Mineralogy, geochemistry, micromorphology and WRB classification of a soil-sedimentary sequence on limestone in Monte Coronichi (Istria, Croatia)

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INTRODUCTION

This work analyzed a soil-sedimentary profile (conventionally considered as *terra rossa,* which is the dominant soil in the study region and a widespread soil across the Mediterranean, found mostly on limestones) found in a vineyard near the village M. Coronichi (Istrian peninsula). Terra rossa is considered and labelled by various researchers very differently (e.g., as Cambisol or Luvisol, relict soil, recent-relict soil, polycyclic or polygenetic soil, vetusol, or pedosediment). Accordingly, it is commonly believed that it might have formed during the Paleogene, Neogene, and/or hot humid periods of the Quaternary. The main aims of this work were to relate the properties of the studied profile to the environmental conditions in the study region, to gain knowledge on its formation, and to classify it according to the WRB as a widely used international system. The climate along the Istrian coastline is humid subtropical (Cfa) according to the Köppen classification. The study area is characterized by maquis shrubland and karst geomorphology developed along a plateau slightly inclined from the east to the west (from about 400 m to 0 m asl).

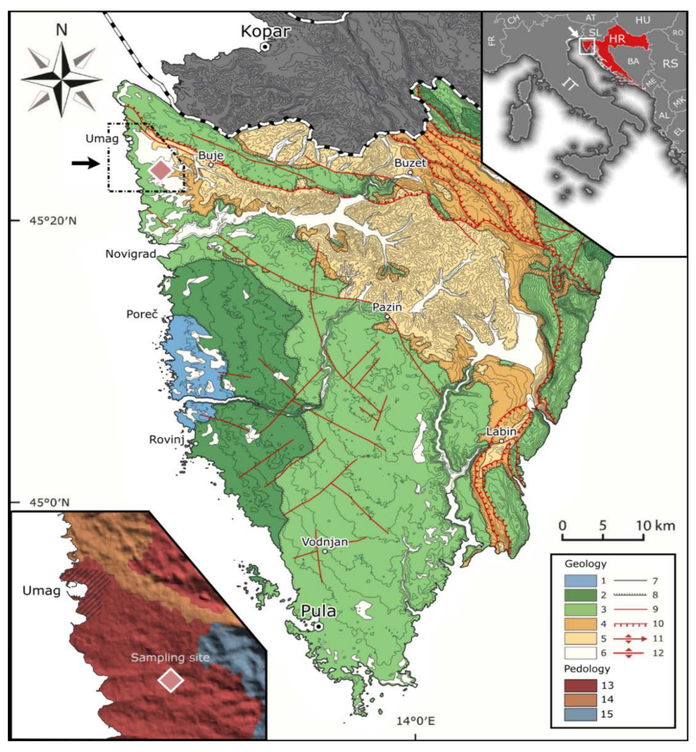
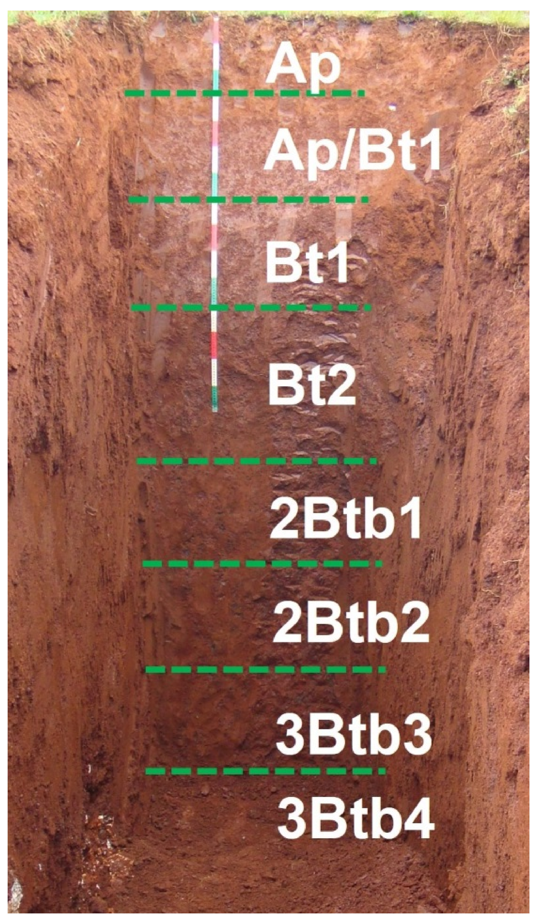
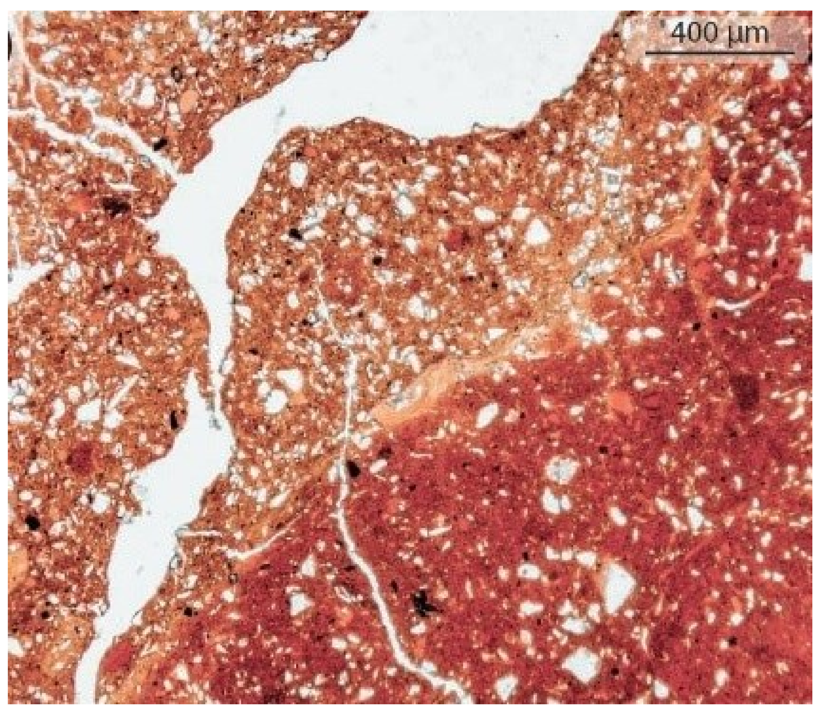


Figure 1: Geological map of the Istrian peninsula with the position of Istria in Europe and the study location: 1 - Jurassic, 2 – Lower Cretaceous, 3 - Upper Cretaceous, 4 - Lower Eocene, 5 - Middle to Upper Eocene, 6 – Quaternary, 7 – normal geological boundary, 8 - erosional geological boundary, 9 - normal fault, 10 - reverse fault, 11 – Western Istrian anticline, 12 – Savudrija-Buzet anticline, 13 – chromic luvisols, 14 – chromic cambisols, 15 – eutric and calcic vertisols

RESULTS

The profile consists of a recent terra rossa overlying two red palaeosols on limestone of Lower Eocene age. Its morphology and micromorphology (color, structure, clay coatings, Fe/Mn nodules, pedorelics…) indicate long and intense weathering and pedogenesis (interrupted by at least two distinct erosion/sedimentation cycles). Accordingly, pH_{KCl} values are lower than 4.3 throughout the profile. The soil is mostly (heavy) clay, with the clay content increasing with depth. However, this increase is interrupted in 2Btb1 and 3Btb3 horizons, which contain less clay (along with the lower fine/total clay ratio) than the horizons immediately above. Nevertheless, both 2Btb1 and 3Btb3 have abundant illuvial clay. Along the profile, CEC increases with increasing clay content, and its values indicate low-activity clays. The main soil minerals are kaolinites and illitic material, with significant amounts of quartz and hematite. Distribution of the three most abundant oxides reflects weathering intensity along the profile: SiO_2 decreases with depth, while Al_2O_3 and Fe_2O_3 increase. The geochemical indices, except confirming the process of lessivage (CIA) and the overall high degree of weathering (CIA, Fe_d/Fe_t), indicate material provenance from the Alpine collisional orogen and the Po Basin.





Figures 2 and 3: The studied profile (left) and the PPL microphotograph of the Bt2 horizon at the boundary with the 2Btb1 horizon (right) - blocky microstructure with accommodated and partially accommodated subangular peds is well developed; partially relict, dusty clay coatings/infillings are observable along the plane void that forms the abrupt boundary between the Bt2 and 2Btb1 horizons.

Table 1: Selected soil chemical and geochemical properties and indices

Soil horizon	Soil depth	pH_{KCl}	pH_{H2O}	SiO_2	Al_2O_3	Fe_2O_3	Fe_d/Fe_t	CIA Al*100/ Al+Ca+K+Na	La/Ce	CEC	CEC_{clay}	BS	Organic C
	cm			%						$_c$mol kg^{-1}		%	
Ap	0-30	3.89	5.29	65.4	16.6	6.6	0.79	85.3	0.46	8.9	5.0	76.5	1.08
Ap/Bt1	30-70	4.01	5.47	54.4	20.9	8.4	0.81	87.7	0.48	13.6	8.2	98.2	0.97
Bt1	70-110	3.97	5.36	54.5	21.0	8.4	0.83	87.8	0.48	14.5	10.0	100.0	0.64
Bt2	110-170	3.97	5.37	54.0	21.4	8.7	0.82	88.7	0.42	14.9	11.0	100.0	0.60
2Btb1	170-200	4.08	5.51	50.6	23.4	9.3	0.83	90.3	0.42	17.8	10.6	91.0	0.48
2Btb2	200-230	4.19	5.45	47.1	25.5	9.9	0.82	91.2	0.42	18.4	15.5	92.9	0.49
3Btb3	230-260	4.25	5.79	45.6	26.2	10.0	0.83	91.6	0.43	19.4	13.5	96.1	0.49
3Btb4	260-300	4.28	5.82	42.5	27.9	10.4	0.85	92.0	0.52	22.4	20.0	93.8	0.36

Table 2: Bulk soil mineralogical composition

Soil horizon	Chlorite	Mica/Illite	Kaolinite	Phyllosilicates	Quartz	K-feldspar	Plagioclase feldspar	Hematite	Rutile
Ap	6	14	25	45	43	2	5	4	1
Ap/Bt1	2	15	40	57	26	2	6	8	1
Bt1	2	15	41	58	25	2	5	9	1
Bt2	2	15	42	59	24	2	5	9	1
2Btb1	2	14	45	61	21	2	5	10	1
2Btb2	2	14	48	64	18	2	5	10	1
3Btb3	2	14	50	66	16	5	5	10	1
3Btb4	1	12	66	79	6	-	3	11	1

Table 3: Soil particle size distribution

Soil horizon	Particles (sizes in mm) extracted after soil dispersion in Na-pyrophosphate											Water-dispersible clay
	Coarse sand 2.0-0.2	Fine sand 0.2-0.063	Coarse silt 0.063-0.02	Fine silt 0.02-0.002	Coarse clay 0.002-0.0002	Fine clay <0.0002	Soil texture	Coarse/fine sand	Coarse/fine silt	Total clay/silt	Fine/total clay	%
	%											
Ap	0.2	2.5	23.0	18.1	21.6	34.6	Silt clay	0.1	1.3	1.4	0.6	18.0
Ap/Bt1	0.2	1.2	14.1	24.0	23.3	37.2	Clay	0.2	0.6	1.6	0.6	5.0
Bt1	0.0	1.0	11.4	18.6	24.6	44.4	Clay	0.0	0.6	2.3	0.6	4.4
Bt2	0.2	1.0	10.0	15.2	14.7	58.9	Clay	0.2	0.7	2.9	0.8	2.8
2Btb1	0.0	0.7	9.0	30.8	29.7	29.8	Silt clay	0.0	0.3	1.5	0.5	1.3
2Btb2	0.1	0.4	4.2	11.4	14.4	69.5	Clay	0.3	0.4	5.4	0.8	3.2
3Btb3	0.0	0.4	3.1	27.0	24.2	45.3	Clay	0.0	0.1	2.3	0.7	3.8
3Btb4	0.1	0.1	1.1	9.4	17.7	71.6	Clay	1.0	0.1	8.5	0.8	2.0

CONCLUSIONS

The whole sequence is named Lixic Rhodic Ferralsol (Clayic, Hypereutric, Raptic). Ferralsols are the classical, deeply weathered, red (or yellow) soils of the (per)humid tropics (found mostly in South America and Africa); minor occurrences elsewhere are considered to be relics from past era with a warmer and wetter climate than today. Therefore, the studied profile is polygenetic and mostly relic, formed primarily under the influence of tropical climate in the past, by both geogenetic and pedogenetic processes, such as colluvial and aeolian deposition and erosion, formation and translocation of clay minerals, rubification, and ferralitization. Today, it represents an extremely rare case of a tropical soil found at the most northern point of the Mediterranean. **This work has been fully supported by Croatian Science Foundation under the project No 2019-04-8054 - WIANLab (Western Istrian Anticline as an ideal natural laboratory for the study of the regional unconformities in carbonate rocks).**

WIANLab

HRZZ Croatian Science Foundation