

# Early basic magmatism in the evolution of Archaean high-grade gneiss terrains: an example from the Lewisian of NW Scotland

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## Abstract

Amphibolite blocks from an Archaean (2.9 Ga) trondhjemite–agmatite complex in the Lewisian at Gruinard Bay have a varied trace element and REE content. Whilst some of the variability is attributable to element mobility during high-grade metamorphism and subsequent trondhjemite magmatism, it is for the main part considered to be a primary feature of the amphibolites. The observed trace element and REE chemistry is best explained in terms of source region heterogeneity and suggests a melting regime comparable with that beneath certain types of mid-ocean ridge. There are geochemical similarities between the amphibolites and the Lewisian layered gabbro–ultramafic complexes, and the two may represent the derivative liquid and associated cumulates respectively from a common parent magma. Thus there is a parallel between the processes which generated some Archaean amphibolites and layered gabbro complexes and those operating beneath modern ocean ridges. Hornblende and amphibolite pods enclosed within tonalitic gneiss, also found as blocks in the agmatite complex, are geochemically distinct from the main group of amphibolites and are probably of calc-alkaline parentage.

**KEYWORDS:** magmatism, gneiss, amphibolite, Lewisian, Scotland.

## Introduction

METABASIC rocks are a volumetrically minor, but significant part of Archaean high-grade granite–gneiss terrains. They tend to form concordant layers of amphibolite and basic granulite within the gneisses which vary from a few centimetres to at least 1 km thick. Detailed field mapping (Rollinson, 1978; Friend *et al.*, 1981) has shown that they are one of the earliest recognizable components of such terrains and some authors have recently suggested they may represent fragments of primordial ocean crust (Friend *et al.*, 1981; Hall, 1980; Rivalenti, 1976; Weaver *et al.*, 1981, 1982). Certainly a detailed understanding of the petrogenesis and origin of these amphibolites will yield valuable clues to the earliest stages in the evolution and growth of Archaean continental crust and provides important constraints on the original tectonic setting of Archaean high-grade terrains. Yet, in contrast to the intensively studied basaltic and komatiitic volcanism of Archaean greenstone belts, little is known of amphibolites from Archaean high-grade terrains. In this paper a distinction is

made between the amphibolites and the better known layered gabbro–ultramafic complexes, which are also characteristic of many high-grade gneiss terrains (Windley and Smith, 1976; Windley *et al.*, 1981). It is possible that the two are related (see Weaver *et al.*, 1981) but for the purpose of clarity they are treated separately.

The Lewisian complex of NW Scotland has become a classic example of an Archaean high-grade gneiss terrain. It is dominated by tonalitic and trondhjemitic gneisses, generated from the mantle about  $2.92 \pm 0.05$  Ga (Hamilton *et al.*, 1979). These igneous bodies became gneissose during subsequent penetrative deformation and associated high-pressure amphibolite to granulite facies metamorphism at 2.8 to 2.6 Ga. Enclosed within the tonalitic and trondhjemitic gneiss are relics of earlier sediments (Okeke *et al.*, 1983; Cartwright *et al.*, 1985), layered intrusions (Sills *et al.*, 1982), amphibolites, and basic granulites. The amphibolites and their higher-grade metamorphic equivalents, basic granulites, have received little attention in the past and their origin is uncertain. The purpose of this paper is to present the results of

# Accretion Evolution Of An Archaean

**J Spring**



## **Accretion Evolution Of An Archaean:**

**The Archaean: Geological and Geochemical Windows into the Early Earth** Andrew Y. Glikson, 2014-08-05 Archaean terrains contain a wealth of structural stratigraphic textural mineralogical geochemical and isotopic features allowing insights into the nature of the early Earth This book is based on studies during 1964 2007 of Archaean terrains in Australia and to a lesser extent in South Africa and India as well as on visits to Archaean terrains in Canada the US and China as well as petrological and geochemical studies of igneous and sedimentary rock suites from a range of terrains The book will include a range of photographic and microscopic images geological sketch maps and diagrams illustrating the lessons derived from field and the laboratory Also other Archaean terrains are being reviewed The book is intended for Earth scientists as well as broader intelligent readership *Origin of the Earth and Moon* Robin M. Canup, Kevin Righter, 2000-11 The age old question of how our home planet and its satellite originated has in recent times undergone a minor revolution The emergence of the giant impact theory as the most successful model for the origin of the Moon has been difficult to reconcile with some aspects of the Earth and the development of an integrated model for the origin of the Earth Moon system has been difficult for this reason However recent technical advances in experimental and isotopic work together with intensified interest in the modeling of planetary dynamics have produced a wealth of new results requiring a rethinking of models for the origin of the Earth and Moon This book is intended to serve as a resource for those scientists working closely in this field while at the same time it provides enough balance and depth to offer an introduction for students or technically minded general readers Its thirty chapters address isotopic and chemical constraints on accretion the dynamics of terrestrial planet formation the impact triggered formation of the Earth Moon system differentiation of the Earth and Moon the origin of terrestrial volatiles and conditions on the young Earth and Moon Covering such subjects as the history and origin of the Moon s orbit water on the Earth and the implications of Earth Moon interactions for terrestrial climate and life the book constitutes a state of the art overview of the most recent investigations in the field Although many advances have been made in our ability to evaluate competing models of the formation of the Earth Moon system there are still many gaps in our understanding This book makes great strides toward closing those gaps by highlighting the extensive progress that has been made and pointing toward future research **Precambrian Crustal Evolution and Cretaceous-Paleogene Faulting in West Greenland** Adam A. Garde, Feiko Kalsbeek, 2006 Economic Mineralization K.L. Shrivastava, 2009-07-01 Economic Mineralization the volume sets out to present various aspects of a very broad details of a narrow field of economic mineralization at a time when the competitively growing global economy and the pressing needs of the society are compelling economic geology to grow and pile of data is accumulating and opinions changing very rapidly The volume incorporates papers a resultant of information explosion and electrifying conceptual revolution in economic geology describing the new and exciting results and timely reviews integrating and immense amount of knowledge in the field of geology exploration

mining environment economics geophysics and geochemistry that has bearing on economic mineralization The book imbibes sections on crustal evolution and economic mineralization economic mineralization of igneous application economic mineralization of sedimentary affiliation prospecting and exploration and mining economics and environments In all the five sections current concepts problems and probable trends of future research are highlighted This book will be an invaluable everlasting reference for both industry and academia specializing in economic mineralization and for those who need updated information and current research in the field It will be equally useful for advance level geology and mining students and research scholars throughout the world

**The Archean Earth** Martin Homann, Wladyslaw Altermann, Timothy W. Lyons, Richard E. Ernst, Christoph Heubeck, Eva Stueeken, Alex Webb, Dominic Papineau, Rajat Mazumder, Paul RD Mason, 2025-12-19 The Archean Earth Tempos and Events Second Edition is a process based reference book that focuses on the most important events in early Earth bringing together experts across Earth Sciences to give a comprehensive overview of the main events of the Archean Eon as well as of the rates at which important geological and geobiological processes occurred in the same time interval Over the last two decades significant progress has been made in our understanding of the processes and events on the early Earth corresponding to advances in the analytical technologies and the continuing efforts of many colleagues that pursue their passion of unravelling the Archean rock record The book addresses the origin of the Earth succeeding impact events and the evolution of the early Earth covering topics such as Archean tectonics volcanism generation of continental crust and the ongoing debate about the onset of plate tectonics the evolution and models for Earth's hydrosphere and atmosphere the Archean atmosphere and chemical sedimentation and sedimentation through Archean time among others Each topic is well illustrated and includes a closing commentary at the end of each chapter leading up to the final chapter which blends the major geological events and rates at which important processes occurred into a synthesis postulating a number of event clusters in the Archean when significant changes occurred in many natural systems and geological environments Provides a comprehensive introduction and overview on early Earth highlighting the Archean Eon in the context of the larger time scales Presents detailed descriptions of the main processes events and rates that occurred throughout the Archean Offers an assessment of the first habitable environments the preserved morphological and geochemical traces of early life and the impact it had on Earth's biogeochemical cycles

*Accretion and evolution of an archaean high-grade grey gneiss-amphibolite complex* Adam A. Garde, 1997

**The Web of Geological Sciences:** Marion E. Bickford, 2017-09-29 The web of geological sciences Special papers 500 and 523 written in celebration of the 125th anniversary of the Geological Society of America

*Orogeny Through Time* Jean-Pierre Burg, 1997 This book presents a series of review articles on nine important ancient orogens on Earth Comparison of these mountain belts provides a wealth of information for the debate on whether there has been a change in mountain building processes through the history of the Earth As a precursor to these papers the rheology of the Earth's lithosphere through time is reviewed Theoretical analysis

and insight into the behaviour of the lithosphere of other planets constrain mechanical considerations of the Earth's lithosphere. It is clear from these overviews that geodynamic concepts and modelling and new techniques such as deep seismic profiling and geochronology are having a profound impact on orogenic studies.

**The Evolving Continents**  
 Timothy M. Kusky, Mingguo Zhai, Wenjiao Xiao, 2010. This volume honours the career of Brian F. Windley who has been hugely influential in helping to achieve our current understanding of the evolution of the continental crust and who has inspired many students and scientists to pursue studies on the evolution of the continents. Brian has studied processes of continental formation and evolution on most continents and of all ages and has educated and inspired two generations of geologists to undertake careers in studies of continental evolution. The volume is organized into six sections including oceanic and island arc systems and continental growth tectonics of accretionary orogens and continental growth and stabilization of continental crust collisions and intraplate processes. Precambrian tectonics and the birth of continents and active tectonics and geomorphology of continental collision and growth zones.

*Bulletin of the Geological Society of Denmark* Dansk geologisk forening, 2000  
**Journal of African Earth Sciences**, 2002  
Structure and Evolution of the Continental Lithosphere V. Rama Murthy, 1984  
*South African Journal of Geology*, 2004  
New Technical Books New York Public Library, 1986  
*Submarine Volcanism and Mineralization* Brian Lloyd Cousens, Stephen J. Piercey, 2009

**Earth Accretionary Systems in Space and Time** Peter Anthony Cawood, Alfred Kröner, Geological Society of London, 2009. Accretionary orogens form at convergent plate boundaries and include the supra subduction zone forearc magmatic arc and backarc components. They can be broken into retreating and advancing types based on their kinematic framework and resulting geological character. Accretionary systems have been active throughout Earth history extending back until at least 3.2 Ga and provide an important constraint on the initiation of horizontal motion of lithospheric plates on Earth. Accretionary orogens have been responsible for major growth of the continental lithosphere through the addition of juvenile magmatic products but are also major sites of consumption and reworking of continental crust through time. The aim of this volume is to provide a better understanding of accretionary processes and their role in the formation and evolution of the continental crust. Fourteen papers deal with general aspects of accretion and metamorphism and discuss examples of accretionary orogens and crustal growth through Earth history from the Archaean to the Cenozoic.

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U.S. National Report to International Union of Geodesy and Geophysics, 1995  
*Bulletin*, 1948

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