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# The Effect of Geomorphology and Subsoil on the Quality Characteristics of Produced Wines: A Review

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**Abstract:** Wine production is a complex process that depends on various natural and anthropogenic factors. One of the most important natural factors is geomorphology, which includes the form and structure of the soil and landscape. The geomorphology significantly influences the growth of the vines and, consequently, the quality characteristics of the wines produced. Understanding the geomorphology of an area and its effect on the vines is critical to successful cultivation and production of high-quality wines.

**Key words:** terroir, wine, geomorphology, subsoil

## 1. Introduction

This Literature review deals with the complex process of wine production that depends on various natural and anthropogenic factors. One of the most important natural factors is geomorphology, which includes the form and structure of the soil and landscape. The geomorphology significantly influences the growth of the vines and, consequently, the quality characteristics of the wines produced. Understanding the geomorphology of an area and its effect on the vines is critical to successful cultivation and production of high-quality wines.

## 2. Geomorphology and Vine Cultivation

Geomorphology, which includes topography, soil morphology, and geological structures, directly influences the characteristics that influence microclimatic diversity, sun exposure, and water drainage, which in turn influence vine growth and wine quality. grapes.

The wine concept of terroir also incorporates the interaction between geogenic and anthropogenic parameters and determines the typicality and quality of wine in a specific geographical area. Geomorphology represents one of the most important geological parameters of terroir.

Starting from the now-classic work of Wilson et al. of 1998 [1] where he proved that the historical separation of several terroirs of Burgundy is supported by geophysical data that reveal geological differences in the substrates, we will refer to similar studies by Trégoat [2] and Renouf et al. [3] in which the soils from seven of the most famous Bordeaux estates were mapped at high resolution and linked to the use over time of the wines of these vineyards in the quality categories of the winery labels. Nine main soil types were identified. The highest quality was produced in PLANOSOL (soil with heavy clay subsoil of Tertiary origin), ARENOSOL (sandy soil of Quaternary aeolian origin), BRUNISOL (sandy gravelly soil on Quaternary alluvial terraces) and PEYROSOL (gravelly soil on Quaternary alluvial terraces) [4].

The main soil-related parameters that influence the quality of wines seem to be:

- Soil temperature in the root zone
- Supply of soil minerals (except nitrogen)
- Supply of soil nitrogen
- Soil water supply

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In a study done in Slovenia from two different sites located in the same vineyard identical in macroclimate and background and with identical viticulture, winemaking techniques, the two sites produced grapes and wines of significantly different quality. The differences are related to soil composition, drainage and microclimate, all directly linked to different geomorphic locations [5] (Fig. 1).

## 3. Topography and Sun Exposure

The topography of the soil, such as the slope, altitude and orientation of the vineyards, affects sun exposure and temperature. South-facing slopes receive more sunlight, allowing the grapes to ripen faster and develop rich flavors and aromas. Vineyards at high altitudes benefit from cooler nights, which help preserve the acidity of the grapes, lending freshness to the wines produced.

## 4. Soil Morphology and Drainage

Soil morphology affects drainage and water availability to vine roots. Vineyards on slopes have better drainage compared to vineyards on plains, avoiding excess moisture that can cause root rot and other diseases. Good drainage allows the roots to penetrate deeper into the subsoil in search of nutrients and water, enhancing plant resilience in times of drought.

The water status of the vine has a significant impact on vegetative and reproductive growth, fruit composition and wine quality. Evidence that a regular, but limited, supply of water to vines is an important factor explaining the terroir phenomenon was first published in the 1960s (Seguin, 1969) and has been confirmed many times since then. Limited water supply to the vines increases the glycosidic complexes of the main aromas in red grapes [6] and improves the aging bouquet of fine red wines and their overall quality [6]. However, severe water deficit can damage the quality of red wines. Water deficit in vineyards is not necessarily an important factor for white wine quality because their aromas can be negatively affected.

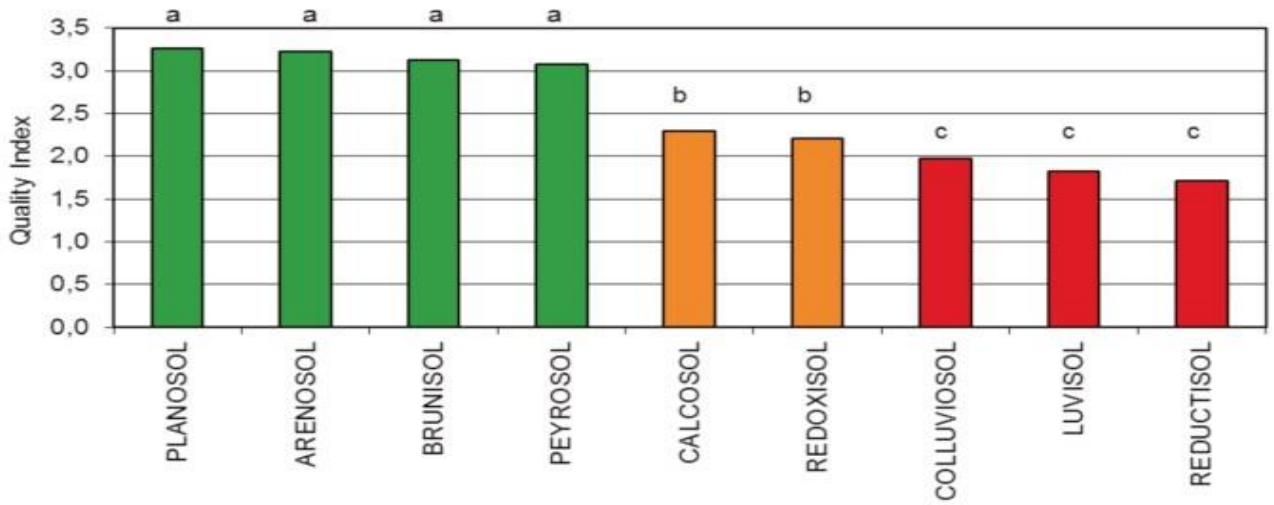


**Fig. 1 Quality potential index, based on the frequency with which the wine produced on a given soil type is blended into the highest quality wine, for the nine major soil types identified in seven highly prestigious Bordeaux winegrowing estates.**

## 5. Composition and Structure of the Subsoil

The composition and structure of the subsoil determine the availability of nutrients and water, affecting the growth of the vines and the quality of the grapes. Subsoils are composed of various materials, such as clay, sand, silt, and organic matter.

In a very important study from the University of Oregon published in the journal of the Geological

Society of America [7] in 2016 the most important effect between the depth of the clay horizons and the pH of the final wine was found and proved. According to this study of Oregon soils the minimum pH of these soils is near the base of the clay (Bw or Bt) horizon and is inversely related to the depth of the clay horizon. Low soil pH is found in thick soils of middle Pleistocene bedrock and high soil pH in thin soils of deposits and yellow calcareous silt from the late Pleistocene and Holocene Lake Missoula glacial outburst floods. Similar relationships exist between pH or soil depth and the pH of the grapes at harvest, which is lower and more variable than the pH in the final wine. That is, the more acidic the pH of the soil, the higher the pH of the wine, and the deeper the clay horizon of the soil, the lower the pH of the wine.

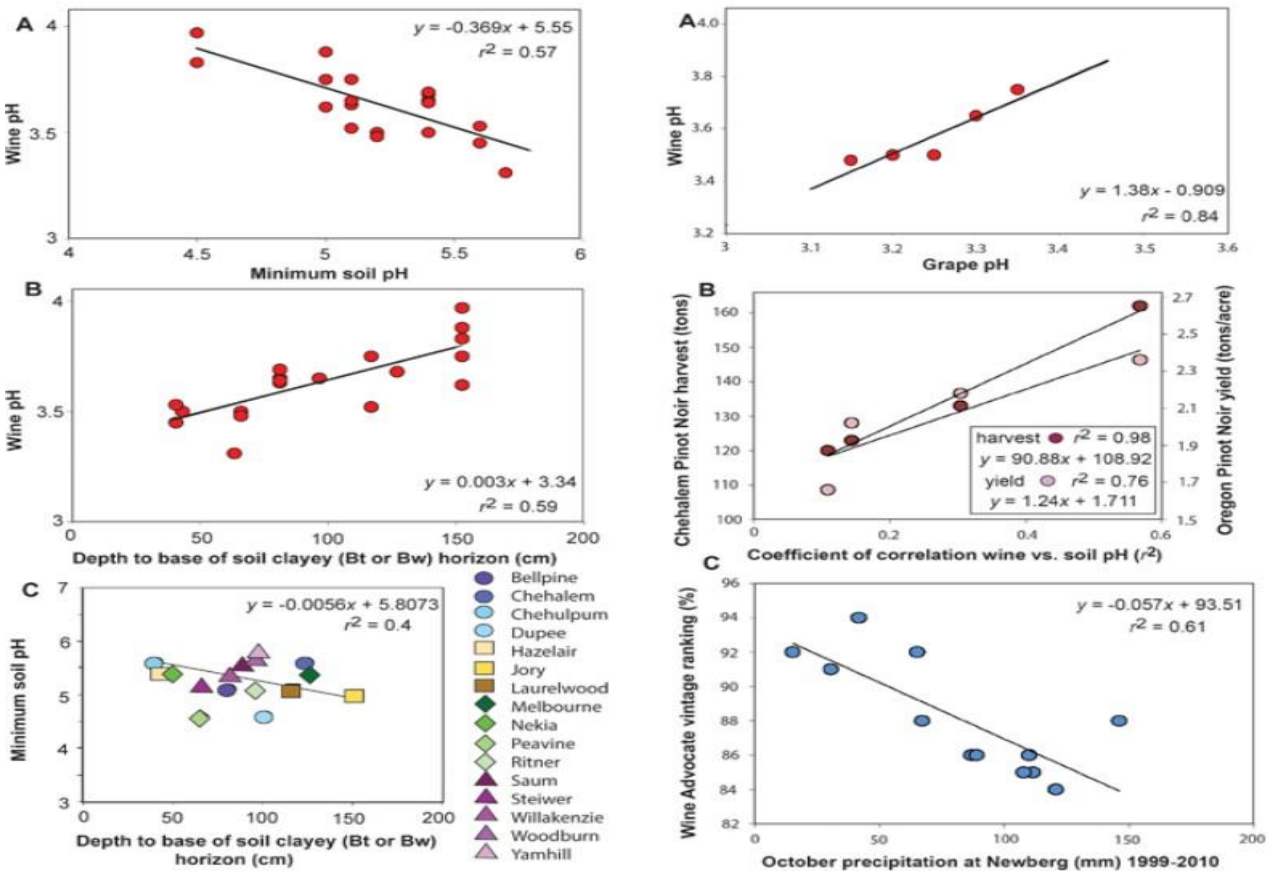


**Fig. 2 Left column: Relationships between wine pH and minimum soil pH (A) and depth to base of clayey (Bt or Bw) horizon (B) in the 2009 vintage Pinot Noir wine from the Willamette Valley, Oregon, USA. These correlations are all highly significant using an ANOVA F test. One relationship is inverse and the other direct, because minimum soil pH and depth of clayey horizon are inversely correlated (C). Comparable correlations for three other vintages are in the GSA Supplemental Data Repository [see footnote 1]. Right column: Correlation between pH of grapes at harvest and pH of wine in the 2009 vintage Pinot Noir from the Willamette Valley, Oregon (A), between variance of coefficient of correlation between wine-soil pH and grape harvest size for vintages 2008–2011 (B), and between Wine Advocate vintage ranking and local October precipitation for that vintage (C).**

## 6. Inorganic and Organic Ingredients

Minerals such as calcium, magnesium and potassium are essential for vine health. The content of these components in the subsoil affects plant growth and the production of high-quality grapes. Clay soils, for example, have a high capacity to hold nutrients and water, providing plants with a constant supply of essential elements.

Organic materials, such as humus, improve soil structure and nutrient availability. The presence of organic matter increases microbial activity, which in turn breaks down organic materials into nutrients that are easily accessible to plants.

Also, the structure of the subsoil affects the permeability and the drainage capacity. Good structure allows water and air to penetrate the roots, promoting healthy plant growth. Sandy soils have high permeability and drainage, but may require more frequent irrigation and fertilization. In contrast, clay soils hold more water and nutrients, but may experience drainage problems during periods of high rainfall. Soil is here an important abiotic driver of terroir expression that affects wine quality by influencing vine growth and grape ripening through soil temperature, water and mineral supply. This is exactly what was shown in a survey by Geo Identity Research in Italy on the Gewurztraminer variety in South Tyrolean vineyards [8].

The results show that in the small research area, climatic parameters, such as air temperature, precipitation and solar radiation, are quite stable between vineyards, while geo-pedological features are more variable.

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Vineyards on fine-textured soils with mixed mineralogy, mainly silicate and clay minerals of glacial origin, and vineyards on mainly sandy dolomitic soils with mainly carbonate minerals from local ancient sediments from debris flows were studied.

These two different soils are evident in the oenological components, flavors and aromas of their lees and final wines: the first vineyards showed a higher content of amino acids and lower levels of β-phenylethyl alcohol, total polyphenols, 4-vinylphenol and 4-vinyl guaiacol (phenolic aromatic compounds with spicy aromas).

The second vineyards revealed a lower content of 3-mercaptohexanol, a thiol compound with a tropical aroma, and higher levels of free form geraniol, 4-vinyl guaiacol and citronellol (characteristic terpenic compounds).

These results show that the composition of "Gewürztraminer" beers and wines is strongly determined by vineyard location, even in a small geographical area with high terroir variability.

## 7. Approaching the Concept of Terroir From A Geological And Geomorphological Point of View

Terroir is a French word, derived from the Latin "territorium", meaning territory. It was long retained in its original meaning of "territory" (territory, country, region) but eventually developed a more specialized meaning as "place" or "territory", considered in terms of its ability to support specific types of agricultural production.

In viticulture, terroir is a concept used to explain the specific combination and interaction of natural and human factors that provide distinctive characteristics to wine. The role of soil and geology in wine characteristics is debated and sometimes considered less important than either climate or the human component. In recent years, an effort has begun by various research groups around the world (from Ontario to the Namibian desert) to define the concept of terroir in objective ways. Obviously in this context the sciences of Geology and Geomorphology are of primary importance just like Oenology and Viticulture. In a study conducted in Canada that focused on just that [6], they highlight the role of geology in the concept of terroir and set the scene for further study. Thinking conceptually, from the ground up, the main elements of the concept of Terroir separate them into:

1) Geological (rock geology, surficial geology, soil, groundwater, topography and water bodies).

2) Climatic (latitude, macroclimate, rainfall, sunshine, temperature and microclimate).

3) Biological (vineyard age, grape varieties, microorganisms, nutrients and yeast strains) and,

4) Agricultural (viticultural techniques, management practices).

In doing so, this report gathers and organizes relevant information and sources so that geoscience can contribute to a better understanding of terroir and to the improvement not only of Canadian produced wines but also of other crops that borrow the term.

In a similar study [4] in the well-known Chianti Classico region of Tuscany, they focused on the effect of terroir on wine characteristics using two different zones. On a broader scale, called macro-terroir (MT), experimental vineyards were selected based on lithology, soil landscape, morphology and mesoclimate. Each vineyard was then subdivided on a detailed scale into two homogeneous zones for soil characteristics, Basic Terroir Units or Unité Terroir de Base (UTB). The study was conducted during three different harvests (2012, '13 and '14), in vineyards located in four different MTs, which are representative of the Chianti Classico wine region.

The vineyards were surveyed with an electromagnetic induction (EMI) sensor and gamma-ray spectroscopy to characterize the spatial variability of the soil and define two homogeneous areas (UTB) of approximately 2 ha in each MT. UTB differed for some soil characteristics, mainly texture, gravel content, soil depth, available water capacity, and internal drainage. Obviously, all the winemaking processes were kept the same. Mixed design analysis of variance of several must and wine characteristics showed that MT played the main role in must pH, as well as total acidity, glycerol content and wine color intensity. Grapevine climate played a stronger role than MT on must malic acid content, as well as polyphenols, anthocyanins and wine dry extract. Blind organoleptic analysis of wines performed for all vintages showed significant differences between wines from different UTBs, particularly for color intensity and wine aroma, but differences between UTBs in each MT were not consistent across the three vintages.

This study demonstrated that features of geogeological landscapes can be used to localize a wine region, while a more detailed soil mapping, leading to UTB determination, is required to differentiate specific wine characteristics.

## 8. Conclusion

Closing this bibliographic summary, I would like to emphasize that there is now a strongly growing interest from the global wine-lovers for wines that are defined by their place. The only way for oenology to approach the subject scientifically and to be able to reap the benefits for the sake of the wines produced is to collaborate with scientific fields such as Geology, Geomorphology or Meteorology.

In an area with a strong Geological and Geomorphological imprint but also very high-quality wines such as the Slopes of Aigialeia and Kalavryta, such synergies at the research level in the form of postgraduate, doctoral or research collaborations with wineries should be considered a no-brainer.

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