# W. Henry Penning, a 19th century applied geologist who may have been the first to use the term ‘engineering geology’

**Martin G. Culshaw and Alan Forster**

**Abstract:** This paper gives an insight into the career and published output of an applied geologist in the latter part of the 19th century. For more than 30 years, William Henry Penning worked in England as an agent for a railway contractor, as a Geological Survey mapping geologist and, in South Africa, as a consultant geologist for gold, diamond and coal mining ventures. Although not an academic, he published frequently on the geology of eastern England, on engineering geology, and on the geology of South Africa. Probably his greatest achievement, a pioneering book entitled *Engineering Geology* (1880), was still being quoted until at least the 1930s. This book was based on a series of articles published in *The Engineer* in 1879. The first of these contains the earliest usage so far discovered of the term ‘engineering geology’. The book contains guidance still valid today. Penning might thus be considered the ‘founder of engineering geology’ as a discipline, for which he deserves to be remembered. Yet, today, he is almost completely unknown.

In the UK, engineering geology was an important part of applied geology from the time of William Smith (Forster and Reeves 2008) and was implicitly included in the brief of the Geological Survey from its founding in 1835 (Lyell 1836). A small number of scientific papers were written in the mid to late 19th century incorporating what would now be seen as engineering geological content (Fookes *et al*. 2005), though none of them used the expression ‘engineering geology’. The great Russian engineering geologist Evgenii Mikhailovich Sergeev noted that ‘In Russia geologists were involved in engineering investigations in connection with constructing railways (1842)’ (Sergeev 1974). However, he later stated that the first use of the words ‘engineering’ and ‘geology’ together in Russia was in 1885 (Sergeev 1984). Sergeev thought that the term ‘engineering geology’ had certainly been in regular use since about 1925, pointing out that the Russian engineering geologist I. V. Popov recalled that it was being used by Russians in the 1920s. In the USA, Reis and Watson (1914) published a text book entitled *Engineering Geology*, so the term must have been in common use before that date. On the basis of evidence gathered so far, W. Henry Penning, a geological surveyor with the Geological Survey of England and Wales (Fig. 1), seems to have been the first person to use the term in print in a series of articles for *The Engineer* magazine, the first of which appeared on 10 January 1879 (Penning 1879a–i). This contention is supported by Hatheway (1990).

William Henry Penning is hardly remembered today by engineering geologists, even though he brought together his articles in *The Engineer* with chapters on geological mapping summarised from an earlier book on that subject (Penning 1876a) to form a short book entitled *Engineering Geology* (Penning 1880a). Kiersch (1955) described the book as possibly ‘the earliest attempt in English to describe the significance of geologic features and conditions on engineering structures.’ He also noted that Penning’s discussion of geology in tunnelling cited many of the geological principles still regarded as good practice. Penning’s book was mentioned by Herbert Lapworth in the published version of two lectures that he gave to students at the Institution of Civil Engineers in 1907–8 (Lapworth 1908). De Freitas and Rosenbaum (2008) have pointed out that in the latter part of the 19th

***Figure 1***. *Official Geological Survey photograph of Henry Penning (undated, but probably early in his career). Photograph P545377 (BGS©UKRI)*

century there was a group of applied geologists based in London that included Penning, Lapworth and another Geological Survey geologist called Herbert Woodward. The last named had written a memoir on the soils and subsoils of London (Woodward 1897) which included a map, considered by Culshaw (2004) to be an early British example of an engineering geological map. The memoir was so popular that a slightly expanded second edition was called for (Woodward 1906). As Penning also worked for the Geological Survey (joining on the same day as Woodward) the question arises as to whether the Geological Survey specifically sought to recruit applied geologists. However, it seems that the recruitment of two applied geologists was not a deliberate act and it is perhaps significant that none of Penning's books were published by the Survey itself. Further, it would be interesting to know why Penning wrote *Engineering Geology* in the first place. To try and answer these questions it will be useful to consider Penning's development as an applied geologist and the early influences upon him.

## Henry Penning's career

A fuller description of Penning's life is provided by Culshaw and Forster (2020) in an open access report for the British Geological Survey. Here, the focus is on Penning's professional career and the publications that resulted from it.

### *Builder*

Penning was born in 1837 at Eye, in Suffolk. While he received a formal school education it is likely that in his teens and possibly early twenties he worked with his father on building projects. Indirect confirmation comes from the completion certificate for the boys and girls school and master's schoolhouse of the Pewsey National School issued on 3 July 1863, with W. H. Penning named as the builder (Document 782/82 in Wilts and Swindon Archives). Between mid-1862 and the end of 1863, Penning was also responsible for the erection of the station (Fig. 2) and other buildings on the Berks and Hants Extension Railway (B&HER) and, possibly, the gas works at Pewsey for which he was the 'archetect and surveyor' (*sic*) (*Devizes and Wiltshire Gazette*, 15 May 1862). An interest in architecture may be indicated by one of the few drawings in his Geological Survey notebooks of a church doorway at 'Wenden Church' (probably St Dunstan's at Wenden Lofts, Essex), dated 13 April 1869 (page 50 reverse, BGS Geologists' Field Notebooks, no 1063) (Fig. 3) showing detailing around the doorway (Penning attributed the doorway to the Saxon period but it is more likely Norman). Similarly, he commented on the architecture of Ickleton Church (page 1 rev, Notebook 1065) and Chigwell Church, Essex (dated 29 August 1867, Notebook 1063).


*__Figure 2__. Pewsey Station booking office (Photograph 2012. © M G Culshaw)*

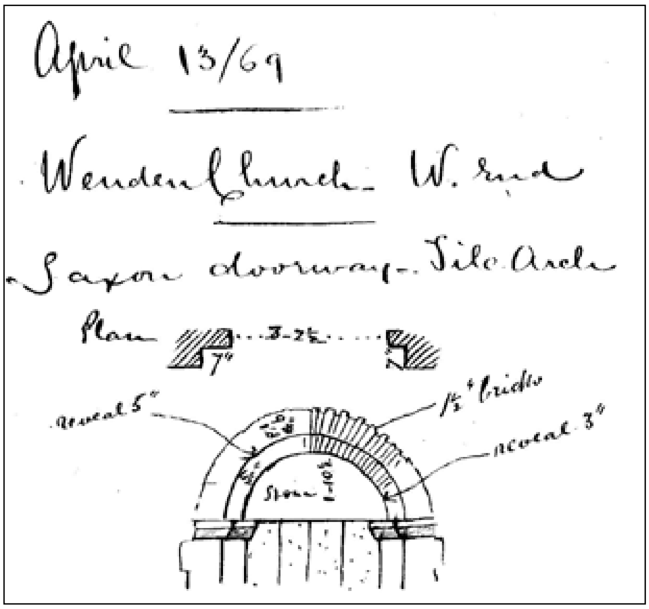



*__Figure 3__. Sketch of Saxon doorway with a tile arch at Wenden Church. Page 50 reverse, of Penning's British Geological Survey field notebook No. 1063, 13 April 1869 (BGS©UKRI)*

### *Civil engineer/surveyor*

By 1861 Penning was living in Pewsey, Wiltshire and working on the construction of a railway. During this time he may have had contact with Charles Hutton Gregory whose mentoring he acknowledges in the dedication of his book *Engineering Geology*. Gregory was an important railway engineer who had worked under Robert Stephenson on the Manchester and Birmingham Railway and subsequently, as Chief Engineer, on the construction of a number of railways in the West Country and overseas. Although Gregory worked on railways in south west England, he was not the engineer for the B&HER. He eventually became President of the Institution of Civil Engineers.

It seems likely that Penning worked for the contractor of the Berks and Hants Extension Railway, Smith and Knight (National Archives Rail 29/1) or for their agents, Baldwin & Co. This line, as the name implies, was an extension of the B&HER that originally terminated at Hungerford in Berkshire (Fig. 4). The new line was to run from Hungerford to Devizes in Wiltshire. Work began at Pewsey where Penning lived, being situated approximately half way along the line. Construction started in 1861 and was finished towards the end of 1862, at which time Penning was selected to construct all the stations along the line. He may also have worked for the contractor of a branch line that ran 5½ miles from Savernake (on the B&HER) to Marlborough (Fig. 4). Construction here began early in 1863 and the line was opened to traffic on 14 April 1864.

The geology of the B&HER was recorded by Thomas Codrington, who was an engineer and a Fellow of the Geological Society (Anon. 1865). In 1862 (while the railway was under construction) Codrington drew a series of geological sections, at least some of which were along the line of part of the railway (Wiltshire Heritage Museum, Devizes records DZSWS: 1982, 1872–77). Later he wrote a paper on the geology of the B&HER and the Marlborough branch line which included many of these sections (Codrington 1865). As Penning worked on the B&HER he would almost certainly have been aware of Codrington's work and it may have stimulated his interest in geology. It is also worth noting that in 1862 Henry Bristow and William Whitaker of the Geological Survey were carrying out field work in Berkshire and Hampshire (Guppy 2000).

### *Geological surveyor*

Penning's letter of application to the Geological Survey was submitted in mid-1867 at a time when the Geological Survey was expanding. Nineteen assistant surveyors were appointed in that year and another fourteen in 1868. Flett (1937) notes that there were 'numerous failures at the first examination in 1867'.

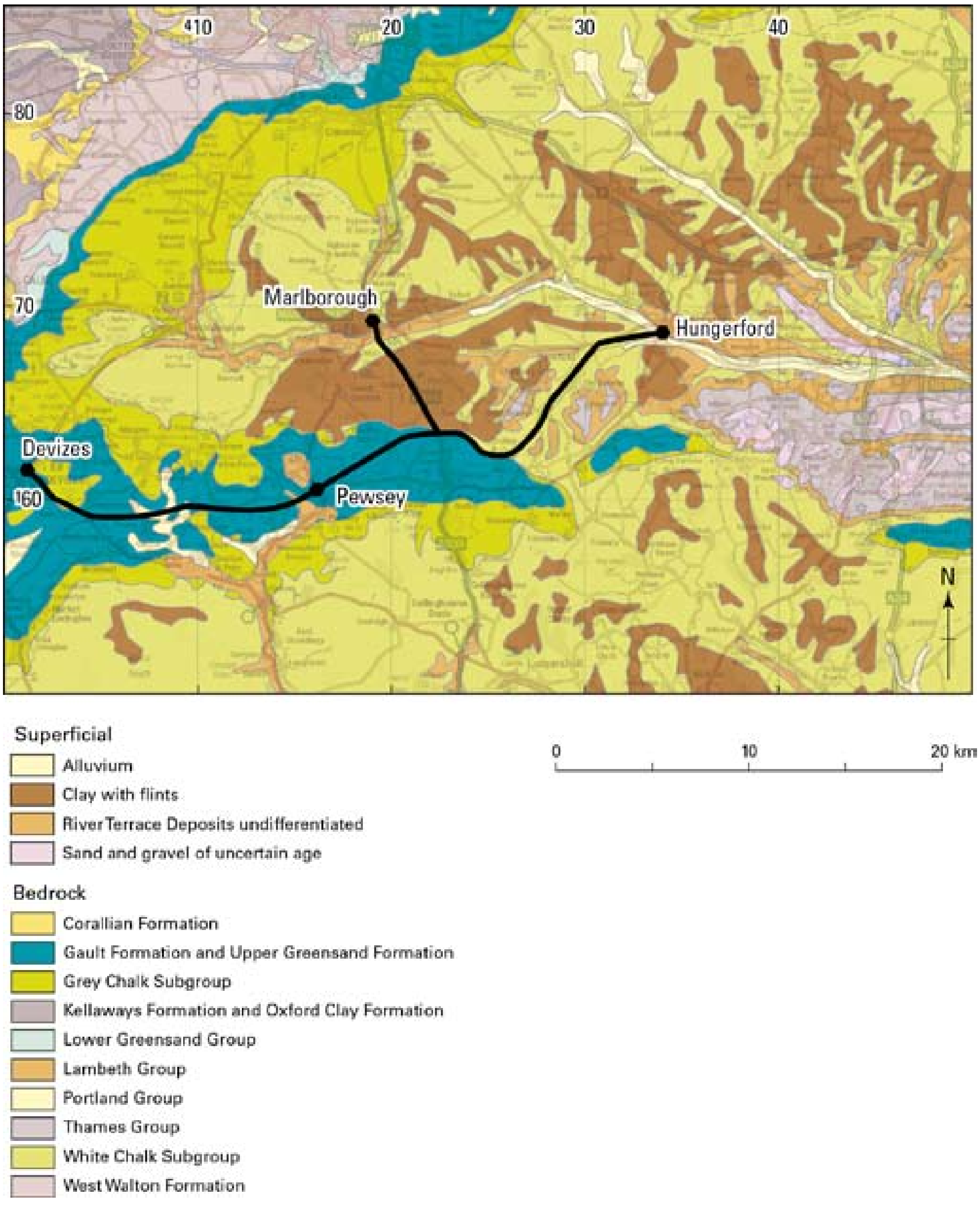



***Figure 4**. Geological map of the area around Pewsey, showing the approximate line of the Berkshire and Hampshire Extension Railway (B&HER) and the Marlborough branch line. The geological line-work is taken from British Geological Survey 1:50 000 scale geological map sheets nos. 266 (Marlborough), 267 (Newbury) and 282 (Devizes) (with permission) (BGS©UKRI)*

There is no evidence that Penning was selected to join the Geological Survey because of any particular skills or experience, simply that he was good enough to pass the interview and examination.

Penning was elected a Fellow of the Geological Society of London in 1868. He was also a Member of the Society of Arts (the Royal Society of Arts from 1908, Fellowship being introduced in 1914), being nominated 15 March 1880 and accepted 18 April 1880.

On arrival at the Geological Survey, Penning was set to work on the production of a series of horizontal geological sections on a scale of six inches to the mile. These were published separately from the maps and were supplementary to them. The publication of these sections, begun in 1844, ceased in 1894. Penning was involved in the preparation of eight sections, though for three of them he seems to have been responsible only for the levelling.

Penning is named on five 'old series' one-inch to the mile geological map sheets (these were sometimes split into quarter sheets): Nos. 1 (NE & NW), 47, 51 (NW, SW & SE), 70 and 83. The sheets cover the counties of Essex, Suffolk, Cambridgeshire and Lincolnshire. He is also a co-author of the memoirs that accompany three of the map sheets (No. 1 NW, Whitaker *et al*. 1868; No. 47, Whitaker *et al.* 1878; No. 51 SW, Penning and Jukes-Browne 1881). He is not a co-author of the memoir for map sheet 70, but Jukes-Browne (1885) includes several extracts from Penning's notebooks on the Lias, Limestone Gravels and the River Trent alluvium. However, Penning also contributed to the mapping of a number of other sheets. The geological memoirs for these sheets record Penning's contributions by quoting from his notebooks. Thus, for sheet 83 (country around Lincoln: Ussher *et al.* 1888) Penning's notes on the Middle and Upper Lias, the Inferior Oolite, the Great Oolite, the Cornbrash and post-glacial Ancient Gravels are referred to more than twenty times. From his work on the 'Ancient Gravels (Quartzite Gravels)' Penning is acknowledged to have developed a 'theory' on their distribution, proposing that they were laid down by an ancient River Trent (Jukes-Browne 1883).

For sheet 84 (East Lincolnshire) Jukes-Browne (1887) records that Penning mapped small areas near Mablethorpe and some of Penning's notes are published in the memoirs for sheets 51 NE (parts of Cambridgeshire and Suffolk: Whitaker *et al.* 1891) and 51 SE (Bury St Edmunds and Newmarket: Bennett and Blake 1886). Penning was also a co-author of two maps of the geology of London and its environs (Bristow *et al.* 1873, solid and drift editions). These maps were accompanied by a memoir entitled *Guide to the geology of London and the neighbourhood*. The maps can be considered as forerunners of the applied/engineering geological maps of the London area published around the end of the century (Woodward 1897, 1906; Culshaw 2004), particularly as Woodward was also a co-author of the two 1873 maps.

Eight of Penning's field notebooks are preserved in the BGS archives. The first of these records that on 5 August 1867 (shortly after he joined the Survey at the start of the month) he received the following tools:

1 box with six colors (*sic*), 2 brushes, 2 coloured pencils
1 prismatic compass (old)
1 clinometer (boxwood)
1 ivory protractor (old)
1 small hammer
1 notebook
1 map case (folding)
1 map case (round)
1 ordnance survey map No 1 SE
1 ordnance survey map No 1 NW
1 small magnifier
1 lot of forms

It is interesting to note that these items are very similar to those received by the authors of this paper on their joining the Survey around 100 years later!

Penning resigned from the Geological Survey on 7 April 1882, following 15 months of sick leave, from an address in South Africa. While no reference to Penning's engineering knowledge has been found in the BGS archives, it is interesting that, in a note to the Director-General (four months after Penning's resignation), Bristow observed that his replacement, R. Russell (who had been appointed an Assistant Geologist on the same day as Penning) had knowledge of engineering and suitability as a 'teacher of engineering'. This could imply that Penning had previously fulfilled such a role (BGS archive GSM1/38, paper 507, 21 September 1882) and that while Penning's engineering knowledge was not the reason for his appointment, it was recognised that having staff with such knowledge was important.

## *Gold and diamond consultant*

It is interesting to speculate on why Penning left the Geological Survey. On the face of it, he left because of ill-health. Additionally, in 1880, Penning had spent a long time in the field, mapping nearly twice as much ground as in the previous two years. However, there seems to be a contradiction between his being granted sick leave as too ill to work, and his almost immediate departure (probably in early 1881) to South Africa to work in the gold and diamond fields (Fig. 5). He must have been quite active in South Africa judging from the foreword to his *Guide to the goldfields of South Africa*, dated 22 February 1883 (Penning 1883), in which he refers to two years of rambling round South Africa. There is further reason to believe that he may have gone to South Africa for reasons other than his health. During the whole period of his employment at the Geological Survey he received no pay increase. In a letter from Bristow to Ramsay (BGS archive GSM1/38, paper 460, 23 June 1880) it was pointed out that there had been no pay rise for 22 years! Furthermore, field

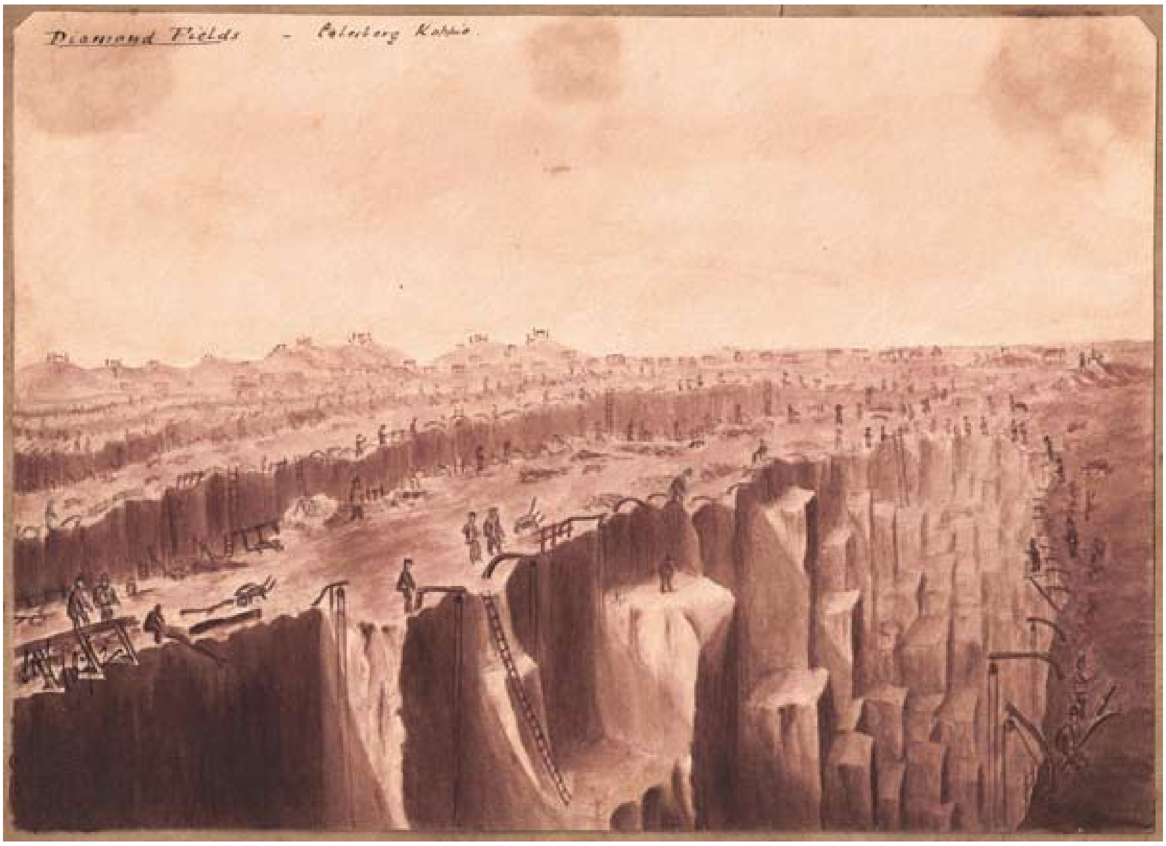



***Figure 5**. 1872 sketch of the diamond fields at Colesberg Koppie, South Africa by Commander Lewis Dod Sampson (reproduced with the permission of Pat and Peter Sampson).*

geologists were expected to live in the areas in which they were working, together with their families, and no field expenses were paid.

Penning must have been aware of the potential financial opportunities available in South Africa (Culshaw and Forster 2020) and it is possible that his resignation from the Geological Survey was, in part, motivated by this knowledge. He is known to have visited South Africa on at least six occasions between 1881 and 1896. Visits seem to have lasted as much as a year or more. During this time, Penning was involved in providing geological advice in relation to the potential for exploitation of gold resources. He wrote reports but also became a shareholder and even a company director. He seems to have invested in at least one Australian gold mining company but no record has been discovered of his ever having visited that country.

Publications by Penning during this part of his career, such as *The Kalahari Desert* (Penning 1893a) and Stanford's map of the Transvaal goldfields, with the geology of the southern part of the Transvaal (cartographic material by Penning 1883) showed that he worked extensively in South Africa, particularly in relation to gold, diamonds and coal. Although he spent most of his time abroad, he did return to England occasionally, on which occasions he presented papers to the Geological Society in 1884, 1885 and 1891 and to the Society of Arts in 1884 and 1888.

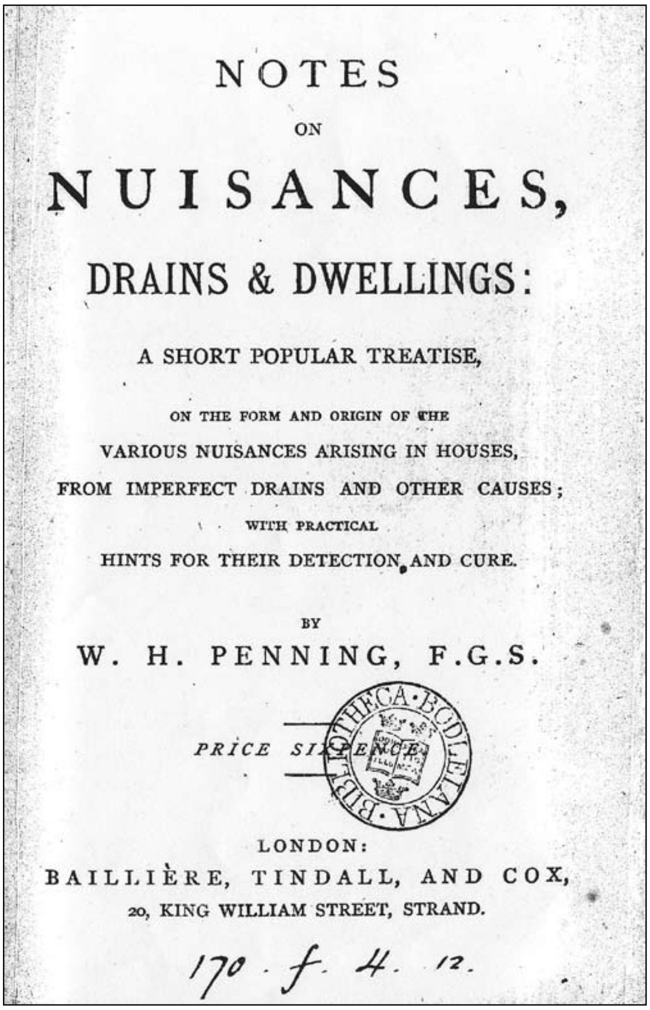
## Henry Penning's publications

Henry Penning was not an academic; rather, he was a practical man and would be called an applied geologist today. He had expertise in building, engineering and surveying, in railway construction, in geological mapping and in mineral exploration. However, the range of his publications indicates that he had a strong desire to communicate his knowledge and his thoughts on a range of matters, not all necessarily in the mainstream of geology. In the mid-1870s he wrote three interesting discussion articles in a popular literary magazine (*Tinsley's Magazine*). These were entitled 'Darwinism' (Penning 1876g), 'Hidden treasure' (Penning 1877a) and 'Science' (Penning 1877b). He also wrote poetry. Sixteen poems, a few of which were published in *Tinsley's Magazine* (Culshaw and Forster 2020), are preserved in a notebook compiled by Penning's step-granddaughter, Constance.

His articles on engineering geology (Penning 1879a-i) have been referred to above and are discussed below, but his first two known publications were concerned with public health. Thus, he wrote a geological note and produced a map for a report on an epidemic of typhoid fever at Wicken Bonant in Essex (Penning 1870). This was followed by a 32-page treatise on problems for houses associated with poor drainage and other unhealthy conditions, with practical hints for their detection and cure (Penning 1872; Fig. 6). Earlier, Penning had submitted a provisional patent application on 11 January 1869 to the London Patent Office (Anon. 1869). The application, which received provisional protection only, concerned a compressed air device that could be used for transmitting signals, being suitable for 'houses, buildings and public places, on carriages, on board ships, steam ships and boats, and especially applicable as a means of intercommunication between the passengers, guards, and drivers of railway trains.' It is not known whether Penning ever took patenting of the device further or commercialised it.

During his time at the Geological Survey he published short articles and letters relating to a wide range of topics: physical geology of east Anglia during the Glacial Period (Penning 1876b), concretions (Penning 1876c), apparent and true dip (Penning 1876d, e), marine erosion (Penning 1876f), divining rods (Penning 1878) and diatoms in the London Clay (Penning 1880b). These were in addition to the three editions of his book on field geology (Penning 1876a, 1879j, 1894) and his contributions to geological memoirs (Penning and Jukes-Browne 1881; Whitaker *et al.* 1868, 1878).

His South African work resulted in a number of publications on goldfields, and on coal and diamond districts (Penning 1881, 1884a, b, 1885, 1887, 1888, 1890, 1891, 1893a, b, c and 1901). According to the web-based Biographical Database of Southern African Science Penning also wrote two newspaper articles in 1883: for *De Volksstem* (Pretoria) on 27 January 1883 (dealing with geological and mining aspects of the De Kaap Valley) and for the *Diamond Fields Advertiser* (Kimberley) on 9 February 1883 (dealing with the future prospects of the Transvaal and its gold deposits).



NOTES

ON

NUISANCES,

DRAINS & DWELLINGS:

A SHORT POPULAR TREATISE,

ON THE FORM AND ORIGIN OF THE

VARIOUS NUISANCES ARISING IN HOUSES,

FROM IMPERFECT DRAINS AND OTHER CAUSES;

WITH PRACTICAL

HINTS FOR THEIR DETECTION AND CURE.

BY

W. H. PENNING, F.G.S.

PRICE SIXPENCE.



LONDON:

BAILLIÈRE, TINDALL, AND COX,

20, KING WILLIAM STREET, STRAND.



***Figure 6**. Title-page of Penning's book,* Notes on nuisances, drains and dwellings, etc.*, published in 1872.*

## *Engineering geology*

Henry Penning may be credited with two significant geological achievements: in engineering geology, and on the geology of South Africa. The first of these was the publication of his book *Engineering Geology* (Penning 1880a; Fig. 7) (and the articles from which it was derived: Penning 1879a-i). These articles record one of the earliest uses of the term 'engineering geology', possibly the first such usage (Koszela and Koszela-Marek 2009). That he understood the importance of geology to building, construction and mining is apparent from the opening paragraph of the first of the series of papers on engineering geology in *The Engineer* (Penning 1879a): '*In the execution of engineering works, however scientific in design and clever in workmanship, failure has frequently usurped the place of success, because due attention has not been paid to geological phenomena. The same may be said of building operations; whilst it is notorious that vast sums of money have been thrown away in mining speculations which would at once have been characterised as hopeless by anyone possessing the slightest acquaintance with geology.*' In addition, Penning stressed the importance of understanding the geology both of the district through which a linear structure (such as a railway) passes, but also *'...for a considerable distance below; their relationship to each other, and the consequent influence they will exert over the works in contemplation.'* Here he was describing the 3D geological model! He felt that *'*trail-pits*'* were too shallow and that, in most cases, *'*borings' were too expensive. He stressed the importance of field-geology: '*One cannot fail to perceive how differently placed or constructed would have been many of the most important works ... had those who designed them been acquainted with the principles, methods, and results of field geology; or how much capital might have been usefully instead of fruitlessly expended, or how many catastrophes would have been averted.*' He then goes on to describe geological strata in terms of what they are, their relationship to one another and how they impact on engineering works.

This theme is continued in the second article in *The Engineer* (Penning 1879b). Here he explains that more information is required for tunnelling than for cuttings. The cost of the former was much larger and so the savings that could be made would be potentially greater. He goes on to discuss superficial deposits and problems created by buried valleys as well as the variability of ‘drift gravels.’ He then discusses the potential value of rock and soil mineral resources though he says that peat is of little agricultural value because of the high vegetable matter content! He notes the varying agricultural value of different soils because of their chemistry, and finishes with a discussion of the drainage capability of different soils.

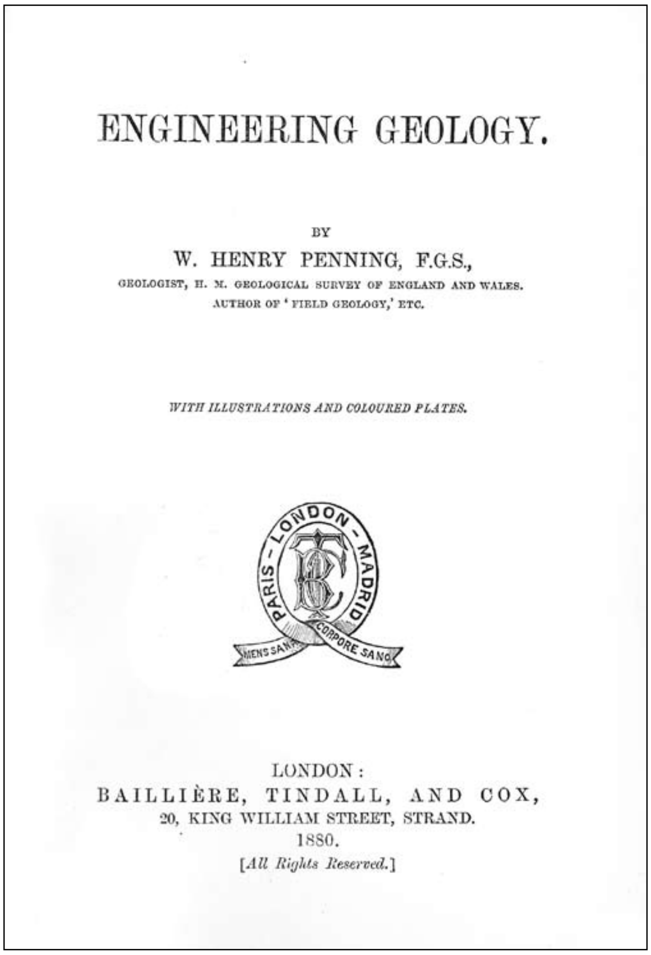
In the third article (Penning 1879c) he discusses drainage, drawing attention to spring lines in cuttings that might ‘*cause serious slips unless means be taken for their prevention*.’ He also points out the increased danger if the strata dip into the cutting. He notes that knowledge of geological structure is more important with regard to tunnelling. He indicates how a knowledge of the rock structure can be obtained by geological mapping at the surface. Penning then turns his attention to embankments. He warns that the embankment loading on a slope may cause slipping, and indicates that his comments may also apply to reservoir embankments and canals. His final discussion in this article is with regard to water supply and how an understanding of the depth to the water table is important. He notes also that ‘*A knowledge of the undoubted relation existing between subsoil and disease must also be beneficial to those who are seeking for themselves a new home*.’

The fourth article (Penning 1879d) focuses on geological surveying methods. He identifies three operations that should be carried out: 1) determination of the character of the strata; 2) identification of the boundaries of the different rocks; 3) measurement and estimation of the dip and its subsurface continuation. These operations result in identification of the lithology and the production of geological maps and sections. These are discussed further in the article.

The fifth article (Penning 1879e) gives a relatively complicated example of geological surveying (mapping) involving: ‘*...the application of the methods of determination of rocks, of observation for dips, and of tracing irregular boundaries, faults, and unconformities*.’ Article 6 (Penning 1879f) is relatively short and discusses geological sections.

Article 7 (Penning 1879g) moves on to ‘*Materials, minerals and metals of practical value and importance*.’ The article covers building materials, alluvium and other Recent deposits, Tertiary or Cainozoic rocks, Upper Cretaceous (Chalk) and Lower Cretaceous. Article 8 (Penning 1879h) continues by discussing Upper Oolites, Middle Oolites, Lower Oolites, the Lias, the Trias, the Permian, the Carboniferous, the Devonian, Old Red Sandstone, the Silurian, the Cambrian including the Lower Silurian (presumably now the Ordovician) and finally the Laurentian (Pre-Cambrian).

The final article (No. 9) (Penning 1879i) turns its attention to groundwater with sections on the nature of springs, artesian wells and absorption wells. The final section returns to the subject of building sites and the importance of geological understanding to sanitary engineering involving urban drainage, disposal of sewerage and supply of pure water.


ENGINEERING GEOLOGY.

BY

W. HENRY PENNING, F.G.S.,

GEOLOGIST, H. M. GEOLOGICAL SURVEY OF ENGLAND AND WALES.

AUTHOR OF ‘FIELD GEOLOGY,’ ETC.

*WITH ILLUSTRATIONS AND COLOURED PLATES.*

LONDON:

BAILLIÈRE, TINDALL, AND COX,

20, KING WILLIAM STREET, STRAND.

1880.

[*All Rights Reserved.*]

***Figure** 7. Title-page of Penning’s book,* Engineering Geology, *published in 1880 (image courtesy of BGS Library).*

It is significant that Penning’s book on engineering geology (Penning 1880a), which is based on the nine articles, strikes right at the heart of its topic by dealing with the role of geology and engineering in construction and land use in the first section; only then, in the second section, does he describe methods of geological surveying. The third section deals, at length, with geological materials as resources, water supply and lastly ‘building sites’. The discussion of the most appropriate choice of locating a building site within a wider context, from a practical as well as an aesthetic point of view, is an early description of land use planning. His advice to look beyond the bounds of the footprint of the building in order to construct it in the most effective and sustainable manner is a principle of engineering geology that is fundamental to the long-term safety of the building or structure and its users. This book was one of the earliest textbooks, if not the first (at least in English), that encapsulated the complete integration of geology and civil engineering, in their widest implications, that defines the discipline of engineering geology and sets it aside from geology and geotechnical engineering. Indeed, if Penning was the first to use the term ‘engineering geology’, this was an important step in the development of engineering geology as a discipline. The power of a name is not to be underestimated. Other works dealing with geology and engineering have tended to start by instructing the reader in geology and only later seeking to add engineering implications; thus, they are 'geology for engineers' rather than engineering geology texts.

## Geology of South Africa

Penning's second achievement, in his papers on the South African goldfields (Penning 1888, 1890), was his naming of the Witwatersrand Beds (Du Toit 1954), later renamed the Witwatersrand System by Mellor (1917): 'The thick, predominantly sedimentary succession which hosts the auriferous conglomerates of the Transvaal was named the Witwatersrand Series by W. H. Penning in 1888' (Kent and Hugo 1978). He further discussed the stratigraphy of the Transvaal System in his papers for the *Journal of the Society of Arts* and the *Quarterly Journal of the Geological Society* (Penning 1884b, 1891).

Rogers (1936) described the *Guide to the goldfields of South Africa* as a 'pamphlet' (it was privately published in Pretoria) but commended the descriptions of gold discoveries in the Transvaal. However, Rogers noted that 'The geological features are hardly dealt with…' Rogers also was critical of Penning's discussion of South African coal-bearing rocks (Penning 1884a) in which he appeared to assume that those from Natal, the Orange Free State and Transvaal were stratigraphically of the same age. Rogers' discussion of Penning's publications closes with further implied criticisms of the 1891 paper on the geology of the southern Transvaal and his final publication in 1901, a booklet (77 pages) on gold and diamonds in South Africa. Hatch and Corstorphine (1909) are much less critical, simply stating what Penning had observed and described, and comparing his results with other workers (including Hatch). In particular, they discussed the three main theories proposed for the origin of gold in the Witwatersrand conglomerate:

1. The Placer Theory – '…the conglomerates (are) ancient marine placer deposits, of which the original pyrites has been partially, and the gold entirely, dissolved and redeposited.'

2. The Precipitation Theory – 'the gold and pyrites are chemical precipitates from the waters in which the conglomerate pebbles were laid down.'

3. The Inflation Theory – '…the cementing material of the conglomerates is so largely composed of secondary minerals shows that the beds must have been subject to much percolation by mineralising solutions before final consolidation. The slow and repeated passage of such solutions, even if carrying only a minute quantity of gold, would gradually enrich the matrix.'

Penning (1888) proposed the Precipitation Theory, but Hatch and Corstorphine preferred the Inflation Theory, though the modified Placer Theory is more favoured now (Tucker *et al.* 2016).

Penning's real motive in these publications was probably to make money through the provision of consultancy advice, particularly in relation to gold exploration. This is indicated by the advert he placed in his *A guide to the goldfields of South Africa* (Penning 1883). The final section contains 39 adverts for businesses ranging from lawyers to shop keepers and hotels. There is only one advert from a geologist, that of Penning himself:

'W.H. Penning, &G.,

*(Late of H.M. Geological Survey of England,)*

PRETORIA AND LYDENBURG

Undertakes to thoroughly examine and fully report upon Gold and Mineral Properties, to assay samples of Ore, to effect the sale of Farms, to form Companies, to provide Machinery, and generally to advise upon the utilisation of the mineral resources of the country.

*List of Farms for Sale on application.*

HIGHEST REFERENCES.'

While Penning may have made only a small contribution to the understanding of British stratigraphy (partly because his early mapping experience was limited to eastern England), in South Africa he was able to apply principles of stratigraphical mapping to older rocks, which led to a more lasting contribution.

Henry Penning was not entirely forgotten following his death. His former colleague Horace Woodward mentions him in his book on geology in relation to agriculture, estates, engineering and sanitation: 'There are also tracts of loam or brickearth over Boulder Clay, as shown here and there on the Geological Survey map; and hard yellow loam is intercalated in Boulder Clay at Wenden, as observed by W. H. Penning (1878)' (Woodward 1912). The reference to Penning (1878) should actually be to Whitaker *et al.* (1878). Woodward's book was intended to be useful '...to students and teachers of agriculture, to those occupied in the management of estates and farms, or in sanitary or engineering works, wherein it is important to consider the geological nature of different sites for residences and other purposes.' Penning would probably have appreciated that!

Perhaps the last non-historical reference to Henry Penning's work was by Greenly and Williams (1930) in their book on geological surveying. They refer to Penning's books on field geology (Penning 1876a, 1879j) and on engineering geology (Penning 1880a). No further reference to Penning's engineering geological work has been found until Kiersch discussed it in 1955. The next reference was by Hatheway (1990).

## Conclusions

Henry Penning was an applied geologist with a background in building, construction, surveying and engineering who worked, initially, on railway construction, and for the bulk of his career on geological mapping and mineral exploration. Despite working for 15 years at the Geological Survey of England and

Wales, he does not appear to have received widespread scientific recognition in his lifetime, even though he published extensively.

However, more recently, he is acknowledged to have named the Witwatersrand Series, which contains the gold-bearing strata of the Transvaal in South Africa, and to be the author of what is almost certainly the first text book on engineering geology (1880). Also, he may have coined the term 'engineering geology' itself in the first of his articles in *The Engineer* in 1879 (Penning 1879a). Indeed, it is not unreasonable to regard him as the 'founder of engineering geology' as a discipline.

It is likely that his role in the development of 'engineering geology' as a modern discipline was the result of his broad background in practical subjects. His early work in his father's building business and, later, in his own business, his engineering training under the guidance of the eminent engineer Charles Henry Gregory and his survey work with the Geological Survey gave him the broad knowledge and experience essential to a modern engineering geologist. However, breadth of experience, alone, is insufficient and it is its application to solving practical problems that characterises a good engineering geologist. His meticulous approach to the construction of geological sections using his engineering surveying skills appeared to be highly regarded by his colleagues in the Survey and may be regarded as an early phase of the development of an engineering geologist's quest for the '3D model'. That he was capable of using knowledge from diverse sources was demonstrated by his paper in which he compares stone tools from Africa with those seen in his childhood from Hoxne in Suffolk (Penning 1887). If not a polymath, an engineering geologist must be, at least, a first-rate generalist and Penning proved himself to be certainly that.

Undoubtedly, his achievements at the Geological Survey helped establish engineering geology as a key part of what national geological surveys should do and his 1880 text book on engineering geology was not rivalled until 34 years later when Ries and Watson (1914) published a text book of the same name, though it lacked the integration achieved by Penning. The efforts of 'ordinary' geologists are rarely acknowledged in the scientific literature but the work of Henry Penning reminds us that achievement in science and its application is not the sole preserve of the well-known and the well-educated!

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Martin G. Culshaw, British Geological Survey, Keyworth, Nottingham, NG12 5GG, and University of Birmingham, Department of Civil Engineering, Edgbaston, Birmingham, B15 2TT.

The late Alan Forster, Radcliffe-on-Trent, Nottingham, formerly British Geological Survey, Keyworth, Nottingham, NG12 5GG.