BETWEEN A ROCK AND A HARD PLACE VINEYARD SOILS

by Alex Maltman

What strikes you first when looking at a vineyard? Perhaps the vines themselves. Your eye may be caught by random scatterings of gnarly old bush vines or by the military neatness of the rows, leafy and trimmed in summer but in winter gaunt and skeletal against their trellising. But possibly more striking might be the land itself—the geology, or at least manifestations of it. For the vineyard may be a vast affair, stretching away across a flat plain, or just a tiny huddle of vines clinging to a vertiginous slope, or anywhere in between those two extremes. It all depends on the bedrock geology. The soil may have an eye-catching color or be astonishingly stony, consisting of little more than rock debris. This, too, depends on the geology.

So, along with the widely held convictions that vineyard soils have a major influence on wine character and taste, it is no surprise that geology is so often mentioned in accounts of vineyards. (I had better mention at the outset that these days the word "geology" covers Earth processes and materials—so, in vineyards, the ground in which the vines are rooted—and also the scientific study of these things.)

The image below is a collage of wine labels—all of which bear something geological—as a graphic reminder of this cherished kinship between geology and wine. Of course, all plants are influenced by the site and soil where they grow—every farmer or gardener knows that—but interestingly only with wine (despite the extensive post-harvest processing of the fruit) are the connections taken this far.

But these geological words that are so commonly used in wine writings, what do they actually mean? Even the most basic terms—rock, bedrock, soil, stones, pebbles, and the like—what exactly are they? There are countless instances where wine writers have them confused. What is the difference between a rock and a stone, for instance, or a rock and a mineral? What are they made of? In other words, what actually makes the ground in which the vines grow? Rarely are such basic terms defined and explained, which presumably accounts for them often being used in a very loose way and sometimes wrongly. In this article, I attempt to explain in the context of vineyards these fundamental, widely used but poorly understood words.

They all have one thing in common: They refer to things that ultimately derive from the solid Earth itself; they are all fragments of one kind or another of the solid part of our planet. So, a consideration of what vineyard ground is made of begins with the makeup of the Earth. And there are three ways of thinking about this.

Chemical elements, minerals, and rocks

First, like all matter, the Earth is made of chemical elements. The remarkable thing here is that although we know of close to 100 different elements in nature, the composition of our planet is dominated by just eight of them. Details vary at different depths within the Earth, but the outermost part, which is what concerns us here, is dominated by oxygen, silicon, aluminum, iron, magnesium, calcium, potassium, and sodium, in that order. Preponderant among these are oxygen, at no less than 46 percent, and silicon, at 28 percent. So, there is a lot of these two things in most vineyards.

Of course, these elements don't exist as separate entities. After all, oxygen is a gas, and a vineyard isn't full of bubbles and gas balloons! Rather, the elements are combined with each other to form rigid amalgamations, and we call these natural compounds minerals. A second way to think of what composes the Earth and the fragmentary detritus at its surface is minerals—that is, the ground of a vineyard is made of minerals. (However, this word, "mineral," has a number of different meanings according to context, even within the world of wine. We will return later to its use for vine nutrients.)

A few elements can exist independently in the Earth, though we still call them minerals. Carbon is an example—the mineral graphite, found, for instance, in some of the vineyards in western Styria, Austria—as is manganese (occurring at Moulin-à-Vent, Beaujolais, France). The element sulfur is found in active volcanic areas such as Etna and Vesuvius, though most sulfur in vineyards has been added artificially, to increase acidity, or as a residue from spraying the vines to combat molds. But most natural minerals, not surprisingly from the numbers given above, involve silicon and oxygen, usually with other elements in attendance. These are referred to as silicate minerals. Thus the vast majority of minerals making up the ground of vineyards are silicates. A notable exception is the combination of oxygen and carbon that makes carbonate minerals, and especially calcium carbonate, the mineral calcite. But other minerals you may have heard of in vineyard descriptions, such as quartz, feldspar, the clay minerals, mica... They are all silicates.

We know of many hundreds of different minerals, but here's another surprising thing: In nature we find over and over again the same few of them collected together in roughly similar proportions and bonded together to form strong, solid masses. The name for these rigid aggregates of minerals? Rocks. This is why we think of the Earth as a rocky planet. It is made of rock. Minerals combine to make rock, and minerals are composed of chemical elements. So, depending on how you look at it, the ground of a vineyard is made of all three things. And incidentally, we can see from this (notwithstanding remarks in some wine writings) that rocks are not the same as minerals.

Rocks have always been problematic things for geologists to classify. They don't fall naturally into boxes like, for instance, animals. An elephant is either an elephant or it isn't; in general, rocks aren't like that. The obvious approach to classification, following the logic of the last paragraph, would be based on which particular minerals are combined—but this turns out to be wholly unhelpful in practice. Rocks made of the same collection of minerals can look vastly different and can occur in very different circumstances. Those composed of carbonate minerals, of which limestone (made of calcite) is the dominant example, are less difficult but rocks made of silicate minerals present an especially formidable diversity and classification challenge.

The most useful rock-classification system so far devised is a very curious one indeed. It is based on how the rock formed: Was it deposited as sediment? Has it undergone changes? Was it once molten? Yet with a few exceptions, no one has ever witnessed such things or is ever likely to. Consequently, naming a rock on the basis of its origin involves a major subjective inference, and there are plenty of examples of geologists disagreeing on what to call a particular rock. Moreover, the resulting single rock name can cover a wide variety of appearances and properties. I emphasize later the complexity of the geological processes operating in a vineyard; my point here is that simply stating that a particular vineyard is founded on, say, schist or marl is disregarding all the subtleties and variations that can be encompassed in a single rock name.

More on elements and minerals

Minerals as crystals

When elements come together to form a mineral, a tough bonding develops between them, involving the very electrons they contain. This not only gives the mineral rigidity, but it locks the elements into the mineral. We shall see later that minerals form the structural skeleton of soils, and this means that the constituent elements are firmly bonded within that framework. Unless special things happen, those elements will not be available for vine nutrition.

Another result of this bonding is that, in almost all minerals, the constituent elements amalgamate not in some higgledy-piggledy fashion but have to organize themselves in a particular, symmetrical arrangement. It's a bit like seeing soldiers on formal parade. This regular pattern, correctly speaking, makes the material crystalline; it is a crystal. In other words, the pieces of mineral in a vineyard are crystalline. (Examples of the very few minerals that are not crystalline include opal, amber, and jet.) We may think of crystals as having the attractive, light-catching facets seen in gem shops and museums, but although this is a manifestation of the crystalline structure of its constituent elements, it is not what defines them as crystals. Consequently, minerals lying in a vineyard may be dull, shapeless chunks, but they are still crystals.

Whether or not a mineral shows smooth crystal faces depends on the circumstances in which the mineral formed. Essentially, to develop attractive external facets, a mineral has to "grow" during its formation into a space and not be constrained by adjacent minerals. In other words, the development of smooth external boundaries in a mineral requires rather special circumstances. The vast majority of minerals will therefore not have such faces—but internally they are still crystals. Therefore, saying that the soils in a particular vineyard are "crystalline" has no geological significance. The ground in all vineyards is composed of crystals of one sort or another. Some of the particles may happen to have smooth faces and catch the sunlight, but this does not make them any more crystalline.

In some kinds of quartz, the crystalline nature is only discernible under a powerful microscope, because the amalgamated crystals are exceptionally minute. This is the case in the variety known as flint, which is particularly well known in the vineyards of Pouilly-Fumé and Sancerre. Bygone peoples learned that striking iron on this hard, strong material was a good way to produce a spark, used at first for lighting fires and much later, utilizing steel, as gunflint. Wine-tasting notes frequently allude to the odor of flint or gunflint. Just like the other silicates, however, flint has no taste or smell. Any odor that is perceived when making a spark comes from the minuscule fragment of burning iron: The flint remains inert. (Curiously, the word silex also appears in wine writings in English, though it is simply the French word for flint.)

Identifying minerals

I've explained that minerals are crystalline because it has important practical repercussions. For example, if we see pieces in a vineyard of what may be fragments of a mineral, how do we go about identifying them—that is, giving them a specific name? The crystalline nature of minerals turns out to be very helpful with this.

Geologists classify minerals on the basis of what elements they contain (hardly surprisingly, seeing that they are combinations of chemical elements). This is straightforward enough in principle (a contrast with the subtle system necessary for rocks). For example, we recognize a group of minerals called oxides, in which some element has combined with oxygen.

Photography courtesy of Alex Maltman

Photography courtesy of Alex Maltman

Left: Mixed pebbles in a channel of the ancestral Columbia River, Newhouse Vineyard, Snipes Mountain AVA, Washington State, USA

Actually, much of the manganese in the ground at Moulin-à-Vent, mentioned above, is combined with oxygen in the mineral called pyrolusite. The distinctive red color of terra rossa, found in areas such as Istria (Croatia), La Mancha (Spain), and Coonawarra (Australia) is due to iron in various combinations with oxygen, particularly in the mineral hematite. Bauxite comprises aluminum combined with oxygen and occurs in vineyards in Les Baux-de-Provence, France (for which the mineral is named), and Pemberton in West Australia. Examples of other mineral groups include the sulfates, halides, and phosphates, and, as introduced earlier, the carbonates and the silicates.

Carrying out a chemical analysis, however, is hardly a realistic proposition for routinely identifying minerals, so we have to use shorthand ways. It can be tricky because, unlike many living things, obvious features like size don't help us, and color can be very misleading. For some minerals, even tiny amounts of impurity, perhaps lodged in an odd position within the crystal lattice, can have an enormous effect. Thinking back to our parading soldiers, the display would have a very different overall look if one or two of them were in the wrong uniform! Quartz is an excellent example. Pure quartz is simply silicon and oxygen, and it's colorless, like glass or ice. (Pliny the Elder wrote that quartz was a permanent form of ice.) However, just a trace, for example, of aluminum darkens it to give the semi-precious stone smoky quartz; titanium turns it pink—rose quartz; and a trace of iron gives the beautiful violet of amethyst. Agate, jasper, onyx: All are varieties of quartz (and all occur in certain vineyards and, as a result, find their way into wine names).

A further complication for identification is that certain locations within the crystal lattice of many minerals can be occupied by one element instead of another, leading to a variable chemistry. This arises in the two groups of minerals that chiefly concern us in vineyards: the carbonates, though these are less difficult, and the silicates, which present formidable problems.

Looking at the carbonates, we have already met calcite, which by definition has the elements calcium, carbon, and oxygen arranged in a particular systematic pattern. But magnesium has rather similar properties to calcium and is able to substitute for it in the crystal lattice—thus, geologists talk about "high magnesium calcite." If as many as half the sites are occupied by magnesium instead of calcite, the mineral is sufficiently different for a new name to be justified. The first person to realize this was a pioneering French geologist called Déodat de Dolomieu, and later on, the half-calcium/half-magnesium mineral was named in his honor: dolomite. Later still, when it was discovered that the mountains of northeast Italy were largely composed of this mineral, the name was extended to them also. (Dolomite is also the name of a rock, one composed almost entirely of the eponymous mineral.) The vineyards of Trentino and Alto Adige contain abundant fragments of dolomite, debris from the nearby Dolomites. If virtually all the sites in the carbonate lattice are occupied by magnesium instead of calcium, then the mineral is different again. It is called magnesite, found, for example, in some vineyards near Mittelwihr, Alsace. (We will return to this commonality between certain elements, because it can be important in vine nutrition.)

The extra difficulty with the silicate minerals is that such substitutions are very usual and commonly involve several elements at the same time. Thus many silicate minerals are defined by whole ranges of possible chemical compositions—all of which makes classifying and identifying them exceptionally challenging.

Fortunately, it is the crystalline nature of the minerals that provides us, in many cases, with practicable shortcuts to identification, for it imparts certain physical properties in a mineral that are consistent, even if the chemical composition is variable and there are ranges of, say, shape and color. Most books on minerals catalog such properties; I will sketch here how two examples work.

First, hardness. The mineral gypsum, for instance, is rather soft as minerals go, because in it calcium shares electrons with sulfur and oxygen in a relatively loose way. (Gypsum occurs naturally in some vineyards at Ribera del Duero, Spain, and elsewhere is sometimes added to soils to help reduce acidity.) So, a piece of vineyard mineral that you can dig your fingernail into is a good clue that it might well be gypsum. Quartz, on the other hand, has its silicon and oxygen firmly linked together and arranged in a very efficient three-dimensional lattice. As a result, although it can look superficially like gypsum, quartz is a noticeably hard mineral—even a knife blade won't scratch it. Together with its chemical stability, this makes the mineral tough, robust, and virtually insoluble. Incidentally, this explains not only why quartz is so common in vineyards, but also why it lacks aroma and flavor (substances have to vaporize for us to smell them or dissolve for us to taste them) and, consequently, is used for wine bottles and glasses.

Second, mineral cleavage. The crystal structure of some minerals has inherent planes of weakness—to the degree that the mineral tends to break along them. In an intact piece, these cleavages may be apparent as hairline traces, such that you can judge how the mineral would fracture. There may be one or more such directions of weakness, or none. Quartz, for the reasons just indicated, has no cleavage at all. It breaks (with difficulty) into shapeless but sharp glassy fragments. Perhaps this is why some wine descriptions refer to a "quartz edge"; as explained above, quartz has no aroma or flavor.

In the crystal lattice of minerals comprising the mica family, there is one direction in which the linking between elements is unusually weak. Hence the micas are distinguishable by their very striking sheet-like shape. It may even be possible to peel the sheets apart. The silvery mica called muscovite (because large translucent sheets of it were once used as window panes in Moscow) accounts for the flat, shiny particles in the soils of Poncie in Fleurie, France. Looking very similar in most ways but distinctively dark colored, even black, is the other common mica: biotite. The ground of the Junrode vineyard of Condrieu, France, tends to be pale in color, but some patches are noticeably darker because they are rich in biotite. The feldspars (also a complex family of silicate minerals) all have two directions of cleavage, causing them to fragment into block-like chunks, the smooth faces of which catch the light in vineyard areas such as Dão (Portugal) and Temecula (California). With practice, physical properties such as these enable us to identify minerals quickly, but this only comes about because of their crystalline nature.

Rocks and rock fragments

The outermost boundary of the solid Earth is bedrock. Such rock is constantly under the chemical, physical, and biological attacks of weathering, which breaks it down (some may be dissolved) into the fragmentary debris that geologists call sediment. In places such as craggy hillsides, the bedrock may be visible, protruding through the sediment in outcrops. These days we distinguish between sediment and solid, rigid rock, but it was not always so. The pioneering geologists were keen on differentiating what they were studying from biological things, so anything made of natural minerals was referred to as "rock." Thus in this historical usage, river mud, freshly settled volcanic ash, or the sand in a dune would all be termed rock. This sense is still found in some wine writings—in fact, the first three editions of *The Oxford Companion to Wine* define rock in this way. Modern geology, however, finds it useful to distinguish between loose sediment and rock, the practical difference being, as one wag put it, that kicking a rock hurts your foot...

Geologists classify sediment by the size of the fragments. The largest—boulders—may be enormous, as in mountainous vineyards such as parts of Elqui, in Chile. But despite their size they are nevertheless fragments; they are loose, detached from the bedrock. With decreasing size, we have cobbles and pebbles (terms that also imply some smoothness), then sand, silt, and clay. A mixture of all of the last three is termed loam.

The word "clay" actually has two meanings, though the difference is subtle. Clay is both the finest sediment, irrespective of what it consists of, and the name of a very complex family of silicate minerals. These clay minerals are always exceedingly small and commonly compose much of the finest sediment: clay. In both senses, clay is critical in vineyards, influencing both water and nutrient supply.

But what about this word "stone"? In vineyards, an easily visible fragment of bedrock can be called either a rock or a stone: The words are synonymous. In this loose usage, however, nothing is being specified about the nature of the chunk of earth material. Larger stones are most likely to be pieces of rock of some kind, whereas the finer ones may well be a single mineral, having broken from their parent rock. To geologists, however, a piece of rock has to be composed of rock, so they studiously avoid the vagueness of the word stone, except in particular contexts such as building stone or a precious stone.

The sediment in a vineyard does not necessarily represent the bedrock directly underneath. It may have moved down-slope under the influence of gravity, in which case it is properly called colluvium; or it may have been brought by rivers, in which case it is alluvium. The difference can be important: Both kinds of sediment occur on the Côte d'Or, but apparently the majority of the grand cru vineyards there are located on colluvium. On the other hand, alluvium is important in many New World regions, such as Marlborough (New Zealand) and the Maipo, Rapel, and Maule valleys in Chile. The sediment in the vineyards of the Finger Lakes region, New York, and the valley floor at Okanagan, British Columbia, was largely brought there by glacial ice. The sediment called loess that blankets substantial areas of the Earth and is important to viticulture in, say, parts of Austria and Washington State, was by definition blown there by the wind.

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Photography courtesy of Alex Maltman

Left: Cobbles, or *galettes*, derived from conglomerate bedrock in a vineyard in Villemajou, Corbières, France

All of this has set the scene for turning now to the word that is pivotal to vineyards: soil. Mixed in with the sediments outlined above may be moist, rotted biological material—humus—and this allows the sediment to be called soil. It is, of course, capable of allowing plants to grow in it. So, soil typically consists of a physical framework provided by the geological sediment, spaces between the sediment particles called pores that contain some combination of water, oxygen, and other gases, and a greater or lesser amount of humus. It is the latter and the moisture that make it soil; the moon is covered by porous rock debris, but it has no soil.

If we dig down into a field or garden, normally we see first the humus-rich soil and then underneath increasingly rocky material—subsoil—in which little can grow, and sooner or later we hit bedrock. Only very specialized plants such as lichens can grow directly on bedrock. In fact, in much agriculture the crops grow solely in the humus-rich soil at the top, and what lies below is of little relevance. But vineyards are different. The distinction between rock and soil is unusually blurred, because vine roots can penetrate deep into bedrock, and vines can thrive in thin, humus-poor, exceedingly stony soils. Some humus, however, has to be involved, even if it is sparse and hidden below the surface stones. The apparent absence of soil, in the conventional sense, in the rocky vineyards of places like Châteauneuf-du-Pape and the Middle Mosel, is legendary, but most of the root activity is out of sight, in different material just below the ground surface.

Minerals as nutrients

We have been discussing what the vineyard ground is made of, but what about the vines themselves? What are they made of? For centuries, the belief was that vines were composed of matter drawn from the soil. Manifestly, the vines were taking water from the ground—if the soil dried out, the vines withered—so they must somehow be processing things in the water to constitute their stems, leaves, and the grapes themselves, including the juice. It seemed self-evident, and what alternative was there? A spiritual dimension was also invoked—and for some, still so today—but essentially it seemed that wine had to derive from the soil. So, whether or not the stories about Burgundian monks tasting soils to gauge likely wine quality are true, they are understandable. And it all helped enshrine the European tradition of a special alliance between soil and wine that is cherished to this day.

A series of scientific advances in the late 1800s, however, revealed that it wasn't really like this at all. Photosynthesis was discovered, a process superficially even more magical. As a result today, at least ten Nobel Prizes later, we know pretty well how plants carry out their growth. It turns out that apart from the water, vines are very largely made not from the soil but from the oxygen, hydrogen, and carbon in the air, everything being driven by sunlight. Even so, in order for the photosynthetic and other organic processes utilizing these elements to work, relatively tiny amounts of other elements have to be involved: nutrients. Most of these come from the ground, and consequently they tend to be called mineral nutrients or, often, simply minerals. And herein lies the source of much confusion. Although most of these mineral nutrients are derived from geological minerals, they are not the same thing.

The mineral nutrients are chiefly metallic elements, such as magnesium, calcium, iron, and zinc. Although they come from the ground, except by the action of certain specialized fungi (micorrhizae), vines cannot obtain these nutrients directly. To be absorbed by the vine roots, the elements have to be dissolved in the soil water. All this contrasts with the minerals that constitute the vineyard bedrock, stones, and the physical framework of the soils—minerals in the geological sense—which as we have seen are almost all rigid compounds, and usually complex and insoluble ones at that. And because, as I emphasized earlier, the elements forming a geological mineral are tightly locked together in a crystal lattice, whole series of processes have to take place before they become detached, dissolved, and transported to the vine roots for possible absorption into the vine system. So, though ultimately linked, there is a major disconnect between these two different kinds of minerals.

Here is a very terse summary of the complex processes that separate the two kinds of minerals. The processes, collectively called weathering, slowly change the nature of the geological minerals and eventually, through a series of intermediate varieties, may lead to the formation of clay minerals. Some of these have a special property (the so-called cation exchange capacity) that allows, in certain circumstances, the release of some of their constituent elements into solution, which now become potential mineral nutrients. Then, if conditions are right, these dissolved elements may be physically transported through films of water between the soil pores toward the vine roots.

Photography courtesy of Alex Maltman

Right: Iron-rich clay-loam derived from limestone—terra rossa—as found in vineyards in Coonawarra, La Mancha, and (here) Istria

All these processes are aided by the presence of humus and the microbiology it contains. In fact, some amount of humus has to be present in order to help form compounds containing nitrogen, phosphorus, and sulfur, which are essential nutrients but not absorbed in elemental form. The take-up of nitrogen is particularly influential on vine growth and depends largely—oddly seeing as the gas abounds in the air all around the vines—on microorganisms in the soil. And so, if all these kinds of processes are happening smoothly, and the clays and some humus are readily making nutrients available in at least sufficient quantities, the soil is regarded as being fertile.

Geological minerals, nutrient minerals, and misunderstandings

Not only are the processes outlined above intricate, but they vary from place to place and through time. Such things as soil temperature, acidity, humidity, permeability, nitrogen content, microbiology, and so on can all be varying such that any generalizations are fraught. Many populist wine writings, however, give little acknowledgment of these complexities, and this leads to misunderstandings. Here are a few clear illustrations of this.

First, let's take the mineral nutrient required in the largest quantities by vines: potassium. The chief constituent of the rock granite is the mineral potassium feldspar, so we might expect this particular nutrient to be in plentiful supply in vineyards located on granite—Dão, Stellenbosch, and Temecula, for example. And some wine commentaries have it this way. But because of the protracted physical and chemical processes that have to take place, as glimpsed above, in reality only a fraction of the potassium is actually freed from the feldspar crystal lattice. In the Lodi district of California, for example, it has been calculated that despite the abundance of potassium in the granite bedrock, less than 2 percent of it actually becomes available to the vines. Moreover, the details depend on very localized conditions. The potassium availability differs between soils of different ages, acidities, varying sand, clay, and humus contents, between terraces and the valley floor, and with local variations in rainfall.

Another misunderstanding is the common inference that the vine roots simply soak up like blotting paper whatever happens to be in the soil: It's as though the vine has to take in whatever the geology throws at it. Vines don't work like this. Seventeen or so mineral nutrients are needed for the processes involved in vine growth, and some of these are needed in very different amounts. For every unit of molybdenum, for example, the vine requires about a quarter of a million units of potassium. Moreover, each element is required within a fairly narrow range of optimal values; too little or too much provokes growth problems. (The extent—if any—to which variations within the optimal range might influence growth mechanisms is at present not known.) As a result, vines have evolved highly sophisticated mechanisms of selecting and balancing the amounts of nutrients they take up, in order that their needs are met but not exceeded. To this extent, vine nutrition isn't dependent on the nature of the vineyard geology, provided it can yield sufficient nutrients. And because of the modest nutritional needs of grapevines, in general most soils can yield sufficient nutrients, unless they are being overcultivated.

That said, there is some passive uptake of soil water and its content, and the vine's selectivity processes are fallible. For example, we have already glimpsed the calcium and magnesium complications within geological minerals, and it is the same when these two elements are acting as nutrients. A vine's "filters" may be unable to distinguish between the two, and the more plentiful one becomes absorbed to the detriment of the other. Hence, vine diseases such as the leaf-yellowing we sometimes see in parts of vineyards don't necessarily mean that a particular nutrient mineral is unavailable in the soil. Some other nutrient, perhaps more abundant or more easily absorbed, may be fooling the vine. The effect differs between different cultivars and, more especially, different rootstocks, which vary markedly in the way they take up mineral nutrients. This is why growers are advised to assess nutrition by analyzing parts of the vines themselves, in order to see what the vine is actually taking up, rather than what the geology contains. This is why a good grower walks his vineyard: The key to monitoring its health lies in watching the vines, not the soil.

Another point often overlooked is that although certain amounts of nutrients are essential for growth, the vine does not care, so to speak, where they came from. Whether a mineral nutrient originated in a particular rock or this or that geological mineral is irrelevant to the growth processes. A vine's hormonal system may signal to its roots the need for some nutrient—magnesium, say—and provided it is available in the soil water, then magnesium will be allowed to negotiate the roots' regulatory screens and gradients to be absorbed into the vine system. But whether the element was originally in a chunk of

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dolomite or a flake of mica (or, for that matter, a fertilizer bag) is immaterial. To the vine, magnesium is magnesium.

Physical properties of vineyard soils, particularly those involving water, are known to affect vines and possibly the resulting wines. I suggest, however, that the above discussion undermines the importance supposed by some of soil chemistry for the finished wine, especially as the amounts and proportions of mineral nutrients change further during vinification and aging. Thus, there would seem to be no basis for the common assertion that a particular kind of bedrock produces certain wine flavors. Of course, relating a single-vineyard wine to its geology has immeasurable marketing value and bestows the very fashionable "sense of place." Vineyard geology is one of the few things that cannot easily be replicated elsewhere.

Anecdotes on the characteristics that certain rocks are supposed to bring to wine are wildly inconsistent and tend to fail in blind tastings. The complications outlined above help account for this and, incidentally, they also explain why it has proved so difficult to find a reliable way of chemically "fingerprinting" the provenance of wines. And in addition to all this, the fact is that, in many parts of the world, the natural soil water chemistry is profoundly altered by fertilizers and other agro-chemicals, as well as by irrigation, which often utilizes water brought from far afield.

Claims are made that a particular grape cultivar does best in a particular soil (almost always ignoring the kind of rootstock, which is actually what governs the vine-soil interaction). There are now even published check lists on this: limestone for Chardonnay, marl for Pinot Noir, slate for Riesling, and so on. But these associations largely reflect the soils where the cultivar first happened to evolve and thrive. While such pairings may be sound in the conditions of one particular place, they manifestly do not apply globally.

Wine writings frequently laud vineyards because their soils are "mineral-rich," not least because this is supposed to lead to certain desirable qualities in the wine. But what does that mean? As we have seen, all rocks and soils are made of (geological) minerals, not some more than others. So, maybe it means rich in nutrient minerals? That's the same as saying very fertile, and it is pretty much axiomatic in viticulture that highly fertile soils are to be avoided, since they normally lead to high vigor and lower grape quality.

I love the idea of old vines, with their gnarly appearance and rich heritage. I can easily imagine that wines from them taste superior. And perhaps they do, bearing in mind the proven pedigree and naturally restricted vigor of old vines. The notion, however, that their deep roots are bringing extra minerals to the vines and, hence, extra nuances to the wine has no basis, in view of the explanations above. The bulk of a vine's nutrition comes from the mix of humus and weathered geological minerals in the upper parts of the vineyard ground. Deep roots may be impressive, but they will have grown very largely in response to the need to tap into any supplementary water available deep down. The bedrock at those depths will be largely intact apart from the fissures in which water may reside. By definition, there will have been little weathering, and hence there will be little nutrient availability.

Toward a clearer view

Where do the kinds of explanations developed above lead us? As I've indicated, for one thing, they should make us cautious about some of the populist claims made about vineyard geology and its importance for wine. It's well demonstrated that various physical properties of vineyard rocks and soils affect vine performance and, hence, perhaps the character of wine. But wines literally tasting, say, of flint or of slate? Or tasting of the geological minerals in the vineyard? Spicy wines from vineyards sited on volcanic rock? Such anecdotal ideas are romantic and great for marketing, but they remain unsubstantiated and, as I have tried to explain, are at odds with our understanding of how vineyard rocks, minerals, and soils work.

I hope my explanations at least help with the proper use of geological terms, which is essential to a clear understanding of things. Science continues to make tremendous progress in helping our comprehension of vines and wines and, as a result, improving all around the standards of wine production. At the same time, in my view science has in no way diluted the romance of vineyards and wines—quite the contrary. If we are brought to recognize more fully the sheer complexity of the natural processes involved in making the solid Earth yield flourishing vines, it increases our admiration, it adds to the marvel. The connection between soil and wine may not be direct and literal, but a kinship exists. We are beginning to understand how this association actually works and to appreciate its dazzling intricacy. So, when we look at a vineyard with an informed view, understanding the role of geology fine-tunes our discernment of what we see and of what's going on out there and, ultimately, enhances the wonder of it all. ■

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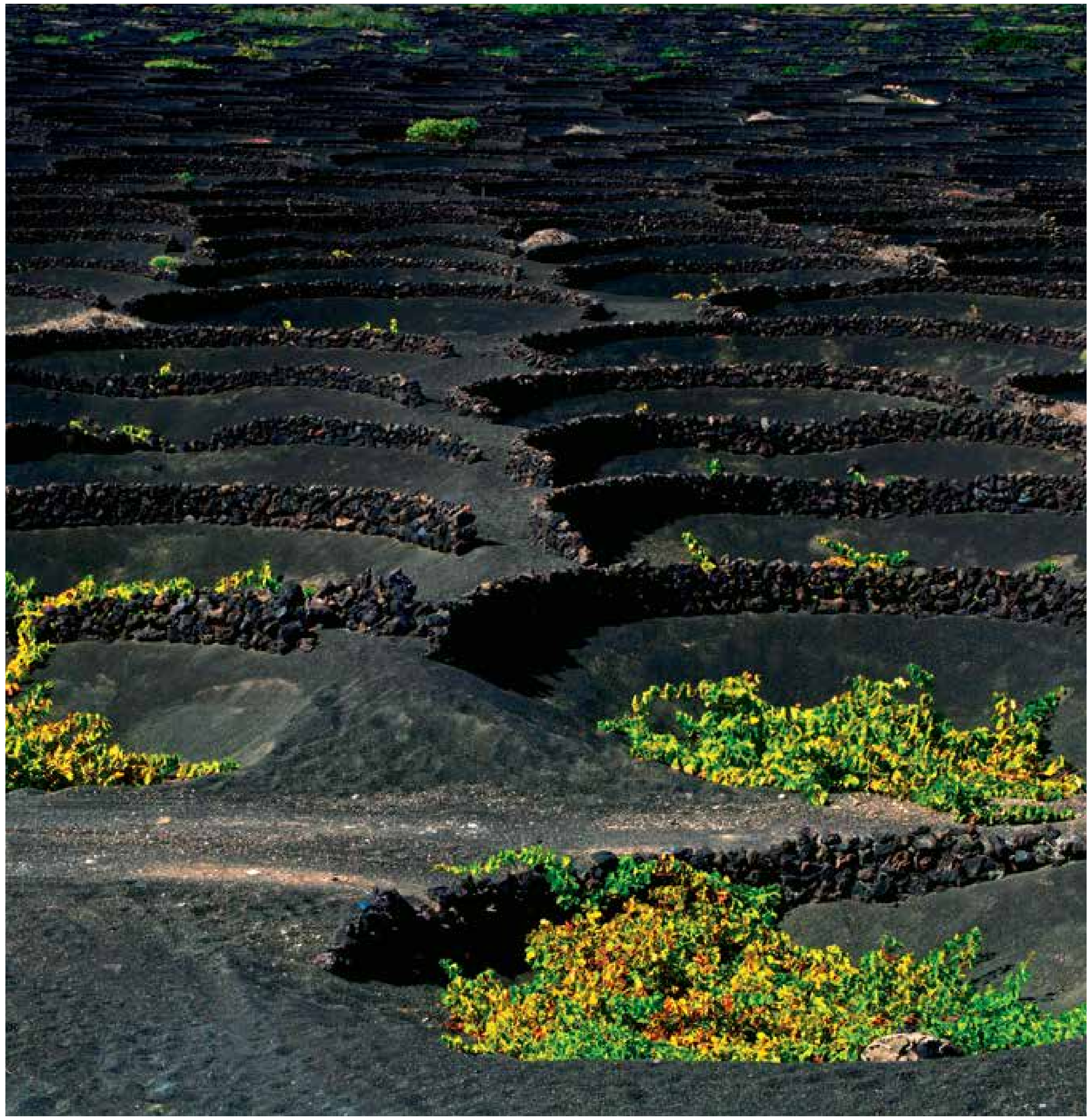

Above: Volcanic areas are known to contain sulfur naturally, though much sulfur in vineyards is added artificially to increase acidity