-grained matrix. The calcarenitic rocks thus possess environmental significance much in excess of what can be expected from their thin sporadic occurrence, an exaggerated role has been ascribed to the formation of these rocks by the breakdown of pre-existing limestones. In the present case, the initiation of conditions favorable to carbonate precipitation is well heralded by this microfacies. "The lithocalcarenites are related to beds and lenses of pure quartz sandstones with carbonate or siliceous cement and as a result, contain appreciable amounts of quartz-sand and quartz silt grains. Current-bedding structures are well realized and associated layers of derived dolomite grains may be present. Probably the most characteristic feature of such lithocalcarenites is that they result from rather local conditions and are likely to reflect this individualism in details of lithology, variability, and lateral impersistence.

The most important and thick horizon in the Kolhan Limestone Member is constituted by the highly recrystallized, diagenetically altered limestone initially deposited as a carbonate mud in the shallow basin. Crystalline quartz and carbonate veins transect this horizon in abundance and it exhibits all the structures like convolute lamination, current lineation, cross lamination, stylolites etc. particularly in the northern part of the basin which thereby attains an individuality of its own. Syngenetic manganese and iron mineralizations form again a characteristic feature of only this part of the basin. Another feature of this horizon is the extreme variation in thickness in short intervals so that it quickly gets reduced from a few tens of feet in the north to a few feet only, in the southern part of the basin. This abrupt variation in thickness is more a reflection of the primary basinal configuration rather than a variation caused by other factors like tectonism, metasomatism, etc.

The initial dome and basin structures are responsible for the variation in sediment thickness. This horizon exhibits as already pointed out marked differences in the broad features as developed in the northern and southern parts of the basin, a fact which is corroborated by the petrographic characteristics described below:

In thin sections, there is a Wide range of variation in the micritic content of the limestones from practically nil to as high as 90 percent. The high micritic content goes parallel with a high content of silt-clay insoluble residue as is obtained from the specimens collected from the southern part of the basin. In contrast, the much less insoluble residue in the more crystallized samples from the north testifies to the digestion of the clay-silty material during recrystallization. Thin sections of limestones with high clay content exhibits micritic granules which in aggregates appear somewhat turbid and dirty due to clay admixture. The clay content has not been a factor promoting neomorphic recrystallization of micrite to coarser "mud" as has been reported in some limestones interbedded with shale or clay. Even some clayey limestones such as the Austin Chalk or the Tonoloway show no evidence of neomorphism to microspar".

In contrast with the above, thin sections of limestones from the northern half show evidence of a much higher degree of neomorphic recrystallization not only in the development of patchy microspar but also in the formation of pseudospar due to continuity of the diagenetic recrystallization. As already seen the clay content may not be the sole factor promoting recrystallization. The displacement of the clayey matter in the initial stage of microspar development is well seen in whereby the former is aggregated into minute clots producing a type of micro-clotted structure.

The microscopic characters alone do not give any positive evidence regarding the possible mode of the origin of the carbonate mud in one of the following ways:

(1) Physico-chemical precipitation of aragonite in shallow to very shallow waters due to agitation, salinity changes, heating etc. or organically by biochemical processes of bacteria, photosynthesis by marine plants, etc.

(2) Disintegration of certain types of calcareous green algae and of algally secreted coccoliths may produce aragonite needles or rod-like calcite fragments of the order of 0.5 to 4 microns.

(3) Abrasion of non-algal skeletal particles by action of waves, currents, living burrowers (Folk, 1965) or rotting of organic tissue to release ultimate crystal units. This is the main mud-producing process on Alacran Reef.

(4) Wave or current erosion of older carbonate outcrops or submarine crops and eolian carbonate dust may contribute a little carbonate sediment (Folk, 1965).

(5) Recrystallization of algal fragments and skeletal materials to microcrystalline and recrystalline carbonate.

The absence of any trace of organic remains due to recrystallization or any other factor makes the inorganic precipitation more likely in the present case in shallow basin by agitation, warming or salinity changes or other changes in physicochemical condition, direct, as opposed to organic, solution and reprecipitation of calcite appears to be negligible in the shallow marine environment. The total absence of pelleted structures, which are mostly regarded organic in origin, is pertinent in this connection. There is a practically no dolomite “primary” or “secondary” in the Kolhan Limestone as already mentioned. The significance of this in terms of the depositional environment is not very clear. The Kolhan basin, admittedly a shallow one did probably never become too shallow to emerge out of the sea level (emergent condition) nor too saline to precipitate dolomite, may “penecontemporaneous dolomitization occur in emergent to extremely shallow hypersaline flats. Probably concurrent precipitation of gypsum also occurs at about this stage”. In the recent symposium on “Dolomitization and Limestone Diagenesis”,that the occurrence of dolomites in sediments with mud-cracks, stromatolites, burrow mottling and boudinage-like structures may be matched with many ancient dolomites, is very pertinent in this connection in view of the face that the present non-dolomitic limestones do not exhibit any of the textures and structures mentioned by these authors.

A related but not genetically connected feature of the Kolhan Limestone is the practically total absence of the effects of certification and the occurrence of very few fine authigenic quartz euhedral. The thin section evidence does not offer any clue to this feature, and the author, in the absence of other evidence would agree with Folk (1965) to conclude that “the main reason for the relatively uncommon occurrence of chert and fine authigenic quartz euhedral in pelleted limestones lies in the ecological preferences shown by the main silica-secreting organisms”.

Textural significance

Various authors have used the micritic matrix content as an indicator of current intensity. A high amount of fines is equated with relatively quiet water conditions (low energy environment characterized by little winnowing) and poor circulation in the depositional basin. This criterion can be particularly applied to the southern part of the basin where specimens containing as much as 80% micritic constituent sometimes occur. The current intensity must, therefore, have been weaker as compared with the intensity in the northern part of the basin. This is in fair agreement with the findings from other features such as current lineations, cross laminations etc. which also indicate a somewhat greater current intensity in the north. However, weak currents do not necessarily indicate greater depths. In certain situations which do not probably apply in the present case, a number of fines do not give a reliable basis, in itself to interpret the current regime of a large area.

Neomorphic crystallization and replacement

Folk (1965) states that the conversion of the carbonate mud into the finest micrite is a neomorphic process taking place early in the normal course of diagenesis, a view with which many other authors are in agreement. The micritic matrix of the Kolhan limestone would according to this view be a product of neomorphism in the very early diagenetic stage. The bursting of the micritic "barrier" (3.5 to 4 microns) to form the microspar (5-25 microns) is also according to Folk (1965) a neomorphic process. Many other authors also subscribe to this view and produce definite evidence of a neomorphic origin for the microsparite. The microspar of the Kolhan Limestone does not represent simply a coarser mechanically deposited silt Calcilutite but is a product of coalescive neomorphism of micrite grains on the strength of the following evidence:

(1) Patchy occurrence of the microspar dispersed in a matrix of unaltered micrite with a sharp but at times a gradational contact.

(2) The uniform fine-grained texture of the microspar with relict patches of micrite enclosed within.

(3) Absence of allochems in the microsparite. This reduces the probability of microsparite. This reduces the probability of the microspar being a direct precipitation around a nucleus – a carbonate or non-carbonate allochems and thus makes it more probably a product of coalescive neomorphism.

(4) Association of the microspar with terrigenous clay minerals and not silt.

The terrigenous clay minerals are represented where due to the force of recrystallization; the clayey material is displaced outwards and sometimes aggregated as micro-clots in the vicinity. This predominance of clay is also proved by the insoluble residue analysis of the microspar bearing impure limestone. However, all clay-rich limestones are not diagenetically recrystallized to microsparite. The association of microspar with clay is due to its hydraulic equivalence with the latter (Folk, 1965). Microspar, whether formed by coalescive neomorphism or as a mechanically deposited calcilutite serves as an index of current intensity in the same way as the micrite and the association of considerable microspar with micrite provides positive evidence of the ineffectiveness of winnowing action in a basin of weak current intensity. On this criterion too, the southern half of the basin proves to have a weak current intensity as compared to the north, though not necessarily deeper.

The continuation of the process of neomorphic recrystallization produces coarser calcite (>30 microns) called "pseudospar", which may closely resemble the true pore filling spar. In the Kolhan Limestone which has already mentioned, exhibits features of coarse recrystallization, the amount of recrystallized calcite is uniformly high and in many samples particularly, from the north it is higher than 75% (Table 1). A unique feature noted in such limestones with a high content of recrystallized calcite refers to the presence of a large amount of quartz in the recrystallized rock. The low-grade limestones belonging to this type analyze nearly 30% SiO_2, and the insoluble residues prove to be sand rich. The recrystallized calcite is thus neither of the nature of neomorphic calcite (pseudospar) nor of the nature of true pore-filling sparry calcite but appears to be a product of replacement recrystallization, a process during which calcite grows in size digesting the micritic matrix, the microsparite (if any) and the clayey impurities. Undigested relics are often found in the coarsely crystalline calcite. On account of the dominance of this type of calcite, the other two types recede in significance so that the criteria for distinction between 'orthospar' and void-filling calcite as given by various students of carbonate-petrology cannot be properly applied in the case of the Kolhan Limestones. Moreover, the evidence for the existence of voids in these rocks is not unequivocal. Folk (1965) has also been able to show that none of the proposed criteria (grain boundaries, grain size, grain orientation and grain contacts) to distinguish directly precipitated spar from neomorphic calcite (pseudospar and microspar) are positive, but are only suggestive.

Table 1: Quantitative mineralogical composition of the Kolhan Limestones.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	25.00	10.00	5.00	-	50.00	20.00	-	-
2	0.71	68.19	2.00	23.47	3.00	-	-	2.62
3*	56.82	17.15	24.65		-	-	0.82	-
4	2.00	70.00	tr	17.00	-	-	11.00	-
5	10.50	43.50	-	25.50	20.50	-	-	-
6	84.67	0.57	5.09	1.67	8.00	-	-	-
7	9.00	68.20	10.10	9.70	3.00	-	-	-
8	15.00	50.40	19.00	5.00	10.50	-	-	-
9	-	74.00	15.00	2.00	2.00	4.00	3.00	
10	10.00	40.00	45.00		5.00	-	-	-
11	10.50	34.50	50.50		5.50	-	-	-
12	68.00	15.48	tr	14.92	1.69	-	-	-
13	5.50	58.00	5.00	16.00	15.50	-	-	-
14	7.50	79.50	10.50	tr	3.50	-	-	-
15	5.00	75.00	10.00	7.00	3.00	-	-	-
16	10.50	35.00	13.50	10.50	5.50	25.00	-	-
17	-	75.00	12.50	5.00	7.50	-	-	-
18	9.50	69.50	2.50	15.50	3.50	tr	-	-
19	9.50	51.00	10.50	25.50	3.50	-	-	-
20	5.00	78.00	5.00	10.00	2.00	-	-	-
21	5.50	78.50	4.00	10.00	2.00	-	-	-
22	4.50	88.00	5.00	tr	2.50	-	-	-
23	9.50	60.00	8.50	25.50	5.50	-	1.00	-
24	15.00	40.00	30.00		10.00	-	5.00	-
25	15.50	56.00	4.50	20.50	3.50	-	-	-
26	7.00	78.00	3.00	7.00	5.00	-	-	-
27	15.00	61.50	10.00	5.50	3.00	-	-	-
28	10.00	35.00	tr	30.00	15.00	-	10.00	-
29	15.50	61.50	6.50	12.50	4.00	-	-	-

30	9.50	60.50	21.00	7.50	1.50	-	-	-
31	9.00	50.00	tr	26.50	9.50	-	5.50	-
32	15.50	65.50	6.00	10.00	3.00	-	-	-
33	10.50	70.00	10.50	7.00	3.00	-	-	-
34	7.50	66.00	10.00	15.00	1.50	-	-	-
35	10.00	60.00	7.00	25.00	3.00	-	-	-
36	5.00	63.00	5.50	24.50	2.00	-	-	-
37	10.00	78.00	7.00	tr	5.00	-	-	-
38	35.00	30.00	30.00	tr	5.00	-	-	-
39	12.00	77.00	3.00	5.00	3.00	-	-	-
40	7.00	78.00	12.00	tr	3.00	-	-	-
41	6.00	79.00	7.00	15.00	3.00	-	-	-
42	7.00	66.00	25.00		2.00	-	-	-
43	36.00	30.50	25.00		2.00	5.00	1.50	-
44	6.00	61.00	30.00		3.00	-	-	-
45	15.00	60.00	23.00		2.00	-	-	-
46	13.00	67.00	20.00		tr	-	-	-
47	10.50	67.00	20.00		2.50	-	-	-
48	6.00	70.00	25.50		1.50	-	-	-
49	28.00	50.00	20.00		2.00	-	-	-
50	50.00	25.00	15.00	-	7.00	-	3.00	-
51	90.00	10.00	tr	-	-	-	-	-
52	5.00	52.00	10.00	25.00	7.00	-	-	-
53	3.00	63.00	18.00		7.00	-	9.00	
54	3.00	78.00	10.00	6.00	3.00	-	-	-
55	10.50	60.50	27.00		2.00	-	-	-
56	tr	76.00	5.00	10.00	1.00	3.50	3.50	
57	tr	52.00	28.00		12.00	-	8.00	-
58	tr	57.00	26.00		12.00	-	5.00	-
59	tr	47.00	30.00		9.00	-	14.00	
60	2.00	58.00	25.50		4.00	-	-	-
61	7.50	70.00	7.00	11.50	4.00	-	-	-
62	tr	77.00	20.00		3.00	-	Tr	-
63	tr	35.00	40.00		15.00	-	10.00	
64	15.00	60.00	13.00	5.00	7.00	-	-	-
65	9.50	74.00	12.00	3.00	1.00	-	-	-
66	tr	90.00	7.00	3.00	-	-	-	-
67	tr	76.00	17.00	4.00	0.50	2.00	-	-
68	tr	82.00	15.00	tr	2.00	-	-	-

69	5.00	70.00	21.00		4.00	-	-	-
70	3.00	81.00	15.00		4.00	-	-	-
71	3.50	83.00	13.50		tr	-	-	-
72	10.00	68.00	15.00	5.00	1.50	-	-	-
73**	7.00	65.00	21.00		4.00	-	2.00	-
74**	7.00	56.00	25.00		5.00	-	3.50	
75	10.50	68.00	20.00		tr	-	1.50	-

Two features commonly associated with this type of late diagenetic calcite formed by replacement recrystallization needs closer scrutiny:

(1) Association of a large amount of introduced quartz as evidenced in thin section studies. This quartz is neither detrital not authigenic varieties which can be easily distinguished from the metasomatic type. In the field exposures, massive quartz veins transect the limestone and engulf small fragments of the original carbonate rock. The origin of the quartz may thus clearly be ascribed to a process of silicification, although source of the silica solution is obscure.

(2) Presence of post-diagenetic carbonate veins with usually a transitional contact with the host recrystallized limestone in thin section. This appears to be a type of a replacement vein formed by recrystallization of the calcite of the matrix and replacement by calcite along certain paths producing a veined structure. This is a post-diagenetic process as it includes relicts of unreplaced micritic matrix and may be referred to as calcitization. The source of the carbonate may be the limestone itself. In the field also coarse calcite veins transverse the rocks and appear to have formed somewhat earlier than the quartz veins on field evidence although both types of veins represent post-diagenetic phenomena.

(3) On account of the above two features, the Kolhan Limestones, particularly in the northern portion have been classified as silicified, calcitized and recrystallized micrite/microsparite.

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