

The contribution of women to Welsh geological research and education up to 1920

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ABSTRACT

The importance of Welsh geology to the development of the science of geology and the stratigraphic column is underestimated and indeed the contribution of women to this process is largely overlooked. This paper explores the scientific contribution and the role that women played to the investigation of Welsh stratigraphy. The work of Gertrude Elles, Ethel Skeat, Ethel Wood and Margaret Crosfield, the so-called Newnham quartet of palaeontologists, and the educational contribution of Dilys Davies, the first female to study geology at Newnham College, Cambridge and of Annie Greenly to the work of her husband Edward Greenly on Anglesey is discussed. Catherine Raisin also contributed work on the metamorphic rocks of Wales and her work is examined. Without their contributions, Welsh stratigraphy would not be as advanced as it is today especially in the use of graptolite identification for correlation. However, scientific research was not the only contribution and other roles such as illustrators, proof readers, field assistants and teachers will also be examined against the background of the time. The fact that there were few higher education institutions in Wales at the time admitting women to geology is a significant factor for geological research. The contribution of female researchers to this research development is largely forgotten by both researchers, educators and the general public. This paper hopes to rectify these omissions.

Keywords: Wales, Women geologists, Welsh geology, education,

1. Introduction

This main aim of this paper is to show the importance of female researchers and educators to research within a Welsh context and to raise the awareness of women's geoscientific contribution at a time when women researchers were few and far between in the UK. The research is ongoing and new discoveries of important contributions by women to this challenging and dynamic time in the Earth Sciences will continue to happen.

Within the broader context of female education the important turning points were 1870 and 1875 which firstly introduced the Elementary Education Act (1870) initiating universal public elementary education in place of private schools and secondly in 1875 the admittance of women into universities (Burek 2009a). The first dictated the need for teachers to be trained and the second gave a mechanism for that process to happen. The Welsh context for that to happen will be covered in section 3.

Wales and Welsh geology have played a key role in the developmental history and understanding of stratigraphy as shown by the naming of the base of the geological Phanerozoic timescale, *i.e.* Cambrian, the Roman name for Wales. This is widely recognised internationally by geologists but the general public living in Wales, let alone the rest of the UK, do not realise the importance of their country's contribution to scientific knowledge. This is coupled with a general lack of understanding of the role that women played in the development of geoscience (Burek & Higgs, 2007a ; Higgs pers. comm.2014), whether in Wales or across the UK. This research on both raising public awareness of the Welsh contribution to geological research and the role of women in its development, was initially developed for the Welsh Assembly Government (WAG) funded Welsh Women's road show (2009–2010) and has since then been expanded. The main female drivers for this research lived outside Wales; Gertrude Elles, Ethel Skeat, Ethel Wood, Margaret Crosfield, Catherine Raisin, Annie Greenly, Dilys Davies, Mary Johnston, Helen Drew and Ida Slater but some did move into the Principality during the time period under study.

1.1 Development of Welsh stratigraphy

The importance of Welsh stratigraphy is shown by the contributions of Roderick Murchison (1792–1871) and Adam Sedgwick (1785–1873) which are legendary (Secord, 1986).

However the violent disagreement between them about the Cambrian/Silurian boundary was only resolved after their deaths by Lapworth (1842–1920) with the introduction of a Mid Lower Palaeozoic Period: the Ordovician proposed by Lapworth in 1879 and accepted by the Geological Community in 1906 (see Table 1). This name comes from a Welsh Iron Age tribe (Figure 1 and Table 1).

Table 1
The Lower Palaeozoic timescale

Era	Period	Origin of name	Origin
Lower Palaeozoic	Silurian	Welsh Iron Age tribe	Sedgwick & Murchison 1835 Global recognition 1839
	Ordovician	Welsh Iron Age tribe	Lapworth 1879 Global recognition 1906
	Cambrian	Roman name for Wales	Sedgwick & Murchison 1835

The role that women have played in this stratigraphic research is less well-known. Two women in particular played an important part in the stratigraphic story: Gertrude Elles (1872–1960) and Ethel Wood later Mrs. Shakespear (1871–1945). Their work is constantly referred to by researcher but many people do not know that they are female as their seminal work is always referred to by their surnames - Elles and Woods (1901-1918).

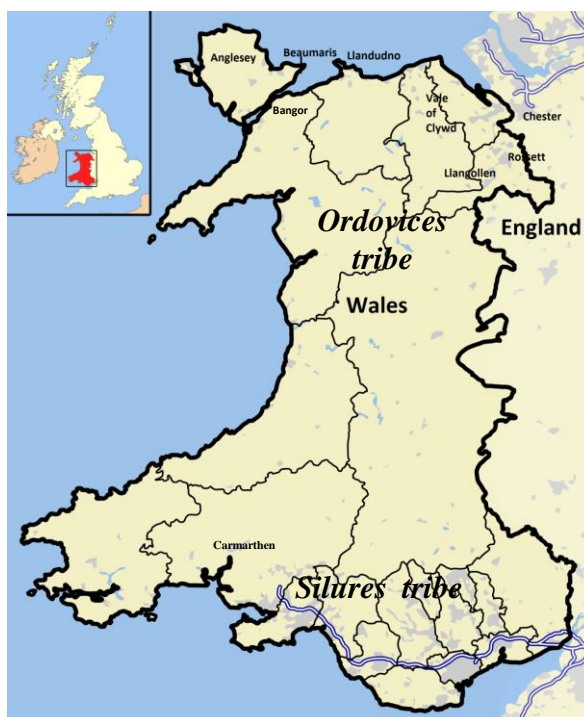


Figure 1.
Map of Wales showing locations mentioned in text and Iron Age tribes.

Alongside the development and naming of the stratigraphic column, North Wales and more specifically Anglesey (Figure 1) have contributed to the understanding and occurrence of some of the oldest rocks in the UK. The associated metamorphism, especially the serpentinites, that accompanies rocks of that Precambrian age was researched by Catherine Raisin (1855–1945) with Professor Bonney (1833–1923) of University College, London, (Bonney and Raisin, 1899; Burek, 2004). Raisin’s work on the petrology of this group of rocks advanced the whole understanding of metamorphic fabrics and serpentinite mineralogy.

Other women have also helped forward the understanding of Welsh geology through their different roles and the contributions of Margaret Crosfield, Ethel Skeat, Annie Greenly, Dilys Davies, Helen Drew and Ida Slater and Mary Johnston will be highlighted later.

2. The wider context of women's roles within geology

The roles that women have played in the development of the history of geology has been extensive and various (Burek and Higgs, 2007a). They have acted as collectors, indexers, and educators to illustrators and researchers. Their research was rewarded by medals and financial awards by the Geological Society of London but despite these achievements, it was only after 1919 that the Geological Society finally admitted female members to read papers and collect their research awards. (Burek, 2009a). Research conducted by female geologists was presented by their male colleagues (Table 2). The use of the funds to forward research when appropriate within Wales is discussed in the write up of the individual female geologist.

Table 2.
Medals and funding awarded to early female Fellows of the Geological Society 1893–1920.

Year	Name	Fund	Accepted by
1893	Catherine Raisin	Lyell £24 16s 3d	Professor Bonney
1900	Gertrude Elles	Lyell £19 6s 0d	Professor McKenny Hughes
1904	Ethel Wood	Wollaston £34 6s 10d	Professor Marr
1906	Helen Drew	Daniel Pigeon	
1907	Ida Slater	Daniel Pigeon	
1908	Ethel Skeat	Murchison £25 8s 4d	Herself
Medal			
1919	Gertrude Elles	Murchison	Herself
1920	Ethel Wood Shakespear	Murchison	Herself

However their contribution has not been widely recognised by the general public, academic researchers and educators in general, (Burek and Higgs, 2007b; Creese and Creese, 1994.). This low profile of geology being recognised as the fourth science is highlighted by the lack of geology in the national curriculum. Recent research presented at the Royal Society WISENet conference (May 2014) *Revealing lives: Women in science 1830-2000*, shows the lack of knowledge of female scientists across Europe (Higgs pers. comm. 2014). The book *Bluestockings: The Remarkable Story of the First Women to Fight for an Education* by Jane Robinson (2009) does not even mention science in the index let alone geology.

The lost or forgotten women of Ireland associated with geology and museum curatorship, for example, have been described by Higgs and Wyse Jackson (2007). The contribution of women to saurian research has been extensively studied by Turner, Burek and Moody (2010). But to date no one has researched and brought together the contribution that women have made to the history, education and development of geology or wider geodiversity in Wales (Creese and Creese, 1994).

This paper seeks to address this omission, by looking at the contribution of women working on Welsh material during the latter part of the nineteenth and the early years of the twentieth century up to 1920. The paper will deal first with the roles women played in Wales before embarking on an in-depth look at some of the main female drivers. This is followed by an analysis of their contribution to the wider picture.

3. Women's roles - The Welsh context

To date, few papers have been published specifically on Welsh geology and women (Oldroyd 1993, Williams 2007). Those doing substantial work on Welsh stratigraphy have been

Gertrude Elles (1872-1960), Margaret Crosfield (1859–1952), Mary Johnston (1875–1955), Helen Drew (1881–1927), Ethel Skeat (after 1910) Mrs. Woods (1865–1939) and Ethel Wood (after 1906) Mrs. Shakespear. For clarity as both Ethels have very similar names their maiden names will be used throughout except where quotes from others dictate otherwise. Catherine Raisin worked on Welsh petrology and serpentinites (Burek, 2004, 2007, 2009a, 2009b; Burek and Malpas, 2007). The important research of Emily Dix (1904–1972), who was born on the Gower Peninsula, South Wales, graduated with a first class Hons. geology degree from University College Swansea (1925) but who worked just outside our time period (her first paper was published in 1927), must be acknowledged for her internationally recognised contribution to coal stratigraphy (Burek, 2005; Burek and Cleal 2005). The roles and contributions these women played within the rise of geology has been summarised in Table 3 but the importance of their publications will be expanded upon in later section.

Table 3 Summary table of the roles and contributions by the women detailed above.

Name	Dates	Perceived role and contribution in Wales	Principle location
Gertrude Elles	1872-1960	Educator Researcher	Cambridge University
Ethel Wood	1871-1945	Researcher	University of Birmingham
Margaret Crosfield	1859-1952	Researcher Collector Archivist	Reigate
Ethel Skeat	1865-1939	Educator Researcher	Queen's school Chester
Catherine Raisin	1855-1945	Educator Researcher	Bedford College
Annie Greenly	1852-1927	Writer	Anglesey
Dilys Davies	1857-1932	Women's Education	Bangor
Mary Sophia Johnston	1875-1955	Photographer, Archivist Researcher	London
Helen Drew	1881-1927	Educator Researcher	Colston's Girls school, Bristol
Ida Slater	1881-1969	Educator Researcher	Bedford College

Many other women undoubtedly contributed to the development of Welsh geology during the nineteenth century but are lost to history.

3.1 Tertiary Education in Wales

The fact that there were no women geology researchers born and bred in Wales during this time period is perhaps an indication that there were no institutions of higher education which had or allowed female geology students. Lampeter University was founded in 1822 by royal charter, and was the oldest degree awarding institution in Wales and the third oldest in England and Wales after Oxford and Cambridge. The university was founded as St David's College (*Coleg Dewi Sant*), becoming St David's University College (*Coleg Prifysgol Dewi Sant*) in 1971, when it became part of the federal University of Wales. However it was originally a theological college catering for male students and did not teach geology.

The oldest institution of higher education in Wales was founded in 1872 as University College Wales, Aberystwyth. Women were admitted in 1884. Owen Thomas Jones (better known as O.T. Jones) became the first Professor of geology in 1910. The second oldest university in Wales was founded in 1883 as the University College of South Wales and Monmouthshire, now Cardiff University. In 1885, Aberdare Hall in Cardiff was opened by the strong advocate of female education, Eleanor Sidgwick (Principal of Newnham College, Cambridge). This was the first female

hall of residence, allowing women easier access to the university. However the School of Earth and Ocean Sciences was not established until 1891. Cardiff also has the distinction of appointing the first female professor (in Education) in the UK, Millicent McKenzie in 1904. This highlights the importance of the contribution of Dilys Davies to the educational gender issues of teaching not only science but more specifically geology in Wales. Bangor University College had been set up by Royal Charter in 1885 opening its doors to both male and female students in 1886. It granted University of London degrees until 1893. However there was never a geology department *per se* and this subject was taught within the auspices of chemistry, agriculture, botany and later oceanography. The fourth member of the University of Wales at this time was University College Swansea given its Royal Charter in July 1920. Eight female students formed part of the first cohort to be admitted. One of the first departments was geology with Head of Department Dr. Arthur Trueman. It was to this department that Emily Dix went three years later as one of only two females to study geology and botany. Dr. Mary Williams (1883-1977) became the first woman to be appointed to an established Chair at a UK university when she became Professor of French language and literature at University College Swansea in 1921.

Wales is shown as being marginally less conservative than its English counterparts in being early in appointing women to positions of authority in tertiary education.

It is interesting to note that two of the university colleges in Wales were strongly supported by working applied geological professions. Swansea had support from the coal mining industry and Bangor University in the north was financially supported by the quarrying industry. Indeed the opening of the university was heralded by a procession of quarrymen.

4. Female research contributions to Welsh geology

The importance of female contributions to Welsh geological research at this time (1887–1920) is palpable. Of the female sole or co-authored papers in the *Quarterly Journal of the Geological Society* up to 1924 (this later date is taken because of the time lag taken to research, present and publish papers), 11 specifically mention localities in Wales. The authors were Catherine Raisin, Jane Donald (1856-1935) Gertrude Elles, Ethel Wood, Helen Drew, Ida Slater, Ethel Skeat and Margaret Crosfield. All these women with the exception of Ethel Skeat had never lived in Wales and none were born Welsh. Jane Donald, later Mrs. Mary Jane Longstaff, was Scottish the rest were English (Burek, 2009a). These women along with Mary Johnston, Annie Greenly and Dilys Davies not only made significant academic contributions to Welsh research but also played pivotal roles in advancing knowledge through collecting, recording, photographing, editing manuscripts, educating students and providing field assistance. They often had to work alongside men who either ignored them or considered their contributions trivial and society in general had a problem with women working in the field or undertaking field excursions (Burek 2007). Later we will see how the Geological Society and British Geological Survey did in fact regard their contributions as important. The fact that some of the research, especially that of Elles and Wood and Ida Slater is still cited today (over a century after the original research), is justification indeed.

4.1 Newnham quartet of palaeontologists

Gertrude Elles (Figure 2), Ethel Wood (Figure 3), Margaret Crosfield (Figures 4 and 5) and Ethel Skeat (Figure 6) have been termed the Newnham Quartet of Palaeontologists by Burek (2007). They were all students together at Newnham College, Cambridge University, during the late 1890s (Newnham College, 1923) and all studied geology under the watchful eyes of Dr (later Professor) John Marr (1857–1933) and Professor McKenny Hughes (1839–1917). These four women all advanced the understanding of Welsh geology through their published papers with Ethel Wood publishing under her married name of Shakespear (Elles, 1900, 1904; Elles and Drew, 1906; Shakespear, 1906; Skeat and Crosfield, 1896; Wood, 1900; Wood and Elles, 1896). They tended to work in two pairs with Elles and Wood producing their seminal treatise on graptolites over twenty years (Elles and Wood, 1901–1918), while Crosfield and Skeat concentrated more on the stratigraphy and structure which was informed by the palaeontology (Burek and Malpas 2007).

However there is ample evidence in the Margaret Crosfield archives that they all helped each other with identification and verification of fossils and stratigraphy after their undergraduate studies (Burek and Malpas 2007).



Figure 2.
Gertrude Ellis.



Figure 3.
Ethel Wood.

The Newnham quartet made significant contributions to the advance of more than just Welsh stratigraphy and palaeontology. This was acknowledged not only through their publications (see references), some of which are still regularly cited even today, but also by the awards and grants bestowed by the Geological Society of London (Table 2). This was a testament to their peer recognition.

The citations for the awards and the medals they received have been quoted in full to show the esteem in which their work on Wales was held in, by their mostly male peers. The citations are taken directly from the Geological Society journal proceedings.

Gertrude Elles 1900 (Lyell Fund)

President William Whitaker (1835-1925) to Professor Hughes (who was collecting the award on her behalf)

Miss Elles gave special attention to the Graptolites and we have had from her a paper . . . adding much to our knowledge of the characters and range of those fossils followed by the still more important paper on the Graptolite fauna of the Skiddaw slates . . . This has been followed by a paper as yet unpublished in which her knowledge of the Graptolites is applied to the zonal classification of the Wenlock shales of the Welsh Borderland. We hope that this award from the Lyell Geological Fund will show her that her work is valued (Whitaker, 1900).

Gertrude Elles 1919 (Murchison Medal)

President George Lamplugh (1859-1926) to Gertrude Elles (on accepting her own award)

[I]n awarding the Murchison Medal to you, the Council desires to acknowledge the importance and sustained efficiency of your efforts in advancing Geological Science. Your skill as a field geologist has been proved by your excellent stratigraphical work done partly in collaboration with your colleagues Miss Wood and Miss Slater, on the older Palaeozoic rocks of Wales and the Welsh borders, a region

presenting a severe test, both physically and mentally, to the endurance of its investigators. The results, embodied in successive papers published in our journal between 1896 and 1909, have served to clarify our knowledge of the structure and rock sequences of these difficult tracts . . . You and your co-worker Dr. Ethel Wood (Mrs Shakespear) have earned the gratitude of stratigraphers and palaeontologists alike by your patient and exhaustive studies of the Graptolites . . . Not only as an investigator but as a teacher and inspirer of others, your influence has been serviceable in the advancement of our science . . . (Lamplugh, 1920).

Ethel Wood 1904 (Wollaston Fund)

President Charles Lapworth to Professor John Marr (accepting the award on her behalf)

The Council have awarded to Miss Wood the balance of the Proceeds of the Wollaston Donation Fund as an acknowledgement of the value of her contribution to our knowledge of the Graptolites and of the rocks in which these organisms occur. Her papers furnish an excellent example of the application of zonal stratigraphy to groups of rocks which were thought to be already known with tolerable completeness. (Lapworth, 1904)

Ethel Shakespear as she is cited in the citation is actually Ethel Wood 1920 (Murchison Medal)

President George Lamplugh to Ethel Shakespear (on accepting the award)

[Y]ou have produced a monograph of British Graptolites which is and will remain of the utmost service to all students of the Palaeozoic rocks. . . . Fortified with your Palaeontological knowledge your fieldwork on the Silurian rocks of the Welsh borderland . . . has taught us much regarding the sequence & correlation of this difficult system. (Lamplugh, 1920)

Ethel Skeat 1908(Murchison Fund)

Normally collected by their male colleagues, they did exceptionally allow Ethel Skeat to collect her award in person in 1908.

President Sir Archibald Geikie (1835-1924) to Ethel Skeat

The Council has this year awarded to you the balance of the proceeds of the Murchison Geological Fund as a mark of appreciation of your geological work, especially among the glacial deposits of Denmark and the Lower Palaeozoic rocks of Wales. It is with much gratification that we hail in you another woman who is worthily placed on the roll of those who have gained our Awards. (Geikie, 1908)

The foregoing citations by eminent geologists of the day show without doubt the esteem in which these female geologists were held in for their pioneering work in Wales. Indeed some of their research, such as Elles and Wood (1901–1918) and Ida Slater (1907) is still widely cited (Leme et al. 2008), Storch and Loydell, 1996; Wang and Zhang, 2010) and is the authoritative work today.

However a detailed assessment of their geological work remains outside the scope of this paper as it covers more than just Wales and can be read elsewhere (Skeat and Crosfield 1896; Elles and Wood 1906-1918 ; Creese and Creese 1994 ; Burek, 2007; Burek and Malpas 2007; Burek 2009) However in the Geological Society awards and medals citations, the women are praised for their academic achievements, which are often based on their work inside Wales. Their contributions to both the mapping and the understanding of the palaeontology especially graptolite evolution, classification, and the subsequent analysis of stratigraphy, is recognised.



Figure 4.
Margaret Crosfield being used as a scale by Mary Johnston near Much Wenlock, Shropshire, 1913.



Figure 5.
Margaret Crosfield (second left) on a Geologists' Association field excursion to Leith Hill, Surrey, 1912.



Figure 6.
Ethel Skeat (right) and Margaret Crosfield (middle) at Oswestry, 1908.

4.2. Catherine Raisin

The educational role of Catherine Raisin (Figure 7) is well documented elsewhere (Burek, 2003a, 2003b, 2004, 2007, 2009a, 2009b,) but her specific contribution to the understanding of the geology of Wales has not been widely appreciated or extensively evaluated (Oldroyd 1993, 1996). The discovery of serpentinites on Anglesey, Wales (the other well-known occurrence being on the Lizard Peninsula in Cornwall, England) was researched by Raisin though she and Professor Bonney called them serpentines in the literature (Bonney and Raisin, 1905). Nowadays this is the accepted *mineral* name (Conway, 2010). Serpentinite is the rock name of an altered form of an ultrabasic intrusive rock, produced by the hydrothermal break down of olivine and pyroxene (Tregus, 2008). Raisin undertook the fieldwork while Professor Bonney, as he got older and less mobile, preferred to do the microscopy (Bonney and Raisin, 1894, 1899). He acknowledged this in their joint paper of 1905 to the *Quarterly Journal of the Geological Society* (Bonney and Raisin, 1905). The work they did together was sometimes in conflict with another geological mapper of North Wales, John Blake (Oldroyd, 1993, pp. 563–569). Often they did not see eye to eye with their interpretations of the stratigraphy and the age of the rocks (Raisin, 1891), as is shown in their published maps of 1893 and 1894 (Oldroyd, 1993, p. 569). However, the research she did with Bonney did increase the attention and contributed to the debate about the Archaean rocks of North West Wales. Catherine Raisin also wrote extensively on the petrology and mineralogy of the Lleyn Peninsula in North West

Wales (Raisin, 1889, 1893). This work advanced the debate on the age of the rocks in this area with detailed petrological research. Recognition of this was achieved and rewarded by Catherine Raisin being the first ever woman to receive a financial fund by the Geological Society of London. Professor Bonney who had worked with her on the work collected it on her behalf and himself recognises the contribution she has made by adding his own statement.

Catherine Raisin 1893 Lyell Fund

President Wilfrid Hudleston (1828-1909) to Professor Bonney (on accepting the award on her behalf)

Miss Raisin's excellent work, both in the field and with the microscope, so far commends itself to the Council that they have readily made this Award to a pupil of whom you must be justly proud. The considerable number of papers which that lady has contributed. . . all within the last six years—is a proof of her industry . . . and excellent knowledge of Petrology (Hudleston, 1893).

Her acknowledgement was read by Professor Bonney

It is difficult for me to express the gratification which I feel at the honour that has been conferred upon me by the Council of the Geological Society. It gives me also peculiar pleasure to receive an award associated with Sir Charles Lyell . . . who by the terms of his Bequest gave evidence of his interest in the intellectual work of women and even anticipated that they might in the future take part in scientific investigations. . . .

I welcome this recognition as an encouragement, not to myself only, but also to other women who are working at Geology and at different branches of Natural Sciences.

Professor Bonney then added

Here I might sit down but I cannot forbear from expressing my personal gratification at being chosen to represent so earnest and conscientious a worker.



Figure 7.
Catherine Raisin at North Collegiate School, 1877.

Raisin collected serpentinites from all over the world from the Vosges Mountains in France to Sweden. She also had rocks sent to her from as far afield as southern Abyssinia (Raisin, 1903). By 1905 her collection numbered 174 specimens from Anglesey, seventy-nine specimens from Vosges and twenty-seven specimens from the Brenner district (Bonney and Raisin, 1905). Her work on the mineralogy of these rocks developed a greater understanding of peridotite weathering from the lower part of what today we regard as lithological plates. She worried extensively about what would happen to her collection when she retired (originally to be before World War I but finally in

1920) as she felt her collection was unique (Burek 2003b). Current research work by Japanese scientists working alongside British researchers, is still using the material first collected from the turn of the 20th Century. The scientists seek to further understand the processes involved on the western part of Anglesey which is often considered an analogy for an old Japanese island arc (Conway, 2010). A recent international conference in the Anglesey Geopark (August ,2012) adds to this debate, which it could be argued was originally started by Bonney and Raisin (Wood, 2012). However Raisin is better known for her education and staunch belief in equality of higher education for women. She supported geology careers for women, often helping women financially to attain their full potential (Burek, 2007) while also giving them the chance to undertake research with her on Welsh geology. An example of this is Ida Slater (1881–1969 see below).

4.3 Annie Greenly (1852–1927)

The story of Annie Greenly's contribution to the advance of geological understanding on Anglesey through her role as wife assistant (Creese and Creese, 1994) is described in some detail by David Oldroyd (1993) and further by Terry Williams (2007). However she is included here as she represents a role that none of the other women represent. Her contribution as a wife assistant in Wales is crucial to our modern understanding of Anglesey geology.



Figure 8.
Annie Greenly. From an oil painting by Gertrude Coventry. (Greenly 1938, Vol. 1, frontispiece).

Annie Greenly (Figure 8) was born Ann Barnard on 8 June 1852 at 2, Cleveland Place, Bath. She was inspired to become interested in geology after an extraordinary experience at the age of eleven. One night she was woken by a violent shaking of the house. She calmly informed her grandmother 'that's an earthquake!' In fact it was the Force 6 earthquake of 6 October 1863 whose epicentre was near Hereford. Annie first met her husband to be, Edward Greenly (1861-1951), in 1875 at his family's house in Bristol when he was only 14 years old and she was 23years. They got on extremely well together and eventually became engaged in 1879. However after the engagement was broken off they did not meet again for eleven years. Edward Greenly studied chemistry at University College London but after a Welsh walking holiday with friends where he became enthralled by the local geology, he changed to geology under Professor Bonney. On completion of his studies, he joined the Geological Survey in Scotland. It was on leave in 1890 that he found himself in Bristol and met Annie once again. They rekindled their romance and married in 1891

when he was 30 years old. For two people passionate about geology, it was an integral part of their relationship. In fact while preparing to go on honeymoon, Annie decided that she would like to familiarise herself with her new husband's vocation even more

We have agreed that I am not to be ignorant of your subject . . . I can begin by reading. Put into our luggage some lucid elementary books?.

These books included Alfred Jukes-Browne's *The Student's handbook of Historical Geology* (1886) and Alexander Greenly's *Physical Geology* (1882). Greenly adds in his autobiography that he reserved Annie's tuition in metamorphism to himself (Greenly, 1938). It was in Scotland in 1891-92 that Annie decisively influenced the development of her husband's mapping and surveying technique. Although Greenly is principally recognised for the quality of his mapping which embodies the famous 'green line method', he acknowledges Annie's influence his work

had known [C. T.] Clough's maps for three years before it occurred to me to emulate them. It was my wife Annie who sowed in me the seeds of aspiration and steadily sustained me for thirty-five years in effort after improvement of my methods. (Greenly and Williams, 1930).

In his autobiography, Greenly expanded on this:

It has been supposed that my inspiration was the wonderful mapping of Clough. Such however was not the case. True, when once I began to aspire [to a higher standard of geological mapping] it was the maps of Clough which became my models. *But the initial source of my inspiration was no other than Annie Greenly* [Greenly's italics]. Let Clough be your model in precision, but do not follow him in style. Found your style on nature's curves. Watch these wherever you can and where you cannot see them, feel them. To be true, a map must be beautiful (Greenly, 1938).

Thus the green line method was born, without which the Anglesey survey and mapping would have been incomparably inferior. Each exposure would be shown on the map with its own grass-green edging on the outer side. It was always clear which lines on the map were actually visible on the ground (*i.e.* within a green line contour) or inferred (Williams 2007).

In 1895 the Greenly couple moved to Anglesey to start mapping the island. For Edward Greenly this would take 25 years. Annie Greenly, acting as a wife assistant (Creese and Creese 1994), took charge of the logistics; organising lodgings and facilities. The main survey phase was completed at Porth Eilian near Amlwch, on 8 October 1910. However, some additional fieldwork was necessary, including a week-long survey of the remote Skerries islands in July 1911.

At the outbreak of the First World War in 1914, Edward and Annie Greenly left their house near Treborth, close to Menai Bridge and took a succession of lodgings around Anglesey to enable Edward to revisit various key sections as his writing progressed. Annie worked with him. She read each manuscript page, correcting in greater or lesser degree.

Some sheets she pronounced to be hopeless and these, no less than 127 in number, she rewrote altogether . . . we worked on opposite sides of the table, I writing, she *doctoring* (Greenly 1938, p. 325).

It is clear that much of the fine prose quality of the Anglesey Memoir is due to Annie's work (Greenly, 1938). The *Memoir* was complete in manuscript by the end of 1915 and the couple decided to leave Anglesey for London, mainly to see the work through the publication process. Annie undertook the onerous job of constructing the index to the Anglesey Memoir. It had to be written on individual slips of paper, threaded on individual lengths of string for each letter of the alphabet (Williams, 2007). In all there were 1,879 subjects with 10,799 page entries. This index is preserved in the National Museum of Wales and is a testament to Annie's persistence and logical mind-

After completing the Anglesey survey, the couple lived in Bangor. Greenly continued his work on mainland Wales, now the county of Gwynedd. In 1926 he undertook the writing of a short

elementary textbook entitled *The Earth*. The publisher set very strict limits to the size of this introductory volume, no more than fifty-four pages (Williams, 2007). Greenly found this impossible to achieve and turned again to his wife. She was adamant.

This book is extremely difficult to write . . . condensation is excessive . . . [but] being for the general reader *it must be absolutely lucid* and . . . of living interest, or [they] will not read it. I [shall] go through it . . . (Greenly, 1938, p. 368).

This was her last geological undertaking. She completed her meticulous reading on 21 February from what was to be her death-bed, for only days later, on 1 March 1927 she died from heart failure at the age of seventy-five.

It is appropriate here to discuss briefly about how Edward Greenly's career provided a backdrop for Annie's contribution to Welsh geology. Edward had worked with the Geological Survey for a number of years, but after meeting Annie (and being accompanied by her in the field for some time) he decided to resign from Government work and they both retired to Anglesey. An opportunity arose for them to work together as the island had not yet been surveyed in detail by the official Survey. In his uxorious autobiography, Greenly (1938) described how his wife kept him up to the mark for many years and insisted on the immaculate delineation of boundary lines. When the work was completed it was published as an official Survey Memoir (Greenly 1919), even though its author was no longer an official surveyor. It is interesting that Greenly's units and the boundaries were 'immaculate' but the whole sequence was inverted as the use of 'way-upness' criteria based on current bedding, *etc.*, had not yet been recognised. However, it is said that all that needed to be done to correct Greenly's map was to reverse the order of strata in the key!

Annie Greenly was not a professional geologist but by offering to first learn some geology, and then help her husband with his work especially on Anglesey, she proved herself invaluable (Oldroyd 1993). Without her help, Edward Greenly would not have been able to complete his work as efficiently or as quickly. She finished editing his book called *The Earth* only a week before she died in 1927. Her important role as a writer, indexer and editor show how Annie Greenly helped with the advancement of geological knowledge of Anglesey.

4.4 Dilys Davies (1857–1932)

Another female who like Catherine Raisin believed passionately in female education was Dilys Davies. Her contribution as a great force for female secondary and higher education in Wales, including science, which would have undoubtedly contained geology because of her educational background reading geology at Cambridge, is important. Dilys was born in London of Welsh parents, her father, a sculpture, being born in Merthyr Tydfil and her mother in Barmouth. Her mother was born a McKenny the daughter of a baronet who became lord mayor of Dublin. Although they spoke English at home they were bilingual and spoke Welsh in their local chapel in London. Dilys was educated at the Home and Colonial Coeducational School and the North London Collegiate School. Her cousin was Professor McKenny Hughes, the Woodwardian Professor of Geology in Cambridge, which he had taken over from Adam Sedgwick in 1873. He retained this position until his death in 1917. This may have influenced Dilys's choice of subjects at university.

She was reputedly the first female to study geology at Newnham College, Cambridge (1877–1878) along with botany and chemistry but a photograph of the Newnham College class of 1877–1878 shows Dilys Davies holding a geological hammer along with another student (Figure 9).

This attendance was a whole two years before Margaret Crosfield, the first female fellow of the Geological Society (Burek, 2009a) and another early Newnham geology student. Early photos often show students holding a symbol of their chosen study. However, Davies only spent a year at Newnham College, Cambridge having achieved a distinction in both Geology and Botany. She left to become a teacher at her former school, North London Collegiate School under Miss Buss. This was a great opportunity for her as she wanted to further the opportunities for female education Wales. Davies spent ten years here teaching mainly botany but also chemistry. There is no evidence

that she taught geology as a separate subject but clearly she would have used her geological knowledge in her lessons (pers. Comm. Archivist North London Collegiate School, 2012).

She also acted as a champion for female education at all levels in Wales (Davies, 1887a, 1887b), establishing the Society for Promoting the Education of Women in Wales in 1887 in the process. An interesting note here is that when she left the school, Catherine Raisin, another former pupil, took over her position of teaching Botany (North London Collegiate School archive) in 1889.



Figure 9.

Dilys Davies with a group of students at Newnham College, Cambridge 1877 showing two geological hammers around her. She is in the back row second from the right.

At the same time as teaching, Davies was concerned about the methods and teaching materials within science education and in 1886 produced *Botanical Tables for use in schools*, published by Lakeman in London (Davies, 1886). It ran to three editions with the last in 1892 being published under her married name and with a slight change of title *Botanical tables as used in the North London Collegiate School for Girls* (Glynne-Jones, 1892). Her knowledge of geology helped her overall understanding of landscapes and the role of botany within it.

In 1887 the Welsh National Eisteddfod was held in London. As Davies was bilingual having Welsh parents, she was able to participate in this festival and the competitions. She won the *Cymmrodorion* Society literary award for her presentation on Higher Education of Girls. This society is still in existence having been formed in the eighteenth century to preserve the Welsh language. On 13th January 1887, Dilys Davies addressed the Welsh National Society of Liverpool on 'The Problem of Girls' Education in Wales'. This presentation was published as a fourteen-page pamphlet for the Association for Promoting the Education of Girls in Wales (Davies 1887). Her contribution to Welsh female higher education is acknowledged in the Gareth Evans review of Welsh education in 1991 which opened the door for women to study geology at university along with other sciences (Evans 1991).

In 1889, she married John Glynne-Jones (1851-1946), a long-term friend and moved to Bangor, North Wales where they had five children. Dilys was a formidable force for Welsh female education, served on many committees and eventually became a governor of the University in Bangor in 1925. Her papers in the Bangor University Archive (Table 4) are a wealth of information about education and the fight for female education emancipation. Following the success of the Welsh Intermediate Education Act in 1889 and the setting up of Local Councils in the same year,

female education in Wales received a boost. After helping to set up secondary and tertiary education in Bangor she served as a governor on both the Boys and Girls Grammar school (1895). Her insistence that not only single girls should be educated but also married ones, was unusual at the time but held sway as she herself could be seen as a role model. While she did not directly contribute to the research of geology *per se* in Wales she opened the door for other female students to pursue geology as a subject if they wished. In this respect her role and contribution is important.

4.5 Mary Sophia Johnston (1875–1955)

Mary Johnston (Figure 10) was among the first group of women elected to become fellows of the Geological Society on 15 May 1919 (Burek, 2009a). She was born in Folkestone in Kent the second daughter of Reverend W. A. Johnston but on his early death the family moved to Wimbledon in South London. She was educated privately and then became a geology student at one of the London Colleges. Mary had a lifelong interest in geology and she was a staunch member of the Geologists' Association (GA), holding several different positions ranging from librarian to photographer on field excursions (see Figure 5). She was a great friend of Margaret Crosfield and they did extensive fieldwork together (Johnston and Crosfield, 1914). It is here that her work in Wales and the Welsh borders comes to the fore. She considered herself a palaeontologist and was a member of the Palaeontological Association and the Zoological Association. However her legacy to research in Wales is her photographic archive, which is housed with the GA. It has already been used to research women's fieldwork and travel in the later nineteenth and early twentieth centuries (Burek, 2007; Burek and Kölbl-Ebert, 2007). Her work is a unique record of fieldwork, locations and fieldtrips undertaken by the GA when photography was in its infancy as a recording medium and in this regard she is a pioneer. This archive has been discussed in the literature (Carreck, 2007) and is in the process of being housed at the British Geological Survey in Keyworth, Nottingham as part of the national geological archive (Larwood, pers. comm. 2012).



Figure 10.
Mary Johnston.

4.6 Helen Drew (1881–1927)

Helen Drew (Figure 11) was the daughter of Frederick Drew, the geology master at Eton College and he instilled in Helen an interest in his subject. She went to Cambridge in 1900 and graduated in geology in 1904. In 1906 she was awarded the Daniel Pigeon Fund from the Geological Society, a fund aimed at young researchers (Burek, 2009a). The following year her colleague and friend Ida Slater, was also awarded this fund. During 1906 and 1907 Ida Slater and Helen Drew used this money to study the Caradoc and Llandovery rocks of South Wales to the north of the research area of Thomas Crosbie Cantrill, (1867–1931), a Survey geologist. They were looking for stratigraphic boundaries based on graptolite evidence using the work of Gertrude Elles and Ethel Wood. This led to a paper in the *Quarterly Journal of the Geological Society* (Table 3) three years later (Drew and Slater, 1910). It is cited by T. Neville George in his paper on the development of the Towy drainage basin in 1942 as still being relevant, over thirty years later. The importance of their research is key to the understanding of the stratigraphy of the area. Afterwards, like Dilys Davies, her role changed and Helen Drew became a very successful secondary teacher in Bristol, Bradford and Croydon eventually returning to Colston's Girls school in Bristol to become head mistress. She died at the young age of forty-six (Newnham College archives).

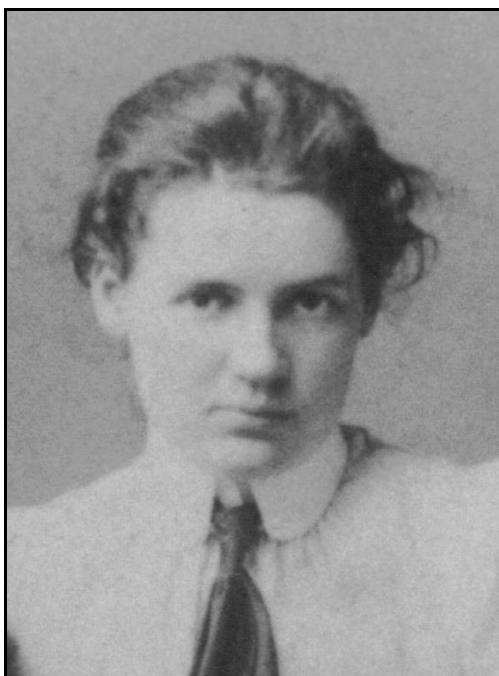


Figure 11.
Helen Drew at Newnham College, 1900.

4.7 Ida Slater (1881–1969)

Ida Slater (see Figure 12) was born in London, the daughter of an architect. After attending Newnham College at the same time as Helen Drew, she was awarded the Daniel Pigeon Fund in 1907 (Burek 2009a). She became a demonstrator for Catherine Raisin at Bedford College in 1910 for two years until she married. As a married woman she had to retire from demonstrating and research which was the common procedure at the time and indeed up until the 1970s in some jobs. She published an article with Gertrude Elles in the *Quarterly Journal of the Geological Society* in 1906 on the Ludlow district which is still widely cited in work on Wales and the Welsh borders (Elles and Slater, 1906) as it provides a context for the border area.

However her most important work was the authorship of a monograph for the Palaeontological Society on British Conularia in 1907. This discusses and classifies the extinct and poorly understood clade *scyphozoan cnidarian* including those from the Lower and Middle Ordovician rocks in Llandrindod Well, St. David's, Pembrokeshire and Garth, Caernarvon in Wales. These fossils helped further understanding of Welsh palaeoecology and stratigraphical correlation. The importance of her work is demonstrated by Sendino and Darrell (2008) when discussing the *Conularia* collection in the Natural History Museum as Ida Slater identified 7 holotypes, 3 paratypes and many syntypes. In 1976 Brood reclassified one of the holotypes and named it after her in recognition of her work. Thus *Conularia aspersa* Lindström, 1884 (Slater 1907: 19-20, pl. 1: fig. 5) became *Metaconularia slateri*, Reference to her work is still being cited especially in Brazil where work on this unusual group of fossils has restarted (Leme et al., 2008). Below is one of the inscriptions from the Natural History Museum for one of the Welsh early conularia fossils.

"*Archaeoconularia coronata* (Slater, 1907)
 SA: G 17660 (holotype).
 PD: *Conularia coronata* Slater.
 SB: Middle Ordovician.
 GL: Ritton Castle, Shropshire (England).
 CDA: Rev. C. Croft, 1873.
 SA: G 7736.
 PD: *Conularia coronata* Slater.
 SB: Middle Ordovician.
 GL: Llandrindod Wells, Powys (Wales).
 CDA: Rev. C. Croft, 1873."

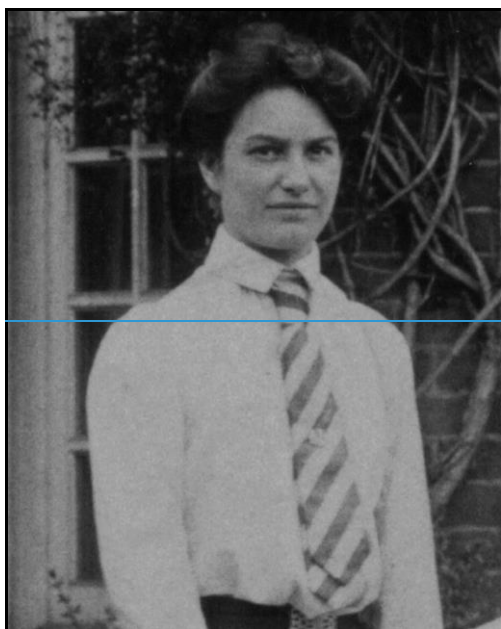


Figure 12.
 Ida Slater in 1904.

5. The importance of recognition for the females advancing Welsh geology

The importance of recognition by your peers in science was and still is essential. In this respect many of the women mentioned above researching Welsh geology obtained this by publishing in major peer-reviewed journals of the time (Table 3) or receiving awards and medals for their work on Welsh geological research (Table 2). These awards are important evidence of their recognised specific contributions to Welsh geology as Wales is often mentioned within the citation itself. The citations for the awards and the medals they received have already been quoted in full to show the esteem in which their work on Wales was held in, by their mostly male peers. The citations are taken directly from the Geological Society journal proceedings.

In Table 3, work on Wales up until 1924 is included as it may take several years of research to produce a published paper.

*Table 3.
Examples of peer-reviewed papers on Wales produced by women, 1889–1924.*

Name	Date	Title of paper
Catherine Raisin	1889	On some nodular felstones of the Lleyn
Catherine Raisin	1891	On the lower limit of the Cambrian series in N. W. Caernarvonshire
Catherine Raisin	1893	Variolite of the Lleyn and associated volcanic rocks
Gertrude Elles and Ethel Wood	1896	On the Llandovery and associated rocks of Conway
Ethel Skeat and Margaret Crosfield	1896	The geology of the neighbourhood of Carmarthen
Gertrude Elles	1899	Zonal classification of Wenlock Shales of the Welsh borderland
Thomas Bonney and Catherine Raisin	1899	On varieties of serpentinite and associated rocks in Anglesey
Ethel Wood	1900	The Lower Ludlow Formation and its graptolite fauna
Gertrude Elles	1900	The zonal classification of the Wenlock Shales of the Welsh Borderland
Gertrude Elles and Ethel Wood	1901–1918	<i>Monograph on British Graptolites</i> , Parts 1–11
Ethel Wood	1906	The Tarannon series of Tarannon
Gertrude Elles and Ida Slater	1906	The highest Silurian rocks of the Ludlow district
Helen Drew Ida Slater	1910	Notes on the geology of the district around Llansawel (Carmarthenshire)
Gertrude Elles	1921	Bala Country : its structure and rock succession
Ethel Skeat (Mrs Woods) Margaret Crosfield	1924	The Silurian rocks of the central part of the Clwydian range

During the 1800's and indeed today, the Geological Society of London is the premier learned geological society in the world and many female geologists sought to be recognised as members and Fellows (Burek, 2009a). Recognition by this Society of your work is one of the highest accolades achievable.

Margaret Crosfield was the first female Fellow listed in 1919 and indeed all the females mentioned in this paper were Fellows except for Annie Greenly and Dilys Davies; The former because she did not consider herself a professional geologist and the latter because after one year at Cambridge studying geology she moved into education and saw that as her forte. The rest of the females mentioned became Fellows after 1919 when they were admitted rather reluctantly it must be said, but forced by pending legislation (Burek, 2009a). Several of these women had been allowed to publish in the *Quarterly Journal of the Geological Society* (Table 3) and had received financial awards (Table 2). However it was often their male colleagues who physically received the financial awards as women were not freely admitted to the Society meetings in person. This started to change as we entered the twentieth century (Burek, 2007, 2009a). For example Catherine Raisin was admitted to the library as an associate to carry out research as early as 1907 as she had "distinguished herself as a geological investigator" and "Shown herself able and willing to communicate to the Society original and important geological information" (Wallace 1969 ; Burek 2009a).

*Table 4.
Locations of archives relating to Welsh female geological researchers.*

Name	Archive Location
Catherine Raisin	Royal Holloway University London

Dilys Davies	University of Bangor, Wales
Margaret Crosfield	British Geological Survey, Keyworth Grosvenor Museum, Chester
Ethel Wood	University of Cambridge Lapworth Museum Archive, University of Birmingham
Ethel Skeat	University of Cambridge Queen's School, Chester Grosvenor Museum, Chester
Gertrude Elles	University of Cambridge Lapworth Museum Archive, University of Birmingham

6, The national context of these women's achievements

The women listed and discussed above are unusual and are pioneers as role models at this time as they were educated to the tertiary level. Most women throughout Wales struggled to gain an education at this level especially in a science subject as very few universities had opened their doors to women. Burek (2007) has discussed the situation at Bedford College in London and Newnham College in Cambridge in some detail. There were some enlightened professors and teachers such as Professor McKenny- Hughes (himself Welsh) and Professor Bonney but university lectures as well as national and local societies were mostly closed to women such as the Royal Society, the Geological Society of London and the Woolhope Field Naturalists Club in Hereford until pending legislation in 1919 forced them to reassess the situation. The Royal Geographical Society (RGS) and the Geologists Association (GA) were slightly different. The RGS allowed women to become members in 1913 (Evans, Keighren, Maddrell 2013) while the GA had opened its doors to women from its inception in 1858 (Burek 2007). The GA ran extensive fieldtrips or local 'excursions' as they were called from 1860 and many of these were to locations further afield after 1871 and later to Wales (Sweeting 1958 ; Green 2008). The first Welsh excursion was in July 1876 for five days to the North Wales border area led by three fellows of the Geological Society; D.C. Davies, Esq., F.G.S., Professor Morris, F.G.S. and Henry Hicks, Esq., F.G.S. The second took place seven years later in July 1883 to Anglesey and Snowdonia.

Some provincial natural science societies had also allowed women to attend their lectures (Burek & Hose in press) and this was a great source of knowledge for women with an interest in both science in general and geology in particular. Interestingly some women actually gave these lectures themselves such as Ethel Skeat at the Chester Society of Natural Science in 1905, 1909 and 1910 thus acting as both researchers and educators (Burek 2009, Burek & Hose in press). They also went on excursions and the Chester society often ventured into Wales for both pleasure and research in all areas of natural history. As Professor McKenny-Hughes took the Society's reigns as the second President when Charles Kingsley moved south he often led field excursions into Wales his homeland, He encouraged both men and women to attend these trips and learn about their landscapes and underpinning geology.

The contributions of the women above can be divided into several categories (Table 3). All can be classified as educators from Gertrude Elles lecturing at Cambridge and Ethel Skeat at the Queen's school, Chester through to Annie Greenly contributing to her husband's book and work on Anglesey for scholars and the public alike. The various roles women undertook in the geological area is detailed by Burek and Higgs in their book entitled *The role of women in the history of geology* (Burek & Higgs 2007). Of course several women covered more than one role and it must be emphasised that while several women lectured outside Wales they drew on their research from that area for teaching especially in the case of Gertrude Elles and her graptolite classification in stratigraphy and Catherine Raisin in metamorphic petrology. They also led fieldtrips to the area for illustration.

7. Conclusions

The importance of the female contribution to certain areas of Welsh geological research is indisputable. Without the painstaking work of Ethel Wood and Gertrude Elles with their over 20

year long collaboration on graptolite research to produce the seminal work on that sub phylum, the establishment of the Ordovician period would have been more problematic and less acceptable. Their monograph is still the key today. The work of Ethel Skeat and Margaret Crosfield on Carmarthenshire helped the Geological Survey with their mapping of the area as did the work of Helen Drew and Ida Slater. Ida Slater's work on *conularia* established the holotypes and is still being used extensively today. The work of Catherine Raisin in helping to solve the mineralogy of that very difficult group of rocks, the Serpentinites, using Anglesey as one of her case studies, was exemplary and widely applauded. The quality of the females' research was high and greatly admired as shown by the citations they received. The work of Annie Greenly helping her husband edit the map of Anglesey was not widely acknowledged at the time and the work of Dilys Davies raising the importance of educating females in Wales at all levels but especially within the field sciences using her own experience was inspirational. The photographic archive left by Mary Johnson, the field notebooks left by Margaret Crosfield, the letters left by all the women writing to each other and the specimens in museum collections are irreplaceable and indispensable to historian of geology. These women have all helped advance geological work in different ways within the Principality at the dawn of women's involvement in geological research.

If I have raised awareness of their contribution I have achieved my aim.

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Archives

Material relating to Dilys Davies is in an uncatalogued archive at the University of Bangor. The photo of Dilys Davies is reproduced courtesy of Bangor University.

Material relating to Catherine Raisin is located at Royal Holloway library, University of London.

The archives at Newnham College (Cambridge) contain much material relating to the women who attended that College.

Material relating to Ethel Skeat and Margaret Crosfield is located in the Museum collection at Grosvenor Museum, Chester.

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