BACKGROUND INFORMATION

2.1. GENERAL

Aravalli Fold Belt *(AFB)* extends from Delhi in the North and to Chhota Udepur (East of Vadodara, Gupta et al, 1992). The Precambrians of this mountain belt are classified as Banded Gneissic complex *(BGC)*, Aravalli Supergroup, Delhi Supergroup with different episodes of basic and acidic intrusion and extrusive phases.

The Precambrian stratigraphy of Gujarat can be assigned to Proterozoic (*BGC*), Palaeoproterozoic (Aravalli Supergroup) and Mesoproterozoic (Delhi) geological cycles. The oldest constituents in the Aravalli region are dated as old as 3000 Ma (Roy, 1988), which is known as Basement Gneissic Complex. The gneissic rocks exposed to of Chhota Udepur region was thought to be overlain by Aravalli Supergroup represented by Udaipur, Jharol, Lunavada and Champaner groups in northeastern and eastern Gujarat, whereas Gogunda, Kumbhalgarh and Sirohi groups (?) of rocks are units of Delhi Supergroup exposed in northern Gujarat. High potash per-aluminous granite and granite gneiss locally designated as Godhra, Idar, Sendra-Ambaji and Erinpura Granites (Neoproterozoic) have intruded Aravalli and Delhi Supergroups. Basic rocks that intruded Delhi Supergroup are meta-gabbro and meta- norite, designated as Phulad Ophiolite Suites. These rocks are exposed in the north Gujarat around Palanpur-Ambaji region along with granitic rocks and exhibit high degree of deformation.

The geological map of this region (**Fig. 2.1**) shows the distribution of major lithounits of the Precambrians of Gujarat viz. Pre Champaner Gneiss, Udaipur Group, Jharol group, Lunavada Group, Champaner Group and Godhra Granite. The area of investigation mainly comprises major part of Pre-Champaner Gneiss. Deccan traps and Lameta Beds overlie the Precambrians in the southern extremity of the area.

The historical perspective of some of the studies carried out in this region comprising Champaner Group, Pre-Champaner Gneiss and intrusive Godhra Granite.

Geological map showing mainly the Precambrian rocks of Eastern Gujarat and adjoining states.

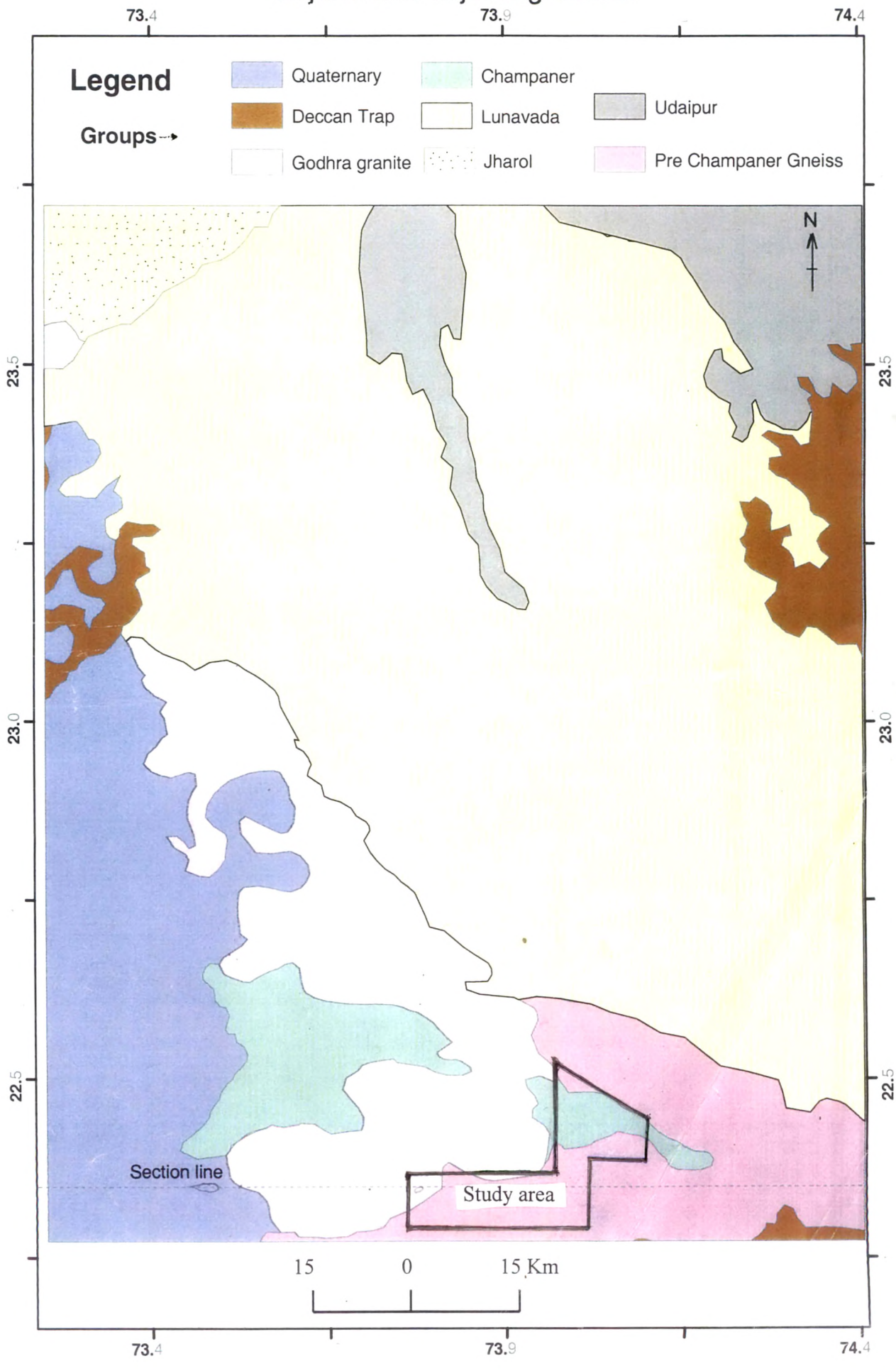

Fig- 2.1

2.2. EARLIER WORKS

Blanford (1869) coined the term *Champaner Series* for the Precambrian rocks of this region. As one of the pioneers of Indian geology he was the first to investigate geology of Western India. He classified azoic rocks of Aravalli Mountain Range as under:

Vindhyan Series
Bijawar Series
Champaner Series
Metamorphic Gneiss.

Subsequently Fermor (1909) believed the Champaners to be a part of Aravallis and those exposed around Jhabua district of Madhya Pradesh as probably contemporaneous with Gondites of Sausar Series. He correlated the manganiferous calc-gneisses and limestones of Jothvad hills near Jambughoda (presently classified Lower Champaners) as Archean metasediments. The Archean Complex of Baria State, which forms part of Rewa Kantha and lies to the north of Chhota Udepur, has been compared by Rama Rao (1931) with the Dharwars of Mysore. These are the oldest rocks of Aravallis as discussed by Rama Rao which consist of biotite gneiss, granite gneiss, amphibolites and calc-granulites, crystalline limestone. The map of Aravalli Mountain Belt is the first systematic map published by Geological Survey Of India (1934), where the worker Heron gave a regional stratigraphic framework of Aravali Mountain Belt (Table.2.1)

Stratigraphic succession of Aravallis is greatly changed from time to time by various eminent geologists. Of these, the important stratigraphic account was given by Heron (1934), who described the Precambrians of Aravalli Mountain Belt. This has been modified by Roy (1988) and then by Gupta et al (1992). The Precambrian lithostratigraphic succession given by Gupta et al (1992) and that of Heron (1934) are tabulated below in Table no 2.1 and 2.2 respectively.

Table 2.1 Lithohostratigraphic succession of Precambrians of Gujarat (Gupta et al,1992)

Age	Group	Formation	Lithology
DELHI POST IGNEOUS SUITE	Idar granite-(Malani igneous suite)		Fine grained undeformed potash granite
	Erinpura Granite		Porphyritic and nonporphyritic granite
	Godhra Granite		Granite and granite gneiss
DELHI SUPERGROUP	Sendra-Ambaji Granite		Gneissic granite , associated with porphyritic granite and migmatite.
	Sirohi Group		Phyllite, mica schist, biotite schist, quartzite.
	Kumbhalgarh Group		Calc gneiss, calc schist, calcitit marble, autoclastic conglomerate.
	Gogunda Group		Quartz arenite, pelitic schist and calc-schist.
	Phulad ophiolites		
ARAVALLI SUPERGROUP	Champaner Group	Rajgarh	Phyllite, gritty subgreywacke.
		Shivrajpur	Manganiferous phyllite and quartzite, dolomitic limestones.
		Jaban	Petromict meta conglomerate, gritty meta-subgreywacke
		Narukot	Petromict meta conglomerate, quartzite and phyllite.
		Khandia	Phyllite, mica schist, petromict conglomerate, proto-quartzite.
		Lambia	Metasubgreywacke, mica schist, quarzite, petromict conglomerate
	Lunavada Group	Kadana Formation	Quartz-arenite and meta-subgreywacke
		Bhukhia Formation	Meta-protoquartzite, meta-subgreywacke and quartz -chlorite schist
		Chamndwara Formation	Meta-protoquartzite and meta-subgreywacke,
		Bhawanpur Formation	Quartz-chlorite-sericite schist
		Wagidora Formation	Subgreywacke, conglomerate, quartzite
		Kalingara Formation	Phyllite, feldspathic mica schist and meta-subgreywacke.
	Syn- Orogenic Granite and Gneiss		
	Jharol Group	Shamlaji Formation	Muscovite-sericite schist and phyllite, gt-biot schist.
		Goran Formation	Magnetite bearing phyllite, chlorite-sericite phyllite
	Udaipur Group	Balicha Formation	Chloritic phyllite and quartzose phyllite, quartzite

In the stratigraphic classification of Gupta et al, 1992, however, the existence of Banded Gneissic Complex was not taken into account, although Banded Gneissic Complex was described by Heron (1934), Roy (1988) and other later workers.

Table 2.2 Stratigraphic successions of Precambrians of Aravalli Mountain Belt (Heron, 1934)

System	Series	Metasediments	Intrusives/extrusives
	Malani Series	Rhyolite Tuff	Granite and ultrabasic rocks
Delhi System	Ajabgarh Series	Upper Phyllites Limestones Biotite limestones and calc-gneisses Calc gneisses Phyllite and biotite schists/ Composite gneisses	Erinpura Granite, pegmatite and aplite
	Alwar Series	Quartzites Arkosic grits	
	Raialo Series	Garnetiferous biotite schists, Marbles Limestones, Local basal grits.	Aplogrinite , epidiorites and Hb-schists, ultrabasics
Aravalli System		Impure limestones, quartzite, phyllites, biotite schists, composite gneisses, conglomerates	
Banded Gneissic Complex		Schists, gneisses and composite gneisses	Pegmatites, granite, aplites

2.3. A BRIEF ACCOUNT OF ARAVALLI SUPERGROUP IN GUJARAT

Aravallis were considered as horst structure by Fermor (1909) and similar opinion was advocated by Reddy and Ramakrisna (1988a), Roy (1988) refers to linked or partially detached fault troughs forming linear basin, similar to East African Rifts. Roy also refers to intercratonic rift basin on which Delhi Sediments were deposited and later folded during the closure of rifts. Sychantavong and Desai (1977) modeled Aravali-Banded Gneissic Complex protocontinent in the east and Mid-oceanic ridge to the west with a major crustal basin between the two. Sugden et al. (1990) advocated a Wilson cycle for Aravalli-Delhi Orogen. The model explains initial rifting of rigid Archean continent (Aravalli- Banded Gneissic Complex) at 2.2 Ga with the formation of Bhilwada Aulacogen in the east. Rupturing of the Banded Gneissic Complex along Rikhabdev lineament with the development of passive continental margin. The collision involves thrusting and obduction along Rikhabdev lineament.

Structural and metamorphic history of the Precambrian rocks around Chhota Udepur region, however, was not paid much attention by the earlier workers. The present study provided adequate information with quantitative data for a better understanding of the tectonics of this region. The present study is an attempt to interpret the Precambrian

stratigraphy and tectonics of Chhota Udepur region, which was interpreted differently by various authors, viz; Basement Gneiss (Heron, 1934 and Merh, 1995), Banded Gneissic Complex equivalent to Mewar Gneiss (Roy, 1988), Lower Aravalli Gneisses (Gopinath et al, 1973) and granite gneiss as a part of Godhra Granite (Gupta et al, 1992). Aravalli Supergroup in Gujarat is represented by Udaipur, Lunavada and Jharol groups (Gupta et al, 1992).

2.3.1. Udaipur Group

Oldest Proterozoic rocks in Gujarat are represented as metasedimentaries of Udaipur Group and occur as linear patches covering about 50 Sq. km area around Santarampur and north of Jhalod. This group comprises conglomerate, impure crystalline limestone, phyllite, and metagreywacke and designated as Balicha Formation by Gupta et al (op, cit). The Formation is dominated by Grey pyritifeous phyllite and has undergone four phases of deformation of which the first generally represented as rootles (E-W trending isoclinal) folds, but wherever undisturbed occur as inclined folds with steep axial planes with easterly and westerly plunge. The second phase is recumbent in nature and is coaxial with the first phase (Roychowdhury, 1999). However, in the regional correlation F_2 could be correlated to the first Delhi deformation. The third and fourth generation folds are upright in nature. Axial planes of the third phase trend N-S, NNE-SSW, whereas fourth generation folds have axial trace trending E-W (Roychowdhury, op.cit).

2.3.2. Jharol Group

This group consists of phyllite, chlorite schist, and garnetiferous mica schist with minor intercalations of quartzite and is represented as Shamlaji Formation in Sabarkantha district of Gujarat. Although there is no break in lithological trend between Jharol and Lunavada group on the basis of lithofacies (dominance of argillaceous metasediments) it has bee given separate group status.

2.3.3. Lunavada Group

Lunavada Group occupies about 9900-sq.km areas in parts of Sabarkantha and Panchmahals district and comprises thick pile of arenaceous and argillaceous

metasediments. It is represented by quartzite; phyllite, schist and minor carbonate facies. Rama Rao (1931) considered Lunavada to be northern extension of Champaners. But later works (Gopinath, 1973; Srikarni and Das, 1996) proved them to be different groups. Lunavada Group represents shallow marine depositional environment. Kadana Formation of Lunavada group is mainly exposed in Gujarat. The Lunavadas in Gujarat has undergone three phases of deformation. The F_1 and F_2 folds are coaxial and have NNE-SSW axial trends, whereas the F_3 has NW-SE axial trend. Degree of overturning of F_2 folds increases towards south (Mamtani, 1998).

Continuation of the Precambrians of the Chhota Udepur – Moti Sadli area seem to have physical continuity in the Central Indian Precambrian Mobile Belt below the thick Deccan Trap cover. Because of the similarity of the regional structural trends of these two physically separate belts regional structure of the Sausar Mobile Belt is described below.

2.4. SAUSAR MOBILE BELT

ENE-WSW trending Son-Narmada lineament is a conspicuous Central Indian Tectonic feature that divides the southern and northern Indian Shield. The Son-Narmada Lineament zone is characterised by Mahakoshal Greenstone Belt having intrusion of granitoids during 2.4 o1.8 Ga (Bandopadhyay et al, 1995). The northern part of Narmada Fault delineates the southern boundary of Mesoproterozoic Vindhyan Basin. The Mesoprotozoic Satpura Mobile Belt, that lies to the south of Narmada River comprises strongly deformed and metamorphosed sediments and reworked basement rocks. Rb/Sr age of felsic metamorphics (1300 Ma) and deformed intrusive granite gives an age of 1200 Ma, which possibly indicates the age of metamorphism and deformation (Bandopadhyay et al, 1995). The tectonothermal events of Satpura Mobile Belt closed during Neoproterozoic time (1.2Ga to 0.9Ga).

The Sausar Mobile Belt (***SMB***) of Central India occupies parts of Madhya Pradesh and Maharashtra having 300 km long strike length and 70 km average width and forms a curvilinear E-W to ENE-WSW belt, bounded by two cratonic blocks, Bundelkhand protocontinent and to the north and Bhandara to the south. Two episodes of deformations are experienced by the ***BGC*** equivalent rocks of this terrain, which indicate Pre-Sausar metamorphism (PSM_1 and PSM_2). Of these two the earliest one was high temperature and moderate pressure metamorphism followed by episode of cooling. Later events have been overprinted by Sausar tectonothermal event synchronous with amphibolite facies

metamorphism. The central domain is a supracrustal suite of metapelite-quartzite-metacarbonate, which belong to Sausar Group. It represents a stable platform facies (Narayanswami et al, 1963). Volcanic rocks are episodic felsic intrusions. Two phases of granite intrusives are present in the supracrust. The early one is extremely deformed and coeval with earliest Sausar deformation. Recent structural studies indicate three phases of deformation in the Sausar Group (Pal and Bhoumik, 1988). Earliest is localised shear deformation particularly at the contact of supracrust and gneisses and therefore, the basement cover relationship is mostly tectonic. The second deformation has produced shallow plunging E-W and ENE-WSW trending upright folds and the third one is shallow depth deformation having NNE-SSW trending subvertical axial traces and conjugate shear fractures. Geochronological data of ***SMB*** is meager. Collating data on field disposition, structural framework and metamorphic evolution of different lithotectonic domains of ***SMB***, correlated the main phase of Sausar Orogeny as Grenvillian event (Bhoumik et al. 1999), while the 1525 Ma whole rock isochron age from the basement. Tirodi biotite Gneiss (Sarkar et al, 1986) reinterpreted as Pre Sausar Mesoproterozoic tectonothermal event.

2.5. CHAMPANER GROUP

Champaner Group is represented by argillaceous, arenaceous and carbonate rich metasediments, which occur as a isolated folded basin in the south western most fringe of the Precambrian terrain of Gujarat. It is distributed around Bodeli, Shivrajpur, Poyali and Rajgarh of Panchmahals and Vadodara districts of Gujarat. Although the term was coined by Blanford (1869), Fermor (1909) correlated it with Dharwars and Rama Rao thought it to be equivalent with Delhi System. But Gupta and Mukherjee (1934 thought it to be equivalent to Aravallis. It has suffered two episodes of folding .The earlier one has WNW-ESE to E-W trending upright axial plane, whereas the later one has N-S axial trace. There are several polymict and conglomeratic horizons within Champaner Group of which Jaban Conglomerate is the thickest one (Jambusaria, 1967, Srikarni and Das,1996)) Contact metamorphic effect of Godhra Granite on the carbonate rocks of Champaner Group has given rise skarn zone, whereas on pelitic rocks hornfelses are formed (Jambusaria, 1970).

2.6. PRE-CHAMPANER GNEISSES

This group described under 'study area as the major lithology of the area under study belong to Pre-Champaner Gneisses and occur in three isolated regions in this fold belt.

a) Around Poyali, stratigraphically just below the Champaner Group

b) Around Chhota Udepur

c) South of Devgarh -Baria (south of Panam Fault)

Pre Champaner Gneisses were considered as Lower Aravalli Gneisses by Gopinath et al, (1977), and subsequently Srikarni and Das (1999) described their structures. However, a new account to the deformational episodes is described during the present study.

2.7. BACKGROUND INFORMATION OF THE STUDY AREA

Precambrian Rocks in the eastern part of Gujarat State cover an area of 1400 sq. km in Panchmahals and Vadodara Districts. The region to the south of Chhota Udepur is considered by most of the workers as the southernmost extension of Aravalli Supergroup of rocks although no structural details are put forward for this region. Notable contributions with regional scale as well on 1:50000-scale mapping have been carried out in this area. A brief account of previous work is given below.

2.7.1 Heron (1934): Champaner Group and underlying metamorphics of Chhota Udepur – Baria region belongs to the Aravalli Supergroup. He also showed in his map that the granite gneiss and associated metasediments and metabasics of Chhota Udepur – to south of Baria are having older status than metasedimentaries exposed around Baria Lunavada tracks and Shivrajpur region. Therefore, the granite gneiss of Chhota Udepur region was considered to be the part of BGC.

2.7.2 Gupta and Mukherjee (1934) on the basis of their pattern of manganese mineralisation as litho-assemblages these workers considered the rocks of Shivrajpur-Jambugoda region (presently known as Champaner Group) as similar to the metasedimentaries of Udepur region of Rajasthan (presently known as Udaipur Group

2.7.3 Gopinath et al. (1977) classified the Precambrians of southeastern Gujarat into Champaner Group and Pre-Champaner Group (equivalent to Lower Aravalli Gneisses), which according to them are the southern most extension of Aravalli Supergroup.

Table – 2.3 Stratigraphic successions of Precambrians in Gujarat (Gopinath et al. 1977)

AGE	Supergroup	Group/Subgroup	Lithology
Upper Proterozoic	Post-Delhi Intrusive	Godhra Granite	Granite and granodiorites.
Middle Proterozoic	Aravalli Supergroup	Upper Champaner Group	Calcareous quartzite and calc- gneiss
			Phyllites
			Quartzite
		Lower Champaner Group	Dolomitic limestones and calc-silicate rock
			Biotite schists
			Quartzites & phyllites
		Pre-Champaner Group & Upper Aravalli Gneisses	Mica- schist
			Quartzite
		Lower Aravalli Gneisses	Biotite gneisses & schists with sillimanite quartzites
			Para-gneiss and schists
			Granite gneiss

2.7.4 Roy (1988), however, expressed a view that the Champaner Group has undergone simple deformation when compared to the complexly deformed underlying gneissic rocks and thus it could be much younger than Delhi Supergroup. In his map he has correlated the rocks of the study area with ***BGC.***

2.7.5 Gupta et al. (1992) clubbed Champaner and Pre-Champaner Group of Gopinath et al. (op cit) into Champaner Group and subdivided it into six formations without mentioning the status of 'Lower Aravalli Gneiss' of Gopinath et al. (op.cit).

2.7.6 Merh (1995) has described the study area (Chhota Udepur area) as a probable part of basement gneissic complex and separated it from much younger Godhra Granite and suggested proper geochronological studies for the area.

2.7.7 Srikarni and Das (1999) considered the Champaner Group as Younger Aravallis, which has undergone simple deformations, whereas the underlying complexly deformed gneissic suite of rocks as Older Aravallis and named the latter as ***Pre-Champaner Gneiss***.

They further classified Pre-Champaner Gneiss into ***'paragneiss'*** comprising some schistose components and micaceous quartzite, and ***'granite gneiss'***. According to them the **Pre-Champaner Gneisses** has undergone three phases of deformation of which the earliest one is reclined fold with 5 to 15° plunge in different direction, this has been superimposed by E-W, WNW-ESE trending upright folds. N-S trending warps and kink bands represent the third phase of deformation. While the Pre Champaner Gneisses have undergone three episodes of folding, the overlying Champaner Group exhibits two episodes of folding.

2.7.8. Karanth and Das (2000) have observed N-S trending early reclined folding which have not been recorded by earlier workers. They described it as F_1 , which has subsequently been folded by E-W trending F_2 reclined folds. E-W trending F_3 upright folds, coaxial with F_2, have been superimposed on the rocks of the region. One more open folding F_4, coaxial with F_1 have also been recognised by them. Thus, they have altogether recognized four episodes of folding of which the first two episodes are isoclinal in nature (F_1 and F_2), which in turn are disposed at high angles. The latter superimposed F_3 and F_4 folds are open upright in nature and their fold axes are mutually perpendicular to each other. Folds generated by the third phase of deformation (F_3), coaxial with F_2 are the most conspicuous folds of this region.. The younger Champaner Group exhibits only F_3 and F_4 foldings, whereas the older Pre Champaner Gneisses are involved in all the four folding events. Stratigraphic succession modified by them is shown in table 2.4.

Table 2.4. Stratigraphic succession of Champaner Fold Belt. (Karanth and Das, 2000)

Age	Group	Subgroup	Lithology
Cretaceous to Tertiary	***Deccan Traps***		Tholeitic basalts with alkaline and carbonatite intrusives
Cretaceous	***Bagh and Lameta Beds***		Calcareous sandstones with quartz-pebble conglomerate beds.
	U n c o n f o r m i t y		
Neo Proterozoic	***Godhra Granite***		Porphyritic and non-porphyritic per-aluminous 'S' type granite
Meso Proterozoic	***Champaner Group***	Upper	Slates, Manganiferous phyllite, quartzites, dolomitic limestones, metagreywacke and polymict conglomerate.
		Middle	Grey carbonaceous phyllite, meta-arkose, quartzite and conglomerate.
		Lower	Phyllite, quartzite, impure dolomitic limestone and conglomerate.
	U n c o n f o r m i t y		
Paleo - Proterozoic	***Pre-Champaner Gneisses***	Pelitic Gneiss	Kyanite, sillimanite and garnet bearing mica schist, quartz-mica gneiss, micaceous quartzite.
		Granite Gneiss	High potassic peraluminous granite.