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MICROMORPHOLOGY OF "CANGAHUA": A CEMENTED SUBSURFACE HORIZON IN SOILS FROM ECUADOR

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ABSTRACT

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Soils in Ecuador with a cemented subsurface horizon, locally called "cangahua" are common in the Interandean Valley at elevations from about 1500 m to 3500 m. Soil moisture regimes are udic, ustic and aridic bordering on ustic. The soils are formed on fine pyroclastic products, deposited as eolian sediment during the Quaternary.

The abrupt upper boundary of the cemented horizon commonly occurs at a depth varying from 50 to 100 cm, and the cementation may extend to a depth of more than 150 cm. It is slowly permeable to water and it does not permit the penetration of roots. The cemented horizon was tentatively classified as duripan, although no clear evidence, such as silica coatings on ped faces, was observed in the field. There is a divergence of opinion regarding the genesis of the cementation and the nature of the cementing agent.

Study of thin sections with the optical microscope indicated the presence of many birefringent coatings of silicate clay. These coatings cover the major part of the walls of the planar voids that divide the dense loamy matrix into subangular blocky aggregates. Dark field illumination of the clay coatings revealed the presence of an additional constituent, which was subsequently identified by micro-chemical analysis to consist mainly of silica.

It is inferred that the cementation of the cangahua is of pedogenetic origin. Silicate clay and amorphous silica have been deposited along a framework of interconnected planar voids, creating a seemingly cemented soil material.

1 INTRODUCTION

About one third of Ecuador is covered by soils developed on pyroclastic deposits, mostly consisting of andesitic and dacitic ash. These deposits are of Pleistocene or Early Holocene age and they occur under a wide range of topographic and climatic conditions. Most of the soils are classified as Andosols or Cambisols (FAO-Unesco, 1974), or as Andepts or other Inceptisols (Soil Survey Staff, 1975). Natural vegetation and land use vary according to the environmental conditions.

A minor percentage of these soils is characterized by having a weakly cemented subsurface horizon, locally called "cangahua". In eroded soils this horizon may be at the surface, and, if the cementation is disrupted as by ploughing, the cangahua is highly susceptible to erosion because it is low in organic matter and has a high silt content. If it occurs deeper in the profile, the cangahua seriously impedes downward percolation of water. Furthermore, this horizon prevents the penetration of roots and so it forms a serious constraint to crop production.

There is uncertainty about the origin and the nature of the cementing agent of the cangahua. It has been considered either as a duripan or a fragipan, or possibly as an older compacted ash deposit.

A soil with a cangahua subsurface horizon has been sampled and studied by ISRIC in cooperation with PRONAREG-MAG. This paper presents some of the results of the investigation and postulates a cause of the cementation of the cangahua.

2 DESCRIPTION OF THE SOIL

2.1 General information

The site is about 1 km W of Cayambe (0°1'N, 78°7'W), Province Pichincha, Ecuador, on the lower footslope (14%, E) of the Cayambe volcano, at an elevation of 2900 m. The parent material is andesitic ash.

The mean annual precipitation is 1185 mm with a dry season from June to September. The mean annual temperature is 17.4°C with a seasonal fluctuation of 0.8°C. The soil climate is ustic and isothermic.

The soil is moderately well drained, but the cangahua horizon at 75 cm depth is slowly permeable and causes a lateral flow of groundwater downslope. In many places there is a moderate sheet and a slight rill erosion. The effective soil depth in the area is controlled by the depth of the cangahua which may range from very shallow to deep, depending on the physiographic position.

The land is used for medium level farming, seasonally irrigated, with crop rotation of maize, potato, barley, wheat, beans, and Lupinus alba.

2.2 Description of the profile

Horizon	Depth (cm)	Description
Ap	0-17	10YR 3/3 moist, 10YR 5/3 dry; sandy loam; weak fine to medium subangular blocky and weakly coherent porous massive; non-sticky, non-plastic, very friable moist, soft dry; common very fine random tubular pores; many very fine and fine roots throughout; gradual smooth boundary to
Ahg	17-40	10YR 3/3 moist, 10YR 5/3 dry; sandy loam; weak fine to medium subangular blocky and weakly coherent porous massive; non-sticky, non-plastic, very friable moist, soft dry; common medium distinct clear mottles; many very fine and fine random tubular pores; few very fine roots throughout; abrupt smooth boundary to

Bg	40-75	10YR 3/2 moist, 10YR 5/2 dry; loam; moderate medium subangular blocky; slightly sticky, slightly plastic, friable moist, slightly hard dry; common medium distinct clear mottles; many very fine to medium random tubular pores; few very fine roots throughout; abrupt smooth boundary to
2Cm	75-130	10YR 3/3 moist, 10YR 5/4 dry; loam; strongly coherent massive, parting into medium moderate subangular blocky; slightly sticky, slightly plastic, firm moist, very hard dry; common to very few fine to coarse pores; common dark coloured continuous thin coatings on ped faces in the upper 20-30 cm. The soil material is difficult to dig or cut in moist condition, but separate fragments part under pressure into fine and very fine subangular aggregates. This horizon is considered to represent a weakly cemented continuous duripan.

2.3 Analytical data

Depth	Particle size distribution(wt%)								Bulk dens	pF(vol%)							
cm	2000 1000	1000 500	500 250	250 100	100 50	50 20	20 2	<2	kg/l	0.0	1.0	1.5	2.0	2.3	2.7	3.4	4.2
0-17	1	4	11	30	16	14	15	9	1.42	41	41	34	28	24	21	14	12
17-40	1	3	9	28	15	17	17	10									
40-75	1	4	7	21	13	15	22	18	1.43	41	40	38	35	34	31	26	24
75-130	6	11	10	14	10	14	22	14	1.31	45	45	42	40	39	37	29	27

Depth	pH		C	Exch. cations(cmol(+)/kg)					CEC	Base	$CaCO_3$
cm	H_2O	KCl	%	Ca	Mg	K	Na	sum	soil	sat%	%
0-17	5.7	4.8	1.1	3.8	1.3	0.1	0.1	5.3	5.9	91	
17-40	6.8	5.3	0.6	4.9	2.1	0.2	0.1	7.3	7.3	99	1.2
40-75	7.0	5.4	0.6	7.0	4.1	0.5	0.7	12.3	11.4	100	1.2
75-130	7.3	5.5	0.3	8.4	5.8	0.9	0.3	15.4	14.7	100	1.4

Oxalate and dithionite extractable aluminium and silicon do not exceed 0.1%. The highest dithionite extractable iron content is as low as 1.3%.

Halloysite, smectite and clay-size feldspar are present in small amounts throughout the profile. Traces of clay-size quartz have been detected in the upper 40 cm.

The analyses were carried out by the methods as described by Van Reeuwijk (1987).

2.4 Soil classification

FAO-Unesco (1974)	: Eutric Cambisol
Soil Survey Staff(1975)	: Typic Ustropept, coarse loamy, mixed, isothermic.
Local	: Suelo de Cangahua

3. THE CANGAHUA

3.1 Observations in the field

The structure of the examined cangahua seemed to be massive and coherent. The horizon was difficult to dig or cut when the profile was moist, and the material was considered to be weakly cemented. On closer examination, a moderate medium blocky structure became apparent. Separated fragments parted under pressure into very fine subangular blocky peds. The consistence was firm when moist and very hard when dry.

In adjacent areas where the cangahua was at the surface as a result of erosion, mechanical disturbance by ploughing created a soil material which was easily dispersed and very susceptible to erosion.

3.2 Observations in the laboratory

Examination of undisturbed samples, taken at 75 and 85 cm depth, confirmed the consistence as observed in the field. Moist samples were moderately brittle.

Air dry fragments did not slake in water or in 1N HCl, not even after immersion for some days and occasionally rocking the sample. Some fragments parted into two or three pieces but after wetting for ten days the samples still showed a weak brittleness. Immersion in hot concentrated KOH produced almost instantaneous slaking of the complete fragment.

Inspection of air dry fragments under the stereomicroscope revealed the presence of abundant coatings on the faces of very fine and fine subangular blocky peds. These coatings have a dull lustre and colours with lower chromas and values than the ped interiors. Fragments of the coatings, examined under the polarizing microscope, were birefringent or isotropic, and had a refractive index lower than 1.55.

If water was dripped on separated peds, it was quickly absorbed by the soil material where the ped was broken and not covered by a coating. If sufficient water was added, the ped quickly slaked and the soil material dispersed completely.

3.3 Observations in thin section

The soil material shows a moderately developed pedality, being subdivided into very fine and fine subangular blocky peds. The inter-aggregate planar voids are straight or curved and occasionally interconnected by elongate vughs. The planar voids normally are not wider than 200 μm. The microstructure of the peds is massive, with only very few intra-pedal vughs.

The coarse components of the soil material consist dominantly of very fine and fine sand-sized angular grains of feldspar and medium sand-sized fragments of vitric-lithic tuff or glass. Accessory are hyperstene and augite, and very few green hornblende and quartz. The content of green hornblende is markedly less than in the horizons overlying the cangahua, which implies that this horizon constitutes a different ash deposit.

The micromass consists of brownish yellow (10YR) speckled clay which, under crossed polarizers, shows an undifferentiated b-fabric at low magnification and a very weakly speckled b-fabric at high magnification. The related distribution is porphyric. The soil material is devoid of recognizable plant remains.

Almost all planar voids have yellowish brown to dark yellowish brown (10YR) coatings or dense incomplete infillings of microlaminated clay, locally grading to very pale brown to almost colourless limpid non-laminated clay. Under crossed polarizers the microlaminated clay shows pale yellow to orange first order interference colours, indicating the presence of strongly oriented phyllosilicate clay. Transitions to limpid clay are less strongly oriented and have a lower birefringence, or are isotropic. Using dark field illumination, the coatings and infillings show a conspicuous contrasting very dark brown colour, without masking the translucency of the material.

One sub-horizon has common diffuse ferruginous mottles.

No features indicating the presence of secondary quartz or chalcedony were identified.

3.4 Microchemical analyses

Samples of cangahua were mounted on aluminium stubs and coated with carbon in a vacuum disperser for examination using a Jeol 35C scanning electron microscope at the university of Wales, Swansea. Attention was focussed on the coatings and intergranular bridge material. Qualitative analysis by the Link 290 system revealed that some parts of the coatings had a very high silicon content and others a combination of silicon and aluminium which suggested the presence of silicate clay.

A thin section of cangahua, pre-treated in a similar way, was investigated by the Technical and Physical Engineering Research Service (TFDL), Wageningen. Investigation of the coatings using a Philips 535 SEM-EDXRA fully confirmed the results obtained at the University of Wales.

4 DISCUSSION

4.1 Cause of the cementation of the cangahua

It is postulated that cementation of the cangahua is caused by a three-dimensional framework of continuous interconnected coatings that are associated with the planar voids. Presuming these coatings are coherent to some degree, they create a rigid skeleton throughout the soil material, which gives the horizon a cemented nature.

The coatings envelop almost all peds and they appear to consist of a mixture of silicate clay and amorphous silica. The consistence of the coatings could not be established, but it is inferred from observations in the field and in the laboratory that the coatings are sufficiently coherent to hold together and envelop the soil material within the peds, as long as they are not disrupted. The soil material within the peds is non-coherent and very rapidly dispersed if water is added. Since fragments of cangahua material immersed in water for prolonged periods do not slake, it is assumed that the coatings are coherent and do not easily disperse. Disruption of the coatings allows water to enter the peds, and the soil material easily disperses.

Percolation of water in the cangahua horizon is mainly restricted to the planar voids which in the course of time have been partly or completely infilled causing an increasingly impermeable horizon.

4.2 Classification of the cangahua

The cangahua meets many, but not all requirements of a duripan. The definition (Soil Survey Staff, 1975) requires a cementation by silica. This statement is vague enough also to include a cementation as suggested in section 4.1 All duripans, however, have a very firm or extremely firm moist consistence, whereas the cangahua has a firm moist consistence. Furthermore, there are no vertical opal coatings, durinodes or silica pendants recognizable in the field. The presence of amorphous silica in the coatings of silicate clay was suspected during the study of the thin sections, but could only be confirmed by microchemical analysis.

As the cangahua does not meet the criteria for a duripan, either in Soil Taxonomy (Soil Survey Staff, 1975) or in the legend of FAO-Unesco Soil Map of the World, it cannot be taken into account in the process of classification. However, in the opinion of the authors, it is a significant constraint for crop production and so should be considered at least in the lower levels of classification as a protoduripan.

5 REFERENCES

FAO-Unesco, 1974. Soil Map of the World, 1:5000.000. Vol.I Legend, 59pp.

Soil Survey Staff, 1975. Soil Taxonomy. A basic system of soil classification for making and interpreting soil surveys. Agric. Handb. no.436 SCS., USDA.

Van Reeuwijk, L.P. (Editor), 1987. Procedures for Soil Analysis. Techn. Paper 9, 2nd. ed., ISRIC, Wageningen.