Arthur Holmes' Scientific Legacy

1. Arthur Holmes

It's a great pleasure to be here honouring Holmes in this way, but for the very reason that he left us such a vast scientific legacy, it's been extremely difficult to decide what to cover in just 25 minutes. In the end I decided to focus on three areas where I feel he made the greatest impact: his textbook, because it influenced such a large number of people; his work on developing a geological timescale; and his theory of convection currents in the mantle.

2. Principles of physical geology

The *Principles of Physical Geology* was written during the Second World War, when all University staff were required to sit and 'fire watch' in case the building was bombed or set alight. Holmes took his turn in the Durham Science Laboratories where he was head of Department, and during the day he lectured large batches of RAF cadets who came through the department as part of their university course.

Now expected to cover a full year's syllabus in six months, Holmes soon found himself needing a textbook for them but there simply were no modern text books available. The three stalwarts of the first year reading list had all been written in the previous century, thus none of them contained anything about radioactive dating, continental drift or any of the more recent developments in geology.

Eventually it dawned on him that actually there was a book he could use – but it was still in the form of his lecture notes. Immediately he resolved to remedy the situation and to utilise the peace and quiet of fire watching duty to put a book together. Night after night he sat at his upright typewriter – he did all his own typing

even when he had a secretary – turning his notes into one of the most celebrated books on geology ever written.

The rather cumbersome title was chosen by Holmes as a tribute to Charles Lyell and his ‘Principles of Geology’, but the full title was soon dropped by those who read the book, and ever since it has been known more simply and fondly as ‘Holmes’ or 'Principles'.

3. Preface text

Principles of Physical Geology was published in 1944, shortly after Holmes moved to Edinburgh, and it immediately became an international best-seller, selling for the princely sum of thirty shillings. The first print run of three thousand copies sold out almost immediately and, despite a paper shortage both during and after the war, it was reprinted no fewer than eighteen times over the next twenty years, becoming the geological bible for generations of geologists and non-geologists alike. I'm particularly fond of his allusion to the 'wild miracle' of the world we live in. It was this kind of imaginative phraseology that made the book so readable.

4. Quotes

Since I wrote my book on Holmes, many people have contacted me from all over the world and almost without exception, everyone has mentioned that they had read and been inspired by Holmes’ book. Its extraordinary popularity was due not only to an enthusiasm for geology engendered by Holmes’ text, but also to the outstanding quality of the illustrations, largely photographs, which Holmes went to tremendous lengths to obtain, despite many firms having lost all their photographic stock in the bombing raids.

Thus Holmes the man and ‘Holmes’ the book did much to revive a failing interest in geology which, for more than half a century, had been in quite a moribund state. So I thought you might be interested to hear someone whose voice, I'm sure, is very familiar to most of you, being interviewed about this situation and the impact that Holmes’ book had on him.

Well, that was of course, Dan McKenzie – But it wasn't just his writings style that was so exceptional, by all accounts his lecturing style was remarkable as well.

5. **Holmes’s lecturing style**

and this led to a number of students deciding to become geologists after they had experienced his lectures when they opted for geology as their compulsory science during their first year as undergraduates. Kingsley Dunham was one of these, for example, changing from chemistry to geology after he heard Holmes lecture, and becoming only Holmes’ second PhD student. Twenty years later, Dunham was to tread in Holmes’ footsteps as Professor of Geology at Durham, eventually becoming the Director of the British Geological Survey.

So having looked at the way that Holmes influenced generations of geologists, it's interesting to speculate on what might have influenced him.

6. **Influences on Holmes?**

I was recently contacted by Martin Laan, a geologist who spent his life working in Australia and Tasmania. When Laan decided in the early 1970s to take an evening course in geology in order to qualify for university, the recommended text was, of course, Holmes’ 'Principles'. It was only then that Laan realised the significance of another book he had found in Australia in the 1960s. Being interested in minerals,

Laan had bought a second-hand copy of John Pepper's 'Boys Book of Metals', and there on the inside was this inscription to Arthur Holmes:

7. **Inscription**

Quite how this book ended up in Australia, we shall probably never know, but on 2nd January, 1902 Holmes would have been just 2 weeks short of his 12th birthday. But apart from a general interest in the inscription, why should this work be of interest to us?

8. **Formation of Coal**

The Boys book of Metals was written in 1875 and the first chapter discusses the formation of coal and summarises the two theories then prevailing as to how coal had formed. The first of these, the coincidentally named drift theory, suggested that vast rivers such as the Mississippi had carried thousands of trees down stream and deposited them in the beds of the ocean.' Pepper then goes on to explain, how

9. **Pepper 1875**

the "ancient ocean" is supposed to have been very different from the present one, and the arrangement of land and water quite dissimilar to the present order of these ancient elements'.

To illustrate how different this arrangement was, Pepper provides two remarkable diagrams taken from a work written in 1858 by the French geographer, Antonio Snider (1802–1885).

According to Snider, the left hand figure shows the continental landmass as it was on the first day of Creation, while the right figure shows the continents after they were separated on the sixth day of creation, following a massive eruption of

volcanic material along a North-South fissure between the two. Little did he realise how close he was to do the truth.

Pepper, however, does not refer to any of Snider's religious arguments to explain the diagrams, but instead concentrates on the known geological evidence:

> "The uniformity of the fossil plants of the coal measures of Europe and North America is a convincing proof of the former existence of a continent or chain of islands where the Atlantic now rolls its waves."

10. Holmes 1944

In Holmes controversial chapter on continental drift which, against much advice, he included at the end of *Principles*, he reproduces Snider's diagram and I feel certain that the logic of Pepper's arguments, combined with Snider's figures, appealed to the young Holmes, and at a very early age stimulated his interest in the possibility of continental drift.

11. Date of Creation

Another influence seems to have been his parent's bible, which he read as a child and in which the date of Creation of the world, 4004 BC, appeared in the margin of the first page. From an early age Holmes questioned such ideas, and even more so once he fell under the spell of his inspirational physics teacher, Mr. James McIntosh from whom he learned about Lord Kelvin and the 'Age of the Earth' debate, a scientific controversy that had endured for the past fifty years.

12. Kelvin in 1899

To the consternation of many geologists, in 1899 Lord Kelvin argued that the age of the Sun and the Earth could not be more than 20 million years. However with the discovery of radioactivity in 1902 and radioactive decay in 1903,

13.Geiger and Rutherford in 1904

Ernest Rutherford was able to date the first rock 1904, obtaining a minimum age of 40 million years, so overnight the age of the Earth had more than doubled.

14.Excelled at School

Thus it was against this background of debate and exciting scientific discoveries that Arthur Holmes won a scholarship to the Royal College of Science in London (soon to become Imperial College) to study physics. Having obtained his BSc within two years, he then decided to change over to geology, largely because he thought he was more likely to get a job as a geologist than a physicist. But during his first year of studying geology he ran out of funds and was forced to take a job in Mozambique to prospect for minerals, but before he left he had three months in which to start some research.

15.Robert Strutt

His tutor, the physicist Robert Strutt, had worked with Ernest Rutherford at the Cavendish laboratory in Cambridge, exploring methods for dating rocks. At the time it was considered that lead might be the final decay product of uranium, but as this had not been proved conclusively, Strutt suggested to Holmes that he should investigate it further in order to determine whether it would be suitable for dating rocks. Thus Holmes set out to determine the age of a thorite-bearing nepheline-syenite from Norway. He spent many hours in the laboratory painstakingly extracting no less than 17 radioactive minerals from the crushed rock, before performing exquisitely delicate chemical preparations to isolate uranium and lead for measurement. At one point Strutt made him discard all the data and start again because radon had been leaking into the room, contaminating everything and giving spurious results.

16.*The Association of Lead with Uranium in Rock-Minerals*

Eventually, in March 1911, Holmes wrote up the results for his first-ever paper, the publication of which we are celebrating today. His diary records that he wrote this seminal work in just a single morning, a few days before he left for Mozambique. Holmes left the paper with Strutt who submitted it to the Royal Society on March 20 and, in Holmes's absence, read it there on April 6; it was published a few months later whilst Holmes was in deepest Mozambique, where he eventually received a dozen copies sent to him by Strutt.

What I believe is particularly significant about this paper is how, at the age of only 21, Holmes appreciated the enormous implications of developing a geological timescale. He realised that each radiometric date he determined became a control point in time, thus it was essential to know the exact position in the geological column of each rock he dated. He therefore went to great lengths to assign a geological age to each of a few previously published U/Pb ratios and calculated their radiometric ages.

17.Holmes first date

The results from his own analyses fitted well with these data, enabling him to conclude that lead was indeed the final decay product of uranium, and that the uranium/lead technique could be used for dating rocks:

> "For minerals of increasing geological age the value of Pb/U also increases as the following table clearly shows …"

This is the first attempt ever made to produce a geological timescale from radiometric dates and it's important to remember that Holmes was doing this work two years before the discovery of isotopes by Frederick Soddy in 1913.

At 1,640 million years, the oldest rock in the data set demonstrated that the Earth must be at least that age, pushing time further back than most people could possibly comprehend. His results were truly shocking and not accepted by the majority of geologists who still believed the Earth was less than 100 million years old. For Holmes, however, an idea of the vast aeons represented by the Precambrian began to emerge and he writes excitedly how, with this new dating technique, it should be possible to impose order on the hitherto ‘almost hopeless task’ of sorting out the Precambrian. But it would be at least another 10 years before most geologists accepted that the age of the Earth should be measured in billions, not millions, of years.

18.Letter to Lawson

With this work he embarked on a lifelong pursuit of the geological timescale and while in Mozambique, he wrote to his school friend Bob Lawson about his vision of how to develop it: "I intend writing all over the world to surveys and societies for material of known geological age to analyse for uranium and lead. I am in hopes of gradually building up a geological timescale".

19.Holmes' vision 1913

Today, the geological time scale has become the framework onto which we hang all geological events and without it we would never have been able to discover the unifying theory that explains all geological processes. This surely must be his greatest scientific legacy.

20.Wegener 1912

At around the same time, Alfred Wegener published his ideas about continental drift which must have reminded Holmes of Snider's map in the boys of metals. We know that in 1912, Holmes visited Germany shortly after Wegener had first presented his theory of continental displacement. It therefore seems likely Holmes discussed the theory while he was there and he undoubtedly read his book in German, since it was not translated into English until 1924.

21.1915 - 1925

From then on, Holmes started thinking about the processes involved in the Earth's interior and over the next decade, as well as continuing his interest in establishing a geological time scale, he was preoccupied with constructing a thermal history of the earth. In the course of this, he wrote a series of five papers entitled 'Radioactivity and the earth's thermal history', of which the first two appeared in 1915, the third in 1916, and the last two in 1925, after he had returned from Burma.

22.Hallmark of a great scientist

During those 10 years his ideas evolved considerably and the fourth paper became a critique of the first three. In it he rejects his previously held belief that the Earth had been cooling, and thus contracting, ever since it had first formed, because, he argued, it simply would not be hot enough today to facilitate the generation of magma.

He therefore reasoned that there must be more uranium and thorium in the mantle than previously thought possible. But abandoning contraction left him with further difficulties, as he explains:

> Unfortunately, once the straightforward conception of a continuously cooling earth is abandoned, the possibilities become hard to visualize, unwieldy in

> their complex interrelations, and difficult to check except by the most complete details of geological history …

But, it's what he says next that, to me, makes him stand out as a really great scientist:

> Nevertheless an attempt must be made, and if mistakes are involved at first, then at least their recognition and correction in the future will mark a beginning of sound progress.

He is not afraid to attempt the impossible, he's not afraid to change his mind and he's not afraid to be wrong. This attitude is the hallmark of his life's work.

23.Christmas 1927

Holmes was in a unique position to solve the problem of continental drift - which was, of course, just how did the continents move around the globe? With his profound understanding of the Earth's interior – the physics of radioactivity, the heat that it generated within the Earth, and the enormous amounts of time it conferred on incredibly slow geological processes – Holmes was probably the person most likely to come up with a solution.

And thus in December 1927, when writing to his friend Charles Schuchert, an American palaeontologist who, like most Americans, was adamantly opposed to continental drift, he confided, 'I am trying to develop the idea of convection currents'.

24.Convection currents

Two weeks after that, when he gave his now famous lecture to the Glasgow Geological Society, his early concept of convection currents in the mantle as

a mechanism for driving continental plates around the globe had become a distinct theory.

Holmes believed that the material on which the continents floated behaved like a very thick liquid. Heating of this material, which was generated by the decay of radioactive elements, caused convection cells to form, rising beneath continents and descending at their edges. As hot material reached the top of a convecting cell it would travel horizontally for some distance, producing a force that was sufficient to drag the continents sideways, so they were very slowly pulled apart, allowing the material underneath to rise up and take their place in the ocean floor.

Holmes himself was only too aware that this that what he was proposing was completely accurate, but like much of his earlier work, he was erecting 'wickets to be bowled at' – a cricketing analogy he was fond of making – in the hope that his ideas would stimulate others to help him take the work forward.

25.Bowie to Schuchert

But Schuchert and his colleagues were not convinced, as the geophysicist William Bowie revealed in a letter to Schuchert:

> I really cannot figure out how the continents can drift about in an aimless sort of way … [and] Holmes brings out a new thought which is even more impossible than Wegener's hypothesis.
>
> [He considers] that the submerged ridge through the Atlantic Ocean is the place at which North and South America separated from Europe and Africa … I do not see how the same force operating to send one mass westward, could make another go eastward. I believe that we need to apply elementary physics and mechanics to the continental drift problem in order to show how impossible that drifting would be.

26.Holmes and Doris

So although Holmes had to wait almost 40 years for his work on continental to be recognised, in his lifetime he was considered one of the outstanding geologists of his time and won many medals for his contribution to geology, including the highest awards given by the Geological Societies of London and America.

27.Vetlesen Prize

Then in 1964, the year before he died, he was awarded the Vetlesen prize, the geologist's equivalent of the Nobel Prize, for his *'uniquely distinguished achievement in the sciences resulting in a clearer understanding of the Earth, its history, and its relation to the universe'*. Only 3 other British scientists have subsequently received it – maybe it is time someone else was nominated!

But by this time Holmes was frail and unable to travel to the United States, so the United States came to him and Maurice Ewing presented him with the medal at the Royal Society. His mind, however, was as sharp as ever when he made his response:

28.Holmes' response

'Looking back it is a slight consolation for the disabilities of growing old to notice that the Earth has grown older much more rapidly that I have – from about six thousand years when I was ten, to four of five billion years by the time I reached sixty.'

29.Principles 2

The following year, the fully revised second edition of principles was published and, as if he had decided that his life's work was now complete, he died a few months later. Arthur Holmes' legacy to our science cannot be overstated.