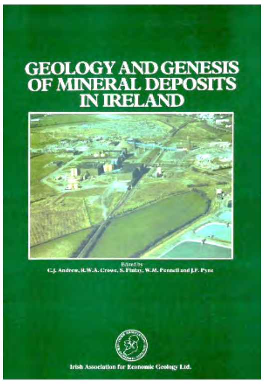

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A quantitative regional gamma-ray survey on the Main Galway Granite, western Ireland.

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Abstract

The results of a regional radiometric survey on the Main Galway Granite show that the radioelements K, U and Th increase with fractionation in the batholith. They also confirm the radioelement-rich nature of the Murvey Granite facies. Thorium is abundant throughout the batholith. The Main Galway Granite is a low to medium heat production granite, but the Murvey Granite at Costelloe has high heat production values.

Introduction

The radiometric survey is the initial part of an assessment of the potential of the Main Galway Granite as a source of geothermal energy. A Geometrics GR 410A four channel gamma-ray spectrometer was used on outcrops to determine the bedrock radioelement (K, U and Th) abundances throughout the Granite. This method assumes secular equilibration in the U decay series. The spectrometer has a 7.5x7.5cm NaI scintillation detector. It was calibrated at the Riso National Laboratory, Roskilde, Denmark.

The calibration method for gamma-ray assays on rock outcrop is based on large pad sources made of uniformly radioactive concrete which simulate outcrops of known radioelement concentrations. The overall error of a field assay using a spectrometer with known calibration constants is estimated to range from 5% to 10% on the K, U and Th channels (see Lovborg, 1984).

Spectrometer readings were calculated from the average of five two minute counts spaced at 1m intervals on flat outcrop. At least one determination was measured in each square kilometre in areas of good exposure. However, peat overburden in the central part of the Granite greatly reduced this density of coverage. A total of 661 determinations of radioactive K, U and Th were obtained during the survey, 640 on the Granite and 21 on the metamorphic rocks of the South Connemara Group.

Geological setting

The Main Galway Granite is a late-kinematic Caledonian intrusion with an age of approximately 400Ma (Leggo et al., 1966; Pidgeon, 1969). The Granite is exposed over an area of 600km^2 north of Galway Bay (Fig. 1). It is primarily composed of granodiorite, adamellite and granite, and was intruded as several major domal units (Max et al., 1978). These are the Carna Dome (granodiorite), Spiddal Dome (granodiorite) and the Galway-Kilkieran Dome (granodiorite, adamellite and granite). A fourth dome, the Roundstone Dome, was not covered by this survey. Three minor granodiorite plugs occur in the central zone, while numerous diorite xenoliths form a banded zone extending for 30km along the margin of the Spiddal Dome. The margins of the Granite commonly display a leucogranite (Murvey Granite) which passes inwards to less silicic granite (Errisbeg Townland Adamellite) which is a reverse zonation to that usually found in zoned granite bodies. The Murvey Granite also occurs in the central zone of the Granite, e.g. at Costelloe (Fig. 1).

A history of radiometric and radioelement studies on the Main Galway Granite.

Aucott (1968) studied the relationship between total gamma activity and geochemical variation and layering at the western end of the Granite. Coats and Wilson (1971), Lawrence (1975) and Feely (1982) presented K_2O%, Uppm and Thppm determinations for the several Galway Granite varieties in their respective areas. The U and Th abundances were obtained by whole rock XRF analysis and are susceptible to errors from inadequate lower limits of detection. Feely (1982) showed that the more evolved granites viz. Errisbeg Townland Adamellite and the Murvey Granite, fall outside the field of normal granites on a Th vs. U diagram. O'Connor (1981a) published the results of a nationwide gross gamma-count survey which showed that the Murvey Granite at Costelloe is one of the most radioactive granites in Ireland. Furthermore, O'Connor (1981b and this vol.) and O'Connor et al. (1983), in reviewing radioelement abundances in Irish granites, classified the Main Galway Granite as a radioelement-rich granite.

Uranium distribution was studied by Feely (1982) in nine thin sections of the Costelloe Murvey Granite. The method used is described by Kleeman and Lovering (1967) and involves the recording of induced fissions of ^{235}U on a solid state nuclear track detector called lexan plastic. The plastic is pressed flat on the polished thin section which is then irradiated and subsequently etched in 6M NaOH at 70°C for 8-10 minutes. The fission tracks are then clearly visible and are readily matched with the appropriate phases in the thin sections. The thin sections were irradiated for 24 hours and received a dose of 2.76 x 10^{16} thermal neutrons per cm^2 at the Atomic Weapons Research Establishment in Aldermaston, Reading, England. The results showed that U is sited in zircons within chloritized primary biotite (Fig. 2a) and also along grain boundaries and microfractures (Fig. 2b), both of which indicate the passage of hydrothermal fluids containing uranium through the granite after crystallization. In view of the high levels of U and Th in the Costelloe Murvey Granite, it is likely that U and Th are also located in primary resistate accessory phases (e.g.

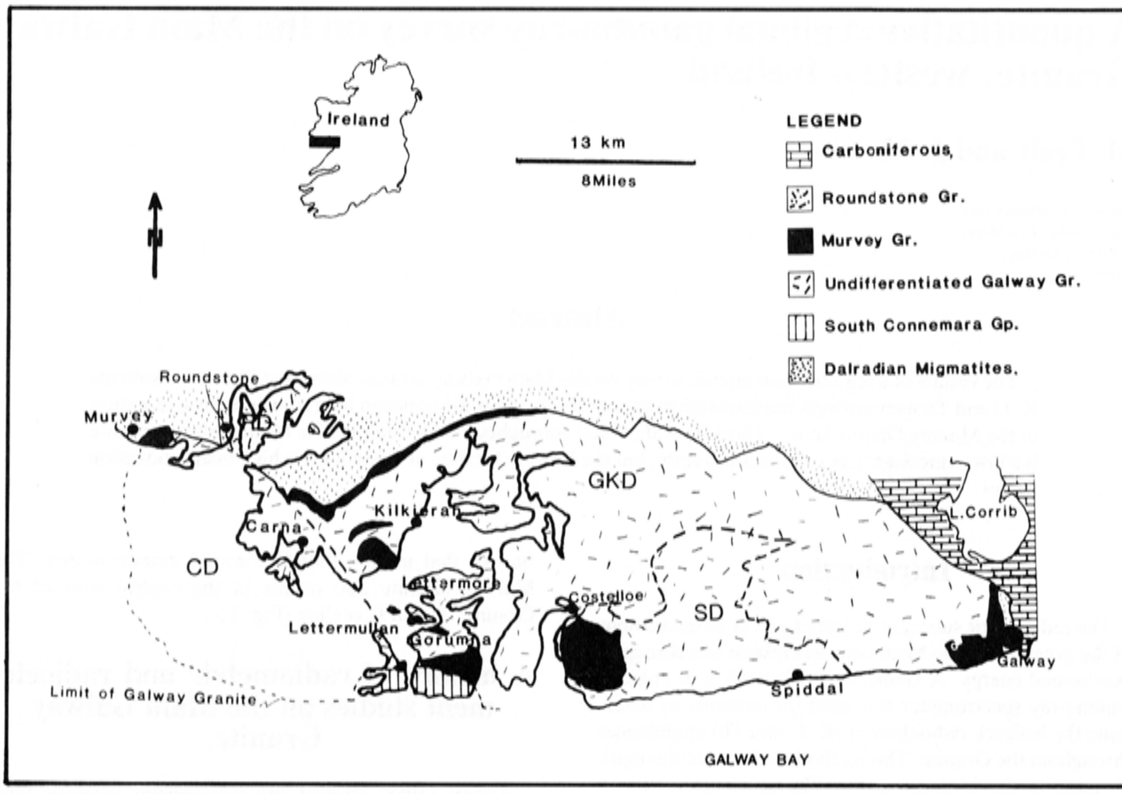

Figure 1. Generalized geological map of the Main Galway Granite. The domal units are outlined by dashed lines (CD=Carna Dome; GKD=Galway-Kilkieran Dome; SD=Spiddal Dome; and RD=Roundstone Dome).

Table 1.

Mean and standard deviations of K, U and Th and heat production estimates in the Main Galway Granite and country rocks. Determinations from each of the Murvey Granite locations sampled are also shown separately.

Unit	Lithology (No. of samples)	Mean and Standard Deviation			
		K%	U ppm	Th ppm	Heat Prod. μWm^{-3}
Spiddal Dome	Granodiorite (75)	3.20(.50)	4.66(1.84)	16.08(4.77)	2.67(.75)
Carna Dome	Granodiorite (50)	3.48(.45)	5.79(1.79)	17.22(4.62)	3.01(.71)
Galway-Kilkieran Dome	Granodiorite (140) Adamellite (262)	3.30(.55) 3.70(.36)	4.38(1.38) 6.39(1.52)	15.75(4.84) 22.10(3.25)	2.53(.50) 3.50(.52)
Banded Zone	Diorite and granodiorite (22)	3.11(.59)	4.47(1.83)	14.91(4.79)	2.48(.75)
Murvey Granite	Granite and alkali granite (74)	3.97(.40)	9.67(4.35)	32.91(8.40)	5.14(1.43)
Minor Plugs (Lettermore)	Granodiorite (6)	3.46(.50)	4.79(1.83)	17.96(4.78)	2.81(.75)
Granitic Dykes	Aplites, porphyries (11)	3.74(.49)	7.78(1.91)	33.68(5.79)	4.70(.85)
Country rock South Connemara Group	Metasediments and metavolcanics (21)	1.71(.66)	1.90(1.9)	6.95(5.54)	1.13(.86)
Murvey Granite	Costelloe (31) Lettermullan-Gorumna (23) Kilkieran (8) Carna (6) Murvey (6)	3.89(.50) 4.06(.50) 3.94(.50) 3.75(.50) 4.32(.51)	12.38(2.72) 5.43(2.23) 11.35(2.44) 9.10(2.32) 10.30(2.41)	41.21(7.6 3) 28.57(5.93) 24.11(5.85) 24.65(5.87) 26.65(5.89)	6.41(1.18) 3. 77(.91) 4.96(.95) 4.40(.93) 4.90(.95)

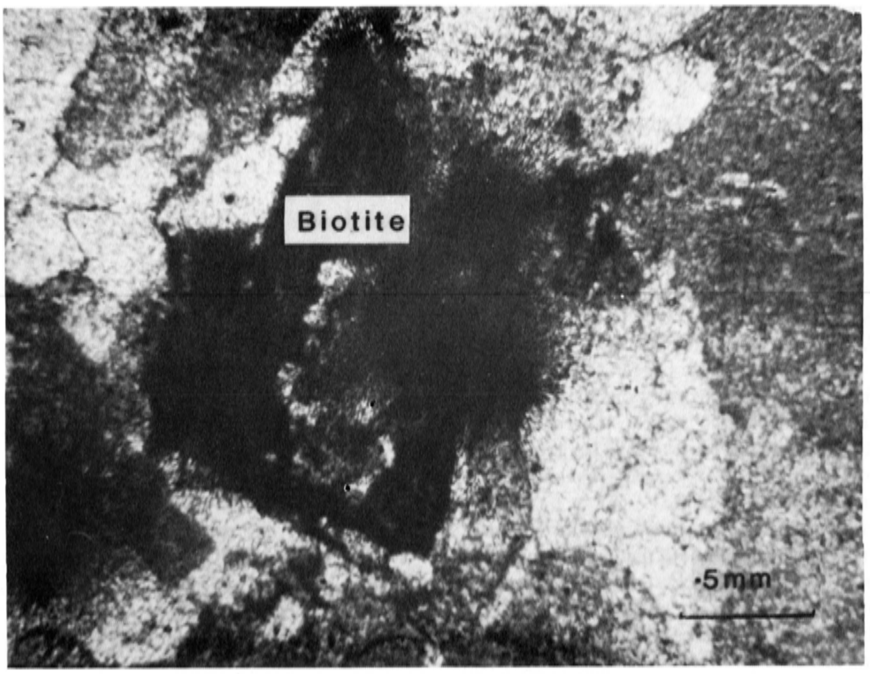

Figure 2a. Transmitted plane polarized light photomicrograph showing fission tracks associated with zircon inclusions in heavily chloritized biotite.

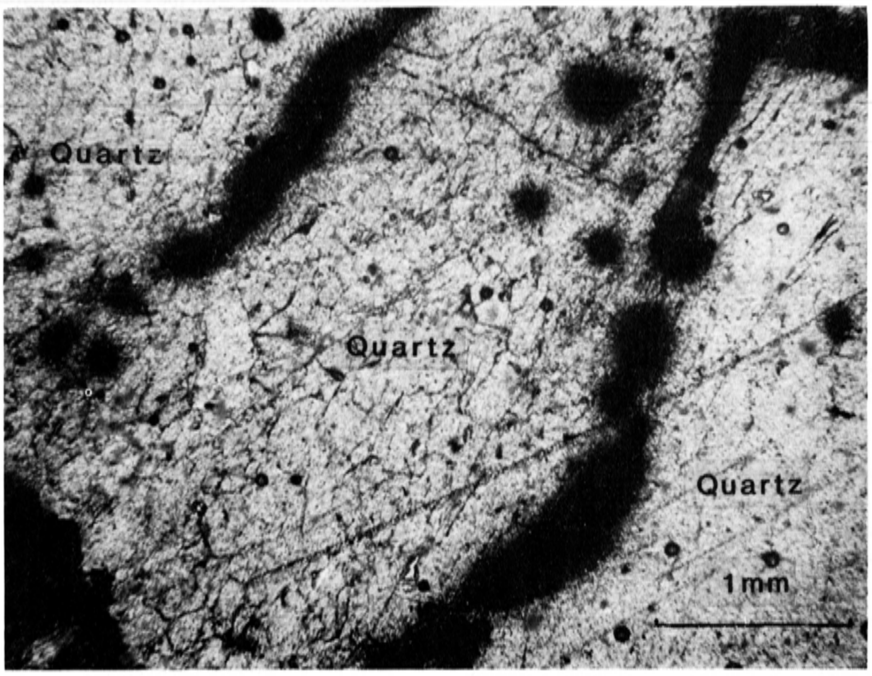

Figure 2b. Transmitted plane polarized light photomicrograph of fission tracks delineating grain boundaries along three optically discontinuous quartz grains.

uranothorite, thorite and monazite). However, no such phases were seen in the small number of thin sections studied.

Results of present studies

The radioelement determinations show that there is a progressive increase in activity from the least evolved granodiorites through the adamellite to the most evolved Murvey Granite and aplites (Table 1). This trend reflects the incompatible nature of U and Th and, to a lesser extent, K in early crystallizing fractions of granite magma.

The Th vs. U plot in Figure 3 confirms the radioelement-rich nature of the Murvey Granite facies, while the means of the other Galway Granite types plot outside the field of normal granites. Table 1 shows that the Murvey granites vary in activity, and range from the high activity of the Costelloe Murvey Granite to the lowest levels in the Lettermullan-Gorumna Murvey Granite.

The mean value for U in the Lettermullan-Gorumna Murvey Granite is approximately half that determined from the other Murvey Granite localities. Loss of U from this Murvey Granite to the South Connemara Group rocks may account for the relatively low abundance of U. Table 2 compares the mean radioelement abundances for the Main Galway Granite and the Costelloe-Murvey Granite with other Caledonian, Hercynian and Tertiary granites from Britain and Ireland. It can be clearly seen from this table that the Costelloe Murvey Granite is radioelement-rich, while the mean concentration of Th in the Main Galway Granite is high, being exceeded only within Britain and Ireland by some Irish Tertiary granites and the Caledonian Barnesmore Granite.

Mean heat production values (μWm^{-3}) for all rock types sampled are shown in Table 1. Heat Production A was calculated from the relationship $A=(0.0963 \times Uppm + 0.0264 \times Th\ ppm + 0.0358 \times K\%)p$ where p=rock density in Mgm^{-3} and A is in μWm^{-3}. These values reflect the combined radioelement (K+U+Th) abundances in each rock type. Table 3 shows the mean heat production from a range of granites. The Costelloe Murvey Granite is second only to the abnormally radioactive Conway Granite, New Hampshire (Fehn et al., 1978) and can be considered as a high heat production granite. The mean heat production figure for the Main Galway Granite as a whole indicates that it is a low to medium heat production granite.

The significance of these heat production estimates in terms of geothermal energy in the Main Galway Granite is difficult to quantify at this stage. However, the heat production associated with certain facies of the Granite (e.g. the Murvey and Errisbeg Townland varieties) compares favourably with the Cornubian batholith of SW England which has anomalously high heat flow ($120\mu Wm^{-3}$) and geothermal gradients in the order of $40°Ckm^{-1}$ (Wheildon et al., 1981). Gravity and heat flow modelling currently in progress will provide further information on the potential of the Granite as a source of geothermal energy. These models of course will have to take into account the apparent restricted development of the Murvey Granite within the space-form of the Main Galway Granite.

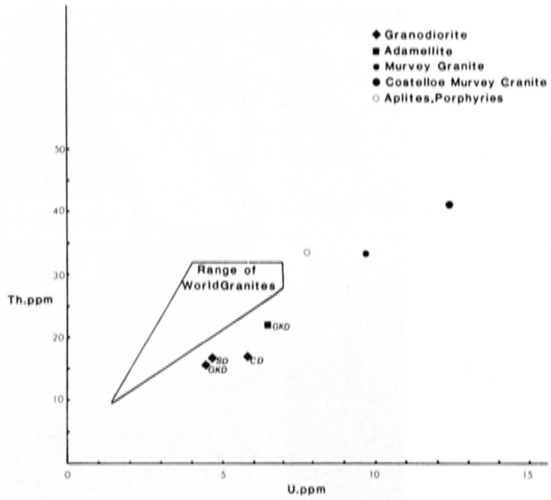

Figure 3. A Th vs. U plot using the mean values determined for the main granite types within the Galway Granite.

Table 2.

Comparison of mean K, U and Th abundances in the Main Galway Granite and the Costelloe Murvey Granite with other Irish and British Granites.

Granite (No. of samples)	Mean Radioelement Abundances		
	K%	U ppm	Th ppm
Main Galway Granite (640)	3.54	5.96	20.81
Costelloe Murvey Granite (31)	3.89	12.38	41.21
Other Irish Caledonian Granites (94)*	3.40	3.60	12.10
British Caledonian Granites (194)*	—	4.30	15.10
Irish Tertiary Granites (34)*	4.52	11.80	39.90
British Hercynian Granites (36)*	4.35	11.40	19.60

*O'Connor et al. (1981b, 1983). All U, Th data determined by epithermal neutron activation except the data for the British Hercynian Granites which were determined by gamma spectrometry. K has been determined variously by flame photometry, X-ray Fluorescence and by normal mixed spectrum activation analysis.

Table 3.

Comparison of mean heat production values in the Main Galway Granite and Costelloe Murvey Granite with other granites. (1) Brock (1979); (2) O'Connor et al. (1982); (3) Fehn et al. (1978).

Granite	Heat Production (μWm^{-3})
Main Galway Granite	3.31
Murvey (Costelloe) Granite	6.41
Weardale Granite (Britain) (1)	4.63
Cairngorm Granite (Britain) (1)	5.57
Cornubian Granite (Britain) (1)	4.68
Leinster Granite (Ireland) (2)	1.83
Conway Granite (New Hampshire) (3)	8.03

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