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# Image analysis in mineralogy and petrology

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'Image analysis' refers to the general family of computational techniques which are concerned with the extracting of quantitative information from images captured in digital form. Such techniques have been in use for several years in areas such as biology and metallurgy, but have been slow to find wide use in the microscopic areas of Earth Sciences. Notable exceptions have included applications in the areas of mineral processing and sedimentary petrography.

The impetus for the meeting held jointly by the Applied Mineralogy Group of the Mineralogical Society and the Geological Information Group of the Geological Society of London in September 1993, was an attempt to take stock of the spread of digital image analysis techniques into the domain of the mineralogist and petrologist. Such techniques are spreading rapidly, spurred by the increasing power and falling cost of computers and related equipment such as video cameras and printers. Moreover, the adoption of graphical user interfaces such as Microsoft Windows® has brought on a generation of image analysis software packages that are easy and attractive to new users. Apart from its measurement ability, such software is used to control electron microscopes and other instruments, and to aid the development of electronic archives of images. With such potential and diversification, there is the inevitable need to take a broad view of development of applications in this field.

Perhaps a note of frustration should creep into the optimism. With such rapid improvements comes the feeling, also experienced when buying personal computers, that any system bought today will be outstripped by cheaper systems available tomorrow. Integrated image analysis systems from only three years ago are able to perform in a few seconds what was on the frontier of capability a decade ago, yet these comparative youngsters are now being replaced by packages that can be mounted on any PC of sufficiently high specification, at a much lower cost. A feature of this meeting was a welcome set of displays of new image analysis systems by the manufacturers.

The prospective user must ask whether a stand-alone image analyser is the solution, rather than have image analysis capability as an integral part of the electron-microscope or whatever other instrument produces the images in the first place. Application of image analysis to optical images suffers from inherent limitations arising from the problems of separating features of interest, such as mineral grain boundaries, from the flotsam of dust specks, cracks, twin boundaries and so on. With backscattered electron images or electron microprobe element-maps such artifacts are greatly reduced, or eliminated altogether, and are thus far easier to deal with.

A set of the papers presented at the meeting follows this introduction, but it is worthwhile first to consider the other presentations. Within the broad

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theme, the papers presented a variety of view points and areas of application. The opening paper by D. Sievewright (Imaging Associates) gave a manufacturer's view of where image analysis was going to develop both in terms of software usability, improved computing power and the performance of peripheral devices, notably video cameras. He stressed the importance of choosing a system suited to the user's needs, and of the importance of improved devices for image capture to raising the limits of what such systems can achieve. This talk was followed by an account of automated coal maceral and rank analysis by image analysis from N.J. Miles, E. Lester, M. Cloke and B.P. Atkin (Department of Mineral Resource Engineering, University of Nottingham), using a computer-driven XYZ motorised stage and grey-scale discrimination to carry out what is in effect a modal analysis of reflectance. As with many applications, the measurement itself is well established, but automation brings immense benefits of speed, lower operating cost and reduction in operator fatigue and subjectivity. P.J. Potts, A.G. Tindle and D. Stanford (Department of Earth Sciences and Department of Biology, The Open University) descibed the development of software which uses digitally scanned thin section images to map coordinates of analytical positions for electron-microprobe analysis, an example of making modest equipment work to lower costs and improve performance in microprobe work. Though precharacterization using optical microscopy was described, this approach lends itself to a variety of other mineralogical imaging techniques. A.H. Rankin and M. Westerman (School of Geological Science, Kingston University) described application of image analysis to measurment of phase proportions in fluid inclusions. The technique worked well for relatively large, flat inclusions, but unacceptably high errors were present for smaller or equant inclusions. New techniques for measurement of fluid inclusion clusters and planes were being developed.

After lunch, J.M. Le Cleac'h and L. Verger-Moutalib (École des Mines, Paris) described a novel method for understanding deformation of rock salt by combining digital images of etched crystal faces illuminated along three different directions. R.A. Herd and H. Pinkerton (Department of Environmental Sciences, Lancaster University) described image analysis applied to vesicularity of volcanic rocks in relation to theoretical phase growth. The results were used to develop a model of gas bubble coalescence, magmatic foam and degassing. M.A. Browne (Confocal Technologies Ltd.) described the applications and limitations of image analysis techniques to stereological measurement. Though presented from the developer's viewpoint, the paper outlined the direction in which this technique can be applied in petrography and mineral processing. The theme of particle characterization was taken up by J. Watt (Department of Geology, Royal School of Mines). This paper discussed the ways in which a stepwise process of microscopy, image analysis and interpretation are combined to construct a derived or synthetic image which can classify particles and reveal their composition and origin.

Posters included the following. D.J. Bland (Mineralogy and Petrology Group, British Geological Survey) described the processing of electron-microprobe microchemical maps to derive a multi-element analysis of fabric and modal proportions in altered basalt. N.M. Chikwo and P.G. Meredith (Department of Physics, Essex University, and Department of Geological Sciences, University College London) described use of computer techniques to determine stereological parameters and the morphology of rock fragments. M.B. Clennel, X. Leng, P. Smart, K.M. Brown, D.N. Dewhurst and G.K. Westbrook (Royal Holloway University of London) described digital image analysis for the measurement of grain fabric anisotropy, pore structure and directional permeability in clays. R.H. Hunter and others (Department of Earth Sciences, University of Liverpool) described the use of serial sectioning and grinding to achieve serial images for three dimensional reconstruction and analysis of rock fabrics. C. McDermott (Geochemistry Group, British Geological Survey) discussed a novel application of image analysis to the quantification of blast fragmentation in quarrying. Results compare well with laboratory sieving and were implemented at two open pit mines. E.R. Phillips and N.J. Fortey (Mineralogy and Petrology Group, British Geological Survey) described an application of image analysis to measurement of relative strain variation in a major shear zone.

Papers presented by L. Aillieres and M. Champenois (Cèntre de Recherches Pètrographiques et Géochimiques, Nancy), A.R.H. Swan and J.A. Garratt (School of Geological Science, Kingston University), N. Petford and J. Miller (Department of Earth Sciences, University of Liverpool and Department of Earth Science, University of Cambridge), D.N. Bryon, M.P. Atherton and R.H. Hunter (Department of Earth Sciences, University of Liverpool), M.R. Cooper and R.H. Hunter (Department of Earth Sciences, University of Liverpool), and P.J. Potts, A.G. Tindle and D. Stanford (Department of Earth Sciences and Department of Biology, The Open University) are included in the following set.