

STUDIES ON INDIAN RED SOILS

IV. NATURE OF THE WEATHERING COMPLEX AS DETERMINED BY THE VAN BEMMELEN-HISSINK METHOD OF HYDROCHLORIC ACID EXTRACT

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VAN BEMMELEN [1877, 1879, 1888, 1904] studied the soil silicates in detail and showed that they can be divided into two groups:—

(1) The unweathered portion which occurs even as crystals in clays and to which definite chemical formulae can be assigned, and

(2) The weathered portion which he considered to be absorption complex of the form SiO_2 , $p\text{Al}_2\text{O}_3$, $q\text{Fe}_2\text{O}_3$, $r\text{CaO}$, etc. and not definite minerals or compounds to which definite chemical formulae can be assigned.

He divided this latter group into two classes*:

(a) Those completely decomposed by boiling hydrochloric acid (Silicate A), and

(b) Those resistant to this treatment but decomposed by hot concentrated sulphuric acid (Silicate B).

Van Bemmelen established the fact that the bases held in silicate B are not on the whole exchangeable and that silicate A displays colloidal properties in a more marked degree than silicate B. The work of Van Bemmelen suggests that silicate A is the reactive body present in the soil. As Russell [1937] has pointed out, however, this distinction between silicate A and B is not sharp. Thus it is to be pointed out that hydrochloric acid decomposes appreciable quantities of many parent rocks, e.g. basalt, often some silicate B, though not as vigorously as sulphuric acid, and it does not decompose all the material possessing base-exchange capacity in the soil. Hydrochloric acid extract has, however, been often used by workers all over the world in order to find out the nature of the so-called weathering complex.

Sigmond [1938] has pointed out that the silicic acid liberated from the silicates by the action of hydrochloric acid, although insoluble in that acid, nevertheless forms an integral part of the hydrochloric acid extract. The silicic acid should be therefore dissolved in potassium hydroxide or sodium hydroxide and added to the SiO_2 soluble in hydrochloric acid.

In the course of the work at the Dacca University on the nature of the lateritic and red soils of India, it was felt desirable to examine the nature of the active part of the weathering complex as defined by Van Bemmelen (Van Bemmelen's silicate A). Determinations of the percentages of the different constituents of soils that are dissolved by boiling hydrochloric acid and of the alkali-soluble silica in the residue after extraction with hydrochloric acid were accordingly undertaken.

* Harrasowitz [Sigmond, 1938] applies the term 'allophane' to materials of group (a) and kaolin to materials of group (b).

EXPERIMENTAL

Procedure for the determination of silica, alumina and iron oxide

The analyses of the percentages of constituents of soils dissolved by boiling concentrated hydrochloric acid were carried out by following essentially Van Bemmelen-Sigmond's method as modified by A. E. A. [1931]. 25 gm. of soil (2-mm. sieve) treated with 250 c.c. of concentrated hydrochloric acid (sp. gr. 1.16) in 600-c.c. tall beaker, covered with a clock glass, were boiled gently for one hour, cooled, filtered and the residue lixiviated with hot water till it was free from acid. This filtrate (filtrate A) was made up to 500 c.c. From this 100 c.c. aliquot was taken in a casserole, evaporated in a water-bath after addition of a few c.c. of strong HNO_3 . When evaporation was complete, a few c.c. of strong HCl were added. After this, when evaporation was complete, the dried residue was heated for about six hours at about 120°C . to dehydrate the silica and then the mass was dissolved with gentle stirring, by means of dilute hydrochloric acid (approximately $2N$), filtered through a gravimetric filter paper and washed till free from chloride. The filtrate (filtrate B) was made up to 250 c.c. The filter paper with the residue was ignited for the determination of SiO_2 , whilst alumina and iron oxide were determined in filtrate B.

Determination of the alkali-soluble silica

In the residue after hydrochloric acid extraction, the alkali-soluble silica was determined by following essentially the method devised by Sigmond [1928]. The insoluble residue after hydrochloric acid extraction was dried on a water-bath. The filter paper was ignited and added to the insoluble residue. By this process, colloidal silica became insoluble in dilute alkali. To avoid this care was taken so that only a small quantity of the insoluble residue from the decantation reached the filter paper. To dissolve the soluble silica, 250 c.c. of potassium hydroxide solution of sp. gr. 1.04 was added and gently heated at 55°C . for five minutes in an Erlenmeyer flask and lixiviation with water was continued until there was no alkaline reaction. Silica was then determined from the solution. The results of analyses of some typical profiles of red soils collected from various parts of India are given in Table I.

TABLE I
Analytical results of some typical profiles of red soils

Locality	Depth	SiO_2 per cent			Sesquioxides in HCl extract (per cent)		$\text{SiO}_2/\text{Al}_2\text{O}_3$ (mole-cular)	$\text{SiO}_2/\text{Fe}_2\text{O}_3$ (mole-cular)	$\text{Al}_2\text{O}_3/\text{Fe}_2\text{O}_3$ (mole-cular)
		Alkali-soluble	Acid-soluble	Total soluble	Al_2O_3	Fe_2O_3			
Bengal— Dacca Farm	0-6 in.	5.03	0.112	5.142	12.96	6.96	0.669	0.499	2.917
	6 in.-2 ft. 3 in.	10.81	0.050	10.860	5.90	6.75	3.106	1.797	1.345
	2 ft. 3 in.-4 ft.	12.13	0.125	12.255	9.81	9.23	2.108	1.317	1.665
Suri, Birbhum	0-1 ft.	5.24	0.034	5.274	2.72	2.44	3.271	2.080	1.746
	1 ft.-1 ft. 6 in.	8.00 (K)	0.023	8.023	6.35	4.60	2.168	1.644	1.799
	* Below 13 ft.	15.62 (K)	0.164	15.784	5.14	8.97	5.178	2.449	0.901
	** Below 13 ft.	7.81 (K)	0.091	7.901	2.73	3.92	4.882	2.546	1.091

* This is a yellow clay from a well at depth below 13 ft. (very near from where the other two samples were collected).

** This is a yellowish white clay from a well at depth below 13 ft. This was heaped by the side of the well and grass was growing on it. The sample was taken from the heap 1 in.-5 in. after removing the top 1 in. to get rid of grass roots, etc.

TABLE I—*contd.**Analytical results of some typical profiles of red soils*

Locality	Depth	SiO ₂ per cent			Sesquioxides in HCl extract (per cent)		SiO ₂ /Al ₂ O ₃ (molecular)	SiO ₂ /R ₂ O ₃ (molecular)	Al ₂ O ₃ /F ₂ O ₃ (molecular)
		Alkali-soluble	Acid-soluble	Total soluble	Al ₂ O ₃	F ₂ O ₃			
Bengal (Barind tract)— Bogra	0-1 ft.	4.62	Very slight	4.62	0.88	2.11	8.855	3.500	6.533
	1 ft.-2 ft.	6.06	0.061	6.121	3.02	1.08	3.486	2.798	4.385
	2 ft.-4 ft.	12.26	0.082	12.342	5.85	2.52	3.575	2.804	2.297
	* 12 ft.-15 ft.	8.37	0.083	8.453	2.39	4.99	6.589	2.674	0.685
	** 25 ft.-30 ft.	8.51	1.462	9.972	3.99	4.39	4.236	2.490	1.425
Khetur Road, Rajshahi	0-1 ft. 10 in.	11.05	0.161	11.211	2.72	2.26	6.983	4.562	1.888
	1 ft. 10 in.-2 ft. 3 in.	14.95	0.069	15.019	6.89	5.46	3.695	1.630	1.979
	2 ft. 3 in.-4 ft.	15.69	0.054	15.744	6.79	5.26	3.928	2.629	2.071
Hyderabad— Bidar	0-1 ft.	34.29	0.055	34.345	19.14	28.56	3.042	1.582	1.063
	1 ft.-3 ft.	28.36	0.043	28.403	18.49	13.46	2.603	1.797	2.283
	3 ft.-4 ft.	20.62	0.211	20.831	24.14	18.20	1.462	0.997	2.144
Mimayath sagar	0-3 in.	6.49	0.067	6.557	5.99	3.32	1.856	1.381	2.917
	3 in.-1 ft. 6 in.	16.53	0.039	16.569	5.50	1.55	5.105	4.347	5.724
	† 1 ft. 6 in.-4 ft.	11.40	0.104	11.504	2.51	7.86	7.764	2.644	0.516
	†† 1 ft. 6 in.-4 ft.	17.73	0.067	17.797	6.97	7.74	4.328	2.670	1.455
Hyderabad— Ahsagar	0-1 ft.	1.62	0.065	1.685	2.90	8.20	1.054	0.384	0.571
	† 1 ft. downwards	12.86	0.110	12.970	10.70	8.60	2.049	1.368	2.011
Central Provinces— Telankhari, Nagpur	‡‡ 0-2 in.	21.06	1.972	27.132	35.41	8.02	1.299	1.140	7.137
	‡‡‡ 2 in.-2 ft. 6 in.	37.19	0.004	37.194	35.21	7.73	1.790	1.576	7.362
	‡‡‡‡ 13 ft.-16 ft.	49.02	0.072	49.092	9.96	9.66	8.352	5.219	1.666
	‡‡‡‡‡ 16 ft.-21 ft.	44.96	0.113	45.073	19.54	6.53	3.909	3.241	4.826

* This is the approximate depth, taken from the digging of a well very near to the place from where the other three samples were collected.

** This is the next layer of the soil marked with * from the digging of the same well.

†† This is a whitish material occurring occasionally in the same horizon of the soil as is marked with †. Said to be due to the decomposition of pigmatite.

‡ This is the second horizon of the soil usually extending 5 to 6 ft. below the surface.

‡‡‡ Decomposed rock from the side of a hill cuttings about 50 yards away from the hill on which the sample marked with ‡ have been collected.

‡‡‡‡ Greenish grey layer of probably more than 5 ft. in depth underlying the sample marked with ‡‡‡

TABLE I—*contd.**Analytical results of some typical profiles of red soils*

Locality	Depth	SiO ₂ per cent			Sesquioxides in HCl extract (per cent)		SiO ₂ /Al ₂ O ₃ (molecular)	SiO ₂ /R ₂ O ₃ (molecular)	Al ₂ O ₃ /Fe ₂ O ₃ (molecular)
		Alkali-soluble	Acid-soluble	Total soluble	Al ₂ O ₃	Fe ₂ O ₃			
Central Provinces—									
Chandkhuri Farm, Raipur	0-4 in.	4.49	0.208	4.695	23.04	21.35	0.346	0.220	1.745
	4 in.-1 ft. 5 in.	9.25	0.265	0.515	24.35	22.05	0.663	0.425	1.784
	1 ft. 5 in.-4 ft.	5.83	0.049	5.879	32.04	24.57	0.311	0.214	2.107
Labhandi.	*0-8 in.	5.67	0.081	5.751	16.25	8.76	0.600	0.450	2.998
	**8 ft.-10 ft.	4.32	0.065	4.385	15.77	5.31	0.472	0.390	4.808
Bihar (Chota Nagpur)—									
Putida, Chybasa	0-1 ft.	35.89	0.091	35.681	7.22	6.54	8.374	5.367	1.787
	1 ft.-2 ft. 9 in.	39.89	0.042	39.932	11.32	7.19	8.375	5.368	1.805
Assam—									
Uzanbazar, Gauhati	0-6 in.	12.84	0.112	12.952	5.46	7.16	4.021	2.219	1.232
	6 in.-11 ft.	13.09	0.113	13.203	4.70	10.82	4.766	1.965	0.702
	11 ft.-16 ft.	14.75	0.068	14.818	12.79	7.24	1.965	1.455	2.852
	†† Below 16 ft.	14.89	0.102	14.992	5.37	2.87	4.734	3.559	3.029
Tura, Garo hills	0-3 in.	11.26	0.102	11.362	7.84	19.47	2.459	0.960	0.651
	3 in.-1 ft. 8 in.	10.68	0.092	10.772	8.99	9.99	2.032	1.204	1.453
	1 ft. 8 in.-2 ft. 8 in.	11.32	0.093	11.413	6.61	15.61	2.926	1.189	0.685
	2 ft. 8 in.-4 ft.	7.78	0.101	7.881	4.06	3.99	3.294	2.048	1.645
Assam—									
Nongpoh, Khasi and Jaintia hills	0-6 in.	2.44	0.081	2.521	5.73	7.67	0.746	0.408	1.208
	6 in.-3 ft. 6 in.	15.22	0.089	15.309	11.12	7.60	2.344	1.641	2.365
	3 ft. 6 in.-4 ft. 2 in.	15.09	0.087	15.177	12.15	8.41	2.117	1.485	2.335
	4 ft. 2 in.-6 ft.	14.18	0.012	14.192	13.66	9.92	1.760	0.633	2.228
Madras (Malabar coast)—									
Kakat, Cannanore	0-1 ft. 3 in.	7.82	0.116	7.936	15.45	13.18	0.871	0.570	1.895
	1 ft. 3 in.-4 ft.	9.77	0.142	9.912	13.46	25.01	1.248	0.581	0.870
Puzathi, Cannanore	16 ft.-30 ft.	5.29	0.276	5.566	8.33	8.21	1.334	0.732	1.641
	‡ Below 30 ft.	6.99	0.276	7.266	2.98	3.02	4.134	2.515	1.561
	‡‡ Below 30 ft.	7.02	0.068	7.088	3.89	3.66	3.088	1.952	1.718

** This is a yellowish white clay occurring further down the darkish clay which occurs just below the soil marked with *

†† This layer extends up to the parent material.

‡‡ White substance, often with fossilized roots occurring as lumps and layers in and between the same layers marked with ‡ and the layer above that.

TABLE I—*contd.**Analytical results of some typical profiles of red soils*

Locality	Depth	SiO ₂ per cent			Sesquioxides in HCl extract (per cent)		SiO ₂ /Al ₂ O ₃ (mole- cular)	SiO ₂ /R ₂ O ₃ (mole- cular)	Al ₂ O ₃ / Fe ₂ O ₃ (mole- cular)	
		Alkali- soluble	Acid- soluble	Total soluble	Al ₂ O ₃	Fe ₂ O ₃				
Madras (Nilgiri hills)—	3,000 ft. a.s.l.	0-1 ft. 8 in.	34.48	0.128	34.558	8.60	11.42	6.811	3.740	1.217
		1 ft. 8 in.-3 ft.	36.67	0.079	36.749	14.63	7.62	4.260	3.221	3.101
		Below 3 ft. (to a considerable depth)	30.21	0.088	30.248	9.06	10.73	5.659	3.266	1.365
5,000 ft. a.s.l.	0-1 ft.	7.82	0.370	8.190	13.73	10.67	1.001	0.683	2.080	
	1 ft.-2 ft.	17.87	0.345	18.215	10.01	8.52	3.085	2.022	1.900	
	2 ft.-6 ft.	36.51	0.017	36.527	2.68	5.00	23.11	10.72	0.866	
7,000 ft. a.s.l.	0-1 ft.	6.27	0.367	6.637	14.79	22.53	0.762	0.392	1.058	
	1 ft.-3 ft.	14.12	0.036	14.156	29.56	22.69	0.812	0.549	2.105	
	3 ft.-4 ft. 6 in.	5.33	0.912	6.242	30.01	24.36	0.353	0.235	1.991	
	4 ft.-6 in.-6 ft.	4.67	0.032	4.702	34.09	11.57	0.234	0.193	4.785	
Madras— Stambhalaguruva, Guntur	0-8 in.	59.87	0.046	59.916	6.46	2.09	15.72	13.1	5.008	
	8 in.-1 ft. 2 in.	51.00	0.057	51.057	12.53	4.78	6.907	5.59	3.366	
	1 ft. 2 in.-5 ft.	52.06	0.062	52.122	14.09	5.32	6.270	5.09	3.400	
Govt. Fruit Farm, Cape Comorin	0-2 ft.	9.55	0.446	9.996	11.51	1.60	1.478	1.36	11.58	
	2 ft.-3 ft.	8.78	0.143	8.923	7.83	5.13	1.931	1.38	2.468	

DISCUSSION

The data in the above table indicate the manner in which the percentages of Al₂O₃ and Fe₂O₃ have been washed down the profile. It will also be seen that the value SiO₂/R₂O₃ of the HCl extract of the profile samples from the following places are considerably low, e.g. Nilgiri hills (3), (7,000 ft. a.s.l.), Kakat (Cannanore, Malabar), Chandkhuri Farm (Raipur, C. P.), Labhandi (C. P.). On the other hand, the SiO₂/R₂O₃ ratios of the HCl extracts are comparatively very high in the following cases, Putida (Chybasa, Bihar), Nilgiri hills (1) (3,000 ft. a.s.l.), Stambhalaguruva (Guntur, Madras). In the case of soil samples from Nilgiri hills, the greater the height of the place from where the sample has been taken, the lower generally is the SiO₂/R₂O₃ ratio.

There is a maximum value for SiO₂/Al₂O₃, SiO₂/R₂O₃ and Al₂O₃/Fe₂O₃, at an intermediate depth in the case of the profile samples from Nongpoh (Khasi and Jaintia hills) and Nilgiri hills (3), whilst with the profile from

Dacca Farm (Bengal), the value $\text{Al}_2\text{O}_3/\text{Fe}_2\text{O}_3$ has got a minimum at an intermediate depth, but on the other hand, in the case of the profile samples from Chandkhuri Farm (Raipur, C. P.), the value $\text{Al}_2\text{O}_3/\text{Fe}_2\text{O}_3$ gradually increases down the profile. Profile samples from Suri (Birbhum, Bengal), Nilgiri hills (1) (3,000 ft. a.s.l.) and Rajshahi (Bengal) show a minimum value for $\text{SiO}_2/\text{Al}_2\text{O}_3$ and $\text{SiO}_2/\text{R}_2\text{O}_3$ at an intermediate depth. The value $\text{Al}_2\text{O}_3/\text{Fe}_2\text{O}_3$ attains a maximum at an intermediate depth in the case of profiles from Suri (Birbhum, Bengal), and Nilgiri hills (1) (3,000 ft. a.s.l.) and on the other hand $\text{Al}_2\text{O}_3/\text{Fe}_2\text{O}_3$ increases down the profile in the case of the profile from Rajshahi (Bengal). The profile samples from Nilgiri hills (2) show a gradual tendency for the value of $\text{Al}_2\text{O}_3/\text{Fe}_2\text{O}_3$ to decrease down the profile, whilst the values $\text{SiO}_2/\text{Al}_2\text{O}_3$ and $\text{SiO}_2/\text{R}_2\text{O}_3$ increase down the profile.

All the profile samples from Assam seem to contain considerable amount of unweathered materials. This is evident from the comparatively small amounts of the total quantity of materials which are dissolved by boiling hydrochloric acid and subsequently by potassium hydroxide. All the red soils of Assam appear, therefore, to be immature and may conveniently be classed, with a few exceptions, as red loams. It may also be suggested from the above data that in the case of soil samples from Nilgiri hills occurring at 7,000 ft. a. s. l., Bidar (Hyderabad), Telankheri (Nagpur, C. P.), Putida (Chybasa, Chota Nagpur), Nilgiri hills (1) (3,000 ft. a.s.l.) and Stambhalaguruva (Guntur, Madras) contain considerable proportions of alkali-soluble silica, and it may be called lithomargic laterite in the sense the term has been used by Fox [1936].

SUMMARY

1. The percentages of silica, alumina and iron oxide dissolved from the soil by treatment with boiling hydrochloric acid and the percentages of alkali-soluble silica in the residue after extraction with hydrochloric acid have been determined.

2. Soils occurring at a height of 7,000 ft. a.s.l. in the Nilgiri hills are considerably rich in the acid-soluble oxides of aluminium and iron. So also are the samples from Bidar (Hyderabad), Telankheri (Nagpur, C. P.), Chandkhuri Farm (Raipur, C. P.), and from Kakat (Malabar Coast).

3. The percentages of alkali-soluble silica do not show any regularity down the profiles. In the case of soils from Nilgiri hills, it is found that the greater the height from where the soils were collected the less is the quantity of alkali-soluble silica.

4. The red soils of Assam appear to be of the class of red loam, and the soils from the Barind tract are similar in nature to the soils of Assam.

5. The trends of variation of molecular ratios $\text{SiO}_2/\text{Al}_2\text{O}_3$, $\text{SiO}_2/\text{R}_2\text{O}_3$ and $\text{Al}_2\text{O}_3/\text{Fe}_2\text{O}_3$ of HCl extract of profile samples have been brought about.

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