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Preface

In appreciation of John Christie

THIS special double issue of the *Journal of Structural Geology* honors John M. Christie on the occasion of his 60th birthday, for his many research contributions to the study of the ductile deformation of rocks and minerals in the laboratory and in the field. John has studied deformed rocks on all scales, but has also served as a congenial advisor, friend and colleague to many other scientists who have studied deformed rocks.

John Christie was born in Calcutta, India, on 4 December 1931. In 1935 his family returned to Dundee, Scotland, where he completed his secondary education in 1949. His university-level education was entirely at Edinburgh University, where he received his B.Sc. with honors in 1953 and his Ph.D in 1956. His doctoral thesis topic, completed under the guidance of Arthur Holmes, Donald McIntyre and Lionel Weiss, was a study of the tectonic history of the Moine thrust zone in the Assynt region of NW Scotland using the techniques of microfabric analysis newly developed by Frank Turner, Dave Griggs and others at the University of California. His thesis is now recognized as a classic study of a mid-crustal ductile shear zone. It was subsequently published as a University of California Monograph (Christie 1963). John has generously loaned samples from his Moine collection and knowledgably contributed to many more recent investigations of the Moine.

In 1956 John moved to California, where he joined the Department of Geology at Pomona College as a research and post-doctoral associate and later Instructor. In 1958 he accepted an Assistant Professorship with the Department of Geology at the University of California at Los Angeles and in 1959 began a 15-year partnership with David T. Griggs of the Institute of Geophysics and Planetary Physics. Griggs was then designing and building a new generation of rock deformation apparatuses with the pressure and temperature capability to explore for the first time the plastic deformation of many rock-forming silicates. John's knowledge of microstructures in naturally deformed rocks was invaluable in guiding and interpreting the subsequent experimental studies. He was also among the first in the geological sciences to apply the then-new materials-science concepts, such as the theory of crystal dislocations, to rock and mineral deformation. In the early 1960s, Neville Carter, Griggs and Christie made a major breakthrough in presenting the first unequivocal evidence for the plastic deformation of quartz in the laboratory (Christie, Griggs & Carter 1964). In partnership with Griggs and others, John contributed to a succession of similar achievements, including the first experimental syntectonic recrystallization of quartz (Carter, Christie & Griggs 1964), the first *T*ransmission *E*lectron *M*icroscopy (TEM) studies of dislocations in experimentally deformed silicates [such as olivine (Phakey, Dollinger & Christie 1972) and clinopyroxenes (Kirby & Christie 1977)], and the first application of X-ray texture goniometry to study preferred orientation development in naturally and experimentally deformed and recrystallized quartz aggregates. By the late 1960s, UCLA was the undisputed center for high-pressure experimental rock deformation and attracted a stream of graduate students and international visitors, all of whom undoubtedly remember the outstanding hospitality at the Christies' home.

John recognized very early the importance of TEM and invested many years advancing sample preparation techniques, such as ion-beam thinning, and demonstrating the power of the diffraction contrast theory of crystal defects. In the late 1960s, John collaborated with Art Heuer and his colleagues at Case Western University and the U.S. Steel Research Center using *H*igh-*V*oltage *E*lectron *M*icroscopy (HVEM) to decipher the histories of cooling and shock metamorphism of lunar rocks returned from the Apollo missions. This collaboration produced some 17 research papers through the mid-1970s. John also began about this time a collaboration with Alan Ardell, a materials scientist at UCLA. Together, they helped to demonstrate to mineralogists and experimentalists the capability of this instrument in the study of microstructures and crystal defects (e.g. Christie & Ardell 1974, 1976). The pages of the *Journal of Structural Geology*, including this issue, testify to the importance of TEM in the quantitative characterization of microstructures in deformed rocks and as a window on the deformation processes that produced them.

John also inspired many students and colleagues to apply what they learned from experimental and microstructural studies to the understanding of natural deformation of rocks and minerals. His classic paper with Clem Nelson, Gerhard Oertel and Art Sylvester (Sylvester *et al.* 1978) explaining the extreme syn-emplacement thinning of aureole rocks around the Papoose Flat pluton in the Inyo Mountains of eastern California was the first to invoke hydrolytic weakening as a facilitating mechanism for the natural plastic deformation of quartz. With Alison Ord (Christie & Ord 1980, Ord & Christie 1984), he applied what he had learned about the experimental recrystallization and plastic deformation of quartz to the interpretation of the physical conditions during mylonitization of several classic ductile shear zones, including the Moine.

This Special Issue *Microstructures and Rheology of Rocks and Rock-Forming Minerals* was initiated in celebration of John Christie's 60th birthday. The papers presented here are representative of the breadth of John's interests and expertise and his sense for the important problems and the tools to solve them. We dedicate this Special Issue to him with gratitude for his guidance and generosity over many years.

Selected key publications of John Christie

Baker, D. W., Wenk, H. R. & Christie, J. M. 1969. X-ray analysis of preferred orientation in fine-grained quartz aggregates. *J. Geol.* **77**, 144–172.

Bussod, G. Y. & Christie, J. M. 1991. Textural development and melt topology in spinel lherzolite experimentally deformed at hypersolidus conditions. *J. Petrol.* (*Lherzolites Special Issue*), 17–39.

Carter, N. L., Christie, J. M. & Griggs, D. T. 1964. Experimental deformation and recrystallization of quartz. *J. Geol.* **72**, 687–733.

Christie, J. M. 1963. The Moine Thrust Zone in the Assynt Region, northwest Scotland. *Univ. Calif. Publ. geol. Sci.* **40**, 345–440.

Christie, J. M. & Ardell, A. J. 1974. Substructures of deformation lamellae in quartz. *Geology* **2**, 405–408.

Christie, J. M. & Ardell, A. J. 1976. Deformation structures in minerals. In: *Electron Microscopy in Mineralogy* (edited by H.-R. Wenk *et al.*). Springer, New York, 372–403.

Christie, J. M., Griggs, D. T. & Carter, N. L. 1964. Experimental evidence of basal slip in quartz. *J. Geol.* **72**, 734–756.

Christie, J. M., Griggs, D. T., Heuer, A. H., Nord, Jr, G. L., Radcliffe, S. V., Lally, J. S. & Fisher, R. M. 1973. Electron petrography of Apollo 14 and 15 Breccias and shock-produced analogs. *Proc. 4th Lunar Sci. Conf.* **1** (*Geochim. cosmochim. Acta* Suppl. 4, 365–382).

Christie, J. M., Griggs, D. T., Lally, R. M., Heuer, A. H., Nord, Jr G. L. & Radcliffe, S. V. 1977. *The Moon Through the Microscope: A Selection of Lunar Micrographs.* NASA Report.

Christie, J. M., Heard, H. C. & LaMori, P. N. 1964. Experimental deformation of quartz single crystal at 27 to 30 kilobars confining pressure and 24°C. *Am. J. Sci.* **262**, 26–55.

Christie, J. M., Heuer, J. M., Radcliffe, S. V., Lally, J. S., Nord, G. L., Fisher, R. M. & Griggs, D. T. 1973. Lunar breccias: an electron petrographic study. In: *Lunar Science IV* (edited by Chamberlain, J. & Watkins, C.) 133–135.

Christie, J. M., Lally, J. S., Heuer, A. H., Fisher, R. M., Griggs, D. T. & Radcliffe, S. V. 1971. Comparative electron petrography of Apollo 11, Apollo 12, and terrestrial rocks. *Proc. 2nd Lunar Sci. Conf.* **1**, 69–89.

Christie, J. M. & Ord, A. 1980. Flow stress from microstructures of mylonites: Example and current assessment. *J. geophys. Res.* **85**, B11, 6253–6262.

Gratz, A. J., Nellis, W. J., Christie, J. M., Swegle, J. & Cordier, P. 1992. Shock metamorphism of quartz with initial temperatures. −170 to +1000°C. *Phys. Chem. Miner.* **19**, 267–288.

Hacker, B. R. & Christie, J. M. 1987. Brittle/ductile and plastic/cataclastic transitions in experimentally deformed amphibolite. *Am. Geophys. Un. Geophys. Monogr.* **56**, 127–147.

Hacker, B. R. & Christie, J. M. 1991. Observational evidence for a possible new diffusion path. *Science* **251**, 67–70.

Hacker, B. R., Yin, A. & Christie, J. M. 1992. Stress magnitude, strain rate and rheology of extended middle continental crust in the Whipple Mountains, California. *Tectonophysics* **11**, 36–46.

Kieffer, S. W., Phakey, P. P. & Christie, J. M. 1976. Shock processes in porous quartzite: Transmission electron microscopy observations and theory. *Contr. Miner. Petrol.* **59**, 41–93.

Kirby, S. H. & Christie, J. M. 1977. Mechanical twinning in diopside Ca (Mg, Fe) Si_2O_6: Structural mechanism and associated crystal defects. *Phys. Chem. Miner.* **1**, 137–163.

Koch, P. S., Christie, J. M., Ord, A. & George, R. P. 1989. Effect of water on the rheology of experimentally deformed quartzite. *J. geophys. Res.* **94**, 13,975–13,996.

McLaren, A. C., Retchford, J. A., Griggs, D. T. & Christie, J. M. 1967. Transmission electron microscopy study of Brazil twins and dislocations experimentally produced in natural quartz. *Phys. Stat. Sol.* **19**, 631–644.

Ord, A. & Christie, J. M. 1984. Flow stresses from microstructures in mylonitic quartzites of the Moine Thrust Zone. *J. Struct. Geol.* **6**, 639–654.

Phakey, P., Dollinger, G. & Christie, J. M. 1972. Transmission electron microscopy of experimentally deformed olivine crystals. In: *Flow and Fracture of Rocks* (edited by Heard, H. C. *et al.*). *Am. Geophys. Un. Geophys. Monogr.* **16**, 117–138.

Sylvester, A. G. & Christie, J. M. 1968. The origin of crossed-girdle orientations of optic axes in deformed quartzites. *J. Geol.* **76**, 571–580.

Sylvester, A. G., Oertel, G., Nelson, C. A. & Christie, J. M. 1978. Papoose Flat pluton: A granitic blister in the Inyo Mountains, California. *Bull. geol. Soc. Am.* **89**, 1205–1219.

Tullis, J. A., Christie, J. M. & Griggs, D. T. 1973. Microstructures and preferred orientations of experimentally deformed quartzites. *Bull. geol. Soc. Am.* **84**, 297–314.

Wegner, M. W. & Christie, J. M. 1974. Preferential chemical etching of terrestrial and lunar olivines. *Contr. Miner. Petrol.* **43**, 195–212.

Wegner, M. W. & Christie, J. M. 1983. Chemical etching of deformation substructures in quartz. *Phys. Chem. Miner.* **9**, 67–78.

Wenk, H.-R. & Christie, J. M. 1991. Comments on the interpretation of deformation textures in rocks. *J. Struct. Geol.* **13**, 1091–1110.

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