ON TEXTURE AND MICROSTRUCTURE

In a recent issue of *Elements* ("Frontiers in Textural and Microgeochemical Analysis"; v3n4), it is unclear if *texture* and *microstructure* have the same meaning. Nearly all known bodies of rock, including sedimentary and metamorphic rocks, consist of assemblies of crystals, and the shape, size, orientation, and spatial distribution of these crystals in small volumes of rock could be referred to as the *microstructure*. Moving down scale, we then have structure, microstructure, nanostructure, and crystal structure. The term *texture* could be dropped, or applied only to crystal orientation, as it is in metallurgy. Also, the word *crystal*, which was redefined 94 years ago, could be used more frequently in place of *grain*.

The papers in *Elements* present a helpful but unbalanced overview of progress in microstructural studies. Crystal shape is defined, but there is nothing on wedge-shaped plagioclase, dentritic magnetite, and exsolution microstructures. The emphasis is on crystal size, making use of an awkward diagram that masks the actual size measurements. Many readers would want to see the measurements, for example, in the form of a simple histogram. The histogram can then be readily transformed into a plot of crystals against time, assuming a constant growth rate. Little attention is given to the spatial distribution of crystals, and none at all to crystal orientation.

The new computer-assisted methods for studying crystal shape, size, and distribution, as described in *Elements* and elsewhere, form a major contribution. With regard to the interpretation of microstructural data, although natural crystallization is complex, guidance could more frequently be found in the classical theory of crystallization as covered by Christian (1975),[1] together with information on crystal structure and equilibrium phase relations.

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[1] Christian JW (1975) The Theory of Transformations in Metals and Alloys. Pergamon Press, Oxford

Response by Dougal Jerram, Jon Davidson, Bruce Marsh and Michael Higgins

As much as we deeply respect the seminal contributions by Prof. Kretz to this field, his comments reflect an awkward view of the current way in which texture is used in the Earth sciences. The *Concise Oxford Dictionary* (1991) defines rock texture as follows: 'In petrology, the sizes and shapes of particles in a rock and their mutual interrelationships'. A similar definition for texture is presented in the *Collins Dictionary of Geology* (2003): 'The general character and appearance of a rock as indicated by relationships between its component particles, specifically grain size and shape, degree of crystallinity and arrangement'. Texture is also widely used in textbooks, research books and research articles worldwide. Although some people prefer the term microstructure, it is not as clearly defined as texture. Indeed, it is not defined at all in the above dictionaries and is not used as commonly as texture in the Earth sciences. In the articles presented in the *Elements* issue, the meaning of the term texture was clearly defined in each case. *Elements* strives to provide articles that are accessible to a wide audience, and so the term texture has been used due to its common use and clear definitions in the literature.

In response to Professor Kretz's comments about the papers in the issue, we make the following points. Each paper examines a specific textural and/or microgeochemical technique, e.g. 3D imaging, kinetic modelling, microsampling, imaging crystal zoning, measuring timescales. These papers were specifically focused on some of the frontier techniques that are being used in *both* textural and microgeochemical studies in igneous petrology, and the articles presented examples of their uses to highlight their application. It was not the aim of *any* of the articles to provide a comprehensive overview of textural studies, and in the limited space available one cannot cover every possible example of the application of a technique, say 3D imaging of exsolution textures, especially when such examples currently are not available. And the suggested use of histograms, for example, is really a dead-end in terms of linking crystallization kinetics to modern continuum mechanics. In any case, a recent book has reviewed research on many aspects of texture, including crystal orientation and position (Higgins 2006); this book is referenced in the *Elements* issue should a keen reader wish to follow this up. In general, in the spirit of the ultimate intended educational goals of these papers, we have received worldwide praise for the issue from students and colleagues. We prefer to focus on the exciting methods which will help us move forward in our understanding of the way igneous textures (or microstructures if you prefer) form, and how these may be applied to processes.

Higgins MD (2006) Quantitative Textural Measurements in Igneous and Metamorphic Petrology. Cambridge University Press, Cambridge, UK

ABOUT GEOSCIENCE CURRICULA

Your editorial in *Elements* volume 3, number 6, by Principal Editor Bruce Watson, triggered remembrances and thoughts about my own education in the Earth sciences and how much things have changed. Thank you for so openly describing the situation and for your well-expressed opinions.

In 1940–1942 and 1946–1948, when I was a student at DePauw University in Greencastle, Indiana, E.R. 'Rock' Smith was head of the department. His rule was for his students to take only the minimum number of courses in geology/mineralogy, etc. (about 30 credits as I recall) and balance them with a combination of physics, chemistry, and mathematics courses. I even took a bacteriology course. At that time oil exploration was active and most geology graduates went to 'sit on wells' and study chips from the drilling using optical microscopy. I was offered a job with Aramco at $10,000 a year in 1948, but I chose to go to graduate school instead where the background recommended by Rock stood me in good stead, as it did in my career in industry after receiving a PhD from Penn State. This general background allowed me to contribute in solid-state chemistry—not as a physicist but as part of a team working with the more quantitative types. So we don't sit on wells much anymore, but the varied experiences in modern Earth science still require a general background of considerable depth as you emphasize.

I am much in empathy with your nostalgia for training with the optical microscope. This was very crucial for much of the research and development I did in industry—microstructural relationships, phase identification, optical properties, and morphology of ceramics and other solid-state materials. I think there's a real gap in Earth scientists' knowledge if they don't have an appreciation of what this simple, relatively cheap tool can do. Sure these modern, high-tech and high-resolution instruments are wonderful, but they can make it hard to see the forest for the trees. Advances in petrology depended on the optical microscope for a long, long time. Metallurgy and ore microscopy also relied heavily on optical studies of polished sections using reflected light. The diamond anvil cell has extended the use of the microscope to a certain extent.

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