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SEDIMENTATION AND DEPOSITIONAL ENVIRONMENT OF THE CHOPAN PORCELLANITE FORMATION, SEMRI GROUP, VINDHYAN SUPERGROUP IN PARTS OF SONBHADRA DISTRICT, UTTAR PRADESH

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ABSTRACT

The Chopan Porcellanite Formation of the Semri Group (Vindhyan Supergroup) represents submarine and terrestrial volcaniclastic and volcanogenic epiclastic sediments. These sediments were deposited in a tidal flat region of the Vindhyan Epicontinental Sea. Fissure and vent types of silicic volcanic eruptions (both submarine and terrestrial types) erupted periodically and resulted in the deposition of these sediments by means of the tidal and turbidity currents, which were operating side by side near the continental platform region to give rise to quiet (stable) and agitated (unstable) depositional cycles, preserved in the lithocolumns of the Chopan Porcellanite Formation, and essentially represents a mixed provenance. The study of the primary sedimentary structures, bedding features and lithologic association, supplemented by the grain size and heavy mineral studies confirm the findings.

Key words : Chopan Porcellanite Formation, Vindhyan Supergroup. Semri Group, Depositional Environment, Sonebhadra.

INTRODUCTION

The Chopan Porcellanite Formation (CPF), Semri Group, Vindhyan Supergroup, (Porcellanite Stage, Auden, 1933) is exposed as a linear belt along the Son river in parts of the Sonbhadra district, Uttar Pradesh. It extends in the Palamu district of Bihar in east and in the Sidhi district of Madhya Pradesh in west (fig.1).

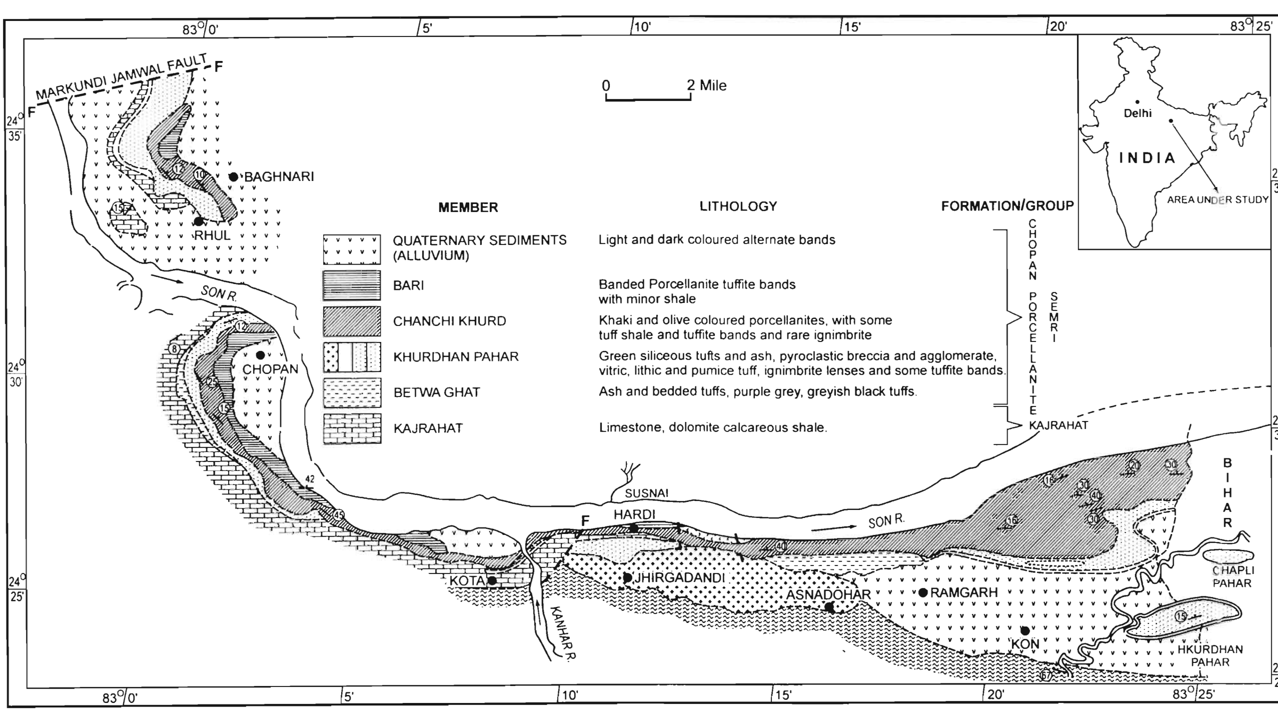

Fig.1. Geological map of the Chopan Porcellanite Formation (Semri Group) and associated rocks of the Son Valley, Sonbhadra District, Uttar Pradesh.

Table-1 : Lithostratigraphy of the Semri Group in the study area.

Group	Formation	Member	Lithology
	Kheinjua Shales	Newari Shale	Shale and siltstone
		Bari	Fine grained, massive bedded silicified and cherty bedded tuff
S E M R I	Chopan Porcellanite	Chachi khurd	Volcanogenic epiclastic sediments, siliceous tuffs, tuffite and some Vitroclastic tuff-ash beds
		Khurdhan Pahar	Lithic, crystal and vitric-tuff-ash, bedded pyroclastic (flows), pyroclastic-breccia, conglomerate and ignimbrite flows.
		Betwa Ghat	Volcanic ash and bedded tuffs
	Kajrahat Limestone		

The CPF is composed of volcaniclastic and volcano-sedimentary rocks comprising vitric and pumice tuffs, mainly pyroclastic-breccia and rarely ignimbrite. They are of explosive origin and associated with tuffaceous sandstone, conglomerate, banded cherty rock, banded porcellanite, tuffites and shales.

The litho-stratigraphic succession of CPF as observed in the area is shown in table 1.

Two distinct litho-facies related to submarine and terrestrial volcanism are identified in the CPF of Sonbhadra segment. The lithologic assemblage being associated with sedimentary structures have been taken into consideration to reconstruct the lighofacies, provenance, mode and media of the transportation and depositional environments. These observations were supplemented with the grain-size and heavy mineral analysis of the coarser sediments.

SEDIMENTATION, PROVENANCE AND DEPOSITIONAL ENVIRONMENT

The Chopan Porcellanite Formation comprises of two distinct facies, (i) the volcaniclastic sediments (submarine and terrestrial pyroclastic), and (ii) volcanogenic-epiclastic sediments with intercalations of shale. These facies are present in Chopan and adjoining area of Hardi-Kon sector of Son Velley. They show variation in lateral thickness and vertical facies along the Son Valley (fig. 2). The basal Betwaghat and Khurdhan Pahar Members are composed of about 80% volcaniclastic and about 20% volcano-sedimentary rocks. The upper Chachikhurd and Bari Members represent mainly volcanogenic epiclastic sediments constituting about 95% to 98% of the rock. The remaining 2% to 5% comprises fine ash fall and surge deposits.

The sedimentation and depositional environments of different litho-members of the Chopan Porcellanite Formation are discussed as follows:

BETWAGHAT MEMBER

The Betwaghat Member mainly comprises of ash fall deposits of felsic composition and consists of volcanic ash and bedded-tuff. Megascopically, the volcanic ash is buff and purple coloured, aphaneric and is composed to cryptocrystalline to very fine grained laths of feldspar and quartz embedded in ground mass of devitrified glass, altering into clays. These rocks are thinly laminated and show lenticular bedding (fig. 3). The finer pyroclastic ash came up through the basement fractures and some volcanic vents, produced by reactivation of Narmada-Son lineament. The shape of the Conical Hill (856) and Khurdhan Pahar in the Kon area geomorphologically resemble the relic-tuff cone formed along the basement fractures occupied by Son river. Probably the felsic melt was generated at a deeper level of the Mahakoshal Group (pre-Vindhyan). The ancient sutures, such as Son Narmada and Amsi-Jiawan

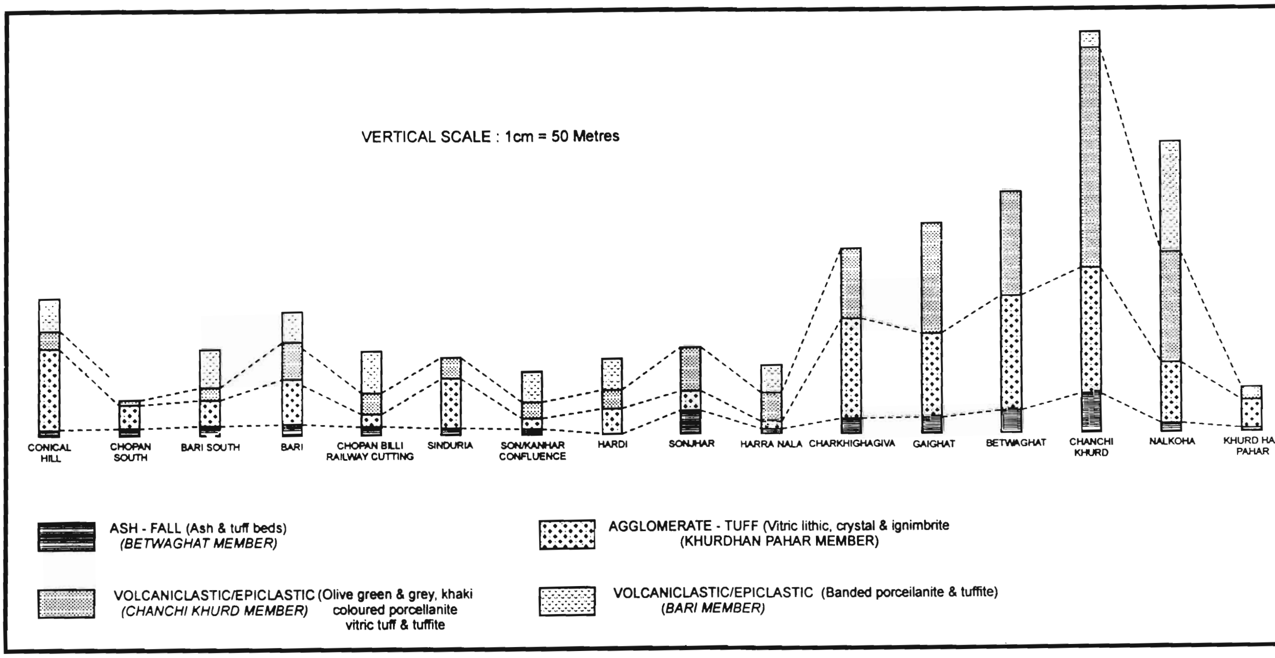

Fig. 2. Lithology of various sections in the Chopan Porcellanite Formation, Sonbhadra District, U.P.

lineaments witnessed repeated rejuvenation in geological past which facilitates acidic effusions. The volcanism was mainly of explosive nature resembling the Plinian eruptions (Srivastava, 1977). It was mainly under the water as indicated by the continuous and undisturbed sedimentation of the Chopan Porcellanite over the underlying Kajrahat Limestone. The Vindhyan Epeiric Sea was micro tidal; the tidal depth was about two meter and occasionally rising to the mesotidal level (Banerjee, 1982). The hydro-phreatic explosions had resulted in the formation of ash-fall and surge deposits. The continuous influx of the pyroclasatic material in the shallow water column made the seawater turbid and the suspended material deposited on the sea floor as thin beds with laminations of volcanic ash.

KHURDHAN PAHAR MEMBER

The rocks of the Khurdhan Pahar Member are mainly composed of tuffs (lithic, crystal and vitric-tuff-ash) pyroclastic breccia, conglomerate tuff – sandstone and ignimbrite. They show columnar and rhomboidal joint patterns. The tuffs are mainly gray, purple and green coloured, with vitroclastic and porphyritic textures and are made up of very fine to coarse grained, bimodal quartz, feldspar and rock fragments (mainly pumice and devitrified glass), embedded in the tuffaceous and devitrified glass matrix. Figure 3 shows lamination and lenticular bedding in the Betwaghat Member (CPF).

The pyroclastic-breccia, conglomerate and tuff sandstone are also of identical composition with crystalline ground-mass of tuffaceous and devitrified glass. The ignimbrite flows, which are of lenticular nature, are composed of euhedral crystals of the

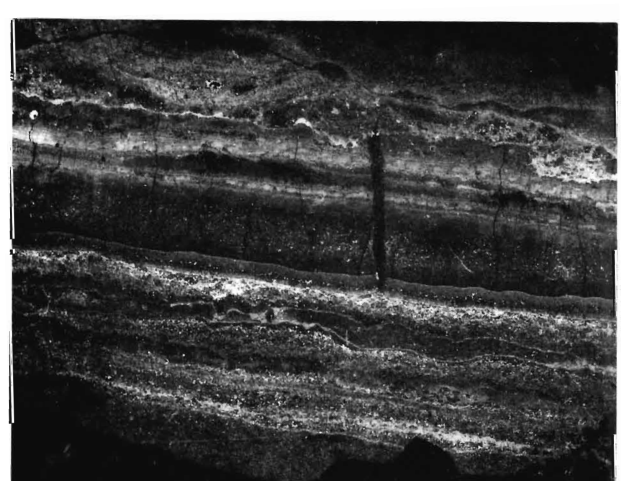

Fig.3. Lamination and lenticular bedding in CPF (Betwaghat Member)

quartz, feldspar and devitrified glass, showing partial or complete welding with the ground mass, which is made up of opaline to cryptocrystalline glassy material. Development of joints in the rocks can be attributed to the rapid cooling under aqueous conditions. The high-energy submarine explosive volcanism produced coarser pyroclastic (pyroclastic-breccia and pumice-tuff) and ignimbrite suite in the Hardi-Kon sector. The deposition of pyroclastic sediments in the form of medium, thick and lenticular beds (fig.-3) have given rise to pile of volcanogenic epiclastic sediments such as silicified porcellanite, tuffaceous sandstone and tuff conglomerate occurring as lenses, tongues and bands of limited aerial extent. The coarser pyroclastic sediments such as pyroclastic breccia and tuffs, which contains very angular to angular clasts, indicate minimum transportation. The volcanic fragments associated with the conglomerate and tuffaceous sandstone lenses are sub-angular to rounded in shape. The proportion of the binding matrix is very less in the coarser volcaniclastic sediments. Since there are not enough sedimentary structures and bedding features present for deducing precise depositional environment, the grain size studies of the coarser pyroclastics are taken into account. The statistical parameters of the grain-size studies and cumulative percentage curves based after Passega (1964) and Visher (1969) were prepared (Table-2 and fig. 4). The mean, median, inclusive graphic kurtosis and simple skewness measures and inclusive graphic skewness based after Folk and Ward (1957) and Friedman (1978), were taken into consideration for deciphering the precise mode and media of transportation and depositional environment (table-2, 3, 4 & 5). Their details are as follows:

INCLUSIVE STANDARD DEVIATION (SORTING COEFFICIENT)

The pyroclastic sediments of Khurdhan Pahar Members in the Chopan Sector show moderately to very poorly sorted mixed sediments whereas in the Hardi-Kon Sector, these sediments are moderately to very poorly sorted. Fuchtbauer and Müller (1970) suggest that sediments of the shallow marine shelf and tidal-flats exhibit poor sorting.

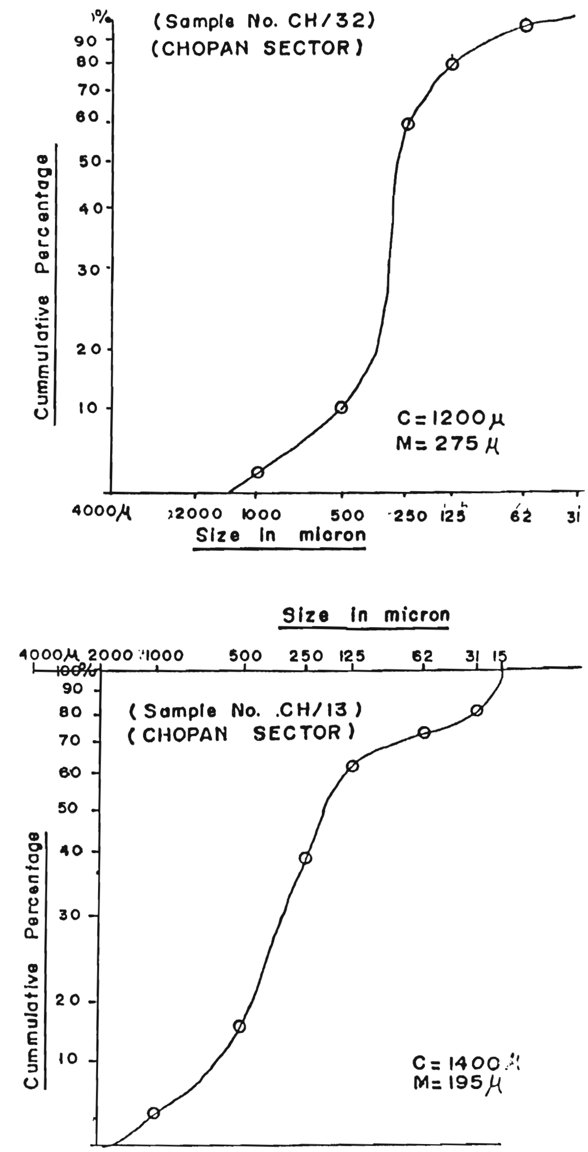

Fig. 4. Cummulative percentage curves based after Passega (1964), Loc : Chopan.

INCLUSIVE GRAPHIC SKEWNESS (SKEWNESS)

The inclusive graphic skewness of the coarser pyroclastics of the Chopan sector indicate mostly negative skewness to near symmetrical range (table 2) and a few samples are also positive skewed. In the Hardi-Kon sector, these sediments indicate very poor negatively skewed to near symmetrical, except for a few samples which show positive skewed range (table 2). Figure 5(a) and (b) show scattered plots of inclusive standard deviation

Table 2 : Grain-size parameters of the volcaniclastic and volcanogenic epiclastic sediments of the Chopan Porcellanite Formation in Chopan and Hardi-Kon Sectors.

Sample No.	Graphic mean	Simple mean	Inclusive Standard Deviation	Simple Skewness measures	Inclusive Graphic Skewness	Granic Kurtosis
Chopan Sector						
CH/Pz	1.27	3.05	1.89	-2.3	-0.23	0.89
CH/30A	0.33	1.45	0.86	-1.5	-1.31	1.08
CH/32	2.00	1.70	1.01	-.70	0.28	1.07
CH/34	2.20	2.20	1.42	-1.40	-0.60	0.75
CH/62	3.71	1.40	0.71	-1.40	-0.35	1.35
CH/74	1.03	2.40	1.33	0.90	0.27	0.95
CH/31	0.73	1.15	1.24	0.90	0.70	1.14
CH/13	1.85	2.50	1.76	2.00	0.22	0.73
Hardi-Kon Sector						
JD/58	1.67	2.00	1.28	0.80	1.01	0.86
JD/77	2.23	1.97	1.29	-0.65	-0.54	0.76
JD/13	2.18	3.10	2.19	1.40	0.34	0.62
JD/30	2.13	3.42	2.59	-0.65	-0.95	0.41
JD/70	2.23	2.17	1.41	0.25	-0.38	0.89
JD/53	1.82	2.05	1.233	1.10	0.32	0.84
JD/69	2.45	2.17	1.73	0.50	1.37	0.69
JD/79	1.42	1.80	1.03	-1.45	0.29	0.98
JD/80	2.98	2.50	1.18	-3.45	-0.23	0.07

versus graphic mean size for coarser volcaniclastic sediments of CPF, in the Hardi-Kon sector and 5(c) represent graphic kurtosis versus inclusive graphic skewness for coarser volcaniclastic sediments of CPF in Hardi-Kon sector. The negative to near symmetrical sign of skewness in both the sectors indicates broadly littoral environment in the tidal flat and tidal inlet regions as suggested by Daune, 1964 and Martin, 1965. A few samples show positive skewness sign is possible due to the transportation of sediments on the adjacent land near the Vindhyan Epeiric Sea.

The sediments of Chopan sector are meso-kurtic to platy-kurtic and meso-kurtic to lepto-kurtic (table 2). Aforesaid numerical values indicate deposition mainly in the shallow protected littoral zones of low energy possibly in the tidal lagoons/ ponds and tidal inlets, which show poor sorting and broad range of skewness and kurtosis. Further, delineating the precise mode of transport and micro depositional environments of these sediments, the cumulative percentage curves were drawn (Fig. 6) which are discussed as follows:

C. M. PATTERN

The cumulative percentage curves (Figs. 7 & 8) based on Visher (1969) later modified by Reineck and Singh (1973), were drawn which show suspension, saltation and rolling population with C.T. (fine truncation), for the coarser/pyroclastics, coarse tuff and tuffaceous sandstone of the Khurdhan Pahar Member. These above referred grain-size parameters have been shown in tables 3, 4 & 5 for the Chopan and Hardi-Kon sectors. The details are

Table 3 : Saltation population.

Sample No.	Coarser Truncation (C.T.)	Fine Truncation (F.T.)	%	Sorting	For Turbidite (After Visher 1969)
HARDI-KON SECTOR					
JD/13	1	5	40 to 60	Very poorly sorted	
JD/30	1	5	22 to 70	Very poorly sorted	
JD/70	1	5	14 to 92	Poorly sorted	Saltation Population 0 to 70
JD/53	1	4	35 to 92	Moderately sorted	Sorting fair and poor (Mixed)
JD/77	1	4	22 to 92	Moderately sorted	C.T. 1.0 to 2.5
JD/58	1	4	35 to 96	Moderately sorted	F.T. 0.0 to 3.5
JD/79	2	4	65 to 97	Moderately sorted	
JD/69	2	4	38 to 55	Poorly sorted	
JD/80	0	4	4 to 70	Moderately sorted	
CHOPAN SECTOR					
CH/31	0.0	3	25 to 93	Moderately sorted	
CH/13	0.0	4	15 to 82	Poorly sorted	
CH/34	1.00	4	27 to 94	Moderately sorted	
CH/32	1.00	3	10 to 78	Moderately sorted	
CH/30 (A)	1	1	13 to 88	Moderately sorted	
CH/82	1	3	15 to 85	Poorly sorted	
CH/74	1	3	10 to 95	Moderately sorted	
CH/62	3	4	12 to 58	Moderately sorted	

Table 4 : Suspension population.

Sample No.	Sorting	F.T. phe	Mixing A & B	Percentage	
CHOPAN	**SECTOR**				
CH/31	Moderately sorted	74	Much	92 to 100	Suspension population 30% to 100%
CH/13	Poorly sorted	75	Much	82 to 100	
CH/34	Moderately sorted	75	Much	94 to 100	Sorting poor
CH/32	Moderately sorted	73	Much	78 to 100	Mixing =A+B= Much
CH/30 (A)	Moderately sorted	72	Much	88 to 100	F.T. = 74.5
CH/82	Poorly sorted	74	Much	85 to 100	
CH/74	Moderately sorted	74	Much	95 to 100	
CH/62	Moderately well sorted	75	Much	58 to 100	
HARDI-KON	**SECTOR**				
JD/13	Very poorly sorted	76	Much	80 to 100	
JD/30	Very poorly sorted	76	Much	72 to 100	
JD/70	Poorly sorted	76	Much	93 to 100	
JD/53	Moderately sorted	75	Much	93 to 100	
JD/77	Moderately sorted	74	Much	92 to 100	
JD/58	Moderately sorted	75	Much	95 to 100	
JD/99	Moderately sorted	75	Much	97 to 100	
JD/69	Poorly sorted	75	Much	52 to 100	
JD/80	Moderately sorted	75	Much	72 to 100	

as follows :

Table 3 indicate, saltation populations varying from 4% to 97%, moderately well sorted to very poorly sorted, C.T. point 1 to 3 and F.T. 1 to 5 (average 3.5) of the coarse pyroclastic and tuffaceous sandstone of the Khurdhan Pahar Member. Table 4 shows the suspension population (A) varies from 5% to 100% to moderately sorted to very poorly sorted. The average F.T. point is more than 4.5 and mixing of saltation population and suspension population (B). Table 5 shows rolling population (C) which indicate variation from zero to 65 per cent (average 25%) both in the Chopan and the Hordi-Kon sectors. The sediments are moderately well sorted to poorly sorted. The mixing of 'A' and 'C' sediments is much and F.T. point (-) to 2.

The suspension population of the turbidity may vary from 30% to 100% show poor sorting and mixing of 'A' and 'B' sediments, and F.T. point is more than 4.5. The rolling population of the turbidity currents ranges between 0% to 40%, poor sorting and fair mixing of 'A' and 'C' sediments and C.T. point has limits.

The above grain-size data of the coarser tuffs and tuffaceous sandstone of the Khurdhan Pahar Member in both the sectors are comparable with Visher (1969). data on saltation, suspension and rolling populations of the turbidite sequence, and C.P. pattern of the turbidite sequence based after Passega (1964). The turbidity currents were generated on the palaeoslopes due to continuous intermixing of the ash-fall and coarser pyroclastic (surge) material erupted periodically through basement fractures and also from the volcanic vents, under the sea. The magma which produced pyroclastic material was of the rhyolitic composition (Auden, 1933). The density of the magma further increased due to the hydrostatic pressure of the water column. The solid fraction of the magma got mixed with the surrounding turbid water and generated turbidity currents on palaeoslopes. There was a continuous influx of the pyroclastic material through the fissures

Table 5 : Rolling Population.

Sample No.	Sorting	C.T.	Mixing of A+C		
CHOPAN SECTOR					
CH/31	Moderately sorted	0.00	Much	0-24%	For Turbility current
CH/13	Poorly sorted	0.00	Much	0-15%	After Vishar 1969
CH/34	Moderately sorted	1.00	Much	0-27%	Rolling population
CH/32	Moderately sorted	1.0	Much	0-10%	Percentage =0-40%
CH/30(A)	Moderately sorted	0.1	Much	0-14%	Sorting=Fair and poor
CH/82	Poorly sorted	-1	Much	0-14%	C.T. =No. limits
CH/74	Moderately sorted	-1	Much	0-10%	Mixing A+C = Much
CH/62	Moderately well sorted	2	Much	0-6%	
HARDI-KON SECTOR					
JD/13	Poorly sorted	1	Much	o-40%	
JD/50	Poorly sorted	1	Much	0-22%	
JD/70	Poorly sorted	1	Much	0-15%	
JD/53	Moderately sorted	1	Much	0.35%	
JD/77	Moderately sorted	1	Much	0-23%	
JD/58	Moderately sorted	1	Much	0-35%	
JD/79	Moderately sorted	2	Quartz	0-65%	
JD/69	Poorly sorted	2	Much	0-35%	
JD/80	Moderately sorted	0	Much	0-4%	

and volcanic vents from the sea bottom and nearby continental platform margins. With each volcanic impulse the ejected material moved downward along the slopes which facilitates the generation of turbidity currents. The palaeoslopes of the Epiric Sea was not steep and the turbidity explains the absence of a typical Bouma cycle of turbidite sequence (Bouma,1962) in the volacaniclastic sediments of CPF.

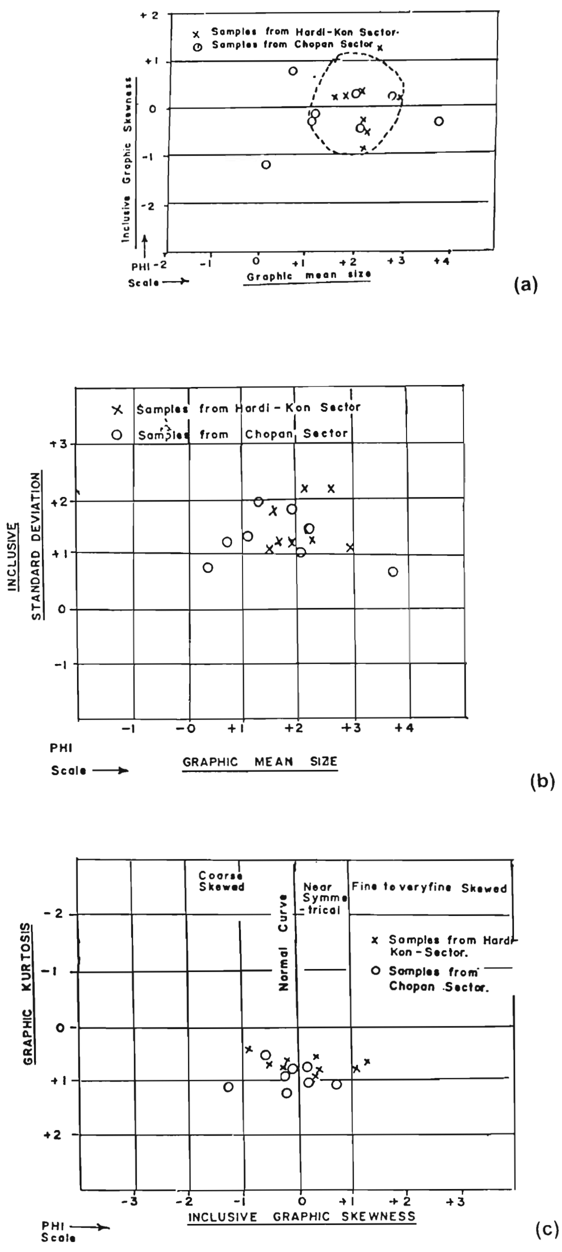

Fig. 5. (a) Scattered plot Inclusive graphic skewness versus graphic mean for the Coarser pyroclastic rocks of C.P.F. (Hardi-Kon Sector) (b) Scattered Plot inclusive standard deviation versus graphic mean size for the Coarser Volcaniclastic sediments of C.P.F. (Hardi-Kon Sector) (c) Scattered Plot Graphic Kurtosis versus inclusive graphic skewness for the coarser Pyroclastic sediments of C.P.F. (Hardi-Kon Sector).

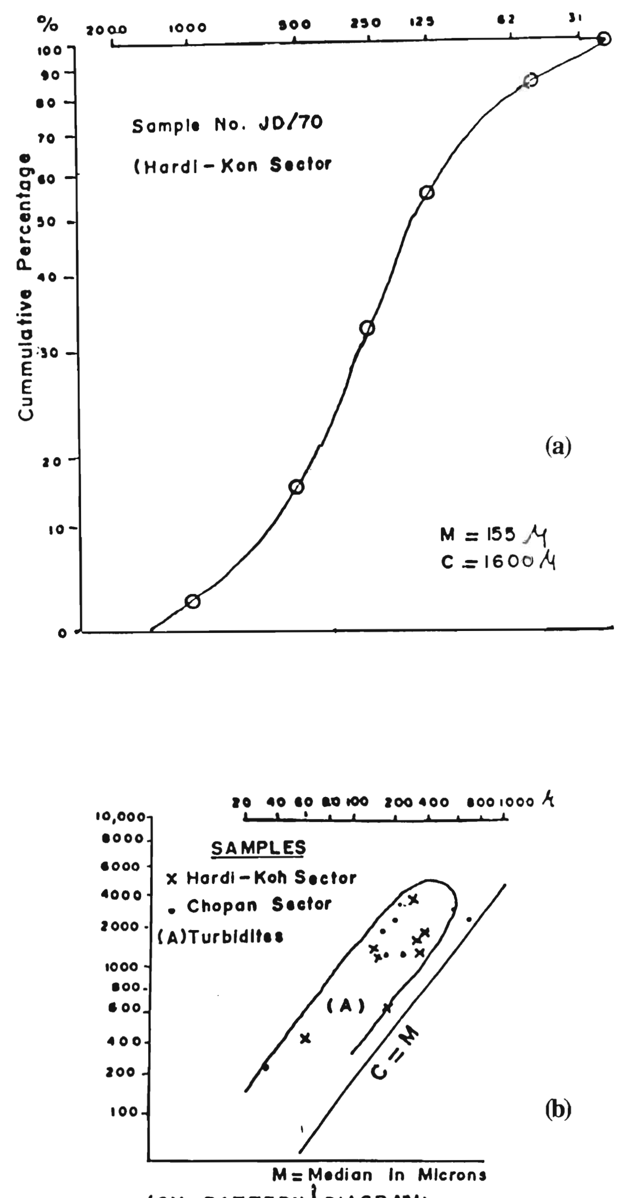

Fig. 6. (a) Cummulative percentage curves based after Passega (1964) (b) C.M. Pattern Diagram Based after Passega (1964).

Table 6 : Comparative study of volcanic eruptions in the Chopan and Hardi-Kon Sectors.

Mode of Eruption	Type of Eruption	Phase of Eruption	Chopan Sector	Hardi-Kon Sector	Remarks
Terrestrial and Hydro-magmatic	Ash-fall and minor surge	Ist phase	Ash-fall and minor surge unequal distribution	Ash-fall and minor surge,unequal distribution.	
Terrestrial and Hydro-magmatic	Ash-fall and surge	IInd Phase	Explosive type of the hydro-volcanic with lithic fragments and some pumice fragments formed by the underwater phereatic explosion.	Extreme hydrophereatic explosion where the coarser pyroclastic rocks are rich in pumice, glass shards and ignimbrite and are formed by rapidly vesiculating magma and glowing avalanche. The pyroclastic lava has erupted under water and fragmented by steam blast explosion.	
			Pyroclastic rocks are weakly welded and do not show any evidence of heat retension.	Pyroclastic rocks especially the ignimbrite and pumice flows show partial and incipient welding with the groundmass and show evidence of heat retention.	
Hydro-magmatic	Ash-fall	IIIrd Phase	Weakening and waning and marked the culmination of hydrovolcanism. Dominant lithology is volcanogenic epiclastic rocks and its diagenetic facies.	Weak and waning and marked the culmination of hydrovolcanism. Dominant lithology is volcanogenic epiclastic rocks and its diagenetic fiacies.	

CHANCHIKHURD MEMBER

The Chanchikhurd Member mainly comprises fine volcanogenic epiclastic sediments consisting of silicified tuff, tuffite and some vitro-tuff-ash beds. The silicified tuffs and tuffites are yellow, olive and gray coloured and are opaline to very fine grained, with a ground-mass of siliceous and cherty material. Blebs and clusters of devitrified glass are enclosed in fine to very fine-grained quartz and feldspar. The sedimentary structures and bedding features though rarely present are mainly asymmetrical wave ripples, small cuspate ripples (fig. 9) and ash tuff cones, mud-cones/small creater (fig. 10) and secondary fumarole pits. The deformational structures are very common and include ball and pillows, boudins and slump structures (fig. 11), convolute laminations, slump bedding, slump-folds and faults. The bedding features present, are thin bed with thin laminations,medium to thick bed with medium to thick laminations, small scale current bedding (fig. 12), lenticular and flaser bedding present in the vitric tuff-ash bed. The small-scale current bedding and flaser are indicative of shallow water environment. The association of small

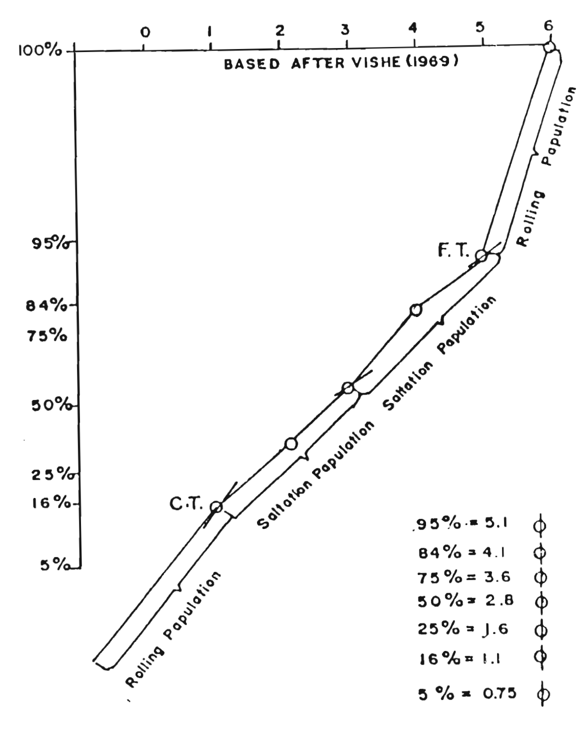

Fig. 7. Cummulative frequency curves for coarser volcaniclastic sediments of C.P.F. (Hardi-Kon Sector).

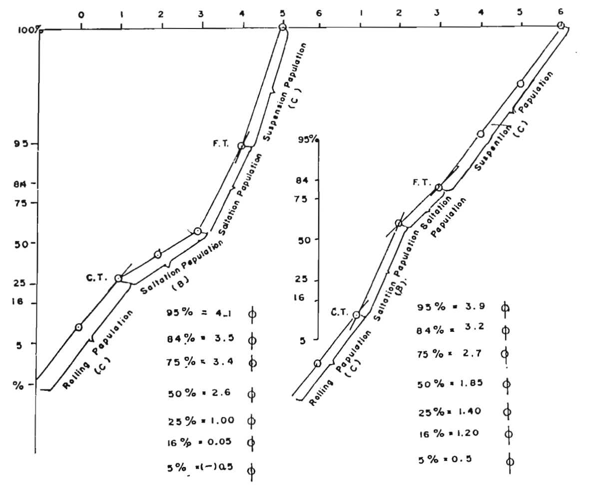

Fig. 8. Cummulative frequency curves for Volcaniclastic sediments of C.P.F. (Chopan Sector), based after Visher (1969).

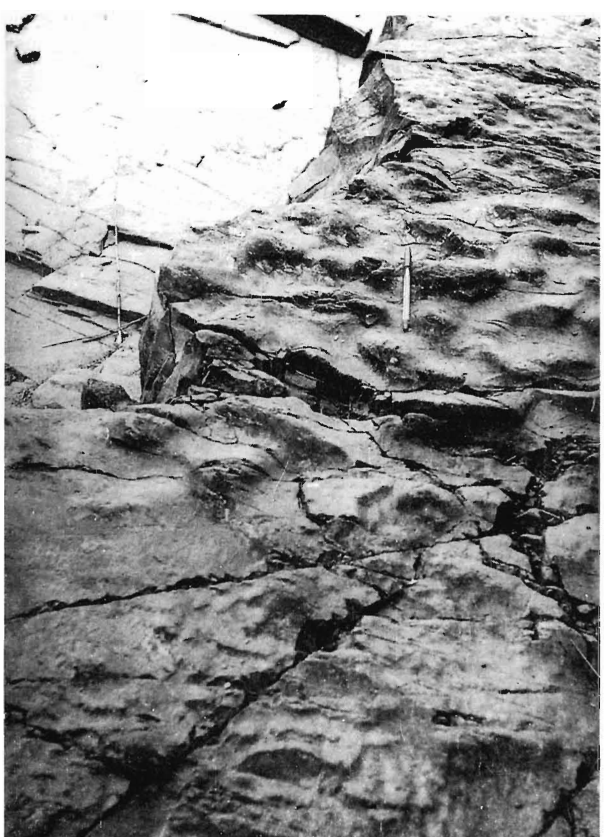

Fig. 9. Asymmetrical, wave ripples associated with small cuspate ripple in Chanchikhurd Member

cuspate ripples which are comparatively high-energy features (Harms, 1969) indicate increase in the energy, in the cycles of the deposition.

The presence of convolute lamination and slump bedding may indicate instability, arising either during or after sediment accumulation and formed by bulk density movement of the sediments during the period of volcanic eruptions.

The ash tuff.cone (puff cone)structure (fig. 10) and secondary fumarole pits are present in the silicified tuffs along with asymmetrical and cuspate ripples in the Chopan area, supports the penecontemporaneous submarine cruptions and deposition. The presence of deformational structures such as slumps, ball and pillows and convolute bedding indicate the unstable conditions prevailed in the basal part of the silicified tuff of the Chanchikhurd Member whereas in coarser pyroclastic, is indicated by the gradual weakening and waning phase of the eruptive impulse by the absence of the deformational structures. The finer

Fig. 10. Ash tuff cones structures in (CPF) of th Chanchikhurd Member near Chophan Forest rest house.

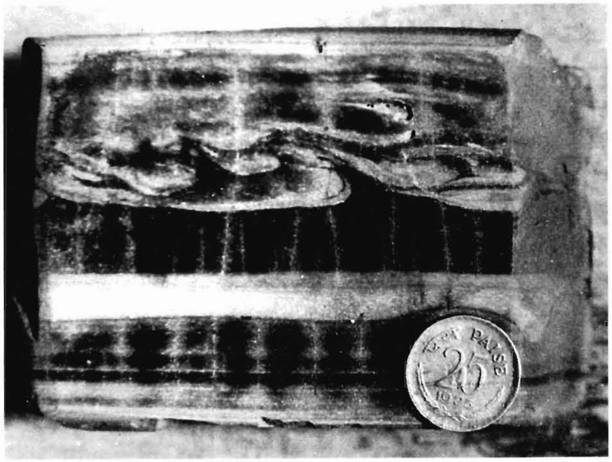

Fig. 11. Slump structues and convolute lamination.

pyroclastics ejected in the shallow water column were deposited as a bedding tuffs and tuffites in comparatively stable conditions. These were later silicified during the diagenesis and had given rise to the silicified yellow coloured tuff porcellanite.

The upper part of the lithologic-column of the silicified tuff shows some high-energy features such as ripples and small-scale current beddings. Their frequency is not much in the lithiologic column of Chanchikhurd Member (fig. 2), thereby suggesting the continuous sedimentation in the tidal-lagoons/ ponds, where the high-energy currents were of comparatively feeble nature.

BARI MEMBER

The Bari Member mainly comprises finer silicified and cherty rocks representing the diagnetic facies such as banded silicified tuffs(banded porecellanite), chert and tuffite. The thin intercalations of the shale are also present. The composition of the rocks is same, as the rocks of the Chanchikhurd Member, except for it shows more of silicification. The rocks of the Bari Member show well preserved bedding features and deformational structures. The bedding features are thin to thick beds with the deformational structures such as load cast, pseudonodules, ball & pillow, boudinage, slump-fold, slump-fault and convolute bedding are present. The deformational structures are known from several environments and are developed on a wide range. These are known in the shallow water and also in the deeper water turbidite sequence (Allen,1982), according to Reineck and Singh, (1973), these structures are also indicative of rapid sedimentation. Crows and Fisher (1973) and Allen (1982) recorded slump sheets from the pyroclastic sequences, formed due to the movement and displacement of already deposited sediment layers mainly under the influence of gravity and also by the pyroturbidity currents. During the sedimentation of rocks of the Bari Member, the volcanic eruptions were periodic and short lived in the basal part. The turbidity currents were gradually weakened and almost diminished during the deposition of finer pyroclastic in the upper portion of the lithologic column. The finer pyroclastic material which was in suspension in the water column were later deposited in the form of banded silicified tuff (banded porcellanite and tuffite). The deformational structures are associated in the basal lithologic column of the Bari Member and are possibly formed due to soft sediment deformation under the influence of gravity. The high-energy sedimentary structures were absent and the deposition continued in the restricted tidal lagoons/ ponds. The association of disseminated pyrite cubes

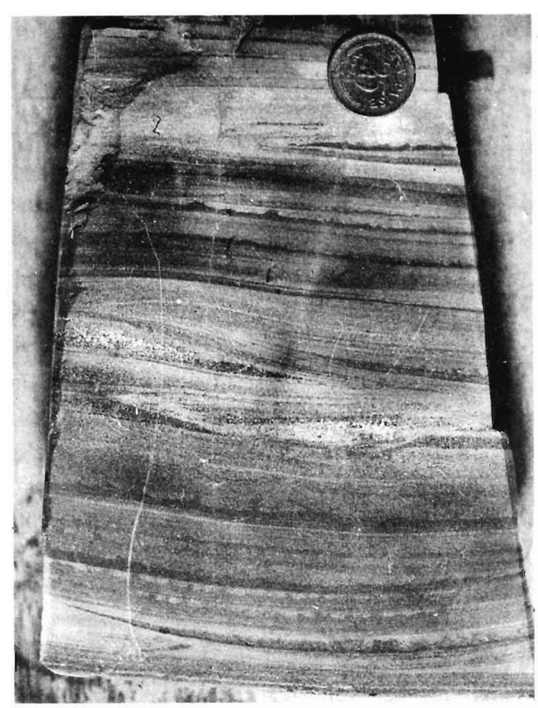

Fig. 12. Medium to thick lamination associated with small scale current bedding.

and specks in the banded porcellanite indicate partly reducing conditions prevailed during the sedimentation.

PALAEOCURRENT ANALYSIS

The directional structures are rare in the rocks of Chopan Porcellanite Formation. The palaeocurrent directions obtained from the Chopan sector indicate north-easterly palaeocurrent.

The authors had extended observations regarding the palaeocurrent measurements in the Glauconitic Sandstone Member (Basuhari Member, Khenjua Formation) of the Semri Group. The directional features such as cross bedding, ripple marks prod marks and pebble-imbrication indicate north-westerly currents, the most prominent in WNW direction (Srivastava, 1978).

The change in the palaeocurrent directions from north-easterly (Chopan Porcellanite Formation) to north-westerly and WNW (Basuhari Member, Khenjua Formation) was possibly due to the unstable conditions prevailing during the deposition of the Chopan Porcellanite Formation due to submarine volcanic impulse in the basin. The paucity of high-energy sedimentary structures is due to protected nature of the basin where the sedimentation of the rocks of the Chopan Porcellanite Formation was taking place. The sedimentation of the overlying Glauconitic Sandstone of the Basuhari Member (Khenjua Formation) had also taken place on the tidal-flats and stable condition prevailed during the deposition (Srivastava, 1978).

PROVENANCE

The heavy mineral assemblages of the non-opaque minerals comprising pink and purple zircon with leucoxene alteration, sporadic brown and blue tourmalines, ilmenite, sphene, rutile and apatite. The opaque ore mineral is magnetite. The variety of tourmaline and its morphology could be related to their provenance (Krynine, 1946; Poldervart,1956 and Vitanage, 1957). The brown pink variety of tourmaline indicate igneous derivation, while the blue variety is indicative of granitic/pegmatitic suite, and the zircons of the Precambrian sequences tend to be purple/ hyacinth (Mackie, 1923). Tomita (1954) suggested that such colour is produced by a prolonged radiation bombardment and represents Precambrian source (Beveridge, 1960). The occurrence of purple zircon, brown and blue tourmalines and apatite along with sphene and rutile indicate stable to ultra stable heavy mineral of igneous parentage (Pettijohn *et al.*,1975) derived from some Precambrian granitic source areas. The types of feldspar present in tuffaceous sandstone suggest an acid plutonic provenance. The presence of some well-rounded tourmaline, zircon and sphene grains might have been contributed by pre-existing sedimentary rocks which were later reworked and formed a mixed provenance. These observations are further collaborated by the petrochemical and geochemical studies of the pyroclastic and volcanogenic epiclastic sediments of CPF which indicate the rhyolitic composition. The reactivation of the Son-Narmada lineament facilitates the silicic volcanism in the area and the melt was probably generated at deeper level of the Mahakoshal belt to contribute to the Chopan Porcellanite Formation.

SUMMARY

Three distinct volcanic eruptions were deciphered in the Son Valley based on the lithologic association and grain size studies (in both the sectors) during the evolution of Chopan Porcellanite Formation. The period of quiescence is marked by uninterrupted sedimentation. The first phase of volcanic eruption started under water with ejection of ash-fall (volcanic ash/dust) and also in the adjacent land through fissures and vents. These finer pyroclastics later settled to give rise the bedded tuffs and tuffites of the Betwaghat Member. The second impulse of the volcanic activity was comparatively violent and explosive, resembling the present day Plinean explosion as indicated by the presence of pyroclastic breccia and ignimbrite. It has marked the climax of the submarine phreato-magamtic volcanism in the area. This has resulted in the formation of the tephre which include pyroclastic breccia (agglomerate), tuff-breccia, coarse-tuff and fine grained green vesicular-tuffs in both the sectors. The volcanic explosions were comparatively more violent in the Hardi-Kon sector which had produced ignimbrite and pumice flows together with the above referred lithologic assemblage. Both fissure and vents-type eruptions were responsible for hydroexplosion and gave rise to the hydromagmatic surge and ash-fall deposits of Khurdhan Pahar Member. Finally, the third phase of volcanic episode was comparatively weaker and marked the waning phase of the submarine volcanism in the area. The submarine explosion was mainly of fissure type which gave rise to the finer pyroclastics, identical to the first volcanic impulse, depositing the bedded tuff, tuffite and silicified tuffs of the Chanchikhurd and the Bari litho members. Large scale diagenesis had taken place resulting in silicification of tuffs, giving rise to the typical porecellanite having unglazed porcelain like appearance. A comparative statement of volcanic phases of eruption in the Hardi-Kon and the Chopan sectors are presented in table 6, suggestive of submarine and terrestrial volcanic eruptions which are short lived and the normal sedimentation continued without any marked hiatus.

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