IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified ⁜ Impact Factor 7.12 ⁜ Vol. 10, Issue 3, March 2023

DOI: 10.17148/IARJSET.2023.10302

Physico-Chemical Behaviour's and Implications for Laterite Genetics from Swarnagadde Plateau of Western Ghats, Karnataka

Rajendrakumar Y. Budihal[1], A. Sreenivasa[2]

Associate Professor, Department of Geology, Karnatak Science College, Dharwad-580 001, India[1]

Professor, P. G Department of Studies in Geology, Karnatak University, Dharwad-580 003, India[2]

Corresponding Author: Dr. Rajendrakumar Y. Budihal

Abstract: The Swarnagadde laterites occur extensively as blanket or cappings on the high plateau and hill ranges in the Western Ghats of Karnataka. The general thickness of the ferruginous laterite in the profile varies between 50 cm to 1.2. Granitic gneisses are the oldest rocks of the study area and these are predominantly tonalite/trondhjemites in nature and comparable to similar early Precambrian granitic gneisses of the world. The lateritic formations of Swarnagadde area receives average rainfall of about 3900 m annually. It is aimed here to discuss the physic-chemical parameters and genetic implications for the formation of lateritic profile in this paper. The laterites in the area are dominantly composed of aluminium and kaolin bearing minerals. Frequently quartz is seen as relict mineral present in the lateritisation profile. The chemical analysis of laterites reveal a high percentage of Al_2O_3, followed by Fe_2O_3 and SiO_2 and all the samples resulted a high value of LOI. These four components together constitute 97.20% of the total component of the laterite profile. The study substantiates that the laterites are the product of chemical weathering under tropical conditions.

Keywords: Include at least 4 keywords or phrases.

I. INTRODUCTION

Laterite is a weathered product first found in India and later, it has been found in almost all tropical countries with high rainfall. Chemical weathering followed by sedimentation processes is the basic processes which convert igneous, sedimentary and metamorphic rocks into laterite. The occurrence of laterite as thin surface blankets on high plateaus or coastal areas, the presence of a clay zone at the base and other features of the laterite profile were identified quite early. On the basis of mode of occurrence laterite was divided into high-level and low-level by Medlicott and Blanford [31; plateau, terrace or valley laterites by Lake [25]. On the basis of the ratios of SiO_2, Fe_2O_3 and Al_2O_3 Martin and Doyne [28] specified that if SiO_2: Al_2O_3 ratio is less than 1.33, the material is termed as 'laterite' and the ratio should be 1.33 to 2.0 for the 'lateritic soils'. Sinha Roy [43], Karunakaran and Sinha Roy [22] proposed if Fe_2O_3: Al_2O_3 ratio is less than 1.33 be termed as 'ferruginous laterite' while those of with having Fe_2O_3:Al_2O_3 ratio less than 1 and SiO_2:Al_2O_3 ratio less than 1.33 as 'aluminous laterite'. Alexander and Cady [3] suggested the definition of 'laterite' as a highly weathered material rich in secondary oxides of iron, aluminium or both. It is either hard or capable of hardening on exposure to wetting and drying. Chemical weathering is the basic process which transforms igneous and/or metamorphic rocks into laterites and aluminous laterites. It is necessary to have a clear understanding of the weathering processes for understanding the genesis of laterites and aluminous laterites.

Laterites are formed from the leaching of sedimentary, metamorphic, igneous and mineralized proto-ores which are predominantly iron and aluminium [45]. The mechanism of leaching involves acid dissolving the host mineral lattice, followed by hydrolysis and precipitation of insoluble oxides and sulphates of iron and aluminium. [17] describes laterites as highly weathered and altered residual soils formed by the *in situ* weathering and decomposition of rocks under tropical condition. Depending upon the specific physicochemical conditions in the respective microenvironment dissolution and neo-formation of kaolinite proceed at different times and at different places in the lateritic profile. Balan et al [5] observed the same kaolinite sequence in lateritic profile above kaoliniteic clays in Brazil. Ollier and Seth [34] suggests and categorized the lateritic crust as massive, pisolithic (isolated concretions), vesicular and vermicular or vermiform (having worm like holes). The study area is represented by granitic gneiss which is the bed rock and highly weathered and decomposed resulting in the formation of Laterite (Fig. 2). The Laterite contains average weight parentage of Fe_2O_3- 3.20 %; Al_2O_3- 26.89%; SiO_2-54.36 % with LOI- 11.62% (Table. 5).

II. GEOLOGICAL SETTING

The laterites of India are occur extensively as blanket or cappings on the high plateau and hill ranges in the inland area and coastal tracts of the country. The main constituents, of the laterite profile are the ferruginous laterite, aluminous laterite and lithomarge clays. However, the aluminous and lithomarge clay zones may be missing in some profiles. The general thickness of the laterite profile varies from 3 to 30 m. and the thickness of the different units within the profile is variable. The thickness of the ferruginous laterite in the profile varies between 50 cm to 1.2 m. The study area falls within the longitudes 14˚18' to 14˚24' N and latitudes 74˚24' to 74˚ 30' E forming part of Survey of India toposheet No.47 J/7 covering an area of 76 km2 is situated on the Mangalore-Karwar coastal highway. The study area lies between the Arabian coast in the west and Western Ghats in the east. Area is conveniently approachable in all seasons by well-connected roads and that reaches up to the top of the plateau.

The investigated area as seen from the valley and nalla sections the rock types which covers the coastal track of Karnataka area. The present study area is characterized by Precambrian crystalline rocks (Granites, Granitic gneisses and Schists), laterites and basic dykes. Granitic gneisses are considered as the oldest rocks of the study area and these are predominantly of tonalite/trondhjemites in nature and are comparable to similar early Precambrian granitic gneisses of other shield areas of the world. Radhakrishna, [6, 35, and 36] have investigated and described the Southern parts of coastal tract of Karnataka and the Northern part has been described by Gupta et al., [21]. The granitic gneiss/granites cover major portion of the coastal tract, which is the North-Western coastal continuation of peninsular gneisses or Northern continuation of South Kanara gneisses/granites. The gneisses form prominent hills and headlands along the coast. However, the occurrences of granites in the study area present as patches within gneissic complex.

Though, the minor intrusions of doleritic dyke have intruded within the gneisses after a long period of metamorphism/deformation and adequate cooling of the country rock witnessed the close of Precambrian geological events of the era about 2.2 b.y ago; [7]. A thick residual laterite-cappings have been formed during the Tertiary period due to intense and prolonged tropical weathering is the only major geological event of the area.

Table 1. Lithostratigraphic succession of the study area

Stratigraphic position	Rock formations	Age values determined for the corresponding rock formation in the Geological continuous South Canara Precambrian.
After Balasubrahmanyan, [7 and 8]		
Sub recent to recent	Sand/Soil and Alluvium	----------------------------
Tertiary to sub recent	Laterite	---------------------------
Proterozoics	Dolerite Dyke Intrusions	2.2b.y K-Ar age obtained for the younger ENE striking set of dolerites.
	Granites	2.2b.y Rb-Sr age obtained for Canara granites.
Achaeans	Granitic Gneiss	3.2-3.6b.y K-Ar, Rb-Sr and Pb-Pb age obtained for Canara gneiss
	Schists	3.2-3.6 b.y

III. MATERIALS AND METHODS

Some basic laboratory investigations in relation to the physical characters of the lateritic profiles developed in the study area. A small number of selected profile samples of laterite, ferruginous laterite/aluminous laterite are subjected to fundamental laboratory studies, such as determination of specific gravity, porosity, acidity (pH) and grinding tests were carried out in the laboratory of Geology department, Karnatak Science College, Dharwad.

IV. RESULTS AND DISCUSSION

A. The primary controls on lateritic profile development are;

1) Parent Lithology- presence of easily soluble minerals yielding rich alumina.
2) Prevailing climate- normal to abundant rainfall with alternating dry and wet period’s mainly tropical and warm climate.
3) Regional geomorphology and tectonic stability.
4) Effective porosity
5) Vegetation.

6) Role of sub-surface water.
7) Topographical relief (low to moderate) allows free circulation of water table but minimum erosion.

B. Climate and Rainfall

A tropical to sub-tropical continuously humid climate in which rainfall exceeds evaporation for the most of time, and temperature and humidity are periodically interrupted by heavy rainfall and contrast wet and dry seasons, has been universally invoked for promoting formation of laterite. Wet and dry seasons are considered to be favourable if not essential to laterite genesis [19, 20 and 39]. Alternating conditions are required for sesquioxides precipitation of laterite and the elevated temperature of percolating water the more effective it is in decomposing the rocks and lowering the silica content [38]. Typical weather and rainfall of the area is considered as one of the most important phenomenon in the process of lateritization and has been greatly supported by many researchers working on laterites [12, 27 and 37].

In order to explain the formation of Swarnagadde laterite generally, this area receives average rainfall of about 3900 mm annually and has not changed much in the past 10 years. The rainfall is mostly received during the month of June and October such a type of condition is favourable for the formation of laterite [12]. Regions with evenly distributed rainfall throughout the year seem to be less favourable for the lateritization [12]. The temperature variation in the study area is between 24˚C to 38˚C. These are typical features of monsoon climate and therefore the area is under the monsoon and tropical type of climate.

C. Topography

Topography influences weathering not only because of its control over micro-climate, vegetation and drainage but also because of down slope movement of constituent elements towards depressions or low relief both at and below the surface. The topographic relief should be hilly but not very rugged (peneplain with gently sloping depression towards the middle of peneplain) which allow free movement of groundwater and subsurface drainage. Many workers have observed laterite and aluminous laterite formation takes place at slope of 3 to 16% [10, 13, 14 and 16].

D. Drainage

Woolnough, [49] has stated that "lateritisation can occur only in areas where drainage is almost at standstill. This usually involves the existence of peneplain more or less at sea level". Drainage of the area plays important role in leaching out of elements released during the process of weathering of the parental rocks. Where there is a large amount of water entering the zone of weathering and drainage is good, even poorly soluble products of hydrolysis may be leached out, ultimately leaving an insoluble residue, largely of Fe^{+++} and A1 hydroxides. The slopes available on the sides of the plateau are helpful in draining out of products of weathering because the slopes are moderate/steep in nature and are thus favourable for the processes of lateritization.

E. Specific Gravity (Sp Gr)

Determination of specific gravity of laterites has been carried out for 20 profile samples covering different verities from the investigated area and the results are presented in Table 2. A careful examination of the values of the specific gravity reveals that, there is a distinct difference between the ferruginous laterite and aluminous laterite. Ferruginous laterites are fairly light, the specific gravity being between 2.21 to 2.26, while, specific gravity of aluminous laterites show to some extent higher than that of ferruginous laterites ranging between 2.35 to 2.77.

F. Acidity (pH)

The results obtained for 20 laterite profile samples are furnished in Table 2**.** The pH values illustrate a distinct change from ferruginous laterite which is on top and aluminous laterite being the bottom of the weathering profile. As a result in the ferruginous laterites the value of pH is approximately constant and is around 5.5, which are always establish towards the upper portions of the profile. In the aluminous laterites the value of pH being between 6.00 and 6.70 correspond to lower portion of the profile section of the study area. The pH of the environment is predominantly significant for the transport of Al and Si, in the solution, migration and their ultimate redeposition. Weathering solutions and zones associated with acidity (pH) and different minerals found in different parts of a weathering profile [32, 33]. Primitive weathering solutions exhibit low cation/H+ and are generally related with gibbsite, kaolinite and quartz. These minerals are constant in acidic solutions, and are found in residual weathering zone which forms uppermost part of a weathering profile [33].

DOI: 10.17148/IARJSET.2023.10302

G. Porosity

The porosity test for 20 laterite profile samples have been calculated following the formula of [50]. Calculated results are furnished in **Table 2**. The values of porosity are quite high in the ferruginous laterite relatively aluminous laterites which are intermediate to low in pore space. The value of porosity in ferruginous laterites ranges between 17.40 and 19.70, whereas in aluminous laterites the value of porosity between 12.00 and 14.20. A systematic decrease in the values of porosity from top to bottom indicating that the porosity decreases towards the depth as the fabric of the rock changes from ferruginous laterite to aluminous laterite.

Table 2 Specific Gravity, Porosity (%) and pH Values of the study area.

Sl. No.	Sample No.	Rock Types	Specific Gravity	Porosity (%)	pH values
1	BS-18	Ferruginous Laterite	2.25	18.55	5.35
2	BS-06	Aluminous Laterite	2.77	13.25	6.40
3	BS-16	Ferruginous Laterite	2.24	19.60	5.50
4	BS-07	Aluminous Laterite	2.36	12.10	6.60
5	BS-15	Ferruginous Laterite	2.21	17.60	5.60
6	BS-08	Aluminous Laterite	2.35	12.20	6.10
7	BS-11	Ferruginous Laterite	2.26	18.60	5.50
8	BS-30	Aluminous Laterite	2.55	13.20	6.20
9	BS-19	Ferruginous Laterite	2.21	19.70	5.40
10	BS-31	Aluminous Laterite	2.46	12.00	6.40
11	BS-10	Ferruginous Laterite	2.25	19.10	5.60
12	BS-32	Aluminous Laterite	2.39	13.50	6.50
13	BS-17	Ferruginous Laterite	2.26	17.80	5.50
14	BS-34	Aluminous Laterite	2.58	12.40	6.70
15	BS-20	Ferruginous Laterite	2.24	19.20	5.60
16	BS-35	Aluminous Laterite	2.63	14.20	6.00
17	BS-22	Ferruginous Laterite	2.22	17.40	5.50
18	BS-36	Aluminous Laterite	2.65	12.30	6.30
19	BS-13	Ferruginous Laterite	2.25	19.10	5.60
20	BS-38	Aluminous Laterite	2.39	13.90	6.20

H. Genetic implications for laterites

In general laterite is of iron-rich, subaerial weathering products that develop as a result of intense, substrate alteration under tropical or sub-tropical climates. Physically, many laterites are rock-like, yet they cannot be easily positioned into any of the principal petrological groupings. Neither do they lend themselves conveniently to description as ‘soils’, other from the fact that they are the products of processes operating at the atmosphere-substrate interface. They are possibly best considered to be metasomatic rock materials; i.e. rocks with chemical, mineralogical and physical characteristics that have been extensively modified through low temperature and pressure alteration processes such as these operating under subaerial conditions.

Laterites comprise an important subset of the wider range of ferruginous and related aluminous weathering products (which also include mechanically resistant aluminium-rich bauxites). These materials most commonly recognized as laterite typically forms the uppermost indurated surface layer of an extreme type of weathering profile developed under tropical or sub-tropical climates. Where preserved, this layer may extend over areas of thousands of square kilometres. Consequently, laterite is perhaps the most widespread of all duricrusts, with lateritic materials, or their eroded derivatives, covering about one-third of the emerged lands [46].

Long-term climatic and tectonic stability, together with slow geomorphological evolution over periods of 10^4-10^6 years are significant to the development and destruction of laterite profiles. This is because laterites are formed and preserved at the Earth’s surface, and thus remains exposed to environmental change. As a result, the evolution and modification of laterite profiles by the agents of weathering and erosion is a protracted and often continuous process. Disturbance through uplift, climate change, or both, is possibly to terminate the lateritization process, and lead to rapid erosion and stripping of the lateritic weathering profile. Nevertheless, the chemical and physical durability of the uppermost, duricrust phase of lateritic weathering profiles has played an important role in the evolution of tropical and sub-tropical landscapes of India, Africa, and Australia [29, 30, 44 and 47].

Thus the genesis of lateritic/aluminous lateritic weathering profiles can develop from the chemical weathering of a variety of sedimentary, metamorphic and igneous parent (i.e., protolith) rocks. However, protoliths that have essentially higher iron contents are most suited for the formation of laterite. Climatic, tectonic and geomorphological evolution over periods of 10^6 years can also be important controls. Accordingly, many lateritic weathering profiles are not simply the result of equilibrium with a single set of prevailing environmental conditions; once formed, weathering profiles remain exposed to the environment and may continue evolving indefinitely.

I. Development of laterite weathering profile over the granitic gneiss in the study area

Generalized vertical section through the autochthonous laterite weathering profile developed upon Granitic gneiss of the study area (Fig. 2a-f), illustrating the compositional and textural progression from the unaltered protolith to indurated laterite. Different lateritic textures may be identified at various levels, with one texture merging into the next [2, 47]. A broad zonal distinction is as follows:

I. Weathering front/Saprolitic Zone- Unaltered granitic gneiss (saprock) progressing up-profile to material displaying limited alteration of primary minerals. Altered granitic gneiss containing 'unaltered' core-stones within a soft saprolitic matrix, and progressing upward into saprolitic zone. Common relict parent rock fabrics, kaolinitic clay, and relict/etched quartz: (saprock <20% primary minerals weathered; saprolite > 20% primary minerals weathered)

I. Pedoplasmation front; Plasmic Zone- Saprolitic to weakly-lateralized zone in which some primary lithological characteristics remain, but becoming increasingly obscured due to an up-profile increase of Fe mottling and segregations. Absence of any parent rock fabrics, kaolinitic clay with relict/etched quartz and amorphous goethite (>90% primary minerals weathered).

I. Cementation front; Mottled Zone- Moderately lateralized zone comprising iron segregations and vermiform textures, and becoming increasingly indurated up-profile. Development of secondary structures and fabrics, with ferruginous (goethite and heamatite) accumulations increasing in size and occurrence upwards, set in a kaolinitic matrix. Well-crystallized to poorly crystallized kaolinite and goethite. Aluminous heamatite and goethite are most common minerals of this zone.

/. Lateritic Zone- Strongly indurated laterite with vermiform textures, becoming highly ferruginous in the uppermost levels of profile. Increasing amalgamation of ferruginous accumulations (carapace) eventually coalesces to form an interconnected 3D structure of mechanically resistant heamatitic and goethitic masses in the uppermost levels (cuirass/duricrust). Well-crystallized to poorly crystallized kaolinite is the common clay mineral found in this zone.

/. Surface erosional/weathering front- Any remaining tubes and voids are infilled with soft/friable Al-rich goethite or kaolinitic/gibbsitic material.

DOI: 10.17148/IARJSET.2023.10302

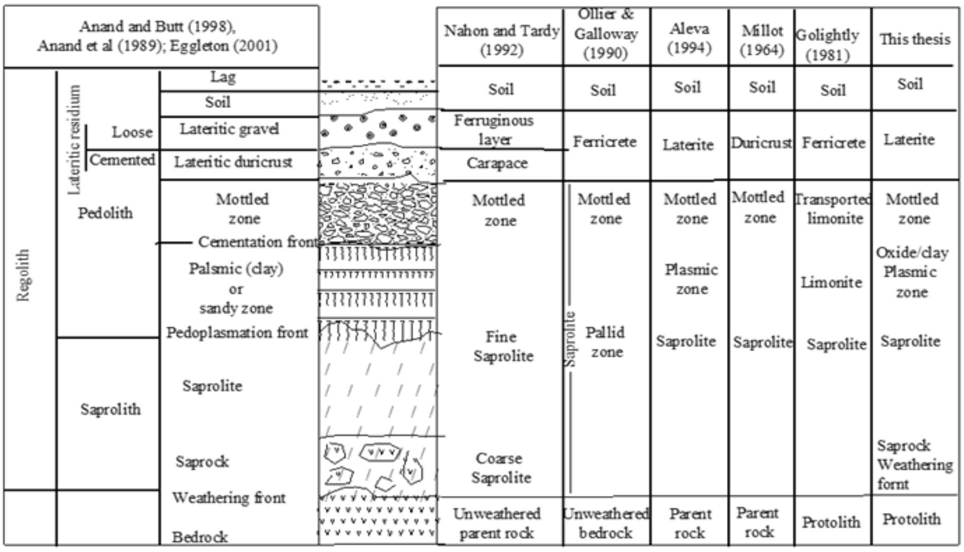

Fig. 1 Typical Laterite weathering profile terminology of the study area.

As described, where complete lateritic profiles are exposed in Swarnagadde plateau and elsewhere in western India, they typically display an uninterrupted series of zones from unaltered bedrock to highly indurated duricrust at the top. These *in situ* lateritic weathering profiles are represented series of reaction zones separated by interfaces which are commonly discernible in outcrop from observable changes in colour, mineralogy and texture (Fig. 2a-f). Thus, on the geological observations, lateritic profiles of study area have been classified into two different weathering fronts following [1, 2, 15 and 47].

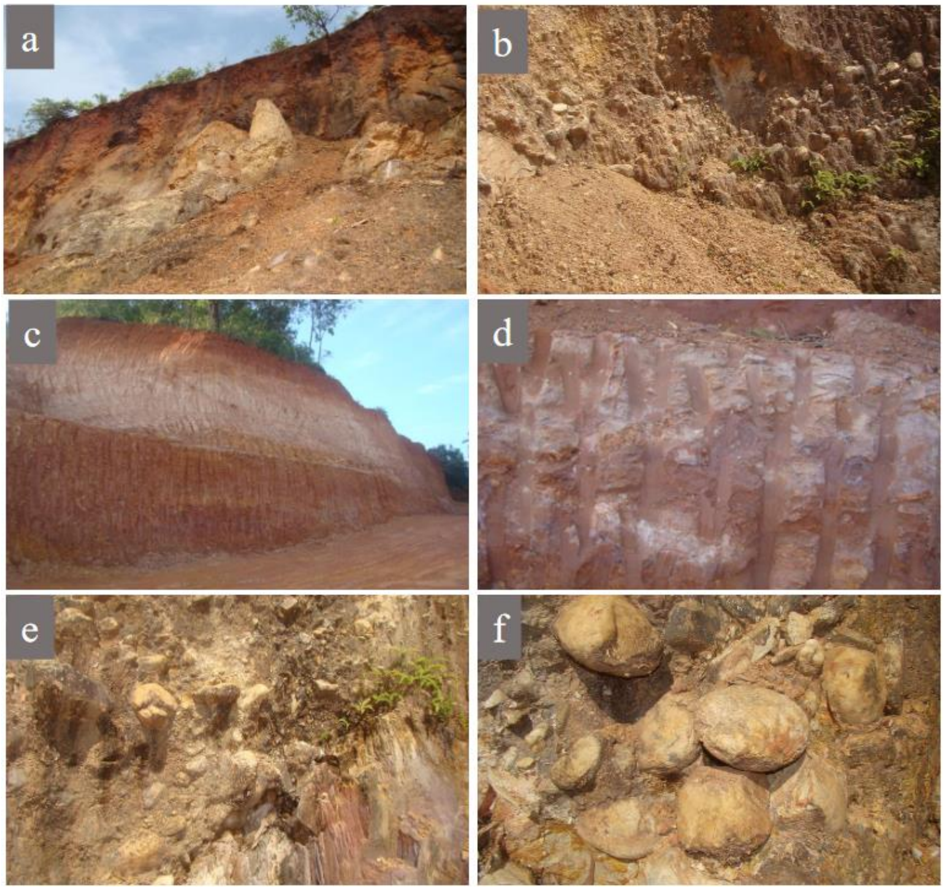

Fig. 2(a-f): Field photo showing different steps in lateritization of Swarnagadde Plateau.

J. Process of lateritization

Most of the lateritization results from a process of chemical weathering under tropical to sub-tropical conditions characterized by heavy/high rainfall, alternating wet and dry conditions, fluctuating ground water levels and drainage. Nearly all of the cases an elevated physiography or topography has served as a very favourable factor (Aleva, 1994), and a chemical classification for defining lateritic materials [40, 41] is important. Following [2], laterites *sensu-stricto* are defined primarily as residual materials formed by rock breakdown *in situ*. They should not contain any significant allochthonous (i.e. externally derived) components. In this definition, laterites owe their composition to the relative enrichment of iron, aluminium and other less mobile elements.

The lateritisation process occurs because parent rock exposed at the surface is subject to weathering, but the degree of alteration diminishes with depth, so producing a laterite weathering profile. As a result, such profiles consist of an upward progression from unaltered protolith at the base to an indurated, iron/alumina rich duricrust at the top. The pattern of enrichment and associated physical change is better termed an alteration profile. Elements such as Fe, Al and some trace metals can be redistributed or introduced into the evolving profile in solution by groundwater. These can then be redeposited at specific levels within the alteration profile by reactions associated with variations in groundwater chemistry, Eh and pH, and/or water-table fluctuations. Consequently, these iron-rich compounds invade the parent rock, then fill available pore spaces and/or replace the parent mineralogy in the profile.

K. Major element ratios in the lateritic weathering profile section of the study area:

The bulk chemical ratios of the lateritic profiles from the different parts of the study area are presented in Table 3. The ratio of TiO_2/Al_2O_3 is moderately increases from granitic gneiss parent rock to topmost ferruginous lateritic zone but with a minimum amount in aluminium lateritic zone. The Fe_2O_3/Al_2O_3 and TiO_2/Fe_2O_3 ratios show different trend from granitic gneiss to lithomargic clay and lithomargic clay to aluminous/ferruginous laterites. On the other hand ratios of SiO_2/Fe_2O_3, SiO_2/Al_2O_3 and Al_2O_3/LOI shows increasing trend from the topmost ferruginous laterites to the basal parent granitic gneiss.

Table 3. Ratios calculation for major oxides and LOI (wt. %) in the Swarnagadde plateau

Ratios	Ferruginous laterite	Aluminous laterite	Laterites	Lithomarge clay zone	Altered granitic gneiss	Granitic gneiss
Fe_2O_3/Al_2O_3	1.99	0.35	0.92	0.11	0.14	0.16
SiO_2/Fe_2O_3	0.37	0.85	1.06	14.19	20.49	30.38
SiO_2/Al_2O_3	0.73	0.30	0.97	1.50	2.86	4.90
Al_2O_3/LOI	1.67	1.75	1.91	2.43	2.48	8.72
TiO_2/Fe_2O_3	0.03	0.11	0.08	0.47	0.37	0.10
TiO_2/Al_2O_3	0.06	0.04	0.07	0.05	0.05	0.02

The laterites on acidic rocks behave quite differently. They frequently show a typical sequence with a pallid zone (saprolite), a mottled zone and a dark brown laterite on top which is often described. Genetically most relevant, however, are the differences in Fe_2O_3/Al_2O_3 ratios. Laterites on mafic and ultramafic rocks show generally similar ratios as the underlying parent rock. This can be easily interpreted by the loss of soluble elements causing an equivalent accumulation of the residual elements iron and aluminium which corresponds with the classic interpretation of laterite formation. On the other hand, laterites on the acidic rocks show generally strongly increased Fe_2O_3/Al_2O_3 ratios [42].

Table 4. The percentages of typical average values of laterite and their parent rocks [42]

Rocks	SiO_2	Al_2O_3	Fe_2O_3	Fe_2O_3/Al_2O_3
Laterite	46.20	24.50	16.30	00.67
Granite	73.30	16.30	03.10	00.19
Laterite	39.20	26.90	19.70	00.73
Clay	56.50	24.40	05.30	00.22
Laterite	23.70	24.60	28.30	01.15
Basalt	47.90	13.70	14.90	01.09
Laterite	03.00	05.50	67.00	12.20
Serpentine	38.80	00.70	09.40	14.10

DOI: 10.17148/IARJSET.2023.10302

All these observed features are typical for the lateritic profile formed by continuous desi1icification and leaching of soluble elements and concentration of aluminium, titanium, and iron oxide and hydroxyl/molecule. The ratio calculated for the different components of the entire profile (Table 3) shows an unusual variation in some of their values. These ratios can be used to describe the different zones. The significant decrease in the ratio of $SiO_2/Al_2O_3$from parent gneiss (4.90) to aluminous laterite (0.30) and laterite/ferruginous laterite (0.97/0.73) respectively indicate relatively high leaching of SiO_2 and concentration of Al_2O_3 in Swarnagadde plateau, whereas, the ratio of TiO_2/Al_2O_3 and TiO_2/Fe_2O_3 are almost constant in the entire profile. These ratios are indication of *in situ* weathering of granitic gneiss and subsequent development of lateritisation process in the study area. The Schellmann system [40, 41] is a quantitative approach which compares the extent of chemical alteration of a weathering product to that of its protolith in order to define increasing degrees of lateritisation. Significantly, the scheme recognizes the importance of the nature of the protolith upon the composition of the weathering product; it also requires that the weathering products are entirely the result of *in situ* alteration processes. Using a SiO_2, Fe_2O_3, Al_2O_3 ternary diagram (Fig. 3), four stages of alteration are recognized in the lateritisation process: (a) kaolinitisation, (b) weak lateritisation, (c) moderate lateritisation, and (d) strong lateritisation. The relative positions of these stages on the ternary diagram vary according to the chemical composition of the protolith. As a result, the Schellmann scheme proves useful for determining the degree of weathering for laterites. Nevertheless, it cannot be applied to separated phases since these involve allochthonous inputs of material into an alteration profile [18, 42].

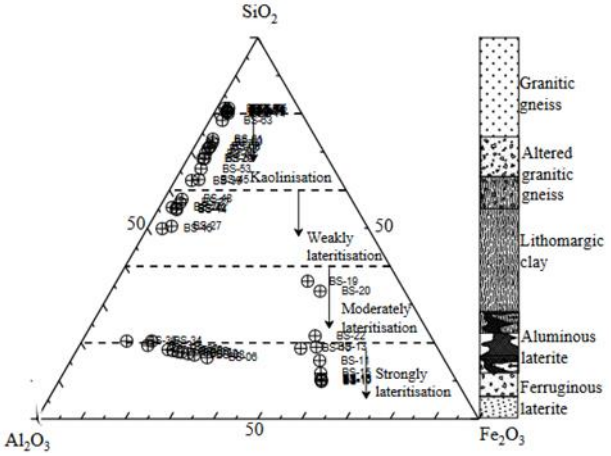

Fig. 3: Ternary plot of Schellmann [40] showing distribution of collected samples from Swarnagadde Plateau area and extent of lateritization.

Table 5: Major (wt. %) and Trace in ppm data for the Swarnagadde plateau (SP) weathering profile.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Oxides	**BS-18**	**BS-16**	**BS-15**	**BS-11**	**BS-19**	**BS-10**	**BS-17**	**BS-20**	**BS-22**	**BS-13**	**BS-06**	**BS-07**
SiO_2	8.55	8.30	9.87	12.76	31.52	15.21	8.04	29.05	18.45	15.75	11.90	12.67
TiO_2	1.66	1.71	1.50	1.12	0.90	1.10	1.75	0.79	1.70	1.36	1.79	1.80
Al_2O_3	24.92	24.99	24.53	23.66	18.03	25.53	25.07	16.60	22.14	22.83	39.67	42.59
Fe_2O_3	48.44	48.55	48.03	47.11	37.78	41.58	48.65	41.12	44.17	45.05	22.66	17.46
MnO	0.03	0.01	0.02	0.01	0.01	0.08	0.00	0.01	0.01	0.02	0.14	0.16
MgO	0.08	0.08	0.09	0.13	0.18	0.12	0.08	0.25	0.13	0.13	0.02	0.02
CaO	0.09	0.09	0.08	0.07	0.06	0.07	0.10	0.07	0.06	0.08	0.07	0.06
Na_2O	0.05	0.06	0.04	0.01	0.05	0.05	0.06	0.06	0.01	0.04	0.02	0.20
K_2O	0.31	0.32	0.28	0.21	0.64	0.24	0.33	1.00	0.07	0.38	0.02	0.02
P_2O_5	0.14	0.14	0.38	0.86	0.14	0.19	0.14	0.17	0.07	0.25	0.13	0.13
Cr_2O_3	0.09	0.09	0.12	0.18	0.12	0.08	0.09	0.11	0.07	0.11	0.11	0.11
LOI	15.25	15.26	14.67	13.51	10.16	15.34	15.26	10.36	12.76	13.62	22.94	24.48
Total	99.61	99.59	99.61	99.63	99.60	99.58	99.57	99.61	99.64	99.60	99.55	99.54

The most widespread of the secondary minerals formed during the development of a laterite weathering profile are iron and aluminium sesquioxides. These may form either directly from the alteration of primary minerals, or else via a series of pathways involving the formation of intermediary sheet silicate minerals and clays (e.g. chlorite, illite, smectite, vermiculite and halloysite), which are then themselves broken down, stripped of their mobile ions and silica, and eventually converted to alumina and ferric oxyhydroxides residua. Under tropical-type weathering conditions these transformation pathways lead to a dramatic increase in the abundance of goethite, heamatite, kaolinite and gibbsite above the saprolite zone. These latter secondary minerals become increasingly important in the mottled zone and eventually form the bulk of the overlying laterite [4, 23 and 48].

L. Chemical variation within lateritic weathering profiles

Weathering in the saprolite zone causes the destruction of feldspars and ferromagnesian minerals. Here, the mobile elements Na, Ca, K and Sr are leached and evacuated from the system; liberated Si and Al are partially retained by kaolinite and halloysite. In addition, K and Rb will be lost if hosted by orthoclase or biotite but, if present in muscovite, can be retained for as long as the mineral survives. The weathering of less stable ferromagnesian minerals in the saprolite produces Fe oxides with progressive loss of Mg and Si, except where retained in smectite (Mg, Si), kaolinite (Si) or quartz (Si); there may be partial retention of minor and trace elements such as Ni, Co, Cu, Mn and Ni. The involvement of smectite as early hosts for selected trace elements (Zn, Mn, Co, Ni and Cu) during the development of the weathering profile. The alteration of all but the most resistant primary minerals occurs in the mid to upper saprolite zones; in addition, less stable secondary minerals such as smectite are also destroyed. Serpentine, magnetite, ilmenite and chlorite are progressively weathered through the zone. Ferromagnesian minerals are the principal hosts for transition metals such as Ni, Co, Cu and Zn in mafic and ultramafic rocks; they become leached from the upper horizons and re-precipitate with secondary Fe-Mn oxides in the mid to lower section of the saprolite.

Most remnant primary minerals, except quartz, are finally destroyed in the mottled and ferruginous duricrust zones. Accordingly, these upper zones become dominated by Si, Al and Fe, resident in kaolinite, quartz, Fe oxides and, in places, gibbsite. The distribution of several minor and trace elements is controlled wholly or in part by the distribution of these major elements, due to substitution or co-precipitation.

M. Physico-chemical and geochemical behaviours in development of the laterite profiles

The chemical weathering of laterites depends on the reactions of silica and alumina contents with water and other extremely dilute solutions, as major constituents of rock are combined as alumino-silicate minerals. Minerals breakdown proceeds through solution or fractional solution of some of the constituent cations present in the minerals. Though, not all cations are taken into solution with the same ease. A few minerals tend to be readily lost in the percolating groundwater, whereas, others are resistant and become progressively concentrated in the residue. In addition, variations in the physico-chemical factors might result in solution of a particular cation in a certain parts of weathering environment and precipitation elsewhere.

In general, in the natural pH range of groundwater, Ca $(OH)_2$, Mg $(OH)_2$, and the alkalis are absolutely soluble, while, TiO_2, Fe $(OH)_3$, and Al_2O_3 remain insoluble and hence cannot be mobilized. Though, the solubility of silica is low, constant and unaffected by variations in the Ph. According to [24] the SiO_2 (amorphous silica) or silica released from silicates and not from quartz, which has a solubility of approximately one-tenth of amorphous silica [26]. Silica is soluble though only slightly at all values between 4 and 8, whereas alumina is only soluble below pH 4 and above pH 8.5. The solubility of silica is 6 ppm; quartz therefore, is a little soluble at the temperature of rock weathering. Amorphous silica is soluble to the amount of 115 ppm, or nearly 20 times as soluble as quartz. In the pH values above 9, the solubility of silica increases rapidly because of the ionization of H_4SiO_4, but in weathering, pH 9 is only attained during the initial alteration when feldspars become hydrolysed. Largely, in geochemical and pedo-chemical weathering, small quantities of silica continuously leached out and alumina accumulates in the clayey residue (Loughnan, 1969). Virtually, alumina is insoluble between pH 4 and pH 8.5, especially, in the pH field of rock weathering and soil formation. Amphoteric nature of alumina; at low pH values it is in solution as Al (OH), and at high pH values as Al $(OH)_4$. Within the lateritic profile, in favour of solution, migration and precipitation of major and trace elements, the groundwater conditions envisaged are (1) net flow towards the sea, (2) groundwater levels must be high and oscillatory in nature and (3) Eh conditions must be reducing, headed for solution and migration of elements.

Though, groundwater Eh-pH implicated in the process of lateritisation is significant. Nearly all the genetic models envisage elemental redistribution through the process of leaching (solution and migration) and of precipitation (deposition), usually brought in relation to fluctuating groundwater and changing Eh and pH values. However, alkaline environment would be favourable for dissolution of Si and Al with pH values 10 or more, Al_2O_3 is extremely soluble and SiO_2 is comparatively soluble. Such that, these are carried in solution if the rainfall is exists. As long as rainfall is scanty, the decay products Al_2O_3 and SiO_2 are not removed however combine to form clay. Consequently, kaolinite would form under alkaline and reduced leaching conditions.

Generally, more mobile minor elements such as Ca, Mg, K and Na along with the comparatively mobile trace elements such as Sr, Rb, Zn, Ni, Cu, Co and Be are released into the solution and create the water more alkaline environment. Such processes, deferrification/desilicification and relative concentration of aluminium lead to the formation of the aluminous laterite zone within the upper horizon of the Swarnagadde laterite profile.

V. CONCLUSION

Two major types of laterites are identified in Swarnagadde plateau. They are autochthonous (primary) laterites and allochthonous (detrital) laterites. Primary laterites developed *in situ* over crystalline rocks viz., granites/granitic gneisses. Primary laterites are more homogeneous, less sandy and are developed in situ through alteration of the underlying rocks. Detrital laterites are derived from alteration of primary laterites. They generally contain sands and rounded pebbles of quartz. Another type of detrital laterite which is observed near coastal region is extensively made up of gravels of tiny specks of quartz cemented together by oxides of iron. Laterites developed from the hill waste usually occur at the base of the hills or in the valleys. These laterites are more limonitic with a little or no alumina. These are derived mainly from *in situ* laterites covering the top of the hills. Taking into consideration field, mineralogical and physico-chemical observations it is concluded that the laterite formation of Swarnagadde area is of *'in situ'* origin derived from the tropical weathering of the precursor granitic gneisses.

REFERENCES

[1] Aleva, G.J.J. (1983): On weathering and denudation of humid tropical interfluves and their triple planation surfaces- Geologie en. Mijnbouw, 62(3).

[2] Aleva, G.J.J. (1994): Laterites: Concepts, Geology, Morphology and Chemistry. Wageningen (Netherlands): International Soil Reference and Information Centre.

[3] Alexander, L.T. and Cady, J.G. (1962): Genesis and hardening of laterite in soils, USDA Tech.Bull., 1282, 1-90.

[4] Anand, R.R. (2005): Weathering history, landscape evolution and implications for exploration. In: Anand, R.R. & de Broekert, P. (Eds) (2005) Regolith Landscape Evolution across Australia. Bentley, Western Australia: Cooperative Research Centre for Landscape Environments and Mineral Exploration, pp. 2–40.

[5] Balan, E., et al. (2007): Inheritance vs. neoformation of kaolinite during lateritic soil formation: A case study in the middle Amazon basin. Clays and Clay Minerals 55, pp. 253-259.

[6] Balasubrahmanyan, M.N. (1973): "Geo-chronology and geochemistry of Archaean tonalitic gneisses and granites of South Kanara district, Karnataka State, India". In Archaean geo-chemistry (editors) Windely B.F. and Naqvi S.M., Elsevier Publication Co., Amsterdam, pp.59-77.

[7] Balasubrahmanyan, N.M. and Chatterjee, P.K. (1975): Some aspects of the Geology of Eastern Ghats region for correlation.Misc.Pub.123, Geol.Surv.Ind, 223-232.

[8] Balasubramaniam, K.S. (1978): Mineralogy, geochemistry and genesis of bauxites of certain profiles from western India. 4th.Int.Congr. For the study of bauxites, alumina and aluminium, Athens.Vol.1, Bauxites, 35-76.

[9] Bardossy, G.Y. (1979): The role of tectonism in the formation of bauxite deposits. Travaux de I' ICSOBA (ZAGREB), 15, 16-34.

[10] Bardossy, G.Y. (1981): Paleo-environment of laterites and lateritic bauxites-effect of global tectonism on bauxite formation. In Lateritisation processes. Trivandrum, India, pp. 289-294.

[11] Bardossy, G.Y. (1982): Comments on Dr. Aleva's suggestions for a systematic structural and textural description of lateritic rocks. News Letter-IV IGCP-129 Lateritisation processes, India.

[12] Bardossy, G.Y. (1983): A comparison of the main lateric bauxite regions of our globe. In Lateritisation Process, Proc.II Int. Seminar on Lateritisation Process, Sao Paulo, Brazil, 1982, Eds. A. J. Melfi and A. Carvalho, 15-52.

[13] Bardossy, G.Y. (1989a): Lateritic bauxite deposits. A world-wide survey of observed facts. Travaux de1' ICSOBA. Zagreb. Vol.19. No.22. pp. 11-18.

[14] Bardossy, G.Y. (1989b): A review of world reserves and their mining and economic importance. Erzmetall. Vol. 42. No. 4. pp. 172-177.

[15] Bardossy, G.Y. and Aleva, G.J.J. (1990): "Lateritic bauxites development in economic geology". Elsevier Science Publishing Co., 624 p.

[16] Bardossy, G.Y. and Szabo, E. (1986): Lateritic bauxite. Lateritisation Processes. Mem. Geol. Surv. Ind., Vol .120, pp. 41-50.

[17] Blight, G.E. (1997): Mechanics of Residual soils. A.A Balkema, the Netherlands.

[18] Bourman, R.P., and Ollier, C.D. (2003): Reply to the discussion of "A critique of the Schellmann definition and classification of laterite" by R.P. Bourman and C.D.Ollier (Catena 47, 117-131). Catena 52, 81-83.

[19] Du Preez, J.W. (1949): Laterite: a general discussion with a description of Nigerian occurrences. Bull. agr. Congo beige, no. 40, p. 53

[20] Fisher, N.H. (1958): Notes on lateritisation and mineral deposits. The Aust. Instu. Min. Metl. F.L. Stiwell Anniversary Vol. pp. 133-142.

[21] Gupta, M.L., Sharma, S.R. and Sundar, A. (1988): Heat flow, heat generation and crustal thermal structure of the northern block of the South Indian Craton. Jour. Geol. Soc. India, v.31, pp.31-33.

[22] Karunakaran, C. and Sinha Roy, S. (1971): Laterites of Birbhum Dist., West Bengal: Their origin and age. Rec. Geol. Surv. India, v. 98, P. 16-40.

[23] Kisakürek, B., Widdowson, M., and James, R.H. (2004): Behaviour of Li isotopes during continental weathering: the Bidar laterite profile, India. Chemical Geology 212, 27-44.

[24] Krauskopf, K.B. (1959): Dissolution and precipitation of silica at low temperature. Geochim. Cosmochim. Acta. Vol. 10, pp.1-26

[25] Lake, P. (1890): The laterite of South Malabar. Mem. Geol. Surv. Ind., Vol.24, 217-233.

[26] Loughnan, F.C. (1969): Chemical weathering of silicate minerals. New York, American Elsevier Publication Co.

[27] Maignien, R. (1964): Review of research on Laterites. UNESCO, Paris.

[28] Martin, F.J. and Doyne, H.C. (1927): Laterite and lateritic soils in Sierra Leone. Jour. Agr. Sci., 17, 530-547.

[29] McFarlane, M.J. (1976): Laterites and landscape: London, Academic Press, 1-164.

[30] McFarlane, M.J. (1983): Laterites- AGIO Guide to Mineral Resource Development, pp.441-487.

[31] Medlicott, H.B. and Blanford, W.T., eds. (1879): Manual of the geology of India, Part I, Geol. Surv. Ind., 348-370.

[32] Murphy, S.F., Brantley, S.L., Blum, A.E., White, A.F. and Dong, H. (1998): Chemical weathering in a tropical watershed, Luquillo Mountains, Puerto Rico: II. Rate and mechanism of biotite weathering. Geochimica et Cosmochimica Acta, 62, 227-243.

[33] Nesbitt and Young, G.M. (1984): Prediction of some weathering trends of plutonic and volcanic rocks based on thermodynamic and kinetic considerations. Geochimica et Cosmochimica. Acta. 48(7), 1523-1534.

[34] Ollier, C.D. Seth, H.C. (2008): The high Deccan duricrusts of India and their significance for the “laterite” issue. Journal of Earth System Science, 117(5):537-551.

[35] Radhakrishna, B.P. (1968): Geomorphological approach to the charnockite problem. Jour. Geol. Soc. India 9, No. I, pp.67-74.

[36] Radhakrishna, B.P. (1983): Archaean granite-greenstone terrain of south Indian shield. In: Naqvi, S.M., Rogers, J.J.W. (Eds.), Precambrian of South India, vol.4. Geological Society of India, Memoir, pp.1-46.

[37] Raman, P.K. (1981): Geomorphic evolution and its significance in exploration planning of the east coast bauxite deposits of India. Jour. Geol. Sco of India, Vol.22, No. 10. pp. 488-495

[38] Russell, R.J. (1962): Origin of beach rock. Zeitschrift für Geomorphologie 6, 1-16.

[39] Sabot, J. (1954): Les laterites. In: C.R. 19th Congr. Int. Geol. Algr, ASGA, fasc. 21.

[40] Schellmann, W. (1982): Eine neue Laterite definition. Geologische Jahrbuch; D58, 31-47.

[41] Schellmann, W. (1986): A new definition of laterite. In: Banerji, P.K. (Ed.), Lateritisation Processes. Memoirs of the Geological Survey of India, 120, pp. 1-7.

[42] Schellmann, W. (2003): Discussion of ‘A critique of the Schellmann definition and classification of laterite’ by R.P. Bourman and C.D. Ollier (Catena 47, 117-131). Catena 52, 77-79.

[43] Sinha Roy, S. (1967): Origin of laterite: a review Jour. Min. Met. Fuel.15, pp.218-219.

[44] Summerfield, M.A. (1991): Global Geomorphology. Harlow: Longman

[45] Tardy, Y. (1992): Diversity and terminology of laterite profiles. Im Martini, I. P., Chesworth, W., (eds). Weathering, Soils and Plaeosols. Amsterdam: Elsevier, 379-405.

[46] Tardy, Y. (1993): Pétrologie des latérites et des soils tropicaux. Masson, Paris, France.

[47] Thomas, M.F. (1994): Geomorphology in the Tropics. A Study of Weathering and Denudation in Low Latitudes. Chichester: John Wiley.

[48] Widdowson, M. and Gunnell, Y. (2001): Laterites of the Konkan and Kanara coastal plateaux as keys to understanding the denudation chronology of the Western Ghats. In: Gunnell, Y. and Radhakrishna: B.P. (Eds.). Sahycidri, The Great Escarpment of the Indian Subcontinent. Geological Society of India, Bangalore,7 19-750.

[49] Woolnough, W. G. (1918): The physiographic significance of laterite in Western Australia. Geological Magazine, 5, 385-93

[50] Zalesskii, B. V. (1967): Physical and mechanical properties of rocks, Translated by IPST Staff, Russian Israel Programme for Scientific translation, Jerusalem.