GRANITE AND GRANITE GNIESS

6.1.GENERAL

Petrographic and geochemical studies of the Godhra Granite and Pre-Champaner granite gneisses of the study area were carried out in detail to know their tectonic status and relation between the former (Godhra Granite) and the latter. The petrographic details, however, are already discussed in Chapter 5. The samples of granite gneiss and intrusive (Godhra) granite were analysed by fusion bead XRF method at The Geological Survey of India, Eastern Region Lab. Calcutta. However, complete trace element data for these samples are lacking. NAA (Neutron Activation Analysis) were carried out at The Geological Survey of India, Central Region, Pune, for generating for a REE data of a few representative samples.

In general the granite gneiss comprises pink coloured K-feldspar with variable amount of biotite. Modal variation of K-feldspar, plagioclase, quartz, biotite, muscovite and magnetite in this rock is also reflected in the chemical composition of samples.

6.2. MODAL ANALYSES

Classification of the granite gneiss is also made on the basis of modal analysis carried out by point counting method under the microscope, which is tabulated below (**Tables 6.1** and **6.2**);

Table 6.1. Modal analyses of granite gneiss of Pre Champaner Gneisses

Sample No.	Location	Quartz	K-Feld.	Plagio.	Biotite	Musco	Opaques
5067	Nalej	42	35	9	9	5	Traces
4019	Singla	40	36	13	8	2	1
4033	Singla	34	32	23	9	-	1
6034	Singla	39	40	14	6	-	1
4118	Manka	38	40	10	8	3	1
4121	Manka	35	42	16	6	1	traces
4036	Gabdya	40	32	18	9	traces	1
5002	Gondarya	36	39	14	8	2	1

Table 6. 2. Modal analyses of Godhra Granite (Das,1998)

Sample No.	Type	Location	Quartz	K-Feld.	Plagio	Biotite	Musco
4735	Foliated	Jhab	30	32	28	7	0
4736	Foliated	Jhab	32	30	22	10	3
4783	Foliated	Bamroli	32	24	35	8	-
4791	Foliated	Bhual	38	34	22	5	-
910	Foliated	Sagarma	35	20	38	7	-
43	Foliated	Borya	24	32	38	6	-
315	Non-foliated	Kanpur	38	20	20	9	3
826	Non-foliated	Sureli	32	24	36	8	2
816	Non-foliated	SE of Deohat	32	36	23	9	1
820	Non-foliated	SE of Deohat	31	35	25	8	-
822	Non-foliated	SE of Deohat	34	38	22	6	-

Based on modal analysis the rocks are classified as true granite in minerological composition and falls in field VIII in QAP diagram based on IUGS classification **(Fig-6.1.)**

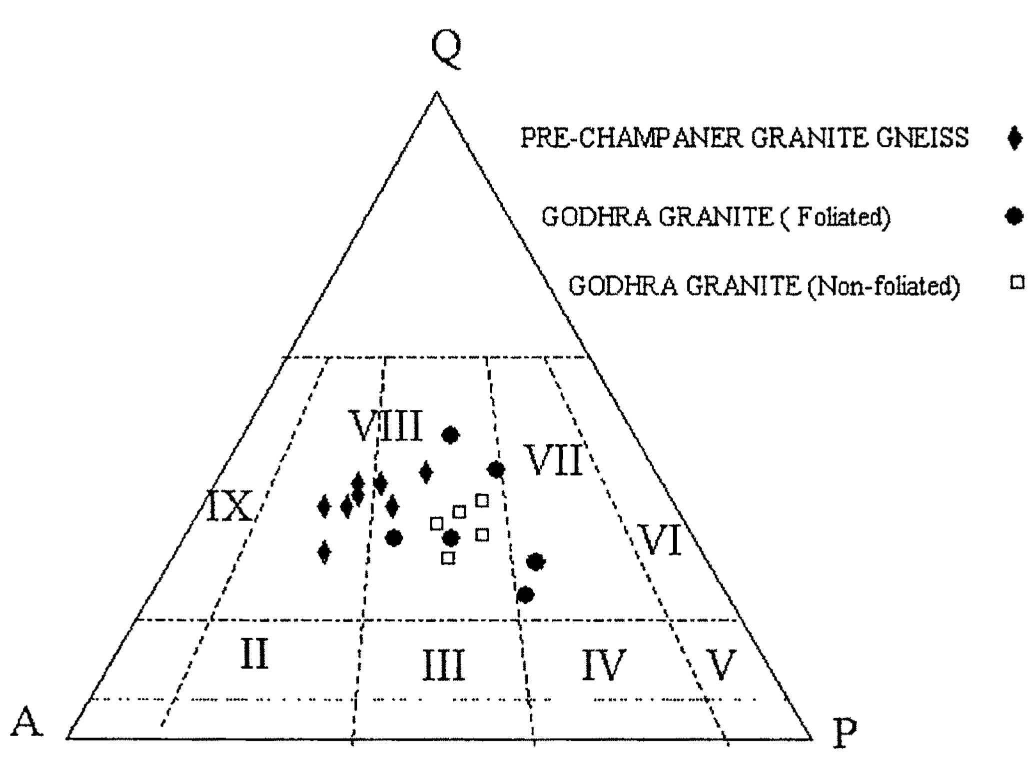

Figure 6.1. IUGS classification (QAP diagram) of granite and granite gneiss of Chhota Udepur area; Q-modal quartz; A-modal alkali feldspar and P-modal plagioclase.

6.3. MAJOR AND TRACE ELEMENT GEOCHEMISTRY

Geochemically the granite gneiss shows a wide range of silica content. But as such these samples contain high amount of silica; variable between 71% and 76.15%. The content of TiO_2 is more or less consistent, 0.2 -0.3% except for one sample which contains 0.65%. The total iron oxide varies between 1.12 and 2.36%. The rock is fairly potassic and the K_2O/Na_2O ratio varies between 1.2 and 1.7. The Al_2O_3 content is somewhat variable, 12.1-14.6%, The molar Al/CNK (Molar Alumina/Molar Na_2O+ K_2O+CaO) ratios varies between 1.00 and 1.39, whereas molar Al/NK (Molar Alumina/Molar Na_2O+ K_2O) ratio varies between 1.02 and 1.45. Major element chemistry is shown in **table 6.3.** Rb/Sr ratio also varies considerably. But in general the value is very high. Depletion in Higher REE and enrichment of LREE is exhibited by this rock (**Table 6.4**). REE data for five samples of the granite gneiss analysed. The La/Yb and Ce/Yb ratios vary from 220 to 25 and from 367 to 47 respectively. The content of *Cr* and *Co* were the outcome of XRF analyses of Geochronology Laboratory, The Geological Survey of India, Calcutta and the rest were generated by NAA (Neutron Activation Analysis) Laboratory, The Geological Survey of India, Pune. The Rb/Sr ratios of the granite gneiss are fairly high (30.9 - 2.15) whereas in the in the intrusive granite (Godhra granite) analysed the Rb/Sr **values** are much lower (Table **6.5**).

Table-6.4: Trace element distribution in granite gneiss (Pre-Champaner Gneisses) in *ppm*.

Sample no.	4019	4118	5002	5020/GJ31	34/96
Cr	9.6	4.4	n.d.	n.d.	8.5
Co	2.8	0.41	n.d.	n.d.	2.5
La	145	77	n.d.	n.d.	148
Ce	220	145	n.d.	n.d.	209
Nd	84	72	n.d.	n.d.	75
Sm	16	16	n.d.	n.d.	15
Eu	104	0.4	n.d.	n.d.	1.4
Tb	0.75	0.79	n.d.	n.d.	0.5
Yb	1.1	3.1	n.d.	n.d.	0.57
Lu	0.13	0.43	n.d.	n.d.	0.12
Th	76	23	n.d.	n.d.	0.12
Sc	3.6	1	n.d.	n.d.	3
Hf	12	7.2	n.d.	n.d.	10
Ta	0.6	1.3	n.d.	n.d.	0.7
Rb	218	175	154	125	40
Sr	102	22	5	6	16
Rb/Sr	2.15	7.98	30.9	20.78	2.50
La/ Yb	137	25	nd	nd	220
Ce/Yb	200	47	nd	nd	367

Table 6.5: Trace elements in non- foliated Godhra Granite around Baria and Jhoj, in *ppm*, (Das,1998)

Sample no	2678	4226	4370	4371
Cr	67	9.6	8.5	13
Co	60	2.8	2.5	3.5
La	105	145	148	89
Ce	171	220	209	136
Nd	75	84	75	65
Sm	13	16	15	16
Eu	2.9	1.4	0.4	1.6
Tb	0.9	0.75	0.5	1.4
Yb	3	1.1	0.57	2.54
Lu	0.53	0.13	0.12	0.88
Th	14	76	85	22
Hf	16	12	10	12
Ta	0.7	0.6	0.7	1.9
Rb	455	101	120	150
Sr	132	11	279	25
Rb/Sr	3.4	9.09	0.4	6
La/ Yb	35	132	254	35
Ce/Yb	57	200	366	53

6.4. DISCRIMINATION DIAGRAMS

Various discrimination diagrams are used to classify the granite gneiss to chemical categorization and to ascertain its probable mode of origin. Diagrams are Shand's Diagram (Moniar and Piccoli, 1989)and Moniar and Piccoli's tectonic discrimination diagram(1989) , Batcher and Bowdens tectonic discrimination diagrams.

In the present work the discrimination diagrams of Shand (Moniar Piccoli,1989),and Batchler and Bowden (1985, in Moniar and Piccoli,1989) are used to verify its tectonic status and probable mode of origin.

The analyses of the granitic rocks are plotted in the different figures as mentioned below:

1. Molar A/CNK vs. Molar A/NK (**Figure 6.2)**
2. Al_2O_3 vs. SiO_2 (**Fig 6.3.a),** Moniar and Piccoli ,1989
3. K_2O vs. SiO2. (**Fig 6.3.b)** Moniar and Piccoli, 1989
4. Fe_2O_3vs. MgO. Weight percentages were taken from ACF ternary plots. (**Figure 6.3.c)** Moniar and Piccoli ,1989
5. SiO_2 vs. TiO_2 plot. (**Figure 6.3.d)** Moniar and Piccoli, 1989
6. Bathelor & Bouden's tectonic discrimination diagram **(Fig.6.4)**, 1985

Table 6.3

CHEMICAL ANALYSES OF GRANITE GNEISS OF PRE CHAMPANER GNEISSIC COMPLEX

Sample no	**34/96**	**4019**	**4118**	**6034**	**5067**	**5002**	**5020**	**4021**
Oxides wt%								
SiO2	75.58	74.68	76.15	71	75.57	74.11	75.51	74.68
TiO2	0.23	0.2	0.2	0.2	0.23	0.2	0.3	0.2
Al2O3	12.1	13.86	13.11	14.6	12.74	12.26	12.4	13.66
Fe2O3	1.58	0.46	1.04	1.44	0.63	2.18	1.58	0.46
FeO	0.36	1.26	1.08	0.39	0.9	0.18	0.18	1.26
MnO	0.01	0.2	0.05	0.04	0.01	0.03	0.01	0.04
CaO	0.25	1.15	0.21	1.2	0.14	0.29	0.1	0.05
MgO	0.06	0.57	0.65	1.56	0.1	0.08	0.1	1.15
Na2O	3.26	3.34	2.29	3.55	1.91	3.05	1.93	3.34
K2O	5.78	4.1	4.85	5.35	5.64	5.67	5.71	4
H2O	0.25	0.52	0.29	0.5	0.48	0.7	0.35	0.45
P2O5	0.15	0.45	0.05	0.03	0.35	0.15	0.35	0.05
TOTAL	**99.61**	**100.06**	**100.22**	**100.03**	**98.7**	**98.9**	**98.53**	**100.06**
A/CNK	1	1.16	1.39	1.07	1.32	1.03	1.27	1.16
A/NK	1.02	1.4	1.45	1.26	1.35	1.08	1.3	1.4
				CIPW NORM				
QUARTZ	34.46	36.44	42.67	25.22	43.84	34.98	43.99	37.12
CORUNDUM	0.39	2.88	3.83	0.87	4.15	0.96	3.78	1.89
Or	34.37	24.25	38.82	31.82	33.94	34.13	34.49	23.91
Ab	27.75	28.15	19.44	30.23	16.45	26.28	16.69	28.58
An	0.26	2.79	0.73	5.79	0	0.47		5.44
Hy	0.23	3.41	2.53	3.91	1.04	0.2	0.25	1.82
Ol								
Di								
Wo								
Mt	0.53	0.66	1.51	0.81	0.39	0.1		0.67
Hm	1.22			0.89		2.15	1.3	
IL	0.44	0.38	0.38	0.38	0.44	0.39	0.41	0.38
Ap	0.36	1.07	0.12	0.07	0.84	0.36	0.85	0.12
Rut							0.09	
Cc								
Total	**100.01**	**100.08**	**100.03**	**100**	**101.64**	**100.01**	**101.85**	**100**

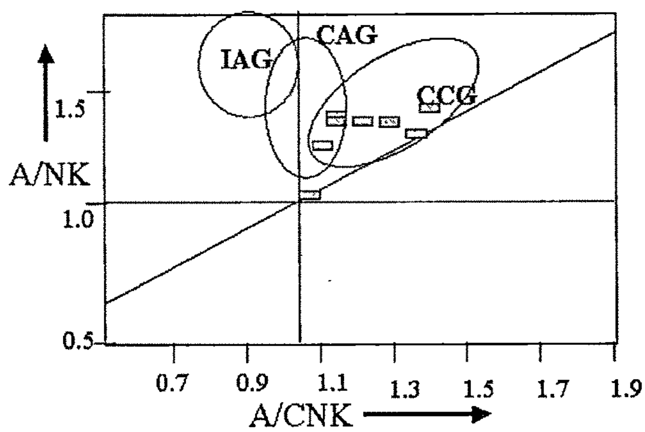

Fig.6.2. Shand's diagram for Pre-Champaner Granite Gneiss: Molar $Al_2O_3/(CaO+Na_2O+K_2O)$ vs. $Al_2O3/(Na_2O+K_2O)$
A/CNK= $Al_2O_3/(CaO+Na_2O+K_2O)$ and A/NK= $Al_2O3/(Na_2O+K_2O)$

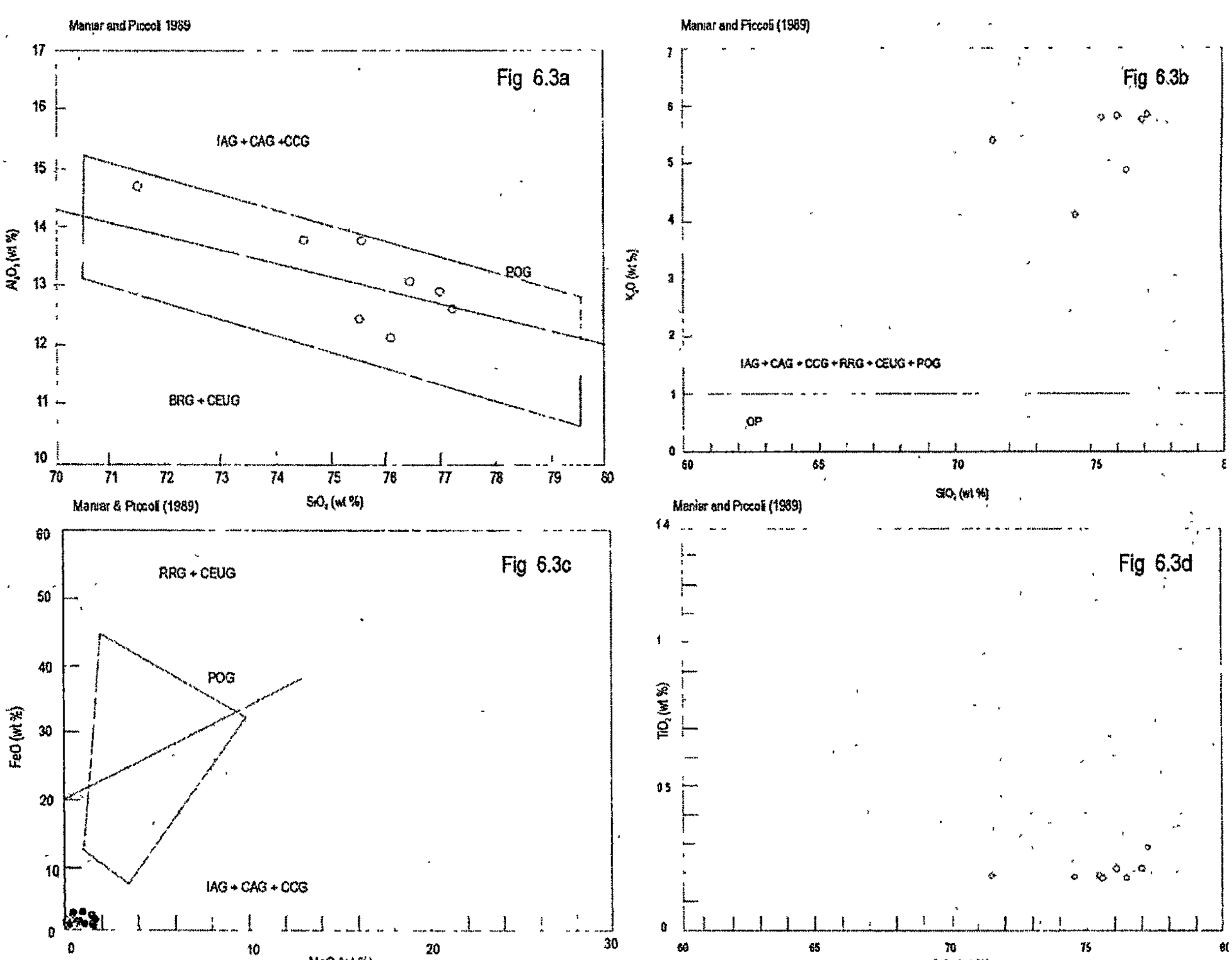

Fig 6.3a to 6.3d: Different variations diagrams of Moniar and Piccoli, 1989 for granitoids. CCG=Continental collision Granitoids,CAG=Continental Arc Granitoids, IAG= Island Arc Granitoids, OP=Oceanic Plagiogranite, POG=Post Orogenic Granitoids, CEUG=Continental Epirogenic Uplift Granitoids, RRG=Rift related Granitoids.

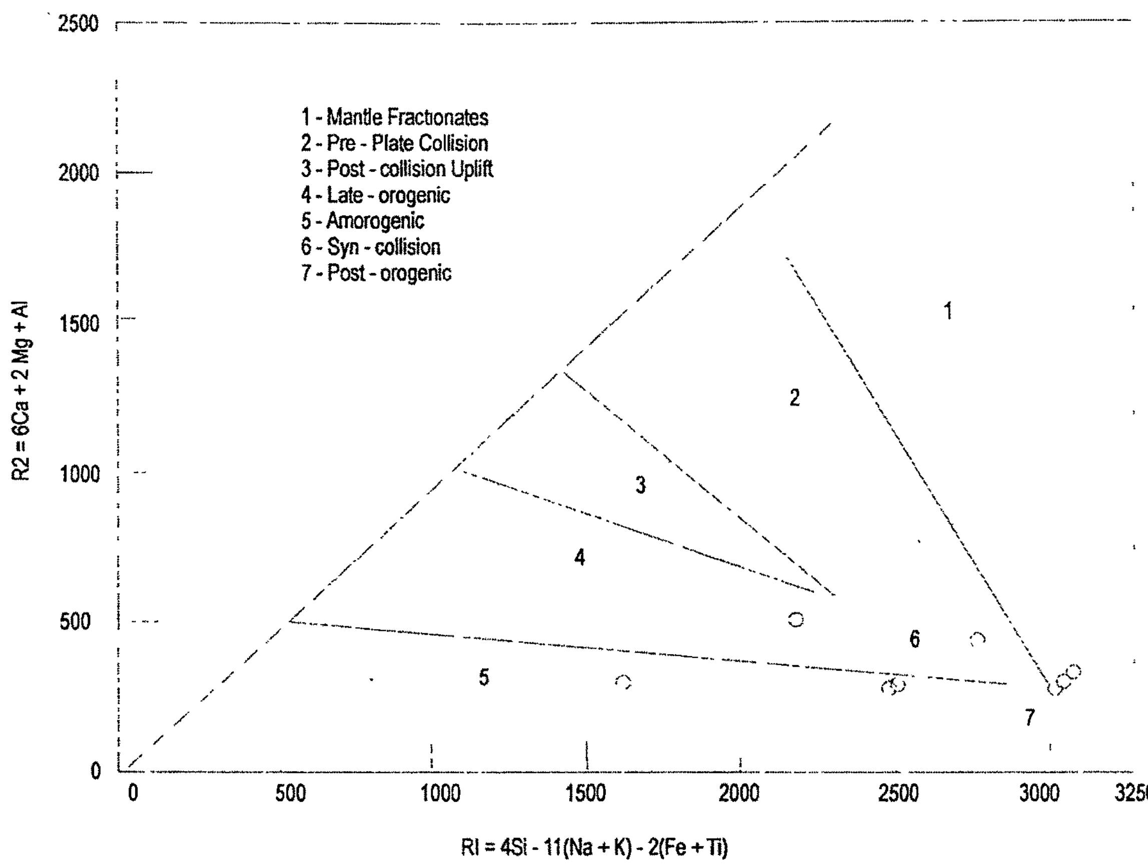

Fig 6.4. Bathelor & Bouden's tectonic discrimination diagram

6.5 . PROBABLE MODE OF ORIGIN

Shand's diagram (**Fig.6.2**) indicates that the Pre-Champaner granite gneiss falls in per-aluminous field and has A/CNK ratios more than 1.0. Thus it may be considered as ***S-type*** (Chappel and White,1974) and therefore, might have been derived from partial melting of the continental crust (Nabalek et al ,1992). The large variation in (FeO +Fe_2O_3) and MgO values also indicates anatectic source of intermediate composition. However, low TiO_2 content indicate lack of extensive melting. The uneven distribution of Sr with respect to Rb and Ca also supports the view of crustal remelting. High $^{87}Sr/^{86}Sr$ is also a supportive data for classifying the granite gneiss into *S-type*. High La/ Yb and Ce/ Yb ratios also indicate the origin from partial melting of sialic crust. Further the higher values of Rb, scatter of Rb/Sr 2.15 to 30.9 and presence of profuse biotite in the mode indicate a biotite bearing crustal source. The enrichment of LREE compared to HREE also supports similar origin and at the same time very high content of K in this granite gneiss indicate non-eutectic melting from a biotite bearing rock (Harris and Inger, 1992).

Various discrimination diagrams suggest that as per as the tectonic status is concerned the granite gneiss is 'Continental Collision Granitoid'.

6.6 GEOCHRONOLOGY

Different workers have put divergent views regarding the age of Champaner Group and associated Precambrian rocks forward. These rocks were considered as the southern most extension of Aravalli Fold Belt (Heron,1934; Gupta Mukherjee1938). Rama Rao(1931) and Hobson(1927) considered them to be Dharwars. Gopinath et al. (1977) considered Champaner Group to be the youngest Aravallis. and the Gneissic complex of Chhota-Udepur area as the basement for Champaner Group. Gupta et al. (1992) considered Champaner also as the youngest Aravallis. But they have correlated the Gneisses of Chhota Udepur area as Godhra Granite. Roy (1988,1999) has however, considered Champaner as younger than Aravallis and Delhis and in his regional geological maps has shown the area covered by Pre-Champaner Gneisses as Banded Gneissic Complex (Mewar Gneiss).

Various workers have dated some of the rocks of this region. Rb-Sr dating of schistose clasts from Jaban Conglomerate (Upper Champaner Subgroup) shows an Rb-Sr age of 950 Ma (Crawford,1973). Rb-Sr age of Godhra Granite reveals an isochrone age of 955±20 Ma (Gopalan et al,1979). According to Shivkumar et al (1993) core of the Champaner Group is intruded by Jambugoda Granite, which indicates Sm-Nd age of 1050±50 Ma. Based on 18 isochron data Gopalan et al. (op.cit) deduced an age of 955±20 Ma age for Godhra granite. However, they have not tried to differentiate between Godhra granite and the Pre-Champaner gneisses. They collected samples from the intrusive granite (Godhra Granite) as well as Pre-Champaner Gneiss as though they belonged to a single group. At the same time they advocated the existence of an older granite gneiss in this region which is the parent of Godhra Granite. Their sample locations are all to the north of Chhota Udepur which extends from Godhra to north of Alirajpur.

In all Rb-Sr dating of 5 samples of granite gneiss of Pre-Champaner Gneisses and 5 samples of intrusive Godhra Granite have been carried out. (Srimal and Das,1998), the result of which is discussed in a later section.

6.6.1 Operating condition for the XRF and Chemical separation:

Sequential X Ray spectrometer PW 1400 coupled with a P-851 computer and a 100- KV generator using 3KW side window tube, LIf 220 crystal scintillation detector were used.

For isotopic analyses, rubidium and strontium were separated from rock samples by standard ion exchange chromatography. About 200 mg of rock samples of –200 mesh were taken for analyses. The rock is digested in HF and $HCLO_4$ for 16 hours and them they were heated to achieve dryness. Then the samples were treated with 6N Hl after that they were centrifuged. Five point Rb-Sr isochron age of Godhra Granite shows 935 ±20 Ma. The samples were collected from Kevdi near Gundi, Sukhi Dam area, Phangia, Marchiipani and Jamli . All these samples are having variable modal composition of K-feldspar, biotite and muscovite, therefore showed different Rb/Sr ratios (tables 6.6 and 6.7). Similarly five granite gneiss samples with distinct modal variation, were collected from Pre- Champaner Gneisses.

Table 6.6: Rb/Sr data for Pre-Champaner Granite Gneiss

Sample no	***Rb/Sr ratio***	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
GJ-21/96	30.90	105.1814	2.513179±0.000054
GJ-26/96	4.47	13.2322	0.945353±0.000028
GJ-29/96	3.27	9.6478	0.910605±0.000058
GJ-30/96	20.78	13.1959	0.963496±.0.000044
GJ-31/96	30.90	66.9096	1.862906±0.000170

Table 6.7: Rb/Sr data for Godhra Granite

Sample no	***Rb/Sr ratio***	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
GJ-11/96	0.2901	0.8405	0.722699±0.000042
GJ-12/96	0.2275	0.6590	0.720108±0.000040
GJ-13/96	1.6655	4.8511	0.777346±0.000030
GJ-18/96	1.4644	4.2616	0.768288±0.000022
GJ-34/96	2.5001	7.3272	0.800176±0.000026

Locations of these samples (east and south-west of Chhota Udepur) are shown in **Fig 3.2**

6.6.3. Caculation

The initial $^{87}Sr/^{86}Sr$ has been calculated from the graphs (**Fig.6.5a** and **Fig.6.5b**) and the following equation has been adopted to calculate the age:

$^{87}Sr/^{86}Sr = {}^{87}Sr/^{86}Sr(\text{initial}) + (^{87}Rb/^{86}Sr)(e^{\lambda t}-1)$
$t = 1/\lambda \ln(1+D/P) = 1+(\text{initial Sr ratio- present Sr ratio})/\text{Rb/Sr}$ $\lambda = 1.42 * 10^{-11}$

Initial Sr ratio for Godhra Granite is calculated as 0.711689 and
Initial Sr ratio for Pre Champaner Granite Gneiss is calculated as 0.736722

The Age of Godhra Granite is calculated as 938.8±20 Ma.

The Age of strongest metamorphism of Pre Champaner Granite Gneiss is calculated as 1168±30 Ma.

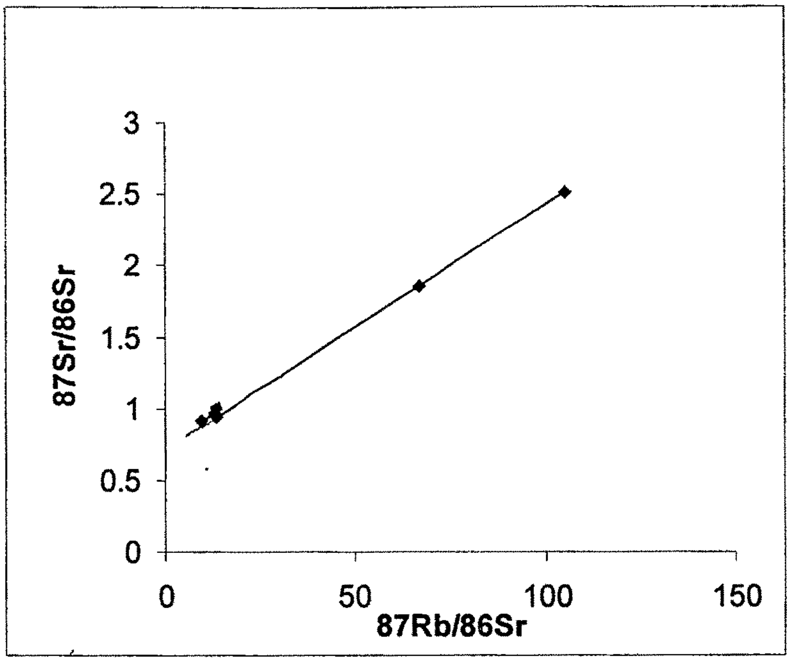

Fig 6.5a Rb-Sr isochron plot for Pre Champaner granite Gneiss(five point isochron)

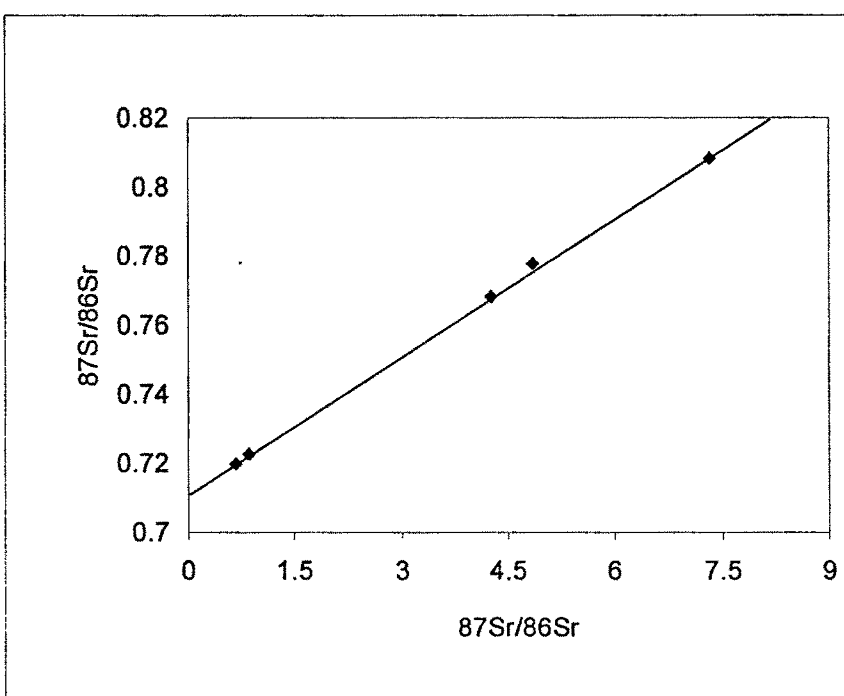

Fig. 6.5b. Rb-Sr isochron plot for nonfoliated Godhra Granite(five point isochron)

Rb/Sr dating of this granite gneiss gives an 5 point isochron age of 1168+/- 30 Ma with initial $^{87}Sr/^{86}Sr$ of 0.740 which definitely indicate a metamorphic age (as $^{87}Sr/^{86}Sr$ is very high), but not the absolute age of Pre-Champaner Gneisses. Thus the age of evolution/ crystallisation (in case it is orthogneiss) must be older than 1168 Ma. Therefore, the conclusion made by Gupta et al. (1992) that these gneisses are also part of Godhra Granite of younger age does not hold good.

6.6.4. Inference based on Geochronological data

High initial strontium ratio indicates that the source was isolated from the mantle for a long time before it melted to form the present rock. Otherwise one would not get such high initial Sr ratios (the more ^{87}Rb will take time to decay to ^{87}Sr, the higher $^{87}Sr/^{86}Sr$ ratio the rock will have. If such an old rock is melted with high $^{87}Sr/^{86}Sr$ ratio, a new rock with the same $^{87}Sr/^{86}Sr$ ratio can be expected (personal communication, Srimal,1997). High $^{87}Sr/^{86}Sr$ ratio indicates that 1168±30 Ma age for Pre-Champaner Gneisses is the age of strongest metamorphism and do not give actual age of crystallisation, which may be much older.

Although Palaeoproterozoic age is assumed for Pre-Champaner Gneisses exact whole rock isochron will only prove its correct status. However, strongest tectonothermal event was during 1168±30 Ma.

6.7. Geophysical Data

Bouguer gravity data of National Geophysical Research Institute have been interpolated for producing an interesting (modified published map of NGRI,1977) regional gravity map which covers the study area. This map shows a contrasting difference of gravity values of the area. The Bouguer gravity map (**Fig4.5**) reveals the following features;

1) Gravity highs (~ –30mgl) located around 23°10'E : 74°05'E and 22°15'N : 74°10'E. A linear gravity high zone extends between these two areas; which in turn is intersected by a gravity low belt (~ –42mgl) in WNW-ESE direction along 22°30'N latitude.
2) Around 22°30'N to73°35'E a polygonal zone of gravity high (~ –33mgl) that extends in southwest direction is conspicuous. This gravity high zone is separated from the gravity high zone mentioned above by another gravity low belt that extends in NE-SW direction.
3) Gravity lows are mainly located in the northwestern part (~ –50mgl).

From the regional lineament and geological maps (**Figs 3.1.a** and **b**) the above anomalies can be interpreted as given below;

1) The gravity highs mentioned above (~ –30mgl) are due to the presence of basement rocks. The sharp WNW-ENE trending zone that intersects the gravity high linear zone is due to the presence of Panam Fault, which separates Lunavada group from Godhra Granite.
2) The gravity high around 22°30'N: 73°45'E is on account of the crescent shaped exposure of younger Champaner metasediments, which extends in southwest direction. The gravity low belt (~ –42mgl) trending in NE-SW direction separates the Champaner Group in the west from Pre-Champaner Gneisses in the east. Possibly there is a concealed fault in this zone. Although, the WNW-ESE trending gravity low belt mentioned above is adequately manifested in the form of Panam Fault, the surface expression of the latter is lacking.
3) The gravity low in the northwestern part is on account of the thick blanket Quaternary alluvium.

By and large two views exist regarding the above-described granite and granite gneisses, which have been described in chapter 2. One view is that the intrusive Godhra Granite as well as the Pre-Champaner Granite Gneisses are same (Gupta et al,1992) and second view is that both these rock types are different (Heron,1934 and Merh,1995). From the above geochronological data supported by geophysical data as worked out by the author is indicated that the Godhra Granite is distinctly different from (Pre-Champaner) granite gneisses. However, determination of absolute age of Pre-Champaner Granite Gneiss is needed to strengthen the above view.