Elemental Composition and Mineralogy of Alkali soils on the Siwalik Hills

RAJ KUMAR*, S.K. GHABRU**, R.L. AHUJA AND N.T. SINGH

Haryana Agricultural University, Hisar-125 004.

Abstract: *Formation of alkali soils on steeply sloping Siwalik hills with high rainfall and udic moisture regime is difficult to explain from the development of sodicity from alumino silicates weathering. The clay fractions have relatively high content of iron and magnesium. Loss on ignition in it, varies from 8 to 11 per cent. Sand fraction mineralogy is dominated by quartz followed by mica, feldspar, calcite and chlorite. Semi quantitative estimates of clay fraction indicated dominance of smectite (31-43 per cent) in Ramgarh soils followed by illite, chlorite and kaolinite. Geological formations around these soils are rich in these clay minerals. Hence, most of these clay minerals do not seem to be the result of any pedogenic activity and instead belongs to much older geological formations deposited under the marine environment of Tethyan basin in the Eocene peroid.* (**Key words:** *Inherited smectite, tethyan basin*)

Occurrence of alkali soils in the steeply sloping Siwalik hills with high rainfall and udic soil moisture regime has been reported by Kumar (1992). Interestingly, these reports are different from most of the earlier reports (Aggarwal & Yadav 1954; Bhumbla *et al.* 1973; Vinayak *et al.* 1981; Bhargava & Bhattacharjee 1982; Sharma 1989; Szabolcs 1989, and Acharya & Abrol 1991) which suggest their occurence only in the microdepressions of the alluvial plains mostly, with ustic to aridic soil moisture regimes. The mechanism of the formation of alkali soils, as proposed by these workers, is the release of sodium by the weathering of alumino-silicates and subsequent formation of alkali carbonates. The surface runoff washings have been supposed to be laden with the products of weathering as brought by various streams from Siwaliks causing intermittent flooding in various micro-depressions. Thus, these small concavities facilitated periodic accretion of salts and served as evaporating pans resulting in evolution of sodic salts. Na feldspars owing to its

* *Department of Soils, Punjab Agri. Univ. Ludhiana - 141 004*

***Central Soil Salinity Research Institute, Karnal - 132 001*

less stability in alkali environment, acted as diffused source of sodium. Thus, more or less these mechanisms dwell on the in situ development of sodicity from alumino-silicate weathering in the micro-depressions.

However, occurrence of soils with alkali character in the steeply sloping hilly areas can not be explained by these mechanisms. The objective of the present work was to understand the formation of these alkali soils based on their elemental composition and mineral assemblage.

MATERIAL AND METHODS

The study area is a part of Ghaggar river catchment in sub-Himalayan hills situated in the western parts of Sutluj-Yamuna divide of the Indo-Gangetic plains. The depth-wise soil samples from two representative pedons have been used for this investigation. The air dried samples (<2 mm) were used for dispersion after removal of soluble salts, organic matter and free iron oxides. Clay fractions (<0.002 mm) were quantitatively separated by sedimentation. Mg and K saturated clay were used for X-ray diffraction analysis. (Jackson 1975). X-ray diffraction pattern of basally oriented clay specimens on glass slides were obtained after Mg-saturation, glycolation, K-saturaion and heat treatments. To differentiate between kaolinite and chlorite, clay samples were boiled with 4N HCl for half an hour. X-ray diffraction pattern were obtained using Philips PW 1050/25 Vertical Goniometer with Ni-filtered Cu-K radiation. Semi-quantitative estimates were prepared from relative peak area ratios after necessary corrections for back ground (Gjems 1976; Ghosh & Datta 1972).

Sand (2-0.05 mm) samples were ground separately in an agate mortar and pestle and random powder X-ray diffraction pattern were obtained by packing the sample in an aluminium sample holder. Since HCl treatment was not given to sand, the absence of kaolinite could not be confirmed and thus expressed as chlorite plus kaolinite. Elemental composition of sand and silt fraction was determined by digesting the samples with hydroflouric acid in a closed polypropylene vessel (Jackson 1975). Loss in weight between 110°C and 950°C has been reported as loss on ignition.

RESULTS AND DISCUSSION

Elemental Composition

Sand: The SiO_2 and Al_2O_3 content of sand fraction (Table 1) varied from 85.2 to 90.5 and 2.53 to 3.42 per cent respectively. Fe_2O_3 ranged between

1.33 and 2.03 per cent. CaO was always less than 1 per cent. MgO and Na_2O ranged between 1.17 to 2.50 and 1.01 to 1.24 per cent respectively. K_2O content of both the sand fractions was almost similar. MnO content varied from 0.030 to 0.107 per cent. Loss on ignition varied from 1.25 to 3.86 per cent.

Clay: The SiO_2 and Al_2O_3 content of the clay fraction were almost uniform and varied from 49.8 to 53.1 and 22.9 to 24.2 per cent respectively (Table 2). Similarly, Fe_2O_3 and MnO ranged between 4.64 to 5.10, and 0.065 to 0.080 per cent respectively. MgO content of these clays varied between 2.19 to 3.14 per cent. Higher contents of iron and ma- gnesium is also reflected mophologically in their reddish brown colours. Na_2O and K_2O content of these clays varied from 0.10 to 0.16 and 1.47 to 1.69 per cent respectively. Loss in ignition of these clays varied from 7.94 to 10.91 per cent.

Mineralogy

Sand: In the sand fraction of the Ramgarh pedon the quartz (0.426nm) was dominant followed by the mica (1.0nm), plagioclase feldspars (0.321 to 0.328 nm), calcite (0.303 nm), chlorite (1.4 nm), mixed layer mineral (1.2 nm) and amphiboles (0.845 nm) (Table 3). However, in the middle layer plagioclase feldspar were relatively higher than mica. Similarly, the semi-quantitative estimates of various minerals in the Panchkula sands indicated the dominance of

TABLE 1. Elemental composition (%) of sand fraction

Depth (cm)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	P_2O_5	MnO	Loss on Ignition
Ramgarh										
0-10	89.3	3.14	1.43	0.81	1.50	1.10	0.46	tr	0.045	1.64
10-46	85.2	3.42	2.03	0.26	1.50	1.24	0.56	tr	0.059	3.86
46-100	88.5	2.53	1.35	0.39	2.50	1.01	0.32	tr	0.107	1.77
Panchkula										
0-50	90.5	2.98	1.33	0.7	1.58	1.16	0.33	tr	0.061	1.25
50-200 +	88.1	3.34	1.58	0.0	1.17	1.23	0.44	0.25	0.030	1.29

TABLE 2. Elemental composition (%) of clay fraction

Depth (cm)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	P_2O_5	MnO	Loss on Ignition
Ramgarh										
0-10	53.1	23.2	4.79	0.5	2.56	0.10	1.53	0.15	0.080	10.0
10-46	51.4	22.9	4.84	0.0	2.52	0.12	1.69	0.22	0.065	9.30
46-100	49.9	23.6	5.10	0.0	2.19	0.12	1.36	0.16	0.074	10.9
Panchkula										
0-50	52.2	23.1	4.64	0.2	3.14	0.12	1.47	0.17	0.080	9.82
50-200 +	53.1	24.2	4.85	0.0	2.34	0.16	1.62	0.13	0.066	7.94

quartz followed by calcite, orthoclase feldspars, plagioclases, mica and chlorite in the upper layer.

Silt: Semi-quantitative estimates of silt sized minerals in both the pedons (Table 4) were almost similar as that sand sized minerals except that mica and chlorite + kaolinite content increased and that of amphiboles and calcite decreased with fineness.

Clay: X-ray diffractograms of clays (Fig. 1 and 2) indicated very strong and well defined peaks for illite (1.0 nm). A major portion of 1.4 nm peak resolved to 1.8 nm on glycerol solvation and was attributed to smectite. Remaining part of 1.4 nm was unaffected by K-saturation and heating thus confirming the presence of chlorite and absence of vermiculite in Ramgarh pedon. In case of Panchkula pedon, a part of 1.4 nm peak collapsed to 1.0 nm on K saturation and heating of the sample thereby confirming the presence of vermiculite.

In these clays chlorite and mica are both diocta type and smectites are fairly well organized. Mixed layer minerals are composed mainly of mica-smectite and mica-chlorite type minerals. Persistence of 0.72 nm peak in HCl treated clays confirmed the presence of kaolinite. In general, 1.0 and 1.4 nm diffractions were strong and peaks were symmetrical. Sharp and small peaks at 0.426, 0.845 nm and 0.312 to 0.323 nm indicated the presence of minor amounts of quartz, amphiboles and feldspars in these clays. Semi-quantitative estimates of various clay minerals as calculated

TABLE 3. Semi-quantitative estimate of sand minerals.

Depth (cm)	Chlo-rite	Mixed layer	Mica	Amphi-bole	Chlorite + Kaolinite	Quartz	Ortho-clase	Plagio-clase	Calcite
Ramgarh									
0-10	+ +	+ +	+ + +	+	+ +	+ + + + +	+ +	+ + +	+ + +
10-46	+ +	+ +	+ + +	+ +	+ +	+ + + + +	+ +	+ + + + +	+ +
46-100	+ +	+ +	+ + +	+ +	+ +	+ + + + +	+ +	+ +	+ + +
Panchkula									
0-50	+ +	+	+ +	-	+ +	+ + + + + +	+ + +	+ +	+ + + +
50-200+	+ +	+ +	+ + + +	-	+ +	+ + + + + +	+ +	+ +	+ +

from the corrected peak area value (Table 5) suggested the dominance of smectite followed by illite, chlorite, kaolinite and mixed layer minerals in the Ramgarh pedon. Smectite in clay fraction of these alkali soils in hilly areas ranged between 31 to 43 per cent. In case of Panchkula clays the semi-quantitative estimates suggested the dominance of illite fol lowed by smectite, chlorite, vermiculite and kaolinite. Smectite content ranged from 19-20 per cent.

Genesis of clay minerals : Geologically, the area around these hills is covered primarily by the molasse like deposits of the Sirmur geological

TABLE 4. Semi-quantitative estimate of silt minerals

Depth (cm)	Chlo-rite	Mixed layer	Mica	Amphi-bole	Chlorite + Kaolinite	Quartz	Ortho-clase	Plagio-clase	Cal-cite
Ramgarh									
0-10	+ +	+ +	+ + + +	+ +	+ + +	+ + + + +	+ +	+ + +	+
10-46	+ +	+ +	+ + + +	-	+ + +	+ + + +	+ +	+ + +	-
46-100	+ +	+ +	+ + + +	-	+ +	+ + + + +	+ +	+ + +	-
Panchkula									
0-50	+ +	-	+ + +	-	+ + +	+ + + + +	+ +	+ + +	+ + + +
50-200+	+ +	-	+ + + +	-	+ + +	+ + + + +	+ +	+ + + +	+

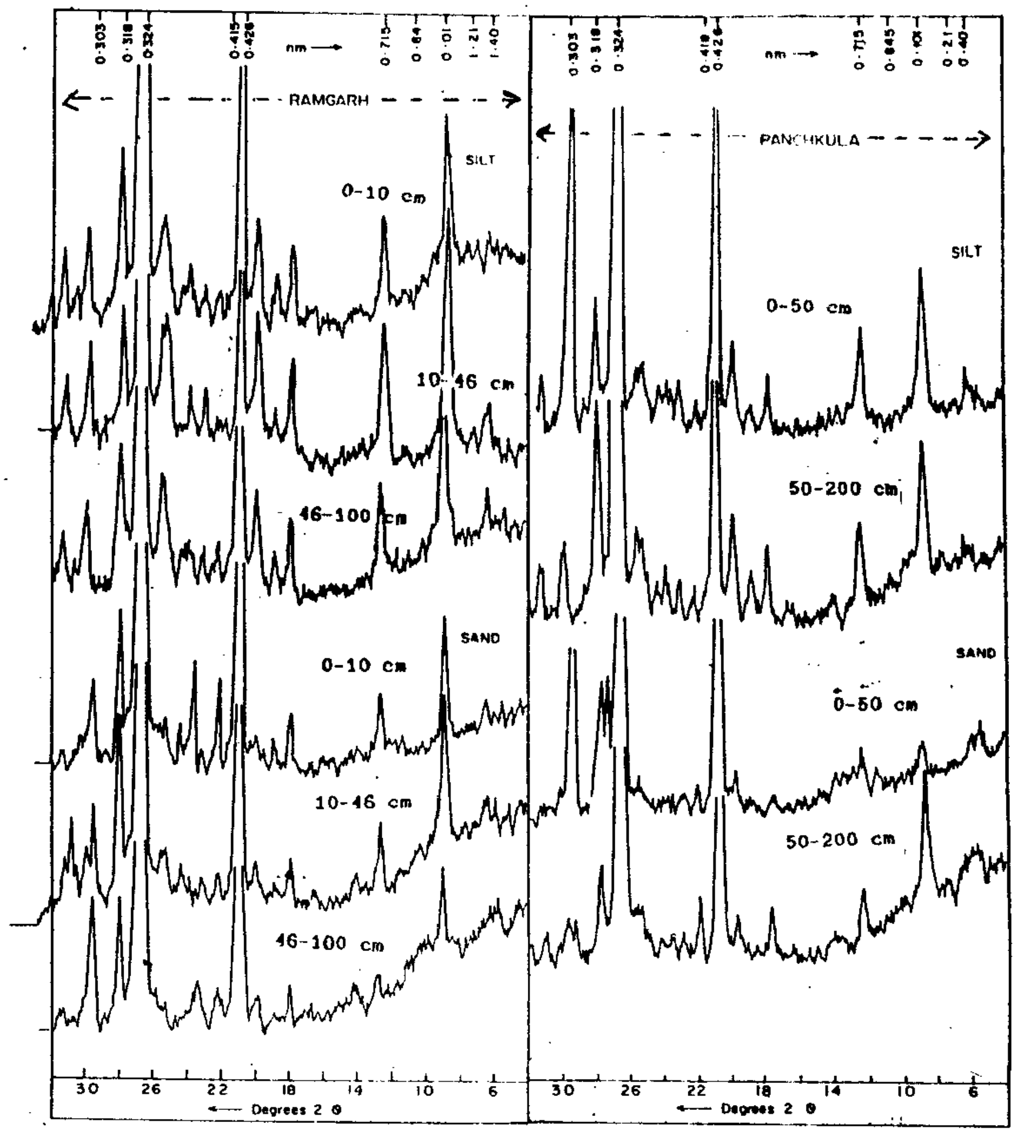

Fig. 1. XRD Pattern of sand & silt minerals

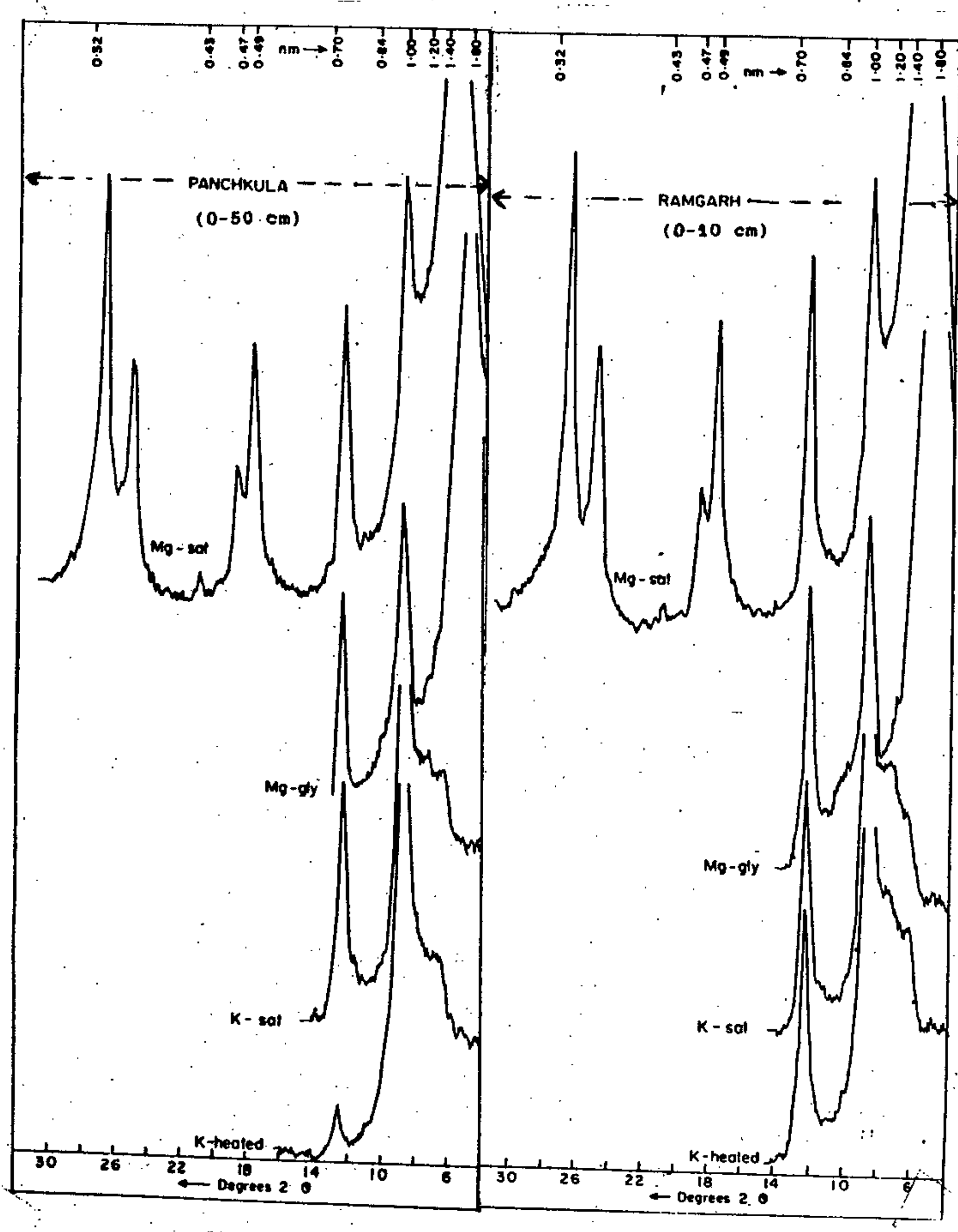

Fig. 2. XRD Pattern of clay minerals

TABLE 5. Semi-quantitative estimates of clay minerals.

Depth (cm)	Smec- tite	Chlo- rite	Vermi- culite	Illite	Mixed layer	Kaoli- nite	Quartz	Feld- spars	Amphi- boles
	<				%				>
Ramgarh									
0-10	40	7	-	36	5	8	1	2	1
10-46+	31	8		45	6	6	2	2	-
46-100+	43	8	-	34	5	7	1	1	1
Panchkula									
0-50	20	13	9	43	8	4	1	1	2
50-200+	19	11	10	44	7	5	1	2	1

formation (Gansser 1964; Wadia 1965; Srikantia.& Sharma 1977). These formations contain il lite, smectite, chlorite, kaolinite alongwith primary minerals like quartz, feldspars, micas and amphiboles. Invariably nummulitic limestone, calcite and diolomite also form a significant part of these formations. The high quantities of illite and smectite alongwith kaolinite, chlorite and vermiculite present in these clays are simply part of these formations. Soils in the downstream simply inherited minerals from the parent material as such.

Presence of kaolinite in soil clays is also detrital origin as the conditions of the present environment are not conducive to its formation of (Sidhu and Gilkes 1977). Formation of kaolinite has taken place through complete hydrolysis of feldspars during ancient times.

The formation of vermiculite and mixed layer minerals are the result of weathering that has occurred in the geological formation itself prior to their transportation by the river network. Thus, pedogenesis has very little to do with in situ formation of these minerals. Minor changes in this regard can not, however, be ruled out because of the loss of potassium and hydration to some extent caused by biotic influence. This generalization is well supported by the sand sized mica particles in fresh river sands containing only 2.40 per cent K_2O instead of generally believed figure of 10.0 per cent K_2O for unweathered mica.

Smectite Controversy: There have

been several reports regarding the formation of smectite in the alkali soils of N-W India (Sehgal 1974; Ghosh *et al.* 1976; Sharma 1989). It is opined that poor drainage, high Si:Al ratio and presence of alkalis, alkaline earths and alkaline pH are the conditions most conducive and globally accepted for in situ formation of smectites (Grim 1968); but such occurrences in the alluvial soils of this area seems doubtful.

The mineralogical data on clays from Panchkula and more Ramgarh pedon; are not affected by pedogenesis, and are part of only geological formations (Subathus) that have contributed to the alluvium of the floodplains, which clearly indicate the smectite richness of the deposits. If the mechanism of smectite formation as mentioned above are to be believed, it would be impossible to justify the presence of 19 to 20 per cent smectite in the clays of Panchkula soils and 31 to 43 per cent in Ramgarh soils as these sites are located on the eroding hill slopes. Both the sites are alkali in nature. Present geomorphology of these sites does not allow stagnation of water or existence of poorly drained conditions. On the contrary, the geological formations observed in Subathus and lower part of Dagshai, have red and purple shales, deep red and purple clays with abundance of nodular lime. These shales and clays are rich in smectites as they are marine/salt water lagoon sediments and contain large quantities of illites along with other clay minerals like kaolinite, chlorite and mixed layer minerals. Smectite present in these clays is not the result of any pedogenic activity and instead belongs to much older formation in the geological history, perhaps even prior to the period of deposition of the Murees or the Sirmur series and must have occurred under marine environment of the Tethyan basin in the Eocene period.

REFERENCES

Acharya,C.L. & Abrol,I.P. (1991) Soil water reclamation and root water extraction in alkali soils. CSSRI Karnal, India. Bull. No.16.

Aggarwal,R.R. & Yadav,J.S.P. (1954) Saline alkali soils of Indo-Gangetic alluvium in Uttar Pradesh. *J.Soil Sci.* **5**:330-336.

Bhargava,G.P. & Bhattacharjee,J.C. (1982) Morphology, genesis and classification of salt-affected soils. In: Review of Soil Research in India Vol.II, Indian Soc. Soil Sci. pp 508-529.

Bhumbla,D.R., Abrol,I.P., Bhargava,G.P. & Singla,S.K. (1973) Soils of the Experimental Farm. CSSRI Karnal, India Bull.1. pp 51.

Gansser,A.(1964) Geology of the Himalayas. Interscience Publishers, 289.

Ghosh,S.K., Das,D.K. & Deb,D.L. (1976) Clay minerals in soils of India. *Indian Soc. Soil Sci. Bull.* **11**: 117.

Ghosh,S.K. & Datta,N.P. (1972) X-ray investigations of clay minerals in the soils of West Bengal. Proc. Indian Nat. Sci. Acad. B. 40: 138-150.

Gjems,O. (1967) Studies on clay minerals and clay mineral formation in soil profiles in Scandinavia. Meddelelser fra Det Norske Skogforoksveson, No.81, Bind 21, Vollbeek, Norway.

Grim,R.E. (1968) Clay Mineralogy, McGraw Hills Borok Co., NY.

Jackson,M.L. (1975) Soil chemical Analysis - Advanced Courses, (2nd Edtn), 10th printing, published by the author, Madison, Wis. 53705.

Kapoor,B.S., Singh,H.B., Goswami,S.C., Abrol,I.P., Bhargava,G.P. & Pal D.K. (1981a) Weathering of micaceous minerals in some salt-affected soils. *J.Indian Soc. Soil Sci.* **29**: 286-292.

Kumar,R.(1992). Genesis of alkali soils at different geomorphic locations in Haryana. Ph.D. Thesis, Haryana Agri. Univ., Hisar 125 004.

Sehgal,J.L. (1974) Nature and geographic distribution of clay minerals in soils of different moisture regimes in Punjab, Haryana and Himachal Pradesh. *Proc. Natn. Acad. Sci. India*: pp 408-451.

Sharma,R.C. (1989) Mapping and characterization of salt affected soils in Haryana using remote sensing techniques. Ph.D. thesis, Kurukshetra Univ., Kurukshetra.

Sidhu,P.S. & Gilkes,R.J. (1977) Mineralogy of soils developed on alluvium in Indo-Gangetic Plain (India). *Soil Sci. Soc. Am. J.* **44**: 1194-1201.

Srikantia,S.V. & Sharma,R.P. (1977) The Pre-Cambrian salt deposit of the Himachal Pradesh Himalaya- its occurrence tectonics and correlation. pp. 221-236. In: Himalayan Geology, Vol.I (ed.) A.G. Jhingran, K.S. Valdiya, A.K. Jain. (Pub.) byWadia Inst. of Himalayan Geology.

Szabolcs,I. (1989) Salt Affected Soils, CRC Press Inc. Floria. pp 1-5.

Vinayak,A.K. Sehgal,J.L. & Sharma,P.K. (1981) Pedogenesis and Taxonomy of some alluvium-derived socic soils in Punjab. *J. Indian Soc. Soil Sci.* **29**(1): 71-80.

Wadia,D.N. (1965) Geology of India. English Language Book Society of MacMillan and Co.Ltd. London, pp. 536.