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Clay mineralogy of soils formed from various parent materials of Anantapuramu district in Andhra Pradesh

G. SASHIKALA[1], K.V. RAMANA[2]AND M.V.S. NAIDU*

Department of Soil Science and Agricultural Chemistry, S.V. Agricultural College,Acharya N.G. Ranga
Agricultural University, Tirupati, 517502, Andhra Pradesh

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ABSTRACT

Identification and semi-quantification of clay minerals is essential for evaluatingphysical and chemical properties of soils formed from various parent materials. Mineralogy of clay fractions in soils of Tatrakallu(Anantapuramu) developed from granite-gneiss and limestone parent materialswas studied by X- ray diffraction (XRD) analysis during 2018. The clay fraction of these soils invariably exhibited the characteristic peaks of kaolinite, smectite and illite. Semi-quantification of clay fractions based on relative areas under corresponding peaks indicated that the pedons 1 and 3 were dominated by kaolinite followed by smectite and illite. Pedons 2,4,5 and 6 were dominated by smectite followed by kaolinite and illite.Semi-quantification of X-RD peaks of clay fractions revealed that smectite ranged from 30 to 84 %, kaolinite from 16 to 66 % and illite from traces to 27 % in these pedons. The formation of smectite suggests that these soils were formed through a progressive landscape reduction process and appears to be under basic environment.Kaolinite present in these soils might have been formed from smectite whereas illite might have been derived by alteration of micas from the parent material

Keywords: Clay mineralogy, kaolinite, smectite, illite, Tatrakallu (Anantapuramu), X-ray diffraction

INTRODUCTION

Clay is an important component of soil system andplays a very important role in various soil processes, its management and productivity. Clay minerals are basically hydrated aluminum silicates with very fine particle size, usually < 2µm. Clay minerals have been confirmed to affect the properties of soils and rocks because they possess unique structures and surface properties, such as swelling (Naithani and Singh, 2013), cation exchange capacity and solid acidity (Zhou *et al,* 2018). They are also “recorders” of geological processes such as weathering, transportation, sedimentation, and digenesis and can provide abundant information on soil or rock transformations, which have very important bearing on genesis and physical and chemical properties of soils. Soil mineralogy, which is closely linked to soil texture, is a major determinant of physical and chemical properties of soils (Nagarjuna *et al.,* 2018). Soil mineralogy defines the capacity of soil minerals to adsorb and protect nutrients like organic carbon, K^+ and NH^+ ions and also adsorbs many toxic elements which depends on the specific surface area and surface charge characteristics of the minerals (Zinn, 2005). Knowledge of clay minerals in soils is thus critical to our understanding and use of soil. Over the past century, X- Ray Diffraction (XRD) analysis is believed to be the most suitable method for routine quantitative analysis (Zhou *et al.*, 2018). However, there is no information available on the clay mineralogy of Tatrakallu village of Anantapuramudistrict in particular and in Andhra Pradesh in general. Hence, the present investigation was carried out to identify the clay minerals inthese soils for their sustainable management by using XRD.

MATERIALS AND METHODS

The study area, Tatrakallu (Anantapuramu district) Andhra Pradesh lies in between 14°58′ to 15°00′ N latitudes and 77°19′ to 77°25′ E longitudes. This area comes under the scarce rainfall zone of Andhra Pradesh. The soils of this area were developed from granite-gneiss and limestone. The mean annual rainfall was 528.40 mm of which 92% was received during May to November. The mean annual temperature is 33.03 °C with a mean summer temperature of 40.5 °C and mean winter temperature of 26.13 °C. The area qualifies for isohyperthermic temperature regime. The soil moisture control section remains dry for more than 90 cumulative days or 45 consecutive days in four months following summer solistice and qualifies for ustic soil moisture regime. Six representative pedons (P1 to P6) were selected

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Corresponding author: Professor, Dept. of SSAC, S.V Agricultural College, Tirupati- (Email: mvsnaidu66@gmail.com),
[1]PhD Scholar, [2]Vice-President, Andhra Pradesh Space Applications Centre, Vijayawada, (A.P).*

after surveying the area in 2017. The horizon-wise soil samples were collected for analysis of chemical parameters whereas surface soil samples of the pedons1 to 6 were analyzed for clay minerals. The samples were air-dried at room temperature and stored in polyethylene bags. The air-dried samples were crushed, passed through a 2 mm sieve, mixed and stored for analysis. The chemical parameters were determined by following standard procedures. The clay fractions were separated by sedimentation technique (Jackson, 1976). The clays (< 2μm) were isolated by removing organic matter, sesquioxides and allophanes. Basically, oriented clay samples (Ca-25^{o}C, Ca-glycerol, K-25^{o}C, K-110, K-300 and K550^{O}C heated) were subjected to X-ray diffraction studies. Identification and semi-quantitative estimation of clay minerals was also carriedout based on peak intensities (Gjems, 1967).

RESULTS AND DISCUSSION

Pedons 1, 2 and 3 were developed from granite – gneiss parent materials, while pedons 4, 5 and 6 were originated from limestone (Table 1). The soils were developed on granite-gneiss parent material. Pedons1, 2 and 3 were located on uplands while 4, 5 and 6 were developed on uplands. Pedon 1 showed severe erosion while other pedons did not show any erosion. Drainage conditions varied from poorly drained to well drained and most of the area was under agricultural field crops.

Table 1: Salient site features of the profiles

Pedon No.	Location	Elevation M (msl)	Drainage	Slope (%)	Landform	Parent material	Erosion
1	14°58′16.1″N 77°25′48.3″E	397	Well drained	5 – 10	Upland	Granite - gneiss	Nil
2	14°59′12.8″N 77°24′39.5″E	406	Well drained	3 – 5	Upland	Granite - gneiss	Nil
3	14°59′33.7″N 77°23′33.7″E	433	Well drained	1 – 3	Upland	Granite - gneiss	Nil
4	15°00′04.2″N 77°20′54.2″E	464	Poorly drained	0 – 1	Plain	Limestone	Nil
5	14°59′57.0″N 77°21′16.6″E	460	Some what poorly drained	0 – 1	Plain	Limestone	Nil
6	14°59′54.2″N 77°21′44.3″E	464	Poorly drained	0 – 1	Plain	Limestone	Nil

Chemical composition

The data on chemical composition (Table 2) revealed that the pH of the soils ranged from 6.6 (slightly acidic) to 9.0 (strongly alkaline). Cation exchange capacity of the soils varied between 8.9. and 50.6 cmol (p^{+}) kg^{-1} in different horizons and was positively and significantly correlated with clay (r = +0.843**). The base saturation ranged from 55 to 99%. The higher base saturation in some of these pedons might be due to higher amount of Ca^{+2} occupying exchange sites on the colloidal complex and also may be due to recycling of basic cations through vegetation. Higher values (14.34) of loss on ignition (LOI) may be due to the presence of expanding type of clay minerals. The K_2O content in all the pedons indicated the presence of K-bearing clay minerals (Raina *et al.*, 2006). Relatively higher values of P_2O_5 in the soil might be due to the presence of P-bearing minerals such as calcium apatite and also due to use of higher doses of phosphatic fertilizers.

X-ray Diffraction

The X-ray diffraction pattern of clay fraction indicated that pedon 1 contained kaolinite (66.00 %) was the dominant clay mineral followed by smectite (34.00%) and traces of illite.The intense dominant peak at 0.720 nm and 0.355 nm d-spacing in Ca saturated ethylene glycol solvated treatment indicated the presence of kaolinite (Fig.1). The Ca-saturated sample showed a peak at 1.500 nm d-spacing and its shift to 1.700 nm in calcium saturated ethylene glycol treatment indicated the presence of smectite. Illite was recognized by

Table 2: Chemical characteristics of the Tatrakallu village

Pedon no. & horizon	Depth (m)	pH	EC (dS m^{-1})	CEC [cmol(p+)kg^{-1}]	P_2O_5 (%)	K_2O (%)	LOI (%)
Pedon 1							
Ap	0.00-0.20	6.6	0.08	21.1	1.2	186	8.73
R	0.20		Hard Granite - gneiss				
Pedon 2							
Ap	0.00-0.20	8.2	0.26	15.8	80.0	331	6.44
C1	0.20-0.40	8.4	0.14	9.5	71.0	141	5.73
2C1	0.40-0.70	8.5	0.12	7.0	79.1	104	3.30
2C2c	0.70-1.20	8.4	0.16	8.9	60.6	119	6.00
Ck	1.20	Soil mixed with lime					
Pedon 3							
Ap	0.00-0.19	7.9	0.16	11.0	60.1	233	2.90
Bt	0.19-0.40	7.5	0.02	19.1	59.5	112	4.53
R	0.40	Hard granite - gneiss					
Pedon 4							
Ap	0.00-0.22	8.4	0.77	38.0	83.1	372	9.73
Bss1	0.22-0.48	8.5	1.83	39.6	67.9	182	8.83
Bss2	0.48-0.84	8.6	1.83	45.3	51.5	149	11.76
Bss3	0.84-1.17	8.7	1.90	42.4	16.3	135	10.73
Bss4	1.17-1.51+	8.5	1.80	47.3	11.3	171	10.57
Pedon 5							
Ap	0.00-0.24	8.9	0.22	40.5	59.0	192	10.32
Bss1	0.24-0.50	9.0	0.29	43.4	53.1	184	11.30
Bss2	0.50-0.85	8.9	1.11	42.0	85.5	163	13.05
Bss3	0.85-1.19	8.6	1.67	41.1	46.5	190	14.34
Bss4	1.19-1.60+	8.3	0.09	42.1	8.8	185	12.68
Pedon 6							
Ap	0.00-0.27	8.0	0.15	50.6	69.6	161	10.84
Bw	0.27-0.55	8.1	0.08	43.2	66.6	130	12.30
Bss	0.55-0.75	8.2	0.12	40.1	11.3	140	13.14
R	0.75+	Limestone					

the presence of small peaks at 1.000 nm and 0.500 nm and 0.333 nm. These results were in corroboration with the findings of Nagarjuna *et al.* (2018).

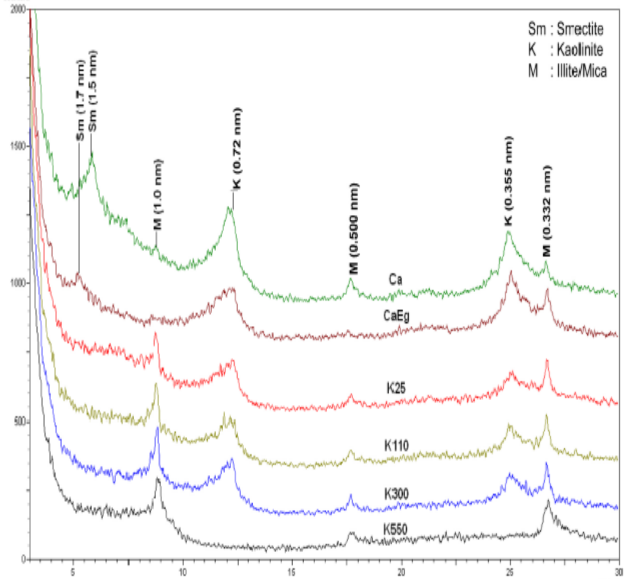

Fig.1: Representative X-ray diffractogram of pedon 1

In clay fraction of pedon 2,smectite (60.00%) was the dominant clay mineral followed by kaolinite (22.00%) and illite (18.00%).Presence of smectite was detected by an intense large peak at 1.700 nm d-spacing in Ca-saturated with ethylene glycol solvated treatment (Fig. 2).

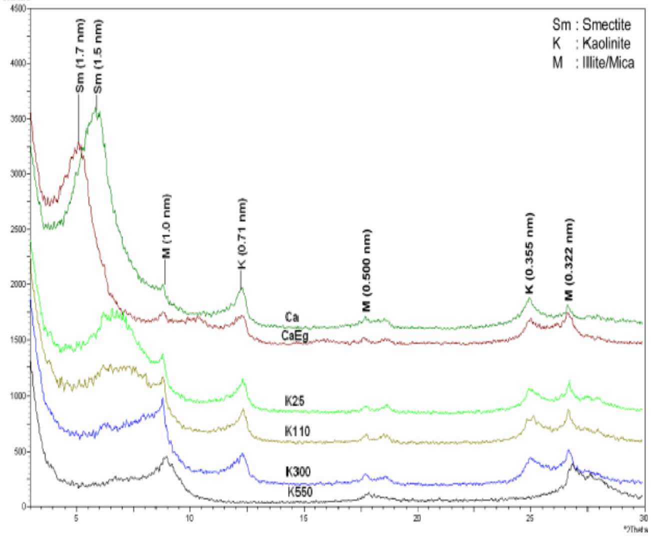

Fig.2: Representative X-ray diffractogram of pedon 2

The X-ray diffractograms of clay exhibited an intense large peak at 0.710 nm d-spacing followed by a higher order peak at 0.355 nm d-spacing in Ca-saturated ethylene glycol solvation treatment and persistence of these peaks in Ca-saturation at room temperature (25°C), K-saturation at room temperature (25°C), K-saturation at 110°C and K-saturation at 300°C but collapsed in K-saturated and heated to 550°C treatment, confirmed the presence of kaolinite.A sharp small peak observed at 1.000 nm d-spacing followed by higher order peaks at 0.500 nm and at 0.322 nm in Ca-saturated with ethylene glycol solvation treatment and persistence of these peaks in all other treatments indicated the presence of illite clay mineral (Sireesha and Naidu, 2015).

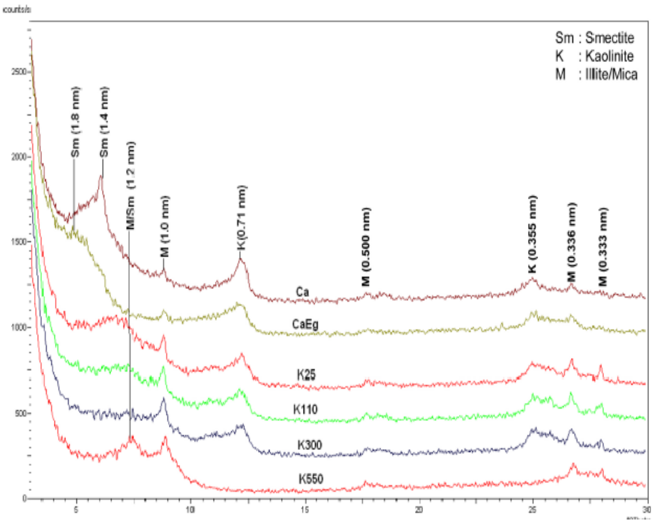

Fig 3: Representative X – ray diffractogram of pedon 3

Kaolinite (43.00 %) was the dominant clay mineral followed by smectite (30.00 %) and illite (27.00 %) in pedon 3.A large peak at 0.710 nm d-spacing followed by a higher order peak at 0.355 nm d-spacing in Ca-saturated ethylene glycol solvated treatment and persistence of similar peaks on Ca-saturated at room temperature(25°C),K-saturation at 25°C, K-saturation at 110°C and K-saturation at 300°C treatments, but their disappearance at K-saturation at 550°C treatment, confirmed the presence of kaolinite. Furthermore, an intense large peak at 1.400 nm in Ca-saturated sample which expanded to 1.800 nm on ethylene glycolation confirmed the presence of smectite (Fig.3).Presence of large peaks at 1.000 nm, 0.500 nm and 0.333 nm d-spacing in all the treatments suggests the presence of illite.These results were in good agreement with the findings of Devi and Naidu (2016).

Table 3: Relative proportion (%) of clay minerals (from X-ray diffractograms of soil clay)

Pedon No.	Smectite	Kaolinite	Illite
1	34	66	Tr
2	60	22	18
3	30	43	27
4	66	21	13
5	83	17	Tr
6	84	16	Tr

Tr: Traces refers to less than 1%

The XRD analysis indicated that smectite mineral was dominant (66.00 %) followed by kaolinite (21.00 %) and illite (13.00 %)in pedon 4(Table 3 and Fig. 4). The peak position at 1.500 nm d-spacing in Ca-saturated sample which is expanded to 1.700 nm d- spacing upon ethylene glycol solvation suggested the presence of smectite. The intense dominant peak at 0.710 nm and 0.355 nm d-spacing in Ca-saturated ethylene glycol solvated treatment and their collapse at K 550^{0}Ctreatmentindicated the presence of kaolinite. A sharp large peak at 1.000 nm d-spacing followed by higher order peaks at 0.492 and 0.332 nm d-spacings in Ca-saturated ethylene glycol solvation treatment and in K-25^{o}C treatment and persistence of these peaks at K-550^{o}C treatment indicated the presence of illiteclay mineral.Similar composition of smectite, kaolinite and illite was noticed by Leelavathi*et al.* (2010) in soils of Chittoor district of Andhra Pradesh.

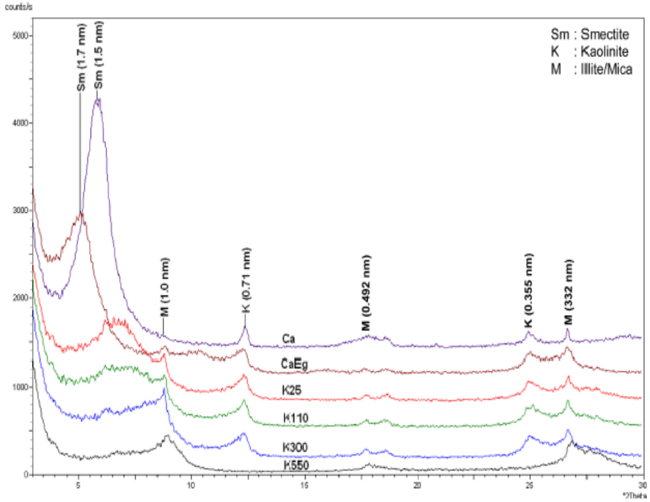

Fig 4: Representative X–ray diffractogram of pedon 4

In the clay fraction of pedon, 5,smectite (83.00 %) mineral was dominant followed by kaolinite (17.00 %) and traces of illite (Table 3 and Fig. 5). A strong peak at 1.500 nm d-spacing in Ca-saturated sample which expanded to 1.700 nm d-spacing with Ca-saturated with ethylene glycol solvated treatment indicated the presence of smectite. Small peaks at 0.710 nm and 0.350 nm d-spacings and their persistence in all the treatments except at K-550°C treatment, confirmed the presence of kaolinte. The presence of weak peaks at 1.103 nm, 0.500 nm and 0.333 nm in all the treatments is an indicative of illite.

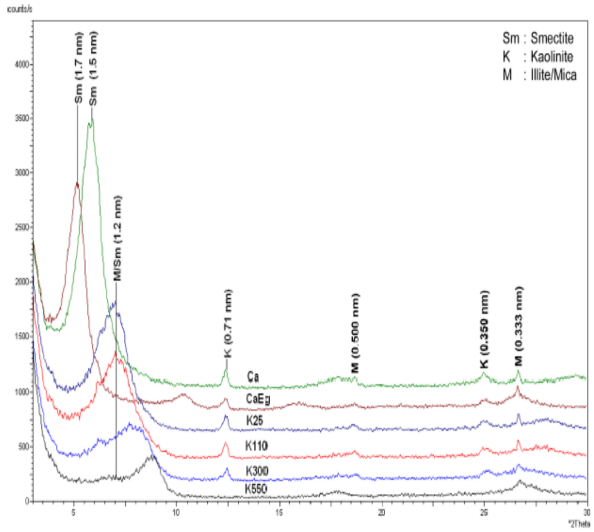

Fig 5: Representative X-ray diffractogram of pedon 5

Semi quantitative estimates had shown that smectite (84.00%) was the dominant clay mineral followed by kaolinite (16.00%) and traces of illite in pedon 6 (Table 3 and Fig.6).The Ca-saturated sample in this pedonshowed a peak at 1.500 nm d-spacing which expanded to 1.700 nm d-spacing one ethylene glycol salvation confirmed presence of smectite.The peaks at 0.710 nm and 0.355 nm d-spacings in all the treatments except in K-550°C treatment confirmed the presence of kaolinite Presence of a weak peaks at 0.500 nm and 0.332 nm d-spacings in all the treatments and these peaks were not affected by K- 550°C, treatment , confirmed the presence of illite indicating that the degree of hydration of illite was not much (Thangasamy *et al.*, 2004).

Genesis of clay minerals

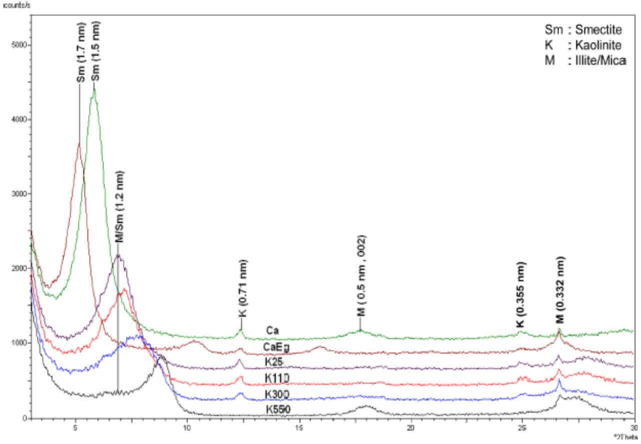

Fig 6: Representative X-ray diffractogram of pedon 6

The clay fraction of soils in the present study was found to be a mixture of three clay minerals viz., smectite, kaolinite and illite. Smectite was the single dominant mineral in the surface horizon of pedons 2, 4, 5 and 6 than other minerals. It is quite unlikely that such a high amount of smectite in these soils could be produced during the low rainfall period of the present semi-arid conditions (Rao *et al.,* 2012). Smectite was also formed possibly from plagioclase during earlier geologic period and is an ephemeral in humid environment (Sireesha and Naidu, 2015); however its retention is possible because of climate change from humid to semi-arid during pleistocene transition period (Selvaraj and Naidu, 2012). Kaolinite is the dominant clay mineral in surface horizon of pedons 1 and 3. Kaolinite present in these soils might have been formed from smectite (Nagarjuna *et al.,* 2018). Kaolinite minerals could be formed by neosynthesis from the products of hydrolytic decomposition of feldspars and other primary minerals (Leelavathi *et al.,* 2010) and by conversion of smectite or vermiculite to kaolinite following hydroxy interlayering in the expandable mineral or mixed layering between 2:1 and 1:1 layers (Kumar and Naidu, 2011). Further, the kaolinite was formed in an earlier geological period with more rainfall and greater fluctuations in temperature. However, the study area is also experiencing the above conditions, which may lead to the synthesis of kaolinite mineral in pedons1 and 3. Similarly presence of kaolinite in the soils of Banaganapalli mandal of Kurnool distict was reported by Sireesha and Naidu (2015). Illite was present in small quantities in all the pedons. Illite present in the clay might have been derived by alteration of micas from the parentmaterial. Potassium bearing minerals of rocks under the prevailing conditions of the soil formation had led to formation of illitic type of minerals (Thangasamy*et al.*, 2004)

Semi-quantification of X-RDA diffractograms of clay fraction showed 30 to 84 % of smectite, 16 to 66 % of kaolinite and traces to 27 % of illite.Clay mineralogy investigation by X-ray diffraction technique indicated that smectite was the dominant clay mineral in almost all the pedons except pedons 1and 3. Such a high amount of smectite in these soils could be produced during the low rainfall period of the present semi-arid conditions.Furthermore, smectite was formed possibly from plagioclase during earlier geologic period and is an ephemeral in humid environment. Kaolinite was dominant mineral in pedons1 and 3. Kaolinite minerals could be formed by neosynthesis from the products of hydrolytic decomposition of feldspars and other primary minerals Transformation and neo-formation are the principal processes in the genesis of clay minerals. Transformation modifies a clay mineral without altering its structure while neo-formation leads to formation of new mineral. The process of elimination and recombination led to formation of 2:1 (or) 1:1 type mineral. The information regarding the relative proportion of various minerals is vital for effective management of soils to achieve sustainable production as well as sustainable management of soils.

REFERENCES

Devi, P.A.V and Naidu, M.V.S. (2016) Clay mineralogy of sugarcane soils formed on granite-gneiss parent material of Chittoor district, Andhra Pradesh. *Annals of Plant and Soil Research* **18**: 189-195.

Gjems, O. (1967) Studies on clay minerals and clay minerals formation in soil profiles in Scandinavia. *Meddelelserfra De Norsek Skogforsoksveen* **21**: 303.

Jackson, M.L. (1976) *Soil Chemical Analysis-Advance Course*. Madison, USA. Department of Soil Science, University of Wisconsin.

Kumar, Y.S.S and Naidu M.V.S. (2011).Clay mineralogy of soils developed from granite-gneiss and alluvium in the Vadamalapeta mandal of Chittoor district, Andhra Pradesh.*Agropedology* **21**: 52-55.

Leelavathi, G.P., Naidu, M.V.S., Ramavatharam, N and Sagar, G.K. (2010) Clay mineralogy of soils formed on granite-gneiss of Chittoor district, Andhra Pradesh. *Journal of the Indian Society of Soil Science* 58: 376-383.

Nagarjuna, V., Naidu, M. V. S.,Munaswamy, V., Sumathi, V and Sudhakar P. (2018) Clay mineralogy of groundnut growing soils formed on different parent material of Srikalahasti Division of Chittoor district, Andhra Pradesh, India. *International Journal of Current Microbiology and Applied.Science* 7: 3837-3848.

Naithani, V. and Singh, A.P. (2013) A Comparative study of Clay minerals of South-Western Region of Punjab, India. *2nd International Conference on Environment, Chemistry and Biology*(IPCBEE)**59:**107-113.

Raina, A.K., Sharma, S.D and Jha, M.N. (2006) Sand and clay mineralogy of saltaffected soils of Uttar Pradesh.*Journal of the Indian Society of Soil Science* **54**: 65–74.

Rao A.P.V.P., Naidu M.V.S., Ramavatharam N. and Rama Rao G. (2012) Clay mineralogy of soils developed from granite-gneiss and alluvium in Ramachandrapuram mandai of Chittoor district in Andhra Pradesh. *Agropedology.***22**:56-60.

Selvaraj, S. and Naidu, M.V.S. (2012) Identification of clay minerals with different parent soils of Reniguntamandal in Chittoor district, Andhra Pradesh. *Madras Agricultural Journal* **99**:754-758.

Sireesha, P.V.G and Naidu, M.V.S. (2015) Clay mineralogy of soils developed from granite-gneiss of Kurnool district in Andhra Pradesh. *Journal of the Indian Society of Soil Science* **63**: 16-23.

Thangasamy, A., Naidu, M.V.S and Ramavatharam, N. (2004) Clay mineralogy of soils in the Sivagiri micro-watershed of Chittoor district, Andhra Pradesh. *Journal of Indian Society of Soil Science* **52**:454-461.

Zhou, X., Dong. L., Hongling, B., Deng, L., Liu, H., Yuan, P., Du, P and Song, H. (2018) XRD-based quantitative analysis of clay minerals using reference intensity ratios, mineral intensity factors, Rietveld, and full pattern summation methods: A critical review*. Solid Earth Science.***3**: 16-29.

Zinn, YL. (2005) Textural, mineralogical and structural controls on soil organic carbon retention in the Brazilian cerrados.PhD thesis, Ohio State University, USA.