chapter ii

PREVIOUS WORK

In the course of the last 150 years, the Saurashtra peninsula has attracted many geologists, who have investigated one or the other facet of its geology. Broadly, the following aspects of Saurashtra geology have received attention:

(i) The Deccan Trap and its interesting differentiates,

(ii) The Quaternary carbonate sand (miliolite), both coastal as well as inland,

(iii) Juro-Cretaceous and Tertiary rocks, and

(iv) Tectonic framework.

The geological occurrence and possible geological age of the laterites/bauxites has been given by many authors, though not many have postulated about the genetic aspects. Since the present study is restricted to the bauxite occurrences in Jamnagar district, a brief account of the various previous work pertaining to these deposits in Saurashtra as a whole has been made.

Fedden (1884), gave an exhaustive account of the geology of Saurashtra as a whole. His monumental work, even today provides an excellent source of information on almost all aspects of Saurashtra geology. He clearly recognised and described the major stratigraphic units of Saurashtra and gave the succession as below:-

Formation		Approximate geological position
Alluvium (Sand dunes, tidal flats, fresh water alluvium, Rann clays, raised beaches and miliolite)?		Recent and sub-Recent
Dwarka beds	?	Higher Tertiary or Post-Pliocene
Gaj beds	?	Upper Miocene (Lower Manchar in parts, and Gaj of Sind.)
Lateritic rocks	?	Lower Eocene (Sub-nummulitic (Wynne) of Kutch, and
	?	High level laterite of Deccan.7
Traps		Cretaceous-Eocene (Deccan Trap)
Trappean grits	?	Cretaceous (Infra-Trappean grits (Wynne) of Kutch./
Wadhwan sandstone	?	Cretaceous (Infra-Trappean of India).
Umia beds		Jurassic (Upper Gondwana)

According to Fedden (1884, PP. 34,35), the lateritic rocks were, "to all appearances identical with the high level laterites and its associates of peninsular India". Regarding the origin of these rocks, he remarked, "The material of the rocks of this formation have undergone so much change, by decomposition and 'lateritisation' that its original aspect, or primary condition, has ever been a subject of conjecture and speculation, but there appears good evidence, in the character of some of the Kathiawar rocks, that the original material was mostly volcanic ejactamenta, and that the group represents an eruption subsequent to, and differing in many respects from the Trap out-flows". He also said that 'Gaj beds' included all the Tertiary rocks of the SE part of Saurashtra, Upper Miocene in age and equivalent to Manchar (in parts) and Gaj beds of Sind. Fedden did not distinguish Tertiary rocks from Quaternary, and included his agatiferous conglomerate with the Gaj beds through the reported fossil wood from the agate bearing conglomerate.

Gupta and Mukherjee (1938), in their classic report on "Geology of Gujarat and Rajputana", recorded the occurrences of bauxite for the first time near Kapadvanj in Kheda district. They considered these laterite/bauxite as homotaxial with Ahmednagar sandstone series viz. Infratrappean. The laterites in Saurashtra and Kutch in their opinion, were of late Eocene age and represented alterations of pyroclastic rocks of the Deccan volcanic episode and their transported and reworked facies. According to him, the stratigraphic sequence of the area in descending order of antiquity is as follows :

Sand dunes, tidal Rann clays and alluvium	Recent and sub-Recent
Gaj beds	Upper Miocene
Laterite	Upper Eocene (?)
Deccan lava flows	Lower Eocene

Roy (1953), also studied the bauxite deposits of Jamnagar district. He examined these deposits and summarized his observations by stating that high grade bauxite and bauxitic clays appeared to be of limited occurrence.

Sahastrabudhe (1958-59), carried out a preliminary investigation of bauxite deposits in Kalyanpur Mahal, Jamnagar district. He regarded the bauxite deposits of Saurashtra and Kutch as "high alumina, low titania type" invariably having a brecciated or tuffaceous appearance. He further stated that bauxite deposits occurred in the zones of laterite which separated the Deccan lava flows and the overlying Tertiary sediments. The consistent occurrence of laterite fringing Tertiary sediments, suggested alternative possibilities as to the genesis of laterite. According to him the stratigraphic sequence of the area was as follows :

Sub-Recent and Recent	Sand dunes, tidal flats, Rann clays and alluvium
Lower Miocene	Gaj beds
Upper Eocene (?)	Laterite
Early Eocene to late Cretaceous	Deccan lava flows.

He recognised three types of bauxite deposits :

Type I : Bauxite deposits formed by <u>in situ</u> alteration of pyroclastic facies of the Deccan lava flows. These have to some extent retained the original textural features of the parent rock viz., volcanic agglomerates, breccia and tuff.

Type II : Bauxite deposits formed by reworking and transportation of <u>in situ</u> bauxite formed as above. The deposits of this category can be sub-divided as :

(i) those close to source area, resulting in the pseudo-brecciated bauxites and with depositional features, and

(ii) those far from the source area as indicated by bauxite, conglomerates and grits with well rounded pebbles and grains of bauxite.

Type III : Formed by laterisation and bauxitization of supra-Trappean limestones. Out of the three types of deposits, only the first two viz. Type I and II occur in the study area, in fact in the whole of Gujarat.

Since 1963, the State Directorate of Geology and Mining, Gujarat State, conducted a detailed programme of bauxite estimation. Vyas and Shah (1966-67), worked on different localities in Jamnagar and described in detail each bauxite deposit. Reports on different bauxite deposits were submitted in 1974 by both of them.

Sabot Julliet (1967), a French geologist of the Pechiney Company, studied the Kutch bauxite from an economic point of view. In his report, he mentioned that "the bauxite deposits of Kutch were formed by laterisation of basaltic rocks, like those of Saurashtra". He also opined that these laterites, formed by weathering from the underlying Traps, must have been entirely ferruginous in nature when they were first formed. "Deferrification" by percolating waters is given as the explanation for the formation of the bauxite patches in the laterite. The profusion of joints, fractures etc., enabled free and deeper penetration of water, enabling a good thick bauxite layer to be formed. In places where such drainage facilities were lacking the rock was left more or less unaltered. The higher iron content in lithomarge underlying the bauxite, is in his view, the result of impregnation of ferric oxide by the above percolating water whose dissolved iron was precipitated on encountering this clay zone.

Shrivastava (1968), described the geology, stratigraphy and geological history of the Saurashtra peninsula in his unpublished O.N.G.C. report.

Balasundrama (1970), reviewed and summarised the work done on the geological set up, distribution, mode of occurrence and norms of exploitation of bauxite deposits of western India.

During 1970-72, the Geological Survey of India made exploratory bores in the bauxite bearing areas of Jamnagar district. Estimation of quality and reserves was done. Most of the technical data is confined to their unpublished reports.

Valeton (1972,1983) has mentioned in detail the Mewasa bauxite deposits (Jamnagar district), from where she collected samples for detailed geochemical studies. She has reported relict microtextures and microstructures of basalt (intergranular texture and columnar joints) in the bauxite deposits, and opined that the latter were an in situ alteration product of basaltic flows.

She established a definite pattern of lateral petrographic and geochemical differentiation. The lateral sequence showed enrichment of Fe to the north-east and enrichment of Al in the opposite direction. Using the isovolumetric method to calculate the geochemical balance, she proved that besides the relative enrichment, there was absolute enrichment of Fe in the north-eastern part, whereas Al and Ti were enriched absolutely in the south-western area. She explained this phenomenon of the lateral movement of all major elements (Al, Si, Fe, Ti) leading to lateral facies differentiation from a kaolinitic laterite to an Al-rich bauxite. Her reconstruction of Lower Tertiary shorelines showed that most Indian occurrences were situated on Palaeocene or Eocene coastal plains indicating a sea-land transition zone where the type of sediments also varied with minor tectonic movements or sea-level changes. In her opinion, many high level bauxites were formed in coastal plains and they were subsequently uplifted to their parent altitude.

Shah (1974), in his investigations found that the Trap basalt cropped out as inliers near Nandana and Mewasa villages (Jamnagar district). Scattered horizons of bauxite in the laterite belt were seen by him. The bauxite deposits seen in the laterite belt and in most of the pockets occurred on the gradual slopes of the hillocks.

Vyas (1974), in his investigations of the bauxite deposits of Jamnagar district found that Traps and limestones were the dominant country rocks covering major portions of the area. The bauxite deposits were invariably found associated with laterite. It was observed that the bauxite horizon rested directly on the Deccan Traps, and at places were found covered by the Gaj beds. Traps also out cropped as small inliers, forming hillocks surrounded by laterites and Gaj beds.

Rao (1976), published a report on "Bauxite deposits of Gujarat state" and observed that bauxite deposits were very closely associated with laterite formations, within which they occurred as segregated pockets. The deposits of Saurashtra overlie either Trap or other sedimentary formations and occur on top of the ridges and mounds. The stratigraphic table given below, gives an idea of the geologic setting of the bauxite deposits as worked out by him :

Alluvium, blown sand etc	Recent	
Miliolite limestone	Pleistocene (?)	
Nummulitic limestone, shale, yellowish limestone and sandstone	Manchar, Gaj, Kirthar (upp.Eocene)	Miocene to Pliocene
------------- Unconformity- -----------		
Bauxite or laterite	Pre-Gaj/Post-Laki (?)	
------------- Unconformity- -----------		
Sand beds, shale, carbonaceous shale, lignite seams, sandstone	Lower Eocene to Middle Eocene (Laki formation)	
------------- Unconformity- -----------		
Bauxite / laterite	Palaeocene (?)	
Lithomarge and ferruginous clay		
Stratified basaltic lava flow	Deccan Trap	Upper Cretaceous to Lower Eocene

McFarlane (1983), has raised objections to Valetons' (1983) extension of this model to all elevated bauxitised plateau in India, by stating that in such a littoral palaeoenvironment, for the formation of laterite/bauxite, there must have been a string of islands along a former coast, but the absence, on one side of the belt of islands, of a more or less continuously bauxitised strip corresponding with the former postulated coastline argues against this hypothesis. Also it seemed quite an incredible coincidence that scarp retreat had so consistently reached precisely the bauxitised part, neither progressing beyond it nor falling short of it. Moreover, if a palaeocoastal environment is relevant here, the bauxitization should be at a constant altitude around the plateaux, whereas, it flanks plateaux of considerable relief. It seemed unlikely, therefore, according to her that a littoral palaeoenvironment explained the present peripheral enrichment.

Shukla et al., (1983), stated that the Gujarat bauxite deposits were seen in different geological environments. They also stated that bauxites were derived from a variety of rocks viz., basalt, shale, sandstone and granite, inland and coastal, in situ and transported, and this was in contrast to other major segments of Western India where laterite included bauxite; and formed a thick capping over basalt at different elevations. Two types of geological setting were recognised by them viz. continental and marine. In the continental type, basalt/granite - altered zone - clay or without clay - laterite - aluminous laterite/bauxites were identifiable as successive stages of the weathering sequence, whereas selective desilicification and deferrification were the main processes of bauxite formation in a marine environment. In the marine environment, different small detached isolated shallow basins were subjected to marine transgression and regression in the past. Further, based on geochemical conditions, the basins were subsequently filled up with valuable economic viable deposits like bauxite, siderite, clay, lignite with sporadic occurrence of phosphatic nodules, baryte, gypsum, etc. Gibbsite was the main mineral in bauxites along with bayerite, boehmite, diaspore, goethite in minor amount. Allophane, cliachite, leucoxene, dickite, halloysite and maghemite were the other constituents. Microscopic studies illustrate two generations of gibbsite and also the evidence of four or five stages of weathering leading to to the formation of bauxites. Chemical studies of <u>in situ</u> profiles demonstrated that nearly 60-70% leaching took place to produce a residue of laterite. Vanadium and gallium were the major elements that recorded higher concentration. In the case of basin environment, desilicification and deferification processes of shales was advocated for the formation of bauxites. The deposition of gypseous shales and siderites reflected the change in the environment.

Balasubramaniam (1987) developed a geomodel for the bauxite deposits of Kutch, which were derived from basalt (continental environment), and those associated with the marine environment. His geomodel offers ore prognosis upto 60%.

Recently, McFarlane (1987), has put forward a new aspect for the genesis of bauxite, emphasising upon the key role of micro-organisms. According to her, geochemistry has been the main input in the interdisciplinary study of bauxite and laterite. Whereas bauxitization can occur on many rock types, emphasis on a geomorphological control was made, with sites favourable to aggressive leaching being predisposed to bauxitization. Better bauxitization on higher and older landsurfaces appear to indicate that time could be as effective as leaching aggression. However, alternative explanations for the variation in bauxitization with altitude, in terms of present and palaeoclimates, required adequate assessment of the relative roles of leaching aggression and time. Though data indicated increased bauxitization during hot and wet periods in the past, these fluctuations were set within a pattern of overall increase, to the present time, where in the world climates had become cooler and drier since the Oligocene. This pointed to another control-biological, which became even more logical by the failure of geochemical explanations for the accumulation of both Fe and Al enriched residues, following kaolinite dissolution. The simultaneous removal of Al and Si in solution during congruent kaolinite dissolution was impossible as immediate co-precipitation occurred. Following incongruent kaolinite dissolution, Al enriched residua, were difficult to explain in conjunction with removal of iron. Up-profile changes in Fe minerals and loss of Fe from the pallid zone similarly presented serious difficulty. The geochemical constraints on element mobility, the source of the difficulty, do not apply to biologically complexed materials.

Sychanthavong and Patel (1987), have given a very good account of the relevance of the drift tectonics of the Indian plate to the formation of laterites in northwest India.

Bardossy and Aleva (1990), have dealt with the occurrence, genesis, exploration and uses of global lateritic bauxites. They have classified the Indian bauxite occurrences into 5 districts depending upon their geographic location, parent rocks, geomorphology and height:

(1) The Eastern Ghats district, over Archean metamorphic rocks in high-level positions;

(2) South India district, over Archean metamorphic rocks partly in high-level, partly in low-level positions;

(3) West Coast district, partly over Deccan Trap, partly over Precambrian metamorphic and magnatic rocks in low- and high-level positions;

(4) Central and Eastern India district, mainly over Deccan Trap in high-level position, partly over Archean and Late Precambrian rocks;

(5) Gujarat district, mainly over Deccan Trap in low-level position.

The following geological succession has been worked out by them for the entire Gujarat bauxite district :

Age	Rock type	Thickness	Formation
SubRecent	alluvial sediments	0-10 m	
Pleistocene	limestone	0-10 m	
Mio-Pliocene	shales, marls, limestones	0-50 m	Manchar
Miocene	shales, marls, limestones	0-50 m	Gaj
L. Eocene	laterite, bauxite	0-05 m	U. Laterite
------------------ Unconformity ------------------			
Early-M. Eocene	shales, sandstones at the base lignite beds	0-200m	Laki
Palaeocene	laterite, bauxite	0-15 m	L. Laterite
------------------ Unconformity ------------------			
L.Cretaceous - Paleocene	basaltic lava flows	20-50 m	Deccan Trap
------------------ Unconformity ------------------			
L. Jurassic	sandstone		

From the fore-going discussion, it became clear that the majority of the earlier workers considered the Deccan Trap lava flows as the parent rocks, which under favourable conditions gave rise to the laterite/bauxite deposits.