Environment and Ecology 41 (1) : 160—167, January—March 2023
ISSN 0970-0420

Soil Mineralogy of Kavalur Sub-Watershed (4D4A2P) of Koppal District, North Karnataka

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Received 8 September 2022, Accepted 28 November 2022, Published on 27 January 2023

ABSTRACT

The soils of Kavalur sub watershed of Koppal district, Karnataka are inherited from granite-gneiss under semi-arid climate at an average elevation of 463.27 m above mean sea level. The mineralogical composition of these soils was investigated using X-ray diffraction technique. The soil samples of two depths of nine pedons belonging to different soil series were subjected to mineralogical studies to assess their mineralogical composition. These nine pedons represented both red (GHT and MRD series) and black (BDR, AWD, KVR, RNK, MTL, BGP and DL-7 series) soils pedons. In case of clay mineralogy of red soil pedons, the kaolin (indicative of mixed mineralogy) was dominant among secondary clay minerals followed by smectite in the Ap horizon. In the Bt horizon, smectite was dominant followed by kaolin. In addition to secondary minerals, clay sized particles also contained primary minerals like mica, quartz and feldspar. Red soil pedons had more kaolin content than black soil pedons and its content decreased with depth. In contrast, smectite content was quite low and its content increased with depth. The black soil pedons showed relatively higher content of smectite than kaolin. The other mineral present was quartz. In most of the black soil pedons, smectite content increased while kaolin and quartz content decreased with soil depth.

Keywords Horizon, Smectite, Kaolin, Red pedon, Black pedon.

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INTRODUCTION

As we all know, soil is the weathered product of rocks and minerals and in many ways the soil represents its parent material in most of its properties. The extent and composition of nutrients in a soil is usually inherited from its parent material. Soil mineralogy is important for proper understanding of the soil development as well as for managing soil fertility and enhancing crop production. The amount of different clay minerals present in soil controls the nutrient availability to crops. The kind of minerals present and their distribution with depth in a soil profile often serve as an index of the pedogenic and weathering processes operative in soil development. The fact that various minerals common in soils weather at differential rates has been recognized by many investigators in the field of soil mineralogy. Since some minerals weather more easily than others, there tends to be accumulation of minerals of similar stability in soil profile or horizon reflecting the intensity of

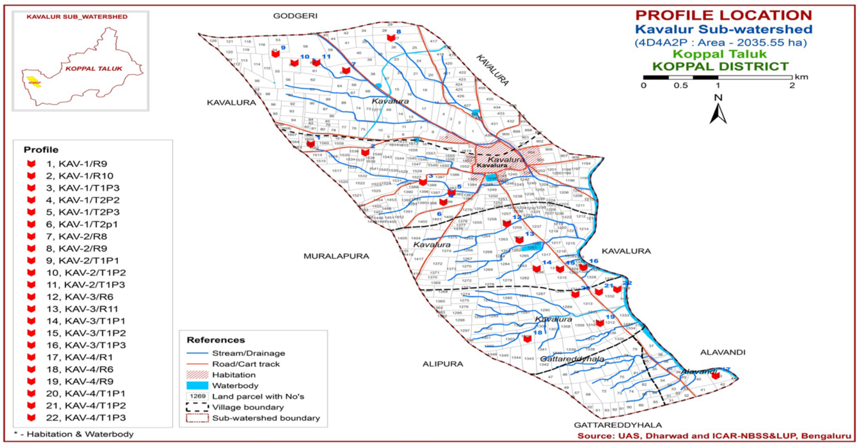


Fig. 1. Soil profiles location map of the Kavalur sub-watershed.

the various agencies of weathering (Jackson and Sherman 1953).

Koppal District is mainly underlain with gneisses, granites and schists. These hard rocks do not have any primary porosity however, weathering, fracturing, joints and tectonic features like folds and faults have created secondary porosity and permeability. Pink granite is more susceptible for weathering than gray granite and its presence is considered an indicator of good aquifer. The wells taping schistose formation are considered poor yielders compared to granite and gneiss formations. The soils of Koppal District are expected to have varied mineralogy owing to mixed geology. Keeping in view the above mentioned facts and figures, present investigation entitled Soil Mineralogy of Kavalur Sub-watershed (4D4A2P) of Koppal District, North Karnataka" was carried out.

Table 1. List of selected pedons for mineralogical analysis.

Sl. No.	Series name	Ped-on No.	Pedon description	Horizons
1.	GHT	2	Kav-1/ T_2/P_3	Ap (0-25), Bt (25-47)
2.	MRD	4	Kav-1/ T_1/P_3	Ap (0-24), Bt_2 (74-129)
3.	BDR	5	Kav-1/ R_9	Ap (0-20), Bw_2 (82-148)
4.	AWD	8	Kav-2/ T_1/P_2	Ap (0-30), Bss (66-94)
5.	KVR	11	Kav-2/ R_9	Ap (0-26), Bw (26-64)
6.	RNK	12	Kav-3/ T_1/P_1	Ap (0-11), Bw (11-32)
7.	MTL	14	Kav-3/ T_1/P_3	Ap (0-11), Bw (11-30)
8.	BGP	19	Kav-4/ T_1/P_3	Ap (0-35), Bw_2 (90-119)
9.	DL-7	21	Kav-4/ R_6	Ap (0-21), Ck_1 (21-57)

MATERIALS AND METHODS

An investigation was carried out on soils of Kavalur-3 micro-watershed, situated at an elevation of 463.27 in nearly level to very gently sloping land of Koppal taluk, Karnataka (India) with an objective to know the physical and chemical properties of the soils. The micro-watershed lies in low rainfall zone (zone 3, northern dry zone) with an average annual rainfall of around 572 mm. For the purpose of understanding genesis and formation of these soils, nine representative series-red (GHT and MRD series) and black (BDR, AWD, KVR, RNK, MTL, BGP and DL-7 series) soils pedons were selected for mineralogical study (Table 1 and location map of profiles Fig.1). Morphologically important two soil horizons in each pedon were selected for mineralogical analysis. Separation of sand, silk and clay particles, slides of clay fraction for XRD and mineralogical composition of these soils was investigated using X-ray diffraction technique (Jackson 1979).

The semi quantification of minerals present in the clay fraction was done by drawing the triangle to the sharp first order peak of representative mineral. The height and breadth of each such triangle was measured to calculate the quantity of that mineral by using the formulae (Gjems1967) and expressed in the percentage.

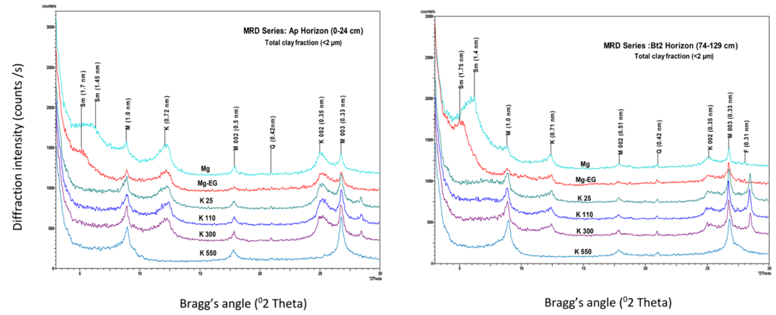
Table 2. Semi-quantitative estimates of minerals (%) in clay fractions. (Sm, smectite ; Vm, vermiculite ; Ch, chlorite ; M, mica ; K, kaolin, Q, quartz; F, feldspar).

Horizon	Depth (cm)	Sm	Vm	Ch	M	K	Q	F
				Pedon 2 (GHT series)				
Ap	0-25	32.4	Nil	Nil	24.3	35.6	7.8	Nil
Bt	25-47	54.1	Nil	Nil	12.6	23.5	Nil	9.8
				Pedon 4 (MRD series)				
Ap	0-24	25.1	Nil	Nil	28.6	35.4	10.9	Nil
Bt_2	74-129	53.7	Nil	Nil	12.4	15.8	11.3	6.8
				Pedon 5 (BDR series)				
Ap	0-20	57.3	Nil	Nil	19.8	17.6	5.3	Nil
Bw_2	82-148	71.5	Nil	Nil	11.1	13.6	3.8	Nil
				Pedon 8 (AWD series)				
Ap	0-30	70.5	Nil	Nil	Nil	16.1	13.4	Nil
Bss	66-94	70.7	19.1	Nil	Nil	5.1	5.1	Nil
				Pedon 11 (KVR series)				
Ap	0-26	72.7	Nil	Nil	5.7	14.3	7.2	Nil
Bw	26-64	87.7	Nil	Nil	Nil	7.8	4.5	Nil
				Pedon 12 (RNK series)				
Ap	0-11	72.2	17.3	Nil	Nil	5.4	5.1	Nil
Bw	11-32	74.6	16.6	Nil	Nil	5.4	3.4	Nil
				Pedon 14 (MTL series)				
Ap	0-11	87.4	Nil	Nil	Nil	8.4	4.2	Nil
Bw	11-30	85.4	Nil	Nil	Nil	9.7	4.9	Nil
				Pedon 19 (BGP series)				
Ap	0-35	63.7	24.2	Nil	Nil	8.1	4.0	Nil
Bw_2	90-119	87.7	Nil	Nil	Nil	7.5	4.7	Nil
				Pedon 21 (DL-7 series)				
Ap	0-21	88.8	Nil	Nil	Nil	6.9	4.3	Nil
Ck_1	21-57	71.0	15.8	Nil	Nil	9.0	4.2	Nil

RESULTS AND DISCUSSION

The relative abundance of diffenrent clay minerals present in clay fractions as indicated from the XRD are summarized in Table 2.

In red soil pedons, the kaolin was dominant among secondary clay minerals followed by the smectite in the Ap horizon and smectite followed by kaolin in the Bt horizon (Fig. 2). The clay minerals had relatively more kaolin and its content decreased



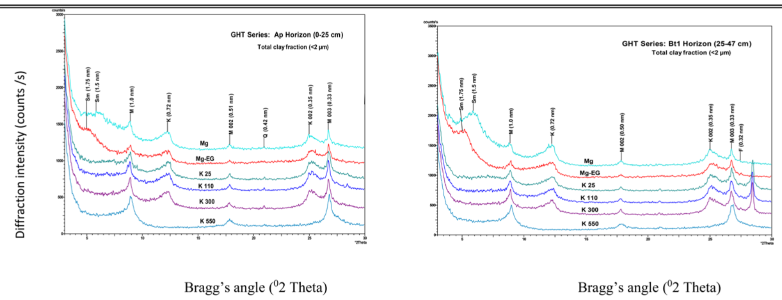
(Sm, smectite; M, mica; K, kaolin; Q, quartz; Mg, Magnesium saturated; Mg-EG, Mg-saturated and ethylene glycolated; K25, K110, K300, K550 -K saturated and heated at 25°, 110°, 300° and 550°C, respectively)

Fig. 2. X-ray diffractograms of clay fraction (MRD series, Ap horizon and Bt_2 horizon).

with depth, content of smectite was low and its content increased with depth. Kaolinite present in these pedons might have been formed from smectite. 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 hydroxyl interlayering in the expandable mineral or mixed layering between 2:1 and 1:1 layers (Pal *et al.* 1989, Bhattacharyya *et al.* 2000, Chandran *et al.* 2000). Similar report was made by Sireesha and Naidu (2015). This suggested that kaolinite possibly developed at the expense of smectite with progressive weathering (Jagadeesha 2002).

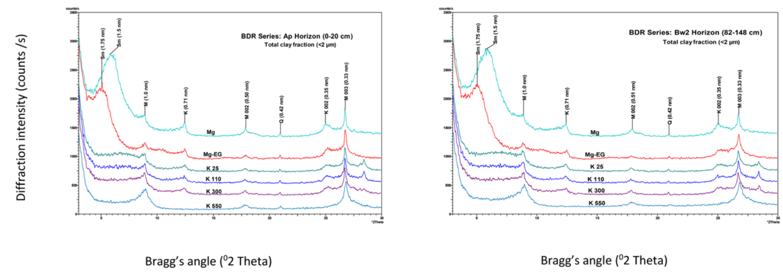
In addition to secondary minerals, the clay also contained the primary minerals like mica (dominant) followed by quartz and feldspar. Feldspars and quartz were present in traces in all the pedons, which suggest that these minerals have been derived from coarser alluvial sediments by physical weathering (Sireesha and Naidu 2015).

It was not a true kaolinite (in future discussion,



(Sm, smectite; M, mica; K, kaolin; Q, quartz; Mg, Magnesium saturated; Mg-EG, Mg-saturated and ethylene glycolated; K25, K110, K300, K550 -K saturated and heated at 25°, 110°, 300° and 550°C, respectively)

Fig. 3. X-ray diffractograms of clay fraction (GHT series, Ap horizon and Bt_1 horizon).



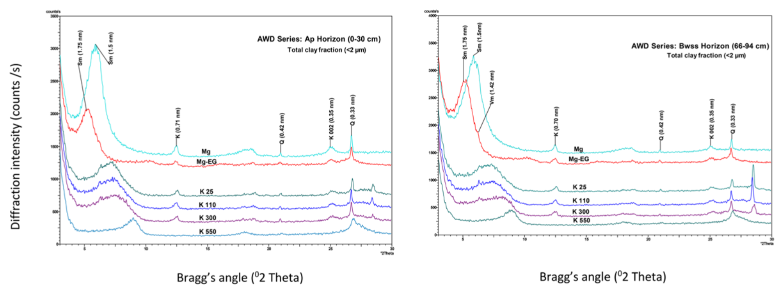
(Sm, smectite; M, mica; K, kaolin; Q, quartz; Mg, Magnesium saturated; Mg-EG, Mg-saturated and ethylene glycolated; K25, K110, K300, K550 -K saturated and heated at 25°, 110°, 300° and 550°C, respectively)

Fig. 4. X-ray diffractograms of clay fraction (BDR series, Ap horizon and Bw_2 horizon).

it was referred to as kaolin) as the peak was not sharp peak. The broadening of the basal spacing of 0.7 nm peaks at lower angle in all clay diffractograms indicated some amount of interstratifications of kaolinite with 2:1 minerals. It contained more than 85% kaolinite while the remaining was smectite (Bhattacharyya *et al*. 2000, Chandran *et al.* 2000).

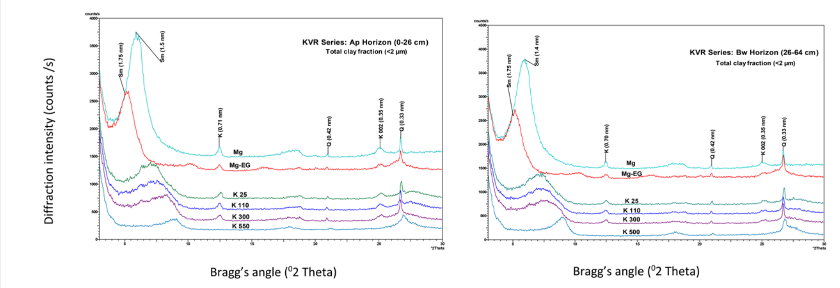
In clay fractions of the black soil pedons (BDR, AWD, KVR, RNK, MTL, BGP and DL-7 series) (Figs. 3-10), Smectite was the dominant clay mineral. It varied from 57.3 to 88.8% in Ap horizon and 70.7 to 87.7 % Bw horizon, followed by kaolin and quartz. Kaolin and quartz varied from 5.4 to 17.6% and 4.0 to 13.4 %, respectively in Ap horizon and 5.1 to 13.6% and 3.4 to 5.1%, respectively in Bw horizon. Vermiculite was present only in RNK series (17.3 and 16.6 % in Ap and Bw horizon, respectively), AWD series (19.1% in Bss horizon), BGP series (24.2% in Ap horizon) and DL-9 series (15.8% in Ck_1 horizon). Mica was present in BDR series (19.8 and 11.1% in Ap and Bw_2 horizon, respectively) and KVR series (5.7 % in Ap horizon). In case of most of the black soil pedons observed, smectite content increased while kaolin and quartz content decreased with depth.

In black soil pedons, the smectite content was relatively more when compared to other clay minerals.



(Sm, smectite; M, mica; K, kaolin; Q, quartz; Mg, Magnesium saturated; Mg-EG, Mg-saturated and ethylene glycolated; K25, K110, K300, K550 -K saturated and heated at 25°, 110°, 300° and 550°C, respectively)

Fig. 5. X-ray diffractograms of clay fraction (AWD series, Ap horizon and Bss horizon).

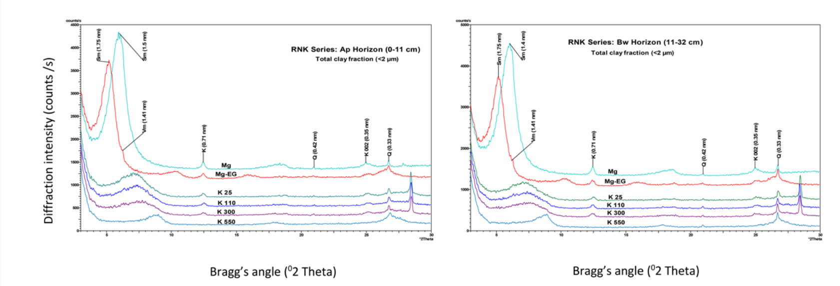


(Sm, smectite; M, mica; K, kaolin; Q, quartz; Mg, Magnesium saturated; Mg-EG, Mg-saturated and ethylene glycolated; K25, K110, K300, K550 -K saturated and heated at 25°, 110°, 300° and 550°C, respectively)

Fig. 6. X-ray diffractograms of clay fraction (KVR series, Ap horizon and Bw horizon).

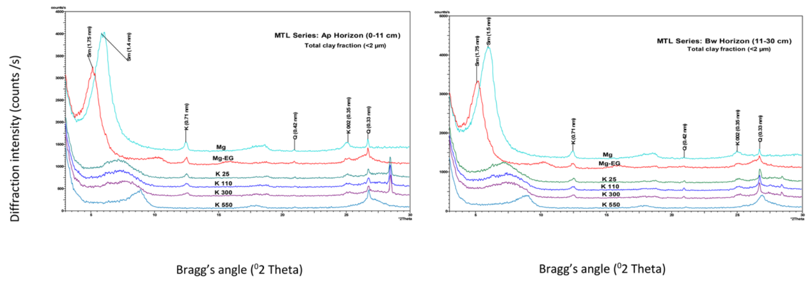
The smectite content increased with depth. It was quite unlikely that such a high amount of smectite in these soils could be produced during the low rainfall period of semi-arid conditions (Bhattacharyya *et al.* 1993). Smectite was also formed possibly from plagioclase during earlier geologic period and is an ephemeral in humid environment. However, its retention is possible because of climate change from humid to semi-arid during Pliocene-Pleistocene transition period (Pal *et al.* 1989). Under acid weathering conditions of the humid climate, the Al-hydroxy cations formed occupy the interlayer spaces of expanding minerals namely smectite (Pal *et al.* 1989, Bhattacharyya *et al.* 1999, Chandran *et al.* 2000) and the weathering of primary minerals contributes very little to the formation of smectites in the present semi-arid climate (Srivastava *et al.* 2002, Nimkar 2004). The smectite must have been formed in an earlier humid climate and its crystallinity was preserved in non-leaching environment of the dry climate that followed. Pal *et al.* (2003 and 2006) and Deotare (2006) opined that the climate changed to drier condition in Peninsular India during Holocene period.

The higher kaolin content in surface soil as compared to sub-surface indicated that the weathering of surface soil clay was higher than subsurface soil clay, which indicated the probability of *in-situ* soil



(Sm, smectite; M, mica; K, kaolin; Q, quartz; Mg, Magnesium saturated; Mg-EG, Mg-saturated and ethylene glycolated; K25, K110, K300, K550 -K saturated and heated at 25°, 110°, 300° and 550°C, respectively)

Fig. 7. X-ray diffractograms of clay fraction (RNK series, Ap horizon and Bw horizon).



(Sm, smectite; M, mica; K, kaolin; Q, quartz; Mg, Magnesium saturated; Mg-EG, Mg-saturated and ethylene glycolated; K25, K110, K300, K550 -K saturated and heated at 25°, 110°, 300° and 550°C, respectively)

Fig. 8. X-ray diffractograms of clay fraction (MTL series, Ap horizon and Bw horizon).

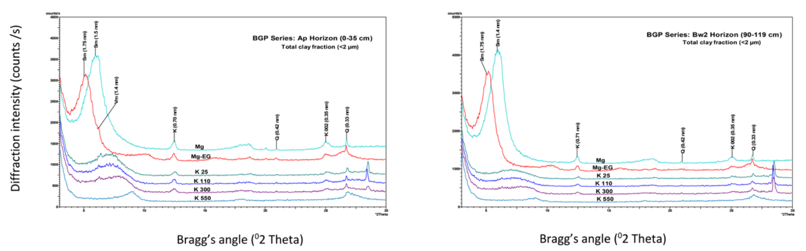
formation (Deb and Sahu 2010).

The formation of high quantities of smectite and kaolin is not possible in the present semi-arid environment. But, its presence in the present climate indicated that these soils were formed in the humid climate of the past. Since, the smectite is not stable under humid climate, it transformed to kaolin through smectite-kaolinite interstratified mineral. Presence of small amount of kaolin in all the pedons confirmed this hypothesis. Small amounts of Sm/K indicated that humid climate did not prolong for a long time. In addition to smectite and kaolin, the presence of vermiculite in black soil indicated that weathering of biotite to vermiculite stage as induced by tropical humid climate earlier. Kaolin was present in both red and black soils. In red soil pedons, occurrences of kaolin in relatively more quantities indicated that red soils are more weathered than black soils and kaolin is an indicator of humid environment which prevailed earlier (Jagadeesha 2002).

Along with the secondary minerals, the presence of primary minerals in appreciable amount indicated that weathering has not reached an advanced stage (Jagadeesha 2002).

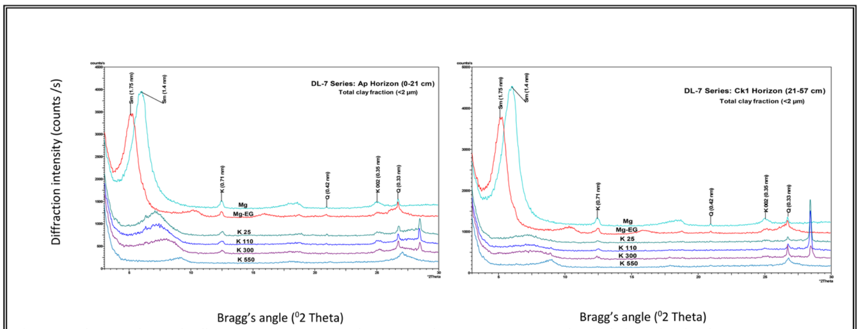
CONCLUSION

The clay mineralogy of red soil pedons, the kaolin (indicative of mixed mineralogy) was dominant among secondary clay minerals followed by smectite in the



(Sm, smectite; M, mica; K, kaolin; Q, quartz; Mg, Magnesium saturated; Mg-EG, Mg-saturated and ethylene glycolated; K25, K110, K300, K550 -K saturated and heated at 25°, 110°, 300° and 550°C, respectively)

Fig. 9. X-ray diffractograms of clay fraction (BGP series, Ap horizon and Bw_2 horizon).



(Sm, smectite; M, mica; K, kaolin; Q, quartz; Mg, Magnesium saturated; Mg-EG, Mg-saturated and ethylene glycolated; K25, K110, K300, K550 -K saturated and heated at 25°, 110°, 300° and 550°C, respectively)

Fig. 10. X-ray diffractograms of clay fraction (DL-7 series , Ap horizon and Ck_1 horizon).

Ap horizon. In the Bt horizon, smectite was dominant followed by kaolin. In addition to secondary minerals, clay sized particles also contained primary minerals like mica, quartz and feldspar. Red soil pedons had more kaolin content than black soil pedons and its content decreased with depth. In contrast, smectite content was quite low and its content increased with depth.

The black soil pedons showed relatively higher content of smectite than kaolin. The other mineral present was quartz. In most of the black soil pedons, smectite content increased while kaolin and quartz content decreased with soil depth.

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