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Genesis of Alluvial Soils in Arid and Semi-arid Tracts*

by
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Synopsis: The genesis of alluvial soils in arid and semi-arid tracts of West Uttar Pradesh is reported in this paper. The analysis of clay fraction has given a clue that the clay fraction comprises a mixture of clay minerals like hydrous mica (Illite) and montmorillonite. The mineralogical analysis of fine sand fractions indicated that quartz, mica and feldspar were the commonly occurring minerals in the light fractions and constituted more than 95 per cent. Heavy minerals like magnetite, rutile, zircon, and apatite are found in traces. The mineralogical analysis of fine sand fractions thus indicated the origin of these alluvial soils from granitic and gneissic rocks and their further transport, by the action of water, to the plains. Depending upon the influence of local climatic factors and degree of weathering they have given rise to soils and clays with a mixture of clay minerals.

Introduction: The study of soil genesis embraces the raw materials from which soils are formed, the factors converting them into soils and the pedogenic processess which lead to the development of distinct soil types according to the conditions under which soil formation takes place. Upon the soil forming factors depend the peculiar structure, physical, chemical and biological properties.

The word 'alluvial' refers to the mode of transportation of parent material; the deposition of parent materials under varying conditions reflects mainly the trends in sedimentation. As the name implies, these soils are limited to areas bordering stream channels, flood plains, river deltas and bottom lands. Alluvial soils comprise about 30 per cent of the soils of India, constituting the most fertile and prosperous areas of the country. In most countries, alluvial soils have attracted less attention than residual soils, as they show lesser interactions of the five soil forming factors, parent material, climate, vegetation, topography and time, than residual soils.

Importance of the study of soil genesis hardly needs any stress. A soil is not really understood until its genesis and the reasons why it varies from other soils are known. Not until the morphology and genesis of a soil are known can research to discover new and improved management systems be planned most effectively. Soil genetical studies will be of immense use to soil scientists as a basis for soil classification and for the effective implementation of the new and improved techniques.

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In order to study the genesis of alluvial soils in arid and semi-arid tracts, four profiles were examined in West Uttar Pradesh, two in the district of Aligarh and one each in the districts of Agra and Mathura and soil samples were collected for laboratory analysis.

Methods of Analysis: *Separation of clay and Hydrogen clay preparation:* After the usual pretreatment with hydrogen peroxide to oxidise the organic matter and hydrochloric acid to decompose the carbonates, the dispersion of clay was carried out with dilute ammonia. The clay was collected in separate bottles after allowing the other size fractions to settle for the requisite time, depending upon the temperature of the suspension. The collected clay was flocculated with dilute hydrochloric acid and filtered through Buchner funnel, leached with 0·02 hydrochloric acid and the excess of acid washed with distilled water. The hydrogen clay thus prepared was dried in an electric oven at 105 degrees Centigrade, ground in an agate mortar and used in the following analysis.

Fusion Analysis: Sodium carbonate fusion method was adopted as prescribed for standard silicate analysis. (A. O. A. C. 1950). The fused material was taken in concentrated hydrochloric acid and fusion extract was prepared. Silica, sesquioxide, iron, alumina and titanium were estimated in a known aliquot of fusion extract according to Piper's method (1950). Potash was estimated in flame photometer.

Total Cation exchange capacity of clay: (Swindale 1952) One gram of clay was leached with successive portions of 40 c. c. of distilled 95 per cent ethyl alchol and finally with 40 c. c. of neutral normal ammonium acetate. The last leachate was made up exactly to volume and in an aliquot, potassium was estimated by flame photometer.

Minerological Analysis: The fine sand fractions separated from the soils in the routine mechanical analysis were analysed for their minerological composition. The experimental methods followed were the usual sedimentary petrographic methods. Sieving of fine sand fraction was carried out with 80 mesh sieve. Iron coatings were removed as suggested by Jeffry. The sand fraction was then separated into heavies (Specific gravity greater than 2·85) by using bromoform (Specific gravity 2·85). The different minerals in the two groups were identified by the usual methods and their frequencies were determined by random counting of grains.

Experimental Findings: It is quite obvious from Table I that silica forms the major constituent in the clay fraction of profile I to IV. Alumina in a few soils is nearly twice or less than that of Iron while in some, the difference is not so marked. Oxide of titanium does not carry much significance in these clays. The cation exchange capacity of clay varies from 28·7 m. e./100 gms to about 65·0 m. e./100 gms covering a wide range. Silica/sesquioxide (SiO_2/R_2O_3) ratio ranges between 2·4 and 2·9. Moisture and loss on ignition show some minor variation.

The minerological analysis of fine sand fraction of profiles I to IV is given in Table II. The most common minerals that occur in the light fractions are quartz, mica, feldspar and limonite, their individual content varying from profile to profile depending upon various factors. The heavy minerals constitute a smaller percentage and they also have their own peculiar characteristics. These minerals comprise of magnetite, tourmaline, rutile, sphene, garnet, zircon, kyanite, apatite and the like.

Discussion: For arid soils Ukil *et al* (1944) have suggested silica/sesquioxide ratio of 2 to 3, silica/alumina ratio of 2 to 3, and alumina/iron ratio of 3 to 4. Although silica/sesquioxide ratio of these soils falls within the above range, the silica/alumina ratio is higher than alumina/iron ratio. Silica/sesquioxide ratio of less than 2 marks the presence of kaolinite, greater than 2 of montmorillonite and between 2 and 3 of illite. It is seen that the clay fraction of all the profiles under study have shown silica/sesquioxide ratio varying between 2·4 and 2·9, showing thereby that they appear to consist of a mixture of illite and montmorillonite.

The common minerals that occur in the fine sand fraction of these soils are quartz, mica and feldspar. In profile I, the highest percentage is that of mica, while quartz and feldspar predominate in profile II; mica content is also high in profile III while feldspar with limonite coating constitute nearly 54 to 77 per cent in profile IV.

The above minerals are predominant ingredients of most of the crystalline rocks and it is natural that one has to trace them in the sediments of such rocks. Potash feldspar (orthoclase) with quartz and mica is the major constituent of granites and gneisses. The feldspars are decomposed by weathering rather readily and are important in being the chief source of clays as well as of potash in soils.

Ganeiss is composed comparatively of the same minerals as granite but weathers more readily than granites. Owing to the frequent occurrence of quartz in gneisses, the soils developed from them are more commonly of siliceous nature than those from true granites.

Mica schist is another rock (a metamorphic product of clays) in which mica and quartz are predominant minerals. Mica schist, however, contains very little of feldspars. The weathering of this rock is poor as compared to the granites and gneisses.

By seeing the mineral constituents in the sand fraction, it appears that the sediments indicate their origin in such granite and gneissic rocks which have been carried away by the action of water and deposited on the plains. Depending upon the influence of local climatic factors and the degree of weathering, they might have given rise to soils and clays with a mixture of clay minerals.

Summary: The analysis of the clay fraction of the alluvial soils of West Uttar Pradesh for silica/sesquioxide (SiO_2/R_2O_3), silica/alumina (Sio_2/Al_2O_3) and alumina/iron (Al_2O_3/Fe_2O_3) ratios, cation exchange capacity of clays have all given a clue that the clay fraction comprises of minerals like hydrous mica (illite) and montmorillonite. Quartz, mica and feldspar are the commonly occurring minerals in fine sand fractions and constitute more than 95 per cent. Potash feldspar with quartz and mica contribute to the formation of granite and gneisses. The sediments which are the products of such crystalline rocks are likely to be carried away by rivers and streams and deposited on the plains. They, in their turn, have undergone some genetical changes in soil formation. They are still in the process, and will continue to be so for long.

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TABLE 1

Composition of Clay — (Percent on oven dry basis)

Depth (inches)	Moisture	Loss on Ignition	Silica (SiO_2)	Sesqui-oxide (R_2O_3)	Iron (Fe_2O_3)	Alu-mina (Al_2O_3)	Tita-nium (TiO_2)	Potash (K_2O)	MOLAR RATIOS $\frac{SiO_2}{R_2O_3}$ Silica Sesqui oxide Ratio	MOLAR RATIOS $\frac{SiO_2}{Al_2O_3}$ (Silica Alumina Ratio)	MOLAR RATIOS $\frac{SiO_2}{Fe_2O_3}$ (Silica Iron Ratio)	MOLAR RATIOS $\frac{Al_2O_3}{Fe_2O_3}$ (Alumina Iron Ratio)	Total cation exchange capacity
Profile I													
0—6	2·5	5·6	49.9	34·4	13·6	20·0	0·8	4·4	2.8	3·7	11·6	3·2	28·7
6—26	5.5	10·2	50·7	39·2	14·5	23·7	0·9	5·7	2·6	3·6	9·3	2·6	53·4
26—33	6·0	10·2	50·6	39·5	16·3	22·4	0·8	5·5	2·8	3·8	10·5	2·7	46·9
33—47	5.3	10·7	51·0	43·9	17·5	25·7	0·7	4·8	2·4	3·4	7·8	2·4	43·7
47—54	4·8	9·2	50·4	39·3	16·3	22·5	0·5	4·6	2·6	3·8	8·2	2·2	50·4
54—72	5·0	10·0	54·5	37·6	14·1	23·3	0·2	6·7	2·9	4·0	10·3	2·6	58·5
Profile II													
0—60	5·7	9·0	51·4	38·8	13·8	24·8	0·2	4·7	2·6	3·5	10·0	2·8	62·6
0—28	5·6	8·7	53·0	44·1	20·1	23·6	0·5	5·8	2·5	3·8	7·2	1·9	57·2
28—43	7·3	8·9	55·3	40·3	15·7	24·1	0·5	5·1	2·8	3·9	9·4	2·4	49·8
43—72							*Kankar*	*Lime*					
Profile III													
0—6	6·0	8·9	51·7	37·8	11·9	25·4	0·4	5·3	2·7	3·5	11·6	3·4	58·3
5—19	6·3	9·5	52·2	38·5	12·3	25·7	0·5	3·8	2·6	3·5	11·3	3·3	53·4
19—41	7·0	10·1	51·0	39·0	13·6	24·8	0·6	4·2	2·5	3·5	10·0	2·9	53·0
41—72	5·9	11·5	55·1	36·6	12·5	23·9	0·2	4·6	2·9	3·9	11·7	3·0	50·9
Profile IV													
0—6	4·3	7·0	54·1	39·1	12·9	25·7	0·5	6·4	2·7	3·6	11·2	3·1	45·2
6—27	5·1	7·5	52·0	37·4	12·9	24·0	0·5	6·2	2·7	3·7	10·8	2·9	56·7
27—41	5·1	8·8	52·2	37·8	14·5	22·7	0·6	6·1	2·8	3·9	9·6	2·5	58·9
41—65	5·8	8·9	52·7	38·7	15·6	22·6	0·6	6·1	2·8	4·0	9·0	2·3	65·0
65—72	5·4	9·0	52·1	39·4	17·4	21·6	0·4	6·5	2·6	3·9	8·2	2·1	55·8

TABLE II.

Minerological Analysis of Fine Sand Fraction.

Minerals (per cent)	Profile I (Aligarh)						Profile II (Aligarh)			Profile III (Agra)				Profile IV (Mathura)				
Depth	0—6″	6″—26″	26″—33″	33″—47″	47″—54″	54″—72″	0—10″	10″—28″	28″—43″	0—5″	5″—19″	19″—41″	41″—72″	0—6″	6″—27″	27″—41″	41″—65″	65″—72″
Light																		
Feldspar	26	21	22	21	20	16	43	40	48	21	18	13	14	54	60	67	71	77
Limonite	5	6	5	5	8	8	5	6	9	5	6	4	3	—	—	—	—	—
Mica	46	53	55	58	60	65	8	6	5	42	46	60	57	25	15	11	13	8
Quartz	18	16	15	13	10	8	40	43	35	28	25	20	21	19	20	17	12	10
Heavy																		
Apatite	—	—	—	—	—	—	—	—	—	×	×	×	×	—	—	—	—	—
Garnet	×	×	×	×	×	×	—	×	—	×	—	×	—	×	×	×	×	×
Kyanite	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—
Magnetite	×××	××	××	××	××	××	××	××	××	×	×	×	×	×××	×××	×××	×××	×××
Rutile	××	××	××	××	××	××	×	×	×	×	×	×	×	—	—	—	—	—
Sphene	××	××	××	××	××	××	—	—	—	—	—	—	—	—	—	—	—	—
Tourmaline	××	××	××	××	××	××	×	×	×	×	×	×	×	—	—	—	—	—
Zircon	—	—	—	—	—	—	××	×	×	—	—	—	—	×	×	×	×	×

××× — 1-2% ×× — 0·5 to 1% × — < 0·5 and Traces