Geochronological investigations of Caledonian history in Western Ireland

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Geochronological Investigations of Caledonian History in Western Ireland

by PETER J. LEGGO[1]) and ROBERT T. PIDGEON[2])

ABSTRACT

Detailed structural and stratigraphic knowledge of the Dalradian rocks in Western Ireland make this a key area in an investigation of the history of the Caledonian Orogeny. Whole rock Rb-Sr, zircon U-Pb and K-Ar mica ages combine to demonstrate a coherent picture of sequential events which can be directly related to the geological history.

Introduction

The Caledonian rocks of Co. Donegal in the north-west and Co. Galway in the west of Ireland have been the subject of detailed geochronological investigations (Fig. 1) (MOORBATH et al. 1968, LEGGO et al. 1966, LEGGO et al. 1969, PIDGEON 1969). Both areas have been mapped on a large scale and chronological sequences of igneous and metamorphic events have been established (PITCHER and READ 1958, LEAKE 1958, LEAKE 1969). Through the determination of the ages of individual events it is our aim to investigate the kinetics of the Caledonian metamorphism in this region.

The metasediments in Donegal and Connemara, Co. Galway have been correlated with the Dalradian Series of Scotland (KILBURN, PITCHER and SHACKLETON 1966) by means of the very characteristic Dalradian boulder bed series which can be traced from Connemara, Western Ireland through Donegal into the outlying islands of Islay and the Garvellachs and across the Scottish Highlands as far as north east Aberdeenshire.

In north Connemara the Dalradian Connemara Schists are unconformably overlain by Lower Ordovician rocks of the D. bifidus zone (SKEVINGTON and STURT 1967). This unconformable relationship places an upper limit on the age of the regional metamorphism of the schists. Mica ages from the Connemara Schists (MOORBATH et al. 1968) are generally younger than Llanvirn ($\sim$ 490 m.y.) and thus reflect the regional metamorphism. These age results could, however, be cooling ages recording periods of uplift which are known to have occured during lower paleozoic time (MCKERROW and CAMPBELL 1960).

This paper summarises recent work applying whole rock Rb/Sr and U/Pb zircon studies to the metasediments and intrusive igneous rocks of the region. From the results of these studies pre-Ordovician ages of metamorphism have been determined.

[1]) Dr. Peter J. Leggo, Department of Geology, The Florida State University, Tallahassee, Florida, USA.

[2]) Dr. Robert T. Pidgeon, Scottish Research Reactor Centre, East Kilbride, Glasgow, Scotland, U.K.

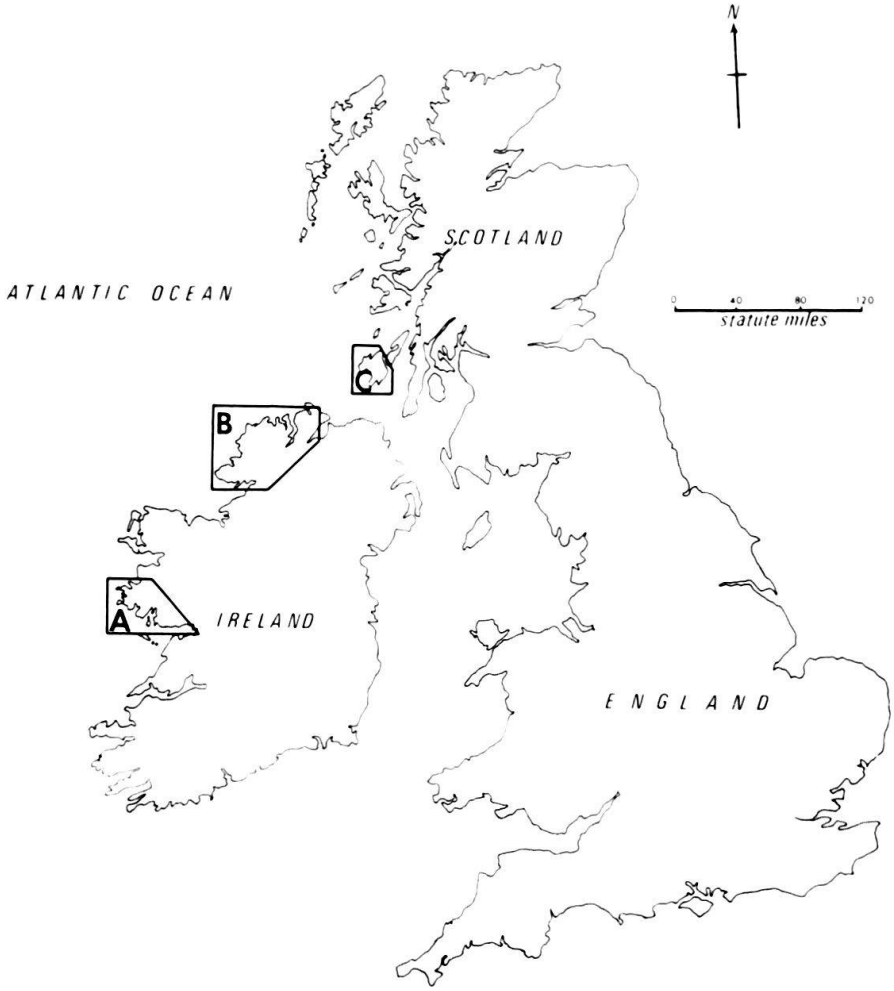

Fig. 1.
Sketch map showing location of Co. Galway (A), Co. Donegal (B) and Islay (C) in the British Isles.

Geological setting

The main geological work in Donegal has been associated with the problem of the origin and mode of emplacement of the Donegal granites (PITCHER and READ 1958). In Connemara excellent exposure of the country-rock metasediments has facilitated a detailed investigation of these rocks and the magmatic bodies which intrude them. According to MOORBATH et al. (1968) the sequence of geological events in the pre-Ordovician rocks of Connemara is as follows:

1. Deposition of Dalradian sediments followed by intrusion of dolerite sills.
2. Regional metamorphism to sillimanite-garnet grade (M 1) and isoclinal folding (F 1).
3. Intrusion of ultrabasic-basic magma producing contact metamorphism (M 2) in the enveloping schists.
4. Later amphibolite facies metamorphism (M 3) effected the ultrabasic-basic magmas which suffered injection and consequent magmatisation by a quartz-andesine magma. At the same time folding (F 2) took place. The final phase of this migmatisation produced potash feldspar gneisses.

5. Recrystallisation of hornblende, mica and feldspar in some of the rocks is designated as metamorphism (M4) which is accompanied by another phase of tight folding (F3).
6. In some areas a later metamorphism unaccompanied by folding (M5) is seen as producing a patchy development of andalusite pegmatite and schist whereas cordierite and chloritoid porphyroblasts, also associated with this event, occur elsewhere.
7. Following (M5) large scale folding (F4) took place and the Connemara antiform and complementary synform were produced.
8. In some areas the strain-slip cleavage developed by (F4) folding is accompanied by sufficient metamorphism to recrystallise biotite in the cleavage planes, this metamorphism is termed (M6).
9. The fifth fold period interfering with (F4) produced locallised doming in South Connemara.
10. The end of the tectonic episode was followed by the emplacement of adamellite and granodioritic magmas.

The geochronological summary is made by first describing the analytical results of the post-tectonic granites followed by the results of investigations made on the ages of the older events.

Geochronology of the post-tectonic granites

Whole rock Rb/Sr isochron work has been conducted on granitic bodies in both Co. Galway and Co. Donegal (LEGGO et al. 1966, LEGGO et al. 1969).

In Connemara, Co. Galway, this work has been further supplemented by a U/Pb zircon study of the Galway Granite (PIDGEON 1969). This work showed the age of the Galway Granite to be 415 $\pm$ 15 m.y., which is significantly older than the age obtained by LEGGO et al. (1966) (385 $\pm$ 5 m.y.) by whole rock Rb/Sr work. However, if the ^{87}Rb decay constant of 1.39×10^{-11} yr^{-1} (ALDRICH et al. 1956) is used for the age calculation instead of 1.47×10^{-11} yr^{-1} (FLYNN and GLENDENIN 1959) the Rb/Sr isochron age becomes 407 $\pm$ 6 m.y., which is within the error of the zircon result, assuming error in the U decay constants to be insignificant. In order to bring the Rb/Sr isochron results into conincidence with the U/Pb work the Rb/Sr ages have been recalculated using the 1.39×10^{-11} yr^{-1} decay constant, and the post-tectonic granite results are listed below. But for the Inish and Roundstone Granite isochrons, which are each based on four data points, the other isochrons all have more than four data points.

Galway Granite	Connemara district	13 data pts.	407 $\pm$ 5 m.y.
Omey Island Granite	Connemara district	5 data pts.	411 $\pm$ 20 m.y.
Roundstone Granite	Connemara district	4 data pts.	419 $\pm$ 85 m.y.
Inish Granite	Connemara district	4 data pts.	428 $\pm$ 10 m.y.
Donegal Granite	Donegal district	10 data pts.	498 $\pm$ 5 m.y.

The oldest post-tectonic granite in Connemara, the Inish Granite, places a minimum age of 428 m.y. on the metamorphism of the country rocks. This limit is further lowered when the Donegal Granite is taken into consideration. Using this result the age of metamorphism of the Dalradian in Western Ireland can be placed at 498 m.y., or older.

Geochronology of the ultrabasic-basic suite

The ultrabasic-basic intrusion phase marks a distinct event in the metamorphic history of the Dalradian Series.

In Connemara this intrusion post-dates (F 1) but pre-dates (M 3) and (F 2) and according to LEAKE (1958) was emplaced during but towards the end of the regional metamorphic episode (M 1).

Any attempt to date the gabbroic rocks themselves using the Rb/Sr method would be hindered by their unfavourable Rb and Sr concentrations. However it was found that certain parts of the suite contained appreciable quantities of zircon and so a U/Pb zircon study was made (PIDGEON 1969).

Analysis of a population of zircons from this rock type showed them to be slightly discordant but on extrapolation of this data an age of 515 $\pm$ 15 m.y. was obtained. This age is taken to be the age of magmatic crystallisation of the gabbroic suite and defines the age of the (M 2) metamorphic event in Connemara.

Note should be taken here that work on the ultrabasic-basic intrusion phase in the Dalradian of Aberdeenshire by PANKHURST (1969) shows this event to be synchronous within experimental error with that of Connemara. PANKHURST obtaining a Rb/Sr whole rock isochron of 510 $\pm$ 13 m.y., for the Insch Gabbro of Aberdeenshire. This result was calculated using the 1.39×10^{-11} yr^{-1} ^{87}Rb decay constant.

Geochronology of the metasediments

The main regional metamorphism of the Connemara Schists, M 1 of LEAKE (1958), pre-dates the intrusion of the ultrabasic-basic suite. The M 1 event must therefore be older than 515 $\pm$ 15 m.y., the age obtained for the ultrabasic-basic rocks.

A whole-rock Rb/Sr isochron age of 520 $\pm$ 30 m.y. has been obtained by LEGGO et al. (1969) on six samples of Connemara Schist. The samples are a varied group of pelites and semi-pelites of amphibolite grade collected from a single quarry located well outside the migmatite zone.

This age is similar to the age of the ultrabasic-basic rocks (515 $\pm$ 15 m.y.) and therefore must record a pre- (M 3) isotopic event. We interpret the schist isochron age as recording either the age of diagenesis of the sediment or possibly the age of regional metamorphism (M 1). Discordant zircon systems reported by PIDGEON (1969) suggest a major isotopic disturbance at approximately 500 m.y. However to shed more light on the interpretation of the schist Rb/Sr isochron age, essentially unmetamorphosed siltstones of near stratigraphic equivalence to the Connemara Schist were collected from Islay (see Fig. 1) and analysed by the whole rock Rb/Sr method (LEGGO et al. 1969). Five siltstone samples define an isochron with an age of 572 $\pm$ 20 m.y. This age is significantly older than the age of the Connemara Schists (520 m.y.). The 572 m.y. sedimentary isochron age records an age of isotopic equilibrium within the siltstones. This equilibrium could possibly have resulted during diagenesis, in which case the age would be close to that of deposition, or it could have occured during the later very weak greenschist metamorphism which has affected these rocks. This age however (572 m.y.) places a minimum age limit on the deposition of the Dalradian sedimentation in Connemara and requires the (520 m.y.) event recorded by the schists to be due to

metamorphism. We therefore interpret the 520 m.y. metamorphic event to be the regional high grade metamorphism (M 1).

This is in accordance with the age of the post-tectonic Donegal Granite (498 ± 5 m.y.) and the overlying unconformable Ordovician rocks.

Zircon samples were analysed from the Bens Quartzite and a sample of pelite from the Connemara Schists both suggesting a metamorphism in the vicinity of 500 m.y. (PIDGEON 1969). These zircons also have old lead components which indicate that the original sediments were derived from source rocks containing zircons with ages of at least 1000 m.y.

Summary and Conclusions

(a) The correlation of the geological events and the age determinations are given in the following table:

1.	Post tectonic granites of Connemara	420 — 400 m.y.
2.	Ordovician unconformity in North Connemara	490 ± 10 m.y.
3.	Donegal granites	498 ± 5 m.y.
4.	Ultrabasic-basic intrusion phase (M 2) of Connemara	515 ± 15 m.y.
5.	Regional metamorphism (M 1) in Connemara Schists	520 ± 30 m.y.
6.	Minimum age of deposition of Dalradian sediments in Western Ireland	572 ± 20 m.y.

(b) The main tectonic interval took place over approximately 20 m.y., from close to 520 m.y. to about 500 m.y., indicating that the structurally defined events are nearly contemporaneous. This result demonstrates that the duration of the Dalradian metamorphism in Western Ireland was short, reaching a single climax at ~ 520 m.y. A similar conclusion has been made by HARTE and JOHNSON (1969) who working on the metamorphic history of the Dalradian rocks in Scotland state that, "Temperature variation with time during a regional metamorphic event is suggested to approximate to a smooth curve with a single peak of higher temperature".

(c) The sequence of metamorphic and igneous events appear to be the same in both North East Scotland and Western Ireland (PANKHURST, op. cit., p. 118; MOORBATH et al., op. cit., p. 266). The identical age of basic igneous intrusions (515 ± 15 m.y.) and most post tectonic granites (400 ± 10 m.y.; BROWN et al., 1968) in both regions indicates that besides a parallel geological development the kinetics of the Caledonian orogeny in Scotland and Ireland were the same.

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