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Microfacies Studies of Sakesar Limestone Central Salt Range, Pakistan

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ABSTRACT: *The early Eocene Sakesar Limestone of Central Salt Range is represented by thin to thick bedded, nodular limestone and subordinate calcareous shale. Petrographic studies of four stratigraphic sections indicate that two major microfacies i.e., wackestone and packstone constitute the Sakesar Limestone. Each further contains six sub-microfacies. These are Algal wackestone and packstone, Rotaliine wackestone and packstone, Milioline wackestone and packstone, Rotaliine-milioline wackestone and packstone. Vertical variation in the studied sections indicates repetition of the interpreted environments (asymmetric cyclicity). These low energy progradational sequences laterally indicate more shallow water conditions in the west (Baghicha Nala, and Khura sections) than in the east (Bhadrar and Nilawahan sections).*

INTRODUCTION

The study area is located in the Central Salt Range (Lat. 32° 28' N to 32° 41' N; Long. 72° 2' E to 72° 39'E) in the District Chakwal and Khushab (Fig. 1). The early Eocene Sakesar Litnestone is well exposed and distributed along the northern slope of the Salt Range throughout its extent.

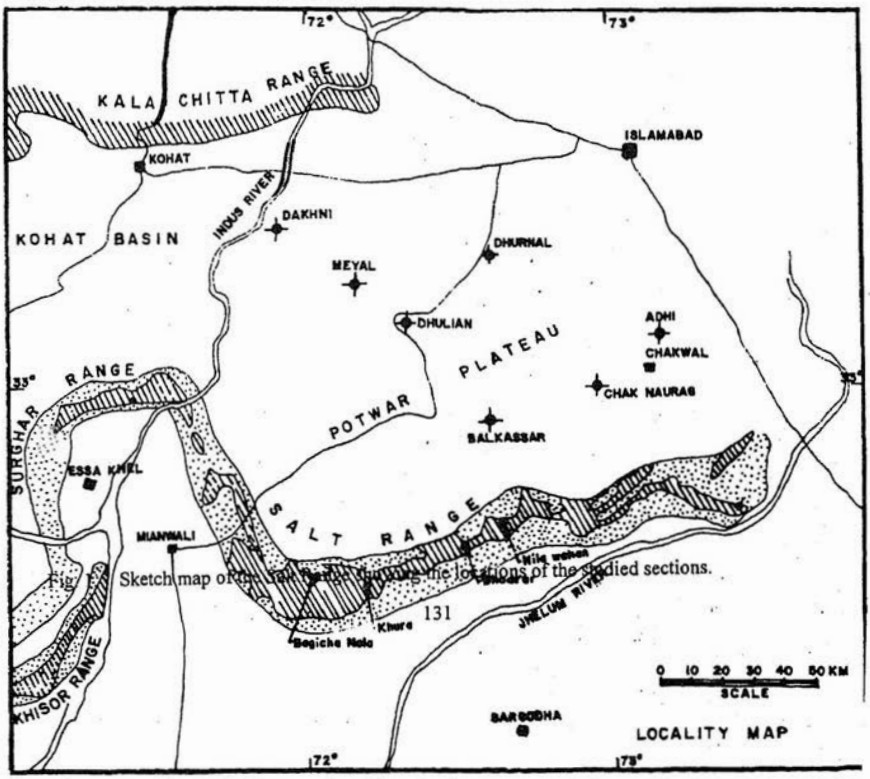

Fig. 1. Sketch map of the Salt Range showing the locations of the studied sections.

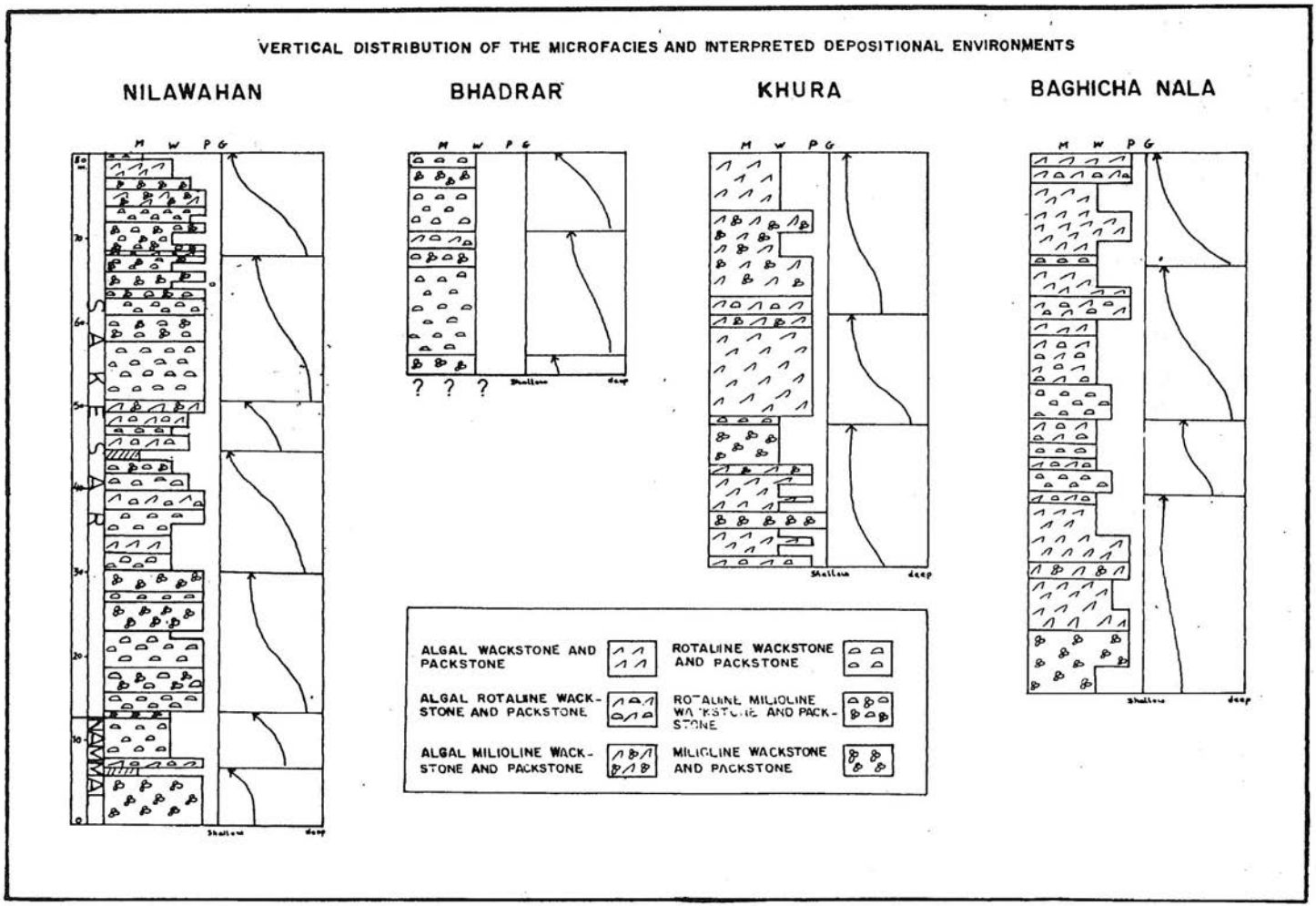

Fig. 2. Vertical distribution of the microfacies and interpreted depositional environments.

A number of workers have contributed towards an understanding of geology of the area, but no Published sedimentological details of the Sakesar limestone exist. The purpose of this study was to recognise the microfacies and infer the depositional environment of a part of the Sakesar Limestone that is exposed in the Central Salt Range.

In the 4 sections studied, two major microfacies (wackestone and packstone) are identified, which contain different combinations of Green algae, Foraminifera (Rotaliine and Milioline).

GENERAL GEOLOGY

The Salt Range is a part of an active foreland fold and thrust belt of the Himalayan collision zone in northern Pakistan, where Indian plate is being underthrusted beneath its own Phanerozoic sedimentary (Baker, et.al 1988).

The Sakesar Limestone (Early Eocene-Ypresian) is a thin to thickly bedded, in parts massive limestone with subordinate calcareous shale. It is mostly nodular (of 10-30 cm size) with chert nodules mainly present in upper part of the formation. The limestone is light to dark grey and in parts creamy in colour. Bioturbation (vertical, horizontal and random) is common.

The upper contact of the Sakesar limestone is conformable with Chorgali Formation at Nilawahan and Bhadrar and unconformable with late Pleistocene Kalabagh conglomerates at Khura and with the Siwaliks at Baghicha Nala. The lower contact is transitional with Nammal Formation. The Sakesar Limestone is highly fossiliferous. Larger and smaller benthic foraminifers along with other fossils such as Ostracods, Gastropods, Pelecypods and Echinoids are present in this formation.

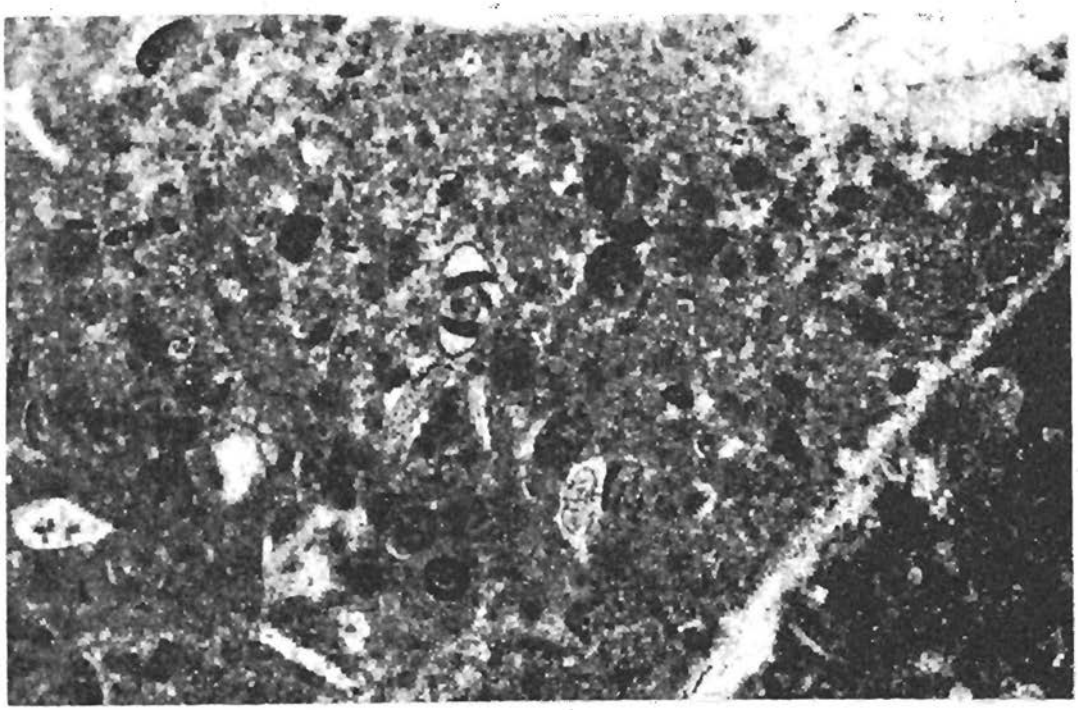

Fig. 3. Pellets in a dominantly micrite matrix.

PETROGRAPHY

Petrographic studies of 144 samples collected from Nilawahan, Bhadrar, Khura and Baghicha Nala sections were carried out. Few samples were stained with potassium Ferricyanide and Alizarin red S solutions (Dickson 1966).

The Sakesar limestone in these 4 sections is mostly represented by skeletal grains followed by minor amounts of pellets and intraclasts in a micrite matrix. A few samples contain sparse sparite. Some samples from Nilawahan and Bhadrar contain dolomite also.

The most common skeletal grains are the forams with Rotaliines and Miliolines in variable proportions being the most abundant (see Figs. 6, 7, 8, 9). The Rotaliines arc mostly well preserved and represented by Nummulites, Operculina, Assilina, Lockhartia, Sakesaria, Rotalia etc. Miliolines are represented by Miliolidae, Soritidae and Alveolinidae. The latter show effects of dissolution.

Small Gastropods and Pelecyopods (whole or broken) alongwith Echinoid fragments are also present. At Baghicha Nala, a 3 m thick unit near the base of the section contains well preserved dominantly large Gastropod shells. This unit can be traced laterally for a considerable distance. A similar unit but with relatively lesser amounts of Gastropods is observed at Khura. Green algae (dasyclads) is of widespread occurrence specially at Baghicha Nala and Khura. Red algae in minor amounts occurs in the basal part of Khura section only. Corallin algae occurs rarely in Nilawahan and Bighicla Nala section.

Peloids occur in 47% of the samples ranging between 2-30%, With a mean of 8%. These are surrounded by micrite or spar. In case where spar is in less amount or absent, they appear to have been welded together (Fig. 3). Intraclasts are present in 41% of the samples ranging from 1-8% with a mean of 3%. These are mainly micritic in composition and sometimes biomicritic. Rounded flat pebble (intra formational) conglomerate has been observed at one horizon in Baghicha Nala. They are angular to subrounded ranging in size between 0.47-2.35 mm (Fig. 4).

Following Dunham (1962), two major carbonate rock types recognised in the studied samples are wackestones and packstones. These two major microfacies as mentioned above contain skeletal material mostly represented by forams (Miliolines and Rotaliines) and dasyclads in variable proportions. Considering their distribution within the wackestones and packstones, the following undermentioned microfacies have been established.

ALGAL WACKESTONTE AND PACKSTONE

The distribution of this microfacies in the studied sections is 44% at Baghicha Nala, 41% at Khura and 7% at Nilawahan. None of the samples from Bhadrar showed its presence. Ovefrall 24% of the studied samples represent this microfacies.

Common to abundant Green algae characterise this microfacies, mostly in the form of circular shapes (thalii) which are commonly believed to be cross-sections through the stems/branches. Majority of the samples contain rare smaller benthics, Rotalia Lockhartia and Miliolidae. Other forams observed in some samples are Nummulites and Operculina. Fig. 5 shows the presence of abundant Green algae with some unidentified (rare smaller benthics + Echinoid fragments) in a micrite matix. In addition to the forams rare fragments of Pelecypods, Gastropods, Ostracods and Echinoids occur in most of the samples. Like the forams they are randomly distributed in a micrite matrix.

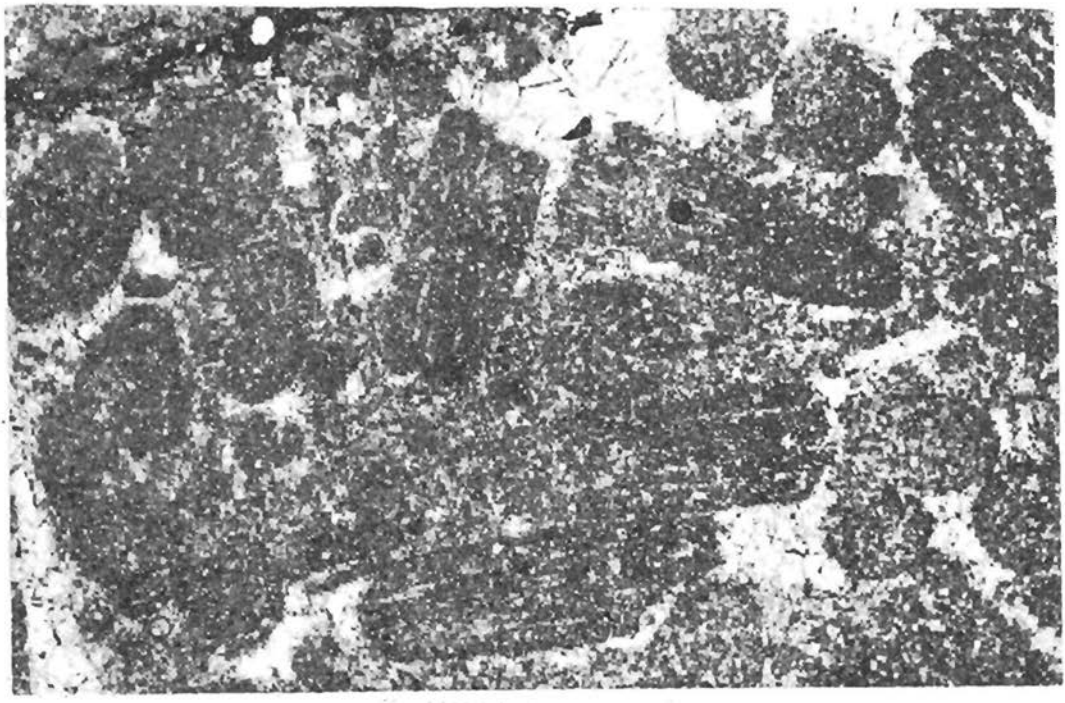

Fig. 4. Angular to subrounded intraclast in one horizon of Baghicha Nala.

Fig. 5. Algal wackestone and packstone microfacies showing common green algae with some smaller benthic, Echinoid and unidentified skeletal fragments in micrite matrix.

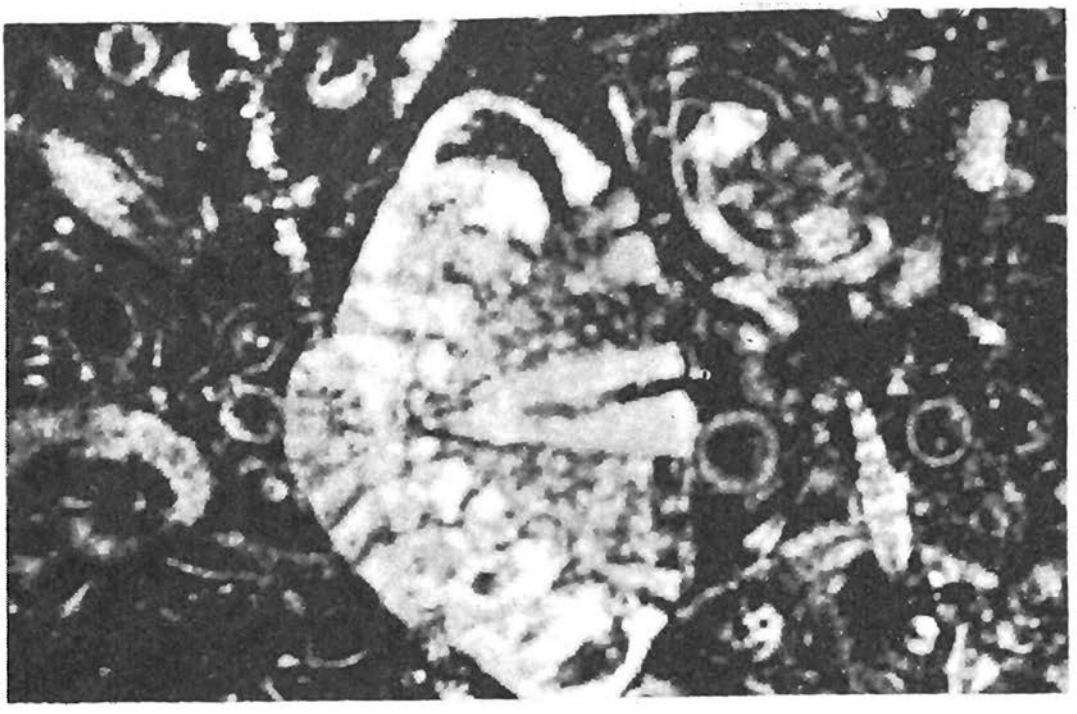

Fig. 6. Algal-Rotaliine wackstone and packstone microfacies containing green algae alongwith Rotaliine (Lockhartia, Operculina, Rotalia) fossils.

Fig. 7. Green algae with Miliolidae, smaller benthic and some skeletal fragments in Algal-Milioline wackestone and packstone microfacies.

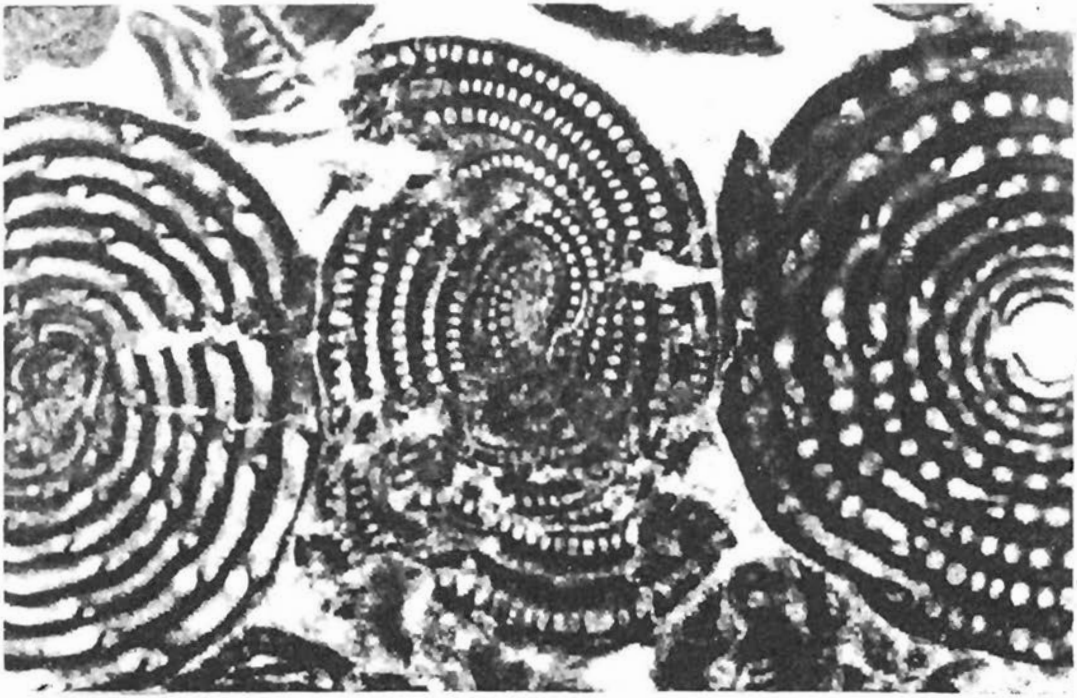

Fig. 8. The effects of compaction on Alveolinidae.

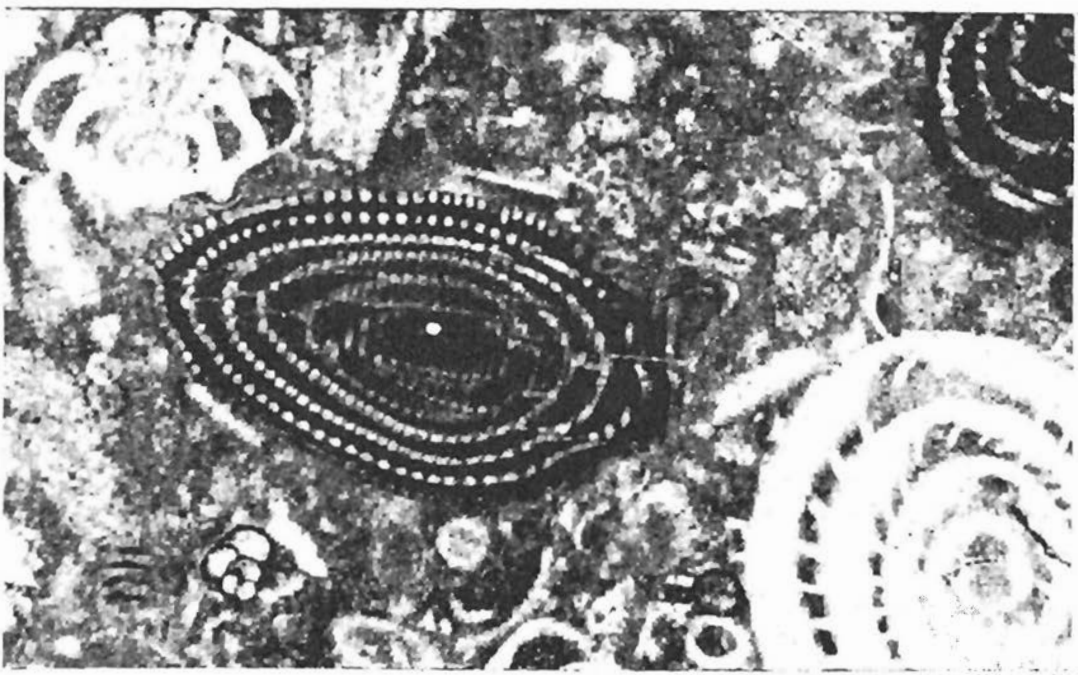

Fig. 9. Rotaliine (Nummulites and Lockhartia) and Milioline (Alveolinidae), green algae, smaller benthic and Echinoid fragments a micrite matrix in Rotaliine-Milioline wackestone and packstone.

The Algal wackestones and Packstones are found to be similar to each other in their bioclast constituents, the difference being a slight increase in the amount of Alveolina and Green algae within the Packstones. In a few cases angular to subrounded intraclasts with or without pellets are present. The only structure observed are the bioturbation features including the mottled structure.

ALGAL-ROTALINE WACKESTONE AND PACKSTONE

As the name suggests this microfacies is characterised by the presence of both Green algae (dasyclads) and Rotaliines. In fact the major difference between this facies and the earlier mentioned Algal wackestone and packstone facies is the increase in the amount of Rotaliines. Nummulites, Rotalia and smaller benthic are more widespread (occuring in 80% of the samples representing this microfacies). In some cases, the type of Rotaliine found is also different i.e. Operculina, Assilina, Sakesaria, Lockhartia and Discocyclinidae which were not observed in the Algal wackestone and packstone may be found here. A large Lockhartia, Operculina, Rotalia with abundant Green algae are shown in Fig. 6. The smaller randomly distributed fragments are believed to be parts of Green algae also.

The distribution of this microfacies is as follows: Baghicha Nala 33%, Khura 21%, Nilawahan 90% and Bhadrar 7%. They constitute 19% of the total samples. The bioclast composition is common to abundant Green algae and Rotaliine (Fig. 6). Among the Rotaliines, Rotalia, smaller benthic and Nummulites are rare to common and present in all the studied samples. In some samples, rare to common Assilina and common Operculina may be present. Rare Sakesaria may also be observed. Miliolines represented by Miliolidae, Alveolinidae and Soritidae. Besides rare Planktons, Ostracods, Pelecypods and Echinoids with or without Gastropods may occur. Three samples showed the presence of Coralline algae.

Angular to subangular intraclasts (in 58% of these samples) and peloids (in 48% samples) are present. The intraclasts (0.4 to 0.6 mm in size), composed of micrite range from 2-8% and may occur independently or in association with peloids which range from 3-20%. The peloids sometimes occur in clusters and in such cases the boundaries between them become diffuse. Whole to broken bioclasts occur scattered randomly in a micrite matrix. The only structure observed are horizontal and random burrows in nearly half of the samples. This burrowing activity where of greater intensity shows mottled structure.

ALGAL-MILIOLINE WACKESTONE AND PACKSTONE

This microfacies is represented by the abundance of Green algae and Milioline (Miliolidae and Alveolinidae) in all of the samples. The difference with Algal-Rotaliine wackestone and packstone is that Miliolines are in greater numbers as compared to the Rotaliines in all of these samples. The distribution of this microfacies in the studied sections is 17% at Khura, 7% at Nilawahan and 2% at Baghicha Nala section. It is not present at Bhadrar. In all, it represents 7% of the total studied samples.

Most of the forams occur as whole fossils with only 13% occurring as broken forms. The Miliolines are dominated by Miliolidae whereas rare to common Alveolinidae and rare Soritidae are present in most of the samples (Fig. 7). Among Rotaliines dominant fauna are rare Rotalia, Lockhartia and smaller benthics (Rotalidae & others). Occasionally rare Nummulites, Sakesaria and Operculina occur. Other fauna present are rare Ostracods. Echinoids and Pelecypods in all the samples. In few cases, Gastropods and Planktons were observed too.

Other allochems which may occur in association with the bioclasts are peloids and intraclasts. The peloids if present range between 8-20%. They are of slightly darker colour than the micrite and are found preserved in patches where very fine spar occurs between them. At other places, where spar is absent they seem to merge with the micrite matrix. Intraclasts range upto 5% and are mostly subangular to subrounded. Size of intraclasts ranges between 0.2 -0.5mm and are of micritic composition.

Overall micrite dominates over spar, the spar as mentioned earlier is occurring only in a few cases with the peloids. Micrite is mostly brown in colour. Random burrows are present (in 25% of the samples) and show a lighter shade of brown as compared to the micrite preserved outside. Small broken unrecognizable fossil fragments occur within the burrows. No other sedimentary structure has been observed.

ROTALINE WACKESTONE AND PACKSTONE

This microfacies is dominantly characterised by the Rotaliines which may or may not occur in association with rare Miliolines and Green algae. In such cases where the latter (Miliolines and Green algae) occur, the Rotaliines still constitute more than 50% of the bioclasts. The difference between wackestone and packstone is the increase in the amount of the bioclasts in the packstone. The percentages of this microfacies in the studied sections are as follows: Bhadrar 73%, Nilawahan = 42%, Baghicha Nala = 18% and Khura = 3%. They constitute 31% of the total samples.

Bioclasts range from 11 to 60% with a mean content of 33%. As mentioned above Rotaliines are the dominant constituents. Amongst them, common to rare smaller benthics and Rotalia are present in all the samples followed by Lockhartia (in 82% samples). Nummulites, Assilina or Operculina, wherever present, dominate over the other forms. In 25% of the samples, rare Sakesaria occurs. A noticeable feature observed is that Nummulites and Assilina may be present together, but in all cases they occur without Operculina and Sakesaria. This probably indicates an association between Operculina and Sakesaria which is observable in 30% samples from Nilawahan and Khura. Other forams present are rare Miliolines mostly represented by Miliolidae with or without Alveolinidae and Soritidae. In addition, rare Green algae, Ostracods and Echinoids occur. Few samples show the presence of Pelecypods and Coralline algae.

The above mentioned skeletal material (whole 83%, broken 17%) are the dominant allochemical constituents. Besides, nearly 40% of the samples contain peloids ranging from 3 to 18% and with a size range of 0.05 to 0.1 mm . Most of these peloids from their appearance and distribution appear to be broken smaller pieces of larger intraclasts. These intraclasts (in 30% samples) are composed of micrite, and angular to subangualar in shape. In addition, elongated forms (most probably flat-pebble conglomerates) with rounded to angular edges aligned parallel to bedding occur. Sometimes as in Fig. 4 they may be seen broken in two pieces and randomly oriented.

Spar to micrite may be present in different parts of the same sample and at places the concentration of the allochems in a single sample may be such that the name grainstone can be applied to these parts. However, overall the groundmass is micritic in composition. The only structure observed in about 20% of the samples are random burrows.

MILIOLINE WACKSTONE AND PACKSTONE

This microfacies is characterised by greater amount of Miliolines as compared to Rotaliines or Green algae. The distribution of this microfacies in the studied sections is 14% at

Khura, 12% at Nilawahan and Bhadrar each, and 2% at Baghicha Nala. It represents 10% of the total studied samples.

The wackestones and packstones are quite similar to each other except that the amount of Miliolidae and Green algae increases in the Packstones. Also, rare Assilina and rare Operculina alongwith peloids and intraclasts may occur in the Packstones. Major constituents of this microfacies are Alveolinidae and Miliolidae along with rare to common smaller benthics (some identified as textularia) and rare Ostracods.

Other components in decreasing order of abundance are rare Green algae (in 65% samples), Echinoids (60% samples), Pelecypods (50% samples), Gastropods (45% - samples), Soritidae (49% samples), Lockhartia (39% samples), Nummulites (22% samples), Assilina and Operculina (11% each). Most of the forams (80%) are whole and well preserved. Other shelly fauna mostly consists of broken forms. In some case orientation of bioclasts is observed and in some cases, the bioclasts are packed together to become grainstones. Besides, effects of compaction are quite prominent in some samples as shown in Fig. 8.

Peloids ranging from 4 to 25% with a mean of 10% occur in 40% of the samples. Their size varies from 0.04 to 0.14 mm and where spar is absent they are difficult to distinguish from the micrite matrix. Intraclasts are present in 28% of the samples.

Overall dark brown micrite dominates over spar. The micrite at places contain minute unrecognizable skeletal material also. No structure except the effects of bioturbation in the form of random burrows is observable and this too in only 48% of the samples.

ROTALINE-MILIOLINE WACKESTONE AND PACKSTONE

As the name suggests, Rotaliines and Milliolines are well represented in this microfacies. In most of the samples, the Rotaliines are slightly, in greater amount than the Miliolines. However, samples in which content of Miliolines is more are also present. Only two sections, Nilawahan and Bhadrar contain this microfacies where they constitute 21% and 7% of the studied samples respectively.

Skeletal material whole 86% and broken 14% are the major allochemical constituents. Nummulites, Rotalia and smaller benthic (smaller Rotalidae and other smaller benthic such as Textularia etc) are the common forms of Rotaliines observed, although Lockhartia, Assilina and Sakesalia may also be found. Among the Miliolines, the most common are Miliolidae with Alveolinidae and Soritidae occurring occasionally. Planktons, usually less than 1% are also present. Fig. 9 shows the presence of Nummulites, Alveolina and Lockhartia alongwith smaller benthics, some Green algae and other broken skeletal material in micrite matrix.

Other shelly fauna are rare Ostracods and Echinoids in all the samples with or without Pelecypods. No Gastropods were recognized. In addition, rare Green algae, mostly showing effects of abrasion occurs randomly distributed. Rare Coralline algae is present in two samples. Peloids ranging upto 15% may occur. Commonly they have diffuse boundaries and appear to be merging with the micrite matrix. Probably they were in greater amount than now suggested. No sedimentary structures are observable and the micrite of brown colour gives a uniform appearance.

DISCUSSION

Sakesar Limestone has a restricted range in terms of its allochemical constituents and

depositional structures. The microfacies established above are mostly based on the variation observed in the algal and foraminiferal contents . Many workers have commented on their environmental significance. (e.g. Lehmann, 1970; Luterbacher, 1970; Heckel, 1972; Hottinger, 1974; Dodd and Stanton, 1981; Haynes, 1981; Hallock and Glenn, 1986).

In the present case, the distribution of Green algae, Miliolines and Rotaliines in association with other bioclasts (notably Gastropods, Pelecypods and Echinoids) have been considered alongwith the bioturbation features to infer the depositional environment of these dominantly micritic limestones. The interrpreted environments and their vertical variation is shown in Fig. 2. This variation indicates that cyclic deposition took place. The asymmetric cycles show that most of the limestone was formed during depositional regression i.e. represents progradational sequence.

It is believed that overall lagoonal conditions prevailed. This is based on the prevalence of Green algae following Bossellini and Ginsburg (1971 in Dodd and Stanton 1981). Green algae (dasyclasds) occurs in warm water (Heckel, 1972), not more than a few meters deep (Wray, 1977) and is common between depths of 12-15 meters (Wilson, 1975). Moderate to low water turbulence specially in lagoonal and shelf settings (Dodd and Stanton, 1981) dominantly in subtidal to intertidal areas are the site of Green algae occurrence (Reeckmann and Friedman 1982).

In the present study the association of above mentioned bioclasts which are characterized of very shallow water environments (e.g. Lehmann, 1970) substantiate our interpretation. The Rotaliines are considered to be depicting slightly deeper environments (subtidal to intertidal) than the Miliolines (intertidal to subtidal). However, both mostly occur in lagoonal area (Luterbacher, 1970; Lehmann, 1970 and Hottinger, 1974).

Peloids and intraclasts occur only occasionally and commonly are minor - constituents. Generally their total content never exceeds 30%. Overall peloids are in slightly greater amount than the subangular to rounded intraclasts. Most of the peloids seem to be smaller broken products of the intraclasts i.e. product of reworking where as the faecal pellets are mostly poorly preserved and because of the absence of spar difficult to distinguish from the micrite matrix. Possibility of their being in larger amount than now exists. In fact the mottled wackstones and packstones (as in this study) are considered to have formed by compaction of soft faecal pellets (Tucker, 1990). Their presence indicates low energy areas (Flugel, 1982) of Protected environments such as lagoons and tidal flats (Bathurst, 1971; Davis, 1983; and Tucker, 1990).

Intraclasts of variable shape (subangular to rounded) present within the same sample probably reflect their abrasional history most likely due to the wave action. According to Flugel (1982) they form in the intertidal to supratidal zones. Association of pellets and intraclasts in the intertidal zone and of pellets and fossil fragments has been reported by Woods and Brown (1975) from Shark Bay. Following these workers it is believed that samples containing intraclasts and bioturbation features most likely indicate intertidal environments, whereas those lacking burrows reflect supratidal environments.

Predominance of micrite indicate mostly quite water conditions. Extensive burrowing in some parts of the sequence indicates slow rate of deposition for these carbonate rocks. Lateral distribution within the four studied sections indicate more shallower conditions (intertidal) in the west (Baghicha Nala and Khura) and subtidal conditions in the east (Bhadrar and Nilawahan).

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