

impressive study on Siberian loess formation including analysis of wind direction). The rest investigate deformation recorded in sedimentary rocks, and thus should be placed in one of the last sections.

The next section on *Igneous Fabrics* is quite humbling for the method. While the study by Petronis et al. concludes that magnetic fabrics are parallel to emplacement directions in a lacolith, the other 3 papers suggest that magnetic fabrics in igneous rocks are, at best, complicated functions of flow direction, mineralogy, and boundary conditions. In contrast, the fourth section on *Tectonic Fabrics* (6 papers) includes several successful studies for magnetic methods. I would like to highlight the paper by Chadima et al. who compare neutron goniometry to low and high field magnetic fabrics on deformed Bohemian metasediments.

The last section, on *Complex Fabrics, Superposition and Alteration* has 4 papers revealing difficulties in magnetic methods on rocks with rich geological histories. A particularly impressive work (De Wall and Warr) used heat treatment on the rocks to oxidize siderite in order to the more magnetic magnetite to make better measurements. They applied a paleomagnetic tilt test to the magnetic fabrics to establish the relative timing of diagenesis and deformation.

The book includes most of the significant members of the magnetic fabric community. Two authors stand out in the collection: František Hrouda with four papers, and Graham Borradaile with three. They have been leaders over the recent decades, and it is good to see them properly represented here. I am sorry not to see a paper by Ken Kodama or his colleagues who have been working on magnetic fabrics and the deflection of magnetic remanence (e.g. inclination shallowing) which has an important application to paleomagnetic studies.

This Geological Society Special Publication is a substantial book, much larger than their typical 200 to 400 pages. While it may be too expensive for individuals to purchase, it should be included in all earth science library collections. Researchers in all fields concerned with rock fabric and deformation will find it useful.

## Fine Wine and Terroir: The Geoscience Perspective

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There is an apocryphal story that many readers may have heard, about the geology student (sometimes a geochemist) whose summer project involved catching lake trout so their livers could be collected for geochemical analysis. Regardless of the feasibility of this method for identifying exploration targets, or of whether or not one enjoys angling, the implication is clear – nice work, if you can get it. A similar sentiment arises when admiring photographs of the sunny climes and spectacular scenery that provide the backdrop for diverse studies of world viticultural regions presented in *Fine Wine and Terroir: The Geoscience Perspective*. Certainly, the element of humour is not lost on some of the authors, who, for example, may point out that wine samples from studied vineyards were tested to fully understand the meaning of terroir, and that “some samples required repeated evaluation” (Meinert and Busacca, p. 51). I have a suspicion that my declared fondness for wine led to my being asked by a certain *Geoscience Canada* co-editor to pen this review. Be that as it may, it has led to an appreciation of the vine-growing/wine-making science (art?) at a whole different level, and one might say that I have become a terroir-ist. But for the uninitiated, an explanation of what is meant by terroir is in order.

The term “terroir” has its origin in Burgundy, and has no precise English translation, or, stated differently, a translation may potentially run to several sentences. It encompasses all aspects of the physical environment of

vine cultivation underlying and shaping the character and quality of the wine including meteorological, physiographic, pedological, geological and (often) viticultural controls. The significance of terroir may be understood by the simple occurrence of two adjacent vineyards that share most aspects of physical environment and viticulture, but produce very different wines. A corollary is that any given terroir may vary in quality from, say, a warm dry year to a cool wet year, where vineyard A produces better wine under the former conditions, and vineyard B better wine under the latter conditions. Outside of France, the concept of terroir is commonly misrepresented or misunderstood, and geologic and physiographic considerations may be ignored. In France, no such confusion exists, the French having had thousands of years of hands-on viticultural experience in matching particular grape varieties with specific settings. In one of the subdistricts of Burgundy, for example, *vignerons* have known for hundreds of years where the vineyards that produce top-quality wines should be located; it is only recently that geologists have shown that, in this instance, the borders of vineyard designations correspond almost exactly with stratigraphic boundaries. As testament to the importance attached to the subsoil/bedrock, the French Appellation Laws of 1935 protect the quality of winemaking regions under the auspices of L’Institut National des Appellations d’Origine, whose team of six scholars includes two geologists.

*Fine Wine and Terroir* is a collection of seventeen papers and two short “overview” articles; thirteen of these have previously been published in *Geoscience Canada* as part of the “Geology and Wine” series, whereas the remaining six are taken from the Simon J. Haynes special session, held at the GSA annual meeting in Seattle, in 2003. Simon Haynes is widely considered to be the godfather of terroir studies, at least on this continent, and the book is dedicated to the former Brock University Earth Sciences Department professor, who served as founding editor of the “*Geology and Wine*” series until his death in 2002. Seven papers describe the terroir of specific grape-growing districts, includ-

ing Ontario (Niagara Peninsula), Washington (Walla Walla and Red Mountain), Idaho (Snake River plain), California (Napa Valley), South Africa (western Cape Province) and Italy (two selected areas). Aside from two papers explaining the history and meaning of terroir, the remainder generally deal with thematic studies of specific aspects of terroir, or with means of processing the diverse, inter-related terroir components to generate “suitability” maps for guiding future vineyard development in particular areas.

Focusing on any single factor will not reveal the difference between an average and an exceptional wine. Hence, terroir designations, especially at local scales, require exploration of the permutations and combinations possible when coping with multiple varieties of grape and changing physical environments. To quote Meinert and Busacca once more, “This is not to say that any one component is *insignificant*, but...that no one factor is *transcendent*” (p. 39), and “What remains to be done ...is to examine the relationship between specific physical factors...and the quality of wine produced from individual vineyards” (p. 50). Several papers set out to address this problem. Taylor et al. conclude that trace-element concentrations in wine can be correlated with vineyard of origin, and can be traced, at least in part, to bedrock geology, although the influence of wine processing methods also plays a role. Similarly, Greenough et al. use discriminant analysis to show that trace-element “fingerprints” of wine from five regions across Canada are predominantly related to region of origin (along with wine colour). In this case, trace-element solubility and concentration are attributed to variations in climate. Eggers et al. perform a statistical analysis of the concentration of 31 organic volatile compounds to demonstrate that fermentation and processing factors constitute a strong overprint on geographical variations. The implied goal of such quantitative studies is to establish a link between chemical compositions and the *sensory* characters that come together to make fine wine (e.g. flavour, aroma, texture, etc). Because of the dynamic interplay of so many other factors, however, such a formula seems likely to remain

elusive.

A different approach is taken by Jones et al., who mapped terroir potential by spatial analysis of several of the major terroir components (e.g. climate, soil, physiography) using GIS software to produce suitability maps for each component. Similarly, a GIS was used by Bowen et al. in comparing patterns of varieties planted with wine quality (as determined by medals received) to show significant differences in varietal suitability. The results of such studies point to potential for increased development and production in the former case, and for improvement in wine quality by fine-tuning varietal choices and viticultural methods in the latter case. The paper by Jones et al. explores the possible impacts of climate change on viticultural regions, pointing out that the best terroirs have narrow climatic windows and are therefore vulnerable. Although in some areas this may be beneficial because of longer growing seasons and less frost risk, global warming may alter wine quality in traditional viticultural regions, and different varieties may have to be planted. Geophysics may also contribute to terroir studies. Hubbard et al. used ground-penetrating radar to investigate the influence of small-scale soil variations and moisture content. Using different frequencies to penetrate to varying depths, a soil-water-content block diagram can be constructed, opening the way to a precision irrigation approach to vineyard development.

The editors have carefully alternated thematic studies and descriptions of individual terroirs, but it’s clear that the final product is a collection of stand-alone articles as opposed to a true textbook treatment. However, there should be no surprises as it is clearly identified as a reprint volume, and at a member price of just over \$37, the handsome, hardcover text is a reasonable value. The individual papers are amply illustrated with maps, figures, graphs, tables and photographs. They also feature a certain uniformity of style and structure, so the reader is assisted by an expectation of how an article will develop. As stated in the introduction, “what ties all the studies together is the application of science to better understand the physical environ-

ment that affects grape and wine quality”. To a geoscientist, it is somewhat satisfying to see the extension of geoscience principles into a “non-traditional” field. And, terroir studies may represent a largely untapped method of selling geological field work to students. The final paper in the book (Suthren et al.) describes a “terroir, wine, and geoscience” field school (in southern France no less), in which terroir is touted as a theme to “link aspects of regional and applied geology, introduce new geological field skills, and increase student engagement” [!]. In the words of the authors, “superb outcrop exposures and scenery, and excellent regional museums, as well as fine wines, make for instructive and memorable student experiences”. Of that I have no doubt. They did not have field schools like this when I went to university.