THE IMPORTANCE OF SOIL AND GEOLOGY IN TASTING TERROIR; A CASE HISTORY FROM THE WILLAMETTE VALLEY, OREGON

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Abstract
Wines differ from each other based on seven different factors: the type of grape; the bedrock geology and resulting soils; the climate; the soil hydrology; physiography of the site; the winemaker and the vineyard management techniques. The first five of these factors make up what the French call terroir, "the taste of the place". All around the world the geology and soils make up an important component of the terroir of the wine. In the Willamette Valley of Oregon in the United States, the terroir is strongly influenced by the bedrock geology and soils. The three dominant groups are the volcanic soils, the Jory Series, that are developed on the Columbia River Basalts and the Willakenzie Series of soils developed on uplifted marine sedimentary rocks in the foothills of the Oregon Coast Range. The third group is developed on Laurelwood Soils in weathered loess with pisolites in it on weathered Columbia River Basalt. The wines developed out of grapes from the three different soils are very different. They are so different that the Willamette Valley AVA has been subdivided into six new AVA's based on the differences in terroir, primarily the soils and geology.

Keywords: Pinot Noir, mineralogy, wine chemistry, soil chemistry, sensory analysis, Willamette Valley

1 INTRODUCTION

The soil and the underlying geology are very important factors in the making of a fine wine. A central theme of this paper explores how the physical environment of the vineyard shapes the character of great wines. Are soil and the geology the most important factors? The answer is probably no, but they are important. The French have a term for all of the physical parts of the vineyard, terroir. This paper will focus on the geology and soil parts of terroir (Wilson, 1998, 2001; Unwin, 2010; Haynes, 1999).

First, I will set the stage for the discussion by discussing the seven important factors that affect the quality of wine. Next, I will briefly discuss the meaning of terroir and its origin by referring to those seven factors. Lastly, I would like to concentrate on a case history of soils and geology from Oregon's Willamette Valley where one can really taste the terroir.

Seven Important Factors in the Making of a Wine:

When I talk about wines, I like to say that there are seven factors that influence the character of each wine. Each has its importance in helping produce a different taste compared to the next bottle of wine. First, one has the **grape** itself. A cabernet sauvignon is going to be different from a pinot noir. A pinot gris is going to be different from a merlot. We even go further and talk about the clones of each grape and their importance. Second, one has the **bedrock geology** which through weathering will produce a soil with a particular character. Limestone soils will produce completely different wines than vineyards on granite bedrock. Sometimes the soil will have a different character than the bedrock because it is a sediment deposit put there by a glacier, landslide, stream, or wind. These are surficial deposits. White (2009) states that the five important soil factors are: depth, structure, strength, chemistry, and organisms. Third, one has the **climate** (Jones, 2006). One wants a climate that will be dry at the end of the growing season of the grapes. One would also like a climate where the temperature goes up and down during the day and night to help build complexity in the grape juice. Fourth, one has the **soil hydrology**. The texture and structure of the soil will affect the drainage characteristics of the soil. Clay rich soils tend to produce poorly drained soils which are not liked by grape plants. They prefer well drained soils. In the Napa Valley the soil drainage is so important in determining the best sites (Swinchatt and Howell, 2004; Swinchatt et al., 2006). Fifth, is the **physiography** of the site. What is the orientation of the vineyard? What is the elevation? In the northern hemisphere one needs a south-facing slope to maximize the solar radiation. There is a top elevation above which the grapes do not ripen at the end of the summer. Sixth, one has the **winemaker** who has great influence. They choose what types of yeast and what types of oak barrels to use. They decide if there is to be malolactic fermentation or not. Do you use a cork or screw top? How long do you leave the wine in the barrel? Lastly, one has the **vineyard management techniques**. Do the rows go north-south or east – west? What type of trellising do you use? How many times do you trim the vines? Do you irrigate? All of these factors are important! Each has a different importance depending upon where the vineyard is located.

Others have different approaches to these factors. Haynes (1999) lists his five factors as: meteorological, physiographic, pedological, geological, and viticultural. All of these are included in my seven factors.

Terroir

Tim Unwin (2010) has an excellent paper that discusses what terroir is. He emphasizes that the meaning of the term has been debated for years. Everyone has a different interpretation of its meaning. I agree with him that the meaning is more than just the soil. It is a complex interaction of all of the physical aspects of the vineyard: the geology, soils, climate, geomorphology and grapes. Wilson (1998) also agrees – to him it is the vine, the subsoil, siting, drainage and microclimate. To me, it is the first five factors I have listed above: the grape, the geology/soil, climate, physiography and soil hydrology.

I believe the French would agree! It is the "taste of the place". On their wine labels, they do not put the name of the grape (except in Alsace region). It is the place of the vineyard that is important! The terroir is important! If it is a red wine, and it is from Burgundy, you are supposed to know that it is pinot noir. If it is white from Burgundy, then you should know it is chardonnay. If it is red and from Beaujolais, then it is the gamay grape.

In Burgundy, terroir has been studied for over 400 years, first by the monks and then by the winemakers. Consistently, the best wines were found at the top of the slopes in the Corton area and were given the classification as "Grand Cru" in the mid-1800's when France decided to brand the best wines. The next region down the slope was the next best wine zone year after year and was given the classification of "Premier Cru". At the bottom of the slope were the common wines.

Geologists found that the boundaries of the three classification zones were geological boundaries (Wilson, 1998). The terroir is controlled by the underlying rock units (Figure 1). The Grand Cru zone is underlain by marl limestone (Argovian facies of the Pernand marl), the Premier Cru has underneath it the Dalle Nacree flagstone limestone, and the common wine zone is a mixture of limestone and marl (Digonella divionesis) (Figure 1).

In Oregon, one of our four "founding fathers of modern winemaking", Dick Erath, has said many times, "80% of the quality of the wine comes from the vineyard and 20% from the winery". He is a believer in terroir.

Geology and Soils in Viticulture

After centuries of wine making, vintners have found that certain physical soil characteristics are important for quality vineyards. Seguin (1986) and Pomerol (1989) argue that these physical characteristics are more important than chemical characteristics of the soil in producing distinctive terroirs. Soil depth affects the rooting depth and possible waterlogging of the plants (White, 2009). Grape root systems have been known to penetrate to 5-6m depths in gravelly and sandy soils in areas such as Medoc, France and Sunraysia, Australia (White, 2009). Grape vines can perform well in shallow soils as evidenced by the shallow soils over limestone on the mid-slopes of Burgundy (White, 2009). Some grape varieties like different soil depths, e.g. chardonnay does better on deep soils, whereas syrah (shiraz) does best on shallow soils (White, 2009).

Soil pH is important for it affects the availability of several nutrients, and extremes in pH inhibit root growth (White, 2009). Values below 5.5 or above 10 are deemed too acidic or too basic to sustain grape-growing activity (Neirynck, 2009). High pH values reduce the availability of iron, copper, zinc, and manganese whereas low pH values reduce phosphorus uptake (White, 2009). Common salt (excess sodium and chloride) is not good for soils because it reduces the availability of potassium to the vines which is an essential nutrient.

Soil texture (amount of gravel, sand, silt and clay) influences the soil's water holding capacity, drainage, and ease of cultivation (White, 2009). Soil structure and consistence relate to how the soil particles are held together and also affects the strength of the soil, the drainage, and the ease of root penetration (White, 2009). Soils need to be well-drained because excess water causes grapes to swell. Soils with too high clay content tend to be compact which prevents vine roots from penetrating to depths with essential nutrients and water (Neirynck, 2009). The color of the soil affects the temperatures of the soil: the darker the soil, the warmer the soil temperatures and the faster the maturation of the grapes (Neirynck, 2009). Red colors indicate good drainage (White, 2009). Rocky soils also hold warmth and promote maturation. Stony soils force grapes to search deeply for water and nutrients and are particularly suitable for grapes such as syrah (Neirynck, 2009). Presence of limestone indicates a neutral to alkaline pH (White, 2009). Presence of hardpans such as caliche horizons also restrict rooting depths and cause roots to extend laterally which affects grape quality.

White (2009) discusses the soil and geological characteristics of low and high potential sites for growing grapes. Low potential sites have clastic sedimentary or metamorphic rocks with little weatherable mineral remains, and exhibit shallow soils, sandy soils with little water holding capacity, little organic matter with low nitrogen content, weak soil structure and poorly drained subsoil. High potential sites are often on igneous rocks, especially with mafic (dark colored) hues, or unweathered shales or limestones plus metamorphic rocks and alluvium from the above rocks. The soils are generally deep with some fine particles for water- holding capacities, pH from 5.5-7.5, no exchangeable aluminum, no salt, high organic matter in the A horizon, well-aggregated soils, and well drained. Low potential sites need closer vine spacing to increase production per hectare; high potential sites need wider spacing (White, 2009).

Low vigor in a grape plant is important to the production of great wines. Excess vigor reflects a lack of balance between the vegetative and reproductive parts of the vine where too much vegetative growth happens. It results in poor fruit set and shading that slows the fruit ripening and lowers the quality of the grapes (White, 2009). Excess vigor in red grapes creates excess shading of the grapes during ripening which retards the development of color and phenolic compounds (White, 2009). Excess vigor can result from to many nutrients coming from the soil or from too much water through irrigation. In moist climates, a perfect soil has low nutrients and in dry climates, one restricts the water available no matter what the soil nutrient status. Stress reduces vigor, and Seguin (1986) believes that the stress that contributes to the terroir of the region may be induced by the rate at which the vine can withdraw water from the soil which goes back to the physical characteristics of the soil.

Grapevines depend upon the soil for two things: water and nutrients (White, 2009). Of all of the elements know to humans, there are 16 elements that act as nutrients that grape vines need to grow normally, flower and produce fruit (White, 2009). The ten macronutrients that are required in relatively large concentrations are: carbon, hydrogen, nitrogen, oxygen, phosphorus, sulfur, calcium, magnesium, potassium and chlorine. The six micronutrients which are required in smaller concentrations are iron, manganese, zinc, copper, boron, and molybdenum. The carbon and oxygen come mainly from the atmosphere through photosynthesis, and oxygen and hydrogen from water through the root system, so the rest of the nutrients come from the soil.

The soil gets its nutrient supply from the weathering of the bedrock below the site, from sediments of the surficial deposit of the site or from windblown dust. Other trace elements (found in low concentrations) are not essential to the plants but do give different flavors to the grapes. Examples include elements such as chromium, selenium, iodine, cobalt, arsenic, mercury, cadmium, lead and nickel (White, 2009). Soil mycorrhizas are important parts of the soil biota because they enhance the vine's uptake of the immobile elements in the plants.

Soils do well in different soil parent materials (Neirynck, 2009). White wines do best on calcareous soils (chalks, limestone, and marl). Rieslings also do well on slates, and sauvignon blanc and semillon do well on gravel soils. White wine grapes do not do well on granitic soils (which tend to be very sandy) or on clay-rich soils. Red wines seem to do better on calcareous soils, but also mature well on granitic soils, especially syrah and grenaches. Red wines no not do well on slate soils (Neirynck, 2009).

Certain parent materials produce flavors and aromas in the wines (Neirynck, 2009). Calcareous soils produce lemon and citrus flavored wines with a long acid finish. Marl soils and silty calcareous soils tend to generate peppery flavors. Sandstone soils tend to bring a "nervy" character to the wines, and the fine-grained clay soils emphasize tannic characteristics. Schist- rich soils stress the austere nature of the wine, and volcanic soils produce full-bodied wine with smoke-based aromas. John Livingston (1998) states that volcanic parent material in the soil gives a distinctive character to the cabernet sauvignon wines of Stag's Leap are of Napa Valley, California.

2 MATERIALS AND METHODS

The Northern Willamette Valley, Oregon: Best place in the world to taste differences in Terroir

The northern Willamette Valley of Oregon is the heart of wine country in Oregon. It is where David Lett started modern winemaking in Oregon in 1961. It is a cool climate region similar to Burgundy in France, and is a perfect place to grow pinot noir, pinot gris, chardonnay, and German style wines like riesling, gewertztraminer, and Muller-Thurgau. It stretches from Portland to Eugene and occupies this wide valley from the Cascade Mountains to the Coast Range. The wine industry in Oregon has really matured since those early days of the 1960's. Today, there are over 700 wineries (3rd in the nation) with over 900 vineyards. Over 40 grape varieties are grown.

In the late 1990's my graduate student, Dionne Starr-Peace (2002), and I surveyed the vineyards in the northern Willamette Valley to see what soils were being used to grow wine grapes. The summary of our findings is found in Table 1. A total of 23 soil series were found. We classified each to the order level of Soil Taxonomy (Soil Survey Staff, 2009), determined the bedrock under each vineyard, and calculated the total acreage of that soil. We got data from over 5250 acres of soils on over 200 vineyards.

3 RESULTS AND DISCUSSION

The number one soil is the Jory series with 1504 acres, and it has formed on Columbia River Basalt and is an Ultisol (Figure 1). This Xeric Palehumult is the state soil of Oregon and has cousins like Nekia (shallow Jory), Saum and Yamhill series. The number two soil is the Willakenzie Series with 1245 acres, and it has formed on uplifted marine sediments of the Oregon Coast Range of mainly sandstones and shales and is an Alfisol (Figure 2). This Ultic Haploxeralf has similar cousin soils like Bellpine, Dupee, Peavine, Wellsdale, Steiwer, and Melbourne. The third place soil is the Laurelwood Series with 825 acres. This Ultic Haploxeralf soil has developed on the basalt bedrock, but has mid-Pleistocene loess mixed into the soil giving it more nutrients and therefore a classification of an Alfisol. It also has abundant iron-manganese concretions called pisolites. It is like a hybrid between a Jory and and Willakenzie soil. Other loess soils are the Cornelius (with old loess mixed in and a classification of a Mollic Fragixeralf) and the Cascade Series (with young loess and a classification of Typic Fragixerept) making up most of the soil.

The last group of soils has been developed on the valley bottoms and is not great for wine production. These are in the nutrient rich Missoula Flood deposits (Allen et al., 2009) and the soils are primarily the Woodburn Series (Aquic Xerept) but also included are the Willamette, Carlton, Aloha, Amity, Dayton, and Hazelair Series. In the last 15 years the "great debate" has developed in the northern Willamette Valley as to which soil series produces the best pinot noir wine (Burns, 2002). Some say it is the Jory soil and its cousins developed on the basalt bedrock, while others say that it is the Willakenzie soil and its cousins developed on the marine sediment soils. There is a big difference in the wines produced on these two soils. If you keep all of the factors constant except the soil series (i.e. same grape, same year so same climate, same vineyard management, and same winemaker), one will experience two completely different pinot noir wines. To me, the Jory soils produce a wine that is light red in color, has a strong bouquet, and has fruit flavors of red cherries, raspberries, red plums, and red currents whereas the Willakenzie soils produce wine that is dark red in color, has a strong finish, and has fruit flavors of dark cherries, blackberries, and black plums. Ken Wright, a leading winemaker in Oregon, says that the Jory soils produce fruit driven flavored wines and Willakenzie soils produce floral and spice flavors like lavender, cola, tobacco, cedar and anise. Each person has a different opinion. The bottom line is that there is a major difference in the two wines and it comes from the soil differences. Since these different bedrocks are so close to one another, it is easy to taste wines from the different soils while wine tasting in the same day. Because of the close proximity of the different bedrocks and the big differences between the two wines, I feel that the northern Willamette Valley is one of the best places in the world to taste the terroir differences based on the soil differences.

Up until a couple of years ago, the whole Willamette Valley was one AVA (American Viticultural Area). In 2008 it was subdivided into 6 sub-AVA's based on the different local terroirs. First, the vineyards of the Dundee Hills declared that their Jory soils developed on basalt needed to have their own label (Figure 3). Then, the rolling hills of the area to the west of the Dundee Hills declared that they wanted Yamhill-Carlton as the AVA because their geology is marine sediments with Willakenzie soils. Then the Eola-Amity Hills in the middle of the valley declared that their Jory/Nekia soils were special, and they wanted their own AVA. Ribbon Ridge at the north end has mainly Willakenzie soils and marine sediments, and they applied for their own AVA based on the soil, geology and the physiography of the ridge. Chehalem Mountain followed suit with their declaration of having mainly Laurelwood soils and basalt bedrock was special. Finally, McMinnville asked for its own AVA in the marine sediments of the Coast Range with uplifted basalt sea floor.

4 CONCLUSION

Seven main factors affect the taste of a wine. They are the different types of grapes, the geology and resulting soils, the climate, the soil hydrology, the physiography of the site, the winemaker, and the vineyard management techniques. The first five of these factors comprise what the French call "terroir", the taste of the place". Terroir differs from wine region to wine region around the world.

In Oregon's Willamette Valley in the United States, there are two main terroirs based mainly on the geology and resulting soils. The Jory Series of soils developed on the Columbia River Basalts in western Oregon produce pinot noir wines that are light red in color and have red fruit flavors. The Willakenzie Series of soils developed on the uplifted marine sediments of the nearby Coast Range produce pinot noir wines that are dark red in color and have dark red fruit flavors. Because of these differences in wines, the Willamette Valley AVA has been subdivided into six new AVA's based on the geology/soil characteristics of the Willamette Valley terroir.

Acknowledgments

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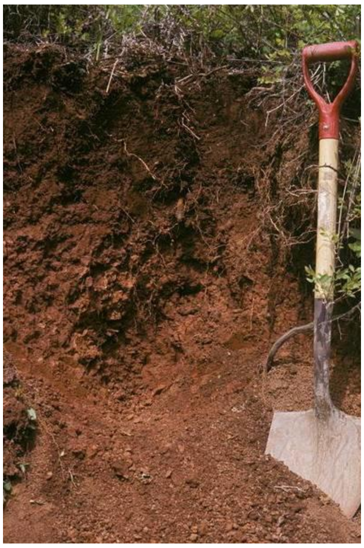

Figure 1: Jory Soil which is the state soil of Oregon

Figure 2: Cross section view of the Willakenzie soil taken at the Elk Cove Winery with a wine bottle for scale

Figure 3: Red Jory soils of the Dundee Hills AVA in the Willamette Valley

Table 1: Distribution of soils in vineyards in the northern Willamette Valley

Soil Series	**Parent Material**	**Order**	**Acres**
Jory	Basalt	Ultisol	1504
Willakenzie	Marine Sediment	Alfisol	1245
Laurelwood	Basalt	Alfisol	825
Yamhill	Basalt	Mollisol	333
Woodburn	Missoula Floods	Alfisol	298
Nekia	Basalt	Ultisol	195
Cornelius	Old loess	Alfisol	141
Saum	Basalt	Inceptisol	126
Bellpine	Marine Sediment	Ultisol	118
Willamette	Missoula Floods	Mollisol	110
Dupee	Marine Sediment	Alfisol	58
Peavine	Marine Sediment	Ultisol	50
Helvetia	Mixed	Mollisol	45
Cascade	Young loess	Inceptisol	31
Wellsdale	Marine Sediment	Alfisol	31
Steiwer	Marine Sediment	Mollisol	28
Carlton	Missoula Floods	Mollisol	25
Amity	Missoula Floods	Mollisol	24
Melbourne	Marine Sediment	Alfisol	18
Aloha	Missoula Floods	Inceptisol	15
Hazelair	Missoula Floods	Mollisol	12
Chehalem	Mixed	Mollisol	10
Dayton	Missoula Floods	Alfisol	6

23 different soils found–being remapped