THE GREYWACKE

How a Priest, a Soldier and a Schoolteacher Uncovered 300 Million Years of History

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INTRODUCTION

Some years ago relatives of mine moved to the Welsh borders, and I began to spend long, exhilarating days walking the heather- and bracken-clad uplands of the Berwyn Hills. I liked to gaze down from Thomas Telford's nineteenth-century trunk road, now the A5, at a point known as Pont Glyn-diffwys. There, the land plunges hundreds of feet to the fast-flowing River Ceirw, and human life is tucked away in narrow lanes and hamlets. I tramped across moorland as the bracken turned to autumn gold and grouse took to the air, squawking in alarm. And I followed damp sheep tracks up steep river gullies overhung by ferns and moss.

Such a landscape seizes the imagination: it's impossible not to wonder how it came to exist. But as I started to read about the region's past, one place in particular kept drawing me back. On the western flank of the Berwyns, where the land drops gently towards the wind-flecked waters of Lake Bala, there are a series of moss-draped pits and quarries. Once upon a time, blocks of dull grey limestone were dragged out of the earth here to build nearby farms and outbuildings. The spot is known as the Gelli-grin, an old Welsh term meaning 'parched or withered woodland'. It isn't much to look at. Nevertheless, I learned it had played a remarkable role in the effort to unravel the history of our planet.

When nineteenth-century mining engineers and naturalists first started to classify the limestones, chalks and clays that cover much of England, the Welsh hills – along with much of upland Britain – remained a complete mystery. They were widely acknowledged to be old, perhaps among the oldest rocks in Britain, and were therefore presumed to hold the key to such questions as the age and origins of the Earth, and when and how life had begun: controversial matters in Victorian Britain. And yet there was a maddening problem. The rocks themselves were so twisted and apparently chaotic, the strata so difficult to trace, the fossil record so slender and obscure that they defied all attempts to place them in any order. As a result, a jumble of very different minerals was lumped together in a holdall category known as the Greywacke, an anglicisation of the German mining term *Grauwacke*, meaning 'grey earthy rock'. By the early 1800s this limbo category 'for the reception of everything that was ancient or obscure in the geology of Britain'[1] had become one of the great challenges facing the developing science of geology.

Amid all this obscurity there appeared to be one coherent and identifiable bed of stone that offered a clue to the meaning of the Greywacke: the band of limestone running through the Gelli-grin. But as some of the greatest geologists of the nineteenth century attempted to use it to unlock its secrets, tracing the faint band of limestone as it snaked its way through the rocks of north Wales like the stripe in a tube of toothpaste, they found they couldn't agree on what it was telling them.

First into the field was the Rev. Adam Sedgwick, a brilliant but troubled Cambridge University professor dogged by ill health and bouts of depression. He had an exceptional talent for reading the rocks, but owing to some mysterious inner impediment was incapable of putting his ideas down on paper. Hard on his heels came Roderick (later Sir Roderick) Murchison, a

retired soldier and ambitious socialite who treated geological fieldwork as a military campaign and conducted forced marches along Wenlock Edge and central Wales with the help of copious quantities of laudanum and the bemused support of the local gentry. For Murchison, conquering the history of the rocks was akin to conquering Africa or India: a manifestation of Britain's imperial glory.

During the 1830s these improbable companions formed one of the great scientific partnerships of the nineteenth century. Together they painstakingly mapped large areas of the Welsh Greywacke and followed the strata south as they dipped under the Severn Estuary and into Devon and Cornwall. But at the Gelli-grin they hit a band of rock that, for all its apparent clarity, they simply couldn't agree upon. Their difference of opinion – at first a hairline fracture so subtle that neither really noticed it – became increasingly acrimonious. The collaboration, initially so fruitful, collapsed, turning friend against friend, colleague against colleague, and for the next thirty years divided the Victorian scientific community.

Resolution had to wait until the 1860s, when a young provincial schoolteacher and amateur geologist called Charles Lapworth began his own investigation into the ancient rocks. He started tracing a little-understood family of fossils known as graptolites across the hills of the Scottish borders. His meticulous examination of the graptolites enabled him to definitively classify the Gelli-grin limestone and, in doing so, finally make sense of the Greywacke.

As I sat in the cool green shade of the Gelli-grin one summer day, with a chainsaw buzzing far away in the valley below, I became caught up in this remarkable story and its curious cast of characters. And so I decided to reconstruct their journeys around some of the most rugged parts of Britain.

I climbed the bare slopes of the Berwyn Hills with Adam Sedgwick and followed him west across the empty expanses of the Denbigh moors and into Snowdonia. I tracked Roderick Murchison along the Wye Valley and through the Welsh Marches into the green, gently rolling hills of central Wales. And I travelled north to the Scottish borders where Charles Lapworth crawled, sometimes literally on his hands and knees, in pursuit of graptolites.

As I walked in their footsteps I found myself entering the strange, almost entirely masculine world of a remarkable group of scientific pioneers. I became familiar with Sedgwick's curious blend of bonhomie, hypochondria and religious puritanism, Murchison's ruthless ambition and love of king and country, and Lapworth's patience, humility and occasional mental fragility. What amazed me was that, apart from a handful of invaluable academic works, their story has never really been told before. Yet it is a deeply involving saga of friendship and rivalry, success and failure, courage and ambition.

I also found myself entranced by the mysterious power of the rocks: so prosaic and unremarkable in their appearance, yet unimaginably old. Most nineteenth-century observers, influenced by biblical versions of the history and origins of the Earth, put their age at perhaps 5,000 years.[2] Better-informed geologists guessed at many thousand years more. But we now know that the Gelli-grin limestone is about 450 million years old, while some of the neighbouring sandstones go back another 100 million years. In the world of stones, time is measured not in years or even hundreds of years, but in hundreds of millions of years. I once picked up a very ordinary piece of slate on the slopes of Snowdon and found it utterly incomprehensible that I was holding something more than 400 *million* years old: an unremarkable object with an astonishing history.

Moreover, in the last hundred years these minerals have disclosed a record of events whose grandeur defies belief. For millions of years the land mass that is now Wales sat on a shallow coastal shelf somewhere south of what is now Cape Horn, on the borders of the Antarctic Ocean. Underwater volcanoes spewed out lava across the sea floor, sometimes shaped by the pressure and movement of the ocean currents into soft pillowy forms, at other times burying itself between layers of mud and sand. Occasionally the eruptions were so violent that they broke the surface of the water, sending clouds of dust and ash into the air, which rained back into the sea, forming yet more beds of volcanic ash among the sediments of the seabed.[3] Then things quietened down, the tectonic plates moved and 'Wales' travelled north towards the equator at the speed of a growing fingernail. The land sank under a shallow sea that alternately left beds of calcium-rich limestone such as the Gelli-grin and the muddy sandstones of the Berwyn Hills.

This is the early history of much of what now constitutes the British Isles. It's a sequence of events that Sedgwick, Murchison and Lapworth might have found hard to credit. Yet their determination to classify the Earth's early rocks laid the foundations for much of what followed.

Today, thanks to their efforts, we know the Greywacke can be broken down into a variety of different rocks: the fragments of volcanic ash and lava that cascade down the slopes of Snowdonia; the grey pebbly sandstones of the bleakly magnificent Rhinog Hills that run down the coast of the Irish Sea; the muddy silts and shales of the Berwyn Hills; and the magnificent red sandstone peaks of the Brecon Beacons.

And in breaking down the Greywacke, these geologists also gave us four distinct periods in the Earth's early history: the Cambrian, Ordovician, Silurian and Devonian, a stretch of

around 150 million years during which entire continents formed and re-formed, new species of life appeared, thrived and vanished, and our world changed beyond recognition – shifting, shaping and evolving into the world as we find it today.

Chapter One

THE ERRATIC PROFESSOR SEDGWICK

At the end of July in the damp summer of 1831 a self-taught Cambridge University geologist called Adam Sedgwick climbed into a horse-drawn gig and set off from his rooms in Trinity College on the long journey to north Wales. For some years he had been casting curious glances at the region's poorly mapped mountains, but as he rattled through the lush summer countryside past banks of yellow flowering gorse, he worried that he had left it too late and would run into bad weather. Only the year before, he had been forced to abandon a trip to the Welsh hills in the face of unceasing rain.

After a day of jolting over the rutted roads, with the gig periodically engulfed in swirling storms of dust, Sedgwick stopped that evening in the booming Midlands town of Dudley.[1] At a limestone quarry near the town centre quarry men had stumbled on one of the richest fossil beds in the British Isles: a treasure trove of hundreds of marine species, many never found anywhere else in the country.

The sheer number of species suggested that this had once been an exceptionally busy underwater reef.[2] Among the unique fossils was an unusually large trilobite called *Calymene blumenbachii* – an extinct, marine, insect-like creature – known locally as the 'Dudley Bug', an aristocrat of the early seas so striking it was proudly displayed on the town's coat of arms right up

until the local image was sharpened up in the 1970s. Relics like this had turned Dudley into a national centre of the fossil trade. Impromptu 'rock shops' advertised trilobites, crinoids or 'sea lilies', corals and shells for sale,[3] and Sedgwick spent a pleasant day buying specimens for the Cambridge University collection.[4]

The next morning he pushed on west across the Shropshire plain, until the road crested a wide ridge and, in a magic moment, the hills of Wales and the border country sprang up on the horizon, range after range as far as the eye could see: the Breidden Hills, the Berwyns, the Arenigs and, beyond them all, the wild emptiness of Snowdonia.

In Shrewsbury, Sedgwick bounced along wide streets of handsome buildings, the cobbles worn and polished by the passage of traffic, to a large Georgian house on the northern outskirts. He was in town to pay a visit to a certain Charles Darwin, back from Cambridge, twenty-two years old and waiting to join HMS *Beagle* as an enthusiastic but inexperienced geologist on an expedition to South America.

By way of preparation for this voyage, Darwin had offered to help Sedgwick on his tour of the Welsh hills.[5] Sedgwick was particularly well received by Darwin's three unmarried sisters, who welcomed the 'attractive and fascinating' visitor.[6] But after a day spent exploring the road cuttings and quarries around Shrewsbury the two men pushed on for Wales. Time was short and Sedgwick, perhaps flustered by all the female attention, was in a hurry to get to the hills.

In the early 1800s geology was one of several newly emerging fields of enquiry dedicated to exploring, labelling and cataloguing the natural world. The Zoological Society of London had recently opened a zoo in London to house the greatest collection

of animals in the world. The Royal Horticultural Society was about to lay out Kew Gardens on the western fringe of the city, to study and display one of the world's biggest plant collections. And in the wake of the Industrial Revolution and its frenzied hunt for minerals such as coal, iron and limestone, the recently established Geological Society of London had begun identifying and mapping Britain's rocks, grouping them into simple, easily understandable categories.

The Earth had begun, they assumed, in a 'fiery baptism', which had laid down a series of hard, weather-resistant rocks. The heat and fury of their birth had turned their minerals into crystals that were usually clearly visible to the naked eye. These granites, basalts and gneiss could be found across the western extremities of Britain, where they appeared to form the core of ancient mountain ranges. They became known, for obvious reasons, as Primary rocks, the foundation on which everything else rested.

Vast ages later ancient seas had covered these rocks in water, leaving a succession of sediments that formed beds of chalk, limestone, sandstone and coal. These became known as the Secondary rocks: neat bands of strata, one on top of the other, that lie across much of England.

Finally, resting on top of them all were the sands and gravels found in areas such as Norfolk, Suffolk, Essex and the Thames Estuary, which had not yet been compressed into 'true' rock. These were the so-called Tertiary strata.[7]

This simple scheme gave early geologists three distinct categories in which to place the Earth's rocks, and a crude understanding of the temporal relationship between them. There was, of course, no way of knowing their absolute ages, so they were usually represented in a 'stratigraphic column' – a tabular representation of their relative ages, with the oldest at the bottom.

BASIC CATEGORY	COMMON NAME, 1830	MODERN NAME/ EQUIVALENT
TERTIARY	Tertiary mud, sand and gravel	Tertiary and Quaternary
SECONDARY	Cretaceous Chalk	Cretaceous
	Jurassic or Oolitic Limestone	Jurassic
	New Red Sandstone	Permo-Triassic
	Carboniferous Coal-bearing strata	Carboniferous
	Old Red Sandstone	Devonian
TRANSITION ROCKS	Greywacke	Silurian Ordovician Cambrian
PRIMARY	**Primary/Primitive**	**Precambrian**

1.1 A simplified stratigraphic column of circa 1820, showing the relative position of the different rocks found across Britain.

During the early years of the nineteenth century a proliferation of guides and handbooks, many going into multiple editions, presented these new ideas to an avid lay readership. Yet there was a problem at the heart of their simple tripartite classification, and it threatened the coherence of its whole story of the Earth.

The problem concerned a great jumble of grey, gritty sand and mudstone blocks, sometimes interleaved with volcanic ash and thin veins of limestone, that lay between the Primary and Secondary strata. This peculiar stone had nothing in common with the crystalline Primary rocks, yet it appeared to contain none of the easily discernible bands of strata characteristic of the Secondary rocks. Indeed, in some places there were no visible strata at all; in others, it looked as if they had been smashed by

a giant hammer, sending thousands of fracture lines running in all directions.

In continental Europe these 'obscure heaps of sediment', as one commentator called them,[8] covered large areas of Scandinavia, the Rhineland and Bohemia, where they went by the German mining term *Grauwacke*, or 'grey, earthy rock'. In Britain they were found in parts of Devon and Cornwall, Wales, the Lake District and Scotland. The German name was anglicised to 'Greywacke', sometimes with an emphasis on the last e. They were also known as Transition rocks, because they appeared to lie at that point in the stratigraphic table where Primary rock 'transitioned' into the Secondary.

To nineteenth-century geologists and mining engineers the Greywacke rocks were so 'hardened, squeezed and broken as seemingly to defy all attempts to classify them'. 'If any one had proposed to apply to this puzzling old Transition or Grauwacke series the same tests by which the secondary and tertiary deposits had been brought into such clear and intelligible order,' wrote one observer, 'he would have raised a smile among his geological friends.'[9] They were 'an unknown land, a pathless desert', a limbo category 'for the reception of every thing that was ancient or obscure in the geology of England,' wrote another, that would require 'such a labour and devotion, in order to effect any important results' as to deter most investigators.[10]

In 1815 the land surveyor William Smith published the first geological map of Britain. It showed in considerable detail how most of the country divided neatly into Secondary and Tertiary strata: the sands and gravels of East Anglia, the chalk of the Chiltern Hills, the clays and sandstones of the Midlands, the limestone hills of the Cotswolds and the coal-bearing seams across the Midlands and northern Britain. But to the west and into Wales the neat divisions vanished and the entire area was

loosely depicted as a jumble of sandstone, volcanic lava, granite and slate. Smith labelled this morass 'Red and Dunstone' – an umbrella term for the blend of sandstone, volcanic lava and granite that covers much of the region – and 'Killars and Slate', 'killars' being a Cornish mining expression for crushed and folded slates.

Smith wasn't alone in fudging the matter. The influential *Outlines of the Geology of England and Wales*, published in 1822, described the Secondary and Tertiary rocks in detail, but stopped entirely when it reached the Greywacke.[11] The equally popular *Geological Manual*, published by the West Country geologist Henry De la Beche in 1831, said of it, 'when we consider the extremely perplexing character and the geology of many of the districts where these old rocks occur, we cannot wonder that they should have continued to be a stumbling block in the progress of science ... [it would be] a hopeless task to reduce the apparent chaos to order'.[12] And in the same year Charles Lyell, one of the great Victorian theoreticians of geology, published the first edition of his enormously successful *Principles of Geology*, in which he devoted 300 pages to the Tertiary muds, sands and gravels of eastern England. The Greywacke, by contrast, got twelve lines.[13]

And yet, in so far as the fossil record could be understood, it suggested that these mysterious rocks might contain the first evidence of life on Earth. To a nineteenth-century audience deeply curious about the age and origins of life, and increasingly doubtful about the literal truth of the Bible, that gave the Greywacke an added significance.[14] If it could be mapped and logged in the same detail as the Secondary and Tertiary rocks, then geologists might begin to unravel the miracle of life itself. The Greywacke was a challenge waiting for a champion.

Sedgwick had been contemplating it for some time. He'd

grown up in the small village of Dent in the Yorkshire Pennines, rambling, hunting and fishing across a landscape of wild, empty hills and fast-flowing rivers that were remarkably similar to the Greywacke uplands of parts of Britain. It was a type of countryside he knew well and was almost instinctively curious about. Moreover, several years earlier he had struck up a correspondence with an Oxford-educated gentleman geologist called William Conybeare, a leading light in the Geological Society and joint author of the best-selling *Outlines of the Geology of England and Wales*. Conybeare had always planned a second volume on the Primitive and Transition rocks, but soon after the publication of the first volume, his co-author William Phillips, a London printer and bookseller, died unexpectedly, leaving Conybeare in need of a new collaborator. Sedgwick had agreed to step in.

A start had already been made. Sedgwick had traced the Greywacke rocks in the Lake District and had superficially surveyed the rocks of Devon and Cornwall.[15] But nobody had even attempted to analyse their composition or strata in any detail, and the Welsh hills, one of the most important areas of Transition rock in Britain, remained virtually unexplored. This was the task that was now taking Sedgwick to north Wales: to unravel the tangled knot of obscurity at geology's heart and carve out an area of expertise that he could call his own.

The journey from Shrewsbury to the Welsh border is roughly 40 miles. By midday on 5 August 1831 Sedgwick and Darwin had reached the Welsh slate-mining village of Llangollen in the Dee Valley. A river cascades through the town, passing below an old stone bridge in a series of seething rapids and whirlpools. High above the rooftops of the houses are the ruins of a thirteenth-century border castle called Castell Dinas Bran. And

behind this stand the limestone cliffs of the Eglwyseg escarpment – pronounced 'Egg-lui-seg' – rearing hundreds of feet in the air and running north for mile after mile in an almost unbroken chain of crags, like a prehistoric version of the Great Wall of China.

Sedgwick had brought with him the latest map of the geology of Britain, completed only ten years earlier by George Greenough, a former president of the Geological Society. The map had been completed with the assistance of local geologists across the country and was considered the most accurate and complete chart of the rocks of Britain then available. It suggested the Eglwyseg escarpment was composed of limestone from the Carboniferous period sitting on top of a bed of Old Red Sandstone, which in turn rested directly on the Greywacke. As their gig clattered into town, Sedgwick and Darwin agreed that this was the ideal place to start mapping the Transition strata. They would log the point where the Secondary rocks gave way to the Greywacke and then travel west through Wales, moving back in geological time and charting the changing strata until they reached the even older Primary rocks along the coast of the Irish Sea. Indeed, a single journey from Llangollen to Anglesey should enable them to map the entire history of the Greywacke.

That afternoon the two men toiled up a steep zigzag footpath of loose stone and shale to Castell Dinas Bran, then stumbled across slopes of slate and scree to the foot of the Eglwyseg escarpment. Sedgwick was carrying an assortment of geologist's hammers, some with long wooden handles and heavy metal heads, and every now and then he would stop to knock off the weathered outer layer of a rock and inspect the freshly exposed surface through a hand-lens: this was really the only way to be sure of the identity of many types of rock. He may also have

dripped dilute sulphuric acid onto the broken surface: it fizzes violently in the presence of calcium carbonate and is an instant identifier of limestone.[16]

As they climbed, the two men collected specimens of typical Carboniferous fossils, including mussel-like brachiopods (also known as 'lamp shells' because of their resemblance to oil lamps) and several varieties of tube-shaped branching coral, which they carefully placed in leather specimen bags. Darwin struggled with the geology, but it's said that Sedgwick's encouragement made him 'exceedingly proud' and they worked well as a team.[17] After several hours of searching, however, it was clear to Sedgwick that they had hit a problem: no matter where they looked there was absolutely no sign of the Old Red Sandstone. The Carboniferous Limestone strata sat directly on top of the Greywacke. As one Victorian writer explained, the geological record was 'thus rendered as imperfect as an historical narrative would be if several important chapters were torn out of it and destroyed'.[18] How could Sedgwick map the Greywacke if he didn't have a clear starting point? How many other unread chapters at the top boundary of the Greywacke might also be missing?

The following day the two men climbed out of the Dee Valley on the Llangollen-to-Ruthin turnpike, tracing the line of the Eglwyseg escarpment north towards the coast. Again Greenough's map clearly showed outcrops of Old Red Sandstone lying directly below the limestone. Again it was misleading. They followed the valley of the River Clwyd, their gig trailing dust and mud through settlements of small whitewashed cottages busy with the noise of dogs, geese and bare-footed children. Occasionally they separated, taking different routes in the hope of running across outcrops of the elusive 'Old Red'. To their east the Carboniferous Limestone crags of the Eglwyseg escarpment marched across the landscape, before reaching the coast and

plunging hundreds of feet into the sea in a series of spectacular cliffs at the Great Orme, an ancient centre of copper mining. 'Very obscure stratification,' noted Sedgwick as he rested in the impoverished fourteenth-century walled town of Conwy. He would later observe, 'The Old Red all round by Orm Head etc etc is a pure fiction, at least I can't see a trace of it. There is not a particle of it between Denbigh and the Isle of Anglesey.'[19]

A vital piece of the geological record – what we now know to be tens of millions of years of the Earth's history – appeared to be missing. The rocks of north Wales floated in what has been memorably described as a 'temporal vacuum'.[20] 'No amount of labour or skill,' wrote the Victorian geologist Archibald Geikie some years later, 'could possibly connect the history of the Transition rocks with that of the younger strata by which they are covered, for a great gap occurs there in the geological record.'[21]

Frustrated by this puzzling circumstance, Sedgwick decided on a new approach: he would move west. If he could not work down from the Secondary rocks into the Greywacke, perhaps he could work up from the Primary beds in Anglesey and along the north-west coast of Wales. Once again, the task looked simple enough on paper. The multicoloured, crystalline Primary rocks, their crystals catching the sunlight, would stand out against the dull brown, gritty sands and silts of the Greywacke, making it relatively easy to identify the boundary between the Primary and Greywacke strata. Sedgwick's search would switch from the limestone hills and escarpments of Llangollen, the Vale of Clwyd and the Great Orme to what he described as the 'ancient slates and porphyrites' of Snowdonia,[22] 'porphyry' being the Victorian term for crystalline, or igneous, rock.

The geologists followed a steep, stony track south along the Conwy Valley and then climbed up through the treeline and

onto the bracken-covered slopes of the surrounding hills. It was hard going; Sedgwick complained of his limbs being 'jostled out of their sockets'.[23] When the going got too difficult, they abandoned the gig and continued on foot or horseback, stumbling between outcrops of rock and skirting patches where the path disappeared into brown, peaty bogs and the cold gleam of water reflected the sky.[24] On the slopes above Bangor, with the Menai Straits floating in the distance, they found a jumble of dark sandstone mixed with crystalline patches of feldspar and quartz. But still there was no obvious boundary between the rock types.

From Bangor they moved south to the grey slate quarries of Bethesda, with their chaotic hills of collapsing spoil heaps left behind by generations of miners. Several days later they took Telford's recently opened suspension bridge, vaulting 100 feet over the treacherous waters of the Menai Straits – 'the most spectacular feat of engineering ever accomplished in Britain' – to Anglesey.[25] At inlets along the coast, and in freshly worked quarries and road cuttings across the flat interior of the island, they found outcrops of unmistakable gneiss and schist. Here, intense heat and pressure had lined up the minerals into extraordinary coloured bands: the pale-grey crystals of quartz and feldspar standing out against the darker bands of mica. These were everybody's idea of quintessential Primary rock, and meant that somewhere between Bangor and Anglesey they had crossed out of the Greywacke.

Back on the mainland, confounded about where to draw the boundary, the two men separated. Darwin returned to Shrewsbury, where he would find the famous letter confirming his place on the *Beagle* and the scientific expedition that would change his life. He would later acknowledge his Welsh excursion as the origin of his interest in 'the noble science of geology'.[26]