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and the Structural Geology of the Moine Petrofabric Controversy

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The Life of Frank Coles Phillips
(1902–1982) and the Structural Geology
of the Moine Petrofabric Controversy

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Preface

The English petrographer, mineralogist and structural petrologist Frank Coles Phillips is best known to mineralogists and geologists today for his now-classic textbooks *An Introduction to Crystallography* (1946) and *The Use of Stereographic Projection in Structural Geology* (1954); and to gemmologists for his major revision of Herbert Smith's *Gemstones* (1958). The adoption in Britain of the stereogram as a fundamental interpretational tool in structural geology owes much to the second of Phillips' books, and the development of structural geology in Australia was influenced by a lecture-tour which he undertook in 1953. A superb teacher, Phillips' main legacy lies in the students he trained and in the influence of his textbooks.

As a result of his fluency in German, by 1932 Phillips, by then a young lecturer in the Department of Mineralogy at Cambridge University, had taken up the new techniques, first advocated by the Austrian geologist Bruno Sander (1884–1979) in 1930, for the analysis of *Gefügekunde* (petrofabrics) of geological bodies; i.e. the interpretation of the three-dimensional fabric of rocks, based on the determination of the statistical distribution of the orientation of particular crystallographic axes of minerals such as quartz, muscovite and biotite, accomplished by means of the 'universal' microscope stage (the petrofabric method). In 1937, at a time when the interpretation of structural geology in Britain was largely a field-based, qualitative practice, Phillips published a pioneering study in which he applied Sander's quantitative methods in an attempt to unravel the complex structural history of the Moine rocks of NW Scotland. Much of Phillips' subsequent research focused on the application of the petrofabric method to the Moine, and later to the metamorphic rocks of SW England, doggedly following the rules for kinematic interpretation as laid down by Sander in the 1930s and later embodied in his cryptic and partly incomprehensible magnum opus *Einführung in die Gefügekunde der geologischen Körper* (*An Introduction to the Study of Fabrics of Geological Bodies*; 1948–50), eventually made available to a wider audience in a heroic English translation by Phillips, published in 1970.

Unfortunately, as time went on, suspicion began to grow amongst structural geologists that Sander's rules were both ambiguous and meaningless as regards the deformation of real rocks. Their application to the Moine, in which the 'girdles' defined by the orientation of the optic *c*-axes of the quartz crystals in the rock fabric, were found to lie in NNE–SSW planes, perpendicular to the common lineation, led Phillips to the conclusion that 'the *origin* of the linear structures is connected with folding due to movements along south-west to north-east lines, earlier than the post-Cambrian displacements . . . it is the lineation parallel to the *b*-axis of the fabric which has provided the direction of yield during the later thrust-movements,' a deduction rejected by his contemporaries as inconsistent with the NNE–SSW strike of the Moine rocks. This resulted in Moine petrofabrics becoming embroiled in a long-running controversy. Another principal conclusion of Phillips' work, which subsequently became rather overlooked in the disagreements which arose over movement direction in relation to petrofabric girdles, was his apparent demonstration that the Moine metasediments have a regional metamorphic fabric that pre-dated the Moine Thrust movements and was broken down in the Moine Thrust Zone – a view erroneously taken by H. H. Read as confirming his 1934 hypothesis that the Moines were Lewisian in age.

The present depth of understanding of multiple folding (a phenomenon which was unrecognized in 1937) and the complex relationships which can develop between folding, pre-existing lineations, and petrofabrics simply did not exist at the time that Phillips was undertaking his pioneering studies. The on-going controversy regarding the interpretation of Phillips' petrofabric

results was initially resolved by D. Flinn's demonstration in 1962 that neither fold axes nor axial planes necessarily indicate movement directions or the directions of flow in rocks, but the situation has only been completely resolved since the mid-1980s, as a result of four crucial findings.

- (1) Pre-thrusting structures (?Precambrian) have been discovered throughout the Moine rocks of the northern Highlands; these include an early bedding-parallel foliation and a weakly preserved north–south to NNE–SSW trending mineral lineation.
- (2) The examinations of deformed conglomerates and related fabric studies have convinced many geologists that both the regional WNW–ESE 'stretching' (extension) lineation and its associated quartz *c*-axis girdles, found by Phillips, result from the WNW-directed Caledonian movements which formed the Moine Thrust.
- (3) The widespread recognition of sheath folds in the Moine rocks has revealed that fold axes originally formed oblique to the WNW–ESE lineation have often been rotated into parallelism with this lineation during ductile deformation; the geometry and facing directions of the sheath folds and related flow perturbation folds are consistent with top-to-the-WNW-directed thrusting.
- (4) A continuity of structures has been recognized between (i) the cover rocks and the Lewisian basement, and (ii) the Moine Thrust Zone and the overlying Moine Nappe, which Phillips first recognized but did not interpret correctly.

In effect, therefore, Phillips was not entirely wrong but, as Flinn put it, 'right (to some extent) for the wrong reasons', largely because of Sander's confusion between the movement directions of externally applied forces and those of internal movements in response to the applied forces.

One of us (R. J. H.) was taught by Phillips (1960–1963), while the other was a colleague of his on the staff at the University of Bristol for ten years (1957–1967). Our critical review of Phillips' research is set in the context of contemporaneous developments in structural and Moine geology. It was promoted by the lack of any obituary notice, or account of his scientific work, by either the Mineralogical Society or The Geological Society of London. It is unfortunate that he died at a time when obituary notices no longer appeared in the *Proceedings of The Geological Society* and before their present system of including them in the *Annual Report* began.

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