CHAPTER VIII

SUMMARY AND CONCLUSIONS

General

The study area covering about 5250 sq.km is a part of Saurashtra peninsula and lies between 22°30' to 22°50'N and 70°50' to 71°25'W in part of one inch to a mile toposheet $\frac{N}{2\ \&\ 6}$, $\frac{J}{13}$, $\frac{J}{14}$. Within the area all roads and railways lead to fireclay based industrial town Than. The temperature variations and the average rainfall in this area are 56 to 43.2°C and 500 mm respectively. The climate is semi-arid type. The natural vegetations are thorny and have stunted growth. The area is plain ground with a few isolated hillocks. The rivers are mostly seasonal and influent type.

Major production of fireclay in Gujarat is from the study area having 51 out of 66 opencast mines. Gujarat is the second largest producer of fireclay in India. The estimated reserve in Gujarat is 0.98 mt.

Geology

The general geological sequence based on field observations is given in Table.

	Lithostratigraphic Unit	Gross lithology	Geochronological Unit	Facies
Dhrangadhra Formation	Ranipat	Ferruginous sandstone with iron concretions, Quartzite, Grit, conglomeratic bands with Graded bedding	Middle Cretaceous - Lower Cretaceous	DELTAIC
	Suraj Deval	Red friable shale and feldspatic sandstone with common Graded bedding and current bedding	to	
	Than	Grey and carbonaceous shale with thin coal stringers and plant fossils, fine grained sandstone with occassionally pyritic nodules	Upper Jurassic	

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The Dhrangadhra Formation consists of ferruginous (red) sandstone, felspathic sandstone, fine grained argillaceous sandstone, quartzite, lenses of fireclay and shale with thin stringers of coal. Fireclay as bedded, sedimentary rock is common in this formation. The general dip varies from nearly horizontal to 5° except near the contact of dykes and Deccan trap. Current bedding, graded bedding, parallel lamination, lenticular lamination, distorted lamination, riffle drift lamination and iron concretions are the common sedimentary structures observed. Minor faulting, intrusion of basaltic dykes, slickensided surfaces and joints are also observed in fireclay as well as in sandstone beds.

The base of Dhrangadhra Formation is not exposed anywhere. This formation represents epoch of time from Upper most Jurassic (Tithonian) to Lower Cretaceous (Neocomian) and probably upto Middle Cretaceous (Albian). It is overlained by Wadhwan Formation.

Occurrence

In Surendranagar district fireclay occurs as underclay whereas in Rajkot district overlying coal strata is missing.

The generalized cross section showing lithological variation in areas of Saurashtra where fireclay occurs as underclay, is as follows:

Soil (Top)
Sandstone
Fireclay (Seggar clay)
Coal
Fireclay (Body clay)
Siliceous finegrained sandstone (Bottom)

Siliceous finegrained sandstone shows dedritic material of quartz, pyrite and carbonaceous matter cemented together. Fireclay is plastic comparatively less siliceous with remains of plant fossil near the top of bed. Coal stringers upto 25 cm thick are of low grade Bituminous variety. Seggar clay - semiflint to flint variety of fireclay is at some places more than 10m thick.

The generalized cross section showing lithological variation in areas of Saurashtra where fireclay does not occur as underclay is as follows:

Soil (Top)
Sandstone
Siliceous white clay
Fireclay
Sandstone (Bottom)

Sandstone is devoid of organic matter and pyrite. It is white, yellowish and medium to fine grained. Color of fireclay is generally grey, but at some places it turns red due to leaching of ferruginous material from overlying strata into fireclay. White clay overlying fireclay is more silicious and economically not workable.

Fireclay mining in Saurashtra is carried out by opencast mining methods and in most unsystematic and unscientific manner. To improve quality of fireclay it is recommended that air flotation process may be used to remove silica and pyritic grains. Washing with water will change pH and other important properties of clay.

On the basis of field observations and visual properties fireclays of Saurashtra are classified into plastic clay, semi-flint clay, flint clay and Nodular clay.

In Saurashtra there are fifteen localities viz. Thangadh, Songadh, Khanpar, Tarnetar, Sadala, Palasa, Gadhada, Vinaygadh, Ratidevali, Lunsar, Saltanpur, Matel, Paneli, Jambudia, Makansar, where at present working mines are located.

c. Fireclays with high refractoriness, more than 10% water absorption at 1350°C, moderate to high plasticity (25% and above) are suitable for porcelain and electrical procelain.

d. Fireclays with white color in raw state, in spite of their low values of plasticity and refractoriness are useful in the paper, textile, paint and rubber industries either as filler or coating clays, provided the particle size is fine.

2. Buff burning fireclays include Seggar clays, stoneware and Sewer pipe clays.

a. Fireclays with moderate to high refractoriness more than 5% water absorption at 1350°C, moderate to high plasticity (water of plasticity more than 20%)are suitable for fireclay refractory.

b. Fireclays with moderate shrinkage (upto 5% at 1350°C), low to moderate plasticity (upto 20%), low refractoriness and 5% water absorption, are suitable for stoneware and Sewer pipe.

3. Fireclays firing red, brown or other dark colors are mainly used for red pottery, roofing tile and constructional ceramics.

Refractory and near to refractory fireclays are suitable to manufacture high heat duty and moderate heat duty refractories with addition of bauxite and removal of silica. Low refractory and semi-refractory fireclays are suitable to manufacture low heat duty and medium heat duty refractories.

Fireclays of Saurashtra shows 17 to 52 percent clay ($<$0.002 mm. particle size) and most of the clays fall in textural class - silty loam to silty clay loam. Particle size influences properties such as plasticity, dry strength and base exchange capacity. Finer the particles superior will be the product.

The percentages of major constituents of fireclays studied are as follows:

Loss on ignition	10.84 to 14.31
SiO_2	49.84 to 53.84
Al_2O_3	26.01 to 33.45
Na_2O	0.22 to 0.96
K_2O	0.10 to 0.33

Mineral make-up calculated from chemical analysis shows percentages of the following important constituent.

Kaolinite	61.47 to 78.54
Free silica	11.09 to 22.10
Mica	3.51 to 10.18
Coaly matter	Nil to 3.08

Ionic formulas for fireclay mineral (Kaolinite) is calculated from chemical analysis of fireclays studied.

Differential Thermal Analysis shows presence of disordered kaolinite (disordered through crystallographic b-axis), and minor constituents such as pyrite and coaly matter. Presence of pyrite is harmful when fireclay is used for refractory manufacture. It will result into a black core in the centre of firebrick. Black coring is a problem in the firing of refractory fireclays, hence pyrite may be removed by washing the fireclays before use. Kaolinite from fireclays of Saurashtra is strongly to extremely disordered.

Study of combined differential thermal analysis and thermogravimetry of fireclays show 9.85 to 14.3 % loss in weight on heating clays upto 1200°C. Maximum weight loss is recorded between 400 to 600°C due to loss of hydroxyl lattice water. Small amount (2 to 3%) of water is lost gradually between 600 to 750°C due to dehydration. Change in phase on heating fireclay is indicated by differential thermal analysis.

Presence of disordered (poorly crystalline) kaolinite as a major mineral in fireclays is further supported by study under Transmission Electron Microscope and X-ray Diffraction.

Mineralogy of fireclays of Saurashtra identified by X-ray Diffraction, Scanning Electron Microscopy, Transmission Electron Microscopy and Differential Thermal Analysis are as follows:

1. Strongly to Extremely disordered Kaolinite.
2. Poorly crystalline degraded illite with some expandable mineral interlayer in it.
3. Poorly crystalline chlorite.
4. Free Silica.
5. Very few small grains of pyrite.
6. Coaly matter Bituminous variety of coal.
7. Occassional presence of bauxitic mineral such as Gibbsite.

Depositional Environment of Dhrangadhra Formation and Origin of Fireclays.

In present studies grain size analysis was used as one of the tools to know the depositional envrionment. A scatter diagram prepared from calculated statistical parameters show that sediments od Dhrangadhra Formation were deposited in a fluvial environment. 'CM' pattern clearly reveal that deposition of sediments in general was controlled mainly by tractive currents. Log-probability grain-size distribution plots were compared with those of Visher (1969) obtained for sandstones from the Pennsylvanian Blue jacket-Bartlesville delta of the Oklahoma shelf.

In general Dhrangadhra Formation was probably deposited influvial to deltaic environment under the agency of tractive currents.

1. The profile of Saurashtra fireclays reflect change in depositional environment and are not produced by 'in situ' weathering, significant change in texture from base to top of the bed, representing allochthonous soil.
2. Fireclay which occurs as underclay shows reducing (oxygen-deficient) environment.

3. At Paneli, Saltanpur andJambudia fireclay shows sensitivity to different oxidation potentials.

4. The fireclays were probably deposited in humid climate and their enrichment due to leaching by organic acids produced by decay of organic matter took place in dry climate as a result of upward movement of groundwater.

5. Occurrence of fireclay without overlying coal is observed at most of the places. This may be due to small increase in the depth of water in the swamp forest which may be quite intolerable to the established flora. The absence of coal is due to the development of swamp forest being cut short before the peat forming stage could be reached.

6. Low temperature and pressure and acid conditions apparently favour the formation of the kaolinite type of mineral.

7. Kaolinite mineral is more abundant in lower parts of fireclay beds whereas quartz, illite and chlorite minerals are more abundant in upper parts of fireclay beds. This suggest intensive leaching due to upward movement of groundwater.

8. The mineralogical variations in fireclay may be due to change in climatic conditions.

9. The presence of kaolinite and illite suggest the differences in the environments of formation. Chlorite having more stability in dryer condition, suggest that the climate was rather dry. The metallic ions were retained in the clay forming system.

10. Underclay represents the indispensable transitional stage between an oxidizing non-swampy environmental and reducing swampy environment.

11. Amount of quartz increases from bottom to top of the bed indicating, rapid activity of transporting agent