DID THE EARTH MOVE?

Geological faults—fractures in the land on either side of which materials have been physically moved—are common in the bedrock of vineyards around the world. But what role do they play in shaping growing conditions, viticulture, winemaking, and the wines themselves? And what can producers do to protect their wineries and workers from the earthquakes that have caused so much damage in prone wine regions recently? **Alex Maltman** digs deep for answers

"But did thee feel the Earth move?" Robert Jordan famously asked Maria, in Hemingway's novel *For Whom the Bell Tolls*. Certainly in many a vineyard the earth has moved—quite literally. For in the ground of a vineyard, particularly in the bedrock, ruptures are common, and along some of the breaks the materials have been shifted, physically moved. To geologists, fractures that show visible displacement of the rocks either side are known as faults. Well that's the strict technical meaning, though the term has captured the public imagination as a metaphor. California's San Andreas Fault has given rise to poetry, art, novels, films, and music. We talk of fault lines in religion and culture, in commerce and politics. And in lifestyle: "The survey indicates significant fault lines when it comes to marijuana policy."

Geological faults can be important for viticulture, for example by affecting the movement of water and nutrient access in the vineyard ground. In this article, I will look at three relevant aspects of faults, namely their juxtaposing of contrasting kinds of bedrock and soils, their influence on the physical landscape, and the matter of modern faults triggering damaging earthquakes. I end with some comments on what is perhaps the best known geological fault, the San Andreas, as a fine example of how these various effects come together. But first, a few words on geological faults and what they are.

A quick look at geological faults

English miners were talking about faults back in the 17th century. And just as remarking on faults in a wine can refer to some deficiency, in geology this early usage of the word fault—from the Latin *fallita* for shortcoming—meant that something was lacking. When a miner was hacking along a coal seam or a vein of metal ore, he might find that it abruptly gave out, to be replaced by barren rock. So his target was suddenly lacking, though often he could find the same body nearby and could continue working it. The miners realized that such masses had originally been continuous but had become broken and separated—by what at first they called a "trouble," a "slip," a "disarrangement," and so on. Numerous such vernacular terms evolved, including the expression that when the vein or seam ran out the miner found himself "at fault." And it was this term that caught on.

Other geological features, and not just economic deposits, can become physically separated in this way. Diagrams from the 18th century onward portrayed how geological strata could variously be displaced, and some began to label the very "fault" that had caused the shift. Some showed things in exquisite detail (*see John Farey's diagrams overleaf*). The emphasis, though, was on the *appearance* of the shifted strata; as I discuss later with respect to earthquakes, no one understood what actually caused these disruptions. Today, however, geologists know that stresses in the Earth (ultimately due to thermal variations within the planet) are continually waxing and waning, in different places at different times, and that sometimes they can become sufficient to fracture rocks and displace them.

Most ancient rocks will have undergone a degree of faulting sometime in their history; it's a common phenomenon even if we do think first of those special regions where faults are active today and triggering headline-making earthquakes. In fact, every crag or cliff you have looked at will have shown fissures and cracks, but rather like with lichens, because they're ubiquitous we mentally filter them out. Most of these cracks, however, are not faults: they won't show the shifting of the rocks on either side needed to call it a fault. But some probably do. And although that displacement is typically small, just a few feet or so, it can reach the hundreds of miles recorded by the world's big faults. Most of the latter will have formed at the junctions where Earth's tectonic plates moved past each other, and that's exactly what is happening today in some places. For the wine world that means fault movements and earthquakes in such countries as Italy, Greece, New Zealand, Chile, and the USA.

The movement can be in any direction along a fault: sideways or "up and down" (though with little "pulling apart"; faults don't make gaping fissures). Either or both sides of the fault may have moved, and only the smallest faults are likely to be single, clean fractures. So, although we usually picture faults as lines, in the ground they exist in three-dimensions and they usually have some width of broken rock with further fractures splaying outwards into adjacent rocks. Hence geologists often talk of an overall "fault system."

If the Earth's stresses grow in a region that already has geological faults, then these weakened zones will be most vulnerable to further movement. The stresses may grow and eventually overcome the friction that holds the faulted rocks together, so that the rocks shift again and the accumulated energy is released—as heat, noise, and the mechanical waves that we call earthquakes. Thus fault zones that are active today present ongoing earthquake hazards. The vast majority of faults originate deep underground, but the fracture might propagate up to meet the surface, which is why faults can appear in the ground of a vineyard. If some of the displacement was "up and down," then cliffs can result, typically just 3ft (1m) or so high but occasionally much more. They're properly called escarpments (or scarps), a name adopted by a prominent winery in New Zealand's Martinborough district.

Jumping from soil to soil

So now, with that glimpse of the nature of faults, I turn to what all this can mean for viticulture. First, because at any place along a geological fault the rocks on opposing sides will have differentially moved, contrasting materials may have been brought next to each other. And if the overlying soil is derived from this bedrock, then it, too, will show sudden changes. Although there are wineries that boast of the *consistency* of their vineyard ground—Cornas's Reynard vineyard is "entirely pure granite, which gives the wine a purer taste with finesse and elegance"; the Fulldraw vineyard in Paso Robles has only "pure white calcareous shale" such that "the fruit you get is fresh and exciting"—it's more than likely that a winery that finds it has a vineyard straddling a fault or two will be trumpeting the *diversity* this brings. (Although, incidentally, both the Cornas and Paso Robles areas have faults in their bedrock.) Thus: In Sonoma's Rockpile AVA "the Cemetery Vineyard straddles the Rodgers Creek Fault, giving it amazing diversity of soil composition"; Gigondas's "Château de Saint Cosme is exceptionally located at the crossing of two geological faults, which is very rare. This gives us an extraordinary diversity of soils"; "the Umpqua Valley AVA has an incredible 150 soil types because of its fault-lined teutonic (*sic*) geology". These enthusiastic claims of diversity can get quite competitive (and implausible): "Burgundy is a land of faults, and the diversity of vineyard soils has no equivalent anywhere else in France"; "The faults in Napa Valley give a spectacular diversity of soil [...]more than in the whole of France"; "Because of the San Andreas Fault system, there is a greater variety of soil in Sonoma County that in all of Western Europe".

But in any case, why might such soil variations matter? Well, for one thing they may influence a grower's choice of cultivars and rootstocks. For instance, the Truchard vineyard in Carneros has a fault that has juxtaposed clay soils against Mayacamas volcanic material, and the grower believes the former suits Pinot Noir, Chardonnay, and Merlot, whereas the latter are preferred by Syrah, Zinfandel and Rousanne. Some growers in Alsace make a point of matching cultivars with the soil, for example Pinot Noir vines on more calcareous materials, and

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Auxerrois on heavier, clayey soils derived from volcanic rocks. Two roughly parallel faults define the chief vineyard area of Alsace, with subsidiary faults splaying and weaving in between. Hence, together with a series of criss-crossing other faults, the region's geology is divided into an unusually highly intricate patchwork. Consequently, in practice individual cultivars are grown on all kinds of ground; grand cru Riesling vineyards, for example, are found on a wide range of igneous, metamorphic, and sedimentary bedrock.

The soil differences across a fault undoubtedly have a role in the vines' growth, but many commentators believe that they also affect the character of the finished wines. Thus, according to one authority, Alsace Riesling wines from calcareous soils have power and complexity, and in some examples fruit and finesse, but where faulting has brought schist and granite to the vineyard the wines have a "discrete elegance and virility." In the Asnella vineyard in Portugal's Vinho Verde DOC, a fault has brought together two very different soil types, schist and granite. According to the producer, "the granite lends richness and weight, while the schist gives minerality, lift and precision." The faults in Nervi's Valferana vineyard in Italy's Gattinara DOCG (a UNESCO-listed Geopark) are claimed to give the soils an "extraordinary mineral content."

It is, though, seldom suggested how these soil variations actually lead to differences in the wines. Usually it seems to be taken as somehow self-evident that it is the geology that is responsible, and other possible factors are simply ignored. However, along with the differences in the soil there will also be changes in matters such as the aerial and ground microbiology and the whole range of factors that we lump together as mesoclimate. And these are known to affect grape ripening and hence the development of precursor flavor compounds—the trouble is, they can't be seen! It's tempting when glancing at a vineyard just to overlook such things or to assume they are constant across the site, but where the time, effort, and expense has been put in to collect the relevant data, there have invariably been surprising variations.

New technologies have begun to simplify microbiological investigation and the miniaturized sensors and data loggers that have recently become available are enabling mesoclimatic factors to be measured relatively easily and with unprecedent precision. For example, scientists have recently documented—within single vineyards and at a scale less than 80ft (25m)—unexpectedly fine and complex variations in air circulation, humidity, solar intensity, and temperature, in places such as St-Emilion/Pomerol, New Zealand's Marlborough, the Columbia Basin of Washington and Oregon, and Urlați, Huși, and Bucium in Romania. So, perhaps it isn't the differing geology that faults are juxtaposing in vineyards that is primarily responsible for wine differences but other factors that arise from it.

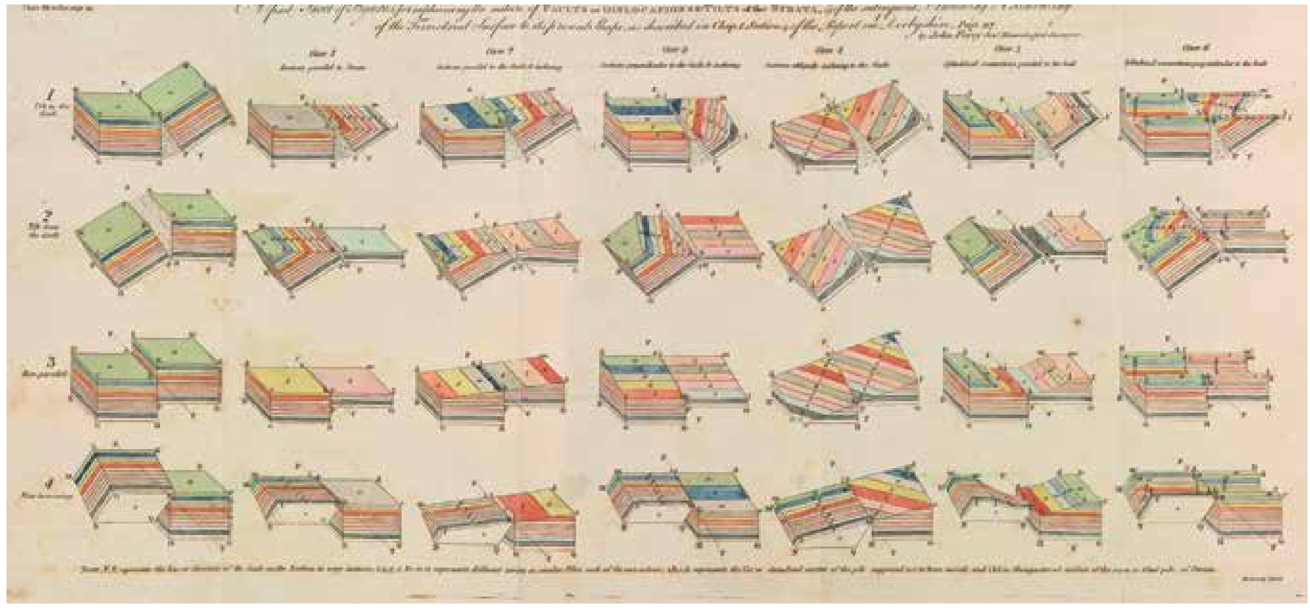

Diagram from John Farey, *A General View of the Agriculture and Minerals of Derbyshire*, 3 volumes 1811–17. Peak District Mines Historical Society, 1989. Reprint of 1811 Edition

Oregon's Klamath-Coastal fault runs right through the Fault Line vineyard, the south-facing slope of the Abacela winery in the Umpqua Valley. It gives marked variations in soil types over small areas, with corresponding changes in the wines. Such wine differences would normally be taken to reflect the geological variations, but in this case, the scientific bent of the owners prompted them to check out the mesoclimate. They installed automated sensors at 23 sites within the vineyard and data was collected every 15 minutes—for five years. The results were surprising. There were marked variations in solar radiation, and temperatures in the ripening period varied by nearly 9°F (5°C), giving a variability of 375 growing degree days *within this single vineyard*. All this, the owners suggested, explains why 16 different European cultivars can be ripened at various places within this single site. They summarized their data with a list of the factors most important in influencing their vines and the way the grapes ripened, and only in the lower part of the list are the soil differences mentioned.

Shaping the land

Whether or not differences in the soils directly affect wine character, faults can have a repercussion fundamental to many vine-growing regions. For the rocks either side of the fault can have contrasting durabilities—different resistances to weathering and erosion—and this can have a profound effect on the landscape. One situation is where the more resistant rocks make higher land and vice versa, with the slopes separating the two, a fault escarpment on the regional scale, providing prime sites for vine growing.

The classic example of this is the Côte d'Or, the revered slopes within the Saône fault zone that separates the Hautes Côtes and high plateaux to the west from the easterly down-dropped valley now occupied by the Saône river. But there are many other examples around the world. The stepped slopes of vineyard sites around Woodside and Lobetha, in Australia's Adelaide Hills, result from a series of faults uplifting the Mount Lofty Ranges to the east from the coastal plains to the west.

Previous spread: The Santa Cruz Mountains in California, on the San Andreas Fault.
Above: John Farey's 1811 diagrams showing different strata as displaced by faults.

The faults continue southwards, to form the eastern boundary of McLaren Vale. The Willunga Fault dominates here, and occasionally produces minor earth tremors.

Vineyards are dotted along the Darling Scarp in Western Australia, which forms a distinct dividing line between the Perth Hills wine region on top of the escarpment, and the Swan District to the west below. The escarpment is primarily due to the major Darling Fault system, which extends for at least 930 miles (1,500km) from the south coast near the Pemberton wine region north to Sharks Bay (famous for its stromatolites, living equivalents of fossils over 3.5 billion years old). The Darling Fault itself is several hundred million years old, such that through time the escarpment has been eroded eastwards by about 9 miles (15 km) from its initial position.

In Texas, USA, the Balcones Fault system curves from the Mexico border north-eastwards to Dallas and has brought the tougher rocks that make the Texas Hill Country AVA next to the softer rocks that underlie the coastal plains. In places it gives a pronounced, hilly escarpment used for viticulture, such as in the San Antonio-Austin-Waco line of wineries. And incidentally, that fault systems affect the flow of water in the ground is illustrated by some of the names along the Balcones escarpment, such as San Pedro Springs, Comal Springs, San Marcos Springs, Barton Springs, Salado Springs, and so on.

Another situation is where vineyards are located in valleys that are at least partly due to faults. In some cases, the valley is the result of erosion following the fault zone itself, picking on rocks weakened by breakage. One example of this is the Breede River Valley, South Africa's most prolific producing region, with summers that are arid and hot. Hence much of the wine is used for brandy. However, fine wines are made toward the southeast, where cooler, moist air can channel up the valley from the Indian Ocean. The reason for this valley being here? It's the result of erosion by the Breede River along the Worcester Fault system, which extends southeastward from the Watervalberge west of Wolseley, through Worcester and Robertson, to Swellendam and beyond. It first formed nearly 200 million years ago but has moved the rocks intermittently ever since. Vineyard workers felt tremors at Ceres in 1969, and again near Worcester in 2010.

Above: Breede River Valley, South Africa, formed by erosion along the fault zone itself. Next spread: The San Andreas Fault from the 2000 Shuttle Radar Topography Mission.

In other cases, faults have brought a strip of softer rocks next to harder rocks that now make upland areas bordering a valley. The eastern flanks of the Hood River valley, Oregon, in the Columbia Gorge AVA, are defined by the north-south Hood River fault, which has displaced the upstanding rocks to the east by over 2,000ft (600m). Vineyards near to the escarpment gain some protection from the famous winds funneling down the Columbia Gorge, one of the windiest places in the northwest USA and a mecca for windsurfing.

The northeastern border of Australia's Barossa Valley is defined by the Stockwell fault. Around 65 million years ago, and again at later times, tough, old rocks were uplifted to the east of the fault to make the Barossa Ranges while subsidence on the western side allowed sediments to accumulate. These yielded soils with greater water-holding capacity and potential rooting depth than those to the east of the fault, no small reason why in the hot, dry climate of the valley, ungrafted, unirrigated vines have been able to survive, in some cases for for over a century.

The west coast of New Zealand's South Island parallels a major fracture called the Alpine Fault and toward the north it splays into a number of sub-faults. And they have a lot to do with defining the landscape of the wine districts there. One strand defines the eastern extent of the Nelson wine region, in Marlborough one fork has given rise to the Awatere Valley, and a more northerly splay—the Wairau Fault—runs through Renwick and Blenheim to form the Wairau Valley. The Wairau River, engorged with clay from mountain glaciers, follows this Wairau Fault down to the coast, where the sea has eroded the weakened rocks to form a marked bay. When Captain James Cook moored there in 1770 he decided to name it after the muddy waters brought there by the river. He called it Cloudy Bay.

Earthquakes

In recent years earthquakes have taken on a new relevance to viticulture, with the series of tremors that has damaged vineyards and winery installations in several parts of the world. The phenomenon has, of course, been known since ancient times, though understanding that earthquakes are related to movement along geological faults was to be a very long time coming. In fact, despite centuries of pondering in the Old World, it fell to the United States—including wine-producing areas of California—to make some crucial contributions.

For millennia, many people assumed that earthquakes were marking the wrath of a god—divine anger over whatever happened to be seen as the heresy of the moment (a belief, it has to be said, that is still with us in some quarters). Other folk followed Aristotle, for whom earthquakes meant that a living, flatulent Earth was breaking "intestinal wind." (Though Shakespeare appears not to have been impressed by this idea, having Hotspur in *Henry IV Part 1* say mockingly: "Diseased nature often times breaks forth in strange eruptions; oft the teeming earth is with a kind of colic pinch'd and vex'd. By the imprisoning of unruly wind within her womb, which, for enlargement striving, shakes the old beldame earth and topples down steeples and mossgrown towers.")

Naturally, modern geologists had to reject such irrational causes, but they were stuck for a reasoned alternative. Because earthquakes affect a wide area, to many early scientists it seemed that the atmosphere had to be involved somehow. People talked of "earthquake weather," though it was unclear what this was. In literature, Winnie-the-Pooh saw Tigger hiding "because Eeyore said that nice weather like this is earthquake weather!.... Hundred-Acre Wood might have an earthquake today! I'm staying here until it's over!" One or two early scientists did come tantalizingly close, though, to making a fault-earthquake connection. In 1760, for instance, the Englishman John Michell argued that earthquakes must travel through the solid Earth as physical waves, and he included in his discussion a diagram of faulted rocks—while making no explicit link.

Knowledge was to improve when the Scotsman James Forbes—after whom the Aiguille Forbes, above Chamonix, and the Forbes Glacier and Forbes River in New Zealand are

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named—demonstrated in 1841 a mechanical device for measuring earthquake waves. The instrument was named (by another worker, John Milne) a "seismometer." It was the first usage of a "seismo-" word in English. Derived from the Greek word for shaking, this prefix is now standard for many terms to do with earthquakes, and it's a further example (together, incidentally, with aftershock and epicenter) of fault/earthquake words that have entered the public domain. For instance, "In a seismic shift in US policy, President Trump..."

Then, in the later 19th century the spotlight swung to the USA. One night in March 1872, John Muir was sleeping in his cabin in the Yosemite Valley and awoke to a series of "shocks so violent and varied" that he ran outside, "both glad and frightened, shouting, A noble earthquake!". He had experienced what is now called the Owens Valley earthquake, by some accounts the largest in US history. Muir noted later that, "After the ground began to calm I ran across the meadow to the river to see in what direction it was flowing and was glad to find that down the Valley was still down."

Grove Karl Gilbert, the first Senior Geologist of the fledgling US Geological Survey, noted that fault escarpments had been produced during this Owens Valley earthquake and began to regard these little faults as integral to the earthquake and not just a side effect. Similar ideas were developing in Japan, but without much international recognition; in the West it was the 1906 San Francisco earthquake that finally nailed it.

Following that event, Gilbert visited Marin County, north of San Francisco Bay, and in places like Paradise Valley carefully documented a range of newly formed features. His photographs can be viewed at web.archive.org. Crucially, he argued compellingly that all these effects and the great earthquake were intimately related. Then another member of the official team tasked with analyzing the earthquake, Harry Reid, took Gilbert's work one step further. He demonstrated mathematically that the earthquake was the result of the stresses accumulating within the ground over many years and then suddenly rupturing along the faults, abruptly discharging the stored-up energy. Thus Paradise Valley, just west of the North Coast AVA and now a key producer of organic food for San Francisco's restaurants, was pivotal in establishing our modern understanding of earthquakes.

Thirty years later, the US contribution was extended further, when Charles Richter devised in California a scheme for comparing the magnitude of earthquakes. And from it, seismology was to provide yet another technical term that has become familiar—as in "buying Clos des Lambrays doesn't really register on the wine investment Richter scale"; the "Jacques Selosse Brut Rosé is off the Richter scale for rarity, depth, and supreme enjoyment"; and "the reverberative finishing intensity of Raveneau's Les Clos needs to be measured on the Richter scale."

The final official report on the 1906 earthquake demonstrated that the San Andreas Fault (although its existence had been known since 1895) was still active. In other words, stresses are continually building up along the fault until it gives at its weakest point at that time. In 1906 that point was just west of the Golden Gate Bridge, where the fault trace lies out to sea. Then, rather like throwing a pebble into water, from that central point the released energy had spread out underground in a series of seismic waves across California. And from that final report, three other surprising things emerged.

First, it was possible to continue the trace of the fault southward away from the San Francisco area all the way to the Mexico border and beyond. So, this was indeed a major structure in the Earth's crust! Second, an astonishing 296 miles (477km) of the fault had ruptured to trigger the earthquake.

In Chile, the San Ramón fault runs north-south to the east of Santiago. It separates, for example, the Maipo and Cachapoal wine regions from the Andes to the east. The 2010 earthquake that caused so much damage to wineries and vineyards was centered on the inter-plate fault itself, just offshore from the Maule wine district

The failure stretched from Cape Mendocino in the north (where now it approximately coincides with the western border of the Mendocino Ridge AVA), to near San Juan Batista in the south, where it makes the northeast boundary of the Monterey AVA. (You can view maps and contemporary photos at https://earthquake.usgs.gov/earthquakes/events/1906calif/.) Third, virtually all the numerous horizontal offsets, when viewed by looking across the fault to the other side, are a move to the right. This fits exactly with our modern understanding: The San Andreas Fault is the junction of two tectonic plates, with the region to the northeast being the southeast-moving North American Plate and, slipping past it toward the northwest, the Pacific Plate. Each little crack is replicating in miniature the movement of these tectonic plates.

An analogous situation occurs with New Zealand's Alpine Fault, which we now know is caused by the Australian Plate moving northeastwards, to the right looking across the fault, past the Pacific Plate to the southeast. Several of the sub-faults that form the Marlborough fault system shifted in November 2016, giving the second largest earthquake ever recorded in New Zealand. Considerable damage was done to vineyards and wineries; more than 1,000 storage tanks were damaged and one estimate had wine being spilled that could have filled over 5 million bottles.

One of the world's most seismically active countries is Chile, its very shape being defined by faults splaying off the north-south junction between the Nazca and South American tectonic plates. Here, however, the plates aren't rubbing past each other sideways, as in the San Andreas and much of New Zealand's Alpine fault, but the oceanic Nazca plate is driving at a shallow angle down beneath the continental plate which is thrusting over it. It's this arrangement, common around much of the Pacific Ocean, that produces the world's biggest earthquakes: In Chile eight major events took place during the 20th century alone, including the largest earthquake ever recorded anywhere, the 1960 event centred on Lumaco, in the Malleco wine region. The fault rupture that generated that earthquake was around 620 miles (1,000km) long, almost equivalent to the entire length of the San Andreas Fault! Major faults splay upward off this plate junction, such as the San Ramón fault which runs north-south to the east of Santiago. It separates, for example, the Maipo and Cachapoal wine regions from the Andes to the east. The 2010 event that caused so much damage to wineries and vineyards was centered on the inter-plate fault itself, just offshore from the Maule wine district.

In the latter part of the 20th century, seismologists put in much effort in trying to find a way of predicting earthquakes. It proved elusive though, at least in constraining the timing sufficiently to be practically useful, say in advising the evacuation of an area. So, the spotlight has swung to earthquake "preparedness", such as engineering structures to resist the tremors and by educating the populace in how best to respond. In the light of earthquake damage in recent years in such important viticultural areas as Napa, Marlborough and central Chile this thinking is being reflected in the wine world.

Winery buildings are now being "seismically retrofitted", such as by stiffening them with steel frames but with flexible linkage to a robust base pad. Storage systems, a principal source of winery losses in the recent events, are being rethought. For example, the traditional stacking of barrels in free-standing pairs up to six levels high is being replaced by the broader base offered by four or even six barrels side-by-side, held in interlocking rigid frameworks strapped to walls and ceilings. Some designs have the framework sitting on ball-bearings in order to ride with the earthquake rather than topple over. A lot of attention has been given to the design and construction of storage tanks; after all, a rocking tank with 10,000 US gallons (40,000 liters) of wine sloshing around in it is potentially a very dangerous weapon! Cellar workers are instructed in procedures such as immediately shutting off power and water, and sheltering beneath some robust support within the building. There has even been talk of installing "shark cages," heavy-duty steel cages where workers can take refuge if bottles and barrels start flying around.

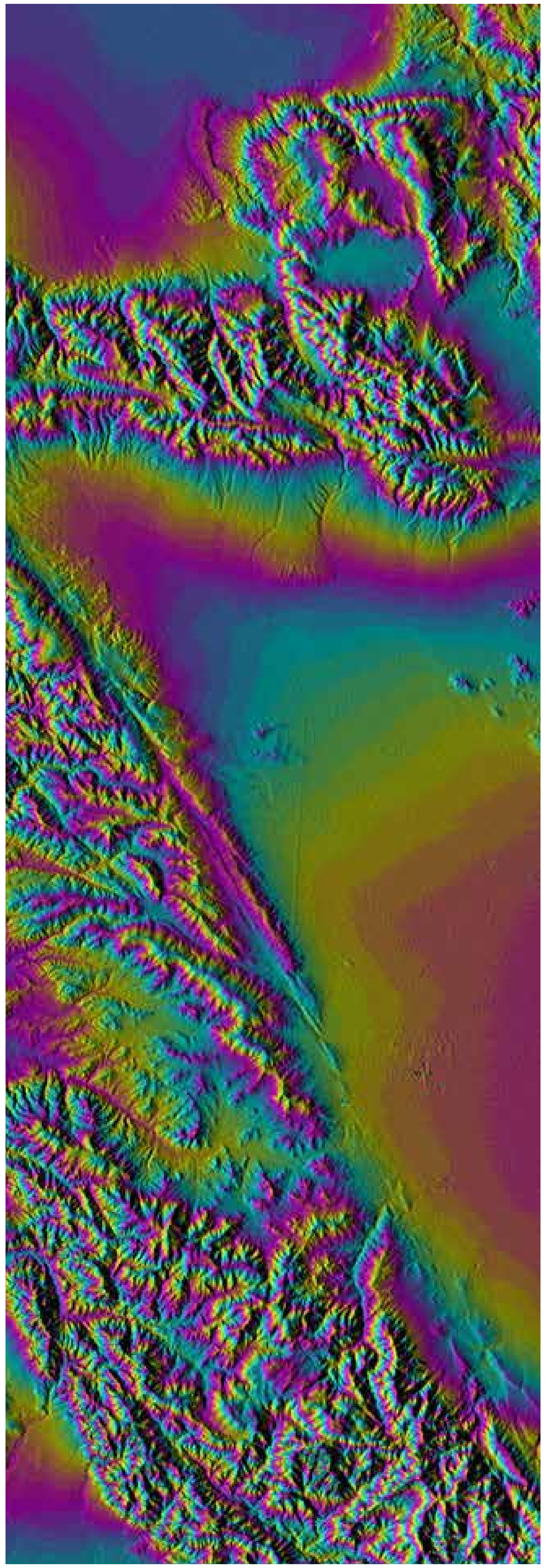
The San Andreas Fault today

The fishing village of Anstruther on Scotland's east coast is well used to loss of life in North Sea storms, together with the expectation that sons will follow in a family's tradition of going to sea no matter what. So, when young Andrew Lawson's father was shipwrecked, his mother decided that, rather than have her son exposed to such risks, she would leave Anstruther altogether and emigrate. Little did she know that Andrew was to become one of the University of California's first Geology professors and, among a host of other things, would discover a geological feature that he named the San Andreas Fault.

The fault, surely now one of the best known of all geological phenomena, runs from the Salton Trough on the California-Mexico border, northwards up to Point Arena, on the Pacific Coast west of Anderson Valley and Ukiah, from where it heads out to sea. It has numerous splays along its length, but especially so in the San Francisco Bay area and to the north, around Sonoma and Napa. One example is the West Napa Fault which more or less defines the west edge of the Napa Valley; it was renewed slip along this structure that triggered the damaging Napa earthquake of August 2014.

Most of the San Andreas Fault's course is characterized by valleys, but in places tougher bedrock gives localized hills. The foggy, coastal hills of the Sonoma Coast AVA, for example, are cut right through by the main fault, very close to wineries such as Hirsch, Seaview and Flowers. Consequently the Hirsch vineyards, according to the proprietors, has a "fearsome diversity of soils, aspects, elevations and microclimates"; the "degree of fragmentation is unmatched even by the famously subdivided vineyards of Burgundy's Côte de Nuits". The winery's signature Pinot Noir is labeled San Andreas Fault. The Flowers winery claims that the pulverized bedrock gives

Photography © NASA/JPL/NIMA



"incredible diversity" to its soils, and leads to low-yielding vines and small grape clusters "with great concentration".

The main fault also cuts through the Santa Cruz Mountains; the parking area and tasting room at the Savannah-Chanelle winery, built a mere six years after the 1906 earthquake, are located right on the structure. Nearby streamlets still show offsets from the faulting, once again towards the right. Three miles (5km) to the northwest is the noted Ridge Winery where, just to the west and located on the fault itself, is the conservation area of Monte Bello, a name well known to lovers of Ridge wines.

DeRose Vineyards, south of Hollister, is also sited right on the San Andreas Fault. A crack in the winery's main building runs through the warehouse between the fermentation tanks and the aging barrels, and continues to move about half an inch (1cm) each year. Some of the damage can be seen at https://www.wsj.com/articles/SB125936328750267155. Notice in the video the displacement of the floor tiles and a drainage ditch—once again toward the right!

Farther south along the fault sits the little settlement of Parkfield, northeast of Paso Robles. It's also right on the San Andreas Fault: drivers entering the village (population 18) from the west see a road sign that reads "Now entering the North American Plate" and cross a kinked bridge that straddles the fault. (On crossing the bridge in the other direction, another road sign says "Now entering the Pacific Plate.") Between 1857 and 1966 Parkfield was shaken approximately every 22 years and so an array of sensors was installed in order to closely monitor the expected 1988 event. The earthquake duly came—in 2003, 15 years late! It damaged irrigation pipes in the Parkfield Vineyard, toppled cases of wine, and plainly illustrated our inability to predict earthquakes.

However, apart from this continuing challenge of predicting the timing of earthquakes, these days the San Andreas Fault is reasonably well understood. Indeed, our knowledge of faults and earthquakes in general is pretty sophisticated. Well, it is in science. It seems, though, that some folks prefer that it all remains veiled in mystique. For instance, I read that the 1906 San Francisco event was partly due to its astrology (♈ 06°05´ ☽♎ 22°59´ Asc. ♑ 25°07´). Paul Giamatti's character in the much-loved film *Sideways* may have known his Pinot Noirs and his Santa Rita wineries, but in the film *San Andreas* his scientist studying earthquake prediction doesn't seem to have known much about earthquake prediction. In the film he makes various implausible pronouncements, based on measuring things unknown to seismology. But then, misconceptions are common: California isn't going to fall into the ocean; earthquakes don't create chasms that swallow things; faults don't radiate mysterious paranormal energies; and so on.

The wine world is not immune: "The energy of the fault permeates everything; it gives the wine its tension"; "his Côtes du Rhône vineyard is run cosmologically... rebalancing cosmic and telluric forces like acupuncture, at the active points of an underground fault"; "the vines benefit from intense energies emanating from the vortex pole south of Sedona down through Oak Tree Canyon along a subterranean geologic fault." It has been a long road from celestial wrath, intestinal winds, earthquake weather, and the like to the scientific understanding we have today about faults and earthquakes, but it seems that not everyone is making the journey. ■