在应用计算机解释 印度拉贾斯坦邦西部贾伊萨梅尔地区 比尔马尼亚盆地地质特征中地质数据的分析

S. C. 马瑟 D. S. 乔汉

(印度乔德普尔 J. N. V. 大学地质系)

最近十年来研究的地质数据包括比尔马尼亚盆地岩相的地层、岩性、岩石、粒度和地球化学资料。这些数据已进入专用的"Foxsedba"数据表以建立比尔马尼亚盆地的数据总库。采用 Harward 制图法在 x-y 轴(粒度参数和地球化学数据)上作图。该盆地各种岩相的环境解释模式都配备有"图象"软件。最后,上述资料被用来解释所推断的比尔马尼亚盆地各种岩相的沉积环境。该盆地的沉积充填物含硅质碎屑、碳酸盐和磷块岩相的混合组合,指示变幻不定的沉积环境,即有若干具间歇海进事件的沉积海退事件。结果,磷块岩主要形成一种浅水正化学沉积和异化学沉积的复杂组合。

ANALYSIS OF GEOLOGICAL DATA USING COMPUTER APPLICATIONS FOR THE INTERPRETATION OF GEOLOGICAL NATURE OF BIRMANIA BASIN, JAISALMER DISTRICT, WESTERN RAJASTHAN, INDIA

S. C. Mathur D. S. Chauhan

Department of Geology, J. N. V. University, Jodhpur, India

ABSTRACT

The geological data including stratigraphic, lithological, petrographic, granulometric and geochemical of lithofacies of Birmania basin have been studied for last ten years. These data were entered into specialized and data sheets of "Foxsedba"to establish data bank on Birmania basin. Graphs on x－y axis (for grain parameters and geochemical data) are constructed using "Harward Graphics". Interpretative environmental model of various lithofacies of the basin are prepared using"Image"software. Finally, the aforesaid data are interpreted to infer the environments of sedimentation of the various lithofacies of Birmania basin. The sedimentary fill of Birmania basin comprising a mixed assemblages of siliciclastic,carbonate and phosphorite facies indicate highly fluctuating sedimentary milieu viz: there were several events of depositional regression with intermittent events of transgression. As a consequence phosphorite formed essentially as a complex assemblage of shallow water orthochemical and allochemical sediments.

INTRODUCTION

The Birmania basin is an oval shaped isolated remnant of the Marwar basin (Early Palaeozoic) located in the heart of the Thar desert of western Rajasthan, India. It is considered to be floored by Malani rhyolite (745 ± 10Ma) which is exposed in south and south-eastern flanks of this basin. The basin comprises around 900 metre thick sedimentary sequence of siliciclastic, carbonate and phosphorite facies. These sequences are uncomformably overlain by Lathi conglomerate of Jurassic age in northern flank of the basin (Fig. 1, Narayana, 1964; Srikantan, *et al.*, 1969; Pareek, 1981, 1984; Mathur, 1987). In the present paper geological data including stratigraphic, lithological, petrographic, granulometric, and geochemical of various lithofacies of Birmania basin were collected for the last ten years. These data are analysed for tracing the sedimentary history of the Birmania basin.

METHODS AND MATERIALS

In order to mark lithofacies distribution and attitude of various lithounits including phosphorite horizon, geological mapping was done on the scale of 1 : 20,000. Systematic samples of all lithounits were collected at a regular interval of 50 metres along the strike. Large samples were cut and polished for megascopic studies. About 250 thin sections of samples of various lithofacies were prepared for petrographic studies. The grain size parameters and statistical properties for quartz, phosphate grains and pellets were determined purely on the basis of thin section study following standard procedures after Folk and Ward (1957); Pettijohn, (1969) and Pettijohn *et al.*, (1987). In all 50 samples of phosphorite and carbonate lithofacies for major and trace elements were analysed following rapid silicate analysis technique after Shapiro and Brannock (1962).

Aforesaid field, stratigraphic, lithologic, petrographic, granulometric and geochemical data were utilized to establish data bank on the Birmania basin. Further, these data were utilized to prepare various types of x—y axis diagrams using "Harward Graphics" package. Interpretative environmental model for various lithofacies were prepared using "Image" software. The aim of aforesaid exercise is to interprete these data and graphics so as to infer the depositional environment of the various lithofacies vis a vis the evolutionary history of Birmania basin.

GEOLOGICAL FRAMEWORK

The sedimentary rocks of the Birmania basin are broadly grouped into two formations viz; lower Randha Formation which comprises mainly siliciclastic facies and upper Birmania Formation which consists of repetitive sequences of siliciclastic, carbonate and phosphorite facies (Figs. 1 and 2).

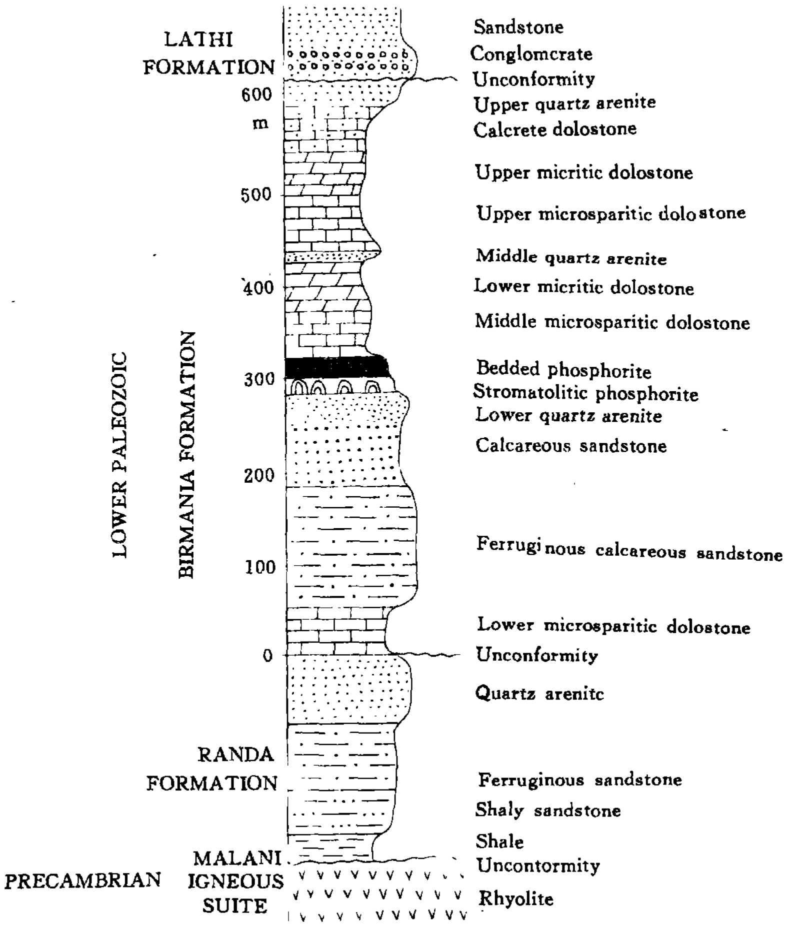


Fig. 1 Lithostratigraphic section of Birmania Basin

Randha Formation

The sedimentary sequence of Randha Formation starts with brown to maroon coloured shale at the base which grades upward into light brown, fine grained shaly sandstone, yellowish siltstone and medium grained brown ferrugenous sandstone. The ferrugenous sandstone is thickly bedded. It occasionally shows development of small scale cross bedding with moderate variation in current direction. Finally, it grades upward into creamish white, clean washed quartz arenite. The Randha Formation rests unconformably over the basement of Malani rhyolite.

Birmania Formation

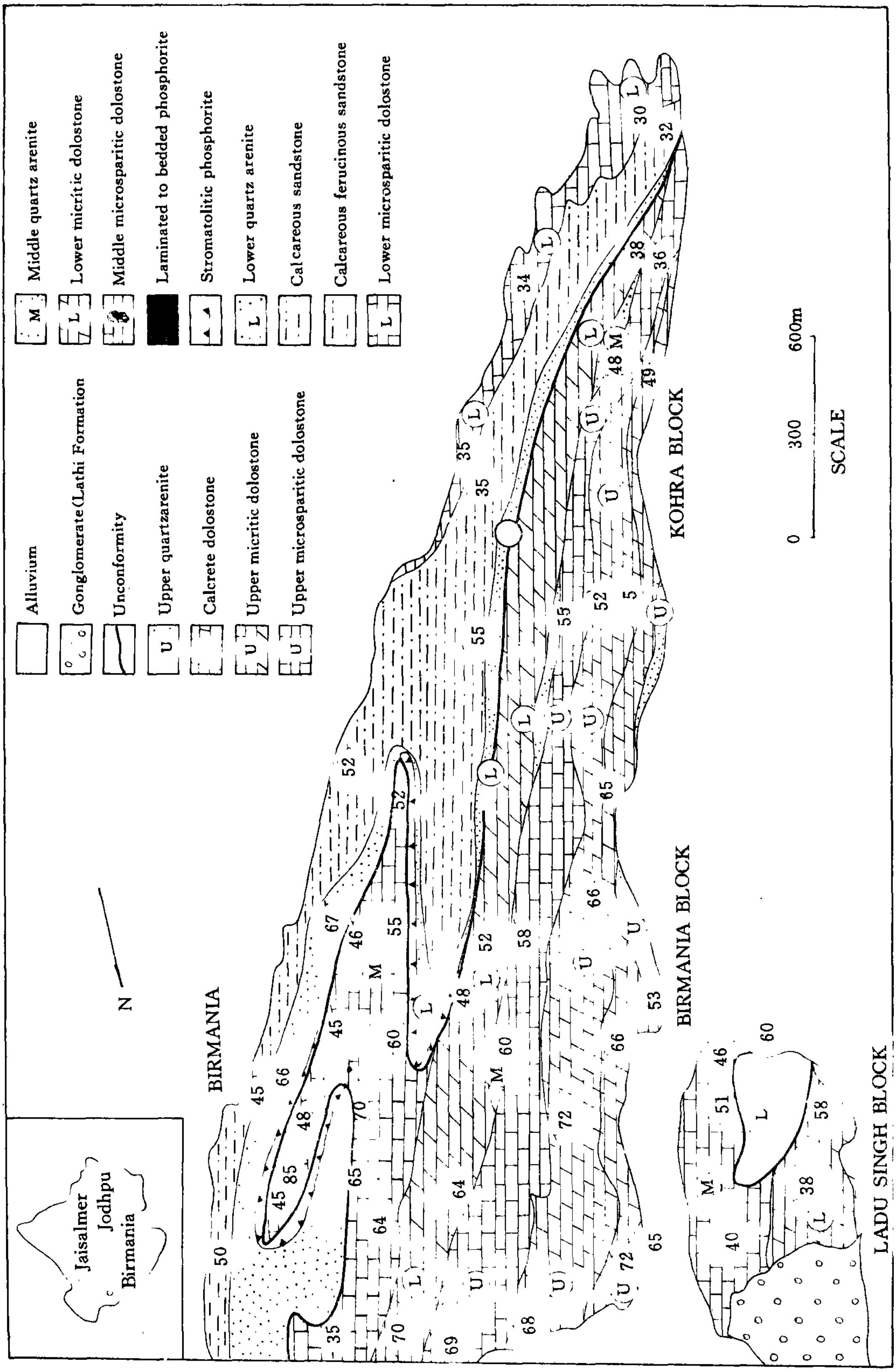


Fig. 2 Geological map of Birmania phosphorite deposit

The Birmania Formation comprises a mixed assemblage of siliciclastic, carbonate and phosphorite facies. This package of mixed assemblage has been divided into three distinct lithofacies associations. The lower siliciclastic dominated, middle phosphorite dominated and upper carbonate dominated lithofacies association(Fig. 2).

The lower lithofacies association comprises gray coloured microsparitic dolostone at the base which grades upwards into deep brown calcareous-ferruginous sandstone, finally culminating into creamy white quartz arenite. These siliciclastic rocks occassionally show development of wavy to lenticular bedding and small-scale cross-bedding with moderate variation in the current direction.

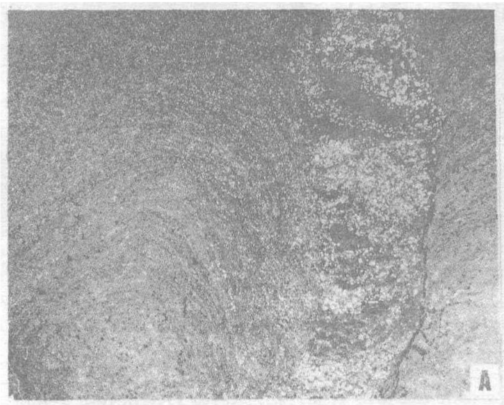
The middle lithofacies association starts with stromatolitic phosphorite horizon. The stromatolites are domical to pseudocolumnar structures of 2.0 to 8 cm in height. They conform to LLH-SH form of Logan *et al.* (1964). They are composed of 2 to 3 mm thick, moderate to steeply convex laminae of carbonate and phosphate. Their intercolumnar spaces are filled with clastogenic material(Fig. 3a). This sort of relationship between stromatolite and intercolumnar material suggests dominant role of erosional process in their shaping (Logan, *et al.*, 1964; Chauhan, 1979). The stromatolitic phosphorite is followed by laminated to bedded phosphorite, which is composed of alternate laminations of carbonate and phosphate minerals with or without quartz and phosphate detritus of different nature(described in detail under petrographic section).

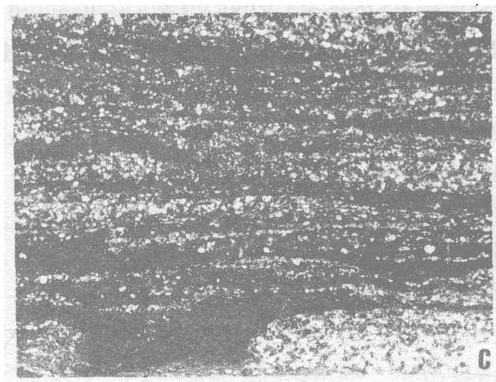
The upper lithofacies association starts with thickly bedded, dark gray microsparitic dolostone. It is followed by massive, hard and tough micritic dolostone which appear light gray in colour. The top layers of the micritic dolostone occasionally show development of mudcracks. The calcrete dolostone overlying micritic dolostone is a grayish brown massive hard rock. It shows gradational contact with the underlying micritic dolostone. The top of this lithofacies association is represented by creamy white clean washed quartz arenite. This sequence of the Birmania Formation is unconformably overlain by conglomerate and sandstone of Lathi Formation of Jurassic age. It is important to note that the top of each of the three aforesaid lithofacies associations is represented by clean washed quartz arenite horizon which exhibit everywhere sharp contact with the overlying lithofacies associations and thereby marks a definite hiatus.

MINERALOGIC, PETROGRAPHIC AND GRANULOMETRIC ATTRIBUTES

Siliciclastic facies

The siliciclastic rocks of the Birmania basin comprises 80 to 95 percent clean washed mediunm to coarse monocrystalline detrital quartz of unimodal nature. Heavy minerals present are tourmaline, zircon, sphene, garnet and magnetite. These detrital constituents are cemented by iron oxide, limonite, siderite, calcite/dolomite, phosphate and silica. These various types of cementing material occur in the form of interstitial and rim cement. Silica cement forms distinct authigenic quartz overgrowth around the detrital quartz grains(Fig. 3b).





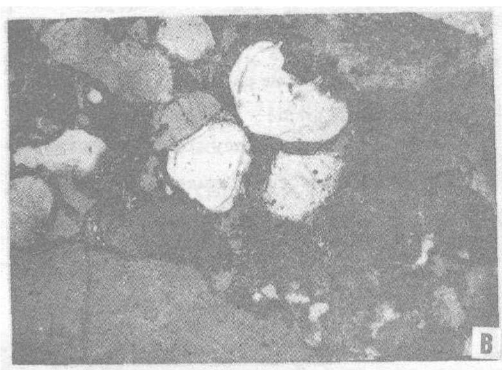


Fig. 3　a, Stromatolite showing columns and intercolumner material, Note. the intercolumner spaces are filled with clastogenic material, $\times 2.6$; b, Photomicrograph of calcareous-ferrugenous sandstone showing authigenic quartz overgrowth around detrital quartz grains. crossed nicols. $\times 48$; c, Bedded phosphorite showing alternate laminations of microsphorite and grainstone phosphate layers. collophane : black, quartz : white to light grey, crossed nicols, $\times 3.5$

Phosphorite facies

The phosphorite facies consisting of stromatolitic and bedded phosphorite is mainly composed of microcrystalline fluorapatite, calcite/dolomite and terrigenous quartz. The stromatolitic phosphorite comprises columnar to pseudocolumnar structures in which each stromatolite columns is composed of alternate laminations of phosphate and carbonate minerals often studded with detrital quartz grains. The intercolumnar spaces of the stromatolies are filled with quartz and phosphate clasts which are in turn cemented by phosphate or carbonate minerals.

The bedded phosphorite is composed of three types of laminations viz. ,primary, 1 to 3 mm thick microsphorite layers purely composed of cryptocrystalline fluorapatite occasionally studded with silty quartz(Riggs, 1984; Cook and Shergold, 1986). The top surface of these layers are highly irregular and marked by numerous erosional and other features such as scour channels, syneresis polygonal cracks and microfractures. These openings are filled with quartz and phosphate clasts and sometimes occupied by carbonate mud (Li Yuenan, 1986;Chauhan and Mathur,1987). The second type of laminations are 3 to 10 mm thick, composed mainly of phosphate grains, pellets and quartz cemented by sparry calcite. This type of phosphorite can be termed as grainstone phosphorite (Fig. 3, cf. Riggs, 1979a; Cook and Shergold, 1986). On the basis of granulometric analysis the reworking history of phosphate clasts is traced using associated quartz grains as a key mineral. The size, shape and other textural parameters of phosphate grains and pellets occurring with specific type of quartz grains suggest that the phosphate pellets were formed due to repeated reworking of phosphate grains (Figs. 4, 5, 6 and 7).

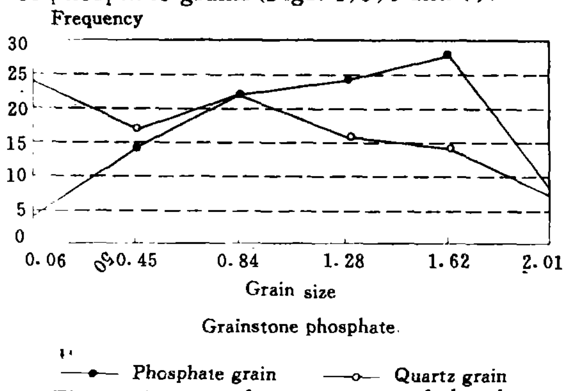


Fig. 4 Grain size frequency curve of phosphate grains and associated quartz grains in grainstone phosphorite

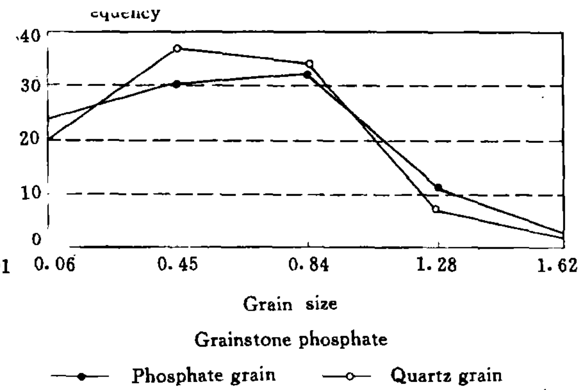


Fig. 5 Grain size frequency curve of phosphate pellets and associated quartz grains in grainstone phosphorite

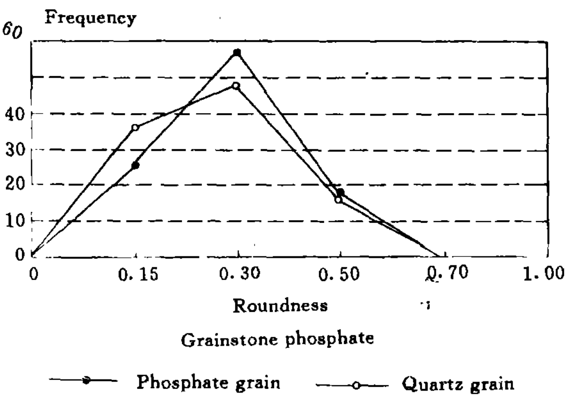


Fig. 6 Roundness grade distribution of phosphate grains and associated quartz grains in grainstone phosphorite

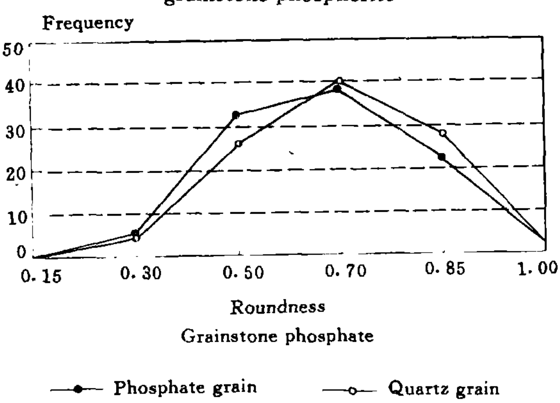


Fig. 7 Roundness grade distribution of phosphate pellets and quartz grains in grainstone phosphorite

The third type of laminations are 4 to 10 mm thick. They are composed of phosphate grains, pellets and quartz cemented by later generation of phosphate. This cement phosphate encroaches over the incorporated quartz and phosphate clasts, thereby replacing them to varying extent. Eventually, intensive replacement of the incorporated grains of phosphate and quartz led to the formation of a homogeneous secondary phosphate lamination having some relict, tiny quartz grains (Fig. 8; Mathur, 1987; Chauhan and Mathur, 1987).

Carbonate facies

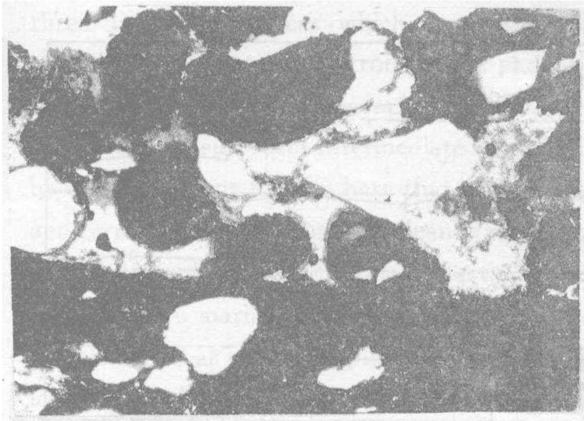


Fig. 8 Phosphate laminations of secondary generation showing coalescence and cementation of phosphate clasts and quartz grains, partially crossed nicols, ×20

Petrographic study reveals that the microsparitic dolostone is composed of equant grains of dolomite/calcite showing xenotopic fabric with a few lenses of sparite. The micritic dolostone appears as structureless homogeneous dolomicrite mud at the bottom (cf. Dunham, 1962). It grades upward into a complex microsparitic mass consisting of clotts of dolomicrite of 1.6 to 2.4 mm diameter. It can be termed as clotted dolor···te (cf. Ceyeux, 1936; Macintyre, 1977; Videich, 1985). Calcrete dolostone represents three distinct textural patterns. Firstly, angular to subangular silt sized quartz coated by micrite. Secondly, spherical to ooidal carbonate bodies 0.64 to 2.3 mm in size, outlined by microsparite and micrite. Thirdly, bigger elongated, irregular carbonate bodies of 0.61 to 2.6 mm diameter. They also possess outer rim of micrite and internally composed of radial fibrous sparite (Fig. 9).

Geochemical attributes

Carbonate facies: The carbonate rocks of Birmania basin contain 28.77 to 33.70% CaO, 15.43 to 21.53% MgO with corresponding 1.3 to 2.05 CaO/MgO ratio and 32.40 to 43.05 % $MgCO_3$. It thereby suggest that carbonate rocks of the area are mainly calcitic dolostone (cf. Pettijohn 1969; Fig. 10).

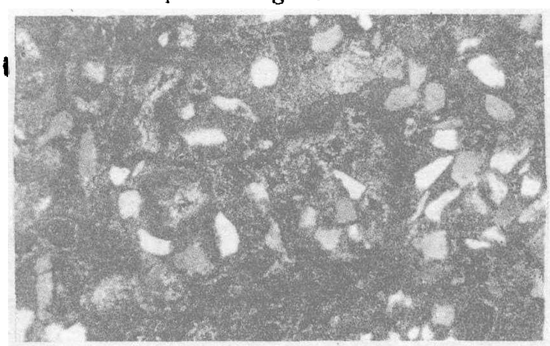


Fig. 9 Calcrete dolostone showing elleptical to circular carbonate bodies having envelops of micrite around an aggregrate of silt size quartz, crossed nicols, ×36.4

Phosphorite facies

P_2O_5 content of phosphorite of the area is as high as 29.37% percent averaging 21.45%. The values of the important oxides, viz., CaO, P_2O_5, MgO, SiO_2 etc. were plotted against the different samples (Fig. 11). The relationship between P_2O_5 and other major oxide is clear from the graph. The CaO indicates positive correlation while SiO_2 and MgO show negative correlation with P_2O_5 contents. This relationship corroborates with the petrographic studies of the phosphorite rocks of the area.

Environmental Evaluation

After analysis of various geological data viz., stratigraphic, lithological, petrographic, granulometric and geochemical of the typical siliciclastic, carbonate and phosphorite lithofacies associations of Birmanea basin, it is suggested that sedimentation in the Birmania

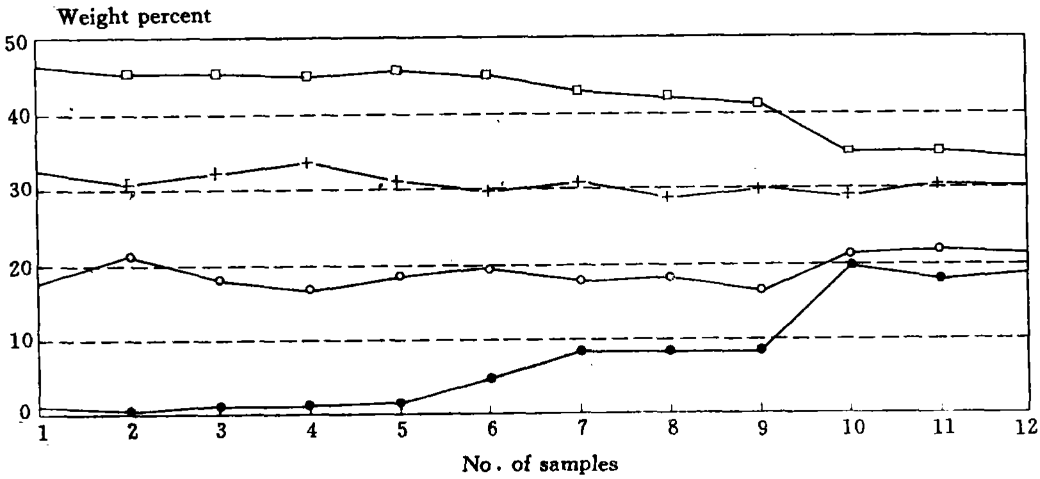


Fig. 10 Distribution pattern of LOI_1, CaO, MgO and SiO_2 and their relationship in carbonate rocks of Birmania basin

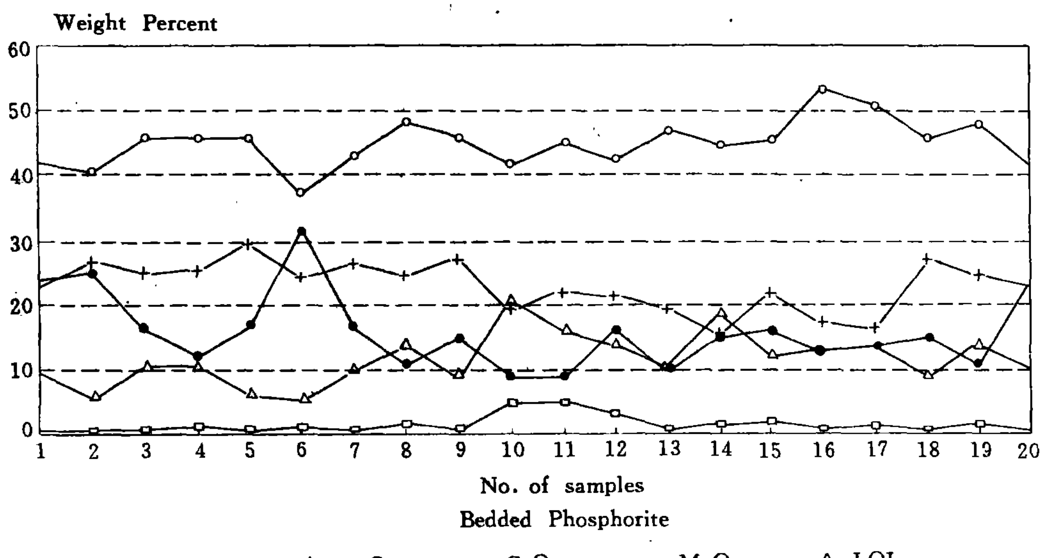


Fig. 11 Distribution pattern of SiO_2, CaO, MgO, P_2O_5 and LOl and their relationship

basin took place in relatively shallow water nearshore environment. The basal Randha siliciclastic facies, characterised by shale at the base grading upward into sandy shale, shaly sandstone, siltstone, ferruginous sandstone and finally into clean washed quartz arenite, constitutes a typical coarsening upward sequence. The sandy facies often shows planar cross-bedding which display moderate variation in paleocurrent pattern. It seems to represent small prograding deltaic sequence (cf. Scruton, 1960; Visher, 1965; Miall, 1976, 1985; Bhardwaj, 1980; Chauhan *et al.*, 1991). The overlying Birmania Formation represented by three distinct sequences which comprise microsparitic dolostone, calcareous-ferruginous sandstone, quartz arenite, stromatolitic phosphorite, bedded phosphorite, micritic dolostone and calcrete dolostone. The carbonate and siliciclastic facies form repetitive sequence while phosphorite facies form intermediate sequence with repetition of quartz arenite horizon only. It is important to note here that each sequence starts with carbonate facies at the base and terminates in the form of clean washed quartz arenite at the top. This sort of vertical distribution of carbonats and siliciclastic facies signify repititive events of sea level changes amounting to marine incursions followed by depositional regressions. Such a sequence can be considered as shallowing upward cycle evolved due to repetitive transgressive events followed by carbonate sedimentation and influx of terrigenous detritus representing regressive events. (see Ginsburg, 1974; Ginsburg and Hardie, 1975; Wilson, 1975; James, 1979; Mack and James, 1986).

It is important to record some of the characteristic features of the carbonate facies, viz., the structureless micritic dolostone, clotted matrix dolostone, micritic dolostone with or without mud cracks, microsparitic dolostone with xenotopic fabric and calcrete dolostone. They indicate subtidal to supratidal environment with intermittent long subaerial exposures especially as indicated by oriented mudcracks developed in micritic dolostone and calcrete dolostone (Fig. 12).

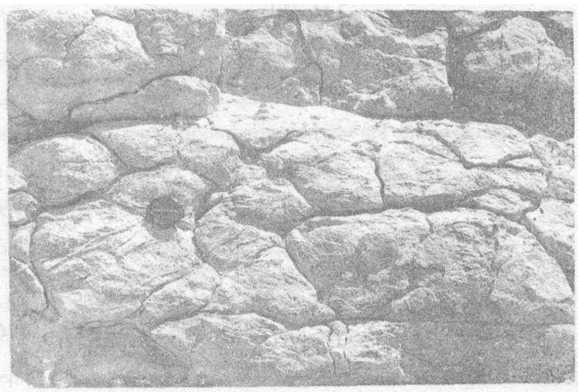


Fig. 12 Polygonal mud cracks developed in the top beds of micritic dolostone

The phosphorite lithofacies association records its first appearence by formation of stromatolitic phosphorite at the base. This indicates intertidal environment under which phosphorite in the area got fixed for the first time within these biogenic structures. The complex assemblage of phosphorite overlying the stromatolitic phosphorite, store the impact of wide variety of environment under which it might have formed. The orthochemical microsphorite laminations signify deposition of phosphate in subtidal setting under quiet water conditions. The lamination must have formed due to precipitation of calcium phosphate at and above the sediment water interface. These laminations are extremely thin and repetitious which suggests short period of tranquil environment (cf. Ginsburg, 1975; Klein, 1977). The secondary phosphate laminations, comprising phosphate grains, pellets and quartz grains cemented by later generation of phosphate, register still complex events of phosphogenesis. It appears that microsphorite layers were formed under the tranquil conditions. They were followed by agitated water conditions which caused fragmentation of primary phosphate laminations (cf. Riggs, 1979a, 1979b). Later reworking of the same produced phosphate grains and pellets. Finally, under diagenesis, phosphate grains got cemented partly with secondary phosphate and partly by sparry calcite leading to the formation of bedded phosphorite of the area which signify repetitious quiet water and agitated water conditions. These conditions seem to be limited within the confines of shoreface to outer foreshore environment of low energy beaches of the Birmania basin (Fig. 13).

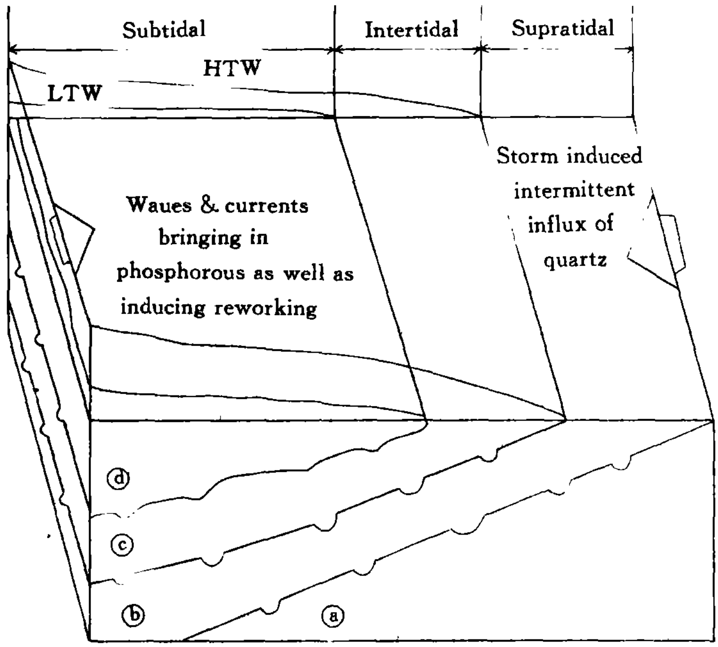


Fig. 13 Schematic reconstruction of depositional environment of phosphorite facies and its relationship with the subjacent lithofacies
a, lower microspaitic dolostone; b, quartz arenite and calcrete dolostone; c, stromatolitic phosphorite; d, bedded phosphorite

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