CHAPTER - V

MINERALOGY

GENERAL

MINERALS PRESENT IN THE VARIOUS HORIZONS

MINERALOGY

GENERAL

The chemical redistribution of major and minor elements, during rock alteration essentially depends on the original mineralogy of the rock, and the agencies responsible for the changes. An igneous rock formed at high temperature, when subjected to new conditions at or near the contact with air, water and living matter, would give rise to a new state involving production of such minerals that are more stable under new conditions, decrease in density and particle size. In such processes water plays a dominant role which can only be understood by first examining the structure of silicate minerals of which the original rock is composed. Lateritisation of basalts, as is the case in the present study, involves the breakdown of minerals present in the parent rock, viz. calcic plagioclase (labradorite), augite, olivine and iron ores. Aspects of chemical alteration of the various minerals of basalt is described in the following lines.

Calcic Plagioclase feldspar

In the molecular framework of feldspars, the tetrahedra are linked through all four oxygen atoms to yield a three dimensional configuration. Aluminium substitution for silicon within the tetrahedral creates a net negative charge on the framework which is balanced by a calcium ion. Breakdown of the calcic feldspar proceeds through the loss of these calcium ions, but, for their escape, the tetrahedral framework must be ruptured. With the loss of the metallic ions, the framework structure breaks down into chains which tend to polymerize into sheets in much the same manner as those released from pyroxene. Where the leaching conditions are inadequate to remove magnesium and ferrous ions as rapidly as they are released from the breakdown of associated minerals, these ions tend to be 'fixed' by the new residual structure, resulting into kaolinite and montmorillonite (Chapman and Greenfield, 1949; Smith, 1957; Craig and Loughnan, 1964).

Olivine

Olivine is composed of discrete silica tetrahedra bounded together by magnesium and ferrous ions in octahedral coordination. Both octahedral cations are potentially mobile and their loss from the surface of the mineral causes the ready release of the individual tetrahedral units, thereby exposing fresh surface to attack. Consequently, Olivine decomposes rapidly. However, the rate of release of silica may exceed its rate of solution and in that ~~which~~ case the residual silica polymerizes into sheets and apparently 'fixes' some of the magnesia, yielding serpentine as the crystalline phase. Generally, a complete balance of silica and magnesia is attained so that neither free silica nor free magnesia remains within this zone. Much of the ferrous iron, if released above the water table, is oxidized, in which state it crystallizes or tends to crystallize, as the oxides, goethite, hematite and sometimes maghemite (Loughnan, 1969).

With the increasing intensity of chemical weathering in an alkaline environment, magnesia is preferentially leached from the serpentine which becomes progressively unstable and is converted to new silica enriched phase as montmorillonite mineral (Craig, 1963).

<u>Pyroxene</u> (Augite)

In pyroxene, the tetrahedra are arranged in chains which are bonded together by metallic ions, the most common being those which enter into octahedral coordination with oxygen, such as Mg^{++}, Fe^{+3}, Fe^{+2}, Al^{+3}. Some alumina may replace silicon in the tetrahedra. Bonding by the octahedral cations is relatively weak and with pronounced cleavage planes approximately normal to each other and parallel to the silica chains. Access of water along the cleavage planes promotes solution of the bonding cations and causes rapid breakdown of the structure. Upon release, the chains tend to polymerize into sheets incorporating residual alumina and magnesia, forming chlorite or montmorillonite or both. Ferrous iron is readily stabilized by oxidation to the ferric state, and at the same time titania crystallizes as anatase and rutile. Where the release of calcium from the breakdwon of the pyroxene exceeds its rate of solution, calcite also develops (Craig and Loughnan, 1964, Smith, 1957).

Iron Ores

Iron ores are mostly magnetite and hematite, though the latter is always subordinate. These occur as equidimensional grains in igneous rocks is resistant to alteration in a reducing environment, but is readily altered in a highly reducing and oxidising conditions to goethite, lepidocrosite, hematite and maghemite (Schellmann, 1969).

MINERALS PRESENT IN THE VARIOUS HORIZONS

The minerals present in various Laterite profiles have been broadly classified into two categories :

(I) Neominerals :

a. Iron bearing minerals (Goethite, Lepidocrosite,Hematite and Maghemite).

b. Aluminium bearing minerals (Gibbsite,Boehmite,Halloysite, Kaolinite and Montmorillonite).

c. Titanium bearing minerals (Anatase and Rutile)

(II) Other minerals

a. Ankerite

b. Calcite

c. Quartz

The various minerals recorded from different localities at successive horizons have been presented in Table V.1. (For details, please refer to Appendix I - i to ii and Appendix II - i to xxx).

On the basis of examination of 29 samples from various localities, the author has prepared a table (Appendix III - i to iv) showing the mineralogy of the different horizons indicating the relative abundance, on the basis of which, he has categorised them as under :

Abundant (more than 30 %)	xxx
Moderate (between 5 to 30 %)	xx
Traces (less than 5 %)	x

Litho Unit	Minerals
1. Parent rock (Basalt)	Augite (xxx), olivine (xx) plagioclase (xxx), and iron ores (xx)
2. Weathered basalt	Goethite (x), Maghemite (xx) Hematite (xx), Gibbsite (x), Kaolinite (xx),Montmorillonite (xx), Anatase (x), Rutile (x), Ankerite (xx),Calcite (xx) and Quartz (xx)
3. Bentonite	Goethite (xx), Maghemite (xx), Hematite (xx), Gibbsite (x), Kaolinite(xx),Montomorillonite (xxx), Anatase (x) Rutile (x), Ankerite (xx), Calcite (xx) and Quartz (xx)
4. Kaolinite	Goethite (xx), lepidocrosite (xx), Maghemite (xx), Hematite (xx), Gibbsite (x), Kaolinite (xxx), Anatase (xx), Rutile (x), Ankerite (xx), calcite (xx) and Quartz (xx).

TABLE V.1 SUMMARY OF THE MINERALOGY OF THE DIFFERENT HORIZONS IN THE STUDIED OF PROFILES

	GOE	LEPI	MAGH	HE	GIB	HALLOY	BOE	KAO	MONT	ANA	RUT	ANK	CAL	Q
Duricrust	xxx	xx	xx	xx	xx			x		xx	xx	xx	xx	x
Unindurated laterite	xx		xx	xx	xx		Rx	x		xx	xx		xx	x
Bauxitic laterite	xx	xx	xx	xx	xx	xx		x		xx	xx		xx	x
Lateritic bauxite	x		x	xx	xx			x		xx	xx		xx	x
Bauxite	x		x	x	xxx			xx		xx	xx		xx	x
Lithomarge	x		x	x	x			xx		xx	x		xx	x
Kaolinite	xx	xx	xx	xx	x			xxx		xx	x	xx	xx	xx
Bentonite	xx		xx	xx	x			xx	xxx	x	x	xx	xx	xx
Weathered basalt	x		xx	xx	x			xx	xx	x	x	xx	xx	xx

x -- Trace (< 5 %)
xx -- Moderate (5 to 30 %)
xxx -- Dominant (> 30 %)
R -- Reworked

5. Lithomarge	Goethite (x), Maghemite (x) Hematite (x), Gibbsite (x), Kaolinite (xx), Anatase (xx) Rutile (x), Calcite (xx) and Quartz (x).
6. Bauxite	Goethite (x), Maghemite (x) Hematite (x), Gibbsite (xxx), Kaolinite (xx), Anatase (xx), Rutile (xx), Calcite (xx), and Quartz (x).
7. Lateritic bauxite	Goethite (x), Maghemite (x), Hematite (xx), Gibbsite (xx), Kaolinite (x), Anatase (xx) Rutile (xx), Calcite (xx) and Quartz (x).
8. Bauxitic laterite	Goethite (xx), Lepidocrosite (xx), Maghemite (xx), Hematite (xx),Gibbsite (xx) Halloysite (xx), Kaolinite (x), Anatase (xx) Rutile (xx) Calcite (xx) and Quartz (x).
9. Unindurated laterite	Goethite (xx), Maghemite (xx), Hematite (xx), Gibbsite (xx), Kaolinite (x), Anatase (xx), Rutile (xx), Calcite (xx) and Quartz (x).
10. Duricrust	Goethite (xxx), Lepidocrosite (xx), Maghemite (xx), Hematite (xx), Gibbsite (xx), Kaolinite (x), Anatase (xx), Rutile (xx) Ankerite (xx), Calcite (xx) and Quartz (x).

Presence of Boehmite (x) is very significantly restricted to reworked laterites only.

The likely derivations of the various minerals present have been briefly summarised as under :

Minerals	Derived from	Environment
Goethite, Lepidocrosite Hematite and Maghemite	Augite, Olivine and Iron ores	Acidic ($pH < 4$)
Gibbsite and Boehmite	Plagioclase feldspar Augite	Acidic ($4 < pH > 10$)
Kaolinite and Halloysite	Plagioclase feldspar Augite and Olivine	Alkaline ($pH > 9$)
Montmorillonite	Plagioclase feldspar, Augite and Olivine	Alkaline ($ph > 10$)
Anatase and Rutile	Titanaugite and Sphene	Acidic ($pH < 5$)
Ankerite	Augite, Plagioclase feldspar, Olivine and Iron ores	Alkaline ($pH > 9$)
Calcite	Augite and Plagioclase feldspar	Alkaline ($pH > 8$)
Quartz	Quartz	Alkaline ($pH > 9$)

Neominerals

The various neominerals, viz. Goethite, Lepidocrosite, Hematite, Maghemite, Gibbsite, Boehmite, Kaolinite, Halloysite, Montmorillonite, Anatase, Rutile, Ankerite, Calcite, and Quartz have been identified by the characteristic x-ray diffraction peaks at different ´d' spacing in Å, which are comparable to those reported in the Standard Powder Diffraction File Data of

JCPDS philadelphia (1974). The intensity of the peaks for all minerals at their 'd' values are directly proportional to the amount of the mineral present.

Iron Bearing Minerals : Goethite accompanied by Hematite, Maghemite and a small amount of Lepidocrosite constitute the secondary iron minerals found in a laterite profile. Although the colour is not a certain guide to mineralogy or chemistry of samples, but in a general way, it is seen that the yellow iron oxides are more hydrated than the red ones. Goethite is present almost universally, in all localities and in all horizons; of course its proportion is quite variable (abundant to traces). It is a dominant mineral in the duricrust except in one or two localities viz. Amliyara bore hole duricrust (sample No. 9). Reworked laterite and bauxite, contain this mineral in moderate amount only (Sample Nos. 15 and 16). Goethite is identified by the characteristic X-ray diffraction peaks at 4.18 A° and 2.69 A°. Hematite is present both in the laterite zone as well as the saprolite zone in all profiles from North and South Gujarat. Its abundance is more or less uniformly distributed in all the horizons and is computed as moderate, except in the Amliyara bore hole, where it is almost absent in the kaolinite horizon (sample No. 12). In reworked bauxite (Sample No. 16) this mineral occurs in traces only. Hematite has been identified by X-ray diffraction studies taking its characteristic peaks at 2.69 A°, 2.51 A° and 1.69 A°. Maghemite occurs in two ways in some profiles, it is present all throughout in all horizons (sample Nos. 9 to 14 and 28 to 34), whereas at some places (sample Nos. 25 and 26) it is restricted to the lower horizons only, viz. weathered basalt and bentonite zones. Its presence is indicative of breakdown of goethite and lepidocrosite minerals under oxidizing conditions. Maghemite has been identified by X-ray diffraction studies taking its characteristic peaks at 2.95 Å, 2.67 Å and 2.52 Å.

Presence of *Lepidocrosite* is rather very limited and, this mineral has been recorded in traces only in three localities from unindurated laterite and kaolinite horizons (sample Nos. 10 and 12) and from the bauxitic laterite of Manjlau (sample No. 19). Lepidocrosite has been identified by x-ray diffraction studies taking its characteristic peaks at 6.26 Å, 3.29 Å.

Aluminium Bearing Minerals : Gibbsite, Boehmite, Halloysite, Kaolinite and Montmorillomite comprise the Al-bearing minerals. *Gibbsite* is almost universally present in moderate amount in the lateritic horizons all over in North as well as South Gujarat. It forms a dominant mineral in a few bauxite and lateritic bauxite horizons (Sample Nos. 3 and 20). It is more or less absent in the saprolite zone, except that in some profiles, it occurs in traces in kaolinite and bentonite horizons (Sample Nos. 12, 13, 31 and 32). Interestingly, gibbsite is a dominant mineral in reworked laterite and bauxite, typically pointing to its concentration by transport through the agency of surface water. Gibbsite has been recognised by the characteristic X-ray diffraction peaks at 4.85 Å, 4.82 Å and 4.37 Å. *Boehmite* : is present only in one of the occurrences of reworked laterite (sample No.15) at Amliyara. This mineral is indicative of the process of rehydration of gibbsite. Boehmite is identified by X-ray diffraction studies taking its characteristic peaks at 3.19 A° and 2.65 A°. The mineral Halloysite recorded in the bauxitic laterite horizon of one profile only (sample No. 19) at Manjlau. Normally, this mineral changes over to kaolinite and its occurrence is always very restricted. Halloysite is identified by X-ray diffraction peak at 4.42 A°. Kaolinite is an important mineral and its presence is recorded throughout the laterite profile, of course in varying proportions. In the study area; it is present in most profiles and it forms distinct horizons within the saprolite zone. Some duricrusts (sample Nos. 11 and 18) also show small proportions of kaolinite, but others do not contain this mineral (sample Nos. 9 and 28). Reworked laterite at some places also shows an appreciable amount of this mineral, obviously representing material transported from nearby kaolinite horizon. This mineral has been identified by characteristic X-ray diffraction peaks at 7.18 A°, 3.58 A° and 1.49 A°. Montmorillonite mineral is the dominant constituent of the bentonite horizon and is also present in the weathered basalts (sample Nos. 5,6,13,24,26, and 33). It is significantly absent from the laterite zone. But in a few reworked occurrences it forms infilling and interstitial matrix between boulders of bauxite (sample Nos. 16 and 17). Montmorillonite has been identified by the characteristic X-ray diffraction peaks at 15.0 A°, 13.6 A°, 4.50 A° and 4.47 A°.

Titanium Bearing Minerals

Titanium bearing minerals are Anatase and Rutile. Anatase is present throughout the profile in all localities except in the weathered basalts (Sample No. 5 and 13) one bentonite horizon of North Gujarat (Sample No. 6) and in some of bauxitic laterite and duricurst (sample Nos. 18 and 19), where it is absent. The reworked profile has good amount of this mineral (sample Nos. 15, 16 and 17). Anatase has been identified by the characteristic X-ray diffraction peaks at 3.52 A° and 1.89 A°. Rutile is restricted to the upper parts of the profiles, viz., duricrust, unindurated laterite and bauxitic laterite (sample Nos. 2,9, 10 and 28). Again it is seen occurring in the lower portions comprising weathered basalt, bentonite and kaolinite horizons (sample Nos. 4,13 and 31). It is not clear why this mineral is absent from the middle part of the profiles. Rutile has been indicated by the characteristic X-ray diffraction peaks at 3.25 A° and 1.69 A°.

Other Minerals :

Ankerite, Calcite and Quartz are the other minerals present. Ankerite is only occasionally present and has been recorded from only a few horizons, viz. duricrust, bauxitic laterite, lithomarge, kaolinite, bentonite and weathered basalt (sample Nos. 1,4,20,23,25,26,28 and 30). It is always restricted to the upper part of the laterite zone and the lower part of the saprolite. Reworked laterite shows a fair content of this mineral (sample No. 15). Ankerite has been identified by the characteristic X-ray diffraction peak at 2.90 A°. Calcite is moderately present in almost all the localities in various horizons, except those of the transitional zone between bentonite and kaolinite horizons and that between kaolinite and lithomarge (sample Nos. 22 and 32). Reworked laterite and bauxite show some amount of calcite, which is mostly seen occurring as infilling along joints and fractures. Calcite shows characteristic X-ray diffraction peaks at 3.4 A°, 2.95 A° and 1.85 A°. Quartz is present in all the profiles at all horizons from North to South Gujarat, but mostly in traces. Reworked laterite and bauxite however show negligible quartz (Sample Nos. 15 and 16). This mineral has been identified by the characteristic X-ray diffraction peaks at 3.40 A°, 1.98 A° and 3.27 A°.