Two for the price of one: Doris Livesey Reynolds (1899–1985)

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Abstract: Doris Reynolds, known less commonly by her married name Doris Holmes, was an English geologist and petrologist. She is best known for her role in the Granite Controversy that started in the late 1930s and continued throughout the 1940s and 1950s, and particularly for her contribution to the concept of ‘granitization’ in the formation of granites. She was greatly influenced by Catherine Raisin, who introduced her to petrology at Bedford College for Women where Reynolds studied for her first degree. Throughout her career Reynolds worked on igneous intrusions and their associated metamorphism, with particular emphasis on the Newry Igneous Complex in Ireland. In her papers she detailed the sequences of chemical changes that led to granitization which she postulated occurred as a series of ‘fronts’. She argued that these fronts altered the sedimentary rocks through which they passed, eventually turning the sediments into granites or other igneous rocks, depending on the ions carried by the front. In 1939, she married Arthur Holmes; in 1949, she was among the first five women to be elected a Fellow of the Royal Society of Edinburgh, and in 1960 she was awarded the Lyell Medal by the Geological Society of London for her research, her original mind and her refusal to be cowed by the Establishment.

Doris Livesey Reynolds (1899–1985) was born in Manchester on 1 July 1899, her parents having moved from Belfast just before her birth. The daughter of Alfred Reynolds, a textile manufacturer, and Louisa Livesey, Reynolds had a sister and three brothers, one of whom was called Stanley, but little is known about her early life (Fig. 1). At some point her parents moved to Grays in Essex where Reynolds (Fig. 2) attended Palmer’s secondary school for girls. Sometime later they are known to be living at 3 Daines Close, Thorpe Bay1 (now Southend-on-Sea) – possibly her parents retired there.

In 1917, Reynolds entered Bedford College for Women, then based in Regents Park. There she studied geology under two of the most outstanding geologists of the time, Catherine Raisin (1855–1945) and Gertrude Elles (1872–1960) who were among the first women to be elected Fellows of the Geological Society of London. It was Raisin who first interested Reynolds in geology and from whom she inherited her love of petrology, while Elles stimulated her interest in the structural setting of crystalline rocks (Reynolds 1960, p. 96). Reynolds graduated with a first class degree in 1920.

Raisin’s research was primarily in the field of microscopic petrology and mineralogy, on which she published 24 papers between 1887 and 1905. Her first paper, concerning the metamorphic rocks of South Devon, was published in 1887, and is notable as representing an early attempt to recognize and map metamorphic facies (Reynolds 1945, p. 237). Raisin also strived for women’s equality in education, becoming the first female to study geology at University College London, the first female Professor of Science at Bedford College and the first female Head of the Geology Department at Bedford College, a position she held for 30 years. Reynolds retired in 1920 at the age of 65, and so Reynolds was one of her last students, but Raisin was greatly influential in guiding the direction of Reynolds’s research. In 1938, Reynolds wrote asking for a photograph of her friend who was then 83. Raisin’s reply is touching:

The photograph of which I have a few copies was taken by a photographer in Baker Street […]. Now I have three versions (one wearing the doctor’s hat, two in which I hold it). Of the two, I had one chosen, and have given the order to have it enlarged. […] If it is satisfactory I thought you would like that version, so that I am sending it. I hope, dear, you will accept it with my dear love and my thanks for your kind wish.2

In the photograph (Fig. 3) Raisin is wearing her doctoral robes; she received her doctorate in 1898,

1Envelope addressed to Reynolds at this address containing a letter from Susan Thompson, 30 April 1928. RHC AR PP21/18, Archives, Royal Holloway, University of London.

2Letter from Raisin to Reynolds, 28 February 1938. RHC AR PP21/9, Archives, Royal Holloway, University of London.


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so would have been 43 when the photograph was taken. The two women remained devoted friends and when Raisin died in 1945, Reynolds wrote her obituary in *Nature* (p. 327), saying:

The originality of Dr. Raisin’s teaching was in no respect better shown than in her celebrated lectures on petrographic provinces, which became the more fascinating since they were illustrated by practical work on rock specimens of her own collecting from many of the classic areas of Europe and North America. […] Rightly unbound by fashion in petrogenetic thought, as time has shown, she stood almost alone in Britain in stressing the work of Lacroix, Termier and Sederholm on granitization even at the time when crystal differentiation was beginning to hold the field as a major petrogenetic process.

Dr. Raisin will be remembered by her students, not only as a stimulating and enthusiastic teacher, who worked ungrudgingly to promote their interests, but also as a generous, brave and sympathetic woman whom they loved.

By all accounts, Reynolds was a highly capable and diligent student, as evidenced by this testimonial from Gertrude Elles written in November 1920 when Reynolds was trying to get her first post after completing her degree:

Miss Doris Reynolds is a very keen student of Geology in all its branches and in palaeontology which she studied under me at Bedford College all last year: she proved herself a most conscientious and hard-working student.

She possesses two important attributes for a successful teacher, her enthusiasm for her subject and a capacity for expressing herself clearly. Her position in the first class in the recent Honours Examination of London University is guarantee in itself of the character of her intellectual attainments.3

Such testimonials no doubt helped Reynolds obtain her first position as an Assistant in Geology at Queen’s University, Belfast, under Professor

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3Testimonial from Gertrude Elles written from Newnham College, Cambridge, November 1920. RHC AR PP21/1, Archives, Royal Holloway, University of London.
J. Kaye Charlesworth (1889–1972). There she lectured students, both men and women, supervised their practical work and accompanied them on field expeditions. Reynolds stayed at Queen’s for 5 years, during which time she obtained an MSc (1924). It was during her time in Northern Ireland that she developed an interest in the Newry Igneous Complex in County Down, on which she was to work and write extensively. Writing in 1942, she said she had spent the last 10 field seasons on the complex (p. 232), and she and her husband continued to go to Northern Ireland most summers for as long as their health permitted. It was also during this time that she met James Richey (1886–1968), who was working on the adjacent Tertiary Ring Complex of Slieve Gullion.

From Belfast, Reynolds moved back to Bedford College for Women in 1927, now under the professorship of Leonard Hawkes (1891–1981), as a Demonstrator in Geology, where she wrote her first paper in 1928. It was on the petrography of the Triassic Sandstone of North-East Ireland and in it she detailed her discovery of authigenic orthoclase (Reynolds 1928, p. 455). She and Hawkes also became lifelong friends (Fig. 4). In 1931, she moved to University College London to take up a post as Lecturer in Geology under Professor William Bernard Robinson King (1889–1963), and in February 1932 she was elected a Fellow of the Geological Society of London, being proposed by Catherine Raisin, William King, Leonard Hawkes and another female geologist of note, Emily Dix (1904–1972), with whom she had worked at Bedford College.

In the summer of 1931, James Richey invited a number of leading geologists to Ardnamurchan in Scotland to examine in the field his recently completed geological map of the Tertiary volcano. Both Doris Reynolds and Arthur Holmes (1890–1965) were on the trip, and it was there that they met for the first time. Holmes, some 9 years older than Reynolds, was then renowned for his work on radiometric dating and petrology (Lewis 2000), and Reynolds would undoubtedly have known his book Petrographic Methods and Calculations (Holmes 1921), a subject of great interest to them both. Two years later, Reynolds took up the post of Lecturer in Holmes’s geology department in Durham, and on 30 June 1939, 9 months after the death of Holmes’s first wife Maggie Howe (1885–1938), they married at Durham Registry Office (Lewis 2000, p. 176). A small party gathered afterwards at their large new house where, lying on the table, were printed cards stating that ‘For professional purposes Mrs Doris Holmes desires to continue to be known as Dr Doris L Reynolds’. This was a highly unusual pronouncement for the time and an indication of her determined independence, both academically and from convention. But their marriage was to have consequences neither anticipated.

For 6 years Reynolds worked as a lecturer in the department unhindered, even though everyone was aware of her affair with Holmes, but as soon as they married her reappointment was questioned:

The [Re-appointments] Committee agree that the work of Dr. D. Reynolds (Mrs. Holmes) in all respects justifies her re-appointment on the higher scale of salary. The Committee suggest that, before a recommendation is made, Council be asked whether or not they approve of the employment of husband and wife in the same Department.

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4Testimonial from Catherine Raisin, 30 April 1926. RHC AR PP21/1, Archives, Royal Holloway, University of London.


6Printed card. RHC AR PP21/1, Archives, Royal Holloway, University of London.
Incensed, Holmes leapt to his wife’s defence and wrote to the Chairman of the Durham Colleges Council in the strongest terms: 7

I can assure you beyond all possibility of doubt that in this particular case the Department has been strengthened rather than weakened [by our marriage], since we both have now more time to devote to it and to the development of our subject by research than was formerly possible. My wife’s career as a geologist is her dominant interest … and it would be a most unfair and cruel blow if Council passed any resolution that would lead automatically to her dismissal. Dr. Reynolds has an international reputation as one of the leading petrologists of this country and, I may add, she is the only member of the Science staff who has earned the degree of D.Sc. since the Laboratories were opened.[8]

Any man of similar achievement would already have been elected to a Professorship. If she had to leave, the Department would suffer a very grave loss, as it would be impossible to fill her place by anyone of comparable attainments, either as teacher or researcher.

When the Durham Colleges Council met later that week it was agreed that if the Board of Appointments recommended the re-appointment of Dr Reynolds ‘for an experimental period of one year’, the Council would agree. The couple must have been further offended by this condition imposed on them for, although Reynolds’s appointment was renewed, the following year they started to think about moving on. Nevertheless, her last years at Durham were highly productive and innovative.

The origin of granites

‘I have been particularly anxious about this subject of granite’ said James Hutton (1726–1797) in 1795 (Hutton, p. 90). Since the time of Hutton, the origin of granites had been one of the most difficult problems that geologists faced, as Holmes (1945, p. 412) exemplifies:

For a century and a half the origin of granite (including granodiorite) has remained one of the most intractable and controversial of the problems geologists have tried to solve. Fouque and Levy’s comment in 1882, that ‘it excites the most lively discussion’, is as true to-day as ever before.

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7The previous and following quotes in a letter from Holmes to Dr Appleby, Chairman of the Durham Colleges Council, 24 January 1940. RHC AR PP21/1, Archives, Royal Holloway, University of London.
8Reynolds obtained her doctorate from the University of London in 1937 (not 1927 as given in many online sources). Durham University Library, Archives and Special Collections, Arthur Holmes Papers. HOL 54.
During the early part of the twentieth century, discussion became focused on the question as to whether a given mass of granite had crystallized from an intrusive magma which mechanically displaced the pre-existing rocks, or whether it had formed from the pre-existing rocks by some process akin to ultrametamorphism. So although the igneous origin of granites was generally accepted, geologists argued as to whether granite magmas did or did not contain sufficient fluids to alter country rocks on emplacement of the magma.

Holmes (1945, p. 412) goes on to explain how these disparate views had come about:

Most of the older English-speaking petrologists of to-day were brought up, like myself, in the faith that granite, being by definition an igneous rock, must have crystallized from a magma; and many of us have had to rediscover for ourselves that the plutonic characters of granite are not in themselves a guarantee of igneous origin: a fact, long overlooked, to which Scheerer had already specifically directed attention so early as 1847. Still worse, we were left in ignorance of the stimulating ideas of the French school, or with the impression that they were old-fashioned and unworthy of serious consideration. Looking back, it is obvious that a carefully balanced historical introduction would have dispersed the fog of dogma and prejudice in which we were unconsciously groping. But no one had undertaken the arduous task of preparing such a survey, and in its absence enlightenment was slow and largely dependent on the luck of one’s personal experience in the field.

To put that into context: by the 1930s the Germanic view that magmas were hot and dry prevailed, while the French view, referred to above by Holmes, that granitic magmas were rich in dissolved volatiles capable of altering country rocks was largely ignored. Writing on the day that Paris was liberated by the Allies in World War II, 9 Robert Rastall (1871–1950), then editor of the Geological Magazine who had studied under the German school at Cambridge wrote: '[P]etrologists could not better celebrate the liberation of France from German tyranny than by reading [the literature of the French school] and giving it a fair and open-minded consideration’ (Young 2003, p. 352).

**Granitization**

In Reynolds’s first paper on the Newry Igneous Complex (Reynolds 1934) she does not specifically mention granitization, although in the discussion afterwards the term is used twice, indicating that it was already in circulation and understood, at least by those interested in such topics. But the controversy about its place in the formation of granites did not really take off until 1938 when Helge Backlund (1878–1958), Professor of Geology at the University of Uppsala in Sweden, published a paper that disclaimed the primary magmatic character of the Rapakivi granites and instead advocated granitization as the method by which they had been formed. Having assessed ‘sixteen well-known characteristics of these granites and their field appearances’, Backlund was led to the conclusion that they must have been formed at the expense of the Precambrian rocks into which they were intruded by a process akin to metasomatism, arguing that: ‘All other hypotheses lead to hopeless contradiction’ (Backlund 1938, p. 339). He suspected that variations in the chemical and mineralogical composition of the Rapakivi granites reflected the upward variation of the sedimentary rocks they replaced, and it was not long before many geologists around the world, including Reynolds, also identified rocks that had been ‘granitized’ in this way.

But what did granitization actually mean? As Harold Read (1889–1970), one of the chief supporters of the theory, said, ‘granitization means different things to different people’. To him it meant ‘the process by which solid rocks are converted to rocks of granitic character without passing through a magmatic stage’ (Read 1948, p. 9), while Peter Misch (1909–1987), the leading exponent of granitization in the USA, envisaged alkali-rich ‘emanations’ rising from the depths into a geosyncline and metasomatically granitizing the rocks by means of infiltration, permeation and diffusion (Young 2003, p. 361). For Reynolds, granitization depended ‘not only on the bodily introduction of magma, but on a complex series of ionic migrations’ (Reynolds 1947a, p. 210). But although there were many differences in the detail of what each understood by the term granitization, these ‘Transformists’, as Reynolds named them (Reynolds 1947b, p. 209), collectively agreed that no great volumes of granitic magma were involved in making the great granite batholiths, instead they were the product of piece-meal transformation of the country rocks, and therefore granites were only incidentally igneous.

An added difficulty associated with the intrusion of huge masses of granite magma was what became known as ‘the space problem’. How had large masses (batholiths) of granitic rocks come to occupy their present positions, and what had happened to the rocks that were previously there? The bodily intrusion of gigantic volumes of magma appeared to be mechanically impossible, so replacing the existing rocks by granitization was an appealing explanation. As Read (Fig. 5) put it: ‘The only

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925 August 1944.
solution is to suggest that in fact no large bodies of granitic magma were in existence. The large granite masses result from replacement, they are granitization products (Read 1944, p. 90).

Those in the opposite camp, known as the ‘Magmatists’, believed that field observations had established a body of geological evidence which supported the concept that granites were generated at some unknown depth within the Earth’s crust, and were emplaced at higher levels as mobile magmas, which then solidified to form crystalline granite. The observation of sharp, cross-cutting contacts, the occasional preservation of a pre-granitic roof and the recognition of contact thermal aureoles supported the concept, and gave rise to the acceptance of molten intrusive granite (Cobbing 2000, p. 109). The chief proponents of this theory were Pentti Eskola (1883–1964), a Finnish geologist who had developed the concept of metamorphic facies and who shared the Vetlesen Prize with Holmes in 1964, and the Canadian petrologist and geochemist, Norman L. Bowen (1887–1956). Based on experiments and field observations, Bowen established the crystallization sequence of a typical basaltic magma undergoing fractional crystallization, known as the Bowen reaction series, and argued that granite magma was the end product of the differentiation of basaltic melts.

The Newry Igneous Complex

In 1934, Reynolds published her first major work on the Newry Igneous Complex, a large exposure of Devonian granodiorite (c. 26 × 6 miles) that had been intruded into Silurian sediments. Following the work by Frederick William Egan (1836–1901) and Joseph Nolan (1841–1902), both of whom had worked for the Geological Survey of Ireland in the 1870s and 1880s, Reynolds had worked on trying to understand the mechanisms involved in the emplacement of the Newry Igneous Complex, which was more generally known as the Newry granite. From her training by Raisin who had introduced her to the concept of granitization, Reynolds was already primed to consider that the Newry granites had formed by the replacement of sediments when she started work there in the early 1930s. Indeed, as she pointed out (Reynolds 1944, p. 206), as early as 1872 Egan had said of the Newry granite (Egan 1872, p. 8):

> At its junction with the grits and shales of Silurian age, it in many places presents appearances which show clearly that it has been formed by the melting up of these rocks. [...] The whole mass has evidently undergone a process of extreme metamorphism, working upwards and outwards into the surrounding stratified rocks.

Over the following 10 field seasons she amassed a vast amount of geochemical and field data, and in the last few months at Durham before the couple moved to Edinburgh she wrote a major work on the granitization of the complex (Reynolds 1944), which brought to prominence her use of the word ‘fronts’ in the granitization process.

In the roof of the complex, basic and ultrabasic gabbros occurred which were hard to explain – either an ultrabasic magma had passed up through the granodiorite or they had occurred as a result of replacement of the country rocks. Reynolds contended that the gradational nature of the whole basic and ultrabasic series represented an Mg–Fe ‘front’ that had migrated upwards through the sediments in advance of an ‘alkali front’ which had produced the granodiorites. In other words, the solutions that formed the basic rocks had not emanated from a granite magma but from fronts of basic elements that had been expelled from the rocks being granitized to form the granodiorite. The whole process was initiated by a Na–Ca-rich front that turned the existing sediments into granodiorite, and once set in motion these fronts continued in a series of more or less concentric waves that explained formation of all the various parts of the complex (Fig. 6). The
granodiorite, she conceded, 'shows signs of having been magmatic’ but by this she appears to mean that it had been molten rather than a magma derived from depth in the sense that the Magmatists would have used the term. In her own words (p. 236):

[T]he basic and ultrabasic rocks, considered as a whole, represent the Mg–Fe ‘front’ that migrated upwards in advance of the alkali ‘front’ which gave rise to the granodiorites.

In the acknowledgements of this 47-page paper she thanked Holmes ‘for discussion and criticism which have helped materially in the construction of the paper’ (Reynolds 1934, p. 632); and in the discussion after she read the paper at the Geological Society, Holmes elucidated a number of the points she had made, illustrating how closely they worked together and understood each other’s work. Harold Read, also in the audience, was particularly complimentary about her ‘first class contribution’ to what he considered to be the most exciting petrogenetic problem of the present time – the origin of the plutonic rocks. He was particularly pleased to see that she had based much of her evidence on field observations, which he himself always argued in favour of, having preached for years that ‘the best geologist […] is he who has seen the most rocks’ (Read 1952, p. 420). Read also thought that Reynolds had provided excellent examples of the various fronts discussed, and that this mechanism – replacement and consequent adjustment of the expelled material – was, in his opinion, ‘the whole secret of the plutonic and metamorphic rocks’ (Reynolds 1944, p. 241).

Others, however, were more guarded in their praise and admitted they needed to read it again in more detail to better understand its complexity. James Richey said he did not understand the difficulty she had in explaining the presence of the gabbros and ultrabasics in the roof of the complex, arguing that there were many examples of the emplacement of magma heavier than the rocks they passed through, and that ‘Intrusion of magma under pressure was surely not a difficult conception in view of the many facts which found a satisfactory explanation in this way’ (Reynolds 1944, p. 242). But the most significant criticism came from James Phemister (1893–1986), who forced Reynolds to admit that she did not know the source of the emanations that had set the various migrating fronts in motion, and the only thing she could say by way of reply was that they must have come from a level below the granodiorite (Reynolds 1944, p. 246).

The Granite Controversy

In 1943, Arthur Holmes was headhunted for the position of Regius Professor of Geology at the University of Edinburgh. The Vice Chancellor, Sir Thomas Holland (1868–1947), was also keen to have Holmes’ wife onboard, ‘your bright fellow worker’, as he called her. While Holland was unable to offer Reynolds a position in the department, he did grant her an Honorary Research Fellowship so that she could continue to research her ‘hobby’. In fact, Reynolds had an international reputation as a research petrologist. Holmes was later to comment that Holland was getting ‘two for the price of one’, for Reynolds effectively became a full-time, but unremunerated, member of staff both lecturing undergraduates and mentoring PhD students. Furthermore, in 1949 she was among the first five women to be elected to the Royal Society of Edinburgh. Her proposers were all geologists of some eminence: Sir Edward Bailey (1881–1965), Robert

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10 Both quotes in a letter from Sir Thomas Holland to Arthur Holmes, 20 March 1943. RHC AR PP21/6, Archives, Royal Holloway, University of London.
Campbell (1881–1957), George Tyrrell (1883–1961) and James Richey.

Some 3 years after the couple moved to Edinburgh, the Granite Controversy was at its height. The Magmatists saw little reason to doubt that granitic rocks were overwhelmingly magmatic in origin in view of their intrusive relations, textures, thermal effects on country rocks, and evidence from a growing body of experimental work performed largely by Bowen and his colleagues at the Geophysical Laboratory in Washington (Young 2003, p. 368). Reynolds, Holmes and Read, on the other hand, had established themselves as the leading Transformists, and in April 1946 Reynolds furthered the cause of the granitizers with a comprehensive paper detailing the sequence of geochemical changes that led to granitization. The reason she provided for embarking on this extensive work, that must have taken her years to assemble, was that she had tried to compile:

[A] logical lecture course on the subjects of reaction, contamination, hybridization, assimilation, and granitization as related to granitic magma. [But] the subject is fraught with so many apparently inconsistent observations that the lecturer has to select illustrative examples with extreme care if the embarrassment of arriving at contradictory conclusions is to be avoided

(Reynolds 1946, p. 340).

In an attempt to ‘tidy up the subject’, she collected together all available chemical data from many granites around the world that related to the problem of the reaction of granitic magma with various types of country rocks, and plotted the results on numerous von Wolff diagrams. These were triangular diagrams on which von Wolff11 had delineated various fields in which rocks of certain types typically plotted, according to their chemistry. Reynolds tells us that the many ‘tedious computations’ involved in this work were carried out with the aid of a new calculating machine (Reynolds 1946, p. 436) which, incidentally, was the same Marchant calculating machine being used by Holmes for his final calculations on the age of the Earth (Lewis 2000, p. 203).

From analysis of the chemical data, she concluded that the emplacement of granitic intrusions was accompanied by a desilication and basification of the country rocks in the adjoining aureoles due to the introduction of alcalis and cafemic constituents. She argued that the changes took place irrespective of the nature of the country rocks, being found alike in igneous and sedimentary types. Inclusions of country rocks within the granitic intrusions were similarly desilicated or basified. The question then arose, of course, as to the source of these basic elements. Following an extensive review of the literature, two schools of thought emerged:

[O]ne believing mafic oxides to be of magmatic origin and derived from granite magma, the other regarding the Fe and Mg as constituents driven from country rocks which have been granitized

(Reynolds 1946, p. 433).

But, she argued, it seemed particularly unlikely ‘that the source is to be found in residual magmatic solutions consisting essentially of silica, iron, magnesia and water’, which ‘again suggests a forward diffusion and fixation of alcalis driven from and ahead of the zone of basification’. However, she still did not address what set the fronts in motion in the first place.

After Reynolds had read the paper at the Geological Society, Read again congratulated her on a clear presentation of the geochemistry of the granitization process and complemented her on demonstrating that the elements involved in desilication were driven from zones where granitization had been completed, and that the reality of fronts had now received very weighty support from her exhaustive analysis, Kingsley Dunham (1910–2001), who had been Holmes’s second PhD student, remarked that he had seen similar chemical changes in ore deposits in Montana. However, it was Arthur Holmes who congratulated the author ‘on her success in introducing law and order into what had hitherto been a wilderness of apparent inconsistencies’ (Reynolds 1946, p. 440). But, as before, there were others who were more critical, particularly Dr Noel Odell (1890–1987)12 who felt that there was ‘too hasty acceptance of the doctrine of granitization’ as taught by what he termed ‘the modern school of “emanationists”’ (Reynolds 1946, p. 441).

John Stuart Webb (1920–2007), the so-called ‘father’ of applied geochemistry but then a young man of 26, reminded Reynolds that questions regarding the nature of these emanations had frequently been put to supporters of the granitization theory but, as yet, they still remained unanswered. He expressed further concern that with the lack of experimental data it was always going to be difficult to find an explanation, and joked somewhat disparagingly that ‘even a convincing speculation would be of material assistance to the cause of the “Huttonwits”’. Nevertheless, an extremely positive review subsequently published by Sergei Tomkieff (1892–1968) considered the paper ‘would eventually occupy a very important place in the history of

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12Odell had been on the 1924 Everest expedition in which George Mallory and Andrew Irvine famously perished during their summit attempt.
petrogenetic ideas. The value of this work is twofold’, he explained:

On the one hand, Dr. Reynolds ‘tolls the knell’ of the passing theory of ‘magmatism’ as an all-embracing explanation of the origin of all plutonic rocks, and, on the other hand, she provides a new and most powerful support to ‘transformism’ as applied to the processes of granitization.

As a result, he believed, not only would a redefinition of petrogenetic terms be necessary, but also ‘the reorientation of our thought along new lines’ (Tomkiewicz 1947, p. 140).

The following year, 1947, Reynolds published three more papers on granitization (see Appendix A of this paper) and then one that reviewed the entire Granite Controversy (1947b). In this she argued that much of the disagreement between the two groups arose from a misunderstanding of Transformist views by the Magmatists and a ‘lack of knowledge or experience of the evidence on which they base their conclusions’ (Reynolds 1947b, p. 209). She insisted that the Transformists did not deny the existence of granitic magma and that, if anything, they actively maintained that the transforming processes could lead to the formation of magma, given the appropriate conditions of pressure and temperature (Young 2003, p. 364). Indeed, she went on to suggest that Transformists might be tempted to preface their writings with a very apposite quotation from Abraham Werner (1749–1817), written in 1781:

I must here present a request to all who would judge of this theory, or communicate their sentiments on it to the public, … to begin by reading through the whole treatise, and then to peruse it a second time, with attention. Such a request will not only appear strange to many persons, but even superfluous; I find myself, however, under the necessity of making it from the manner followed by some individuals [who] have often represented me as saying quite the contrary of what I have expressly written. This may have been done by some, through design, but in by far the greater number of instances, it has happened from that work not having been read through.

Both Reynolds and Holmes were extremely knowledgeable about the history of their subject and their day books are full of such quotes from eminent figures in the history of geology. Continuing her historical theme, Reynolds reasoned that as Hutton had deduced the existence of a heat source at depth simply on the basis of field evidence, although he was not able to identify that source, then why should Transformists not be able to discover the fact of granitization on the basis of field evidence, even though they did not yet have an explanation for it? Adding, as Playfair had said in defence of Hutton’s theory (Playfair 1802, p. 188):

We are not entitled, according to any rules of philosophical investigation, to reject a principle to which we are fairly led by an induction from facts, merely because we cannot give a satisfactory explanation of it.

Although accepting that new ideas will always be challenged and that criticism was inevitable, she was affronted when Cecil Tilley (1894–1973), then at Cambridge, wrote disparagingly of her:

[C]onjuring with von Wolff diagrams, ill suited for the purpose, […] a critical field study taken in time might perhaps have saved her from this strange and fanciful version of the Cornish geological record. I do not propose to dwell further on so gross an error – it may well be left to seek its own level in the heavy score of misrepresentations already standing to the credit of ‘front’ petrology (Tilley 1947, p. 119).

In addition, Bowen called her basic front a ‘basic affront to the intelligence of the geologic fraternity’ (Bowen 1948, p. 88). Reynolds retaliated by condemning such disdainful disregard for serious science ‘merely as authoritarian bluff of no scientific interest’ (Reynolds 1947b, p. 212). It is interesting to speculate whether such derision also had something to do with the fact that she was a woman.

Later that year, in recognition of the important work accomplished by the Finnish geologist Eskola, the Geological Society of Finland published a volume dedicated to him on the occasion of his 65th birthday and retirement. Holmes and Reynolds (Fig. 7) were invited to contribute, which they did in one of only two joint papers they ever wrote together. It is concerned with the effects of chemical migrations in the Malin Head district of Donegal and reiterates their views on granitization in this context. But, given Eskola’s position as a Magmatist and the auspicious occasion, it is rather surprising to read their closing paragraph (Holmes and Reynolds 1947, p. 63):

The minds of most petrologists have been so conditioned by training and practice that ‘granite’ inevitably suggests ‘granite magma’. This psychological tyranny should be consciously realised and deliberately resisted. If in any given occurrence, the magmatic hypothesis is found to be supported by evidence, it should most certainly be adopted. If it is not so supported, then a critical examination of the relevant criteria is likely to lead to further discovery. To avoid any possible misconception as to our own attitude, it should perhaps be added that we are in no way prejudiced against magma in its proper place, but only against facile and unrealised assumptions.

The controversy rumbled on for at least another decade during which time Eskola published a series of papers in which he explained some changes in his views concerning the origin of granite and, as Reynolds expressed it, ‘his concessions to the transformists’ (Reynolds 1958, p. 386). Bowen and
others, however, remained entrenched in their views, and in 1958 Reynolds felt compelled to react to the statement that the Transformists were not interested in applying geochemical and geophysical knowledge to the granite problem (Reynolds 1958, p. 378). This misunderstanding had probably arisen when Read had pronounced ‘I have to confess that I never did understand what many of the triangles meant’ and ‘I have, in fact, a great deal of sympathy with the Victorian statesman in the matter of those “damned dots”’ (Read 1951, p. 6, 1957, p. 345). But Reynolds and other Transformists who were more conversant with triangles and dots resented Read being their spokesman, a position he had taken on himself somewhat to their irritation. In fact, Reynolds at one time felt so marginalized that she was forced to buy herself ‘one of these modern high hats like a witch. I thought that if I kept that on at the meeting I could not be overlooked’ (Lewis 2000, p. 213).

In the same 1958 paper, Reynolds also refuted a statement (p. 378) made the previous year at an Inter-Collegiate Geological Congress held in Edinburgh that:

I myself am supposed to think that granite is not intrusive. This is the more surprising because I was the first in the country to map … the planar lineations in a granite mass (the Newry granodiorite), my object being to test the view held by some of my elders that the planar structures resulted from dynamo-metamorphism; in fact, I found that they depicted flow.

She was, indeed, the first to recognize that such lineations represented flow within a granite melt (Reynolds 1934, p. 595). Searching to explain ‘the astonishing misunderstanding and misrepresentation of my work’ (Reynolds 1958, p. 379) she went on to again review developments in understanding the formation of granite since the time of Hutton. This once more reveals her deep and wide-ranging knowledge of the subject and its history, even though:

[It is not possible, in a brief paper, to recapitulate all the relevant evidence disclosed by a variety of techniques, yet it may perhaps help towards mutual understanding if I attempt, in summary form, to correlate on broad lines some of the tectonic, petrological, and physicochemical aspects of the problem in the light of present-day knowledge.

The controversy came to a close in the early 1960s after publication of a Geological Society of America Memoir (Tuttle and Bowen 1958) that reported the results of experimental studies by Frank Tuttle (1916–1983) and Norman Bowen (Fig. 8) on granitic melts, from which they concluded that their experiments confirmed the formation of granite from crystalization of a basaltic liquid. Despite this, Tuttle later presented a persuasive case that large batholith masses of granite had likely to have been generated by the partial melting of older sediments and metamorphic rocks in a zone of melting deep within the crust which, he argued, would solve the space problem.

After the Controversy

The Granite Controversy occurred before development of the theory of plate tectonics, a concept that enlightened our understanding of many geological processes. Today, we know that granites tend to
form at convergent plate boundaries which we only began to understand in the 1960s, despite Holmes postulating similar ideas in the late 1920s (Holmes 1931). After more than 60 years of study since the Controversy, it is now believed that granitic magmas form from the fractional crystallization of basaltic melts, and/or the assimilation or melting of continental crust. This lighter melt rises towards the surface until it reaches a point where it cools and eventually stops moving. But there is still debate about ‘the space problem’ and the mechanism by which batholiths are emplaced.

So, on balance, the Magmatists won the argument. However, it is important to recognize that the accepted understanding of granite formation does not in any way negate the value of Reynolds’s work, nor that of any other Transformist. Holmes considered that science moves forward by erecting ‘wickets to be bowled at’: that is, by postulating new (often controversial) ideas which he hoped would stimulate new ways of thinking about a particular problem (Lewis 2000 p. 160). Undoubtedly, Reynolds was of the same mind and with Reynolds in the lead on this occasion they together erected the wickets of granitization and basic fronts for others to bowl at. The 20 year controversy this caused unquestionably progressed the understanding of granite formation.

At the age of 60, Reynolds was awarded, belatedly, the Lyell Medal by the Geological Society of London. In presenting her with the medal, the President of the Society, then Professor Cyril St Aubyn (1901–1999), said:

Dr Reynolds is perhaps best known to students of petrology for her writings on granitization, and especially for her development and advocacy of the doctrine of ‘fronts’. Dr Reynolds has been a formidable participant in the lively discussions which have [raged]13 – and continue – concerning the validity of these processes and their importance in large-scale crustal phenomena. In making this award the council marks its appreciation not only of the value of her investigations in the field and in the laboratory, but also recognises the stimulation given to workers in our science by the meditations of an original mind, unawed by the prestige of the ‘Establishment’

(St Aubyn 1960, p. 95).

Reynolds replied stating how deeply conscious she was of the honour conferred on her, adding that it gave her particular happiness that the medal bore the name of Lyell for:

[N]ot only did Lyell set a seal on transformism by inventing the word *metamorphic* but he especially encouraged women to become actively interested in geology

(Reynolds 1960, p. 96).

The Lyell Medal is normally given to someone who has made a significant contribution to the science by means of a substantial body of research14 but in the 84 years before Reynolds received it the medal had only been awarded to three women.15 Perhaps even more shocking is that in the 60 years since Reynolds, only six women have been deemed sufficiently worthy of the honour, and in the 28 years between 1976 and 2004 not a single woman received it. Statistics for the Wollaston Medal, the highest honour awarded by the Geological Society, are even worse with only two women ever having been awarded it since its inauguration in 1831, and both of those were in the last decade (Burek 2020).

Reynolds continued her acceptance speech by thanking those who had particularly helped her in her career – Professor Boswell, Professor Hawkes and Sir Thomas Holland – and, of course, her husband, Arthur Holmes, saying:

I shall very proudly put this medal with his many medals [16] and it will be an ever-present encouragement to me to try to add one or two more stones to the edifice that was so magnificently begun by Hutton and Lyell

(Reynolds 1960, p. 96).

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13 ranged’ was actually written but I assume this was a typographical error.
15 It was first awarded in 1876.
16 Holmes was awarded 11 medals (Lewis 2016).
While all this was undoubtedly true, it must have taken the edge off the occasion to see one of her great rivals in the Granite Controversy, Cecil Tilley, receive the Wollaston Medal.

Reynolds had many letters of congratulations, a number of people having seen the announcement in The Times, including a David Williams who wrote to say it was ‘quite the most cheerful item of news [even] excelling the call off of the railway strike’.17 Harold Read also wrote, commenting that it was well overdue ‘but still, they have done the right thing at last’.18

Never afraid of controversy, Reynolds did not allow received conventions of petrological interpretation to shackle her originality of thought, and she continued to make a unique contribution to the development of geology throughout her long and productive career. She published her last paper in 1961 and when she retired in 1962 the couple moved from Edinburgh to a flat in Putney, London, and Reynolds was made an Honorary Research Fellow of her alma mater, Bedford College for Women. They were living in London when Holmes died in 1965. Even in her later years, when no longer researching on her own behalf, she was much occupied in updating Holmes’s second (1965) edition of his Principles of Physical Geology and in her 80th year this third edition was published. A fourth edition came out in 1993, edited by Donald Duff who had been one of Reynolds’s students. Reynolds had earlier (1969) published an abridged version, designed for use in schools. After completing this she had intended to write her own book on granites entitled Granite: A Geological Quest but, unfortunately, it was never finished. In a letter to James Shepherd of the publishers Thomas Nelson and Sons, written in January 1967, she anticipated finishing the book towards the end of 1969 and says:

Please do not think, on account of the long delay that there has been over this book that it is liable to fall by the way as I know many books do. It is my greatest remaining ambition to complete the book…’.19

Unfortunately, no draft was found amongst her papers. In her latter years, Reynolds’s health deteriorated and she suffered a major heart attack in 1983, although she recovered from it surprisingly well. She died in her sleep at her home in Hove on 10 October 1985 at the age of 95, having outlived her husband by 25 years.

Reynolds (Fig. 9) was very approachable and greatly loved by her students, always making time for them and enlivening their discussions with her fund of anecdotes. She retained her vivacity into her old age and, in her mid-60s, surprised many of her friends by acquiring a car, learning to drive and travelling the country,20 thereby exemplifying an adage she liked to live by: ‘One must learn as long as one is living’ (Reynolds 1958, p. 379).

Fig. 9. Doris Reynolds. RHC AR PP21/19, Archives, Royal Holloway, University of London.

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17Letter from David Williams to Doris Reynolds, 13 February 1960. RHC AR PP21/1, Archives, Royal Holloway, University of London.
18Letter from Harold Read to Doris Reynolds, 17 February 1960. RHC AR PP21/1, Archives, Royal Holloway, University of London.
19Letter from Doris Reynolds to James Shepherd of Thomas Nelson and Sons, 17 January 1967. RHC AR PP21/1, Archives, Royal Holloway, University of London.
20Obituary of Doris Reynolds by George Black, one of her students. Durham University Library, Archives and Special Collections, Arthur Holmes Papers. HOL 54.
Data availability  Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

Appendix A: Publications by Doris Reynolds


Reynolds, D. 1959. The viscosity of rock-glass of granitic composition under various physical conditions: A correction and an addendum. *Geological Magazine*, 96,
References