EVIDENCE OF PEDOLOGIC CHANGES DUE TO RAPID TECTONIC UPLIFT: THE OÑA MASSIF, SOUTHERN PART OF CENTRAL ECUADOR.

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The Oña Massif, located 50 km south of Cuenca between the city of Oña and Saraguro is 3000m above sea level. In that area the climate is equatorial mesothermic semi-humid (Pourrut, 1994). The average monthly temperature is stable, being between 12 and 13°C in the station of Saraguro at 2525m. With a decrease of 0.6° per 100m of altitude, the yearly average temperature of the Oña Massif does not exceed 10°C. The annual average rainfall is 780 mm at Saraguro, but probably even higher on the top of the Oña Massif. Two rainy seasons occur: the main one lasts from January to June and a smaller one lasts from October to November-December.

The Oña Massif is covered by up to 6m thick soils. These soils overlie Miocene flows being dacitic and rhyolitic in composition. The soils are clayey, red in colour at base and yellow on top with a gradual transition of a mottle horizon. Their upper organic horizons are black and up to 40cm thick. These soil were considered as humults (humiferous ferrallitic soil; Segalen, 1994), although the upper horizon has andic-like properties such as (a) high C contents (12 to 8 g/100g), (b) low bulk density (0.6), (c) a water retention at 0.3 kPa of 60g/100g, and finally (d) a (Al+1/2 Fe) oxalate extract being between 1.1 to 1.3%. The lower yellow and red horizons contain (a) much lower C contents, (b) a bulk density of 1.2, (c) a water retention at 0.3 kPa of 35g/100g and (d) a (Al+1/2 Fe) oxalate extract less than 0.4%. These upper-organic horizons have been correlated to andisols (melanocryand) of the Cajas Massif located 50km north of the Oña massif, formed above of recent volcanic ashes. These are likely to have originated from the active volcanoes of Sangay and/or Tungurahua, both located 100 km north of the Oña Massif.

Weathering-resistant relicts of a parent-rock such as the presence of coarse-grained quartz (>2mm in diameter) in these black horizons raise doubts on the origin of the recent ash deposits from so distant sources. An additional source of scepticism is the clay-mineral composition which is predominantly made up with kaolinite with small amounts of in the organic part of these horizons, while the lower yellow horizons is exclusively made up with kaolinite with small amounts of goethite. Geochemical determinations based on rare earth elements confirm the uniformity of the whole profile with Eu/Eu* of 1.15±0.05, Ce/Ce* of 0.67±0.31 and Gd_N/Yb_N of 3.84±0.33 strongly implying not to have any contribution of volcanic ash deposits compared to such as the andosolic profile of the Cajas Massif with Eu/Eu* of 0.97±0.03, Ce/Ce* of 1.08±0.07 and Gd_N/Yb_N of 1.55±0.10.

A major climatic change might be a possible explanation for this major change in the pedological outcome. The evolution of this ultisol into andisols could be the result of rapid tectonic uplift of this area accompanied with weak erosional process of the soils due to the absence of strong slopes on the top of this massif. The high uplift rate is hereby explained by the limited formation of kaolinite. Kaolinite can only be formed with an average temperature largely exceeding 20°C (Fritz and Tardy, 1973; Tardy, 1993). In past time (end of Tertiairy, beginning of Quaternary) the massif was close to sea level with an annual average temperature of 25°C, high annual average temperature favoured exclusively neoformation of kaolinite derived out of Si and Al-rich solutions. Considering the mechanical erosion rate and a temperature decrease of -0.6°C per increasing 100m, while soils are now located at 3000m height with an average annual temperature of around 10°C, a calculated uplift rate fits with previously obtained data with independent methods of the same area to be higher than 0.6 mm/year (Steinman, 1997). At present, average annual temperature is lower, kaolinite becomes unstable favouring the presence of oxides, goethite and amorphous components. These amorphous components associated with lower temperature and low pH values (<5.0) limit carbon mineralization.

This hypothesis is also substantiated by the orientation of south-west trending altitudinal winds which carry high amounts of fine volcanic ash from the active volcanoes of Tungurahua and Sangay. They mainly affect areas including the Cajas Massif or west-Saraguro which located lee-wind., while the massifs located south remain unaffected from these emissions.

References

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Table 1: Some chemical and physical properties of the studied andisol of the Cajas Massif and an ultisol of the Oña Massif. Abbreviations are: B.D. = bulk density ; H = relative humidity (on field) ; pF = water retention.

depth	C	N	pH	pH	Exchangeable cations				CEC	S/T	B.D.	H	pF
			H_2O	KCl	Ca^+	Mg^+	K^+	Na^+					30 kpa
(cm)	$g.kg^{-1}$	$g.kg^{-1}$			cmol(+).kg^{-1}					(%)		$g.100\ g^{-1}$	
CAJAS													
0-30	233	0.87	4.5	4.0	1.32	0.41	0.13	0.09	7.86	24.95	0.35	210	192
60-45	194	0.98	4.5	4.0	2.03	0.54	0.18	0.07	8.85	31.89	0.58	130	120
45-60	54		4.8	4.7	0.57	0.06	0	0.02	1.55	41.92		56	48
60-70 +	16		5.0	4.8	0.5	0.03	0	0	1.08	48.92		21	34
OÑA													
0-15	120	6.7	3.9	3.6	1.00	0.33	0.12	0.21	10.05	16.51	0.59	73	61
15-35	82	4.2	4.2	3.9	0.68	0.14	0.06	0.11	7.28	13.59	0.65	86	70
35-50	23	1.1	4.5	4.4	0.44	0.07	0.03	0.09	4.86	12.95			59
50-80	7	0.5	4.6	4.1	0.46	0.05	0.03	0.14	5.03	13.51	1.14	47	43
80-120	3	0.2	4.5	4.1	0.37	0.05	0.04	0.20	4.98	13.24			33
120-170			4.6	4.1	0.32	0.05	0.02	0.08	4.77	9.84			33
170-250			4.7	4.1	0.32	0.06	0.02	0.09	5.00	9.81	1.29	39	36
250-300			5.4	4.4	0.45	0.05	0.06	0.20	5.12	14.83	1.14	48	43

Table 2: Extraction of amorphous components of the studied andisol of the Cajas Massif and an ultisol of the Oña Massif.

depth (cm)	oxalate ‰			pyrophosphate ‰			CBD ‰			%	
	Al	Fe	Si	Al	Fe	Si	Al	Fe	Si	(Al+1/2Fe) o	Alp/Alo
CAJAS											
0-30	27.60	12.70	0.60	28.80	12.30	0.90	27.90	14.00	1.40	3.40	1.00
60-45	27.20	8.10	3.50	25.30	8.20	2.60	30.80	11.00	3.60	3.10	0.90
45-60	48.60	2.80	14.00	11.80	1.80	0.80	18.40	4.70	2.30	5.00	0.24
60-70 +	25.00	1.60	16.00	4.80	0.45	0.50	7.10	3.00	0.90	2.60	0.20
OÑA											
0-15	7.32	7.92	0.33	7.60	9.25	0.86	11.75	12.40	4.49	1.13	1.04
15-35	8.90	10.72	0.33	9.25	11.95	1.47	12.00	13.10	3.47	1.43	1.04
35-50	4.32	4.78	0.12	3.61	7.25	0.29	6.00	17.45	0.13	0.67	0.84
50-80	2.38	1.41	0.11	1.29	1.73	0.04	3.90	13.80	0.06	0.31	0.54
80-120							2.88	11.35	0.08		
120-170							2.31	10.45	0.14		
170-250							1.79	9.15	0.18		
250-300							1.68	8.45	0.18		

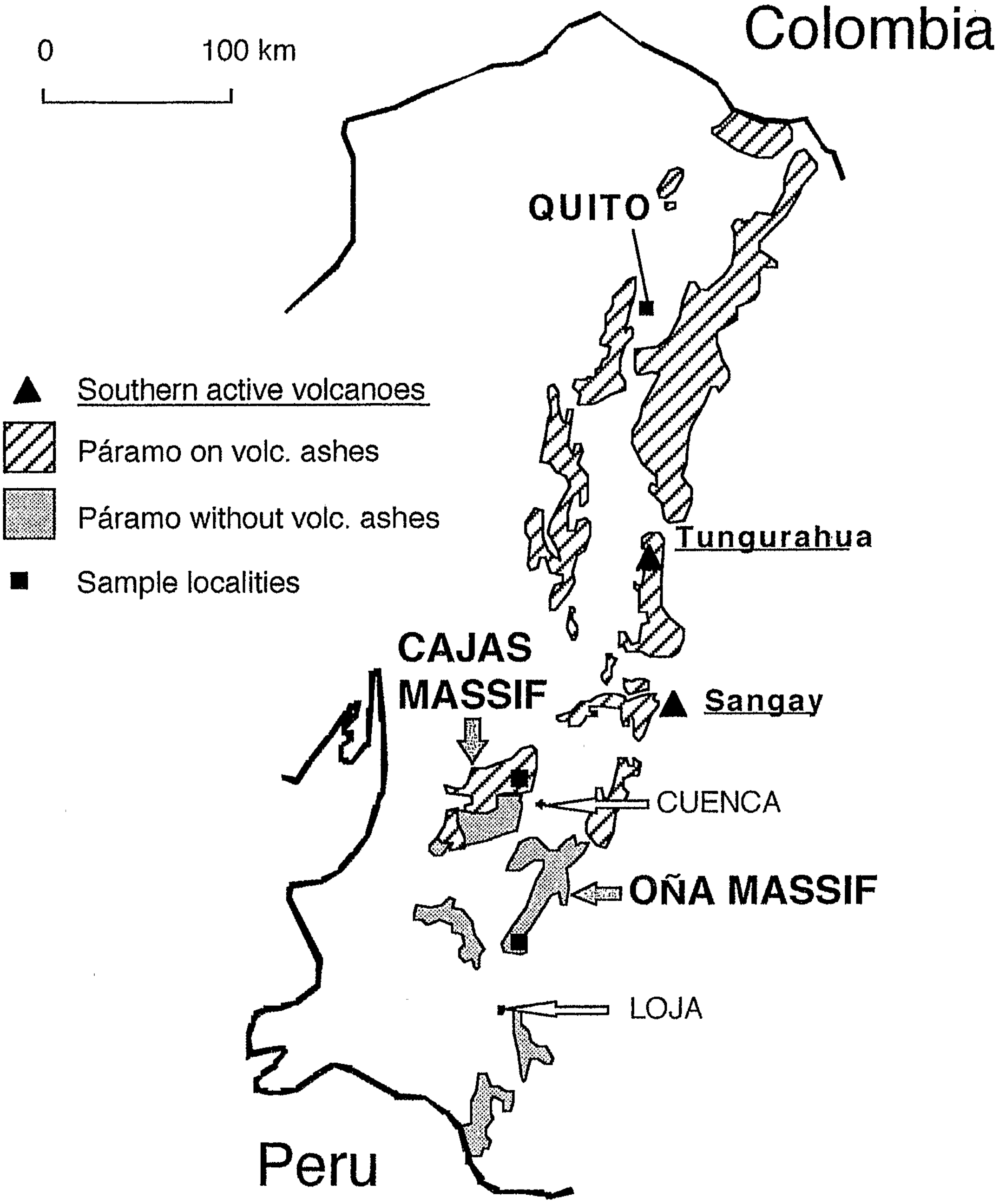

Fig. 1: Distribution of the Pàramo in Ecuador and sample localities.