Pakistan Journal of Hydrocarbon Research
Vol.5, No.1&2 (January & July 1993), P.53-62, 2 Figs., 1 Table, 2 Plts.

Reconnaissance Microfacies Studies of Margala Hill Limestone, Jabri Area, Southern Hazara, Pakistan

Raja Shahnawaz[1], M. Nawaz Chaudhary[1], Munir Ghazanfar[1] and S.J. Sameeni[1]

ABSTRACT

The Margala Hill Limestone of Early Eocene age from Jabri Area, Southern Hazara has been studied in detail for internal units, microfacies and diagenetic fabrics. A total of ten microfacies and five internal facies units have been defined. The ten microfacies from bottom to top are mudstone (fossiliferous micrite), wacke- to packstone (biomicrite), grainstone (biosparite), wackestone (biomicrite), packstone (biomicrite), packstone (sparbiomicrite), packstone (biomicrite), mud to wackestone (biomicrite), mudstone (fossiliferous micrite) and packstone (biomicrite). The five internal facies units from bottom upwards are biomicrite, biosparite, biomicrite, sparbiomicrite and biomicrite. These units correspond to fluctuations in sea level. The study of texture, structure and faunal assemblages shows that the Margala Hill Limestone was deposited under open shelf marine environments. The biomicrites were deposited in low energy environment i.e. below the wave base while biosparite was deposited in high energy environment and at relatively shallower depths. The sparbiomicrite has a complex history. Deposition commenced in low energy environment. But due to change in sea level the still porous biomicrite was transferred to higher energy environments where spar cement was introduced. This paper also deals with diagenetic fabrics and their origin.

INTRODUCTION

The formational name "Margala Hill Limestone" of Latif (1970) has been formally accepted by Stratigraphic Committee of Pakistan for the "Nummulitic formation" of Waagen and Wynne (1872), the upper part of the "Hill Limestone" of Wynne (1873) and Cotter (1933). Middlemiss (1896) regarded this formation as a part of "Nummulitic series". The name is derived from Margala Hills in Hazara, District Abbottabad.

The type section of this formation is located near Shahdara (lat. 33°78' N, long. 73°10' E) in southeastern Hazara.

A reference section of this formation is exposed to the south of Sir BurjianWala, northwest of Jhallar, Kala-Chitta range.

This foraminiferal limestone exposed at many localities in Attock-Hazara Fold and Thrust Belt is used extensively as aggregate and cement raw material but no lithological microfacies studies have so far been carried out. This paper presents microfacies studies of Margala Hill Limestone from a section of southeastern Hazara (Figure 1) and attempts to reconstruct the environment.

LITHOSTRATIGRAPHIC DESCRIPTION

The formation is white grey to pale grey on weathered surface, and dark grey on fresh surface. It is in main a nodular limestone with subordinate marl and shales. The limestone is highly fossiliferous and massive. Some reef beds are also present in the limestone. Generally, bedding is obscured due to well developed nodularity. The nodule size ranges from 20 to 40 cm in diameter.

Its lower contact with Patala Formation is sharp and conformable. Its upper contact with Chorgali Formation is also conformable, but this contact is not exposed in the study area.

The formation is reported as 100 m thick at Shahdara and 80 m at the reference locality. An Early Eocene age is ascribed on the basis of fauna (Shah, 1977).

The top of the underlying Patala Formation comprises mainly shales with interbedded limestone. The interbedded limestone is fine grained, nodular and highly fossiliferous. Some intercalated reef beds are also present. These are relatively hard and show positive relief. The Patala Formation is believed to have much influence on the overlying Margala Hill Limestone in its diagenetic history. The geological map of the area is given as Figure 1 and stratigraphic sequence of the area is shown in Table 1.

[1] Institute of Geology, University of the Punjab, Lahore, Pakistan.

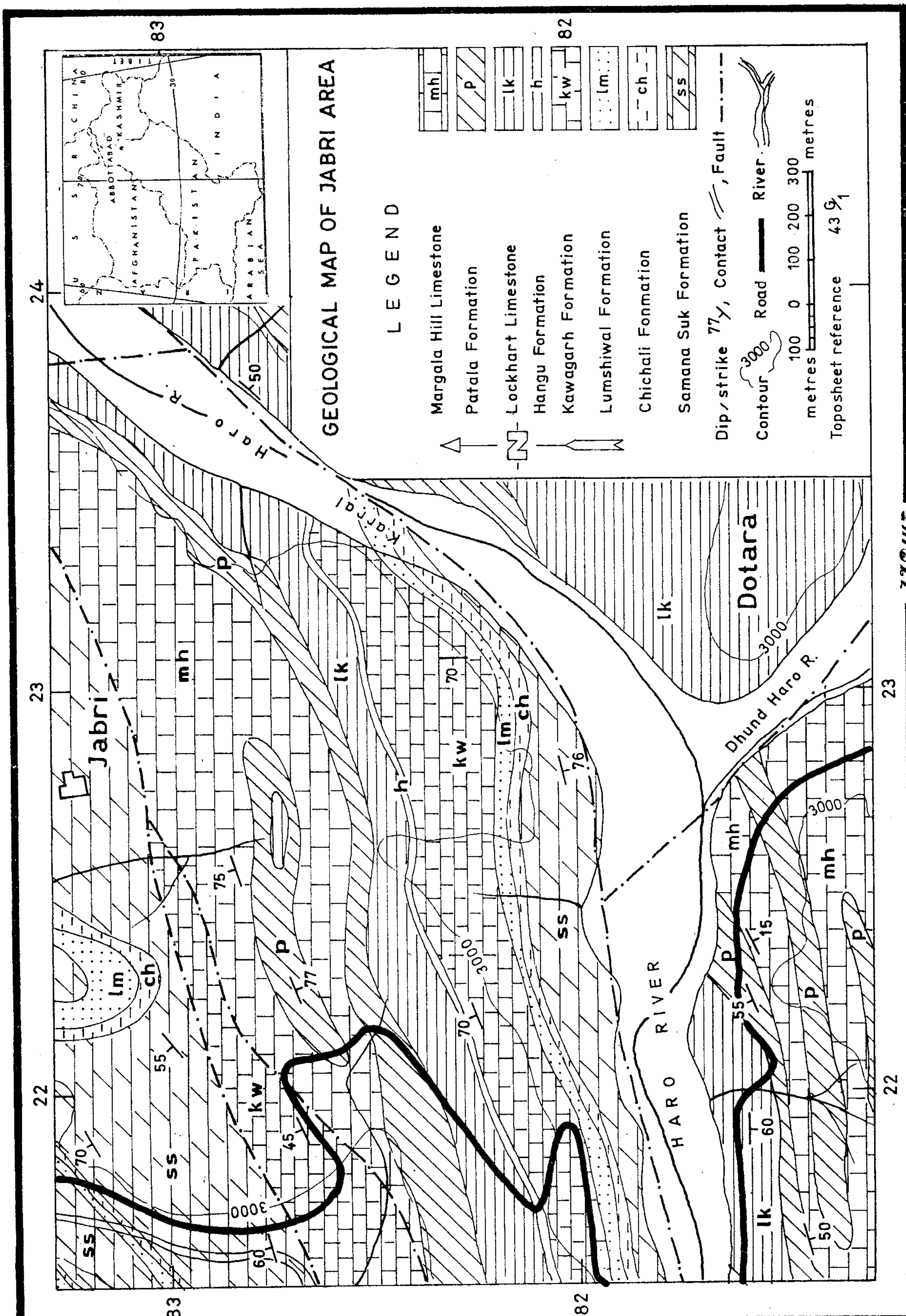


Figure 1– Geological and location map of Jabri Area.

Table 1. Stratigraphic sequence of the Jabri Area.

TIME UNITS		LITHOSTRATIGRAPHIC UNITS	THICKNESS
CAINOZOIC	L. EOCENE	MARGALA HILL LST.	350'-400'
	U. PALEOCENE	PATALA FM.	300'-400'
	M. PALEOCENE	LOCKHART FM.	200'-250'
	E. PALEOCENE	HANGU FM.	15'-20'
		Disconfirmity	
MESOZOIC	U.CRETACEOUS	KAWAGARH FM.	430'-435'
	L.CRETACEOUS	LUMSHIWAL FM.	150'-175'
	U. JURASSIC	CHICHALI FM.	200'-250'
		Disconfirmity	
	M. JURASSIC	SAMANA SUK FM.	550'-600'

PETROLOGIC NATURE OF MARGALA HILL LIMESTONE

The formation is composed of biomicrite, biosparite and sparbiomicrite (Folk, 1959, 1962 and 1974). However, this formation is composed pre-dominantly of biomicrite. It can be divided into the following ten microfacies (Figure 2).

1. Mudstone-Fossiliferous Micrite Facies (Plate I-1)

It is an extremely fine grained micrite (chemically precipitated). Carbonaceous matter ranges upto 1%. Micritic calcite ranges between 91% to 94%.

Fossil shell fragments, which are strongly fragmented constitute from 6 to 8 percent of the rock.

2. Wackestone to Packstone-Biomicrite Facies (Plate I-2)

This facies is composed of bioclasts and is mud supported. The bioclasts identified are *Assilina sp.* (*A.subspinosa* mostly) 12%, *Discocyclina dispansa* 9%, *Nummulites sp.* (*N.atacicus*) 6%. Total bioclast content comprises about 40% of this facies. Carbonaceous matter is upto 0.5%. Micrite is dominant in this facies.

3. Grainstone - Biosparite Facies (Plate I-3)

It is grain supported and generally lacks carbonate mud. Bioclasts are 59.5% in which the *Nummulites mamillatus* contributes 10%, *Assilina subspinosa* 45%, *Discocyclina dispansa* 2.5%, *Discocyclina ranikotensis* upto 2%. The intraclasts are 3%. Clay and carbonaceous matter constitute 3.5%, gypsum 0.5% and secondary iron oxides are 0.5%. Spary calcite ranges upto 31%. Porosity-remains about 2%.

4. Wackestone - Biomicrite Facies (Plate I-4)

It is mainly mud supported. Bioclasts comprise 21.5% of this facies in which *Nummulites mamillatus* is 2.5%. *Assilina subspinosa* 6%, *Assilina laminosa* 1%, *Discocyclina dispansa* 1%, *Discocyclina ranikotensis* 1% along with 10% fragments of bioclasts. Intraclasts contribute 1% to this facies. Quartz is 0.5%, carbonaceous matter 1%, haematite 0.5% and gypsum 0.5%. The ground mass is micritic and constitutes 75% of the rock.

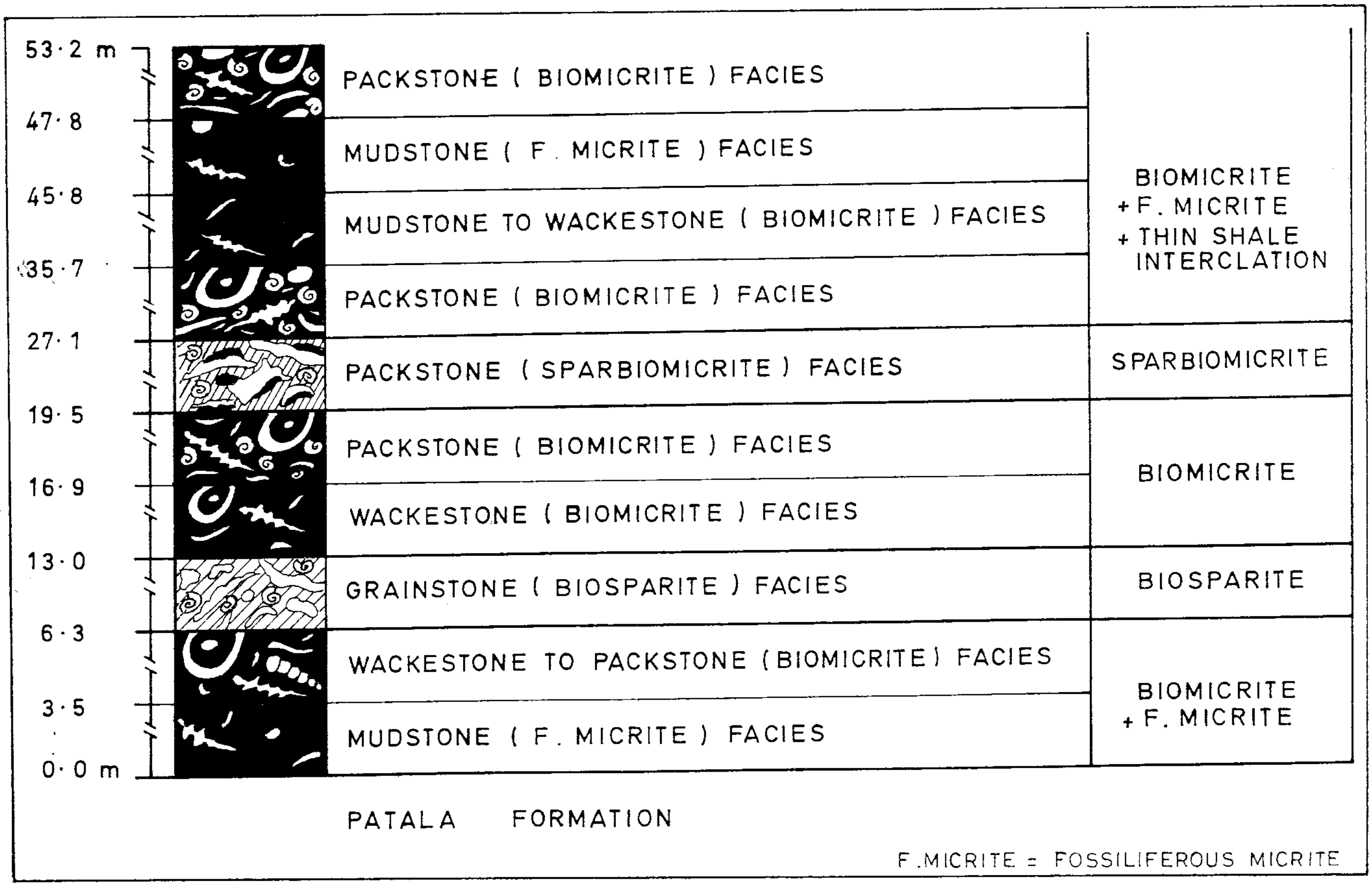


Figure 2– Lithofacies log of Margala Hill Limestone at Jabri.

5. Packstone - Biomicrite Facies (Plate I-5)

It is grain supported facies with carbonaceous mud. Bioclasts comprise *Nummulites mamillatus* upto 15%, *Assilina subspinosa* 7%, *Assilina granulosa* 2%, *Discocyclina ranikotensis* 10% and fossil fragments 20%. Intraclasts constitute about 5% of the rock. Other constituents are haematite 1%, clays 5% and carbonaceous matter 1%. Ground mass consists of micritic calcite that ranges upto 34%.

6. Packstone - Sparbiomicrite Facies (Plate I-6)

It is grain supported facies and also contains some carbonate mud along with spar calcite as pore filling cement (matrix). *Assilina subspinosa* ranges from 38% to 45%, *Nummulites mamillatus* from 2% to 10%, shell fragments from 3% to 10% and intraclast constitutes only 1% of this facies. Micrite ranges from 12% to 26% while spary calcite along with some microspar constitutes 18% to 20% of the rock. Clays and carbonaceous matter range between 2% to 4%. Gypsum and anhydrite are about 1%.

7. Packstone -Biomicrite Facies (Plate II-1)

Bioclasts of this facies are *Nummulites mamillatus* from 3% to 5%, *Assilina subspinosa* 30% to 40%, *Discocyclina ranikotensis* 8% to 10%, *Discocyclina dispansa* 7% to 12% and *Assilina granulosa* 4% to 6%. Intraclasts are upto 2%. Fossil fragments are 10% to 15%. Clays and carbonaceous matter are upto 1%. Ground mass is micritic. Porosity-remains range upto 1%.

8. Mudstone to Wackestone - Biomicrite Facies (Plate II-2)

In this facies bioclasts range from 4% to 13%. Complete fossil identification could not be made. There

PLATE I

(Description on page 59)

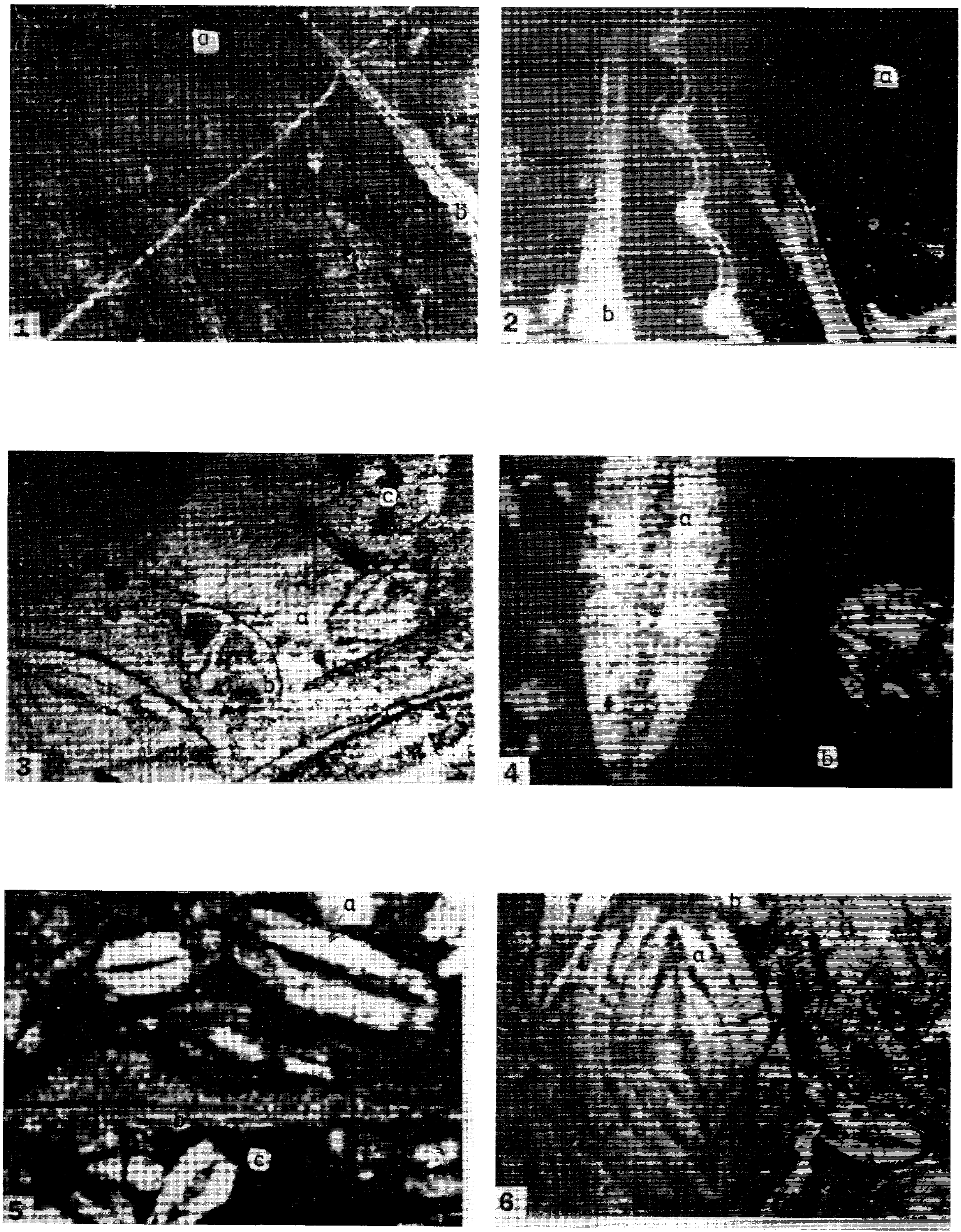
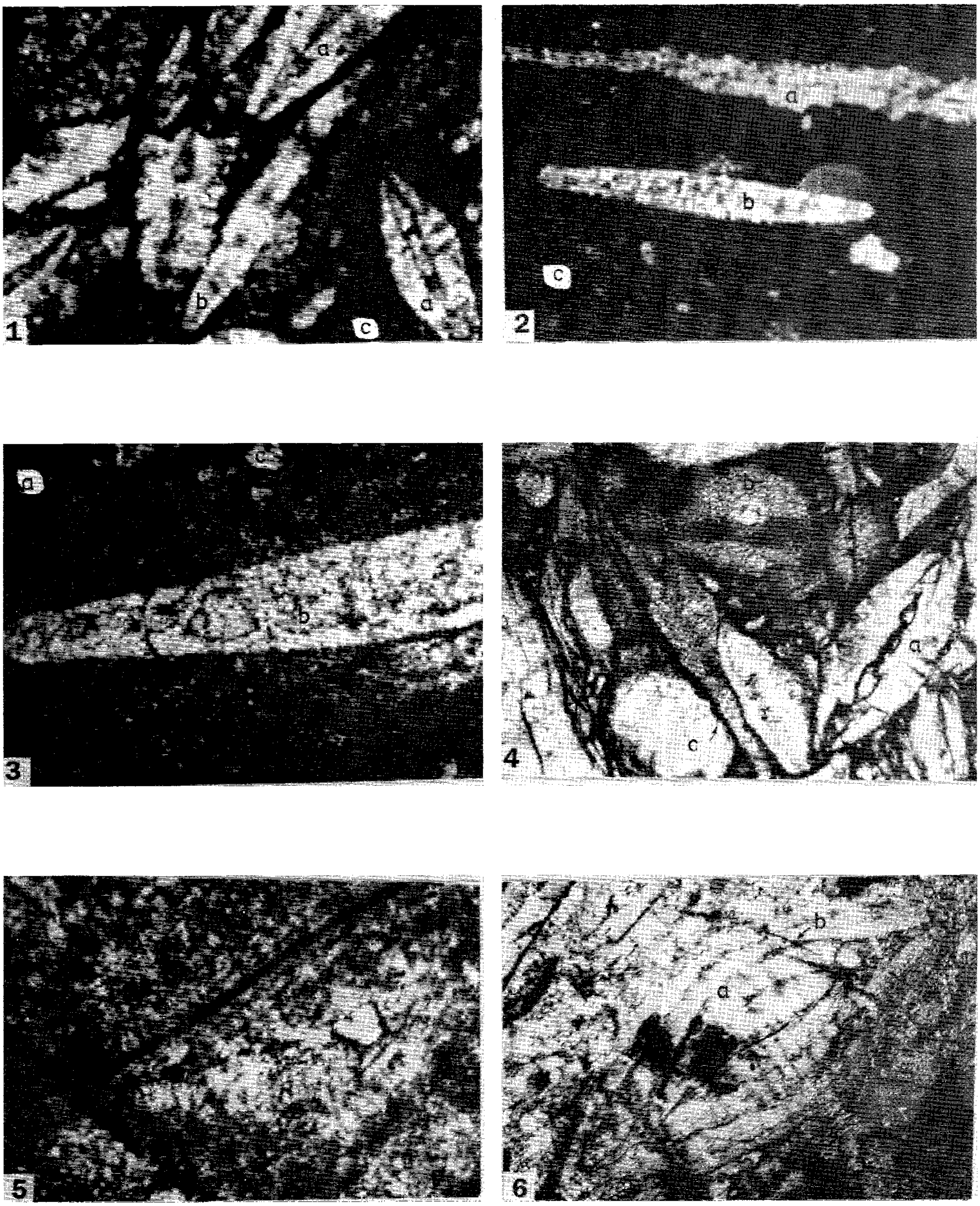


PLATE II

(Description on page 59)



DESCRIPTION OF PLATES

Plate I

1. Mudstone-Fossiliferous Micrite. 10 x 10, X-Nicols.
   a. Micrite, b. Bioclast.
2. Wackestone-Biomicrite. 10 x 10, X-Nicols.
   a. Micrite, B. Bioclast.
3. Grainstone-Biomicrite. 10 x 10, X-Nicols.
   a. Sparite, b. Bioclast, c. Carbonaceous matter.
4. Wackestone-Biomicrite 10 x 10, X-Nicols.
   a. Assilian subspinosa, b. Micrite, c. Gypsum.
5. Packstone-Biomicrite 10 x 10, X-Nicols.
   a. Assilina granulosa, b. Discocyclina dispansa, c. Micrite.
6. Packstone-Sparbiomicrite 10 x 10, X-Nicols.
   a. Nummulites Atacicus, b. Spar.

Plate II

1. Packstone-Biomicrite. 10 x 10, X-Nicols.
   a. Assilina subspinosa, b. Assilina granulosa, c. Micrite.
2. Wackestone-Biomicrite 10 x 10, X-Nicols.
   a. Discocyclina ranikotensis, b. Assilina granulosa, c. Micrite.
3. Mudstone-Fossiliferous Micrite 10 x 10, X-Nicols
   a. Micrite, b. Bioclast, c. Spar.
4. Packstone-Biomicrite 10 x 10, X-Nicols
   a. Assilina subspinosa, b. Discocyclina dispansa, c. solution seams.
5. Neomorphic spar with un-even grain size and irregular boundries. 10 x 10, X-Nicols.
6. Packstone Sparbiomicrite 10 x 10, X-Nicols
   Mechanical compaction leads to fracturing of grains.
   a. Nummulites atacicus, b. Fractures due to mechanical compaction.

are 1% to 9% clays and about 1% carbonaceous matter in this facies. Micritic calcite ranges from 80% to 90%. *Assilina subspinosa* is 0.3%, *Discocyclina ranikotensis* 0.5% and *Nummulites mamillatus* 0.8%.

9. Mudstone - Fossiliferous Micrite Facies (Plate II-3)

This facies is almost devoid of well preserved fossils. However, 6% shell fragments are present. Micrite is 92% while neomorphic spar is 2%.

10. Packstone - Biomicrite Facies (Plate II-4)

This facies includes bioclasts. *Assilina subspinosa* is the major constituent. Other fossils include *Discocyclina ranikotensis, Discocyclina dispansa, Assilina granulosa* and *Assilina laminosa*. Minor amounts of clay and carbonaceous matter is also present. A significant amount of ground mass or matrix is present. The facies is grain supported.

FAUNAL CONTENTS

In the Margala Hill Limestone of Jabri Section the following characteristic benthic larger foraminiferal species have been identified.

Assilina subspinosa (Late Paleocene, Thanetian, to Early Eocene) *Assilina laminosa, Assilina granulosa* (Early Eocene), *Discocyclina ranikotensis* (Late Paleocene, Thanetian, to Early Eocene), *Discocyclina dispansa* (Early-Middle Eocene), *Nummulites mamillatus* (Early Eocene), *Nummulites atacicus* (Early Eocene).

Raza (1967), Cheema (1968) and Latif (1970) recorded a number of foraminifers including all the above mentioned species. This fauna indicates an Early Eocene age for the formation.

LIMESTONE INTERNAL UNITS

The Margala Hill Limestone in Jabri Area can be divided into the following five lithological units.

1. Biomicrite + Fossiliferous Micrite
2. Sparbiomicrite
3. Biomicrite
4. Biosparite
5. Biomicrite + Fossiliferous Micrite

In order to avoid unnecessary repetition the biomicrite horizons will be described together. The biomicrite unit 1 above also contains thin horizons and intercalations of marl, calcareous shale and shale.

The biomicrite, sparbiomicrite and biosparite differ in many ways in their environment of deposition as well as diagenetic history. These are discussed as follows.

Biomicrite + Fossiliferous Micrite Units

There are three such units as given above. They usually have a fine grained dark grey carbonate matrix. This is a micrite with a grain size of less than 4 microns. These are, therefore, clay sized sediments. These units are considered to have been deposited in less agitated environments in deeper areas of open shelf or platform where deposition was largely below wave base.

These units have mudstone, wackestone as well as packstone textural classes. In mudstone transitional to wackestone, the micrite component is considered to be of an inorganic origin having precipitated in relatively clear and calm conditions in deeper areas of open shelf or platform.

In wackestone transitional to packstone and packstone, the micrite has generally been considered to be of biological origin. This view is supported by evidence of mechanical wearing and breakdown. Cementation of this type of micritic limestone has been considered an early diagenetic process (Bathrust, 1980). The presence in Margala Hill Limestone of microspar which grades into areas of normal micrite indicates the operation of neomorphic process. This microspar has most probably formed due to wet diagenetic recrystallisation of micrite (Bathrust, 1975). The evidence for neomorphic origin of most of the spar in this unit is as follows:-

1. It forms irregular boundaries and has no sharp contact with grains.

2. Micritic relics occur in the spar, since it has formed from micrite due to aggradation.

3. Crystals are patchy and crystal size is very uneven (Plate II-5).

4. It may also partially replace shell fragments.

5. Two generations of crystals usually observed in spar cement are not observed in neomorphic spar.

6. Large crystals embay micrite. There is a low percentage of enfacial junctions.

The above criteria for neomorphic generation of spar has been discussed in detail by Bathrust (1975).

Biosparite Unit

In this unit spar is a pore filling cement in grainstone. Spar is both intergranular and intragranular. The mould filling spar may have thin micritic envelope. Spar in this unit is considered to have been deposited in shallow open marine conditions through continuous percolation of water during slow sedimentation. This unit was deposited in shallower water and higher energy environments compared to the biomicrite unit described above. Spar in this unit is a cement and has not formed due to neomorphism. The evidence in this respect is as follows:-

1. This spar occurs as a cement in well sorted and abraded current transported grainstone where the grains are in depositional contact (Dunham, 1962).

2. The spar generally lacks relict structures.

3. The contact between spar and grains is sharp. (Bathrust, 1975).

4. The micrite envelopes around grains are not aggraded to spar.

5. The crystal size of spar increases away from initial substrate.

6. Enfacial junction pattern and triple junctions in spary mosaics are observed (Bathrust, 1975).

7. Compositional boundary is geometrical construction in which adjacent crystals meet interrupting the freedom of others (crystals) growth and tend to maintain contact along a plane interface.

8. There are two generations of cement, finely crystalline followed by a coarsely crystalline one.

Sparbiomicrite Unit

This is basically a packstone unit with micrite as well as spar cement. It reflects, during its formation, an environmental change from relatively lower to higher energy environment. The micritic cement was deposited in low energy area and below the wave base. Detailed petrographic studies indicate that most of the micrite is either chemically or biologically precipitated. Some contribution to micrite through grain diminution is also evident.

While the deposit was still porous, it was brought through a change in sea level to shallower and higher energy environment. This resulted in the precipitation of drusy spar cement.

There is also some neomorphic spar which has a fabric different from pore filling spar (Bathrust, 1980).

DIAGENETIC FABRICS

The diagenetic fabrics of Margala Hill Limestone are briefly described and discussed as under. Since the cementation has already been discussed, therefore, we shall restrict ourselves to mechanical and chemical compaction or pressure solution.

Chemical Compaction or Pressure Solution

Chemical compaction or pressure solution is a very important diagenic event in Margala Hill Limestone. Two ways in which this occurred are:

1. Dissolution at grain to grain contact in uncemented to poorly cemented limestone. But this type of compaction is not very important in this case.

2. Dissolution along specific surfaces (stylolites) within cemented sediments. This phenomena is quite important in the case of Margala Hill Limestone.

The grain to grain pressure solution is indeed responsible for certain amount of cementation and occluding of porosity. But this process is of little significance to major cementation event (Wanless, 1979 and 1983). Such dissolution/precipitation may be explained by under-cutting or solution film mechanism (Weyl, 1959).

In Margala Hill Limestone stylolites and solution seams cutting the cemented sediment are quite common. These appear to have played a much greater role than grain to grain pressure solutioning. Such seams have generally been considered to have developed perpendicular to the axis of maximum stress which may in turn be either due to overburden or operation of tectonic processes (Heald, 1955).

Although most of the stylolites in Margala Hill Limestone are best studied in the confines of thin sections, yet they show a variety of morphological details as well as size range. Such variations have been discussed in general terms by Park and Schot (1968).

These seams transect the pore filling cements. They may overlap or even split into sub-seams. These stylolites cut early generation veins but are cut by late generation veins. Accumulation of insoluble residue of clay, secondary iron oxides and organic matter along these seams is quite common.

Geometrical relations of these veins to bioclasts and other veins of an earlier origin indicate removal of considerable carbonate rock material during stylolitisation.

The stylolitisation is an important factor in volume reduction of this formation. This further reduces porosity due to dissolution of carbonate along seams and its precipitation in remaining pores in the vicinity of stylolites. These clay seams may also serve as migration barriers of hydrocarbons.

Regarding the origin of clay seams it may be pointed out that the insoluble residual material may be dominantly of primary origin. Margala Hill Limestone itself contains clay, some marl and shale. So this material appears to have contributed to the formation of these seams.

Mechanical Compaction

This type of compaction occurs due to progressive increase in overburden which also results in fluid expulsion and organic material migration. However in Margala Hill Limestone this process of compaction compared to the pressure solution along specific surfaces is of secondary importance. Mechanical compaction is much more evident in sparbiomicrite and biosparite than in biomicrite. This process leads to fracturing and breaking down of grains (Plate II-6), their closer packing and preservation of some shelter porosity. The shelter porosity is later occluded by cementation (Vinopal and Coogan, 1978).

ENVIRONMENTS OF DEPOSITION

1. The Margala Hill Limestone started depositing in low energy environment below the wave base. The faunal assemblage of larger benthic foraminifers, paucity of pelagic fossils and the micrite matrix/cement show that this part was deposited in deeper parts of the open marine shelf.

2. The succeeding (upwards) biosparite marks a change in sea level. In this unit the spar cement occurs within well sorted and abraded current transported grainstone where grains are mostly in depositional contact. This unit also contains larger benthic foraminifera. It was, therefore, deposited in high energy shallower environment. This unit remained for at least sometime in the phreatic zone where fresh water mixed with sea water. The conditions were of an open shelf as is shown by benthic faunal foraminifera contents. The maximum depth, therefore, could have been upto 30 m. The dilute phreatic waters encouraged the slow uninterrupted precipitation of larger crystals and coarse spary mosaics (non-ferroan) through degassing of CO_2. It appears that although the environments were quite

suitable for the formation of ferroan calcite, however, it was not deposited most probably due to nonavailability of sufficient iron contents or unsuitable chemical conditions.

Spar could also have formed as a cement during burial diagenesis. But this possibility is ruled out since there is no concomitant dolomitization.

3. Subsidence resumed and the near shore shoal area grainstones were gradually subjected to relatively deeper parts of the open marine shelf with low energy, where next biomicrite unit started depositing. The base of this unit is wackestone followed upwards by packstone. Periodic storms effected the sediments to produce shell fragments. While on sea floor, margins of many shells and shell fragments were micritised producing micritic envelopes. The micrite in this unit is both chemical as well as mechanical in origin. The faunal assemblage shows that the sea water had normal salinity and a state of oxygenation.

4. The next sparbiomicrite unit was deposited initially as a biomicrite. While still porous it was transferred, through sea level change, to shallower and higher energy environments where the spar cement filled the remaining pores as a second cement thus producing sparbiomicrite unit. It may be pointed out that subareal exposure was not attained since no hard grounds or hiatus is present.

5. The topmost biomicrite unit is unique in having thin beds and intercalation of marl, argillaceous limestone, calcareous shale and shale. This biomicrite unit once again indicates subsidence to lower energy and relatively deeper water open shelf conditions. This unit is composed of packstones and wackestone with intercalations given above.

REFERENCES

Bathrust, R.G.C., 1975, Carbonate sediments and their diagenesis: Developments in Sedimentology, 12, 658 p., Elsevier, Amsterdam.

___, 1980, Lithification of carbonate sediments: Sci. Prog. No. 66, p.451-477.

Cheema, M.R., 1968, Biostratigraphy of Changla Gali Area, District Hazara, West Pakistan: M.Sc. Dissert., Punjab Univ., Lahore, Unpub.

Cotter, G.de P., 1933, The geology of the part of the Attock District, West of longitude 72°45' E: India Geol. Surv., Mem., v.55, p.63-161.

Dunham, R.J., 1962, Classification of carbonate rocks according to depositional texture, *in* W.E. Ham, ed., Classification of Carbonate Rocks: AAPG Mem. 1, p.108-121.

Folk, R.L., 1959, Practical petrographic classification of limestones: AAPG Bull., v.43, p.1-38.

___, 1962, Spectral subdivision of limestone types, *in* W.E. Ham, ed., Classification of Carbonate Rocks: AAPG Mem. 1, p.62-84.

___, 1974, Petrology of sedimentary rocks: Hemphill, Austin.

Heald, M.T., 1955, Stylolites in sandstone: J. Geol. v. 63, p.101-104.

Latif, M.A., 1970a, Explanatory notes on the geology of Southeastern Hazara, to accompany the revised Geological Map: Wein IB. Geol. B.A., Sonderb., 15, p.5-20.

___, 1970b, Micropalaeontology of the Galis Group, Hazara, West Pakistan: Ibid., Sonderb., 15, p.63-66.

Middlemiss, C.S., 1896, The geology of Hazara and the Black Mountains: India. Geol. Surv., Mem., v.26, 302p.

Park, W.C., and E.H. Schot, 1968, Stylolites: their nature and origin: J. Sedim. Petrol., v.38, p.175-191.

Raza, S.M., 1967, Stratigraphy and paleontology of Gandhian - Dartian area, Hazara District, West Pakistan: M.Sc. Dissert., Punjab Univ. Lahore, Unpub.

Shah, S.M.I., 1977, Stratigraphy of Pakistan: Geological Survey of Pakistan, v.12, 138p.

Vinopal, R.J., and A.H. Coogan, 1978, Effect of particle shape on the packing of carbonate and sands and gravels: J. Sedim. petrol., v.48, p.7-24.

Waagen, W., and A.B. Wynne, 1872, The geology of Mount Sirban in the Upper Punjab: India Geol. Surv. Mem., v.9, p.331-350.

Wanless, H.R., 1979, Limestone response to stress, Pressure solution and dolomitization: J. sedim. Petrol., v.49, p.437-462.

___, 1983, Burial diagenesis in limestones, *in* A. Parker and B.W. Sellwood, eds., sediment diagenesis: NATO ASI Series C, v.15, p.379-417, Redel, Dordrecht.

Weyl, P.K., 1959, Pressure solution and the force of crystallization phenomenological theory: J. Geophys. Res., v.64, p.2001-2025.

Wynne, A.B., 1873, Notes from a progress report on the geology of the parts of the upper Punjab: India Geol. Surv., Recs., v.6, pt.3, p.59-64.