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Geochemical Detection of Soil Discontinuities in a Relatively Stable Terrain: Wonu, South-West Nigeria

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Abstract

Movement of soil materials resulting in transported overburden occur in relatively stable terrains as described from the Wonu area of South-West Nigeria. The effect of such transported soils may be serious in pedogeochemical studies as they could lead to false anomalies, masked anomalies and incorrect bedrock identification during geological mapping in highly weathered terrains. Several techniques and parameters have been successfully used to detect discontinuities in soil. A lot of these are based on 'abrupt changes' expressed by a departure in depth trends mostly physical between zones of otherwise relative uniformity. This study shows that plots of bases/alumina versus silica/alumina from geochemical analysis can be used to separate the transported soil material from that of the soil formed in-situ.

Keywords: Lithologic discontinuities, pedogeochemistry, bedrock, anomalies, profile
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INTRODUCTION

Modern methods of soil studies as exploration tool in prospecting for economic deposits was first used in USSR in the search for tin in the early 1930's. The success of the exercise was quickly followed by its application in geochemical surveys for copper, lead, zinc, nickel, tungsten and other metals (Levinson 1974, Hawkes and Webbs 1976). Geochemical studies of soils have also become a tool for geologic mapping of bed rock in areas with few or no outcrops and a high degree of weathering (Webb 1970, Matheis 1980, Laming and Gibbs 1982).

The principles underlying the use of soil as a geochemical sampling medium are based on the fact that during the process of soil formation, chemical components of the bed-rock become incorporated in the soil so that the elemental content of the near-surface soil reflects that of the parent rock (Bradshaw and Thompson 1982). Similarly, weathering of sub-outcropping mineralization results in metals being retained in the overlying soil and the formation of a residual soil anomaly.

The major problem posed in the use of this technique is the possibility of the displacement of geochemical anomalies either as a result of seasonal wash (Chowdhury 1982) or mass movement of soil resulting in 'transported overburden' (Michie et al 1972).

This leads to lithologic discontinuity – a situation where soils that are pedogenic and those that are geologic are encountered in the same profile. According to Arnold (1968) a lithologic discontinuity is represented by a more or less horizontal interface between two materials (a) that are separate and distinct from each other in terms of pattern of size grading, fabric, and mineralogy and (b) each of which exhibits internal unity.

Simonson (1959) had shown that the processes responsible for changes that are thought to have occurred or are currently occurring in progress in a solum can be generalized into four broad group types: additions, losses, translocations and transformations although they are not mutually exclusive. The concept that all processes operate in all soil systems and that the combination of past and present rates characterize genesis tends to unify the soil as a system. Thus within a vertical section abrupt changes in the magnitude of a property or in the pattern of variations that do not appear to belong to a general complementary relation are usually interpreted as differences related to depositional changes of materials. This problem is particularly accentuated in tectonically unstable regions. Parameters and methods that have been successfully used to detect lithologic discontinuities are shown in Table 1.

In Nigeria, believed to have been tectonically stable over long geologic period, pedogeochemisty has been used both for exporation for metallic minerals as well a bedrock mapping (Matheis 1980). Asadu and Akamigbo (1987) have discussed lithological discontinuities in soils of Eastern Nigeria. Similarly, studies of the chemistry and mineralogy of soils overlying different rock types in Southwest Nigeria show that minor movement of soils undetected physically do occur and could affect the interpretation of geochemical data obtained during exploration.

The aim of this paper is to show how such soil discontinuities could be detected through plots of bases/alumina versus silica/alumina from geochemical analysis of samples collected from a vertical profile.

ENVIRONMENTAL SETTING

Wonu, the area, of study is in South-West Nigeria and lies within the Nigerian 'Schist belt' (Fig. 1), a part of the basement complex of Nigeria. The 'belt' is made up of a number of well defined, approximately North-south trending schistose rocks that lie in synclinorial troughs separated from one another by uplift of the reworked basement. Olade and Elueze (1979) believe the rocks represent remnants of a supracrustal cover that was steeply infolded into the remobilized Archean gneisses and migmatites during the Pan-African Orogeny.

Lithologically the Wonu area (Fig. 2) consists of gneisses and amphibolites. Lenses of talc schists occur within the area sandwiched between the gneisses and amphibolites and are probably derived from the replacement of the latter. Quartzite and quartz-rich schists form local hills and ridges. A few pegmatite occurrences have also been reported (Elueze 1977).

TOPOGRAPHY AND DRAINAGE

Wonu is a lowland area with a few hills and ridges rising up to 600 metres. The hills have gentle slopes with gradients between 1 in 5 and 1 in 10. A number of seasonal streams occur in the area and drain eastward into the Oshun River. The drainage channels are well developed and deeply entrenched in the amphibolites and gneisses.

CLIMATE AND VEGETATION

The climate is tropical with distinct wet and dry seasons. Annual rainfall ranges between 1270mm and 1524mm. Humidity is high (about 85%) and daily temperatures average 26^0C (Fed. Min. of mines & Power 1978). Tropical rain forest with tall evergreen trees and understorey shrubs originally covered the area. However, increased population and concomitant land use has resulted in over 60% of the forest being cleared for cash crop farms and settlement.

SAMPLING AND ANALYTICAL PROCEDURES:

The soils in the area fall into the red/yellow podzol category with a dark grey solum clearly distinct from the brown A horizon (Mclean and Gribble 1979). They are generally coarse at the top of profiles and become clayey at depths below 1 metre.

The profile studied (Fig.3) is derived from talc schist and is representative of most soils in the area except for a few profiles derived from amphibolite. In these, the A horizon extends to 46cm below the surface and a B_1 and B_2 horizon is present.

Samples weighing about 5kg each were collected starting from the bottom of the profile and labelled TPS1 to TPS9 (See Fig.3).

The pH of the soil samples was measured in a 1:10 soil: water suspension after allowing it to stand for four hours. For the granulometric analysis, 100mg of air-dried and gently disaggregated sample was agitated with a Ro-tap machine for 15minutes. Only four size fractions were obtained by sieving.

Aperture Size	Mesh. No.	Remark
500mm	32	Coarse
250mm-.500mm	32-60	Medium
125-250mm	60-115	Fine
125mm	115	Very Fine

The major and minor elements in the bulk samples were determined by wet chemical methods as outlined by Riley (1958). Colorimetric measurement for Si, Al, Ti and Fe was carried out on a Pye Unicam 300 colorimeter. Mg, Mn, Ca, Fe, Ni, Co, Cu and Zn were determined on a Perkin Elmer 300 Atomic Absorption Spectrophometer with a precision of ± 20 percent of 95 percent confidence limit. Flame emission spectrometer was used to determine Na and K concentration.

RESULTS

Grain size distribution in the samples collected shows a marked increase in the very coarse and pebble fractions in the A and B horizons compared to the relatively fine grained C horizons (Fig. 4). The soil is weakly acidic with PH ranging from 5.8 at the bottom to 6.4 at the top of the profile (Table 1). The variation of chemical components in the profile is shown in Tables 1 and 2 and Fig. 5.

DISCUSSION

Ligthological discontinuities have long been known from the early days of soil analysis (Simonson 1959). The study of these features and the development of a set of guidelines directed towards this accurate detection have great scientific values.

Different parameters have been used successfully to detect discontinuity in soils. Depth functions involving clay-free particles size data, especially the coarser sands and fine silt fractions have been found to be the most indicators of the discontinuity (Schaetzl 1998).

The upper (coarse) section of the profile studied exhibits characteristics of immature soil and is believed to be a result of transportation of materials from a nearby source. This is supported by the sharp rise of $Si0_2$ content from 46% at the base of the saprolite zone to 75% in the topsoil. Mg0 on the other hand shows a marked depletion.

Translocation, mixing processes and transformations leading to intense chemical alteration within the soil profile sometimes tend to blur or obliterate lithologic discontinuities especially where the discontinuity is of small magnitude. Variations of some properties, in such cases, can be so reduced in intensity that consistent detection of a discontinuity becomes difficult (Oertel and Giles (1966). Thus Schaetzl (1998) advised that the ratio of two parameters has an advantage over a depth function of one of the same parameters. This concept of ratios has been applied in this study. Although $A1_20_3$ is relatively enriched in the soil it shows a fairly gradual depletion from 12% at the saprolit to 8% in the top soil. Consequently ratios of bases:alumina and silica:alumina were determined. Plots of these ratios (Fig.6) divide the samples into two distinct populations; Samples TPS 1-6 representing the population formed insitu from the underlying rock and TPS 7-9, the other population from an extraneous source.

Also the trace element relations with the molar ratios show that the trace element Vs bases/alumina plot (Fig.7) is also informative in determining the homogeneity or otherwise of a profile.

Soil samples for chemical analysis are normally obtained close to the surface just below the o horizon most often about 10-30cm below the surface. If discontinuities in the soil profile are undetected, geochemical studies from such soils may be greatly in error since chemical changes between parent rock and soil are usually presumed to be a function of weathering.

The absence of very high hills and cliffs, steeply dipping strata, cleavage planes and the lack of weak formations preclude the possible occurrence of either landslides, slumping or any other form of mass movement of soil within the area. Rather a gradual movement over a period of time is indicated.

CONCLUSION

Soil erosion is thought to be responsible for the transport of surficial soil materials in Wonu, South-West Nigeria. Such transported soil could lead to false geochemical anomalies, masked anomalies and incorrect bed-rock identification during geological mapping in highly weathered terraines.

The study in Wonu area has shown that soil discontinuities could be detected by chemical analysis of the profile and particularly by plots of the molar ratios of bases/alumina vs silica alumina.

It is suggested that such a study to determine soil homogeneity should form an essential aspect of reconnaissance studies whenever soil is to be used as used a sample medium in geochemical investigations.

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TABLE 1: Some parameters used successfully to detect lithologic discontinuities in soils

Indicator	References
Presence, absence or change in the content of a mineral	Barnhisel et al. 1971, Raad and Protz 1971, Karathanasis and Macneal 1994, Kuzila 1995.
Presence or absence of a detrital fossil	
Content of one or more resistant minerals in a silt fraction	Karathanasis and Macneal 1994 Chapman and Horn 1968, Rutledge et al. 1975b
Content of one or more resistant minerals in a sand fraction	Chapman and Horn 1968, Washer and Collins 1988 Arnold 1968
Elemental composition or abundance in a sand fraction	Alexander et al. 1962, Barnhisel et. al 1971, Foss et al. 1978.
Elemental composition or abundance in a silt fraction	Norton and Hall 1985, Ransom et al. 1987, Karathanasis and Macneal 1994
Elemental composition of the entire non-clay fraction	Oertel and Giles 1966
Heavy mineral content	Chapman and Horn 1968, Khangarot et al. 1971, Caberera-Martinez et al. 1989.
Clay mineralogy	Follmer 1982, Nzila 1995
Magnetic susceptibility	Singer and Fine 1989, Fine et al., 1992.
Content of coarse fragments	Follmer 1982, Arnold 196t8, Raad and 1971, Asamoa and Protz 1972, Meixner and Singer 1981, Schaetzl 1996
Total sand content, content of a sand fraction, or mean sand size	Oertel and Giles 1966, Arnold 1968, Borchardt et al. 1968, Gamble et al. 1969, Caldwell and Pourzad 1974, Meixner. and Singer 1981, Follmer 1982, Schaetzl 1992.
Total silt content or content of silt fraction	Oertel and Giles 1966, Caldwell and Pourzad 1974, Price et. al 1975, Meixner and Singer 1981, Follmer 1982.
Clayfree sand or a clayfree sand fraction	Washer and Collins 1988, Busacca 1989, Buasscca and Singer 1989, Karathanasis and Macneal 1994, Schaetzl 1996.
A clayfree and carbonate-free sand fraction	Raad and Protz 1971.
Clayfree silt or a clayfree silt fraction	Chapman and Horn 1968, Barnhisel et al. 1971, Asamoa and Protz 1972, price et al. 1975a,Washer and Colins 1988, Busacca 1989, Busacca and Singer, 1989, Karathanasis and Macneal 1994, Schaetzl 1996.
A clayfree and carbonate-free silt fraction	Raad and Protz 1971.
Any one of a number of fine earth fractions between 20 and 500 **µ**m	Langohr et al. 1976, Santos et al. 1986.

Ratio of one sand fraction to another	Fiskell and Carlisle 1963, Oertel and Giles 1966, Washer and Collins 1988, Cabreera-Martinez et al, 1989, Hartgrove et al. 1993, Beshay and Sallam 1995.
Ratio of one silt fraction to another (in some cases, clayfree)	Follmer 1982, Kuzila 1995.
Ratio of sand/silt or silt/sand (in some cases, clayfree)	Chapman and Horn 1968, Raad and Protz 1971, Smith and Wilding 1972, Asady and Whiteside 1982, Busacca 1989, Busacca and Singer 1989.
Ratio of two minerals in a sand fraction	Chapman and Horn 1968, Beshay and Sallam 1995
Ratio of two minerals in a silt fraction	Price et al. 1975, Follmer 1982, Busacca and Singer 1989, Bigham et al. 1991.
Ratio of an element to a resistant mineral in the silt +sand fraction	Santos et al. 1986
Ratio of two or more elements in a sand fraction	Smith and Wilding 1972,
Ratio of two or more elements in a silt fraction	Smith and wilding 1972, Foss et al. 1978, Bigham et al. 1991, Karathanasis and Macneal 1994.
Formulas involving particle size fractions:	
Uniformity Value	Cremeens and Mokma 1986
Comparative particle Size Distribution Index	Langohr et al. 1976.

Table 2: Profile Distribution of pH and the Molar Ratios Silica: Alumina and Bases: Alumina:

Sample No.	pH	Silica: Alumina	*Bases : Alumina
TPS 1	5.8	6.55	1.75
2	6.2	5.28	1.64
3	6.2	5.04	1.29
4	6.1	6.26	1.80
5	6.2	7.26	1.92
6	6.1	8.65	1.68
7	6.3	11.15	0.52
8	6.3	15.85	0.07
9	6.4	15.18	0.08

*Bases: alumina calculated as $(K_20 + Mg0)/Al_20_3$

Table 3: Chemical Composition of the Soil Profile

	Average Chemical Composition of Rock*	TPS1	2	3	4	5	6	7	8	9
SiO_2	57.80	46.8	45.95	42.00	44.53	45.74	49.78	59.53	72.32	74.74
Al_2O_3	1.53	12.15	12.53	14.23	12.44	10.73	9.87	9.10	7.82	8.45
Fe_2O_3	2.06	10.64	11.47	15.85	12.26	15.65	17.32	16.87	9.88	5.54
FeO	1.20	1.20	1.04	0.87	1.16	1.01	0.40	0.28	-	-
MgO	28.38	8.27	7.88	7.15	8.67	7.94	6.36	1.78	0.06	0.15
CaO	5.00	-	-	-	-	-	-	-	-	-
Na_2O	0.11	0.08	0.08	0.07	0.05	0.10	0.05	0.05	0.05	0.04
K_2O	0.19	0.11	0.13	0.08	0.10	0.12	0.14	0.16	0.33	0.29
LOI	3.38	20.64	20.11	11.78	20.57	18.47	15.73	11.89	9.22	10.37
Total	**99.66**	**99.89**	**99.41**	**99.03**	**99.78**	**99.76**	**99.65**	**99.66**	**99.68**	**99.88**
Ni **	850	99	75	65	87	85	111	79	69	82
Co**	75	54	60	51	70	72	66	71	48	45
Cu **	-	30	25	21	26	42	36	29	20	22
Zn **	88	95	100	110	90	200	140	130	62	120

*Average chemical composition of analysis of 4 samples of Talc schist collected within the study area.
** Results in ppm.

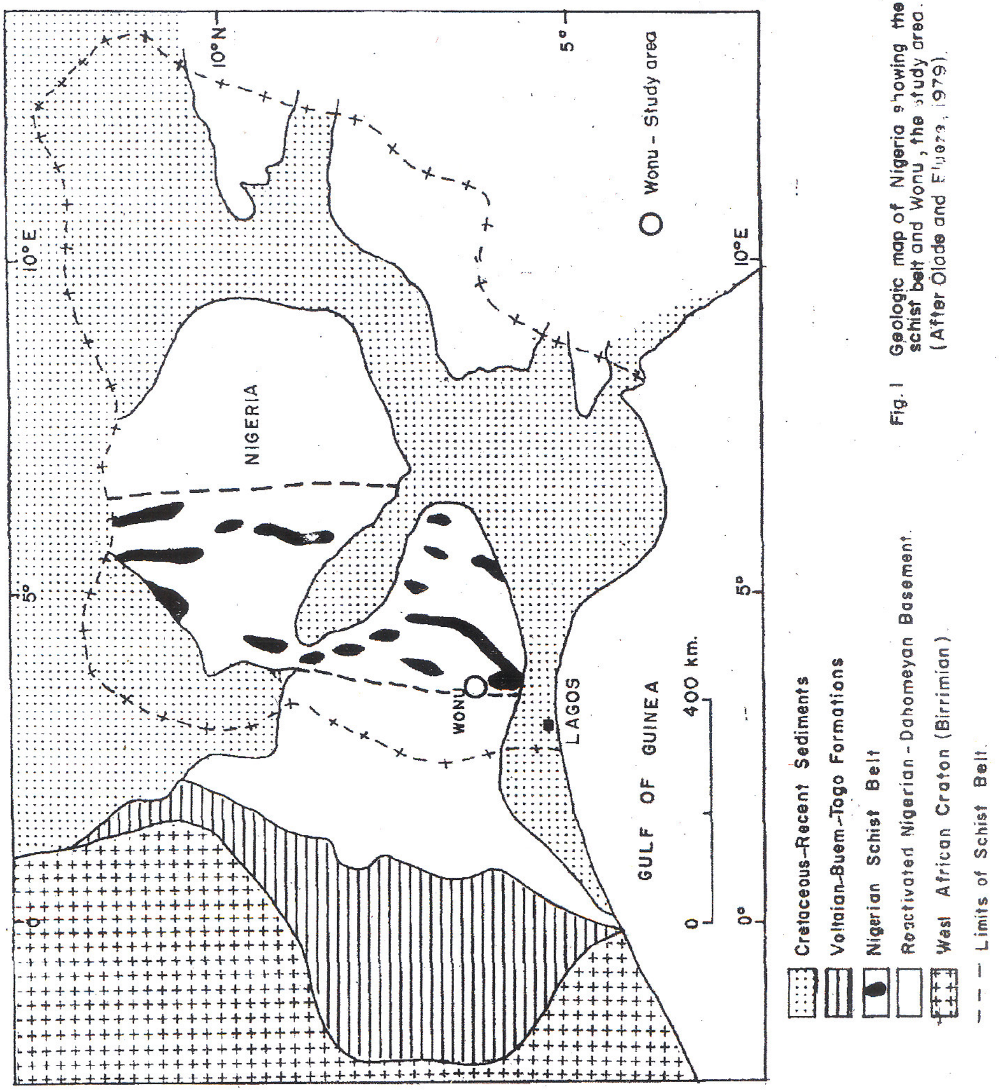


Fig. 1 Geologic map of Nigeria showing the schist belt and Wonu, the study area. (After Olade and Elueze, 1979).

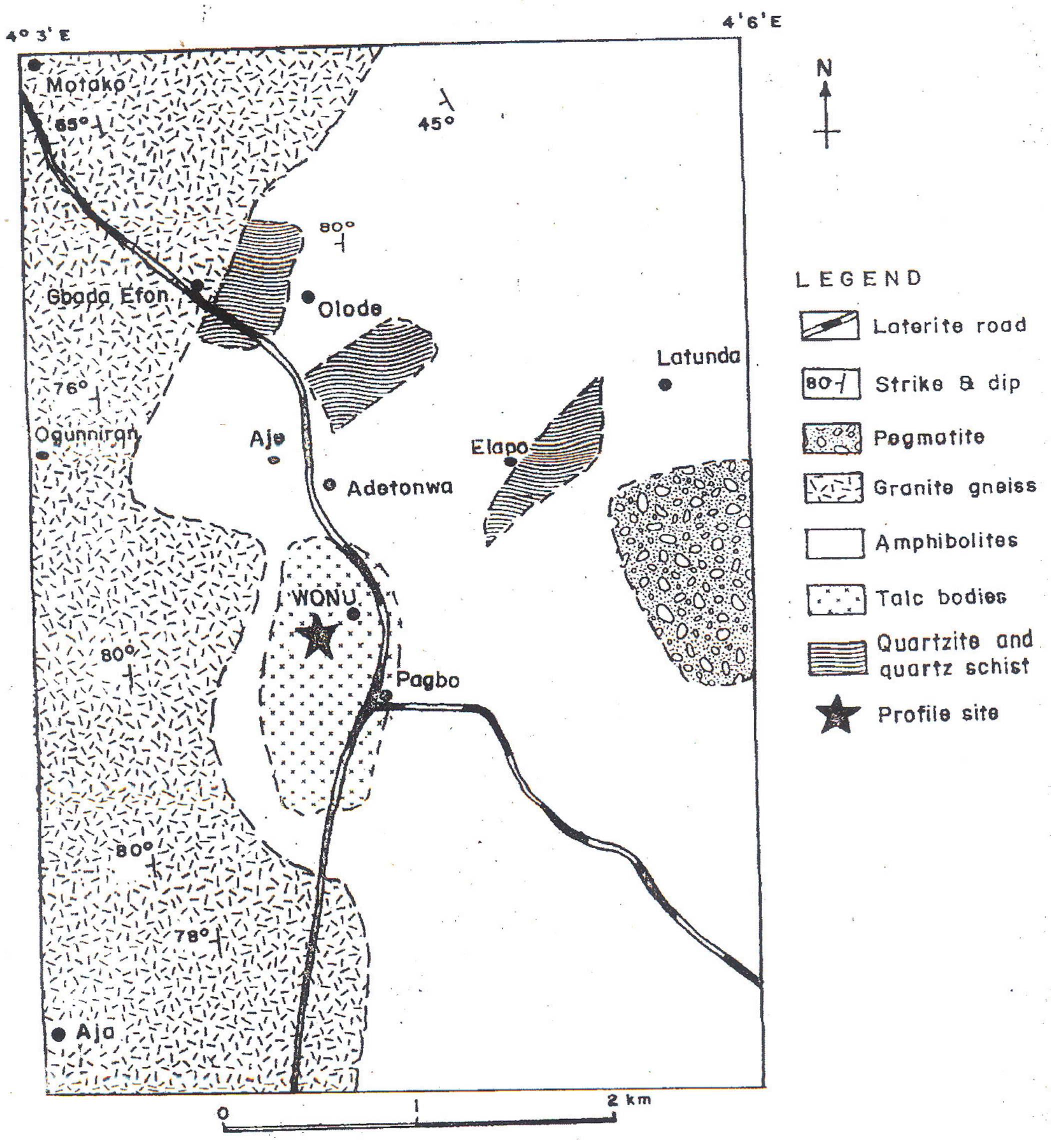
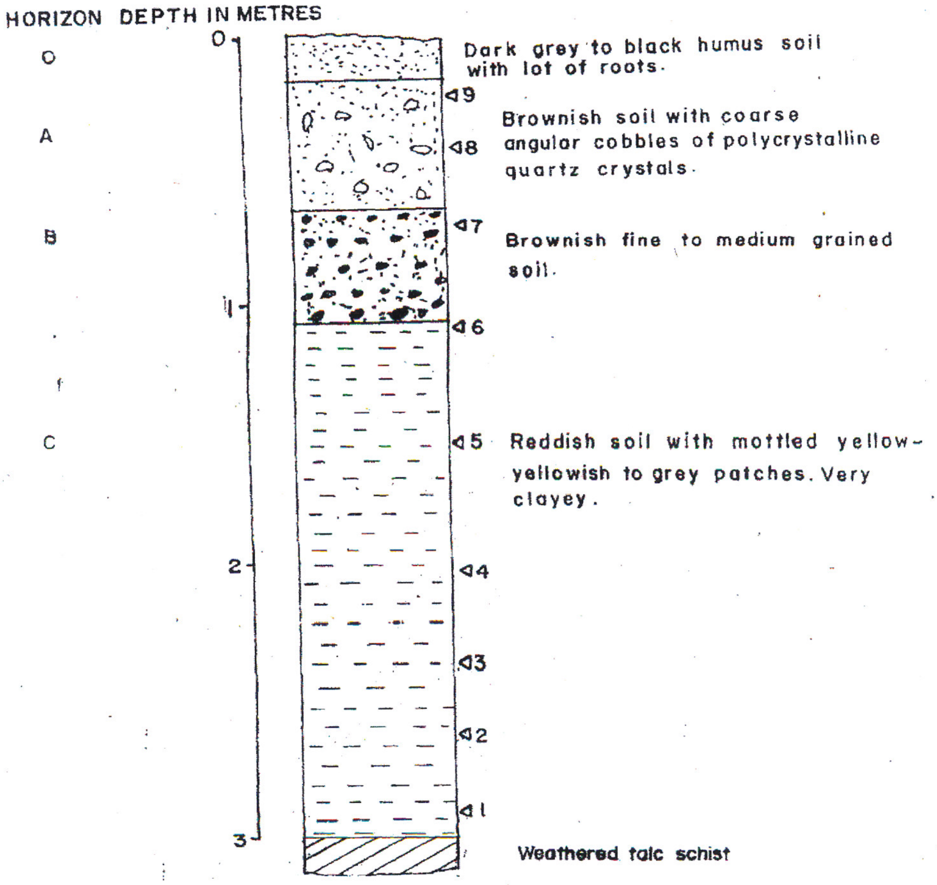


Fig. 2 Detailed geologic map of Wonu, (after Ige, 1982).

Location: Wonu
Elevation: 165m. above sea level.
Slope: 0 – 5%
Plant Growth: Secondary vegetation with few large trees.



◁ Sampling point and number.

Fig 3 Description of Soil profile over Talc Schist.

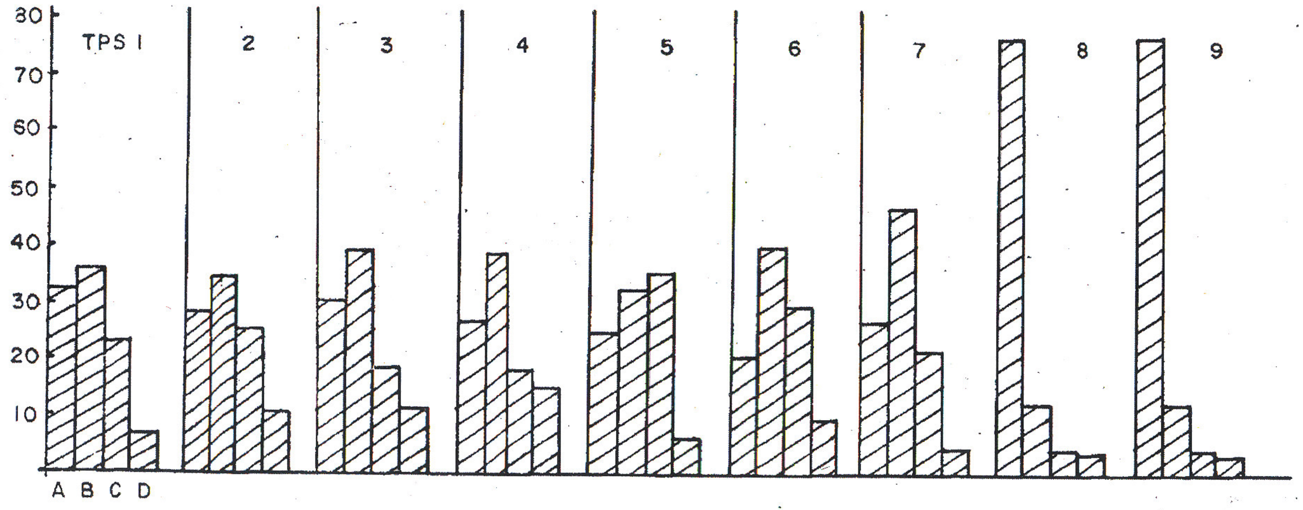
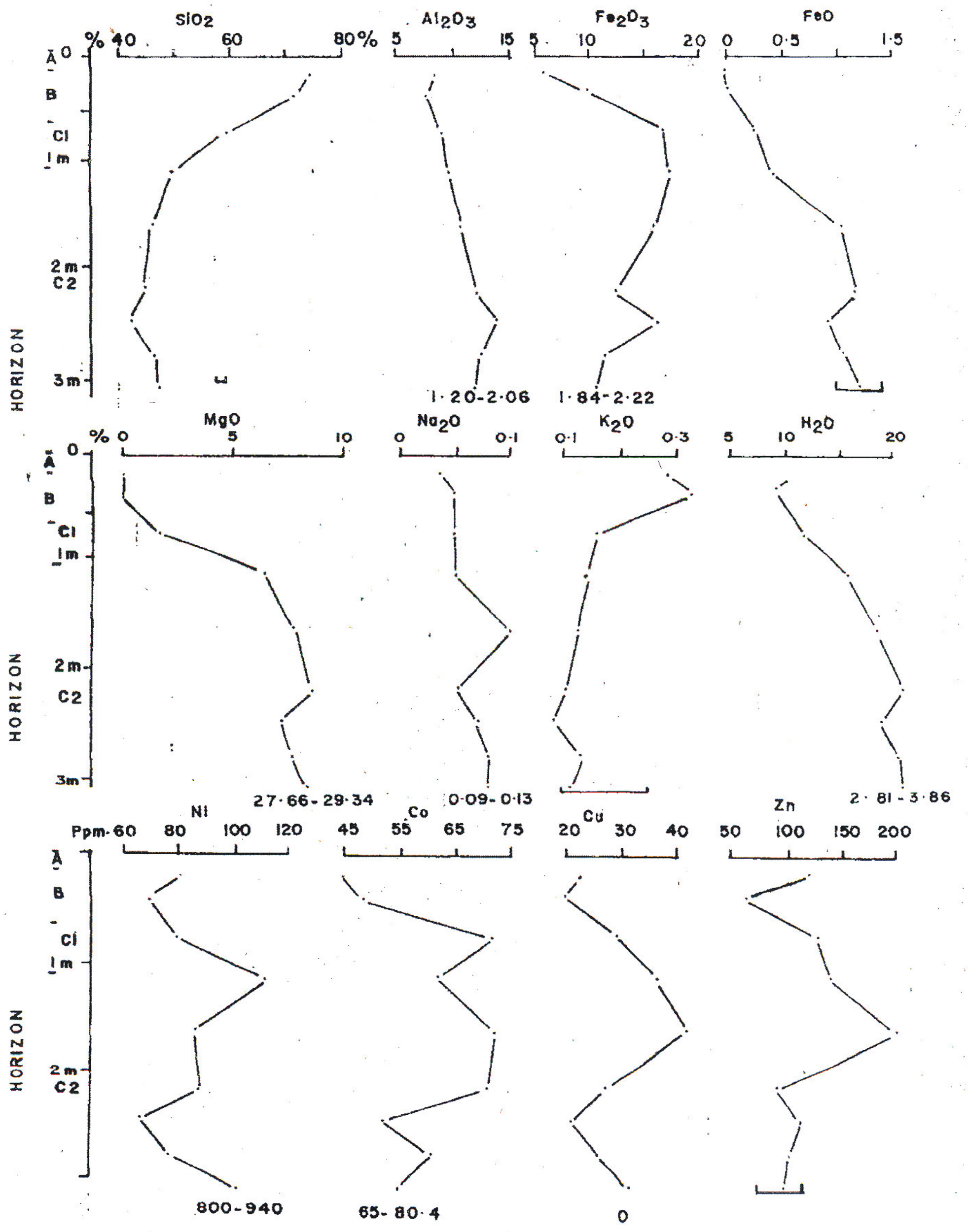


Fig. 4 Histogram showing the distribution of grain size in the soil profile
A = >500 mm ; B = 0·250 - 0·500mm ; C = 0·125 - 0·250 mm ;
D = <0·125 mm .



Fig· 5 Variation in chemical composition with depth in soil overlying talc schist. Range of bulk chemistry of rock indicated by bars or figures·

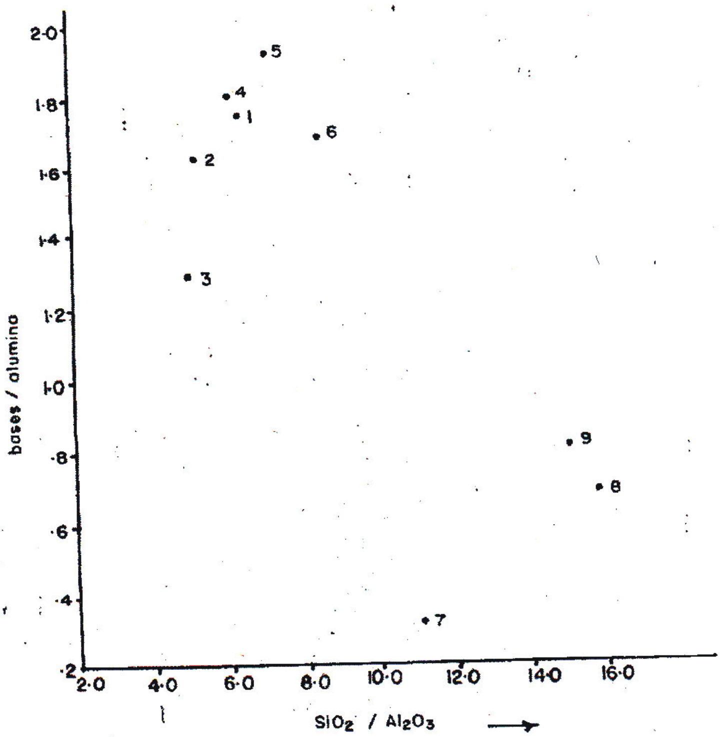


Fig. 6 Plots of bases / alumina vs silica / alumina ratio.

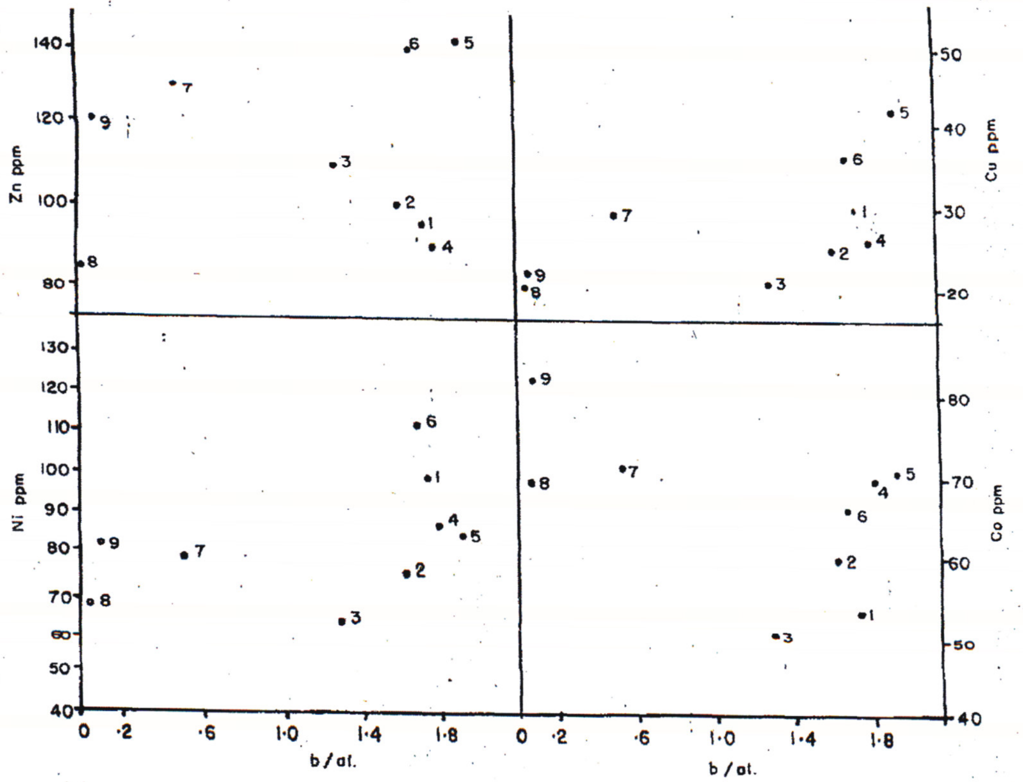


Fig. 7 Plots of trace elements vs bases / alumina ratio .