INFLUENCE OF SOIL CHARACTERISTICS ON VINE GROWTH, PLANT NUTRIENT LEVELS AND JUICE PROPERTIES: A MULTI-YEAR ANALYSIS

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ABSTRACT

Soil physical and chemical properties affect vine nutrition, as indicated by leaf and petiole nutrient content, in a way that may directly impact wine properties. The goal of this multi-year project is to study the relationship between vineyard soils and the wines produced on them using a variety of biogeochemical and mineral analyses, coupled with an analysis of vine properties and juice characteristics. This study examines leaf and petiole nutrient levels, as well as fruit and juice characteristics, of own-rooted Cabernet Sauvignon vines grown on four distinct soil types in the same Paso Robles vineyard. The soils were classified as Palexeralfs, Haploxeralfs, Haploxerolls and Haploxererts. The four soils exhibited important morphological differences in color, coarse fragment content, texture, water holding capacity, and hydraulic conductivity. The soils also showed important differences in chemical characteristics and nutrient availability. The soils covered contiguous vineyard patches planted with the same cultivar, on its own roots. The vineyard was irrigated and fertilized. Mesoclimatic conditions and slope aspect were similar. Soils were analyzed for physical and chemical differences to determine the influence of the four contrasting soil types on differences in vine growth, water stress and plant nutrient levels. Differences in cation exchange capacity and cationic balance in the soil solution appeared to affect nutrient availability to the vines, and likely contributed to the observed differences in the plant and fruit characteristics. Berries harvested on the four blocks exhibited different sensory attributes, as determined by a tasting panel. In an analysis of data from three consecutive growing seasons, many of the observed differences in plant vigor between vineyard blocks were consistent from year to year, as were differences in fruit yield and juice properties. Taken together, these findings support a role for soil texture, water and nutrient availability on vine and fruit parameters, and emphasize that differences in soil properties within a single vineyard may require site-specific management practices.

KEYWORDS

Soil – Biogeochemistry – Nutrients – Leaf – Petiole - Management

INTRODUCTION

The goal of this multi-year project is to study the relationship between vineyard soil properties (i.e., mineralogy, nutrient levels, water availability), vine growth characteristics, juice and wine properties. To date, although much speculation has been devoted to this topic in the popular wine press, few studies have systematically evaluated the relationship between soil characteristics, vine vigor and fruit or juice properties (Andrés-de-Prado *et al*., 2007;

Tomasi *et al*., 2006). Here we present results of an ongoing, multi-year study performed with the cooperation of J. Lohr Vineyards, Paso Robles, CA. The company determined that soils with different chemical and physical properties existed in a contiguous field of Cabernet Sauvignon. The vines in this vineyard were planted at the same time, on the same rootstock, and received similar management practices. Mesoclimatic conditions, as determined by elevation and slope aspect, were also similar. Upon detailed analysis, the four soils were found to be significantly different, and in an informal tasting, small lot wines prepared from vines growing on each of the four sites were also perceived to have different sensory properties. Field observations and laboratory analyses over three growing seasons revealed consistent trends in vine vigor as well as leaf and petiole nutrient levels between sites.

MATERIALS AND METHODS

Soil Analyses

Soil Sampling. Vineyard soils were sampled at four sites designated as Blocks 52, 53, 56 and 57. Two soil pits were excavated in each block, for a total of eight pits. Soil horizons were described in the field following the National Cooperative Soil Survey field description manual (Soil Survey Staff, 1993). A Trimble GeoXH GPS was used to georeference the pit locations and vines, allowing for precise mapping of soil variability within the vineyard.

Soil Physical and Chemical Analysis. Solid-phase soil characterization was performed for replicate samples from each site. Soil texture was analyzed by laser granulometry and by the hydrometer method. Soil pH and electrical conductivity were measured in the laboratory using a 1:1 soil:water paste. Soil samples were processed by passage through a 2 mm sieve to separate coarse fragments from the fine earth fraction. Soil chemical analyses were performed in the UC Davis DANR Analytical Laboratory for exchangeable cations (Ca, Mg, K, Na), CEC, pH, EC, total N, NO_3, NH_4, P, S, Zn, Cu, Mn, Fe, Si, and B.

Soil Solution Chemistry. Soil solutions were collected *in situ* beginning in August, 2007 using implanted suction devices located at depths of 12, 24 and 36 inches under drip emitters. Samples were collected twice: at harvest time and at two months post-harvest during Year 1, and at monthly intervals during Year 2. The following parameters are being measured: pH, EC, K, NO_3, NH_4, Si, B, CO_3, SO_4, Cl, Mg, Ca, and K; these analyses are ongoing.

Plant Analyses

Leaf Petiole and Blade Sampling. Leaf petioles and blades were collected from 3 sets of 10 replicate vines from 2 sampling sites within each of the four soil types, for a total of 240 vines. All vines were marked with identification tags, and vine locations were georeferenced. Petiole and blade sampling was repeated at three phenological stages in 2007 and 2008: bloom, veraison, and harvest. Bloom samples consisted of leaves located opposite the basal-most cluster, while the most recent fully expanded leaves were collected at veraison and harvest. At each sampling date, leaves and petioles were separated, air-dried at 60°C, ground at 60-mesh in a Wiley mill, and sent to the DANR Analytical Laboratory at UC Davis for analysis of total N, NO_3, NH_4, P, K, Ca, Mg, S, Zn, Cu, Mn, Fe, Si, and B.

Plant and Soil Water Status. Mid-day plant water potentials (Ψ) were measured manually with a pressure bomb at bloom, veraison and harvest on the same vines within each vineyard block. Soil moisture was measured at 30, 60 and 90 cm using TDR probes in embedded in soil pit walls at four of the sampling sites. Canopy temperature sensors were installed at each site. Temperature and moisture data are recorded at 30-minute intervals. Soil moisture content was determined by gravimetric measurements in the laboratory, and the results compared to those obtained using the TDR probe.

Vine Growth and Fruit Production. Vine trunk diameters were measured at heights of 25 and 50 cm. Root counts were determined in the field by hand counting root intercepts using a 10x10 cm counting grid. Vine canopy density was measured using a metering system, developed by Dr. Mark Battany, UC Cooperative Extension, based on photovoltaic panels. At harvest, fruit yield was determined by weighing the harvest and dividing by the number of vines at each site. Berry clusters were counted and weighed. The number of berries per cluster was counted for 20 to 25 clusters per group of observation vines. Pruning weights were determined in late December 2007 and in January 2009 for all 240 tagged vines; this included three groups of ten vines per soil sampling site.

Juice and Wine Analyses

At harvest, juice samples were analyzed for pH, sugar content (°Brix), Total Acidity, Yeast Available Nitrogen, and Free Amino Nitrogen (NOPA). Sensory analysis of berries is ongoing in collaboration with Dr. Hildegarde Heymann, UC Davis. Sensory analysis panels have been created using volunteers; 3 replicate tasting events have been held with the same tasting panel comprised of 8 volunteers. Volunteers are blinded to the identity of the samples. Berries were sampled from vines in each of the areas surrounding the 8 individual soil pits and cryopreserved at -80ºC prior to tasting.

RESULTS AND DISCUSSION

Soil characterization

The soils in the four vineyard plots were sampled and analyzed during the first year of the study (Lambert *et al*., 2008). The four vineyard plots and the eight sampling sites (two per plot) are shown in Fig. 1. The soils situated in the four vineyard blocks differed significantly in chemical and physical properties. The soils in Blocks 56 and 57 were classified as distinct, yet related Alfisols: the soil in Block 57 was a fine, smectitic, thermic Typic Palexeralfs and the soil in Block 56 was a fine-loamy, mixed, superactive, thermic Typic Haploxeralfs. The soils in Block 53 were typical of Vertisols: fine, smectitic, thermic Haploxererts with greater than 30% clay content and a tendency to 'shrink/swell' behavior. Finally, the soils in Block 52 had calcareous seams, laminar lime concretions and an angular, blocky structure in the subsoil. These soils were characterized as Mollisols: fine-loamy, mixed, superactive, thermic Calcic Haploxerolls (Lambert *et al*., 2008). Soil chemical analyses revealed several striking differences between sites. Soil extract Nitrogen and Phosphorous were comparatively low in the Mollisols. In addition, both the Mollisols and Vertisols had low K^+ availability throughout the profiles. Potassium levels were higher in the Alfisols, but only in the superficial horizons. Electrical conductivity was particularly high in the Ca-rich Mollisols and increased with depth.

Plant tissue nutrient levels

Plant tissue (petiole and blade) levels of phosphorus (P), potassium (K) and magnesium (Mg) varied consistently between sites over the three-year study period. Vines grown on the Haploxerolls (Mollisols) had consistently low levels of petiole and blade P at all three phonological stages, approaching the threshold (0.1%) considered as deficient at harvest time (Klein *et al.*, 2000), as shown in Fig. 2. Vines grown on the Mollisols and on the Vertisols had higher levels of petiole K at veraison and harvest than vines grown on Alfisols, as shown in Fig. 3. This was also reflected in a high K/Mg ratio in petioles of vines grown on Mollisols and Vertisols, suggesting Mg deficiency (data not shown) (Delas, 1996). Conversely, petiole Mg levels were highest at veraison and harvest in vines grown on the Alfisols. Petiole Mn levels were consistently low in vines grown in the calcic Mollisols, as explained by the insolubility of Mn in calcareous soils with pH 7.5-8 (data not shown). Petiole N levels showed no significant variation between sites.

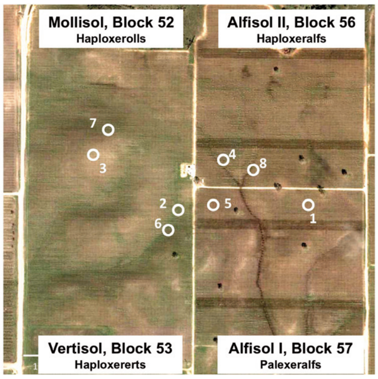

Figure 1. Four contrasting soil types in a Paso Robles Cabernet Sauvignon vineyard. *Soil types and block numbers are shown. Numbered white circles indicate the locations of soil sampling pits.*

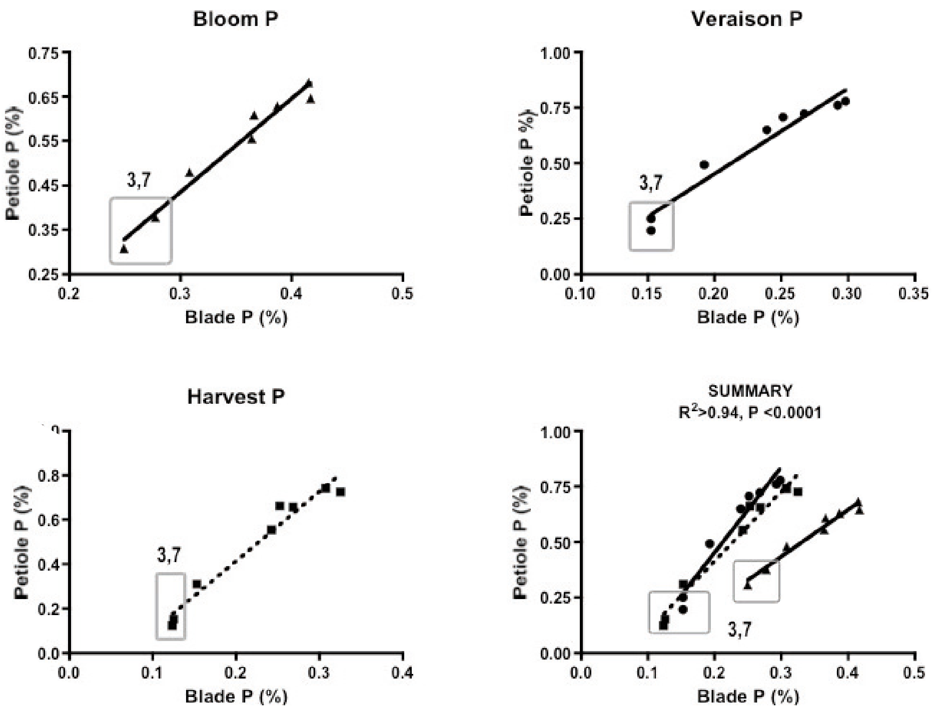

Figure 2. Petiole and Blade P levels are consistently low in plants grown on Calcic Mollisols. *Data shown are three-year averages (2007, 08, 09). Numbers indicate pit sampling sites as seen in Fig. 1; sites 3 and 7 were located in Block 52 (Mollisol).*

Plant vigor and fruit yields

Plant root counts varied considerably with soil type. In the Alfisols, the presence of a compacted layer at depth prevented significant root penetration beyond 40-50 cm. In the Mollisols, root density was greatest at depths below 50 cm, likely due to the high salt content and electrical conductivity at the surface horizon. The Vertisols were characterized by good water distribution throughout the profile, and the presence of macropores allowed root penetration to depths below 100 cm.

Differences in fruit harvest weights were subtle between sites, with vines grown on the Mollisols having lower yields than those grown on other soil types (Lambert *et al*., 2008). Although this trend was consistent from year to year, it only reached statistical significance in the 2008 season. Differences in cluster and berry weight between sites were also subtle, but a similar trend was apparent, with weights generally lowest in vines grown on the Mollisols (data not shown).

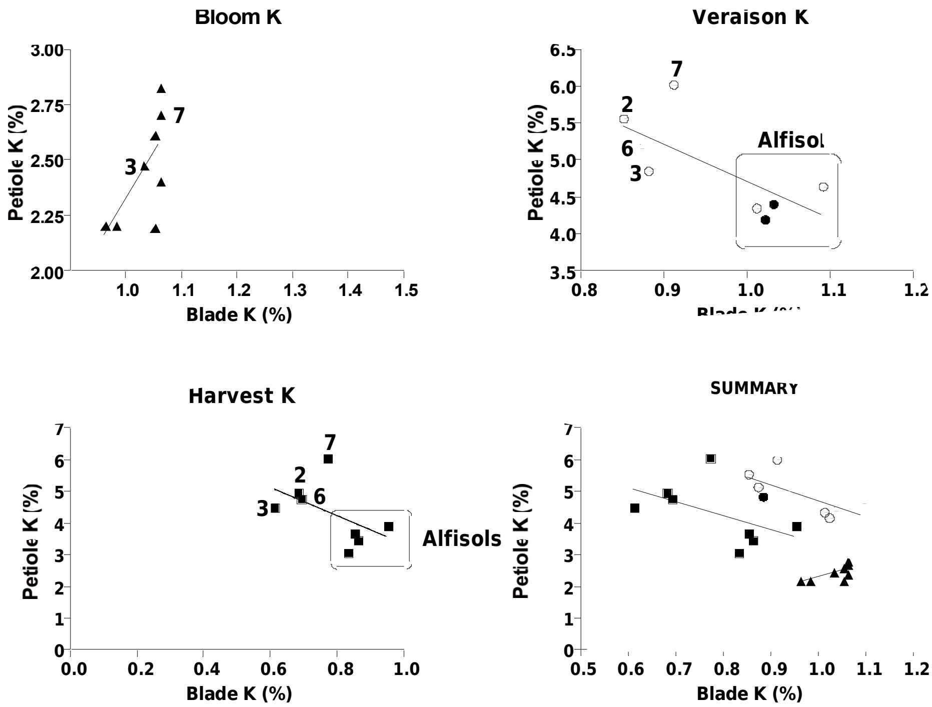

Figure 3. Petiole and Blade K levels cluster by soil type. *This trend was most apparent at veraison and harvest, when Petiole K levels were highest in vines grown on Mollisols or Vertisols, and lowest in vines grown on Alfisols. Data shown are three-year averages (2007, 08, 09). Numbers indicate pit sampling sites as seen in Fig. 1.*

Berry flavor components

Preliminary analysis of results from sensory analysis of berries revealed clustering of flavor components with soil types, with vegetal notes and sourness attributed to wines prepared on the Mollisols (data not shown). These analyses are still in progress along with chemical analyses of small-lot wines prepared from each of the four vineyard plots.

CONCLUSIONS

Detailed characterization of soils on the four vineyard plots revealed four distinct soil types. Blocks 56 and 57 contained two related Alfisols. The soils in block 57 had loamy/sandy loam topsoil and clayey subsoil with an abrupt textural change. Block 56 contained shallower, less developed Alfisols characterized as Haploxeralfs. Block 53 contained Vertisols, characterized by greater than 30% clay content and a tendency to 'shrink/swell' behavior. Lastly, the soils in Block 52 were characterized as Mollisols: fine-loamy, mixed, superactive, thermic Calcic

Haploxerolls. These soils had calcareous seams, laminar lime concretions and an angular blocky structure in the subsoil.

Analysis of plant tissue nutrient levels revealed consistent trends over the three-year study period. Vines grown on the Mollisols had consistently low levels of petiole and blade P at bloom, veraison and harvest. Petiole and Blade P levels were closely correlated. Vines grown on the Mollisols and Vertisols had higher levels of petiole K at veraison and harvest than vines grown on Alfisols. This was also reflected in a high K/Mg ratio in petioles of vines grown on Mollisols and Vertisols, suggesting Mg deficiency. Some nutrients, such as N, showed no significant variation between soil types.

As reported previously (Lambert *et al*., 2008), the Alfisol in Block 57-5 and the Mollisol in Block 52-3 gave contrasting results in terms of vine, fruit and juice characteristics. Vines grown in the Alfisol had average to high diameters, and the highest fruit yield per vine in terms of weight and cluster number. Juice from these vines also had the highest °Brix and lowest total acidity during the first two years of the study. In contrast, vines grown in the Mollisol had the lowest vine diameters in the study, the highest root density at depth, the lowest fruit yield per vine, and the lowest cluster weights. Juice from these vines had the lowest °Brix and among the highest total acidity values. Vines grown on the two other soils showed intermediate characteristics.

Thus, in this study comparing Cabernet Sauvignon grapes of a single clone, on its own roots, grown in four distinct soil types within a single vineyard, vines grown on contrasting soil types had different growth characteristics that were reflected in differences in plant nutrient levels and differences in fruit yield and juice properties. Additional chemical and sensory analyses of grape juice and small lot wines are underway.

ACKNOWLEDGMENTS

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PEDO-GEOLOGICAL ANALYSIS OF GAILLAC "PREMIÈRES CÔTES" TOPOSEQUENCES (TARN, SW FRANCE) CONSEQUENCES ON MICRO-TERROIRS CHARACTERIZATION

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ABSTRACT
Drill-holes performed on a Gaillac appellation vineyard together with mineralogical and chemical analyses on soils samples have given evidence of a micro-scale pedo-geological variability leading to characterization of distinct micro-terroirs. This variability results from the strong interdependence of water regime patterns and chemical element availability from which pedo-geological wine typicity would emerge.

KEY-WORDS
Geochemistry - Microterroir – Mineralogy – Pedogenesis – Solifluction – Water regime

INTRODUCTION
The concept of terroir integrates all factors that work together to define region with specific characteristics to match the needs of wine grapes that will produce high quality wine. These factors start with the rocks and resulting soils through complex pedo-geological processes, continue with climate and vineyard management practices and end with the winemaker's art. Herein, we consider the key pedo-geological factors of terroir: the parent rocks and the soils and their subsequent physical-chemical evolutions.
Our purpose is to illustrate how parent rock characteristics guides the definition of micro-terroirs on the basis of preliminary pedo-geological results acquired from vineyard plots located in the Gaillac appellation in south-western France (Figure 1).
Till now, 3 planting areas have been empirically defined by the winegrower's in the studied vineyard. From top to base of slope (see location on Figure 2), grapevine varieties were planted following especially local-scale climatic parameters as follows:
- sweet white wines area (Mauzac and Loin de l'oeil grapevine varieties) situated at the top of the valley slope characterized by the warmest microclimatic conditions,
- red wines area (Duras, Fer Servadou and Syrah grapevine varieties) in mid-part of the slope,
- dry white wines area (Loin de l'œil and Cabernet grapevine varieties) situated at the base of the valley slope characterized by the coolest microclimatic conditions.

Rootstocks were used according to the soil surface carbonate contents (3309C or 41B).
Several pedological drill-holes have been carried out on two geologically distinct toposequences. Mineralogical and chemical analyses of representative soil samples have been performed. Finally, the association of pedo-geological data with topography and microclimatic zoning lead to characterize new micro-terroirs.

GEOLOGICAL AND MORPHOLOGICAL DATA

Localisation of studied area

Gaillac appellation area is located in SW France, north of Toulouse city (Figure 1a). The studied vineyard is situated on the "Right bank coteaux" area which is one of the four main terroirs of the appellation area (Figure 1b). Precisely, the Terrisses vineyard is located on the first hills of the right Tarn river bank, informally named "Première Côtes" (Figure 1c). Geologically, it is composed of an Oligocene molassic sandy-clayey substratum overlain by detrital material originated from late-Würmian solifluction phase and subsequent Holocene colluviation, principally developed at the base of hillside slopes and in valleys (Figure 2).

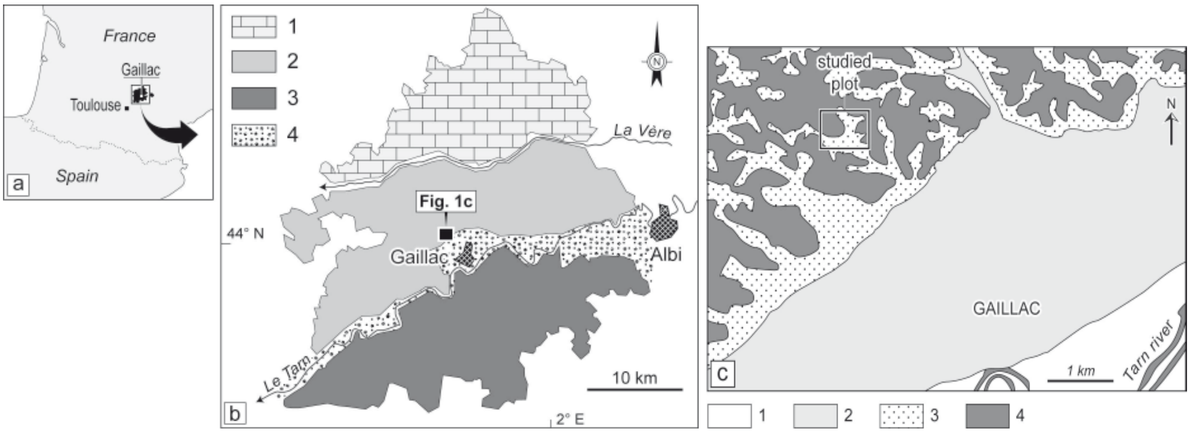

Figure 1 / (a): localisation of the Gaillac appellation area **(b)**: the main terroirs of the appellation area and localisation of the studied vineyard - (symbols: 1, "Calcareous Plateau Cordais"; 2,"Right bank molassic coteaux"; 3,"Left bank alluvial terraces"; 4,Tarn alluvial plain); **(c):** mesoscale geological setting – (symbols:1, present-day alluvium;2, Holocene alluvium; 3, soliflued and colluvial deposits; 4, Oligocene molassic basement).

Description of study toposequences

Two NE-SW oriented toposequences have been investigated (Figure 2). The T_1 toposequence is located on a small valley covered by displaced soliflued materials and the T_2 toposequence is situated on a hill composed of molassic substratum material (Figures 2a and 2b). Both have south-facing weak to moderate-angle slopes (< 15°) and represent about 250 m in length for T_1 and 195 m for T_2 (Figure 2b).

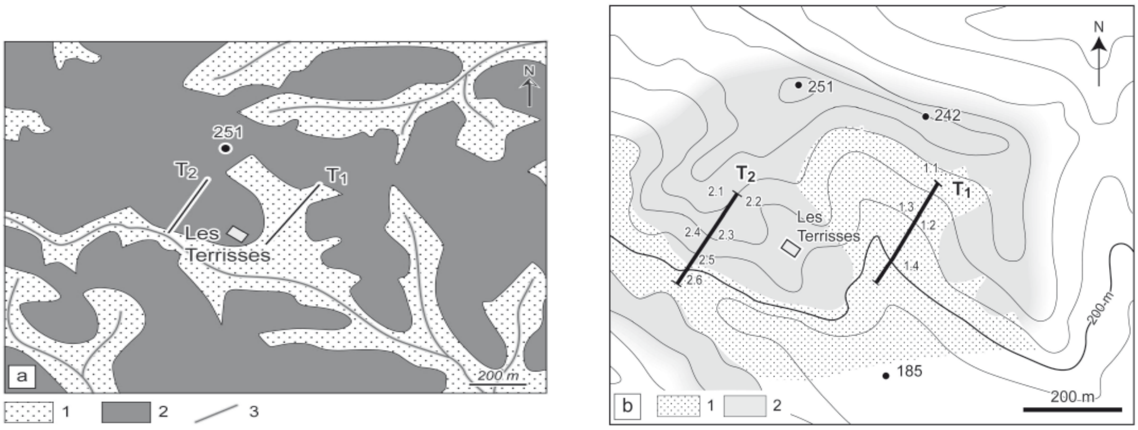

Figure 2/ a: Geological setting with localisation of studied toposequences (symbols: 1, soliflued/colluvial deposits; 2, Oligocene molassic basement; 3, small rivers); **b**: local morphologic setting. T_1 and T_2 toposequences are plotted with samples location (symbols: 1, soliflued/colluvial deposits; 2; Oligocene molassic basement)

The molassic substratum of the studied toposequences is composed of clays, silts, and sands together with scattered gravels and pebbles occurrences. Patchily distributed sandy carbonated lenses and/or layers may also occur.
In the case of valleys (toposequence 1), the molassic basement is overlaid by a thin sequence (up to 2-3m thick) of detrital material inherited from the main late-Würmian (ca. 13,000 years BP) solifluction phase processes. The later has occurred when soil and bedrock were affected by alternate freezing and melting in peri-glacial climate. These mass movements have generated allochtonous sediment lobes on slopes, composed of mixed bedrock and alterite materials concealing the underlying in-situ basement outcrops. Subsequently, this material has suffered from pedogenetic alteration and was transported on short distance, producing clayey-silty colluvial deposits at the base of the valleys.

PEDOLOGICAL AND PEDOGENETIC DATA

Identification of soils

Soils of the 2 toposequences have been identified according to the French soil classification (Figure 3 below).

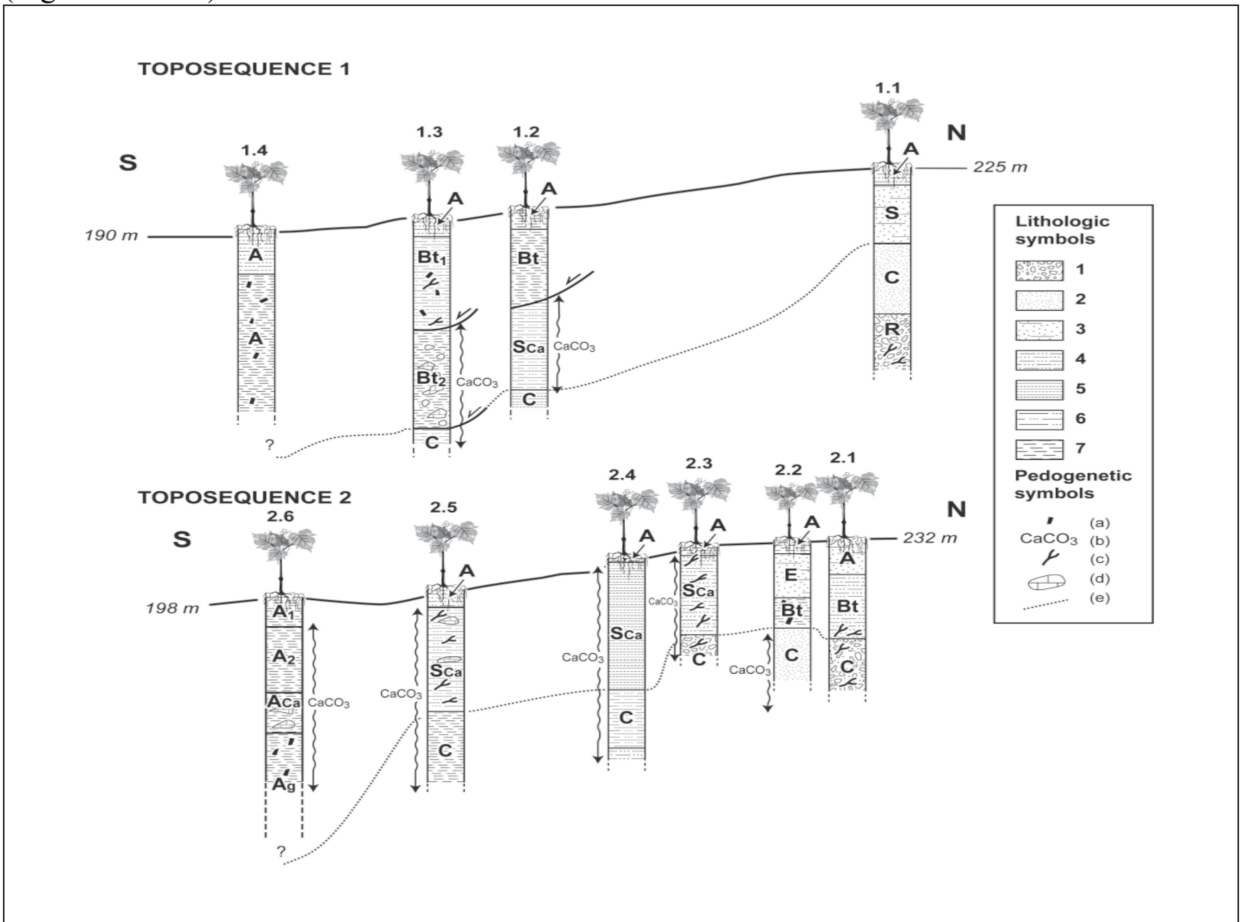

Figure 3 / Synthesis of the different soils sequences along T_1 and T_2 toposequences (not at scale) - Soil horizons are noted using French classification nomenclature (symbols: 1, bed-rock fragments; 2, sand; 3, sand with clay; 4, clay with sand; 5, silt; 6 clay and silt; 7, clay; (a), manganese nodules; (b), occurrence of $CaCO_3$; (c), oxydo-reduction spots; (d), carbonate nodules; (e), estimated soil/altered basement boundary) .

- Toposequence 1 is composed of calcisols at the top (n° 1.1) and clayey colluviosols at the base (n° 1.4.). Complex soils, inherited from solifluction mass movements, are situated in medium part of the slope (n^{os} 1.2 and 1.3). They are composed of allochthonous luvisols overlying the autochthonous altered molassic basement. The limit between the soil sequence and the altered bedrock (= C horizons) varies from less than 1m at the top of the toposequence, about 2.50m in medium part and more than 4-5m at the base.

- Toposequence 2 is composed of luvisols at the top (n^{os} 2.1 and 2.2.), calcosols in medium part (n^{os} 2.3., 2.4 and 2.5) and clayey colluviosols at the base (n° 2.6). The roof of the altered molassic bedrock (C horizons) varies from 0.60m at the top 1.50m in medium part to more than 4m at the base of the toposequence. It is worth noting that no indication of soliflued material has been evidenced.

Mineralogical and geochemical results

Mineralogical investigations (XRD) have pointed out the occurrence of quartz, kaolinite, feldspaths, illite, goethite, smectite and minor calcite amount in all the samples. This spectrum is in agreement with the composition of the molassic basement from which the soils originate as the globally similar REES flat patterns for the soil samples confirm (Figure 4).

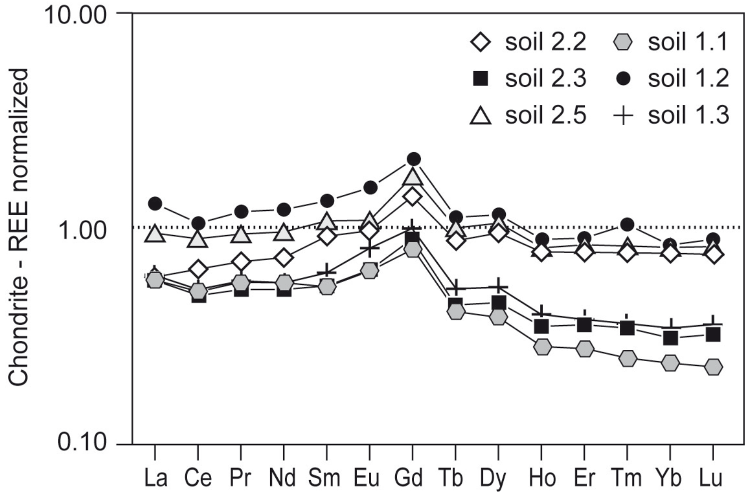

Figure 4: Chondrite-normalized REE patterns of deep-soil horizons (= C horizons).

Measurements of pH and carbonate-content were performed on grinded soil samples and ICP-MS chemical analyses were performed to calculate chemical elements contents (Tab. 1).

Tab. 1 - Principal chemical and mineralogical results of T1 and T2 toposequences

Symbols /: no analysed; -: no detected; tr: traces; **+:** minor; **++:** major; **+++:** dominant

SOIL SAMPLES	Altitu-de (m)	Hori-zons	z (cm)	pH	$CaCO_3$ %	Ca g/kg	Hydro-Morphism	Smectite
T 1.1 Calcisol	225	A S C	10 35 70	7.49 7.82 7.07	1.2 0.1 -	5.0 5.4 2.4	- - Tr	++ ++ ++
T 1.2 Soliflued soil	207	A Bt Sca C	10 60 120 150	7.96 7.78 8.16 8.44	1.7 0.2 6.1 27.8	10.3 5.3 92.6 22.9	- - - -	+ ++ ++ +++
T 1.3 Soliflued soil	202	A Bt C	50 180 230	7.46 8.09 8.32	0.9 0.8 12.5	2.7 6.7 39.6	- + -	++ ++ ++
T 1.4 Colluviosol	190	A	120	7.87	0.2	3.9	++	++

T $_{2.1}$ Luvisol		A	20	7.00	-	/	-	+
	232	Bt	40	6.59	-	/	+	++
		C	60	5.25	-	/	+	+
T $_{2.2}$ Luvisol		A	20	7.46	0.2	3.5	-	+
	230	E	40	7.42	-	1.9	-	+
		Bt	80	7.33	-	3.5	+	++
		C	100	7.90	1.0	3.0	-	++
T $_{2.3}$ Calcosol		A	20	7.95	5.2	18.9	-	++
	227	Sca	50	8.18	18.6	55.3	++	++
		C	60	8.30	22.0	67.0	+	++
T $_{2.4}$ Calcosol		A	5	8.08	16.2	/	-	++
	219	Sca 1	50	8.16	15.4	/	tr	++
		Sca 2	100	8.12	17.9	/	tr	++
		Sca 3	120	8.06	16.8	/	tr	+
		C	150	8.03	22.5	/	-	++
T $_{2.5}$ Calcosol	206	A	20	7.84	11.1	34.7	-	++
		Sca	70	8.25	29.4	66.7	++	++
		C	130	8.38	36.5	110	-	++
T $_{2.6}$ Colluviosol		A1	10	7.91	1.6	7.2	-	+
	196	A2	40	7.97	0.1	2.8	-	+
		Aca	100	8.17	9.1	27.5	++	+
		Ag	140	8.23	6.2	19.5	++	+

The above mineralogical/geochemical soil patterns result from a complex sequence of pedogenetic processes essentially related to different water regimes as follows:
- pH values vary from neutral to basic in agreement with the occurrence of calcite in the bulk of the soil/bedrock sequences. The neutral values correspond to the most decarbonated horizons (calcisols and luvisols). In contrast, the more basic values correspond to calcosols and altered molassic carbonated bedrock horizons (= C horizons),
- hydromorphism associated with conditions of reduction/oxidation of Fe and Mn is of weak amplitude and occurs at depth (≥ ~ 1m) in the case of the toposequence 1; it is of stronger amplitude and occurs near the surface in the case of the toposequence 2; in both cases, it is moderate and only follows temporary state of water saturation (no occurrence of redoxic horizons),
- clay eluviation is the main process affecting the soils situated at the nearly flat area at the top of toposequence 2; it is also observed in the allochtonous soliflued luvisols situated in the mid-part of the toposequence 1,
- decarbonatation and re-precipitation is a widespread process under the regional temperate climatic conditions affecting almost all soil samples,
- smectite occurs in relatively large quantities in all the soil samples. It regulates water resource by swelling (vs. shrinking) processes.

CHARACTERIZATION OF MICROTERROIRS

The above soil patterns associated with geological and topographic data together with the superimposition of micro-scale climatic zoning, lead to characterize different microterroirs (Figure 6). In both toposequences, the bulk of the soil/bedrock sequence is composed of molassic detrital material either in situ originating from alteration of the molassic bedrock or “ex-situ”, displaced by mass transport (solifluction) and/or by erosion (colluvium). This broad division may be regarded as a first order pedo-geological terroir classification.

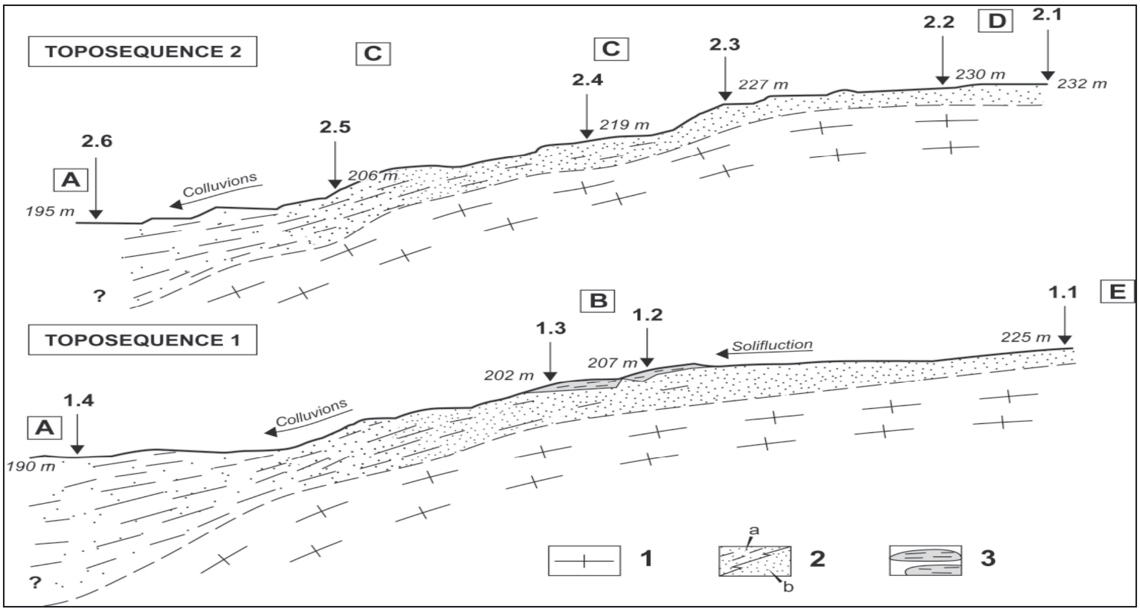

Figure 5/ Characterization of the microterroirs (A to E) integrating topographic, pedo-geological and microscale climatic zoning data (not at scale). Symbols: 1, molassic basement; 2, altered molassic basement (a: clay dominant; b, sand dominant); 3, solifluction lobes.

Micro-terroirs on allochthonous colluvial deposits
- The “Colluvial micro-terroir” (A): a weak sloping area composed of thick colluvial recarbonated (or not) clayey deposits marked by temporary hydromorphism at the surface or deeper (>1m) and characterized by the coolest and dampest microclimate conditions.

Micro-terroirs on allochtonous soliflued material
- The “Soliflued micro-terroir” (B): a moderately sloping area with soliflued luvisols forming lobes onto the altered carbonated molassic basement; hydromorphism is negligible.

Micro-terroirs on in situ molassic basement
- The “Altered carbonated micro-terroir” (C): a moderately sloping area with superficial hydromorphism which may be of moderate amplitude.
- The “Leached micro-terroir” (D): a nearly flat area composed of leached soil sequence (luvisols) marked by moderate superficial hydromorphism.
- The “Decarbonated micro-terroir” (E): a gently sloping area constituted of decarbonated molassic basement without traces of any hydromorphism and characterized by the warmest and driest microclimate conditions.

CONCLUSIONS

The above preliminary results show a great pedo-geological variability despite the relative homogeneity of the original molassic material. Actually, the studied plots of the Terrisses vineyard appears as a mosaic of, at least, 5 micro-terroirs instead of the 3 empirically defined using micro-climate variances. This microscale variability appears to results mainly from the strong interdependence of water regime patterns and chemical element availability. Therefore, the pedo-geological wine typicity should be regarded as an emergent result of this highly complex interaction. The next step of the study will be to follow the fate of distinctive soil chemical elements from the vine crop to the wine glass for each defined microterroirs in taking into account characteristics of each grapevine varieties and rootstocks.