OUTREACH Volume IX 2016 307 – 313
A Multi - Disciplinary Refereed Journal
ISSN (Print) : 0975 1246
ISSN (Online) : 2321 8835
www.voreoutreach.in

Major element geochemistry and depositional environment of Regolith calcrete deposit of Nedungkulam village, near Sathankulam area Tuticorin district, Tamilnadu, India

Perumal V, Udayanapillai A.V, PG Studies and Research Department of Geology, V.O.Chidambaram College, Tuticorin, e-mail: geo6perumal@gmail.com

John S. Armstrong-Altrin, Unidad de Process Oceanicosy Costeros, Instituto de Ciencias del Mary Limnologia, Universidad Nacional Autonoma de Mexico, Circuito Exterior s/n, 04510 Mexico D.F., Mexico.

Satyanarayanan M, CSIR-National Geophysical and Research Institute, Uppal Road, Hyderabad 500007, India.

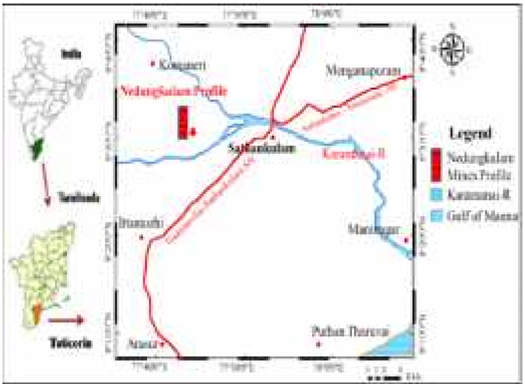
Abstract

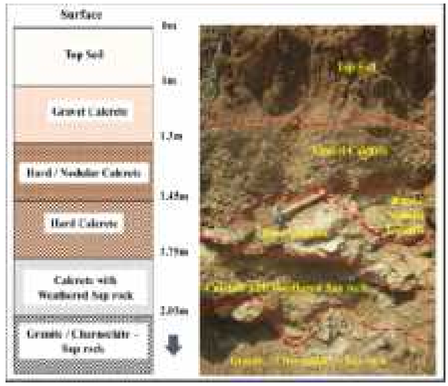
Calcrete is widespread in the regolith profile part of metamorphic basements at Nedungulam village mine section near Sathankulam area, Tuticorin district tamilnadu. The general Stratigraphic succession of the study area and regolith calcrete profile section of the site is given. The field observation proves that the calcrete appear as gravel or granular, oolitic, nodular, laminated and lumpy forms. The major element geochemistry of calcrete profile indicate that CaO, MgO, SiO_2, Al_2O_3 and Fe_2O_3 are in higher concentration above 1% than the other oxides. The major element geochemistry of calcrete deposits are discussed to understand the geochemical implications and depositional environment of the study area.

Keywords: *Regolith, Field observation, Major element geochemistry, Geochemical implication, Depositional environment.*

1. Introduction

Regolith deposit includes palaeosol, weathered rock fragments and calcrete. They are used as signature of semi-arid to arid climate (*Achyuthan et al., 2010; Udayanapillai et al., 2014*). The sources of alkaline rich ground water, rate of evaporation and evapotranspiration in regolith, rainfall, temperature and mode of formation are the important factors for the formation of calcrete (*Soloman et al., 1978*). Calcrete is widespread in the regolith part of metamorphic terrains of Sathankulam region. It also occurs as sub-aerial duri crust exposure after erosion in the river basin and lake basin in the study area. But no much research work has been carried out on regolith calcrete deposits of Nedungulam village of Sathankulam region in Tuticorin district ***(figure, 1).***





Figure, 1. *Location map of the study area.* ***Figure, 2.*** *The regolith profile section of calcrete in Nedungulam granite mines section*

2. Geological setting

The topography of the study area is almost flat and plain with average rainfall of 700 mm. Proterozoic rocks of Calc-granulite, Crystalline limestone, Khondalite, Charnockite and Granite occur as basement rocks. These hard metamorphic rocks are overlain by surface outcrops of black soil, and sand loamy soil. In between black soil, sand loamy soil and metamorphic basement rock, calcrete is developed for a thickness of 1.20 m at the selected site. The general stratigraphic succession is given in ***(table, 1).***

Table, 1. *The general stratigraphy of the study area*

Depth	**Lithology**	**Age**
From 0 -1 m	Black soil and sandy loom soil	Recent
From 1- 4 m	Calcrete	Holocene-Pleistocene?
From above 4 m	Granite, Charnockite, Khondalite, Calc-granulite and Crystalline limestone	Proterozoic

3. Research methodology

Six calcrete samples were collected from Nedungulam regolith profile section of metamorphic terrains of the study area at different depth from top to bottom section. (N8.431, E77.797). These samples are subjected to major element geochemical analysis at XRF laboratory of NGRI, Hyderabad. While collecting the samples, nature of the calcrete deposit is observed from the field. The Total Carbonate (TCO_3) of calcrete is estimated by titration method (Piper 1947).

4. Field observation

Calcrete occur as granular or gravel layer at the top section, whereas the bottom section shows alternate layers of massive, laminated, oolitic, nodular, hard pan calcrete and chalky nature above the metamorphic basement. Such regolith calcretes are widespread in many areas of arid and semi-arid region and its distribution is largely controlled by degree of carbonate and availability of carbonate sources in the Pandalgudi region (*Udayanapillai and Thirugnana Sambandam, 2012*).

5. Distribution of Major Element Geochemistry of Calcrete profile

The major element geochemistry of regolith calcrete profile samples from Nedungulam village are given in (***table, 2***). The average distribution of major element geochemistry of calcrete indicate CaO, MgO, SiO_2, Al_2O_3, Fe_2O_3 and TCO_3 are in higher concentration above 1% than the other oxides, such as MnO, Na_2O, K_2O, TiO_2 and P_2O_5.

Table, 2. *The major element geochemistry of regolith calcrete profile samples of Nedungkulam mine from top (1) to bottom (6) section. (Values in Percentage)*

S.NO	Name of the Samples	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI	TCO_3
1	**NK Sample 1**	44.54	19.71	15.40	0.16	2.07	10.38	2.62	1.37	2.10	0.03	1.62	43.50
2	**NK Sample 2**	25.31	9.63	4.04	0.36	2.18	35.61	1.79	0.80	0.58	0.06	19.64	68.30
3	**NK Sample 3**	21.72	8.21	3.64	0.73	2.44	38.13	1.36	0.66	0.27	0.08	22.76	73.40
4	**NK Sample 4**	27.75	10.09	3.60	0.16	2.92	34.70	2.64	1.00	0.40	0.04	16.70	70.20
5	**NK Sample 5**	43.47	13.26	5.22	0.24	3.94	18.78	8.80	1.37	0.63	0.05	4.24	48.70
6	**NK Sample 6**	66.47	13.70	1.39	0.07	0.95	9.14	2.44	4.45	0.18	0.04	1.17	36.30
7	**NK profile avg**	**38.21**	**12.43**	**5.55**	**0.29**	**2.42**	**24.46**	**3.28**	**1.61**	**0.69**	**0.05**	**11.02**	**56.73**

6. Major element geochemical observation in profile section

The proportion of carbonate generally varies with pure carbonate (calcite) to low magnesium carbonate (low dolo-calcite) from the study area. The high Mg content in the samples may be due to the change in pH, pCO_2 and landscape settings (*Hill et al., 1999*).

The groundwater movement along the bed rock and alluvium boundary in deeper pedogenic calcrete profile may reflect high magnesium content in carbonate genesis (*Queen, 2006*). But in the study area, all the samples show more calcium carbonate content than the magnesium.

This indicate more evapotranspiration processes prevailing in the study area which implies the arid environment. The distribution of K and Al reflect the clay mineral impurities. All the samples of the study area show more montmorillonite, illite and kaoline composition. The iron oxide (Fe_2O_3) shows high degree of negative relation (r = - 0.68) with CaO which indicates that it is not significally present in carbonate phase. But the iron oxide, oxy-hydroxide impurities and blue -

green algal mats from soil may contribute iron content to the calcrete (*Queen, 2006, Paul Grevenitz, 2006*). The clay mineral sesquioxide may be due to the water logging within calcrete which may cause for the mobility of ferrous ion (*Queen, 2006; Udayanapillai et al., 2014, 2016*). The relation of Fe_2O_3 and Al_2O_3 shows high degree positive correlation (r = 0.85) in the study area. This may be due to the preservation of sesquioxide mineral (Fe_2O_3, Al_2O_3) in the calcrete samples of the study area. Such similar observations have also been reported in the Coimbatore and Pandalgudi region (Viruthunagar district), (*Hema Achyuthan, 2004, Udayanapillai et al., 2014*). The presence of silica concentration may be due to the unaltered detrital quartz and felspar grain in the soil profile. The other oxides MnO, Na_2O, TiO_2 and P_2O_5 in calcrete are less significance in geochemical interpretation of the study area due to its less amount of lithogenic concentration in calcrete. In general, the groundwater and surface water composition was controlled to a large extent by calc-alkaline and per-alkaline compositional water derived from Proterozoic basement rocks and pedogenic leaching of surface water from black soil and sandy loamy soil.

7. Depositional environment of calcrete through major element geochemistry

Calcrete genesis is different from other sedimentary rock. The dissolution and precipitation of $CaCO_3$ in the regolith part are expressed by the following reactions.

$$CaCO_3+H_2O+CO_2 \leftrightarrow CO_2+2HCO_3^-$$

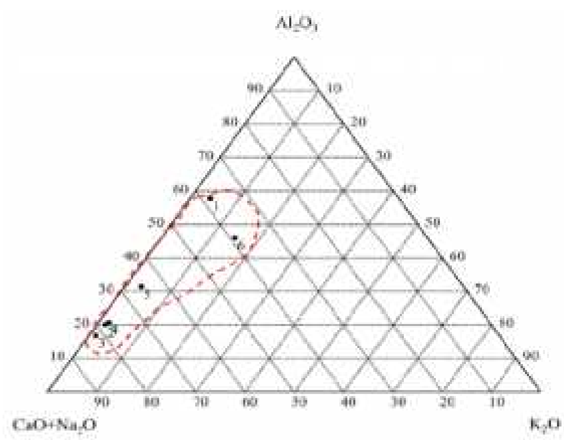
Where CO_2 plays the major role in controlling carbonate dissolution and precipitation from the source rock under arid and semi-arid climatic condition (*Ersel Goz et al., 2014).* Calc-alkaline and Per-alkaline compositional nature of source rocks in the study area causes for the formation of calcrete in the regolith part under arid and semi-arid climatic condition (*Udayana pillai et al., 2014, 2016*). The major element geochemistry of regolith profile samples of Nedungulam section illustrate the properties of CIA, Salinization, Calcification, Clayness, Base loss and Gleization, related with palaeosol. Chemical Index of Alteration (CIA) helps to measure the rate of weathering of the palaeosol. It is measured by formula proposed by *Nesbit and Young (1982).*

$$CIA = Al_2O_3/ (Al_2O_3+CaO+Na_2O+K_2O)*100$$

Where CaO represents the calcium in silicate fraction only. The CIA calues of palaeosols and calcreate profile section at Nedungulam sample shows the values from 20.13 to 57%. Another measure for the chemical index of alteration is CIA-K which omits the K in addition. Considering 50 as CIA and CIA-K standard for palaeosols, the studied top palaeosol samples (values-57) greater than 50%, implies a high degree of chemical weathering for palaeosols. Weathering trends of study area are being displayed on as Al_2O_3-CaO+Na_2O-K_2O (A-CN-K) triangular plot of *Nesbitt and young (1989)*. The regolith profile of the study area show a weathering trend line (***figure, 6***) slightly parallel to the CN-A side of the diagram with a small deviation towards the loss of K. This implies the very early stage of diagenesis.

Figure, 6. *(A-CN-K) triangular plot (after Nesbitt and Young, 1989) in Nedungkulam regolith profile*

Ceren Kucukuysal and Selim Kapur, (2014) discussed depositional process of Salinization, Calcification, Clayness, Base loss and Gleization in the regolith calcrete profile. The process of increasing salt content in soil profile is called Salinization. The geochemical characteristics of pedogenic calcrete can be employed as an important proxy revealing the climate history of the soil. Salinization would reflect the preferential removal of Na_2O relative to K_2O (Na_2O/K_2O ratio) in the soil horizon. The salinization ratio ranges from 0.5 to 2.64‰ in the Nedungulam profile. Salinization of the profile samples shows the value of above 1. The salinization for the aridity climatic condition should be greater than 1. The uniformity in the salinization data above 1 value in the profile supports more evident for the aridity climatic condition. Calcification is reflected by $CaO+MgO/Al_2O_3$ ratio in the profile section. In Nedungulam profile, calcification has a value from 0.63 to 10.16. The overall calcification process is high throughout the section, which reflects evaporation and evapotranspiration process actively involved in the regolith part. Clayness is illustrated with the results of Al_2O_3/SiO_2 ratio. The clayness value of Nedungulam profile sample shows the values from 0.21 and to 0.44. In general, clayness is more in the top soil part and is low and relatively uniform throughout calcrete profile of the study area. Base loss is illustrated with the result of $Al_2O_3/(CaO+MgO+Na_2O+K_2O)$. The base loss values of Nedungulam profile samples show the values from 0.19 to 1.20. The relative base loss



verses depth reflects the removal of mobile cations from the surface horizon and accumulation at depth. Relative base loss values from Nedungulam profile section ranges from 0.19 to 1.28 which documents the medium to high weathering of palaeosol and leaching of carbonate throughout the section. Gleization character is established by Fe_2O_3/Fe_2O_3 ratio. It is s pedogenic process associated with poor drainage. This process involves the accumulation of organic matter in the upper layers of the soil. In lower horizon, mineral layer are stained as blue grey, because of the chemical reduction of iron. The Gleization (Fe_2O_3) values in the Nedungulam profile shows the value from 3.6% to 15.4%. It shows more in top pedogenic part (15.4%) than the bottom calcrete horizon.

8. Conclusion

1, Calcrete appear as gravel (or) granular, nodular, oolitic, laminated lumpy and powder form in the field.

2, Major element geochemistry of calcrete indicates CaO, MgO, SiO_2, Al_2O_3 and Fe_2O_3 are in higher content than the other oxides.

3, Major element geochemistry illustrates weathering, aridity, evaporation, evapotranspiration activity and climatic condition of the regolith deposit.

Reference

Ceren Kucukuysal and Selim Kapur, (2014). Mineralogical, geochemical and micro morphological Evaluation of the Plio-Quaternary paleosols and calcretes from Karahamzal, Ankara (Central Turkey). *Geologica Carpathica*, Vol. 65, No. 3, pp. 241-253.

Ersel Goz, Selahattin Kadir, Ali Gurel and Muhsin Eren (2014). Geology, Mineralogy, Geochemistry and depositional environment of Late Miocene /Pliocene fluvio lacustrine succession, Cappadocian Volcanic Provenance, Central Anatolia, Turkey. Turkish. *J. Earth Sci*, Vol. 23, pp.386-411.

Hema Achyuthan (2004). Palaeo-pedology of the soils around Chennai, Tamilnadu, India. *Revista Mexicana de Ciencias Geologicas,* Vol. 21(1), 133-143.

Hema Achyuthan, Flora O, Braida M, Navin Shankar and Stenni B (2010). “Radiocarbon ages of pedogenic carbonate nodules from Coimbatore region, Tamil Nadu”. *Journal Geological Society of India*, Vol. 75, pp.791-798.

Hill S.M, Queen M.C and Foster K.A. (1999). “Regolith carbonates accumulation in Western and Central NSW; Characteristics and Potential as an Exploration sampling medium”. In; Taylor G.M and Pain C. F. eds. State of Regolith, Proc. of Regolith 98, pp.191-208, CRC LEME, Persth.

Mc Queen K.G (2006). "Calcrete geochemistry in the Cobar-Girilambone region, New South Wales". CRC LEME Open File Report 200, pp. 1-27.

Nesbitt, H. W. and Young, G. M. (1984). **"**Early Proterozoic climates and plate motions inferred from major dement chemistry of lutites", *Nature*, Vol-299, pp.715-717.

Paul Grevenitz and Allan Chivas R. (2006). Statistical methods for determining Geochemical Residence in mineral phases: Evolution of pedogenic calcrete Trace Element Data, Regolith 2005 –Ten years report of CRC LEME, pp.120-124.

Piper, C.S. (1947). **"**Soil and Plant analysis". *Inter Science*, New York. pp.368.

Solomon W, Goudie A and Mook W.G (1978). "Isotope composition of calcrete deposits from Europe, Africa and India". *Earth Surface Processes*, Vol.3, pp.43-57.

Udayanapillai A.V, Thirugnanasambandam R, Venkataraman P, Thangavel M, Kaliammal M, *Perumal V* and Amar Kumar Dash (2014). "GIS based evaluation of major element geochemistry of calcrete deposit in and around Sivalarpatti village, near Pandalgudi, Virudhunagar District, Tamilnadu, India". *Outreach Journal*, Vol. VII, pp.136-141.

Udayanapillai A.V, Thirugnanasambandam R, Venkataraman.P, Jayaranjeetham.J and

Perumal V, (2012). "Petro-mineralogy and major element geochemistry of calcrete deposits at Maravarperungudi Village near Pandalgudi area, Virudhunagar District, Tamilnadu, India". *Outreach Journal*, Vol. V, pp.123-128.

Udayanapillai A.V, *Perumal V*, John S. Armstrong-Altrin and Satyanarayanan M. (2016). "Petro-Mineralogy and GIS based Evaluation of Major Element Geochemistry of Calcrete Deposits in and around Sathankulam, Tuticorin District, Southern Tamilnadu, India". *Journal of Geoscience Research* (JGSR). Vol.1, No.2, pp.111-118.