Soil or geology? And what's the difference? Some observations from the New World

Sol ou géologie ? Quelle est la différence ? Quelques réflexions du Nouveau Monde

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Abstract: Observational historical geology seeks to establish the evolutionary history of the surface of Earth. This approach is applicable not only to bedrock, but to the soft material that lies at the surface, the stuff called soil by most people. The geologic perspective provides a view of this material that is quite different from that of soil science, at least as practiced by many in America. Examples from the Walla Walla Valley of Washington and Oregon, and from the Napa Valley, illustrate the differences between these approaches. In Napa, correlation of grape character and viticultural realities with geologic observations suggests some underlying shared factor, perhaps drainage and water accessibility, but possibly influences of substrate temperature or microbiology. In addition, the geologic approach has proven useful in designing drainage and irrigation systems.

Key words: geology, soil, Napa, Walla Walla, terroir

Introduction

The ideas discussed here arose from a series of projects undertaken at the request of winemakers in the Napa Valley who want to understand more fully the ground on which their grapes grow. The approach of the original work is perhaps embarrassingly primitive, involving observing, measuring thicknesses, describing geologic materials, and integrating the resulting data through a certain amount of thinking. The result is a three dimensional visual understanding of the geologic architecture of a vineyard. The difficult part is communicating this vision to others, particularly to those whose background does not include exposure to the ideas or understandings of Earth science, and doing so cost-effectively. Perhaps a few years from now, technology will allow direct connection of mind to computer, the transmission of visual understanding to graphics programming, and the automatic creation of holograms that can be transmitted wirelessly directly to the client. Until then, we still need to communicate such visions through a combination of words and rather simple graphics. As primitive as these methods might appear, they have produced some thought-provoking results concerning relationships between geology and grape character as well as having been of practical use to winegrowers.

Perhaps the most valuable aspect of these studies is the creation of a science-based contextual framework. Understanding the geologic architecture of a piece of land—seeing how various types of material relate to one another in space—provides a visual and conceptual model within which other data, from spectral analysis to the feel of grape leaves, can be placed and integrated.

Until recently, most studies of vineyard substrate in America have been undertaken from the point of view of agricultural soil science. These studies have been useful to winegrowers, providing them with data on nutrient and mineral content, estimates of water retention, and evaluation of root penetration. Soil science, however, is a descriptive approach that says little about the origin of substrate materials or their history. As a result they are not readily adaptable to the task of establishing or predicting systematic, intra-vineyard, variation. In addition, many soil studies work only with the finer fractions of sediment—sand, silt and clay. In a paper given at a recent terroir conference, one study sought to examine correlations between sensory parameters and sediment texture in vineyards that included glacial deposits with significant cobble and boulder content. The analysis, however, ignored the coarse material and focused entirely on the finer grained sediments, negating any results.

Observational geology speaks directly to these issues. It asks four questions: What are the materials? Where did they come from? How were they emplaced? How do they vary, vertically and laterally? Answers to these questions lie in the materials themselves, which have been imprinted by the geologic processes that formed them.

Discussion

Soils develop through processes of physical, biological, and mechanical breakdown of pre-existing material, either bedrock or granular material derived from bedrock. Soil-forming processes leach elements, transform minerals, and chemically and mechanically redistribute material in the upper few feet. The extreme result is a soil that contains little other than clay minerals and elements such as aluminum that do not readily go into solution.

Soils, however, exhibit a broad range of states of change. Some are little altered from their original form, others show various stages of development. Climate, time, and the character of the original materials condition these variations. In addition, many types of parent material vary both vertically and laterally, sometimes to such an extent that quite different soil types are produced upon weathering. Soil studies give each of these different materials a separate name; when mapped, the result is a fragmented pattern that shows little continuity and reveals nothing concerning origin of vineyard substrate. Often, the proliferation of soil types requires that they be accumulated in larger groups in order to reduce confusion. Viewing the substrate from a geologic perspective tends to simplify map patterns, reveal trends, and provide a foundation for understanding the history of a region. Variation internal to the more inclusive geologic units is implied in the map legend and can be both predicted and established with more detailed field studies. The geologic perspective reveals clearly that physical terroir is scale dependent, and that the history of any area is multi-layered.

The Walla Walla Valley in Washington and Oregon, and the Napa Valley in California provide cogent examples of these issues. In the Walla Walla area, soil scientists have identified and named —on the basis of texture, structure, slope angle, rainfall, and other soil parameters—some 75 different soil types. In the Walla Walla AVA these soils have been grouped into, and mapped, as 8 Soil Associations (Meinert and Busacca, 2000).

A geologic perspective on the same material recognizes four basic types of vineyard substrate that were formed by a turbulent history highlighted by two exceptional events. The first, some 15 million years ago, was the formation of the third largest lava field on Earth, the Columbia Plateau Basalts that locally attain thicknesses of 16,000 feet. The second, occurring between 15,000 and 12,000 years ago, was the unleashing of a series of gigantic floods, the largest ever documented, from glacial Lake Missoula in Montana. With each flood, water backed up behind a restriction at the Columbia River Gorge, forming a series of large lakes. Each time this occurred, a graded bed—sand or gravel at the base, silt and clay at the top—formed. In Walla Walla, at least 40 of these beds (« Touchet Beds ») have been identified. As the lakes dried up, winds scoured the resulting mud flat surfaces, transporting clouds of fine sediment to the northeast where it was dropped to form a layer of loess. Later, the valley fill was partially eroded by the Walla Walla River and its tributaries, which have created alluvial fan deposits that , in their upper reaches, contain thick deposits of basaltic boulders and cobbles. This history, documented by a number of investigators, has been summarized recently by Meinert and Busacca (2000).

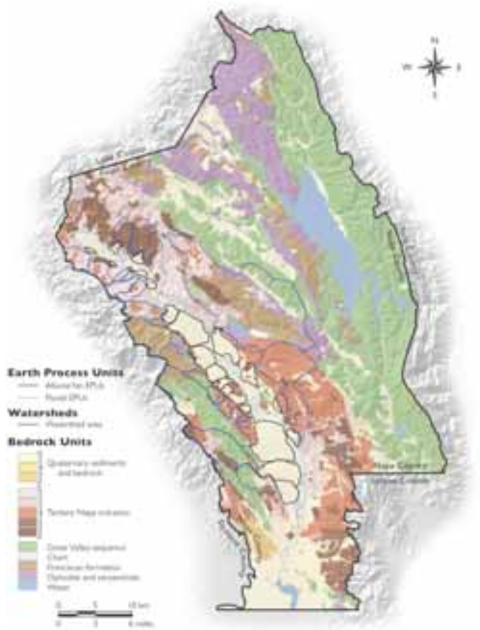
Today grapes grow on four types of substrate: thick loess; thin loess over graded beds; thin loess over basalt; and cobbly alluvial fan sediments. This geologic perspective provides a clear and simplified conceptual framework for the Walla Walla Valley and for individual vineyards within the AVA.

Recent work in the Napa Valley suggests that this geologic approach has significant usefulness, for winegrowers and winemakers in understanding intra-vineyard variation, for design and implementation of drainage and irrigation systems, for choosing rootstocks and clones for planting and replanting, and for defining and understanding physical terroir.

The Napa Valley AVA (American Viticultural Area) has a diversity of bedrock, including a variety of volcanic and sedimentary rocks that underlie the mountains that border the Napa Valley on the southwest and northeast. The valley floor is filled with a variety of sediments delivered from the surrounding hills. Prior to 15,000 years ago sea level was some 100 meters lower than it is today—the Napa River had a very steep gradient that kept the valley free of sediment accumulations. As a result, the valley fill, accumulated over the past 15,000 years, is young and soil profiles have had little chance to develop. In the surrounding hills, most areas have a few inches to a couple of feet of topsoil lying on decomposing bedrock. Deeper soil profiles have developed in some areas, but the normal case is shallow soil over partially decomposed rock.

Some 82 soil types and 30 some-odd soil series have been described in the Napa region. The soils maps bear little resemblance to the bedrock or soft sediment geology. From a geologic perspective, these soft sediments fall into three categories: *Residual materials* have moved little from their place of origin. They commonly form a thin blanket, less than 2 feet thick, over bedrock in the hills. Particulate material carried from the hills by gravity and water accumulate as *alluvial fans* that line the edge of the valley, particularly on the west. Finer material is carried onto the flood plain of the Napa forming *fluvial deposits*. Some might call these three types of substrate macro-terroirs.

On a closer look, each of these types of granular material varies in character. Residual materials on volcanic bedrock tend to form a thin blanket over solid rock with thin transition zones between. In some areas, thick, slightly altered lava flows lie atop more altered material, either thinner flows or beds of volcanic ash. Volcaniclastic sediments, quite fresh, are interbedded with eruptive lithologies. The irregular distribution of volcanic lithologies causes unusual juxtapositions of material, with soft, highly altered, water laid tuff appearing in the midst of resistant welded tuff. Patterns of distribution are not easily predictable.



Alluvial fans in Napa come in two sizes, small and large. The large fans are fed by large watersheds that are underlain primarily by soft sedimentary bedrock. Small fans head in small watersheds cut into more resistant volcanic rock. Of greater consequence, many of the small fans are made up of deposits of tightly packed boulders and cobbles deposited by mudflows, while the coarsest debris in the larger fans tends to be coarse gravel and small cobbles.

These textural differences are sometimes minimized in soil analysis, which tends to emphasize the fine fraction of sediment. Descriptions of Napa soils often read « silty clay loam, 80 percent gravel ». In a geological context, the gravel carries the story, providing information on the origin of the material and how it came to be where it is. This approach is not limited to Napa; a study mentioned in the early paragraphs of this paper that explored the linkage between sensory parameters and sediment texture ignored the coarse fraction of the material.

There would be little use in mentioning these differences were it not for the fact that sediment texture—or something related to it—appears to affect the character of grapes. At Stag's Leap Wine Cellars, a portion of Fay Vineyard underlain by tightly packed boulders deposited as a mud flow underlie what has been recognized for years as a « sweet spot » in the vineyard, a source of some of the finest fruit each year. Away form this area, cobbles and boulders are separated by progressively greater amounts of sand, silt, and clay, while the coarse fraction becomes finer. Some factor related to sediment texture appears related as well to grape character.

At Araujo Estate, vine management appears related to some factor that is also reflected in the geology. There, vines growing either on coarse mudflow debris or gravelly residual sediments are managed with some ease. Where these materials mix, or where mudflow deposits from two separate sources mix, vine management is difficult. Again, some factor that is reflected in the geology is also reflected in the biological milieu of vine and grape.

At first glance, the most likely correlation is with drainage and the way that water is made accessible to vine roots. Different combinations and permutations of boulders, cobbles, sand, silt, and clay might affect the availability of water in ways that condition the development of vine and fruit. But other factors might well be in play, things such as substrate temperature and soil biology (micro flora and fauna). Do boulders and cobbles store and reflect heat differently from finer materials? Is the micriobiology of deposits dominated by boulders and cobbles different from that of fine-grained sediments? Cooperative work involving biologists and geologists might be useful in investigating these questions.

The geologic perspective also informs other aspects of viticulture. In existing vineyards, understanding intra-vineyard variation allows redesign of existing irrigation systems to provide more appropriate water protocols. Often, this variation is masked by soil descriptions. At Rudd Vineyards, for example, much of the substrate is classified as rocky clay loam. A geologic view, however, identifies several distinct types of substrate. Again, this might not be of consequence if the winemaker did not discern significant differences in the fruit coming from the northern and southern segments of the vineyard. The geologic view provides him with an integrated framework within which he can consider these differences and perhaps relate them to other parameters.

Geologic information has also proved useful in designing drainage systems. At Stag's Leap Wine Cellars, two alluvial fans intersect along the edge of a bedrock topographic high that lies below the Stag' Leap fan. Groundwater flowing through the Chase Creek fan hits the bedrock and is channeled across the northwest corner of the Stag's Leap fan (below the dashed orange line) creating moist and overly vigorous conditions in that part of the vineyard. A drainage line along the northern edge of the vineyard now intercepts this underground flow and pumps it into Chase Creek. This replaced several drainage lines within the vineyard that had proven ineffective in dealing with the problem.

At Opus One, an understanding of the geologic architecture again provided a rational framework for designing drainage. Pits in the northern block, (the darker area at the top of the graphic) revealed several groundwater levels; depth to water table varied as much as three feet. Backhoe pits revealed sediments characterized by irregularly distributed beds of silty clay and gravely sand. Pits in the southern block (the lighter area at the bottom of the graphic) showed that this area is dominated by sand and gravel. The perched water tables of the northern block result from ground water flowing from the southern block (and from the west) along the coarser layers, that is impeded by layers of clay. The drainage design involved redirecting the inflow from south and west around the edges of the block to an outflow point to the east.

Conclusions

Soil science provides useful information on soil texture, structure, and composition to grape growers. As is the case with all approaches, it too has limitations, particularly in understanding the origin and variation of vineyard substrate and its relationship to bedrock geology. Correlation of geology with grape character and vine management indicates the importance and usefulness of the geologic perspective. Maps that document intra-vineyard variation provide a framework within which to place and understand other data, from spectral analysis to grape taste. Cross sections documenting variation in three dimensions shed light on such factors as distribution of moisture, differential ripening, and vine vigor. The information derived from geologic studies has been used to select rootstocks and clones for planting and replanting, to design drainage systems, and to re-evaluate irrigation designs. Perhaps most importantly, geologic studies provide a visual and conceptual organizational framework within which to integrate a variety of data.

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References

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