

## The Lewisian: Britain's Oldest Rocks

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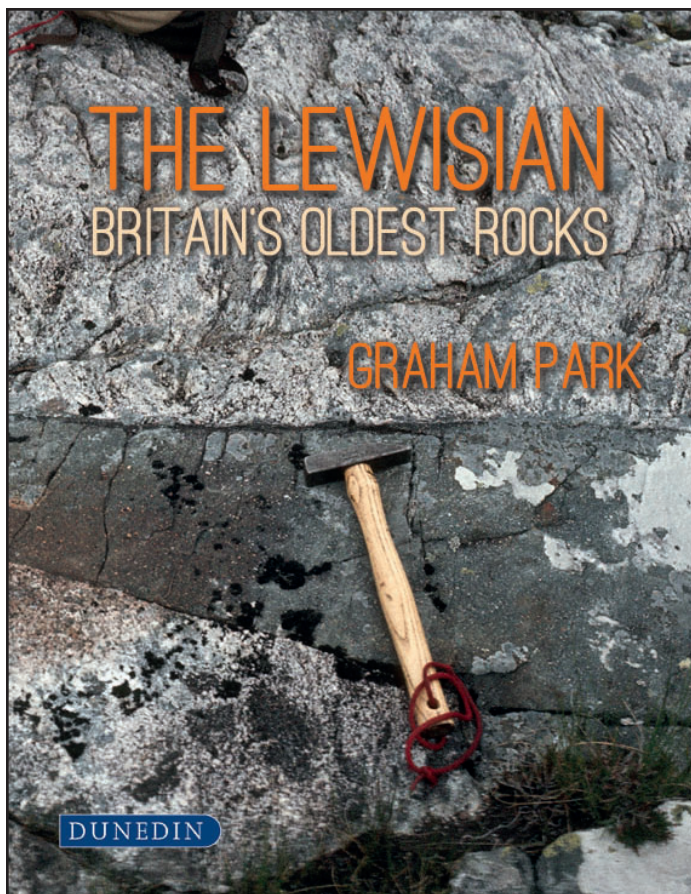
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# REVIEW



## The Lewisian: Britain's Oldest Rocks

Graham Park

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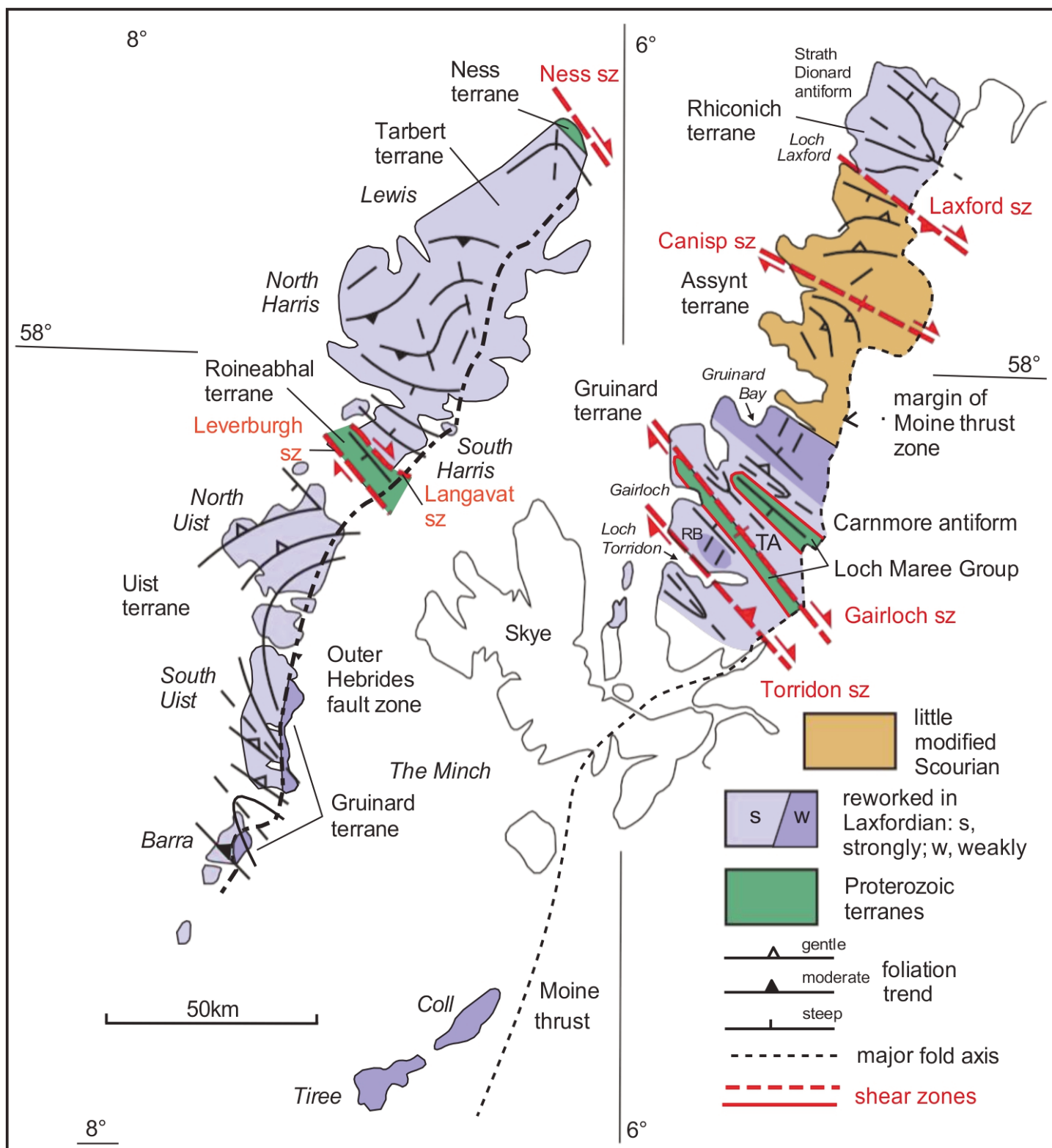
### THE BOOK – A GENERAL OVERVIEW

I must begin this commentary on Dr. Graham Park's splendid historical and geological tome "*The Lewisian: Britain's Oldest*

*Rocks*" by confessing that I have had limited first-hand exposure to the rocks about which he writes so passionately and with such deep insight. I am certainly not 'learned' about the Lewisian when compared to Dr. Park, so I must deflect any specific critiques of his opinions and observations to those more intellectually well-equipped to do so. Nevertheless, I have seen and walked over some of these Precambrian rocks during several field trips in Scotland associated with thematic conferences, in one case in the company of Dr. Park. Furthermore, one such excursion, when I was a graduate student in the mid-1970s, was led by the much-admired Janet Watson, whose name is inextricably linked to these rocks. I have maintained a peripheral interest in Lewisian research for a half-century and amassed a fair collection of Lewisian-related serial literature.

Dr. Park's book is, in my opinion, an excellent review of the impressive, two-hundred-plus-year history of study of the Lewisian rocks (Fig. 1). Researchers and students know that it is customary to review 'Previous Work' in any publication, and this superb monograph is a particularly complete and detailed example of such an overview for an influential collection of puzzling Precambrian rocks. For anyone with a bent towards historical geological treatises, this book should give many hours of pleasurable reading. The back cover summary states that it has been compiled in a "user-friendly form" for the geological fraternity and for "academics" desirous of broadening their knowledge of noteworthy "advances in earth science". As such, it will not appeal to a universal audience and would challenge geologists who lack any background in Precambrian geology, structure and metamorphism. The inclusion of a glossary aids, to some extent, to clarify terminology, but even some specialists may have their capacity to absorb details stymied by discussions of geochemical and isotopic data presented in the latter part of the book (chapters 16 to 18, see below). Nonetheless, for well-informed readers or subject-focused researchers the book is an enlightening traverse across the Lewisian gneisses and through time (both geological and historical), related by a scientist who has had an intimate research connection to these rocks for over six decades. It is impossible in a general appraisal of this book to fully encapsulate the many facets of these rocks, or to address every geologically significant site or event described in it. Therefore, a broad chapter-by-chapter précis is offered in this review.

The book is partitioned into three main sections: *The Pioneers* (chapters 2 to 5), *Gathering the Data* (chapters 6 to 13), and *Models and Hypotheses* (chapters 14 to 19). These three parts are prefaced by a general introduction (Chapter 1) that provides the geographical and geological context of the Lewisian.



**Figure 1.** Distribution of Lewisian rocks in northwest Scotland. Depicted are some of the notable geological features and geographical locations described in the book.



## The Pioneers

Part 1 of *The Lewisian* presents a thorough, yet succinct, history of study of the Lewisian rocks. Chapter 2 introduces the reader to the earliest geological walkabouts on the rocks. Beginning with an account of the seminal work of John MacCulloch from the early 1800s, Dr. Park proceeds to chronicle 19<sup>th</sup> century studies up to those of the British Geological Survey in the late 1800s. It is here that readers are introduced to the “Fundamental Complex”, the collective term Sir Roderick Murchison coined for the ancient rocks of northwestern Scotland.

Chapter 3 is devoted to a “famous” Geological Survey memoir from 1907, “*The Geological Structure of the North-west Highlands of Scotland*”, a comprehensive report prepared under the editorship of Sir Archibald Geikie. It was in this report that “the foundation stones of Scotland” were given the name Lewisian Gneiss, and mafic intrusions subsequently referred to as the Scourie dykes (Fig. 2) were first documented and used as markers to separate discrete episodes of deformation. Dr. Park highlights the part of the memoir dealing with John Horne’s colourful descriptions of the Lewisian and the lithological subdivisions and structural features that he recognized among the rocks.

Chapter 4 examines the seminal work of Janet Watson and John Sutton, the results of which culminated in a landmark paper in 1951. This paper, lengthy but so elegantly written, was required reading for students of Precambrian geology and structural geology during my university days. It was in part a foundational account of how basic intrusions, the aforementioned Scourie dykes, could be utilized to unravel relative ages and superposed structural events in polydeformed high-grade gneiss terranes. The paper demarcated the “Scourian” (pre-dyke) and “Laxfordian” (post-dyke) history of the Lewisian. This fundamental approach to ‘reading the story in the rocks’ was later applied to Archean gneisses in western Greenland, by Vic McGregor, and in many other Precambrian Shield areas.

The final chapter of *The Pioneers* takes the reader from the Scottish mainland to the Outer Hebrides. It initially highlights the work (maps and reports) carried out on these islands by T.J. Jehu and R.M. Craig in the 1920s and 1930s, and then jumps ahead to review the studies of C.F. Davidson, M. Kursten, and R. Dearnley. There is an interesting tidbit of information associated with the Martin Kursten section, viz., the influence of D.B. McIntyre and L. Weiss on his approach to tackling the structural complexities apparent in the Lewisian of the Outer Hebrides. Ray Dearnley’s 1963 account of the South Harris anorthosite and associated rocks was one of the first papers on these Precambrian basic rocks that I encountered as an undergraduate student, leading me to cultivate a further interest in Archean anorthosites in Greenland and India.

## Gathering the Data

In Part 2 of the book the reader is taken on a more focused, eight-chapter tour of the Lewisian. This is the ‘meat in the sandwich’ of the volume, and it is peppered with names that will be well remembered by students from geology courses in the 1970s. The complexities of Lewisian structure and stratigraphy are brought out in much detail. This may make it a chal-



**Figure 2.** Sharp discordant contact between a Scourie metadolerite (metadiabase) dyke and a gneissic foliation.

lenge for readers to keep all the tectonic and compositional nomenclature in mind between one chapter and the next. The text is supported by illustrations and photographs mainly reproduced from important papers that now provide the essential descriptive foundation.

Chapter 6 informs the reader of the challenges the book’s author tackled as he embarked on his late 1950s and early 1960s investigations aimed at unravelling the Gairloch area. It begins with a short discussion of “granitization” and “migmatization”, and from there it reviews the geological aspects of the region, incorporating a treatment of local stratigraphic nomenclature and a chronology of deformation episodes using the numbered F and D modifiers in vogue at that time. Dr. Park tells of a professional disagreement by John Sutton in 1963 of his Gairloch study, one which led him to subsequently re-evaluate his Gairloch work. He relates how Sutton’s commentary prompted him to examine an adjacent area and, as a consequence, “revise my interpretation of the Gairloch area”. Such stories will no doubt be familiar to other readers involved in research.

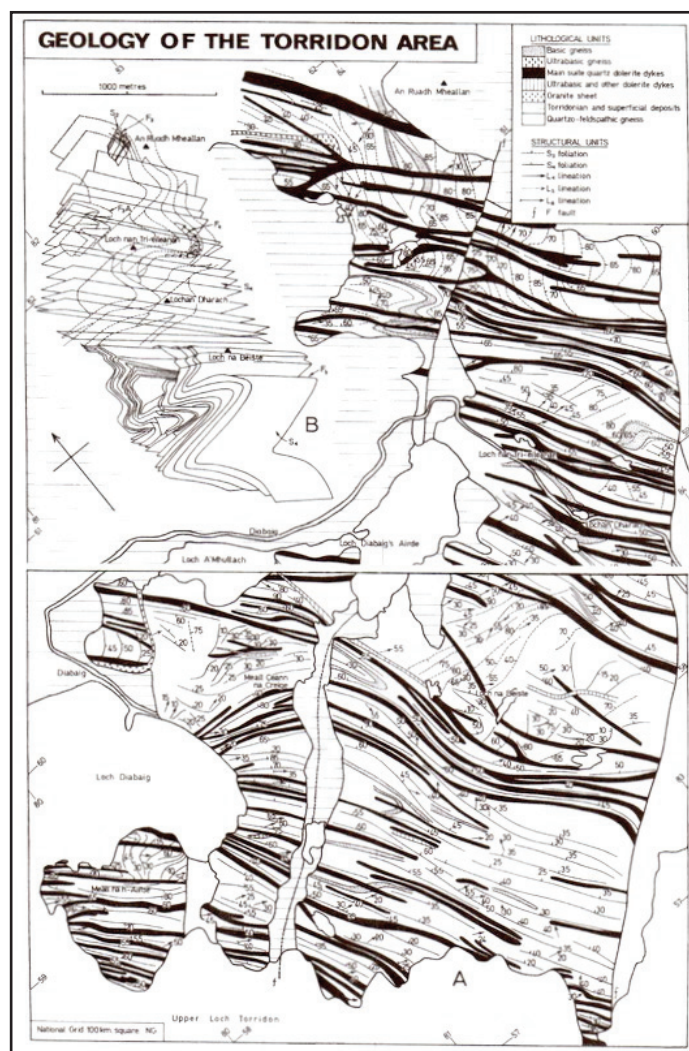


Work undertaken as part of a re-mapping program of the Lewisian on the Scottish mainland by university researchers and their students in the 1960s is given a thorough review in Chapter 7, with much detail illustrated by original field sketches and maps. Of particular note is the study by David Cresswell, who postulated that the notable layer-parallel versus layer-discordant differences between Scourie dykes and gneissic structures at Loch Torridon reflected primary emplacement features; a reproduction of Cresswell's map for the Diabaig area gives a clear picture of dyke density and relation to gneissic foliation (Fig. 3). Dr. Park ends the chapter by commenting on the perils of correlating structural chronologies of gneisses between disparate areas, and returns to it in Chapter 8 under the title "*Problems of Correlation and Nomenclature*". He highlights some interpretative disagreements between contemporary workers, and he supplies examples of differing terminology that sometimes proved to be obstacles in assessing Lewisian structural continuity. This excellent chapter discusses many problems that compilers of regional geological maps elsewhere encounter, and illustrates the frustrations in attempting to correlate geological events documented in a multitude of independent and isolated small studies.

The first attempts to apply the then-new insights from isotope geochronology are reviewed in Chapter 9. The focus here is on the application of K–Ar and Rb–Sr methods, chiefly in the 1960s, but U–Pb studies by Stephen Moorbath and colleagues are also reviewed. A wide variety of ages came from this work. The text rightly includes caveats from the original researchers and Dr. Park pertaining to the interpretation of isotopic results in a time when complications such as Ar loss and Rb migration were not fully appreciated.

Chapter 10 is devoted to understanding the pre-deformation character of the "Fundamental Complex" (i.e. gneisses predating intrusion of the Scourie dykes) and begins with a summary of John Myers' meticulous mapping on the island of Harris. Following its summary of the gneissic subdivisions advanced by Myers, the chapter discusses efforts to characterize the gneisses on the basis of geochemistry. The work of John Sheraton, Don Bowes, Mike O'Hara and several other investigators is highlighted, reviewing the use of specific geochemical signatures to determine protoliths. An informative section addresses the attributes of basic and ultrabasic rocks of the Lewisian, the concluding pages of which outline consideration of these rocks in terms of their origins, including suggestions that they might be slices of oceanic crust tectonically intercalated with older continental crust or be layered intrusions emplaced into the crust.

Chapter 11, "*Re-mapping of the Hebrides*" was, for me, a real delight to read. The accounts of fieldwork addressed here, especially the original papers by Janet Watson, John Myers, Mike Coward, Peter Francis and Rod Graham, were required requisites for my 1970s petrology and structural courses. This chapter also brought back memories of my sense of awe upon seeing, in 1975, the impressive Lewisian slabs used in the construction of the standing stones of Callanish on the Isle of Lewis. For the casual reader this chapter may be a bit of a maze to navigate, but for those involved in structural and metamor-



**Figure 3.** Reproduction of David Cresswell's map published in the *Scottish Journal of Geology*, (v. 8, p. 293–308; figure 2), illustrating the relationship between Scourie dykes (solid black; vertical line pattern), gneissic foliations and lithological subdivisions in the Diabaig area.

phic geology it is a wonderful account of the problems encountered and the astute observers who partly resolved them. Peter Francis' and Mike Coward's observations of relative dyke rheology in relation to metamorphic grade were catalysts for my additional undergraduate reading of Juan Watterson's report on deformed dykes of the Ketilidian of Greenland. Dr. Park again returns to the process of "granitization" by reviewing John Myers' study of the granite-migmatite complex of Harris, before dwelling on some of the mapping undertaken on the Inner Hebridean islands. The last part of the chapter deals with geochemical attributes and element migration in granitic intrusions and granulite-facies gneisses from the inner isles reported, respectively, by Graham Westbrook and Steve Drury.

Chapter 12 reviews an important conference held at Keele University in 1971, steered by Dr. Park and John Tarney, at which a couple of papers delved into potential connections between Scotland and Greenland. The chapter provides an

overview of the conference, recounting contemporary interpretations that were applied to selected features of the Lewisian, but Dr. Park also includes a few supplementary references to subsequent (post-1971) re-interpretations. A particularly interesting section of this chapter is devoted to the Scourie dykes and discussions about their emplacement into a hot crust and the exact relationships between morphology and deformation. The last pages of the chapter give a review of the papers presented at the Keele meeting in which provisional comparisons were advanced between the Precambrian of Greenland and the Lewisian. A dog-eared and pencil-annotated copy of the proceedings of the conference, entitled "*The Early Precambrian of Scotland and Related Rocks of Greenland*", still holds a treasured place on my library bookshelf!

Chapter 13, the final one in Part 2, returns the reader to the 'boots on the ground' field studies, discussing investigations on the Scottish mainland in the 1970s. The opening section of the summary brings to the forefront the work of Mike Coward, Rod Graham and Alistair Beach, and Dr. Park passes comment on their differing interpretations of facets of the Scourie dykes in comparison to his earlier publications with David Cresswell. An impressive and detailed illustration of Scourie dykes in a 12 km<sup>2</sup> area near the Gruinard River, based on mapping by Alan Crane, shows the level of detailed study and the level of geological complexity. References to multiple episodes of deformation (D), folding (F) and metamorphism (M) and their possible regional correlations may not be of particular importance to the general reader but Table 13.1 provides one useful summary for those with a penchant for such things.

## Models and Hypotheses

In Part 3 of the book, the reader passes into the 'arm-waving' and 'big-picture' analyses of the Lewisian. The six chapters here deal with subjects such as shear zones and kinematic models of deformation (chapters 14 and 15, respectively), the petrogenesis of Scourian and Proterozoic parts of the Lewisian (chapters 16 and 17, respectively), an absolute chronology of events (Chapter 18), and finally an evaluation of the Lewisian in the context of Precambrian plate tectonics (Chapter 19). This last part of the book took me back to my undergraduate and graduate student days with its many references to individuals and papers that influenced our thinking on many topics.

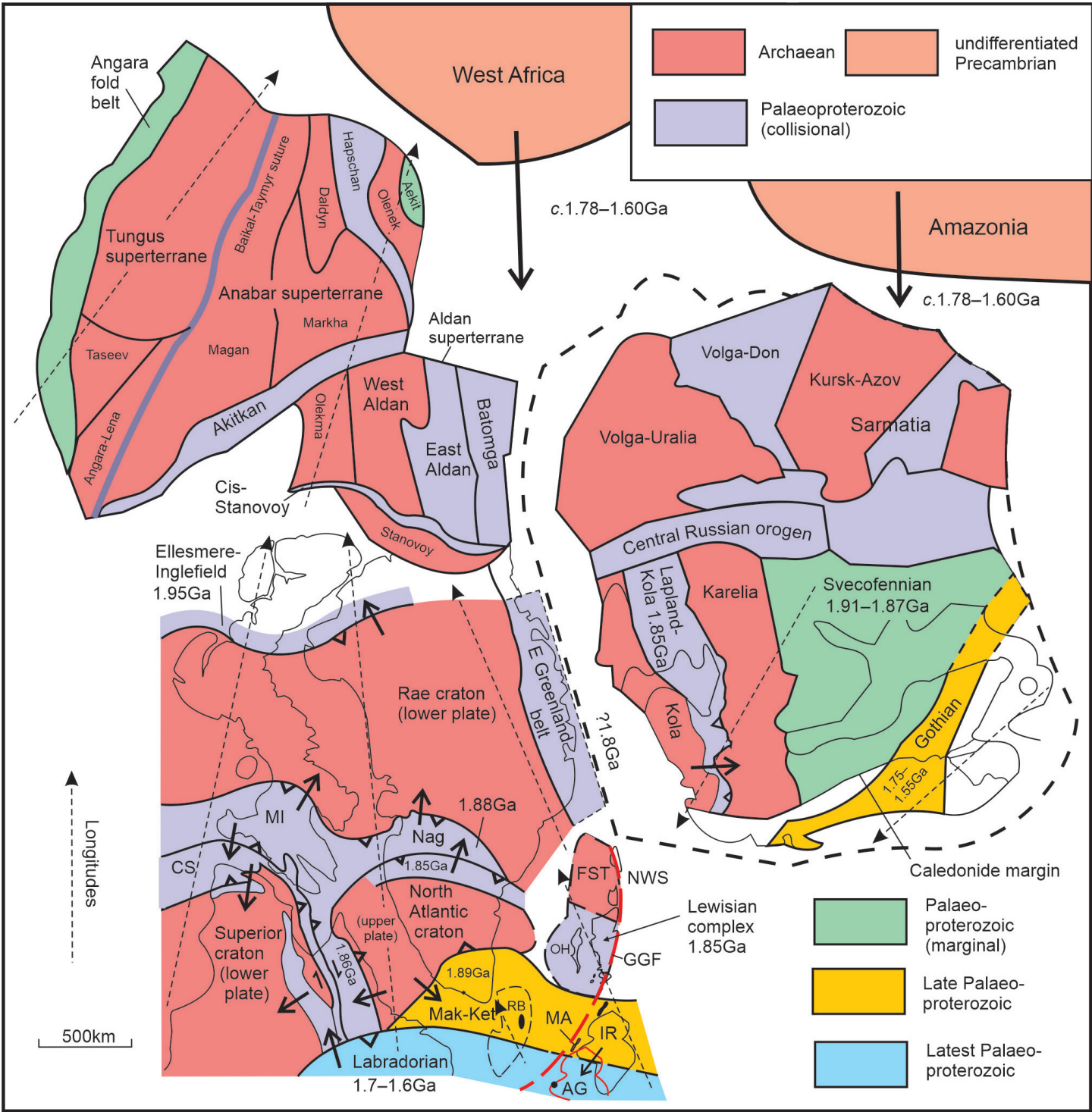
Chapter 14 begins with a discussion of an influential 1962 structural geology paper by Derek Flinn, one which approached deformation through a three-dimensional lens. This paper was required reading for aspiring structural geologists during my student days. Flinn's work influenced Juan Waterson's subsequent research on gneisses in Greenland, a study also given prominence in the chapter. This work in turn brought new ideas to Scotland by showing how prolonged polyphase ductile deformation could produce deceptively simple sedimentary-like layering. Dr. Park then proceeds to a discussion of another classic paper, one on shear zones by John Ramsay and Rod Graham, and subsequently highlights examples from the Lewisian, such as South Harris and Gairloch. Lewisian shear zones also underpin much of the discussion in

Chapter 15, which is related to the "third Lewisian conference" held in 1985 in Leicester. This chapter focuses on some of the most prominent Lewisian shears and evaluates them within the context of crustal deformation processes.

Two chapters on petrogenesis follow, Chapter 16 dedicated to the ancient rocks of the Scourian Complex and Chapter 17 to younger Proterozoic components. The Scourian is approached by a review of conclusions advanced in the mid-1970s to late-1980s, including work by Bryan Davies, Janet Watson, Steve Drury, John Tarney and collaborators. Drury was the first to apply rare-earth element (REE) data and theoretical modelling to ascertain the original character of the Scourian gneisses. This chapter provides a comprehensive summary of several geochemical studies of the rocks, and how inferences from geochemical signatures pointed to plutonic parents likely of variable nature and tectonic setting. The last part of Chapter 16 is dedicated to an overview of the metamorphic evolution of the Scourian, including derivation of P-T conditions and also the new and compelling evidence of multiple thermal events revealed by U-Pb zircon geochronology. Chapter 17 addresses the Proterozoic rocks, including those derived from sedimentary and volcanic precursors. The Loch Maree succession of supracrustal rocks is addressed in detail, Dr. Park having spent many years investigating it, including hypotheses regarding the genesis of its various components. The petrogenesis of the Scourie dykes is approached using work on trace element and isotopic patterns, which suggested derivation from partial melting of the mantle during crustal extension; the "main" dyke set was emplaced ca. 2.4 Ga. Felsic plutonic rocks of the Laxfordian episode, representing crust of ca. 1.9 Ga to ca. 1.7 Ga age, are discussed near the end of the chapter, and ascribed to volcanic arc magmatism and partial melting of older rocks. The final section of the chapter gives an overview of metamorphism imposed on the rocks, including early ultra-high temperature (UHT) and later greenschist-facies events.

Chapter 18 is a review of many geochronological investigations conducted between the late 1960s and mid-2010s, using a wide variety of specialized methods. Trying to keep in mind the multitude of results could bring on giddiness, but general readers and geochronologists will appreciate the protracted geological history. The oldest rocks in the "Fundamental Complex" were formed some 3 billion years ago whereas the youngest isotopic ages record events that occurred some 2 billion years later. The intervening events encompass plutonism, sedimentation and metamorphism, all of which were repeated. A crust-forming event prior to 2.9 Ga produced the precursor igneous rocks, and significant metamorphic imprints occurred ca. 2.7 Ga (termed Badcallian), ca. 2.5 Ga (termed Inverian) and across a temporal span from ca. 1.9 Ga to ca. 1.7 Ga (termed Laxfordian). Dr. Park highlights differing interpretations of diverse data, pointing out how modern laser-based, spot analyses of individual mineral grains (e.g. zircon, titanite, monazite) provide better constraints and detail compared to the previously employed 'whole mineral' and 'whole rock' methods.





**Figure 4.** Distribution of several hypothesized continents in the Proterozoic, showing the possible location of the Lewisian gneiss complex within the tectonic framework. This illustration in the book is complemented by additional interpretative drawings of continental migration and interactions between 1.9 Ga and 1.5 Ga.

Chapter 19 wanders into global geodynamics and is aptly entitled “*The Wider Picture*”. It visualizes the Lewisian in the light of global-scale processes – continent assembly and continent sundering – and is rich in colourful interpretative illustrations (Fig. 4). The chapter includes geographic reconstructions of the Lewisian and the other Precambrian rocks in

terms of plate tectonic processes, with emphasis on correlations with east Greenland, Canada and Scandinavia. The application of the "Terrane Concept" to the Lewisian is introduced as the third section of this chapter. There is particular reference to "controversial" proposals by Clarke Friend and Peter Kinney, who suggested that the Lewisian comprised multiple

welded terranes, having disparate crustal histories. The alternative view, advanced by Dr. Park, is that there are fewer ‘terrane’ and the regional patterns reflect the collisional stacking of two slabs of continental crust. Paleoproterozoic plate interactions are suggested to govern assembly of wandering continental fragments into Earth’s first supercontinent, and the Lewisian tells one part of that story. Dr. Park ends his book with a section that could be summed up by *Where do we go from here?*, a query that not only applies to the Lewisian but also to a further understanding of the evolution of the early Earth.

### SOME CLOSING REMARKS

I have not scrutinized *The Lewisian* with an eye to editorial shortcomings but some, such as the fuzziness of line diagrams reproduced from other sources, are readily apparent. Additionally, a few ‘gremlins’ have crept into figure captions. None of the foregoing poses an impediment to the pleasure of reading this book, and they are expected from the very nature of the publication. The photographs supporting the text are crisp, but some are not very informative and others lack scale references; several photographs are duplicated. I detected a couple of spelling inconsistencies and errors, but anyone who has written detailed scientific reviews will know that such things are inevitable. The use of the past tense in describing existing features of rocks or units as outlined in historical literature irritated me at times, but I acknowledge my own preference for using the present tense for all descriptive uses. A book of such depth, length and breadth would challenge any writer or editor in terms of imposing consistency and clarity to each and every paragraph.

The writing in this encyclopedia of Lewisian research is not all dry and technical. Dr. Park has incorporated numerous informative ‘aside’ comments throughout the book and has recounted differences in geological interpretations between himself and other workers. Professional divergences are not surprising in the geoscience world and they are inevitable in our efforts to understand such cryptic and challenging rocks. Comparative discourse allows differing approaches to ultimately arrive at an acceptable level of uniformity. The history of research on the Lewisian is very much a testament to how field-related geoscience works and progresses.

I would like to end this review with a couple of personal anecdotes and a prediction. My first visit to the Lewisian, in 1975, was a bit disappointing. Having spent several years walking the ice-scoured and barren shorelines of Labrador, features in the coastal outcrops of the Scottish Highlands were harder for me to discern because of the moss and lichen cover. It took me some time to appreciate the details discussed by the excursion leaders. A routine aspect of field work in northern Canada involves tearing back the blanket of vegetation to seek critical features and relationships. On a field trip in the 1980s I attempted this technique on a poorly exposed rock surface – near Gairloch, I believe. Dr. Park cautioned me – in a whispered, friendly manner – that such drastic action was not a regular practice among Scottish geologists and might not receive their blessing! Regardless of whether the Lewisian is stripped bare or hidden beneath a cloak of vegetation, it represents one

of the most fascinating and influential regions for our understanding of the Precambrian. Dr. Park has revealed in his book a personal chronicle of historical, geological and interpretative details that will be an invaluable reference for many future generations of geoscientists. I wholeheartedly recommend this volume to students of Precambrian geology, to geologists who love to absorb historical studies of classic regions, and to anyone having an interest in structurally complex metamorphic rocks. Any geoscientist who is curious as to how a reasonable – but invariably debatable – story can be extracted from such rocks will admire the huge effort involved in writing this book, and appreciate the immense contribution that it makes. Like many of the classic studies that it draws upon for details, it will truly stand the test of time.

All figures come directly from Graham Park's book, *The Lewisian: Britain's Oldest Rocks*, with permission from Dunedin Academic Press Ltd.



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