

Manchester Geological Association

Saturday 15th January 2011 – The Scottish Dalradian

13.30 – 14.30 The Dalradian and its Structure - Dr. Jack Treagus, University of Manchester

14.30 – 15.30 Dalradian Metamorphism: Patterns and Puzzles – Dr. Giles Droop, University of Manchester

15.30 – 16.00 Coffee Break

16.00 – 17.00 Dalradian Mineralisation – Professor Richard Pattrick, University of Manchester

Sir Archibald Geikie, searching for a name to give a group of ancient rocks that stretched across the Highlands of Scotland and the northern part of Ireland, settled on the term 'Dalradian', after the ancient kingdom of *Dal Riada*, which was occupied by a tribe of Scottish and Irish Celts and covered the same area.

The Dalradian succession is a thick sequence of sedimentary rocks with minor volcanics that formed on the southern margin of a continent from late Precambrian to late Cambrian times. In early Dalradian times sandstones, mudstones and carbonates accumulated on a stable platform, but this platform started to founder into a series of basins by late Precambrian. Sea level rose during Cambrian times giving rise to a transgression in which shelf sediments were deposited further into the continental margin (the present-day north-west Highlands of Scotland).

In the early Ordovician this sequence of rocks was deformed, metamorphosed and subsequently mineralised during the Grampian Orogeny (an early phase of the Caledonian Orogeny) following the closure of the Iapetus Ocean. The remnants of this mountain chain stretch across the highlands and islands of Scotland, providing classic areas for the study of intensely folded rocks and the zonation of metamorphic minerals.

The Dalradian and its Structure - Dr. Jack Treagus, University of Manchester

The first talk will introduce the Dalradian succession of Scotland, which comprises a sequence of predominantly sedimentary rocks ranging in origin from that of shallow seas and rivers to a deep ocean, with some volcanic input. Their ages range from about 800 to 500 (Early Cambrian) million years. The talk will concentrate on their deformation in the Caledonian Orogeny, between the late Cambrian and Devonian (470million); this involved repeated episodes of folding, beautifully expressed by minor folds and their related cleavages.

These episodes were associated with variations of temperature and pressure that Giles Droop will address in the second talk. Emphasis will be placed in this first talk on localities where the minor structures can be easily accessed in roadside and shore exposures. An attempt will be made to explain how the complex stratigraphic pattern on the map is the result of a sequence of major folds, including nappe-like structures, which can be related to the sequence of minor structures.

Dalradian Metamorphism: Patterns and Puzzles

Dr. Giles Droop, University of Manchester

From the point of view of metamorphic studies, the Scottish Dalradian has been high in geologists' consciousness ever since the pioneering work of George Barrow in the late 19th and early 20th centuries. It was Barrow who first realised that the mineralogy of the Dalradian schists varies systematically from place to place, and it was he who first mapped the distribution of 'index' minerals across the central part of the terrain (which he managed without the aid of thin sections!), thus delineating what have come to be known as 'Barrow's Zones'. After WWI, the concept of metamorphic isograds was developed by C.E. Tilley as a direct consequence of Barrow's studies. Later in the 20th century the Dalradian continued to influence metamorphic thinking as it became apparent through the work of H.H. Read in the Buchan region that very different zonal sequences can exist within the same metamorphic belt.

In this talk, the metamorphic zonation in the Barrovian, Buchan and Stonehaven areas will be reviewed and interpreted as sequences of reactions, and the information used to make qualitative inferences on the way peak-metamorphic temperatures and pressures vary across the terrain. Methods of retrieving absolute pressures and temperatures will be briefly described, and the results used to map out dramatic variations in depth of burial and geothermal gradient. The textural relationships between large crystals of metamorphic minerals ('porphyroblasts') and their matrices, as seen under the microscope, have enabled geologists to establish the relative timing of mineral growth and periods of deformation (which Jack Treagus will discuss in his talk). Many of the garnet porphyroblasts in the Dalradian appear to have grown during the second major phase deformation. In principle, the chemical zoning profiles of these 'syn-tectonic' garnets can provide constraints on how metamorphic conditions changed during garnet growth and deformation, and thus on possible causal relationships between deformation and metamorphism; I hope to present some new data on this subject. The talk will end with some speculative comments on the causes of Dalradian metamorphism.

Dalradian Mineralisation – Professor Richard Pattrick, University of Manchester

The Dalradian Terraine of Scotland contains evidence of a long geological history and lithologies conceived in a range of tectonic settings and this is reflected in the polygenetic mineralisation located in the Dalradian rocks. The earliest mineralising events were synsedimentary exhalations of mineralising hydrothermal fluids onto the Dalradian basin floor. The most significant of these events produced the middle Dalradian Aberfeldy Barite-Fe-Zn mineralisation which is currently mined for barite for use as drilling muds. The mineralisation occurs along 7 km of strike, now heavily deformed. If this event was related to rifting without magmatism, the subsequent Zn-Cu-Fe mineralisation further up the sequence, seen at Auchtertyre, near Tyndrum, was related to basic sills intruding into wet sandstones causing hydrothermal circulation.

The next mineralising event in the Dalradian was related to magmatic activity at the end of the Caledonian Orogeny, with Ni-Cu mineralisation associated with ultramafic intrusions, followed by widespread (if un-economic) mineralisation associated with the Caledonian granites. In the latter, late stage fluids, expelled from the intrusions, caused porphyry-style

Cu-Mo mineralisation. Epithermal vein gold mineralisation occurred at this time, driven by the high heat flow and focused on developing left lateral fault zones. The Cononish Au-bearing vein system, near Tyndrum, is the economically most promising of this phase of mineralisation. The last stages of mineralisation in the Terraine were Pb-Zn veins, probably of Lower Carboniferous age, seen again at Tyndrum where they were historically mined, and then giant carbonate veins.