CHAPTER-2

GEOLOGICAL SETTING

II.A REVIEW OF LITERATURES

General : C.A. Hacket (1881) was the first geologist to publish work on the geology of Aravalli region and also the pioneer worker who worked in Delhi Supergroup.His description of central and Eastern Aravalli region is quite incommensurate with the size of importance and complexity of the area. The workers who have published work on the Aravallis are B.C.Gupta (1930), Gupta and Mookherjee (1938), Heron (1917, 1936, 1953), Raja Rao et al. (1971), Raja Rao (1976), Sen (1970; 1980), Naha et. al. (1966), 1969, 1974, 1977, 1988), A.B.Roy (1973, 1978, 1985), Roy et.al. (1971, 1974, 1980, $1981_{(a)}$, $1981_{(b)}$, 1984, $1985_{(a)}$, $1985_{(b)}$, Sinha Roy (1984), Sinha Roy et.al. (1988, 1992), Sugden et.al. (1990), Deb and Sarkar (1990), Ram S.Sharma (1977), B.L.Sharma et.al. (1984, 1988), Powar and Patwardhan (1984), Sychanthavong et.al. (1977, 1981), Sychanthavong (1990).

The other investigators who worked in Delhis are - Oldham (1983), La Touche (1902), Middlemiss (1931), Auden (1931), Sharma (1931, 1953), Coulson (1933), Ghosh (1933), Gupta (1934), Fermor (1936), Sharma and Nandy (1936), Heron and Ghosh (1938), Misra (1949, 1969), Merh (1950, 1967), Pascoe (1950), Niyogi (1952), Rode et.al. (1967), Gangopadhyay (1967, 1969, 1970, 1972), Sarkar (1968), Krishnan (1968), Sen (1970, 1971), Naha and Halyburton (1971, 1974), Naha and Majumdar (1971_a, 1971_b), Gangopadhyay and Sen (1972), Lal and Shukla (1975), Sharma and Narayana

(1975) and Patel (1976).

The stratigraphy established by Heron for southern Rajasthan pre-cambrians is illustrated in Table- II.1.

Table- II.1 : STRATIGRAPHY OF THE PRE-CAMBRIAN ROCKS IN SOUTHERN RAJASTHAN (AFTER HERON, 1953).

Post Aravalli	Ultramafics
--------------------Unconformity----------------------------	
	Impure limestone, quartzite, phyllite.
Aravalli System	Quartzite, conglomerate, grits.
	Local amyglaloids and tuffs.
--------------------Unconformity----------------------------	
Pre Aravalli Banded Gneissic Complex	

A.1 :- THE BANDED GNEISSIC COMPLEX AND ITS EQUIVALENT

The Banded gneissic complex is a stratigraphic name introduced by Heron (1917) to designate the heterogeneous rock group which is supposed to form the basement of the Aravalli system. It is mainly composed of various types parametamorphites, migmatites, agmatites, granites, pegmatites, aplites and metabasic rocks of different compositions. The complex covers an extensive tract in the central Rajasthan peneplain and forms a distinct geomorphic unit. Heron (1935) considered the complex to be originally a sedimentary sequence which might have started with quartzite at the base followed up by piles of pelitic sediments. Banded gneissic complex is exposed at places in the form of inliers within the exposures of younger rocks - Aravallis Raialos and Delhis. Heron (1953) correlated a number of the occurences of the gneissic rocks in scattered localities with the B.G.C. though at many places the relationship between the gneisses and the younger rocks is not very clear, and the unconformity is also uncertain.

It is quite obvious that while some of the occurrences of B.G.C. are undoubtely the older basement over which the Aravalli and Delhi rocks have been deposited, at other places it is equally obvious that the gneissic rocks represent granitized Aravallis, Raialos and Delhis.

A.2 THE ARAVALLI SYSTEM (SUPERGROUP)

A.M.Heron (1953) did detail survey of the entire northern, central and southern Rajasthan state (Rajputana). It was a general survey with a view to establish geological succession and their exact geological age. He classified and described the pre-cambrian rocks of southern Rajasthan in detail. Heron established that the Banded gneissic complex (B.G.C.) represent a distinct system of rocks separable from the Aravalli system by an unconformity plane.

According to Heron, the thin and brittle Aravalli quartzites occur amidst immense thickness of slates, phyllites and schists. The discontinuity of outcrop pattern of quartzites might be of tectonic control forming the pinch and swell structures. He also recognised the quartzites deposited as discontinuous lenticular beds along certain horizons.

Amidst the quartzites, according to Heron, are several bands of mica-schist, fairly wide, as were suspected in the very similar section in the 'Barlinal' east of Kotra. Most quartzites have given rise to high ridges or table-lands and between these ridges there are several square-miles of almost flat or gently rolling country occupied by schists and schistose quartzites Lithologically, the Aravalli quartzites vary in thickness measurable from few tens of feet to several hundreds of feet. Overlying the quartzites are Aravalli phyllites of enormous thickness with few bands and lenses of limestones.

The Aravalli outcrops around Udaipur, extending further south through Dungarpur to as far as south of Baria and Jhabua in Gujarat, are considered to be the type area. An interesting feature noted in the area is the inverted nature of the unconformity between the Aravallis and the B.G.C. basement rocks. Here, the gneisses are seen to overlie the basal quartzite and the inversion is ideally revealed by the reversed cross-bedding in the quartzites (Poddar et.al. 1963, 1965; Iqbaluddin, 1966, 1968, Mathur, 1963, 1964 and Chandak, 1965, 1966). Recent workers have all considered the Aravalli rocks to represent marine sediments, except the evaporite of Hemata area. According to Muktinath et.al. (1967), Raja Rao et.al. (1969), and Poddar and Mathur (1966), the Aravallis for the most part comprise a repetitive sequence of greywacke, slate, phyllite of flysch type rocks. It has been visualized that the Aravalli cycle was heralded by transgression of a sea on the continental landmass formed by the B.G.C. and the Bundelkhand-Berach granites and gneisses. This Aravalli sea extended southward upto Panchmahal, where the rocks equivalent to Aravallis have been designated as Champaner series, Gupta and Mukherjee (1938), Prasada Rao et.al. (1965, 1966), Yellur and Gopinath (1966), Mathur (1968), and many others.

According to Raja Rao (1976), the rocks occurring in the Udaipur, Dungarpur and north-eastern part of Gujarat areas were grouped under the Aravalli system. According to him, the rock types of the Aravalli system consist of phyllites, quartzites, conglomerates, dolomites, greywackes, schists and phosphorite stromatolitic rocks. From Parsola and Nathadwara area basic volcanic rocks have been recorded. The various members which grouped into several formations of mica-schists, phyllites, quartzites, biotite schists and hornblende-schists are overlained on carbonate horizons without any break (Krishnaunni et.al. 1968). According to these workers there is gradual increase in the grade of metamorphism to the west of Udaipur and high granitisation observed near and to the west of Udaipur. To the north of Udaipur, the boundary of the migmatites swerves eastwards and the basal beds are granitised in the Kankroli area and towards north- schists, quartzites, carbonate rocks and amphibolites derived from them are preserved in the main Aravalli ranges.

The Aravalli range is characterised by the instrusives of serpentinites in the Rakhabdeo area and to the west of Udaipur extending upto west of Bewar. The ultrabasic rock is found as isolated patches in the granitised terrain from Kankroli to Kishangarh. The serpentinites are found to be derived from olivine-rich peridotites containing pyroxenes in different proporations, often grading to dunites in the Rakhabdeo area (Raja Rao 1976). The ultrabasic rocks have been intruded along the bedding planes of the Aravallis and are folded with them (Rakshit, 1968, 1969). Dykes of dolerite type are also found and at several places they are altered to amphibolites.

The Aravalli rocks of phalasia-Jharol area was first named as Jharol group by Mathur et.al. (1973) consisting of phyllites of different types, chlorite schist, garnetiferous mica schist, intercalating quartzite and minor lenses and bands of calc-schists. Gupta et.al. (1980, 1992) have correlated these rocks with the upper sequence of the Aravalli Supergroup. Roy (1991) has also postulated that the Jharol group is equivalent to upper Aravallis and coeval with the Lunavada rocks and considered them to have been deposited in a deep sea basin as distal turbidite sequence associated with ultramafic rocks.

Gupta et.al. (1992) has put the Jharol group as the upper part of the Aravalli Supergroup between 2000-2500 my. As a whole the Jharol group consists of phyllites, chlorite schists, garnetiferous mica schist with interbedding of quartzite and minor bands and lenses of calc-schist. Regarding metamorphism according to them there is a progressive increase in the grade of metamorphism from low-grade green-schist facies in the east to low-rank amphibolite facies in the west.

The Jharol basin has long been explained as a deep sea facies (Poddar & Mathur, 1965, Roy & Paliwal, 1981, Sen, 1981). According to Roy (1991), the Jharol basin was opened simultaneously with the Lunavada and they were the last to open during the three stages of intracratonic rifting and evolution of the Aravalli depositional basin. The primary factors involving the sedimentation in the Aravalli basins were controlled by the periodic subsidence of faulted blocks (Roy & Paliwal, 1981). Roy & Nagori (1990), however, considered the Aravalli rocks to have been deposited in various linear and discontinuous basins which were developed as a system of complex grabens separated by horsts. They claimed that this interpretation is supported by the stratigraphic relationship and the sedimentary attributes.

Powar and Patwardhan (1984) have recognised the sediments of the Aravalli supergroup to have been deposited largely on the stable shelf associated with contemporaneous volcanics which have been metamorphosed into amphibolites and other metavolcanics.

Sugden et.al. (1990), Deb and Sarkar (1990) considered the upper part of the Jharol sequence as deep water and distal turbidite facies as compared to the shallower sequence of the Aravalli sedimentation separated from the Aravalli domain by a small zone of back-arc spreading. This idea has been put forward based on the occurrence of tectonized basic and ultrabasic rocks along the Rakhabdev lineament. According to these authors the upper part of the Jharol sequence consists of siliciclastic and pelitic phyllites with around 100 meters thick quartzites.

Gupta et.al. (1992) have recognised two sedimentary domains in the Aravalli basin one is geo-synclinal and the other epicontinental. Based on the lithologic association, they have divided the mode of basin sedimentation into five different tectono-environmental settings. viz: (1) as near shore shelf sediments along the cratonic border; (2) orogenic coarse flysch like sediments ie: turbidites; (3) the orogenic shaly flysch like sediments; (4) shelf, beach and tidal flat sediments representing molasse facies and (5) as syn-sedimentational basin volcanics and associated epiclastic. According to them, the Aravalli geosynclinal trough assigned as Jharol group consists of coarse sequence overlain by distal shaly flysch sequence consisting of chloritic phyllites and quartzites acting as the main depositional episode. After the main uplift of the Aravalli orogeny and the transformation from deeper trough to shallower basin, molasse facies has been developed (Gupta et.al. 1992).

A-3 THE DELHI SYSTEM (SUPERGROUP)

The rocks of Delhi system constitute the main mountain belt and extend from Gujarat through Rajasthan and Haryana to south Punjab, having a NNE-SSW trend. In the south western portion, the outcrops of Delhi system are well developed and occur in extensive continuous areas, but on going north-northeast the Delhi rocks form disrupted clusters of hills around Jaipur and Alwar and these continue upto Delhi.

On the basis of lithological characteristics, Heron (1953) divided the Delhi system into two series Alwar and Ajabgarh comprising six subdivisions as under :

	6. Upper phyllites
	5. Biotite limestone = calc gneisses and calci phyres.
	4. Calcarious shales and impure Limstones = calc-schists.
Delhi system	3. Phyllites and biotite schists.
(6000 m thick)	2. Quartzites and limestones.
	1. Arkose grits and conglomerates.

Heron (1953) has assigned them to Algonkian age. The main Delhi synclinorium extending from N.Gujarat upto Khetri in Rajasthan, shows full development of Delhis comprising all the six subdivisions. However, in the Jaipur and Alwar regions, the uppermost formation (upper phyllites) are absent.

The Alwar series is irregularly developed. In the northern part of the synclinorium both the massive quartzite and basement grits occur in force, the latter becoming coarse conglomerates at Barr and Srinagar. In the median part of the synclinorium, taken along the strike where it becomes a simple syncline, the Alwar series dies out, but thickens again in the southern part (southern Rajasthan and North Gujarat).

In the northern and central portions of the synclinorium, the faulted outliers of the Alwars, which to the East are inverted under the Aravallis and the B.G.C. from which they are derived, with an erosional unconformity intervening, are arkose and conglomeratic grits, but in the southern part of the synclinorium,where the basement beds of the Alwar series rest upon Aravalli phyllites that are devoid of acidic intrusions, there are no arkose or grit, and the quartzites are fine grained. Thus, according to Heron (op.cit) the nature of the underlying rocks has controlled the deposition of Alwar basal formation.

The lowest division of the Ajabgarh comprises a great thickness (2000 ft) of biotite schists abundantly intruded by pegmatites and aplites in the form of dykes and veins, and in lit-par-lit alternation. Heron (1953, p.17) observed that this series has undergone metamorphism upto green schist facies. Gangopadhayay and associates (1967, 1969, 1970, 1979) have included Raialo series of the type area into lowermost division of the Delhi cycle.

Recently, Raja Rao et.al. (1971) have raised several doubts about the validity of Heron's classification and have suggested some modification in some localities regarding the stratigraphic position of the exposures of Delhi rocks and the underlying basements.

Recent workers have reclassified the Delhi system of Heron in terms of plate tectonics (Sychanthavong (1978), Sychanthavong (1990), Sychanthavong and Desai (1977), Sychanthanvong and Merh (1981). According to these authors, the Delhi supergroup was accumulated in a paired geosynclinal basins (Table-II.2). The Alwar group consisting mainly of rudaceous, arenaceous and argillaceous materials deposited in the miogeosyclinal basin over the Banded Gneissic complex (BGC) and Aravalli protocontinental shelf area. These rocks have been regrouped as 'Gogunda group' consisting of Richer, Antalia and Kelwara formations by Gupta et.al. (1992). The Ajabgarhs consisting of pelagic deep sea sediments were deposited in the leptogeosynclinal basin over the oceanic crust (ophiolites) and have been metamorphosed to pelitic granulites, migmatites, biotites gneisses, Calc-gneisses and calc-schists, garnetiferous mica-schists and impure crystalline limestones. The Ajabgarh rocks have been regrouped as Kumbhalgarh group by Gupta et.al. (1992). (Table-II.3)

A.4 : INTRUSIVE ROCKS

Based on the works of the Geological Survey of India and on his own, Sharma (1953, Press.Add.) has pointed out that in the preCambrain of north Gujarat and Rajasthan, there were three main acidic and four main basic igneous activities before the deposition of Vindhyan rocks. He has given the following classification (Table -II.4).

4.1 INTRUSIVE ROCKS IN THE ARAVALLIS

Granitic Intrusion :

The most well known granitic intrusives in the

Table - II.2 : Revised Stratigraphy of Delhi system in terms of Proto-plate tectonics (Sychanthavong & Merh, 1981)

		10. Jodhpur Formation			
	Heterolithic Unconformity				
		9. Narrow andesite dykes and dolerites (WNW-ESE), pegmatites, aplites and quartz veins.	Vindhyan autogeosyn-clinal rocks		3. Bhander Series 2. Rewa series 1. Kaimur Series
Intrusive	Newly formed continental margin Magmatisms	8. Malani igneous rocks, Erinpura granites and mafic dykes (NNE-SSW) which are free from F_1 and F_2 foldings		Heterolithic Unconformity (Great Boundary Fault)	
		7. Epidiorites hornblende schists, olivine-bearing dolerites and gabbros, emplaced along longitudinal fault zones and foliated intrusive granites which are derived by remobilization of grranitised granites	Intrusive rocks	Deformation of proto-continental margin	8. Intrusive granites which are free from F_2. Epidiorites, hornblende schists tuffs and olivine-bearing mafic rocks and granites (synchronized with F_1 foldings)
	Inner arc basin (Flysch deposits)	6. Slates, phyllites and quartzites.			6. Slates phyllites and staurolite, andalusite schists and crystalline limestones
	Intra-formational Unconformity				
Delhi System	Ajabgarh Series lepto Geosyclinal pelagic metasedi-mentaries. Layer-1 oceanic crust	5. Crystalline limestones 4. Biotite-garnet schists 3. Calc-gneisses and calciphyres 2. Calc-schists, staurolitel schists, para-amphibo-lites and Calc-granulites 1. Biotite gneisses leptinites and pelitic granulites	Contin-ental shelf miogeo-syncline	Alwar Series	5. Hornstone breccia 4. Kushalgarh limestones 3. Quartzites, arkoses, grits and conglomerates
				Raialo Series	2. Crystalline limestones and biotite schists. 1. Quartzites and conglomerates
	Non-depositional Unconformity (sea-floor spreading			Heterolithic Unconformity	
Pre -Delhis	Basement rocks Layer-2 and 3 oceanic crust	3. Fault zone ortho-amphi-bolites and granulites eclogites ?, and serpentine rocks 2. Fold core ortho-amphi bolites and granulites and granitised hornblende granites. 1. Pyrolite or peridotite, uplifted during Delhi orogeny	Proto-continent	Aravalli	4. Phyllites, cherty limestones and ferruginous limestones. 3. Quartzites and composite gneisses. 2. Basal quartzites grits, grey wackes, Conglomerates and granitised rocks 1. Basic volcanics & Ultramafics
				Pre-Aravalli	0. Banded gneisses complex and equivalents.
		Mohorovicic Discontinuity UPPER MANTLE			

Table - II.3 : CLASSIFICATION OF DELHI SUPERGROUP
(Gupta et.al., 1992)

	Classification of Delhi Supergroup			
	South-western & Rajasthan and North-eastern Gujarat		Ajmer Sector	North-eastern Rajasthan
INTRUSIVES (Post-Delhi)	MALANI IGNEOUS SUITE Plutonic and volcanic			
	ERINPURA GRANITE			
	GODHRA GRANITE GNEISS			
DELHI SUPERGROUP 2000 - 740my	PUNAGARH GROUP (Sojat, Bambolai, Khambal and Sowania Formations)	SINDRETH GROUP (Angor and Goyali Formations)		
	SIROHI GROUP, (Jiyapura Reodhar, Ambeshwar and Khiwandi Formations)			
	SENDRA AMABAJI GRANITE AND GNEISS			DADIKAR, BAIRATH AND SIKAR GRANITES
	PHULAD OPHIOLITE SUITE		KISHANGARH SYENITE	
	KUMBHALGARH GROUP (Todgarh, Beawar, Kotra, Ras Barr, Sendra, Kalakot and Basantgarh Formations)		AJABGARH GROUP (Ajmer Formation	AJABGARH GROUP (Kushalgarh, Sariska, Thanagazi, Bharkol and Arauli Formation)
	GOGUNDA GROUP (Richer, Antalia and Kelwara Formations)		ALWAR GROUP(Srinagar) and Naulakha Formations)	ALWAR GROUP (Rajgarh, Kankwarhi, Pratapgarh, Nithar, Badalgarh and Bayana Formations)
				RAIALO GROUP (Dogeta and Tehla Formations)

Table - II.4

Vindhyan system of rocks	Late precambrian to Early paleozoic
Unconformity	
Malani Igneous suite of rocks	post Erinpura granite
Gabbros (picrites and olivine gabbros) Dolerites (olivine, hypersthene-olivine, biotite) basalts (hornblende, augite, olivine)	post Erinpura, but pre-Malani
Pyroxenites, Epidiorites, Soda-syenite Quartz veins Pegmatites and aplites; quartz feldspathic porphyries	Erinpura granite
Erinpura granites	
Epidiorites, amphibolites, hornblende-schists, actinolite-schists, tremolite-schists. Talc-chlorite schists, talc-limonite serpentine rocks, gabbros, dolerites and granulites	Pre-Erinpura granite
Ajabgarh Series	
Alwar Series	Delhi System (Algonkian)
Unconformity	
Raialo series	Eparchean interval
Soda-syenites and soda-pegmatites Quartz veins Pegmatites and Aplites Granites Epidiorites, hornblende-schists actinolite-schists, talc-serpentine-chlorite rocks	Post-Aravalli
Aravalli System of rocks	Archean
Unconformity	
Quartz veins Pegmatites and aplites Amphibolitic rocks Biotite granite = Bundelkhand and Berach granites Biotite and chlorite schists and quartzose bands	Pre-Aravalli

Aravallis is the triangular area North-west of Udaipur city. Along the northern and north-eastern sides of the intrusive area, it adjoins limestones and phyllites and occurs as indefinite veins or sheets of a white quartz feldspar granite.

There is no special marginal alteration in the limestone, other than very abundant silicification and the granite itself shows no sign of chilled edge nor marginal modification, other than the aplogranite, but their mutual attitude leaves no room for doubt that the granite is intrusive in the limestone, the portions of which adjacent to the granite are copiously injected with lenticular sheets, wisps and knots of aplogranite.

The long and narrow belt of gneiss or granite, 26 miles in length and 1 to 2 miles wide, which runs in a south-easterly direction from near Dakan-Kotra and terminates near the Jaisamand or Dhebar lake is made up of acid intrusive of two varieties, one is a fine grained and schistose biotitic granite, grey in colour. It is a uniform and unbanded rock. The other is white, practically without either biotite or muscovite, and varies streakily in grain from a fine aplite. Tourmaline is seen in the pegmatite, in shreds and crushed crystsls, but is rare.

At localities many miles removed from the main intrusions, minor bodies of the aplite-pegmatite occur singly or in clusters, as for instance near Paduna and in the southern valleys of the great hill mass, west of

Babarmal and also a mile or two to the west and north of the Udaisagar laccolith.

Soda-syenites of Kishangarh

The syenites of Kishangarh were intruded previous to the deposition of the Delhis, the base of which the Alwar conglomeratic grits and arkose, lies a mile to the west of Kishangarh city. None of these syenites penetrates the Delhis ,and the line of the unconformity appears to cut across the strike of the syenites at a low angle.

The associated pegmatites carry the amphibole of the syenite, and interstitial sodalite, both blue and colourless and white or bright yellow cancrinite. Aegirine-augite also occurs in one pegmatite and molybdenite rarely. A contact rock consists of calcite, cancrinite and thulite, a pink zoisite containing manganese.

SERPENTINOUS ROCKS :

They consist of limonite, dolomite, granular and fibrous serpentine (the latter in fine veins), talc and acicular tremolite, weather to form dark brown, rough hillocks bare of vegetation.

Their lack of foliation especially in such intensely compressed country, would indicate that they were intruded after the period of great folding, but on the other hand their unfoliated texture may be due to recrystallization subsequent to compression, and certainly they are profoundly altered from their original constitution.

Besides the numerous occurrences around the Rajgarh anticline, there are blocks to the south east of Budhol. Along this band are scattered small knots of the Ultrabasic rock, which carry lumps of yellow serpentine. Two miles north of pharkia is seen the serpentinous rocks at the apex of a small hill the slopes of the hill all around are amphibolites, through which the ultrabasic appears to form a plug. This occurrence clearly proves that they are intrusives.

QUARTZ VEINS :

Quartz veins are common in the Aravalli phyllites and are distributed at random. They are nearly always small a foot or two in thickness, and at the most are only a few yards in length. With more interfoliar intrusion a greater tendency to form smaller and more numerous veins is noticed. Saddle veining is common in the phyllites wrapping round the southern points of the Aravalli quartzite anticlines of Sagri and Madri. The margins of the veins are clearly defined though highly irregular i.e. there is no merging nor mixing of vein material with country rock. The veins are much jointed and fractured.

In the Aravalli quartzites, quartz veins tend to be small, infrequent and discontinuous and often occupy shatter - cracks or systems of close jointing.

BASALT AND DOLERITE :

Rare small dykes of basalt and rather larger plugs of dolerite are found quite at random in the Aravallis. They have no structural significance and have no effect on the rocks into which they are intruded. Basalt dykes have chilled margins and are fine-grained rocks, with phenocrysts in some cases, of zoned labradorite, augite and olivine, in a ground-mass which may be largely glassy, with abundant magnetite.

Linear arrangement of circular or oval outcrops of coarse dolerite, suggests that they are plug like processes rising from a deeply concealed dyke.

4.2 INTRUSIVE ROCKS IN THE DELHIS :

2. Post-Erinpura granitesa	Olivine basalts, Olivine dolerites and fine grained andesite.
1. Pre-Erinpura granites	Meta-Olvine dolerites and epidiorites.

Meta-olivine dolerites and epidiorites of pre-Erinpura age, has been recorded from the Sai River bed (5 km south of Gunwa village), near Merawas and at Ranpur in the South-west and west of the Posina and Kherod (Sychanthavong, 1978). The former occurrence is exposed as a linear outcrop within the calc-gneiss 1 to 5 metres wide and extending for about 50-60 metres in NNE - SSW direction. On crossing the river Sai, the same rock continues and is exposed again on the road between Amba Mhauda and Lambdia, near the village Gunwa. The rock is an olivine bearing meta-dolerite. The other occurrence near the village Merwas is that of epidiorite. It forms a big (Xenolithic) mass varying from 10 m to 200 m in dimension and striking NNE-SSW within the granites. The exposure at Ranpur is also of epidiorite, but here it is seen cutting the calc-gneiss and the ortho-amphibolites. The strike of the outcrop is NS to NNW-SSE.

The mafic rocks intruded after the Erinpura granite, comprising olivine basalt, olivine dolerite and fine-grained andesites, show widespread occurrence all over the area, in the form of narrow dykes and veinlets, cutting all the metasedimentaries and granitic rocks. The size of the individual intrusive is rather small, one or two metres thick and extending for a 10 to 15 metres. Mostly, they strike WNW-ESE.

GRANITIC ROCKS :

The granitic rocks of Delhis are classified into three varieties characterising successive events marking the folding and uplift of the Ajabgarhs. The remaining two comprise typical intrusive phases, emplaced at different periods during the Ajabgarh folding.

Sychanthavong (1978) has deciphered effects of three fold episodes in the metasedimentaries and he has observed that the two granites were emplaced during the last two fold episodes. The earlier of the two, intruded during the waning Phase of DF_2 (which was co-axial with DF_1), is characterized by elongated exposures trending NNE-SSW.

The later granitic phase is represented by a fine grained unfoliated rock occurring as narrow (1 to 5 mts. thick) dyke - like bodies. At several places, this granite cuts across the metasediments as well as the first phase granite, but occasionally it follows the folded trends of the calc-gneiss. It is revealed that the dykes of the granite cut DF_1 and DF_2 folds and follow the axial trends of DF_3, indicating their emplacement during DF_3 folding.

PEGMATITES AND APLITES :

Pegmatites and aplites are not abundant. When present, pegmatites are fairly coarse and consist of quartz, feldspars, micas and tourmaline. Aplites have more or less same mineralogical composition as surrounding granites, except the micas which are almost absent.

Pegmatites are not only restricted to the granitic rocks, but they are also seen within the calcareous terrain, as in Bhirpur, Dhanmanwa and Naskura villages. Aplites are common within granites such as at AmbaMhauda and east of Posina on the road to Dilwara village.

PREVIOUS WORK ON LITHOSTRATIGRAPHY

This topic deals with the work of various modern workers and provide an outline of the lithostratigraphy of the Jharol group of rocks of Aravalli Supergroup of Rajasthan.

According to Gupta et.al. (1980, 1992) the Jharol group comprise of only two formations namely- Goran and Shamlaji formations. The separation of Goran and Shamlaji formations was done by them due to the pre dominance argillaceous character in the lower part and regular appearance of thick intercalatory sandy layers with impure calcareous layers in the upper part marking a change of facies. Deb and Sarkar (1990), however, have also attempted to classify the Jharol group of rocks as under (Table-II.5)

According to these authors, the Aravalli and Jharol belts is characterized by distinctive lithologies which represent two segments of a single basin, having same deformational history and similar tectonic trends. They have divided the shelf sequence of the Aravalli belt into two groups. The lower group consists of conglomerates, quartz arenites and basic volcanites, overlain by phyllites (locally carbonaceous), dolomites, quartzite and stromatolitic phosphorite. The upper group consists of greywacke slate-phyllite rhythmites, lithic arenites at the bottom overlain by quartzite, dolomite and silty arenite in the middle and slate-phyllite at the top. According to them, there is a deep-seated suture represented by a linear N-S

TABLE- II.5 :

DOMAIN	SEDIMENTATION	MAGMATISM	DEFORMATION AND METAMORPHISM	AGE
Aravalli Jharol belt.	A carbonate and Phosphorite-bearing marginal facies in the east and deep water Pelitic sediments in the west.	A N-S trending highly tectonized belt of mafic - ultramafic rocks (RL) separates the sedimentary facies.	The nature & sequence of deformation is same as in the Bhilwara belt. Green schist to amphibolite facies.	Overlies BGC with erosional unconformity syngenetic mineralization 1700 Ma old.

trending belt of melange, consisting of phyllites, carbonates, sheared amphibolites with possible pillows and chromite bearing serpentinites with ferruginous cherts extending from south of Rakhabdev in the south to north of Gogunda in the north. The shelf sediments of the Aravalli belt is separated by the Rakhabdev lineament from the thick sequence of phyllites and quartzites of the Jharol belt, which was deposited in the deeper parts of the basin. After workers (B.L. Sharma et.al., 1988), have classified the stratigraphic succession of the rocks of Bagrunda area, the northern extension of the Jharol rocks, as under :- (Table-II.6)

	Ultramafics (Talc-chlorite schist) and quartzite.
	Mica schist, phyllite with thin quartzite bands.
Jharol Group ?	
	Amphibolite (partly meta volcanics)
	Quartzite (white mica and high aluminous rocks at the base).

-----------------------unconformity-------------------------

Pre-Aravalli basement.	Banded gneiss and amphibolite

These authors have recognised the banded gneisses and amphibolites which occupy the base of the Jharol rocks as an inlier of the pre-Aravalli basement. According to them, the Aravalli succession starts with high aluminous pockets (metamorphosed to kyanite-bearing rocks) separating the basal quartzites from the banded gneisses which they believe to represent the basement dome over which the Jharol group have been deposited . Roy (1991) has classified the Jharol group of rocks (Upper Aravalli) and the main Aravalli rocks as under :- (Table-II.7)

Table II-7 :

	SHELF SEQUENCE	DEEP-WATER SEQUENCE	
Upper Aravalli Group.	Ultramafic intrusives Lakhawali phyllite Kabita Dolomite Debari formation.	Jharol formation	Mica Schist and thin beds of quartzites and Ultramafics.

According to him, the Aravalli Supergroup shows two contrasting lithofacies association - (1) Sand - Shale Carbonate assemblage representing near shore shelf facies and (2) Carbonate - free Shale sequence with thin interbeds of arenites representing a distal turbidite deep sea facies. This type of interpretation was made by (Poddar, 1966; Roy and Paliwal, 1981).

According to these authors, there is no apparent break between the shelf and deep sea sequences. The topmost bed of the Aravalli rocks of the shelf sequence passes on conformably to phyllites and mica schists of the deep sea sequence.

II.B GEOLOGICAL SETTING OF THE STUDY AREA

GENERAL INTRODUCTION :

Geology of Rajasthan has attracted the geologists for more than a century ago. Various aspects of geology of this pre-Cambrian terrain has been investigated by various authors and valuable information has been provided in the topic of previous work. The geological map published by Heron (1953) is used as a base map for the paresent study.

The present author has given a systematic and detailed account of the distribution, lithology and field characteristics of the various rock types encountered in the study area. The study area comprises part of the Aravalli rocks of Heron (1953). But recent workers have grouped them as Jharol group of rocks (Mathur et.al., 1973; Gupta et.al., 1980, 1990). As the author is establishing the stratigraphic succession of the study area, it is required to accumulate stratigraphic informations revealing the age of the various rocks units. This type of data was obtained by detailed studies of various geological sections exposed in and around the sudy area using purely field relationships of individual lithounit with the other lithounits of a single formation based on the lithostratigraphic concept of Krumbein and

Sloss (1963)

After the scrutiny of modern literatures, it is observed that the Jharol group of rocks have been classified as upper Aravalli comprising mainly of argillaceous and arenaceous rocks of Aravalli Supergroup. However, from the present study, which is based mainly on field observations and petrographic identification, it is revealed that the rocks of Jharol group deserved a reclassification and interpretation. It is a modification of the pre-existing classification of Gupta et.al. (1980, 1992) as follows :-

Jharol Group
- Shamlaji formation
- Goran formation.

II.C REVISED STRATIGRAPHY OF JHAROL AREA

As mentioned above, the proposed stratigraphic classification (Table-II.8) is a modification of the already known classification of Gupta et.al. (1980, 1992). The present author has introduced three more formations, viz : the Barvalli, Kirat and Bagpura formations, in addition to the two fold classification of Gupta et.al. (op.cit) consisting of Goran and Shamlaji formations only. According to the present classification the Goran formation strictly represents only the garnetiferous pelitic schists, and the Shamlaji formation strictly represents only the massive quartzites overlying the garnetiferous schists - The basic oceanic crust, consisting of highly folded amphibolites, Table - II.8 : Stratigraphic succession of the Proterozoic rocks of the Jharol area, south-western Rajasthan.

Age	Group	Formation	Lithology
MIDDLE PROTEROZOIC		Intrusive	- Dolerites and basaltic dykes - Ultramafic rocks(serpentinites, talc chlorite schists, actinolite schist.
	Gogunda Group	Kumbhalgarh/ Richer	- Argillaceous/Calcareous
		Antalia	- Arenaceous (quartzite)
	JHAROL GROUP	Bagpura	- Phyllite schists - Quartz-biotite-muscovite schist.
		Shamlaji	- Massive quartzite
		Goran	- Garnet mica schist - Kamalnath micaceous quartzites
		Kirat	- Staurolite-garnet schists and gneisses. - Sillimanite gneisses alternated with sheared quartzites.
		Barvalli	- Amphibolite garnetiferous gneisses. - Amphibolites, asbestos-bearing serpentinites.

garnet-hornblende gneisses and asbestos-bearing serpentinites (Barvalli formation),represents the basement complex of the Jharol basin. This formation and the overlying gneissic rocks (Kirat formation) have not been described in Gupta et.al's classification. Also, the non-garnetiferous schists and phyllites, occurring above the Shamlaji formation, have not been classified by Gupta et.al. (1980, 1992) as a separate formation. The present author proposes to assign them as Bagpura formation in the new classification. This proposal is made since the rocks belong to a separate sedimentary facies of pelagic argillaceous nature representing deep sea facies (Sugden and Windley 1984; Sugden et.al. 1990).

Critical examination of the various rock formations assigned above, reveals that the Jharol group comprises of several metasedimentary lithofacies, viz - the greywacke-pelite association (Kirat formation), Pelite (Goran formation), arenite (Shamlaji formation) and pelagic argillite rocks (Bagpura formation). This lithofacies classification has been adopted, based on the standard concept of lithostratigraphy described by Krumbein and Sloss (1963) and the code of Indian stratigraphic nomenclature described by Anon (1971). Each of the above described formations is represented by a lithostratigraphic unit, whose genetic basis implies deposition under uniform condition and its limits are placed where lithological change occurs. The names of various formations are assigned, based on the name of places where the particular rock units are well exposed and can be described as type area of such rock units, the strato-types (cotillon, 1992). Based on their occurrences in vertical section, their respective age sequence has been assigned (Table-II.8).

So far stratigraphic positions are concerned, there are two types of talc-chlorite-tremolite schists in this region, which can be distinctly classified. The older retrograded garnetiferous schists associated with strongly deformed serpentinites and highly folded amphibolites, occurring along the cores of the megascopic folds surrounded by gneissic rocks, represent the oldest rocks of the Jharol group. These rocks should not be confused with those younger tremolite-chlorite schists associated with the upper Goran and Bagpura formations. The younger tremolite-chlorite schists are associated with serpentinite breccias and markedly occurring along the major shear zones. These are no doubt of being products of metamorphism of sepentinised ultramafic intrusive rocks emplaced during the later stages of basin uplift. Younger than those metamorphosed ultrabasic rocks, there are few dolerite and basaltic dykes emplaced along the E-W trending fractures, developed during AF_4 folding, reported here for the first time.

THE JHAROL SEQUENCE

According to the proposed classification, the Aravalli Supergroup, consists of various lithounits deposited over the oceanic crust basement rocks (amphibolites and metamorphosed ultramafics). The pelitic garnetiferous gneisses and schists lie conformably over these mafic and ultramafic rocks which occur in the core of the mega-anticlines (fig-II.1). It is observed that the gneisses are intercalated with bands and lenses of highly sheared micaceous quartzites varying in thickness from few centimetres to as thick as several hundreds of metres. These quartzites are overlain by thick garnetiferous biotite schists, followed upward by thick horizon of massive quartzites and non-garnetiferous chloritised schists. Detailed description of each of these lithounits are as under :-

C.1 BARVALLI FORMATION :-

Amphibolites and associated ultramafic rocks exposed around Barvalli, Jhanjhar and north-east of Mohmad Phalasia area, are reported here for the first time. They are highly folded and show concordant structures with the overlying gneisses. These mafic rocks are well exposed in massive form as well as with small bands of quartzo-feldspathic materials, showing intense folding and shearing with various scales of interference patterns. Based on these concordant structures and their occurrence along the core of anticlines, they represent the sea-floor (basic oceanic crust) of the Jharol basin over which pelites and greywackes have been deposited. The various discontinuous quartzo-feldspathic bands in the gneissic amphibolites represent the products of metamorphic differentiation of the same rock mass, the chemical and mineralogical adjustment during metamorphism which was accompanied by intense ductile shearing. Thin section studies of these mafic rocks revealed.

high rank amphibolite facies of Turner (1968) and Winkler (1975). The abundance of diopside and enstatite co-existing with hornblende and calcic plagioclase indicates high temperature-low pressure metamorphic conditions. This metamorphic imprint is also revealed in the overlying pelitic gneisses and meta-greywackes (feldspathic quartzites).

About 10 kms. after Mohmad Phalasia towards Harana villages, a thick exposure of mafic rocks is exposed. Amphibolites found here is very fine grained in field appearance. Adjoining to this pure fine-grained amphibolites epidotized amphibolite is found. Further North, highly folded amphibolites with southernly plunging F_2 folds is found (plate-II.1). Epidotized amphibolites are found with the gashings of epidotes. The mafic rocks found here are in contact with the highly sheared mylonitised garnet-mica schist. It is found in between quartz mylonite.

Amphibolitic gneisses is encountered near Kirat village in the river bed striking N10° and steeply dipping due west. Very tight folds are observed in these amphibolitic gneisses. Few metres after this amphibolitic gneisses, pure amphibolites are found with veins and very tight folds of quartzo-feldspathic materials. Their strike is varying from N-S to N10°E and dipping due west. Interfolial type of shearing is also observed in the field which is very clearly observed in the photograph. (Plate-II.2). The transition stage from gneisses to amphibolitic gneisses and pure amphibolites is clearly observed in the field. The garnet-bearing amphibolitic

Plate - II.1 Folded amphibolites with southernly plunging F_2 folds (Loc. - Mohmad Phalasia).

Plate - II.2 Interfolial shearing observed in amphibolites. AF_2 fold is coaxially folded by AF_3 fold. (Loc. - Barvalli village).

gneisses seemed to represent the metamorphosed products of volcaniclastic materials mixed with pelite overlying the more massive basic rocks metamorphosed to pure amphibolites. The transition stage from amphibolitic rocks to quartzo-amphibolite is also observed in the field (Plate-II.3). In this type of rock more amount of quartz material is found.

As given in Table-II.8 the oceanic crust is represented by the amphibolites and associated ultramafic rocks. The mechanism involving the deformation of these oceanic crustal rocks is purely governed by simple shear deformation, followed by flattening and upright buckling in the next stage. The detail of these will be discussed in the next chapter.

As seen in Plate-II.2, when the AF_2 were folded coaxially by AF_3, the upright AF_3 folds were visible and the quartzo-feldspathic material emplaced during AF_2 have been affected by AF_3 folding. During the folding of AF_3, strain slip cleavages have been developed trending oblique to the shear plane. These cleavages penetrate through the amphibolite rock mass and also the above lying amphibolitic gneisses. Due to the effect of continuous shearing, one tail of the several porphyroclasts has been cut off and detached and mostly only one tail is observed in the field.

The associated ultramafic rocks are also highly sheared and flattened. Detailed mapping by the author (Figure-II.1) has shown that these amphibolitic rocks and associated ultramafics occupy the cores of tight megascopic anticlinal fold representing a narrow linear outcrop within the metasedimentaries.

The contact between these mafic basement rocks and the overlying gneisses, at places, shows a diffused and transitional nature. It is observed that this transitional variety of rock comprises biotite-hornblende gneisses which grade into garnetiferous biotite gneisses (assigned as Kirat formation). The garnetiferous biotite gneisses are derived from the pelitic sediments, transformed by deep-seated metamorphism.

C.2 KIRAT FORMATION

The gneissic outcrops in this area are well exposed around Kirat and ora villages, assigned here as Kirat formation do not show any field characteristics to suggest that they are the basement complex of pre-Aravalli age as claimed by Sharma et.al. (1984) in the adjoining area around Bagrunda NW of Udaipur. The banded structures in these gneisses, comprising of quartz and feldspar leucosomes alternating with garnetiferous biotite mesosomes, indicate the advancing phase from lower gnessification to higher migmatisation processes (Ashworth, 1985). The former are seen folded and at places boudinaged,. and the latter are crinkled almost at all places. Mineralogically, the gneisses consist of coarse crystals of garnet, densely spaced, co-existing with muscovite, sillimanite, biotite, staurolite, plagioclase and quartz. The flaky minerals have have been sqeezed and folded along

Plate - II.3 Field photograph showing more amount of quartz - feldspar material in gneissic amphibolite. (Loc. - Barvalli village).

Plate - II.4 Basaltic dyke cutting across the amphibolitic gneiss. (Loc. - Kirat village).

with aggregates of quartzo-feldspathic bands. Big porphyroblasts of staurolite, upto three centimetres in length, are seen highly folded. It is observed that where staurolite is abundant, sillimanite is absent and where sillimanite and muscovite are abundant, staurolite is not seen. Garnet and biotite are common in both the cases. This signifies the variation in pressure and temperature during metamorphism within a small area.

Boudinaging of quartz veins is seen in the gneisses. Quartz veins emplaced along the foliation planes have been boudinaged indicating that there was maximum stretching along the strike. Quartz veins which have undergone brittle-ductile deformation are found emplaced and boudinaged within the more ductile gneisses.

The gneissic rocks exposed near Kirat village in the river bed also consist plenty of garnets and are seen cut by a basaltic dyke of much younger age, running in E-W direction (Plate- II.4). Along a major fault plane, the dyke has been emplaced. The size of garnet porphyroblasts at this location is medium but increasing towards north around Ora and Akodra villages. Near Dhikliya village these gneisses are seen separated from garnetiferous schists by a few layers of quartzites. Heron (1953) called these gneissic rocks as composite gneisses injected into schists.

This horizon (gneisses) represents the lowest subdivision of the Jharol group of rocks with a thickness of approximately 300 metres. Full sequence is not exposed anywhere in the area because of the complex refolded structures controlling the exposures of the rocks. In a broad way, these gneisses form very conspicuous and rather extensive exposures around 4 km after Bichhwara village towards North upto Ora village and even further North (Figure- II.1). The gneisses are forming continuous outcrop with a NE-SW trend showing progressive increase in the width from south and north. The villages Bichhwara, Melaniya Kelan, Kirat lie within this gneisses. Various outcrops of gneisses are found in these villages on an average, each such outcrop is about 4 to 6 metres wide and intercalated with quartzite bands. These gneissic rocks are well foliated and show mineral elongation as well as microfolds or crinkles in the outcrop. These gneisses can be divided into two types each of which are characterized by its different mineralogical compositions.

1. Garnet - Sillimanite gneisses.
2. Staurolite - garnet gneisses.

Garnet - Sillimanite gneisses are found in contact with the mafic rocks while the staurolite - garnet gneisses are restricted only along the Aravalli-Delhi contact zone. The appearance of staurolite is decreasing on going away from the contact zone.

C.3 GORAN FORMATION :

Between Kirat and Goran formations there is a thin horizon of micaceous quartzite assigned here as Kamalnath micaceous quartzite. No unconformity can be observed between the gneisses and associated greywacke quartzites. Both the units show concordant structures (Plate- II.5). The Kamalnath hill represents a swell anticlinorial noses of southernly plunging megascopic folds of these quartzites. Overlying this quartzite horizon are the garnetiferous schists of extensive thickness. Gupta et.al. (1980, 1992) termed these schistose rocks as Goran formation. The present author retains this nomenclature to avoid further confusion in the stratigraphic classification. Structural features observed in these rocks are various scales of mesoscopic folds, crinkled microfolds and microshear planes, and microfaults displacing the quartzitic veinlets.

The shapes of the exposures are controlled by the topography, structural patterns and property of the schists. They contain more of flaggy minerals and obviously are highly weathered, easily erodable and, therefore, they occupy mostly the low-lying valleys. At some places they are exposed as lensoidal outcrops and, at other places, they occupy as complicated folded structures interbedded with thin bands and lenses of quartzites. In the field exposures, these schists are highly crinkled and kinked showing excellent lineations plunging south at various angles. Along the core of the microfolds big porphyroblasts of garnet along with aggregates of quartz are seen developed. Garnet porphyroblasts, easily observed by naked eye, range in size from one millimetre to half a centimetre at some places even upto one centimetre. But their hand specimen characteristic are differnt from the Kirat gneisses.

C.4. SHAMLAJI FORMATION :

Above the Goran formation lies the Shamlaji formation consisting of massive quartzites. These quartzites are not different from the thin bands and lenses of quartzites found in gneisses in terms of composition. These quartzites also show variation in thicknesses, at some places, they are measurable upto 1000 metres or even more (Figure- II.1) and at other places they are as thin as few tens of metres only. The thickening and thinning of these quartzites may be due to ductile deformation during folding. Since they occur within the more ductile schistose rock mass, major pinch and swell structures have been developed with large scale of rotation of fold hinges. These massive quartzites extend southward through Nenbara (Figure- II.1) to Shamlaji of North Gujarat which Gupta et.al. (1980. 1992) used this name to assign these rocks as Shamlaji formation. At places the quartzites are totally white in colour, while at other places, it is showing pinkish colour. Near Atwal village the quartzites are highly sheared and sliced. The quartzites do

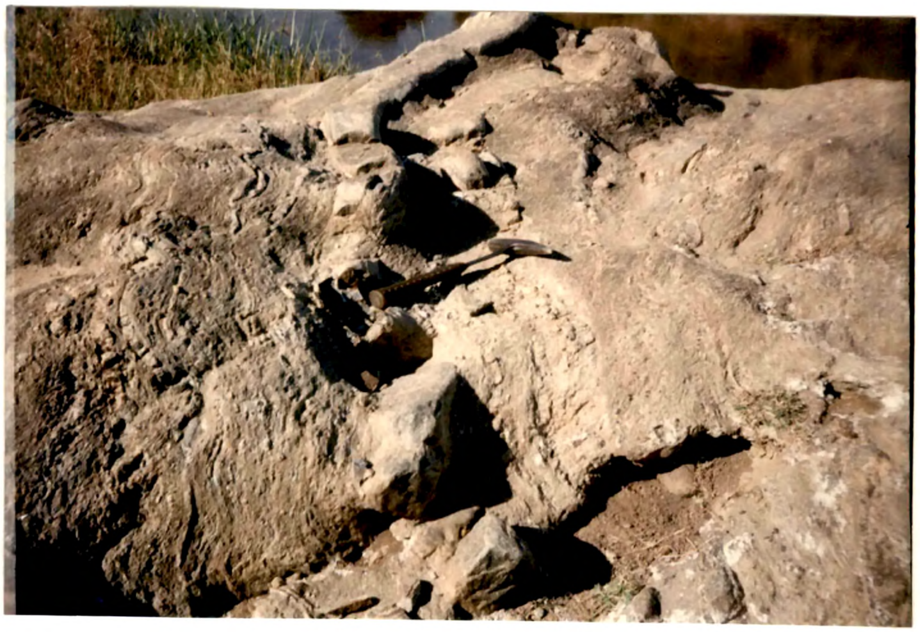

Plate - II.5 Quartzite band within garnetiferous gneisses showing effect of AF_4 folds. (Loc. - Kirat village).

Plate - $II.6_a$ Fractured and sheared quartzite ridge in contact with schist (Loc. - Koliyari village).

not show any stratified structure except fracturing along the axial planes of various megafolds actual bedding planes are very difficult to recognise. The contact between the quartzites and the underlying schists is always sheared showing ramping structures with highly deformed schists (Plate- II.6a,b,c).

The original constituent of this quartzite horizon consists of comparatively pure quartz sands deposited in a basin having clear water environment. It is quite white in colour when freshly broken and is mostly stained by iron oxides along the fracture planes showing an overall pinkish to yellowish appearance. This oxidized limonite originates from the weathering of the overlying phyllitic schists. Due to the scarcity of sedimentary structures like stratification or lamination, it is opined that these quartzites have been deposited quite far away from the littoral zone in the deeper part of the continental shelf having clear water environment, high slope gradient, and free from wave actions. The quartzites of this formation are purely siliceous and vitreous, and breaks with a concoidal fracture. It is massive and homogeneous, with widely spaced joints dividing it into large blocks of irregular shape, but with plane-surfaced sides. Under the alternating expansion and contraction due to changes in temperature the edges of these blocks flake off and they become somewhat rounded, and the quartzite on weathering shows the fine

Plate - II.6_b Sheared contact of schist and quartzite (Loc. - Dhikliya village).

Plate - II.6_c Quartzite lens in schistose rock.

granularity of sandstone.

Near Bichhwara these quartzites are involved in intricate folding. The ridges are twisted. Few kilometres to the west of Jharol, the band of quartzites is completely absent but to the North it again thickens and give rise to a bold ridge having a height of more than 1000 metres. In between the valleys of Jharol and Manas (24° 20' : 73° 31'), the quartzites form a wall like ridge with a height of over 800 metres. About two and a half kilometres to the north of Bichhwara, the thick quartzite of Jharol anticline terminates abrubtly. To the south west of the Kamalnath hill, several thin quartzites strike parallel to the main Kamalnath quartzites indicating that they have been concordantly folded and sheared.

C.5 BAGPURA FORMATION :

Overlying the Shamlaji quartzites are non-garnetiferous schists (considered as pelagic by Sugden et.al. 1990), at places chloritized and talcified. It is observed that chloritization and talcification were developed mostly along the longitudinal major shear zones. They are very even in appearance as compared with the garnetiferous schists of the Goran formation discussed above. These rocks also show varieties of deformational features. Isoclinal and recumbent folds are observed at several places. The formation of duplex structures in the phyllitic rocks occurs due to longitudinal shearing having multiple smaller shear planes within the main shear zones. (Plate-II.7). This formation is extensive in lateral extend as well as in vertical section. Its thickness must be more than 1000 metres. It is somewhat monotonous in appearence showing greyish colour. Crinckling structures (Plate-II.8), Puckering folds and kink bands are common everywhere. The age relationship between these schistose rocks and the Gogunda Group of the Delhi Supergroup is doubtful since the contact between them is highly sheared. Throughout the study area, the Gogunda group deeps beneath the Bagpura formation in the southwest and in the northwest it deeps beneath the Kirat formation. Inverted unconformity of this contact has been suggested (Patel, 1975). Detailed discussions on this problem are beyond the scope of this thesis.

II.D. THE INTRUSIVE ROCKS :

The major intrusive rocks in the study area comprises mainly chromium and nickel-bearing ultramafic rocks, consisting mainly of serpentinites and highly sheared talc-chlorite schists and actinolite-tremolite schists, all of which are trending more or less parallel to the main foliation of the surrounding meta-sedimentary rocks. They occur as discontinuous linear bodies showing highly sheared contact with the metasediments. The intrusion of these

Plate - II.7 Duplex structure in schistose rock. (Loc. - 10 km to the south of Mohmad Phalasia village).

Plate - II.8 AF_4 crinkles in schists (Loc. - Garanwas village).

ultramafic rocks occurred on account of strike-slip faulting trending N-S to NNE-SSW direction. It is visualised that the transcurrent faulting was of Zig-Zag nature and during the course of movement several transtensional openings have been created along which the ultramafics have been emplaced. The detail of this will be discussed in Chapter-V on tectonic implication and geological evolution of the area. All the varieties are highly sheared showing S-C mylonite and pull-apart textures. Several Chlorite fishes are observed in thin sections. Since these rocks are only highly sheared and not highly folded as compared to the surrounding metasediments, which have been affected by three phases of folding, they can be considered intrusive rocks. Their trend is concordant with the NNE-SSW trending AF_2 and AF_3 foliations, and their emplacement might, thus, be synchronous with this NNE-SSW trending orogen, commonly known as Delhi orogeny, which controlled the development of these foldings (Sychanthavong and Desai, 1977; Sychanthavong and Merh, 1981). However, Sinha Roy (1993) considered the Gogunda ultramafic belt as representing a segment of the Aravalli suture zone.

The minor intrusive rocks are dolerite plugs and basaltic dykes both of which are trending in E-W direction. Dolerite is massive and medium grain in nature. Typical spheroidal weathering is well developed indicating that the rock has been affected by more than one set of fractures.

Acidic intrusion like granites and rhyolites are not encountered anywhere in this area except quartz veins. The veins found in the schistose and gneissose rocks are highly folded and those found along the shear zones are highly stretched and boudinaged.