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Laterite and Laterization - A Geomorphological Review

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Abstract: ***Laterite is a typical rock formation found commonly in the tropical monsoon regions as a capping over the hillocks. Laterites are residual sedimentary rocks, reddish or brownish coloured, comparatively soft rocks, containing high degree of porosity and are carrying vermiform structures. Laterite brick is generally red in color. In vernacular, it is called as "chenkallu". Laterite has immense economic value as it contains the ores of iron, aluminium and manganese. The origin of laterite is intimately connected with the physical, climatic and denudational processes of a particular region. The laterization process operates at well under warm and humid warm and tropical climates with seasonal rainfall. Though many hypotheses have been advanced by different geomorphologists, the origin of the laterite is as yet a much debated question. Present investigation is an attempt to analyse the empirical observations on Laterite and laterization from a geographical perspective.***

Keywords: Laterite, Laterization, Sedimentary Rocks, Monsoon Region, Denudation, Tropical Climate, Geomorphology

1. Introduction

Laterite occurs principally as a cap over the summits of Basaltic hills and plateaus and is the characteristic feature of tropical monsoon regions. Its geological nature was described only later by Francis Hamilton Buchanan, a medical officer of East India Company. From Angadipuram in Malappuram District of Kerala, he discovered a type of weathered material which was indurated clay, full of cavities and pores, containing large quantity of iron in the form of red and yellow ochre. It was soft when fresh and could be cut easily and when exposed, it became hard and resisted air and water much better than bricks (Buchanan 1807). He used the term laterite to designate this material (*laterite* in Latin means 'brick stone'). He defined it as "a residual product of weathering, rich in secondary oxides of iron and aluminum or both-nearly devoid of bases and primary silicates and commonly found with quartz and kaolin and developed in tropical or warm temperate climatic regions". These statements were the start of a tremendous number of studies of this strange material, hitherto resulting in more than 3000 publications. Above all geologists dealt at first with laterite but in later epochs also soil scientists, mineralogists, geographers, geomorphologists, mining and construction engineers participated in laterite research. The great interest of so many scientists with their different viewpoints did not only result in a great increase in literature as well as knowledge on the basic understanding and interpretation of laterite and laterization.

2. Studies on Laterites

The term laterite was originally suggested by Buchanan (1807) as a name for highly ferruginous deposits first observed in Malabar in India. Buchanan described a material that was soft enough to be cut with a knife when in situ but hardened on exposure; it was being quarried to make bricks, and he derived the term from the Latin word, a brick.. From Angadipuram in Malappuram District of Kerala. He coined the term laterite when he wrote (1807): "What I have called indurated clay …is one of the most valuable materials for building. It is diffused in immense masses, without any appearance of stratification and is placed over the granite that forms the basis of Malayala. It is full of cavities and pores, and contains a very large quantity of iron in the form of yellow and red ochres. In the mass, while excluded from the air, it is so soft, that any iron instrument readily cuts it, and is dug up in square masses with a pick-axe, and immediately cut into the shape wanted with a trowel, or large knife. It very soon after becomes as hard as brick, and resists the air and water much better than any brick that I have seen in India. … The most proper English name would be laterite, from lateritis, the appellation that may be given to it in science".

Great interest in the study of laterites developed because of the possible use of laterite as an ore for aluminium (Holland, 1903) and in some cases, for manganese. Fermor (1911) suggested the use of the term only for soft material that could be touting into bricks. Fox (1933) during his visit to Malabar reported that all the laterite occurrences seen by him in Malabar, Kanara and Shimoga were associated with granite rocks below them and could be taken as always having been formed from such acid rocks and passed down into them through a zone of Kaolinised rock. He has further reported that in the Nellore quarries laterite overlies gneissic rocks. Fox described two types of laterites in the Nellore area: first is in situ laterites quarried as building stone and the second is recent age laterites made up of pebble gravels, shining reddish brown in colour. Stephen (1961) revisited Buchanan's type site to find that the rock-like iron stone was being packed with pickaxes-not with knife. The property of hardening of such material on exposure to the atmosphere was for some time taken as a criterion of laterite.

Since laterite horizons are developed on almost all varieties of rock types including Precambrian crystalline and Cenozoic sedimentaries on the west coast, a proper description of laterites in terms of composition and texture appears to be very difficult. However the works such as

Stephens (1961), King (1962), Benjamin (1970)Thomas (1974) discusses the complex process of laterization and various factors affecting it. Twidale (1974) analyses the nature of laterization process in South Australia. Wadia (1975) opines Laterites as a typical surface formation in Monsoon regions. He classified laterite as 'high level and 'low level laterites. High level laterites never occur on situation below 2,000 ft. (Bombay, Deccan, Nilgiri mountains). He envisaged that low level laterites are in most cases of secondary origin and are derived from the high level laterites and recombined after deposition in the valleys or plains. Low level laterite is thus mainly of detrital origin. Raghavan Nambiar et al. (1979) have studied the geochemistry of laterization processes.

Narayanaswamy (1986) studied the distribution and properties of laterite in north Malabar especially in Kasaragod and Kannur districts. Santhosh and Omana (1991) conducted a detailed study on gold deposits of laterites in Nilambur region. Shobha and Anish (2003) examined the impact of environmental pollution on ground water in a lateritic region through a case study of industrial belt of Eloor- Kalamassery region. The works such as Narayanaswami (1994) Ollier (1995), Widdoson and Gunnel (1999), etc., tries to unravel the mysteries of laterite genesis in south india. Chandran (2005) studied the physical as well as chemical properties of laterite soil in detail with special reference to that of Kerala. The mineralogy and origin of laterites in Kerala are also studied in detail. Balakrishnan et al. (2010) perceived the ecological significance of lateritic mesas in the midland hillocks through a detailed observation of unique species of flora in Madayipara of Kannur district.

Ugbe (2011) stressed the geological properties of laterite and with its vivid engineering utilities. Lemougna et al (2011) studied the nature and physical properties of laterite and points its advantages as an ideal constructional material. Portelinha, (2012) examined the chemical properties of laterites and its viability as a pavement material for road construction. The hydrological characteristics of laterites are also studied in different dimensions. Alayaki (2012) studied the water holding capacity of laterites. The observations of Akhil et al. (2013) on ground water level in Kasaragod region is also to be noted here. Prasad and Parthasarathy (2015) have carried out a detailed analysis of laterites and its mining in midland hillocks of Kannur district in Kerala.

3. Characteristics of Laterite

Laterites are residual sedimentary rocks, reddish or brownish coloured, comparatively soft rocks, containing high degree of porosity and are carrying vermiform structures. The porosity is due to the in situ weathering of parent rocks. Laterite has the peculiar property of being soft when newly quarried, but being hard and compact on exposure to the air; also, loose fragments and pebbles of rock tend to re-cement themselves into solid masses as compact as the original rock. On account of this property it is usually cut in the form of bricks for building purposes. Laterite brick is generally red in color. It is porous and shows vermicular structure. In vernacular, it is called as *"chenkallu", "Ishtikkallu", "cheekkallu", "vettukallu"* etc.

Laterite Profiles

The general pattern of lateritic profile is similar at all locations, although the individual units of the profiles are not uniform. In the ascending order the parent rock passes through a zone of the partly altered bedrock, followed by a zone of lithomarge, blocky laterite and vermicular laterite. The vermicular laterite represents the uppermost zone of Laterization, which may or may not have a later formed cover of lateritic gravel and/ or a humus zone.

The laterite profiles show that its exposed layers are much harder than the sub surface layers. Two or three layers differing in their texture, physical properties and associations are usually found below the hard, indurated cap. Lateritic terrain may be subjected to problem like landslide and slumping. The role of ground water in such disturbances is found to be similar to that of catalytic agent. The reason for such forms of mass wasting is due to the excess accumulation of ground water in the pores of formation. The lubricating nature of the interface between permeable and impermeable beds might be causing gravity movement of overburden in the form of land sliding and consequent slumping.

Hydrological Properties

Laterite, apart from its use as a promising natural resource as building material, is also regarded to act as ground water recharging source because of its physical properties particularly porosity. Laterite constitutes one of the important hydrological provinces in Kerala, as it holds roughly 55% of the total dynamic ground water storage. The laterite terrain receives heavy rainfall during every monsoon season and is getting recharged year after year. The high porosity of it enhances quick infiltration of rain water. The peculiar vesicular structure is a favourable factor in the vertical infiltration of rain water to join ground water reserve. But the lithomargic clay occurring in between lateritic cap and underlying weathered bedrocks has a low permeability and prevents easy downward movement. This may facilitate retention of water in the pores of laterite for a long period. The ground water condition of laterite is always in a dynamic state due to fluctuations of water table.

Economic Value

Laterite has immense economic value as it contains the ores of iron, aluminium and manganese. The use of laterite as an ore of iron is of very old standing, but its recognition as a source of aluminium is due to the work of Holland and of manganese to the work of Fermor. Contents of gold placer deposits are found in Nilambur valley of Malappuram district in Kerala (Narayanaswamy, 2004). In several parts of southern India and Burma laterite is quarried for use as a building stone. Laterite soils are very poor in lime and magnesia and deficient in nitrogen. Occasionally the phosphate content may be high, probably present in the form of iron phosphate but potash is deficient. There is occasionally a higher content of humus.

Laterites are best developed in the Western Ghats and its foothills. The thickness of lateritic cap varies from few feets to 50 meters. It is the characteristic feature of midland hillocks of north Malabar region of Kerala. Laterite bricks are most ideal for building purposes. In the areas of extensive laterite formations, its mining has emerged as a major economic activity of the local people with multi-faceted effects on socio-economic set up of these regions.

Geomorphology of Lateritic Landscape

Laterite cappings are generally found as isolated but extensive plateaus or as *mesas*. Lateritic cappings over the erosional surface has played a significant role on the denudational processes. The top surfaces are flat to gently rolling with centripetal slope and no significant drainage line and the river valleys that normally follow the lineaments cutting across the laterite are narrow, steep sided but flat bottomed. The erosional intensity on these hard crust duricrusts is comparatively less. The process of valley formation in the laterite mesa region conforms more to the scarp retreat or pediplanation than peneplanation (Narayanaswamy and Chattopadyay, 1996). Although the humid tropics are mainly dominated by peneplanation process the occurrence of hard crust laterites and consequent edaphic arid situation has been conducive for scarp retreat. Moreover, soft clay layer underneath the hard laterites provides favourable condition for lateral widening of stream valleys and scarp retreat. Headward erosion of certain streams is another factor in shaping the mesas (Chattopadyay, 2004). Similar landscape features are also reported in the lateritic terrain of Australia also (Twidale, 1984)

Types of Laterites

On the basis of nature of gradational process leading to the origin of laterite it is classified into two groups: Primary and Secondary laterites (Thomas Varghese and Byju, 1993). Primary laterites are formed by aerial weathering and are known as residual laterite whereas Secondary laterite or detrital laterite is formed by partial or complete consolidation of lateritic material.

Based on altitudes laterite has been classified as low level laterite and high level laterite (Wadia, 1975). High level laterites are those that occur on situations above 600 m. above sea-level. The rock characteristic of these occurrences is of massive homogeneous grain and of uniform composition. The low-level laterite occurs on the coastal lowlands. Low level laterite differs from the high-level rock in being much more massive and in being of detrital origin, from its being formed of the products of mechanical disintegration of the high-level laterite.

Young (1976) anlysed the physical properties of laterite and has distinguished the following five main types and sub-divisions of laterite:

1) Massive laterite: possesses a continuous hard fabric, sub-divided into:
- Cellular laterite – cavities are approximately rounded.
- Vesicular laterite – cavities are predominantly tubular.

2) Nodular laterite: consists of individual approximately rounded concretions (also called pisolithic laterite) sub-divided into:
- Cemented nodular laterite – individual concretions can be seen but are strongly joined together by the same iron-stone material.
- Partly cemented nodular laterite.
- Non-cemented nodular laterite – concretions from over 60 percent by weight of the total soil.
- Iron concretions – concretions are separated by soil but form less than 60% by weight of the total horizon.

3) Re-cemented laterite: contains fragments of massive laterite and wholly or partly cemented.
4) Ferruginized laterite: rock structure is still visible but with substantial isomorphous replacement by iron.
5) Soft laterite: mottled iron-rich clay which hardens irreversibly on exposure to air or to repeated wetting and drying.

Laterite Genesis (Laterization)

Laterization is the process of transformation of an existing rock into laterite. Laterite genesis is one of the most debated areas in geomorphology. A variety of ideas are prevailing on the Laterization process and even today a conclusive explanation on laterite genesis is lacking. One source of difficulty lies in the chemical and segregative changes which are constantly going on in the rock and which obliterate the previously acquired structures and produce a fresh arrangement of the constituents of the rock. It is probable that laterites of all the different places have not had one common origin and that widely divergent views are possible for the origins of the different varieties.

The different interpretations of laterite became occasionally rather exotic because of the conflicting laterite aspects and designations. Even nowadays the differences are not wholly overcome but in the last decades many studies contributed to a better and undivided understanding. Thus the International Geological Cooperation Programme No.129 "*Lateritisation Processes*" which was sponsored 1975-1983 by UNESCO and the Union of Geological Sciences accelerated laterite research in all parts of the world. "*Eurolat*" was started 1984 by French geoscientists as "*European Network on Tropical Laterites*". Moreover, an "*International Interdisciplinary Laterite Reference Collection*" was established at the "International Soil Reference and Information Centre (ISRIC)" at Wageningen, the Netherlands.

From its vesicular structure and its frequent association with basalts, it was at first thought to be a volcanic rock. Its sub-aerial nature was however soon recognized beyond doubt and later on it was thought to an ordinary sedimentary formation deposited either in running water or in lakes and depressions on the surface of the traps. Still later views regard the rock as the result of the subaerial decomposition in situ of basalt and other aluminous rocks under a warm, humid and monsoonic climate.

The origin of laterite is intimately connected with the physical, climatic and denudational processes of a particular region. Laterite can be formed from any type of rock. Laterite provides important information on tropical weathering process by which alkali and alkaline earth metals and silica are leached leading to the enrichment of either iron or aluminium or both.

Maclaren (1906) explains that laterite deposits are formed due to the metasomatic replacement (in some cases the mechanical replacement) of the soil or subsoil by the agency of mineralized solutions, brought up by the underground percolating waters ascending by capillary action to the superficial zone. He concludes that laterites are essentially replacement deposits. According to Martin and Doyne (1927), laterite is a typical tropical weathering product of intensive in situ weathering of surfacial rocks. Marbut (1932) suggested that the laterite zone is considered proportional to the zone of fluctuation of the water table, which also upholds the idea that laterite is an *in situ* weathering product.

Wadia (1975) stated that the laterite distribution is restricted mainly to Koeppen's 'A' climatic zone, extending from 30 ^{o} N to 30 ^{o} S latitudes. Major part of Indian peninsula lies within this zone, which also enjoys typical monsoon climate with alternative wetting and drying conditions. Laterite is a residuum, being formed by physico-chemical weathering that leads to the concentration of iron and aluminum oxides and to the removal of silica and alkalis. Favourable weathering conditions needed for the in situ development of laterites are available in tropical regions with monsoon climate where the temperature and rainfall are the highest and with maximum seasonal contrasts. Invariably all rock types under such weathering conditions ultimately give rise to laterite residuum.

McFarlane (1976) viewed that the laterites are essentially residual accumulations of chemically resistant materials. Laterites are the result of the sub-aerial decomposition in situ of rocks under a warm, humid and monsoonic climate. Under such conditions of climate the decomposition of the silicates, especially the aluminous silicates of crystalline rocks, goes a step further and instead of kaolin being the final product of decomposition, it is further broken up into silica and the hydrated oxide of aluminium (bauxite). The silica is removed in solution and the salts of alkalis and alkaline earths are dissolved away by the percolating water. The remaining alumina and iron oxides become more and more concentrated and become mechanically mixed with other products liberated in the process of decomposition. The vesicular or porous structure, occurs among the products left behind. Removal of top soil (alkaline upper horizon) creates an acidic environment which further accelerates the laterization process. McFarlane (1976) envisaged that laterization process had remained suspended temporarily during the glacial episodes of Pleistocene period due to the unfavourable climate but had resumed during the interglacial periods.

The role of climate regional topography in the laterization process is very significant. Mabutt (1961) stated that pedimented surfaces which typically comprise the low amplitude topography charecterised by sheet flow, sluggish drainage and very slow rate of erosion but are often associated with deep weathering cause widespread laterization. The laterization process operates at well under warm and humid warm and tropical climates with seasonal rainfall (Widdowson and Gunnel,1999). They argued that the west coast laterite of the country are developed from the prolonged alteration of exposed pedimented surfaces, resulting from the recession of Western Ghat escarpment, when climatic and tectonic conditions favourable to deep weathering reached an acme. They uphold the requirement of hot and humid tropical climate with good rainfall and seasonal contrasts for the effective laterization and envisaged that the laterization processes along the west coast intensified after the inception of present monsoon climate, after late Miocene.

4. Conclusion

Laterites are the products of intensive and long lasting tropical rock weathering which is intensified by high and seasonal rainfall; and elevated temperatures. From the highly variable nature of this peculiar rock, it is possible that every one of the above discussed factors may have operated in the production of the laterites of different parts according to particular local conditions. Laterite rocks, besides are subject to secondary changes, a fact which introduces further complexity. Under conditions of free drainage and high rainfall the laterite may accumulate without much further change, the soluble products of hydrolysis being rapidly lost by leaching. On the other hand, under impeded drainage conditions and alterations of wet and dry seasons, the fluctuating ground water, carrying dissolved silica and bases, may effect a complete change in the laterite. Laterite provides important information on tropical weathering process. The principal effects of the various factors on laterite formation are well known but it is difficult to determine them in space and time in the field. At present geographical discourses on laterites are highly inadequate. It is hoped that present attempt can be a spark for further investigations in these dimensions.

References

[1] Akhil, P. S. et al. 2013, Groundwater Hydrochemistry In The Crystalline Laterites/Forest Loams Of Kasargod District, Kerala, India, Water Science & Technology: Water Supply, Vol. 13, No. 2, pp. 486-494

[2] Balakrishnan, V.C., et al. 2010, Observations On The Flora Of Madayipara, A Midland Laterite Hill In Kannur District, Kerala, Malabar Trogon, Vol. 8 (2&3), pp. 14-20

[3] Benjamin, S. Persons 1970, Laterite Genesis, Location, Use, Plenum Press, New York, pp. 38-49

[4] Buchanan, F. 1801, A Journey From Madras Through The Countries Of Mysore, Canara And Malabar, East-India CO. London.Vol. 2, pp. 436-460,

[5] Byju and Thomas Varghese 2001, Soil Acidity Parameters Of Laterite Soils Under Rubber, Journal of Tropical Agriculture, 39 pp.120-123

[6] Chandran, P. et al. 2005, Lateritic Soils Of Kerala, India: Their Mineralogy, Genesis, And Taxonomy, Australian Journal of Soil Research, 43, pp. 839-852

[7] Chatopadhyay, Srikumar and Mahamaya Chatopadhyay 1998, Terrain Analysis Of Kerala- Concept, Methods And Application, State Committee On Science Technology And Environment, Govt. Of Kerala, Thiruvananthapuram

[8] Chattopadhyay, Srikumar 2004, Land Forms Of Kerala- An Overview. In Ravindrkumar, G.R. (Ed.), Earth System Science And Natural Rsource Management, Silver Jugilee Compendium, CESS, Thiruvananthapuram

[9] Daly, B, Twidale, C. R. and Milnes A. R. 1974, The Age Of The Lateritized Summit Surface On Kangaroo

Island And Adjacent Areas Of South Australia, J. Geol. Soc. Austr. 2, pp. 387–392
[10] Darwin, C. R. 1844, Geological Observations On The Volcanic Islands And Parts Of South America Visited During The Voyage Of H.M.S. Beagle, Smith, Elder and co., London, 2nd edition, pp. 647
[11] De, N. K. and Ananya Tharaphder 2003, Land Degradation And Human Action, A Case Study Of Bardhwan. In Jhah V. C. (Ed.), Land Degradation And Desertification, Rawat pub. Jaipur, pp 197-208
[12] Fermor, L. L. 1911, What Is Laterite? Geol. Magazine, 48, pp. 454- 468, 507-516
[13] Fox, C.S. 1936, Laterite, Geol. Magazine, 70, p.558
[14] Holland, T. H., 1903, The Constitution, Origin And Dehydration Of Laterite, Geo. Mag, 10, p.59
[15] Kasthurba. A. K 2012, Characteristics of Malabar Laterite as a Building Material Field and Laboratory Studies International Journal of Earth science and Engeneering June 2012, P.P. 518-523
[16] Mabutt, J.A. 1961, A Stripped Land Surface In Western Australia, Trans. Inst. Br. Geor. 29, pp.101-114.
[17] Maclaren, M. 1906, On The Origin Of Laterites, Geol. Mag. 43, pp. 536-547
[18] Maignien, R. 1966, Review Of Research On Laterites, UNESCO, Natural Resources Research, Se. IV., Paris
[19] Marbut, C.F. 1932, The Soils Of The Amazone Basin In Relation To Agricultural Possibilities, Geogrl. Rev. 16, pp. 414-442
[20] Marsh, W.M. 1991, Landscape Planning: Environmental Applications, 2nd edition, John Wiley, New York
[21] Martin, F.J. and Doyne, H.C. 1927, Laterite And Lateritic Soils In Sierra Leone. J. Agricu. Sci. 17, pp. 530-547
[22] Mc Farlane, M. J. 1976, Laterite And Landscape, Academic Press, London, New York, pp. pp. 12-34
[23] Nair, G.S. et al 1981, Laterites In Polluted Environments Of Kerala, Proc. Seminar On Status Of Environmental. Studies In India, pp. 372-380
[24] Nair, N.G.K., Santhosh, M. and Mahadeven, R. 1987, Laterization As A Possible Contributor To Gold Placers In Nilambur Valley, South West India, Chemical Geology, 60 Elsevier Science Pub. B.V., Amsterdam, pp.309-315.
[25] Narayanaswamy and
[26] Swapan, K. Ghosh 1986, Laterization Of Gabro-Granophyre Rock Units Of Ezhimala Complex Of North Kerala, India, Chemical Geology, 60, Elsevier Science Pub. B.V., Amsterdam, pp. 251-257
[27] Narayanaswamy 2004, Geological Significance And Significance Of Laterites Of Kerala With Special References To Laterite Gold Occurrence. In Nilambur Valley. In Ravindra Kumar, et al., (Ed.), Earth System Science And Natural Resource Management, Silver Jubilee Compadium, CESS, Thiruvananthapuram
[28] Narayanaswamy and Srikumar Chattopadyay 1996, Lateritic Landscapes In Kannur District In Kerala, Annals Of The National Association Of Geographers India , Vol. XVI, No. 2
[29] Ollier, C. D. 1991, Laterite Profiles, Ferricrete And Landscape Evolution; Z. Geomorph., N.F. 35, pp. 165-173.
[30] Ollier, C. D. 1995, New Concepts Of Laterite Formation, Geol. Soc. India Memoir, 32, pp. 309–323.
[31] Ollier, C. D. and Rajaguru, S. N. 1989, Laterite Of Kerala (India), Geogr. Fis. Din. Quat. 12, pp.27–33.
[32] Omana, P.K. and Santhosh, M. 1995, Gold In Laterites: A Challenging Prospect In Gondwana Terranes. In: Yoshda et al. (Ed.), Gondwana Research Group, Memoir No.2, pp. 159-168
[33] Portelinha, F.H.M. 2012, Modification Of A Lateritic Soil With Lime And Cement: An Economical Alternative For Flexible Pavement Layers, Soils And Rocks, Sao Paulo, 35(1), pp. 51-63
[34] Prasad T.K 2013, Changing land use pattern of Kannur District in Kerala with Special reference to Laterite mining, Unpublished PhD thesis, MKU
[35] Raghavan Nambiar et al. 1979, Laterisation Of Anorthocite, Gabro, Granophyre And Charnokite- A Case Study From Kerala. Proc. Int. Sem. on Laterization Processes, Oxford and IBH Pub, New Delhi, pp. 129-138
[36] Ranade, P. 2007, Environmental Impact Assesment Of Land Use Planning Around The Leased Lime Stone Mine Using Remote Sensing Technique, Iranean Journal Of Environmental Health, Science And Engeneering, Vol. 4, No.1, pp. 61-65
[37] Rao, Raja C. S. 1984, The Geological Controls For Formation Of Laterite In Western Maharashtra. In Prakash, B. Et Al, (Ed), Proc. Symp. On Deccan Trap And Bauxite Geol. Survey India Spec. Publ., 14, pp. 262–265
[38] Sangeeth, P.V. 2004, Land Use Land Cover Change And Its Impact On The Bio-Physical Environment- A Case Study In Chalakudy River Basin, Unpublished Ph. D. Thesis, Kalady University
[39] Santhosh, M. And Omana, P. K. 1991, Very High Purity Gold From Lateritic Weathering Profiles Of Nilambur, Southern India. Geology, 19, pp. 746-749
[40] Schellmann W 2009, An Introduction to Laterite, Products and Processes of intensive rock weathering .pp 1-9
[41] Soman, K. 2002, Geology Of Kerala, Geol. Soc. India, Bangalore, pp. 6-29
[42] Sombrock, W.G. 1971, Ancient Levels Of Plinthisation In N.W. Nigeria. In Yaalon, D. H. (Ed.), Paleopedology: Origin Nature And Dating Of Paleosols, pp. 329-336
[43] Stephens C. G. 1961, Laterite And The Type Locality, Angadipuram, Kerala, India J. Soi1 Sci. 12, pp. 214-17.
[44] Thomas, M.F. 1974, Tropical Geomorphology, Focal Problem. Geography, Macmillan, London, p.332
[45] Thomas Varghese and Byju, G. 1993, Laterite Soils- Their Distribution, Charecteristics, Classification And Management, Technical Monograph1, SCSTE, Govt. Of Kerala, Thiruvananthapuram.
[46] Twidale, C. R. et al. 1974, The Age Of The Lateritized Summit Surface Of Kangaroo Island And Adjascent Areas Of South Australis, J. Geol. Soc. Austr., 21, pp. 387-392
[47] Ugbe, F.C. 2011, Basic Engineering Geological Properties Of Lateritic Soils From Western Niger Delta, Environmental And Earth Sciences 3(5), pp. 571-577
[48] Widdowson, M. and Cox, K. G. 1996, Uplift And Erosional History Of The Deccan Traps, India:

Evidence From Laterites And Drainage Patterns Of The Western Ghats And Konkan Coast, Earth Planet. Sci. Lett., 137, pp. 57–69

[49] Widdowson, M. and Gunnell, Y. 1999, Lateritization, Geomorphology And Geodynamics Of A Passive Continental Margin: The Konkan And Kanara Coastal Lowlands Of Western Peninsular India; Spec. Publ. Int. Assoc. Sediment., p. 27

[50] Young, Anthony 1976, Tropical Soils And Soi1 Survey, Cambridge Geographical Studies, No. 9, Cambridge University Press, Cambridge, London, New York, Melbourne, pp. 1-468