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Dimensional orientation of micrite particles and lithification in L-3 carbonate reservoir rocks of Bombay High Oil Field, India

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Abstract

Thin bands of lithified biomicrites separate highly leached, poorly to semilithified biomicrite reservoir rocks of the L-3 zone of Bombay High Oil Field. Among many criteria suggested in literature as to the lithification of limemuds, percolation of carbonate ion bearing solutions principally across and secondarily along the bedding plane appears to account for most of the lime cement. This concept is tested by a dimensional orientation analysis of micrite particles. This indication suggested that lithifying solutions have preferentially moved basically at right angles and secondarily parallel to the bedding plane.

Introduction

The L-3 carbonate reservoir rocks as studied in cores from Bombay High Oil Field reveal cyclicity in the development of porosity. The rocks are basically biomicrites and in terms of Dunham's terminology (1962) may be referred to as mudstones and wackestones and rarely as packstones. There is a band of highly lithified micrite below which the rocks are poorly lithified with abundant leached micrite and skeletal porosity. This band proceeds downwards with continued loss of porosity till it meets another hard band and the cycle repeats itself likewise three or four times, thus giving a somewhat layered structure to the reservoir facies. May be, these porous zones are not correlatable from well to well, thus adding further to the complexity of the reservoir facies. The problem is that while petrographically the porous and the lithified zones are similar, there is difference only in lithification of the hard bands. This paper aims to find a partial petrographic solution to the development of these. hard bands and good leached porosity in the micritic rocks right below them.

Lithification of the hard bands

Bathurst (1971) lists many processes for the lithification of calcite micrites. These are: (1) transformation of original aragonite mud to calcite mud, (2) the dissolution of tiny supersoluble particles and prominences on grains, (3) the transfer of Mg^{+2} from magnesian calcites, (4) dissolution yielding passive voids or leading to compactive collapse, (5) influx of allochthonous calcium carbonate, (6) pressure solution and (7) precipitation of calcite cement.

Among the above mentioned criteria, (1) and (3) belong to the realm of original mineralogical transformations. It is our experience in the L-3 carbonate reservoir rocks of Bombay High (Rao *et al.*, 1976) that the rocks mineralogically are composed of low Mg calcite and biogenic protodolomite. Therefore condition (1) and (3) must have been operative in Bombay High rocks very early in their diagenetic history. But the question arises if the process was operative it must equally apply to the nonlithified rocks also, as the lithified and non-lithified bands are mineralogically about the same. Therefore the reason must be elsewhere. The other operating conditions except (5) may answer the problem of lithification of the hard bands but the amount of cement derived thus appears to be of a limited amount and according to Bathurst (1971) the remaining nearly 30% of the cement must have been derived from the solutions ploughing across and/or along the bedding planes.

Schwartzacher (1961) in a study of lithification of micritic limestones associated with Waulsortian reef complexes of Ireland showed that the micrite particles exhibit a preferred dimensional orientation along and across the bedding planes. He surmised that lithifying solutions must have moved along and across the bedding plane. Therefore it was realised such a situation may be possible in Bombay High lithified bands also and therefore an experiement was conducted to test this hypothesis.

Dimensional orientation of micrite particles

Eight core samples of the lithified micrite bands with respect to depth of the L-3 reservoir facies from a well of Bombay High oilfield were chosen for the purpose of this study. Each sample was sawed at right angles to bedding, a thin section cut from this face and large size photomicrographs obtained from the edge of the thin section where it is likely to be only a few grains thick. Nearly one hundred micrite particles were chosen from each large size microphotograph by point count methods, the outline of the micrite grains drawn by India ink, the long axis of each grain marked and its inclination measured from the vertical line at right angles to bedding as the reference axis by means of a rectangular protractor. The data were recorded as readings on 0 to 360° clockwise scale. As it was difficult to distinguish one end of the grain from the other, for every angular measurement a value of 180° was added to obtain the opposite pole. The data were collected as circular histograms at ten degree class intervals as shown in Fig. 1. An inspection of this figure reveals that the distributions are polymodal but the principle mode is at right angles to bedding or slightly at an angle to the reference axis. Only in one sample the principle mode is at 45° to the bedding. Generally there is an absence of any mode parallel to bedding in the range of 80°-100°, that is, two class intervals of 10° each on either side of 90° position except in two samples (Fig. 1). This would give an indication that among the samples studied there is a general tendency for the alignment of the micrite particles at right angles to the bedding. This result may however, be fortuitous and may be a reflection of many chance causes. In order to check this a very simple statistical test was adopted as given below.

Statistical analysis

Tukey (see High *in* Carver 1971) suggested a X^2 (Chi-square) criterion for the test of randomness of azimuthal data. This test needs the requirement of at least five observations per cell. Middleton (1965, 1967) suggested a modification of this test where there could be less than five observations per cell. It is to be observed however, that Tukey's test either in its original form or as modified by Middleton, (op. cit) the distributions should be unimodal and essentially circularly normal, either skewed or unskewed (Reyment, 1971) and for polymodal circular data computation of vector sense and magnitude (mean and standard deviation respectively) may not be meaningful. All one could do (Reyment 1971) is to test the polymodal circular data for randomness against a uniform distribution by the non-parametric Chi-square criterion. The procedure is as follows:

Chi-square is defined as:

$$X^2 \text{ (Chi-square)} = \sum_{1}^{k} (0\text{-}E)^2/E \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

where,

O = The number of observations per class interval or cell.

E = Expected number of observations in each class interval or cell under conditions of uniform distribution.

$\sum_{1}^{k}$ = Summation sign (1, 2, 3 . . . . k) = number of class intervals or cells.

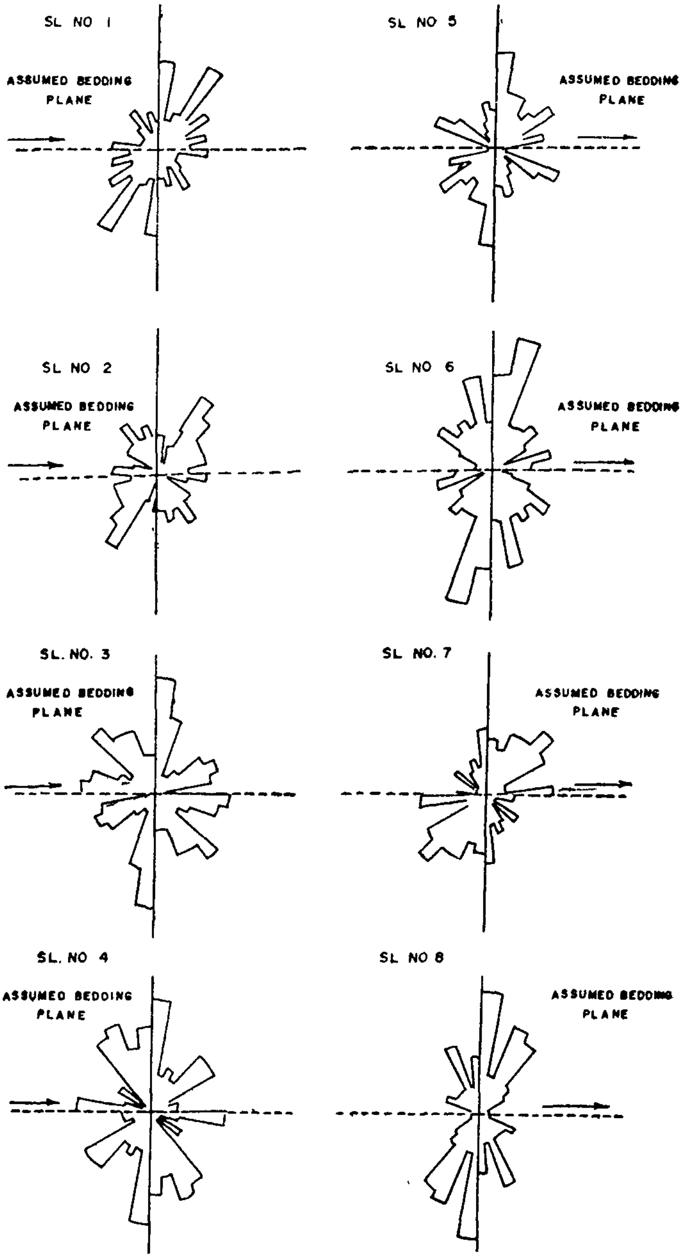

Figure 1. Circular histograms at 10° class intervals of dimensional orientation data of micrite particles in the lithified biomicrites of the L-3 zone carbonate reservoir rocks of Bombay High Oil Field.

If one has to use the test criterion against 36 (thirty-six) classes of 10° class width, the test would be cumbersome. Reyment (op. cit) suggests the regrouping of observations into six classes of sixty degrees (60°) width and apply the Chi-square criterion as given in formula No. 1. The null hypothesis under the test is that the micrite particles in the samples under study do not show any significant dimensional orientation and the differences between the observed and expected circular distributions are due to chance causes alone.

If the computed Chi-square is found significant at 95 per cent confidence level, the hypothesis is rejected, otherwise it is accepted. The computation of the Chi-square was programmed for Honey well-400 digital computer housed in the Institute of Petroleum Exploration, O.N.G. Commission and the results are tabulated in Table I. It may be seen from this Table that all the Chi-square values are highly significant at 5% and 1% level of significance. This would lead to the rejection of the null hypothesis and acceptance of the alternative that the micrite particles in the samples under study show a preferred dimensional orientation more than due to chance causes alone.

TABLE I. Chi-square values for testing the randomness of polymodal distribution of micrite dimensional orientation data of the lithified biomicrites of L-3 zone carbonate reservoir rocks of Bombay High Oil Field

Sample No.	Depth	Degrees of Freedom	Computed Chi-square
1		5	86.7692 **
2		5	57.6923 **
3		5	70.3529 **
4		5	104.7059 **
5		5	88.3077 **
6		5	112.7059 **
7		5	99.6923 **
8	↓	5	114.9231 **

** Significant both at 5 and 1 per cent levels of significance

Conclusion

The foregoing leads to the conclusion that micrite particles in the lithified micrites of L-3 reservoir rocks of Bombay High Oil Field show significant preferred dimensional orientation at right angles to bedding. This would suggest amongst several causes for the lithification of limemuds, the major one appears to be by the carbonate ion bearing solutions percolating primarily across, and secondarily along the bedding planes. This may be one of the reasons for the occurrence of highly leached micrite layers below the lithified ones and these arranged in a cyclic order.

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