CHAPTER - 3

MICROFACIES VARIATION, TEMPORAL AND SPATIAL

3.1 IDENTIFICATION OF MICROFACIES

A major part of the Oligocene section is made up of various carbonate rocks alongwith shale and minor siltstone. Since carbonate rocks are good indicators for understanding environments of deposition and energy of depositing medium, quantitative petrographic study was extended to carbonate rocks to decipher various microfacies types and in turn paleoenvironments.

As such, every carbonate sample was subjected to quantitative thin section petrographic studies. Different rock forming constituents were categorised in nine groups and their percentages were estimated with the help of comparative charts (Beccelle and Bosellini, 1965, cf. Deshpande et al,1991). The nine groups of the rock consituents adpoted are :

1 - Foraminifera

2 - Megafauna-pelecypod, gastropod, echinoids, algae, coral, bryozoa etc.

3 - Peloids

4 - Glauconite

5 - Micrite i.e. carbonate mud

6 - Dolomite

7 - Quartz

8 - Shale

9 - Sparite

Percentages of all the constituents within a sample were plotted as per appropriate stratigraphic positions in a vertical sequence representing each section (Figures 3.1 to 3.4).

In general, the basic microfacies identified are mudstone, foraminiferal/bioclastic wackestone, bioclastic packstone, grainstone and dolomite. At places, thin bands of shale and siltstone are present within a carbonate sequence.

3.2 TEMPORAL VARIATION OF MICROFACIES

Figures 3.1 to 3.4 represent vertical variations of microfacies along Ratipal, Bermoti, Bernani and Waior sections respectively, from northwest to south-east. It is interesting to note that the microfacies occur in an orderly repetitive vertical sequence. A typical sequence is as follows:

Top	Dolomite - Supratidal/shallow lagoon-Low energy	
	Grainstone	Intertidal-Moderate to High energy
	Bioclastic-packstone	
	Bioclastic wackestone	Subtidal to shallow shelf lagoon-Low energy
	Mudstone	
Base	Shale	

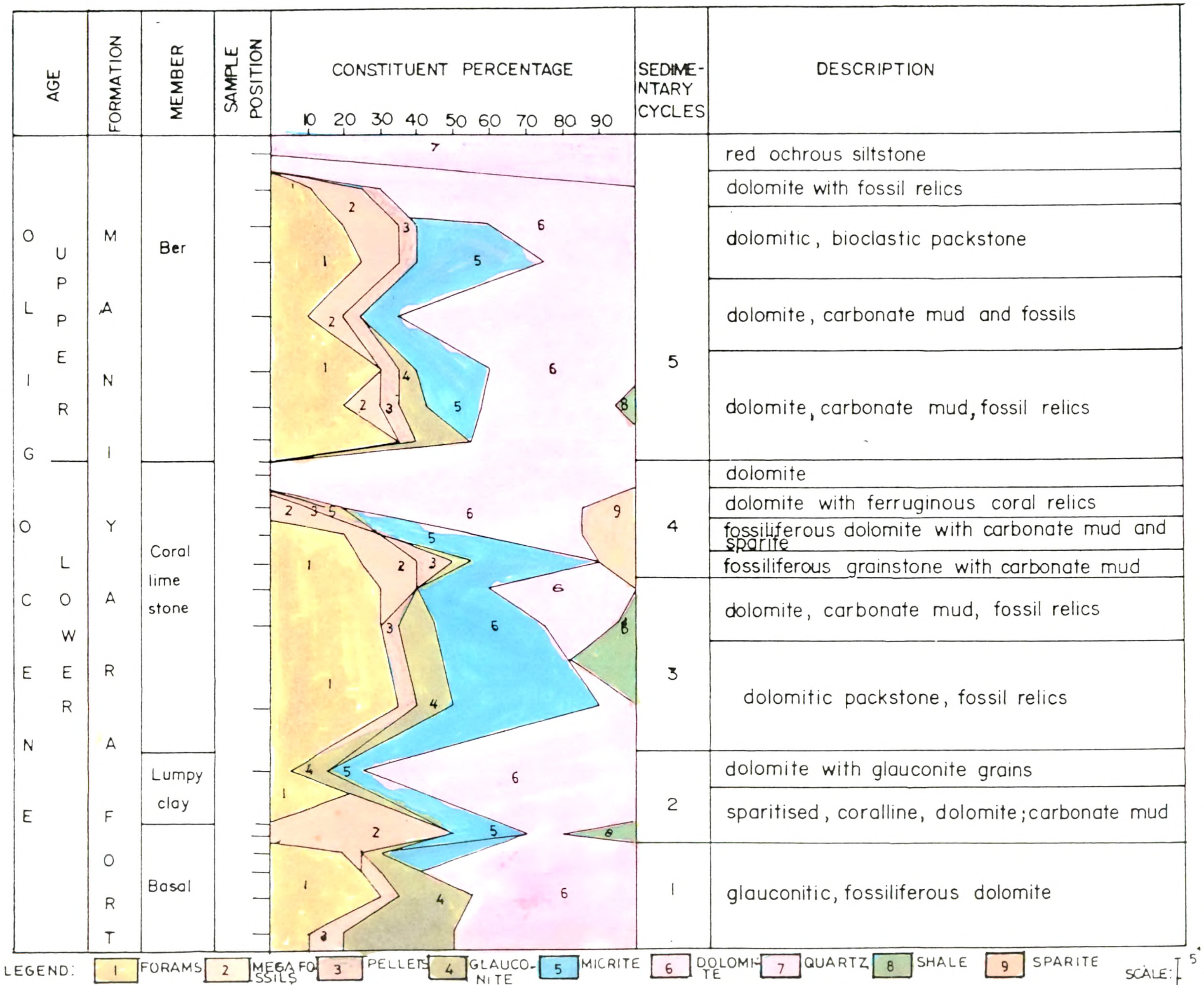


FIG. 3·1 QUANTITATIVE PETROGRAPHIC PLOT : RATIPAL TRAVERSE.

It is obvious that the resultant microfacies are a product of changing environments of deposition, from deeper, low energy subtidal, through high energy intertidal to low energy lagoonal and supratidal. This in turn represents a sedimentation cycle due to fluctuating sea level conditions. Several such cycles are noticed in each of section studied.

A detailed study of microfacies in vertical sequence along the traverses is as follows.

3.2.1 Ratipal Section

This section occurring in the western-most part of the area, is characterised by predominance of dolomatization (Figure 3.1). Highly fossiliferous and dolomitic packstone and dolomite with fossil relics are common microfacies. Sparitisation is observed in samples at the tops of Basal and Coral Limestone members. Often two stages of dolomitizations is observed within one sample (Plate IV. B). Dolomite is a predominant microfacies within late Oligocene ie. Waior stage.

Four sedimentary cycles are observed in early Oligocene, i.e. Ramania stage and one in late Oligocene i.e. Waior stage, in this

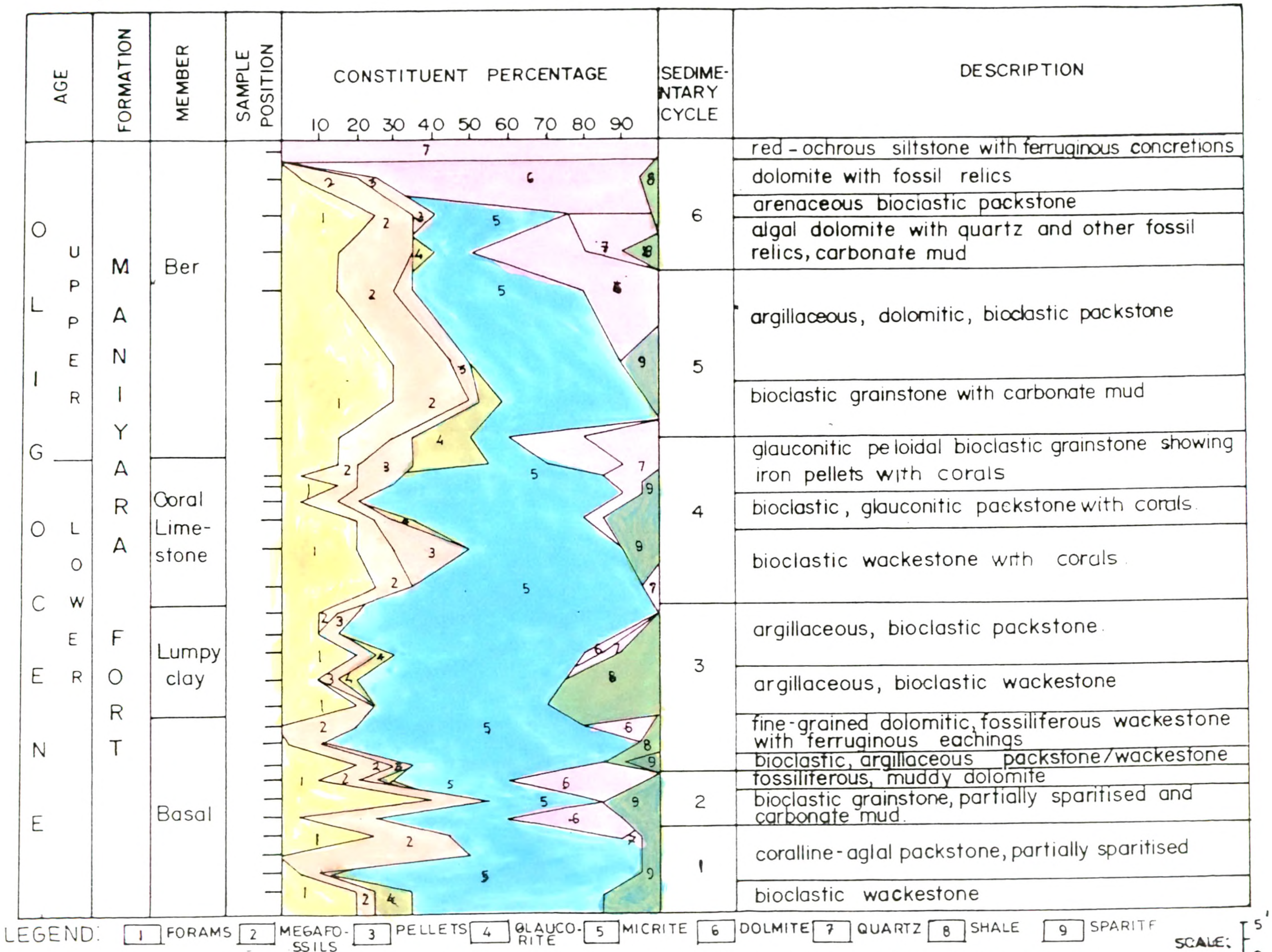


FIG. 3·2 QUANTITATIVE PETROGRAPHIC PLOT : BER-MOTI TRAVERSE.

section. The identification of cycles is based on varying proportion of carbonate mud and dolomites. However, the cycles do not represent a complete transgressive/regression event. But the sequence definitely represents sea level fluctuations i.e. shallowing and deepening.

3.2.2 Bermoti Section

Except at the top of the late Oligocene i.e. top of Waior stage, dolomatization is much less as compared to other three sections, (Figure 3.2). The higher percentage of argillaceous content is obviously complementary to the dolomatization. Coralline reefal developments characterise Coral Limestone Member. Patchy coralline growth is also observed in Basal Member. Glauconite is fairly common, almost throughout the early Oligocene, (Plate IV.C) Foraminifera and corals predominate the fossil content in early Oligocene, Ramania stage, whereas foraminifera and larger benthonics such as gastropod, pelecypoda, bryozoa, echinoderm etc. are common in late Oligocene.

The sedimentary cycles in this section indicate bioclastic wackestone at base of the section to dolomitic packstone and rarely grainstone in an upward sequence. Four cycles are observed in Lower Oligocene ie. Ramania and two in late Oligocene ie. Waior stage.

3.2.3 Bernani Section

The early Oligocene i.e. Ramania section indicates thick

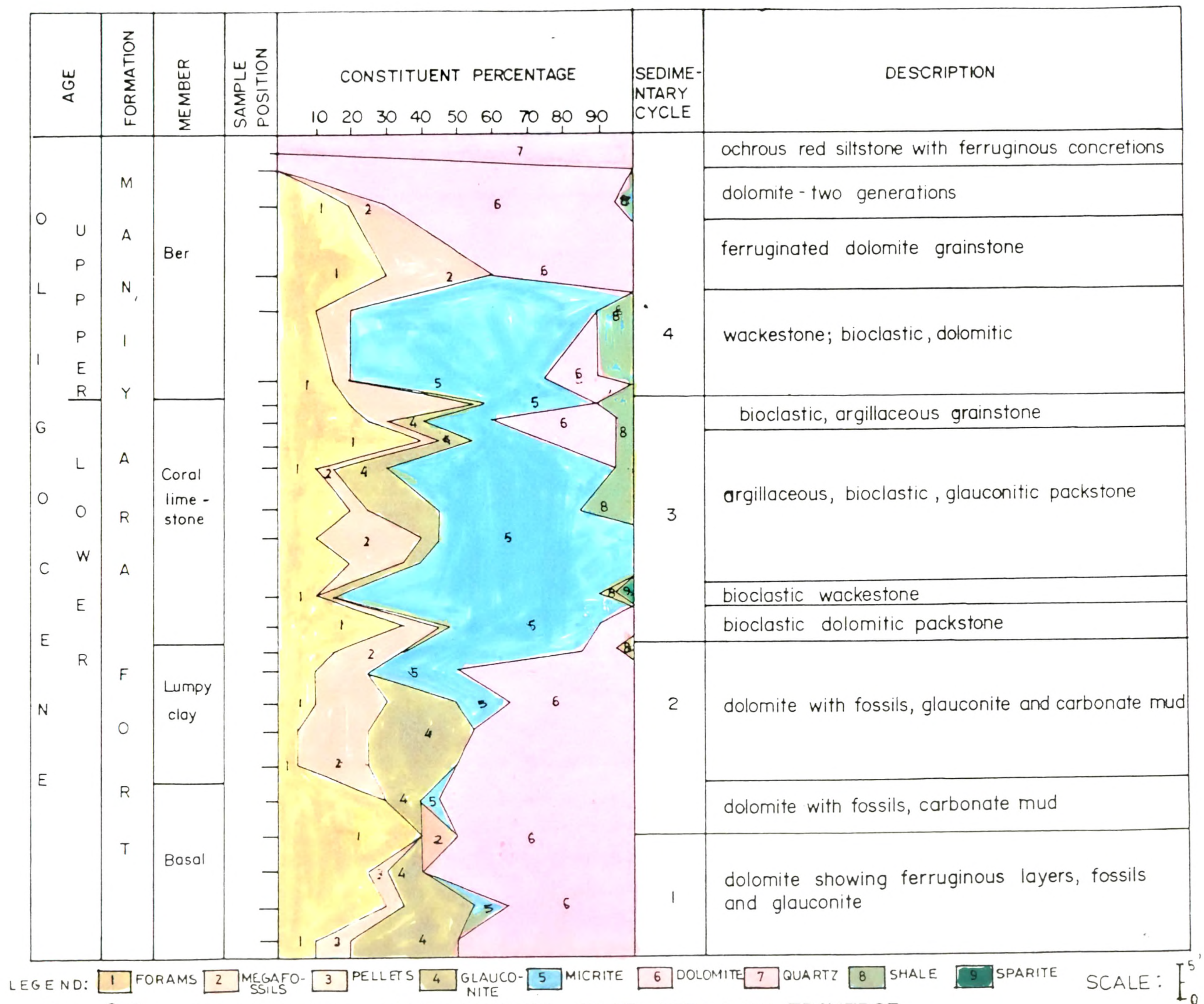


FIG. 3·3 QUANTITATIVE PETROGRAPHIC PLOT 'BER-NANI' TRAVERSE dolomite along with fossil relics and glauconite in the lower part i.e. within the Basal and Lumpy Clay members followed up by foraminiferal and glauconitic wackstone (Plate VA) and packstone in Coral Limestone Member, (Figure 3.3). Partial dolomatization has taken place further up towards the top of the Ramania stage, indicating a minor diastem. Two sedimentary cycles are observed in Ramania stage.

The late Oligocene Waior stage is likewise represented by two sedimentary cycles beginning with mudstone and fossiliferous wackestone and ending with packstone or dolomite.

As compared to Waior section, Bernani section to the west, shows only four transgressive/regressive oscillations covering the Oligocene strata.

3.2.4. Waior Section

The base of the early Oligocene i.e. Ramania stage indicates a thick early dolomite sequence (Plate V.B) suggesting an end of a sedimentary cycle or the beginning of the next cycle (Figure 3.4). This dolomite grades upwards into foraminiferal mudstone. The gradual dolomitizations takes place further up indicating an end of second cycle. This is followed up sequentially by mudstone, fossiliferous wackestone and packstone. The main fossils are foraminifera, corals, pelecypoda, algae etc. (Plate V.C). There is a sharp change in microfacies above this. It is represented by highly

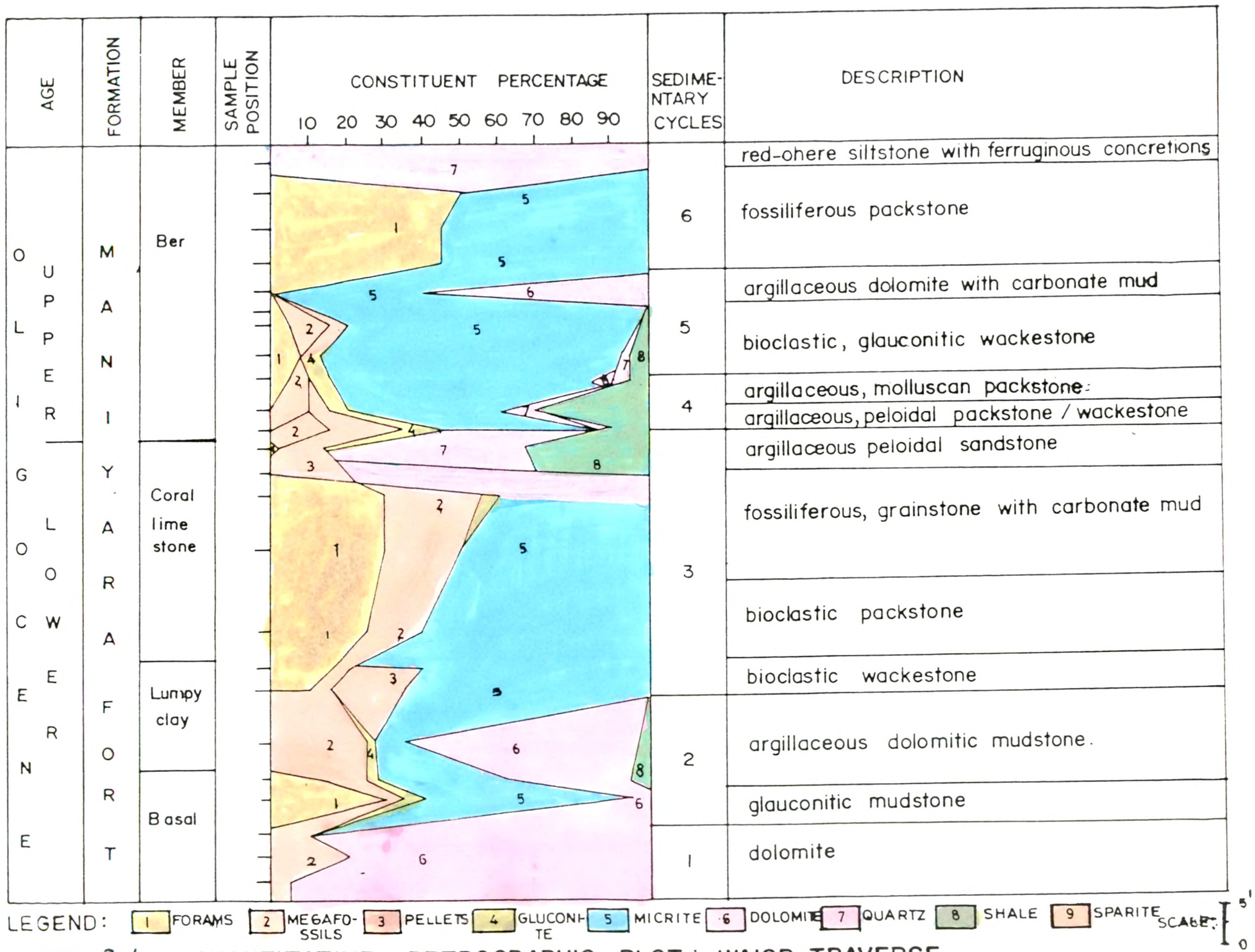


FIG. 3·4 QUANTITATIVE PETROGRAPHIC PLOT : WAIOR TRAVERSE.

arenaceous limestone and calcareous sandstone along with minor shale. This occurs at the early/late Oligocene i.e. Ramania/Waior boundary and clearly indicates an unconformity characterised by unfossiliferous sandstone (Plate VI.C, VII A).

The late Oligocene, Waior stage in this section is represented by three sedimentary cycles each beginning with mudstone along with shale (occurring at the lowermost section of Waior stage only) and endiing up in dolomite of fossiliferous packstone (Plate VII B). The upper part exhibits three distinct bands of highly bioturbated mudstone indicating three repetitive shallowing, tidal flat sequences, withiin one mega-sedimentary cycle.

3.3 MICROFACIES AND CYCLE CORRELATION

The basal Oligocene is characterised by development of glauconitic siltstone and is correlatable all over the area (Figure 3.5). Similarly the central and the upper parts of Ramania stage i.e. early Oligocene is represented by clay and coralline limestone almost throughout the region. The middle part of early Oligocene Waior stage is argillaceous in nature and well correlatable in the region. However, the carbonates of the lower and upper Waior stage show facies variations from packstone-grainstone and dolomite.

Within Ramania stage of early Oligocene age, four sedimentary cycles are identified in western area ie. Ratipal and Bermoti sections. However, eastern area (Bernani and Waior sections) show three cycles within this stage. Figure 3.6 displays that the cycles representing the Ramania strata are broadly correlatable.

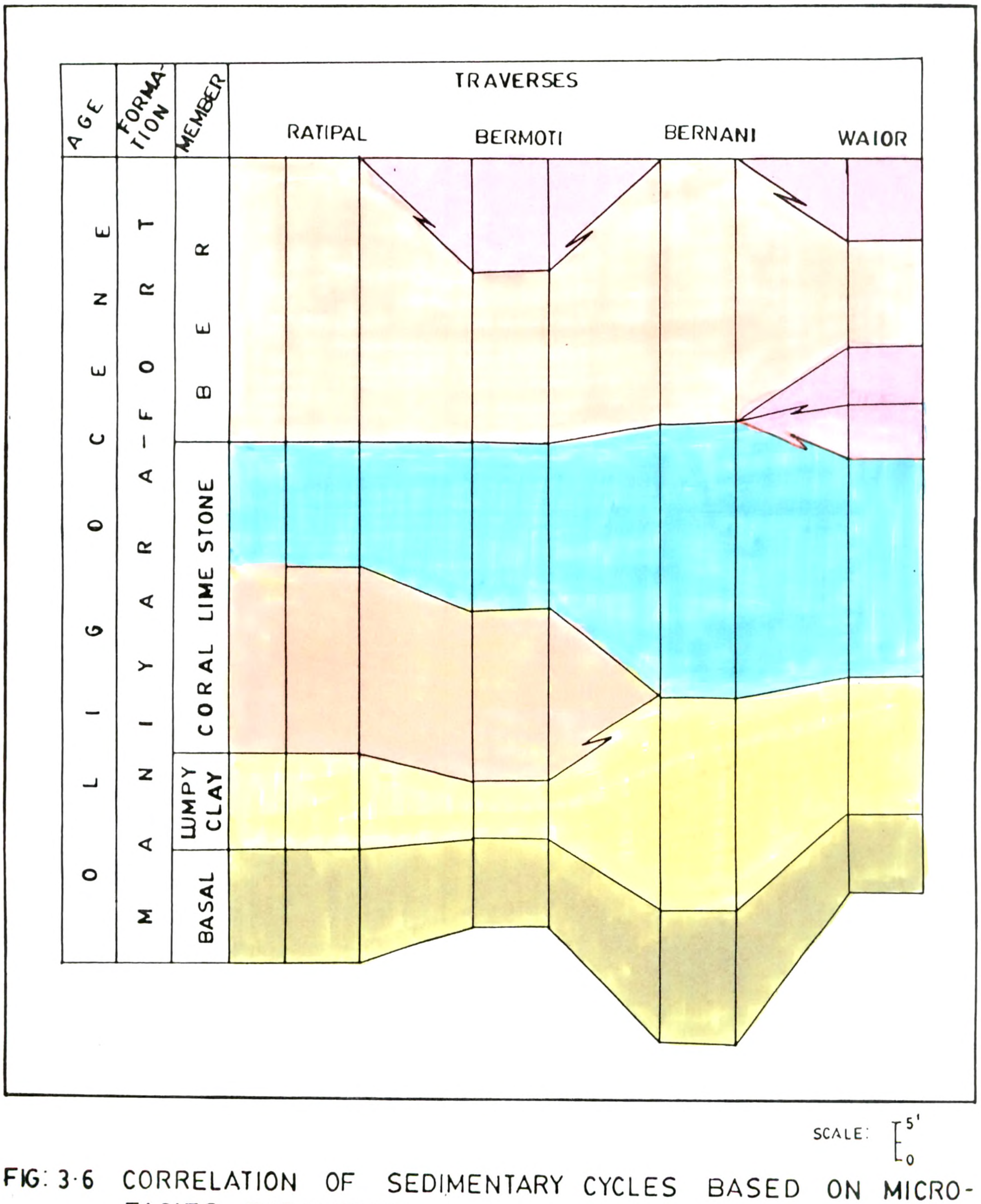


FIG: 3·6 CORRELATION OF SEDIMENTARY CYCLES BASED ON MICRO-FACIES PARAMETER

The late Oligocene Waior stage indicates two cycles in Bermoti area, whereas in Waior proper, the strata is represented by three cycles. This is in addition to the fact that the Waior section shows repetitive occurrence of highly bioturbated mudstone bands indicating periodic shallowing due to oscillatory (Plate IV.A) sea movements within the single upper cycle itself. In Ratipal, Bermoti and Bernani sections, only one cycle is identified in late Oligocene. These facts indicate that easternmost area was the shallowest part of the basin with relative deepening around Bernani. However, broad correlation of sedimentary cycles in most of the area indicates remarkably stable platform conditions of deposition.

3.4 SPATIAL VARIATION OF MICROFACIES

The thickness of each microfacies occurring in the field was calculated and microfacies logs were prepared as discussed before. The cumulative thickness of each microfacies was calculated and those were grouped into three categories viz.

1) mudstone + wackestone
2) packstone + grainstone + dolomite, and
3) shale

The cumulative thicknesses of these categories were calculated for each section, plotted in a triangulation plot ascertained and accordingly plotted on the map. The areas of similar microfacies

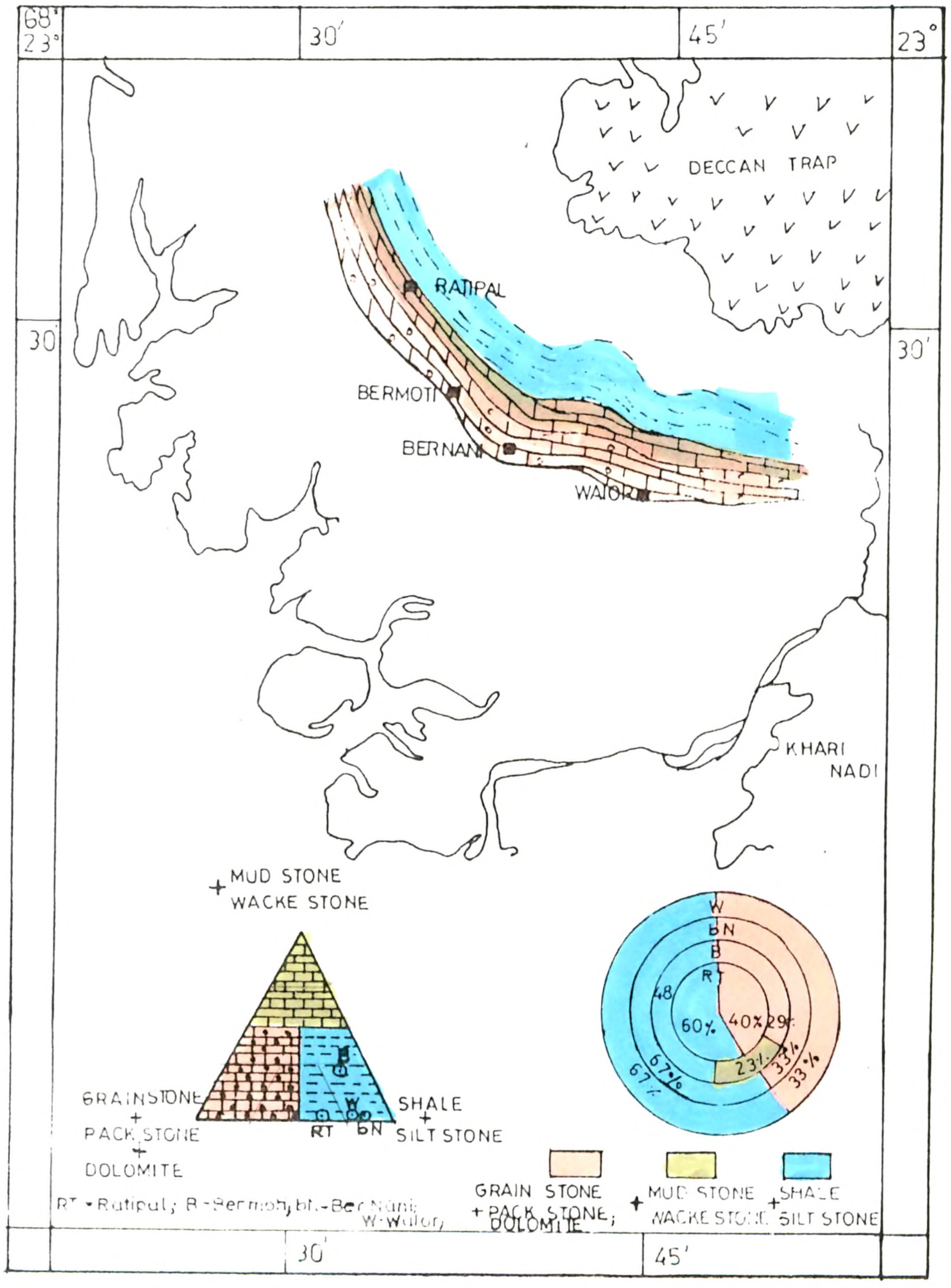


FIG: 3·7 REGIONAL MICROFACIES DISTRIBUTION, LOWER RAMANIA STAGE. (PARTLY INTERPRETED)

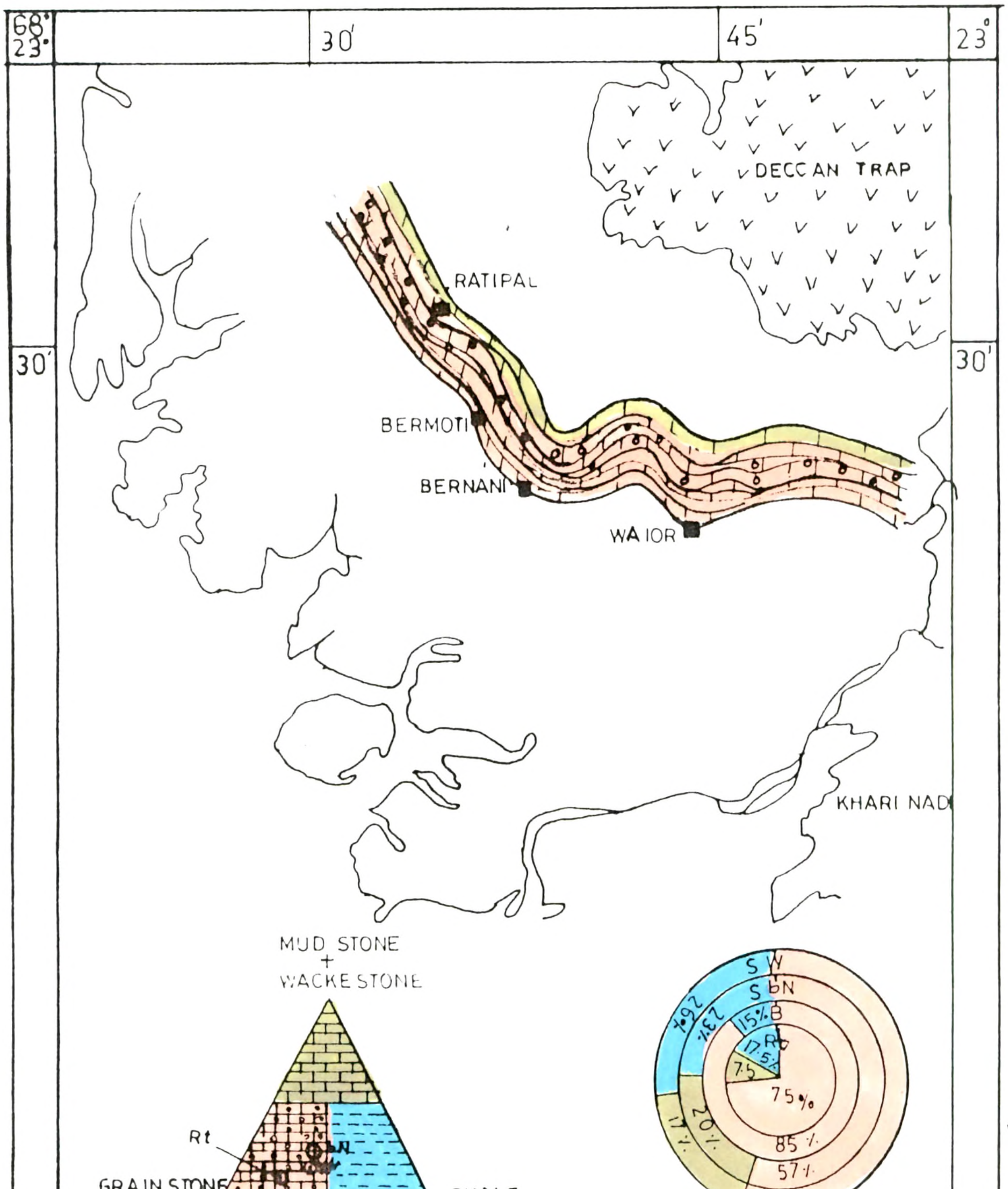


FIG: 3·8, REGIOINAL MICROFACIES DISTRIBUTION, UPPER RAMANIA STAGE (PARTLY INTERPRETED) were contoured and shown by identical symbols and the continuous maps were prepared, two for early and one for late Oligocene.

3.4.1 Early Oligocene, Lower Ramania Stage

The Lower Ramania (Figure 3.7) microfacies pattern indicates three thin arcuate belts representing shale, mudstone/wackestone and grainstone. The outcrop pattern shows predominance of shale with little development of grainstone, packstone and dolomite. However, it is interpreted that mudstone/wackestone and grainstone bands should be present further towards the basinward side i.e. due southwest. The general trend of the facies belts are NNW - SSE through NW-SE to WNW-ESE and obviously concur with the outcrop pattern of the strata.

3.4.2 Early Oligocene Upper Ramania Stage

There is a slight south westerly shift of the facies belts as compared to Lower Ramania stage. Three facies belts are observed as grainstone/dolomite belt in the centre, flanked on either side by clay-mudstone-wackestone. The outcrops around all the sections i.e. Ratipal, Bermoti, Bernani and Waior, however, indicate predominance of grainstone or dolomite facies (Figure 3.8).

3.4.3 Late Oligocene Waior Stage

The general facies distribution trend for late Oligocene (Figure 3.9) representing the Waior stage is as such parallel to the linear

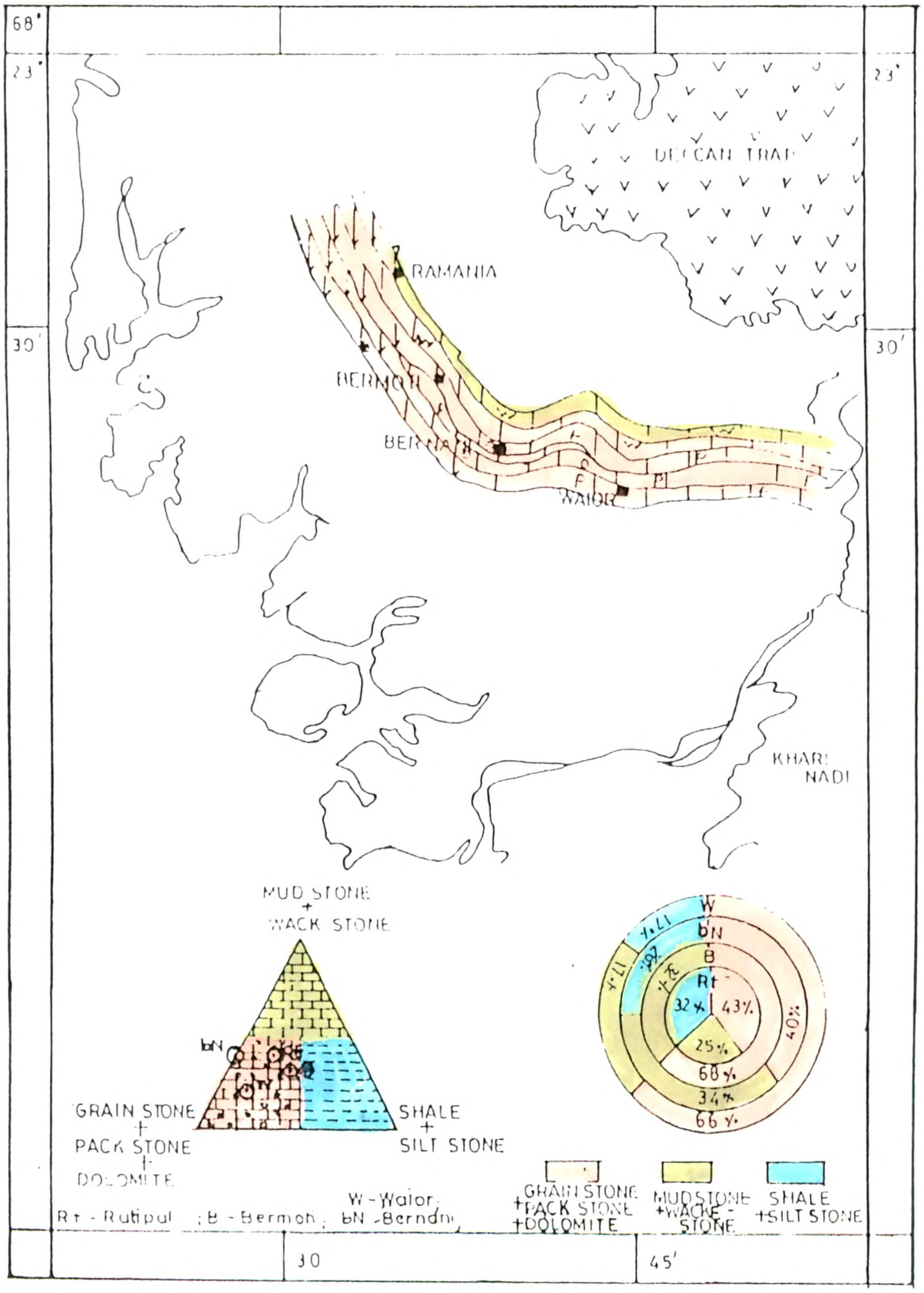


FIG 3.9 REGIONAL MICROFACIES DISTRIBUTION, WAIOR STAGE (PARTLY INTERPRETED)

outcrop pattern. The mudstone/wackestone facies belt forms an arcuate linear belt and occurs to the east and north of a similar thin belt representing packstone and dolomite microfacies.

If the three regional microfacies maps are compared (Figure 3.7, 3.8 and 3.9), it is observed that the upper Ramania distribution pattern indicates a large area occupied by high energy, intertidal, packstone and shallow, low energy dolomite facies. This is in contrast to late Oligocene map which represents an almost equal proportion of packstone, dolomite and mudstone/wackestone facies belts.

3.5 INSOLUBLE RESIDUE

To understand the amount of influx of noncarbonate detritus during the deposition of carbonate rocks, each limestone sample was subjected to dilute hydrocloric acid treatment and the weight percentages of the insoluble residue were calculated. The variations were plotted in terms of vertical logs as well as map .

3.5.1 Vertical Variation

In Ratipal section the insoluble residue percentage in carbonate rocks varies upto 20% (Figure 3.10, Table 3.1). Including at the base and top, there are total five episodic increase in the amount of insoluble residue during the deposition of Oligocene strata. The minimum percentage even goes as down as 0 to 0.1.

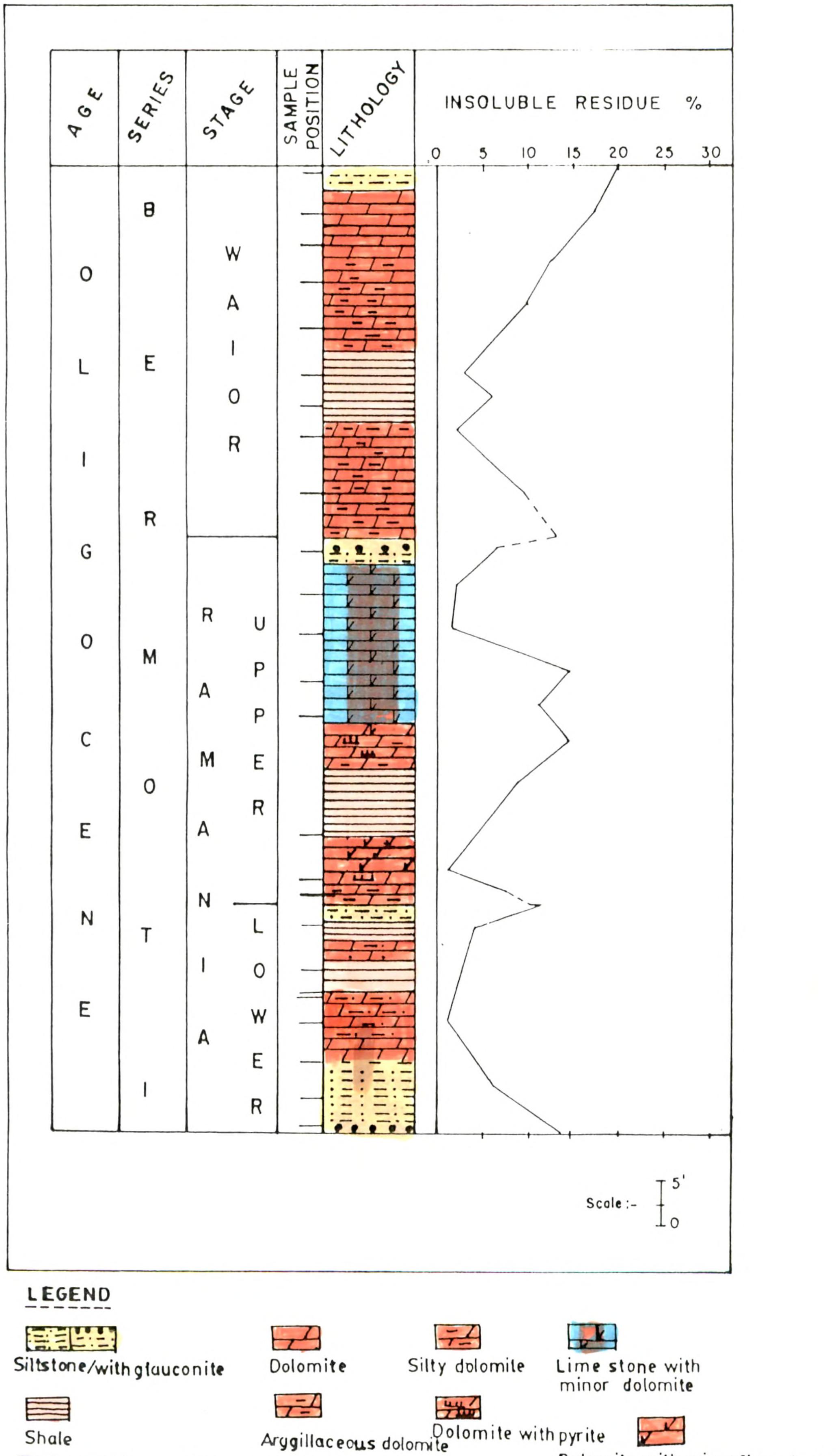


FIG: 3·10, VERTICAL VARIATION OF INSOLUBLE RESIDUE, RATIPAL TRAVERSE

AGE	SERIES	STAGE		SAMPLE INFORMATION		INSOLUBLE RESIDUE VALUE
OLIGOCENE	BERMOTI	WAIOR		Rt	18	19.00
				Rt	17	18.00
				Rt	16	13.00
				Rt	15	10.00
				Rt	12	02.00
				Rt	13	06.00
				Rt	14	01.16
				Rt	25	09.00
		RAMANIA	UPPER	Rt	01	07.00
				Rt	02	02.70
				Rt	03	03.18
				Rt	04	14.60
				Rt	05	11.20
				Rt	06	14.40
				Rt	07	08.80
				Rt	08	00.68
				Rt	23	07.50
			LOWER	Rt	09	04.00
				Rt	10	03.50
				Rt	11	00.32
				Rt	19	04.50
				Rt	20	07.50
				Rt	21	14.00

TABLE: 3.1, INSOLUBLE RESIDUE PERCENTAGE OF SAMPLE OF SAMPLES, RATIPAL SECTION

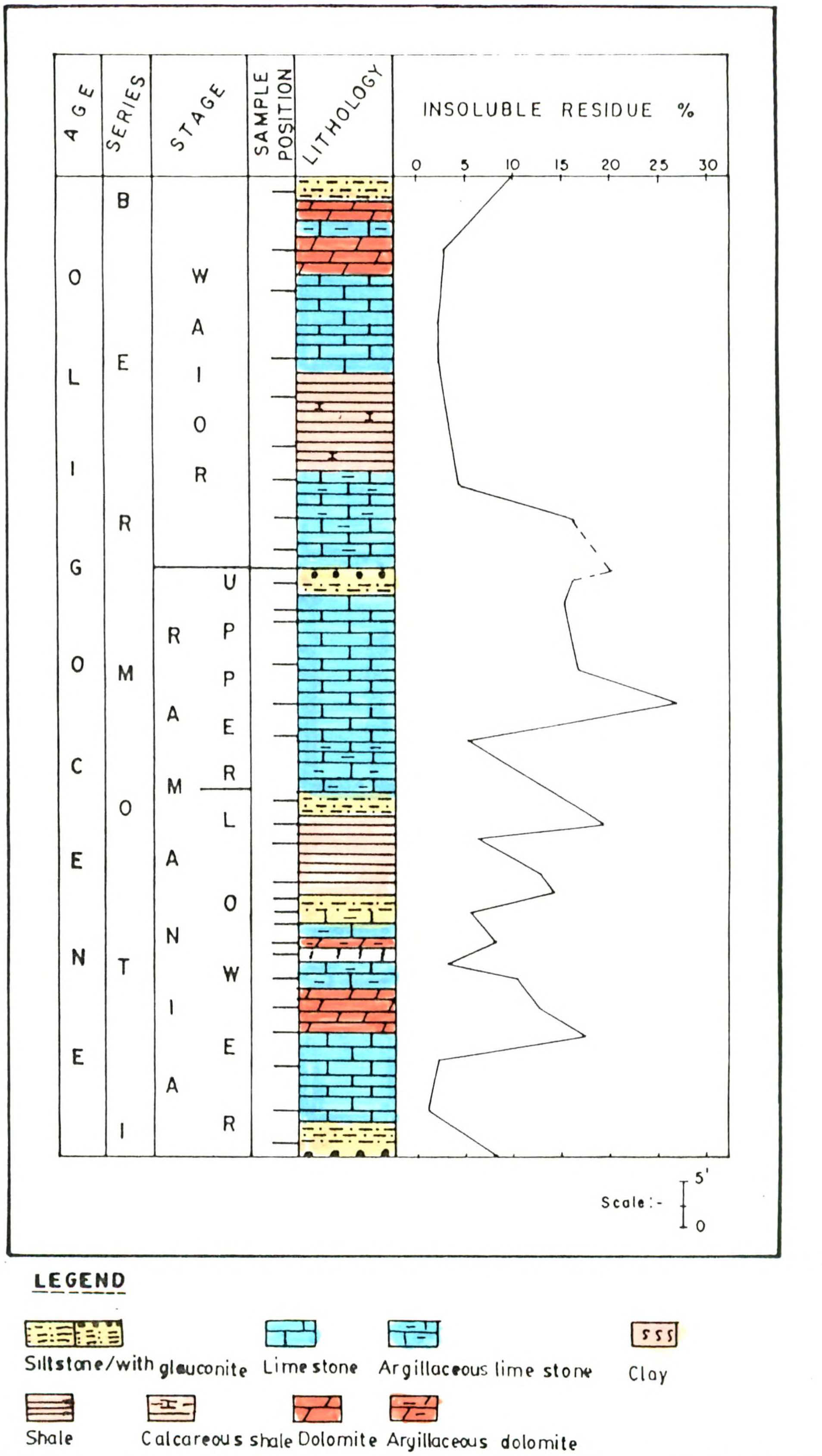
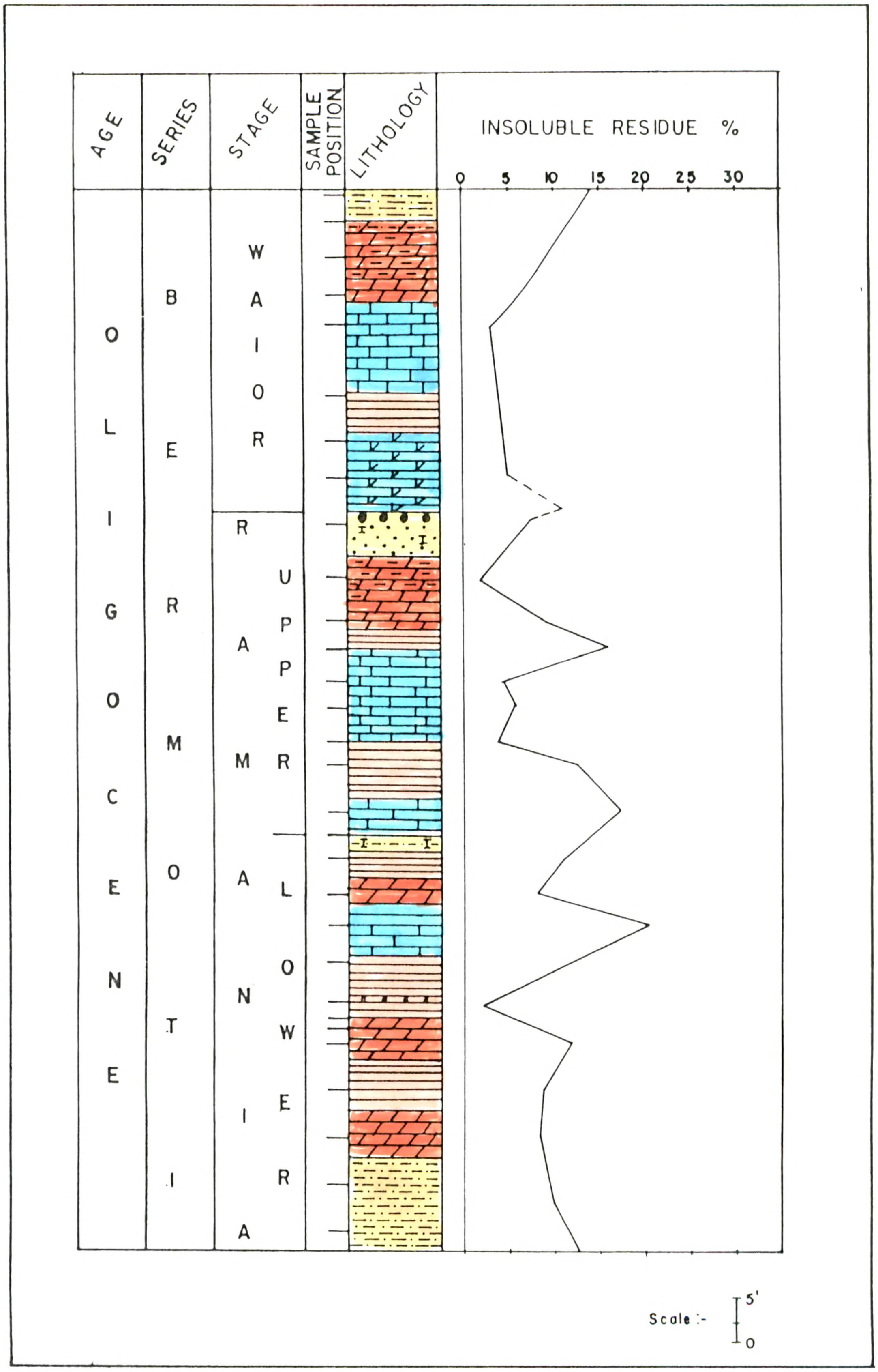


FIG: 3·11 VERTICAL VARIATION OF INSOLUBLE RESIDUE, BER MOTI TRAVERSE

AGE	SERIES	STAGE		SAMPLE INFORMATION		INSOLUBLE RESIDUE VALUE
OLIGOCENE	BERMOTI	WA.IOR		B	31	09.00
				B	30	03.00
				B	29	02.30
				B	28	02.32
				B	27	04.00
				B	26	06.00
				B	25	04.00
				B	24	16.10
				B	23	20.50
		RAMANIA	UPPER	B	05	20.00
				B	04	16.00
				B	03	15.00
				B	02	15.00
				B	01	16.00
				B	06	26.60
				B	07	04.92
				B	08	15.12
				B	09	19.24
				B	10	05.66
			LOWER	B	11	12.46
				B	12	14.68
				B	13	05.66
				B	14	14.00
				B	15	08.20
				B	16	03.00
				B	22	10.88
				B	21	12.60
				B	22	16.88
				B	19	02.00
				B	18	00.46
				B	17	08.46

TABLE: 3.2, INSOLUBLE RESIDUE PERCENTAGE OF SAMPLES, BERMOTI SECTION



LEGEND

Silt stone/with galuconite
Araillaceous dolomite
Dolomite
Shale/with glauconite
Calcareous siltstone/with glauconite
Lime stone
Lime stone with minor dolomite

FIG. 3·12, VERTICAL VARIATION OF INSOLUBLE RESIDUE, BER NANI TRAVERSE

AGE	SERIES	STAGE		SAMPLE INFORMATION		INSOLUBLE RESIDUE VALUE
OLIGOCENE	BERMOTI	WAIOR		bN	27	14.50
				bN	26	10.00
				bN	25	09.50
				bN	00	03.16
				bN	24	03.40
				bN	03	03.50
				bN	01	04.00
				bN	23	04.46
				bN	02	05.00
		RAMANIA	UPPER	bN	05	07.50
				bN	04	01.10
				bN	06	08.58
				bN	07	15.66
				bN	08	04.40
				bN	09	05.08
				bN	10	03.86
				bN	11	12.90
				bN	12	16.82
			LOWER	bN	13	11.60
				bN	14	08.34
				bN	15	20.50
				bN	16	13.00
				bN	17	02.80
				bN	18	11.86
				bN	19	09.70
				bN	20	08.38
				bN	21	09.00
				bN	22	12.00

TABLE: 3.3, INSOLUBLE RESIDUE PERCENTAGE OF SAMPLES, BERNANI SECTION

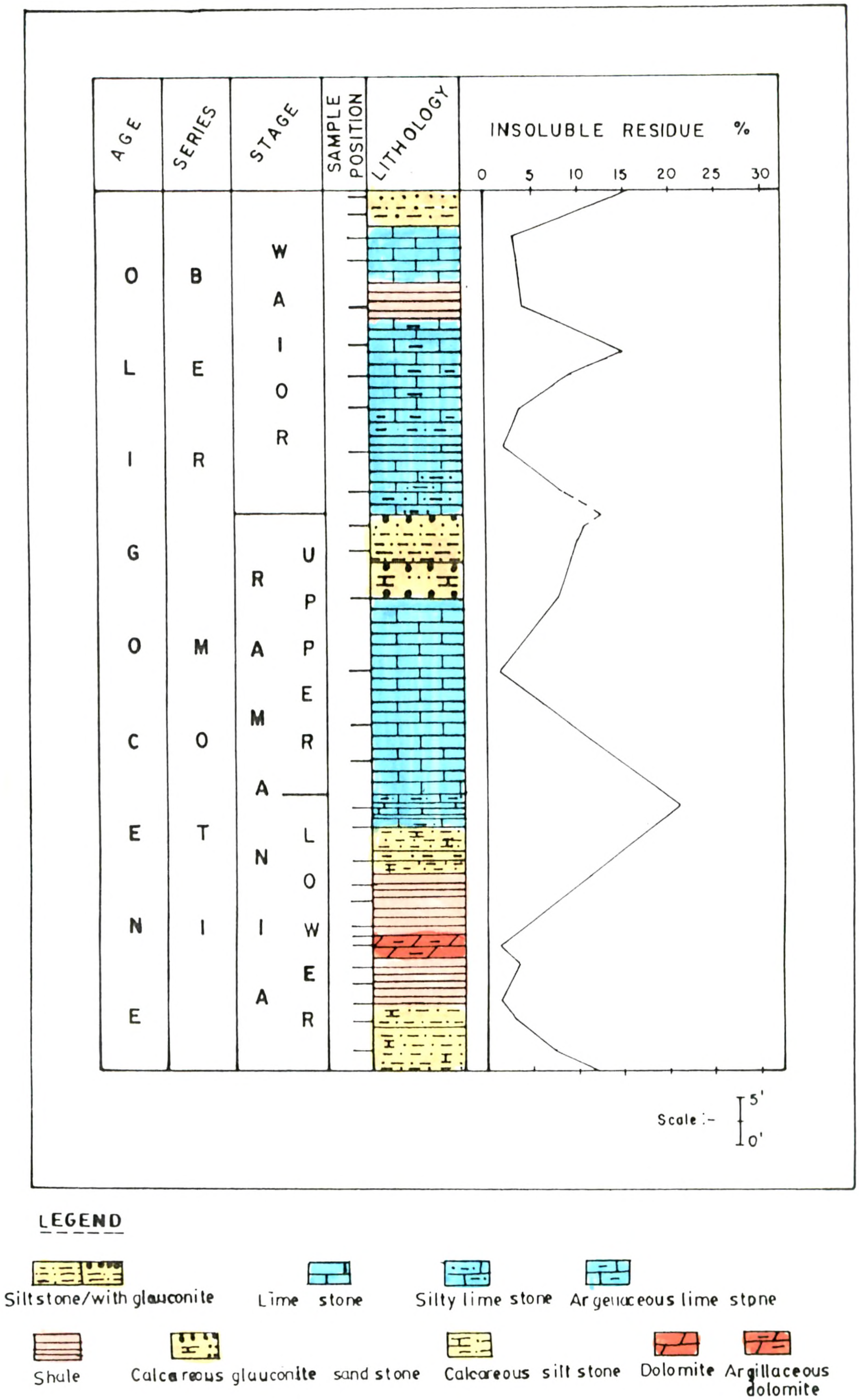


FIG. 3·13, VERTICAL VARIATION OF INSLUBLE RESIDUE, WAIOR TRAVERSE

AGE	SERIES	STAGE		SAMPLE INFORMATION	INSOLUBLE RESIDUE VALUE
OLIGOCENE	BERMOTI	WAIOR		W 28	16.00
				W 01	10.00
				W 11	02.16
				W 10	02.88
				W 09	02.56
				W 08	14.00
				W 07	08.00
				W 06	03.00
				W 05	02.64
				W 04	08.26
		RAMANIA	UPPER	W 02	11.00
				W 03	10.00
				W 12	08.08
				W 13	01.98
				W 14	13.50
				W 15	21.94
			LOWER	W 16	18.00
				W 20	13.00
				W 19	09.50
				W 18	01.42
				W 17	03.86
				W 23	01.22
				W 22	02.62
				W 21	09.72
				W 24	13.50

TABLE: 3.4, INSOLUBLE RESIDUE PERCENTAGE OF SAMPLES, WAIOR SECTION

The early Oligocene Ramania stage shows greater influx of detritus up-to 15 to 20% in Bermoti section (Figure 3.11, Table 3.2). The late Oligocene Waior stage shows paucity of detritus except at the base. This phenomenon is similar to Bernani section where the late Oligocene Waior stage also shows poor insoluble residue content as compared to Ramania stage. The values for Ramania stage range upto 15 to 20% (Figure 3.12, Table 3.3).

Excepting at the base and top, the Waior section shows two episodic maxima of detritus in Ramania stage and one in Waior stage (Figure 3.13, Table 3.4). The intensity of such episodes diminishes upward. The maximum detritus percentage varies upto 20% approximately.

Often the episodic nature of clastic supply ultimately culminates with deposition of clastic facies i.e. shale or siltstone.

3.5.2 Lateral Variation

Both the Ramania and Waior stage indicate a gradual decrease in the insoluble residue from NE to SW i.e. from the peripheral part to the deeper part of the basin (Figure 3.14). The value of the contours range from about 20% through 15%, 10% to almost 0% for Ramania and from about 15% to 0% for Waior.

Figure 3.14 shows lateral variation of insoluble residue for Maniyara Fort Formation.

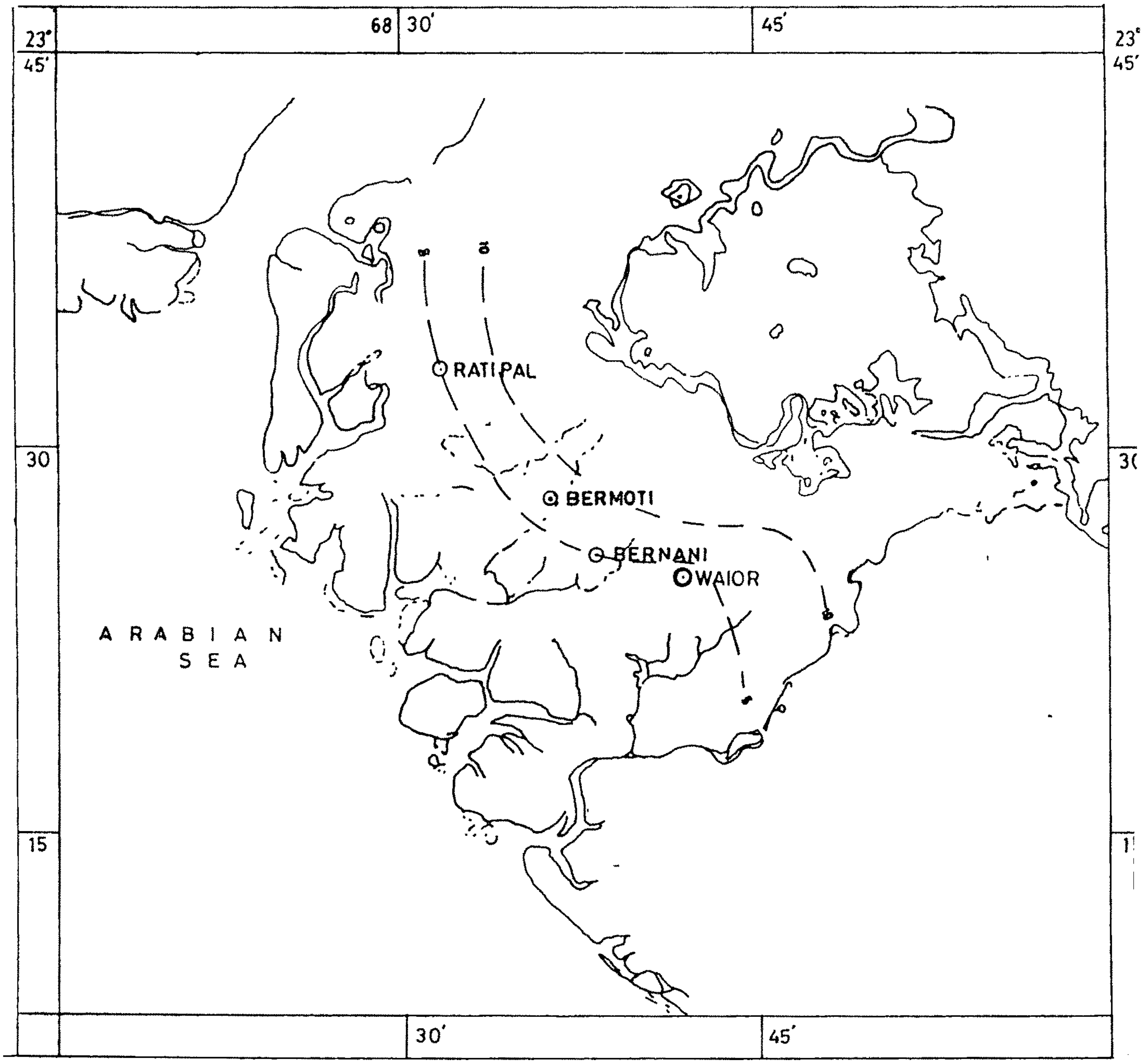


FIG. 3·14, REGIONAL INSOLUBLE RESIDUE VARIATION WITHIN MANIYARA FORT FORMATION

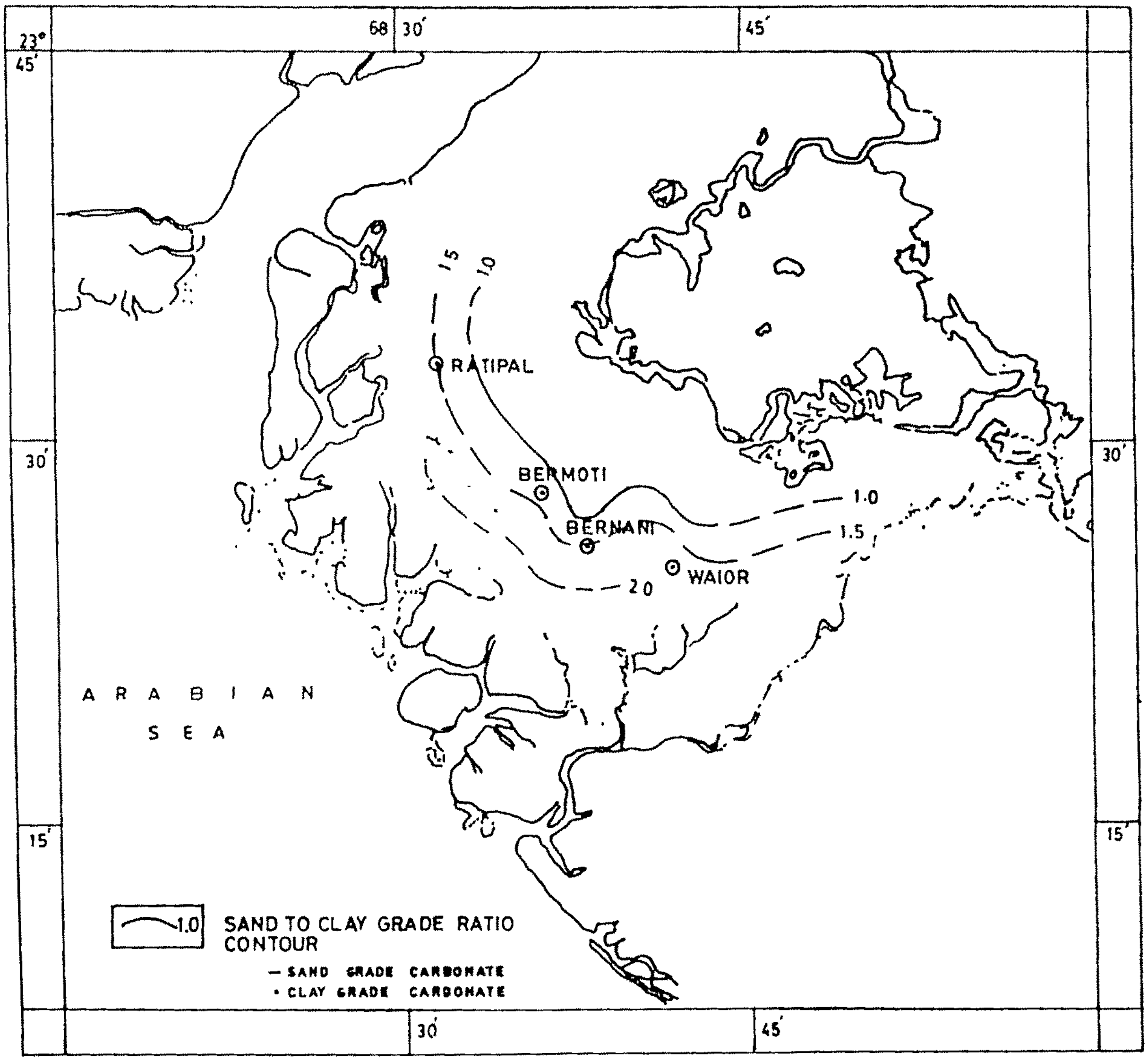


FIG. 3·15, GRAINSIZE RATIO VARIATION WITHIN MANIYARA FORT FORMATION

3.6 GRAIN SIZE STUDY

Because of the detailed microfacies studies carried out in respect of all the samples, only generalised grainsize investigations were extended to representative samples from the total Oligocene section.

The grainsize was calculated on the basis of thin section point-counting method. The grain sizes were grouped in three categories viz. $>$ 1/8 mm, 1/8 to 1/16 mm and $<$ 1/16 mm in diameter. These sizes represent equivalent to fine and medium sand, very fine sand and silt/clay grade respectively. Based on this sand to silt/clay grade ratio was calculated for each sample. The ratio was plotted at appropriate outcrop positions and area was contoured.

Figure 3.15 representing sand to clay grade variation for entire Oligocene sequence indicate increase in the amount of sand grade constituents towards, west and south-west. This sand to clay grade carbonate ratio varies from 1.0 to 2.0 towards south-west.

1) **SKELETAL GRAINS**	3) **GROUND MASS**
NUMMULIDS	MICRITE
LEPIDOICYCLINIDS	SPARITE
MIOGYPSINIDS	DOLOMITE
SPIROCLYPEUS	ARGILLACEOUS MATTER
ROTALIDS	ARNACEOUS MATTER
MILIOLIDS	4) **AUTHOGENIC MINERALS**
OSTRACODA	QUARTZ
MALLUSCA	GLACONITE
ECHINOIDS	GYPSCUM
BRYOZOANS	
GASTROPODA	
CORALLINE ALGAE	
CORALS	
2) **NON SKETETAL GRAINS**	
PELLETS	
PELOIDS	
OOLITES	
LITHOCLASTS	

TABLE:3.5 PETROGRAPHIC ATTRIBUTES.