

**GEOLOGICAL SURVEY OF IRELAND**

**WRITTEN IN STONE**

**A VIDEO PRESENTATION IN SIX PARTS ON THE LANDSCAPE AND  
GEOLOGY OF IRELAND.**

**GUIDANCE NOTES FOR SCHOOLS**

## **INTRODUCTION**

These notes are intended to assist schools, teachers and pupils in deriving the maximum benefits from the video “Written in Stone” and its accompanying booklet of the same name. First shown on RTE television in 1995, this six-part series explores the landscapes of Ireland and how they evolved through geological time. With the development of a new geography syllabus for the Leaving Certificate, which has an increased emphasis on aspects of physical geography, the Geological Survey of Ireland (GSI) considered it timely to provide copies of the video and booklet to all second level schools in the country. It is hoped that these notes will make the series more accessible – and enjoyable – to the widest student audience.

“Written in Stone” is no scenic tour of the country and certainly it is not a county-by-county guide to the geology and landscape of Ireland. Its focus lies in teasing out the processes that shaped our landscape and in unravelling the long but fascinating history that underpins the physical environment which we all share in Ireland. Behind this approach is a very important message that must be emphasized: your locality, wherever it is, has an interesting story to tell. Yes, this applies whether your school is in an urban setting in one of our cities, or on the edge of a town in a farmland setting, or indeed in a scenic valley or beneath a hillside in some other part of the country. The purpose of these notes is to help you unlock the links between “Written in Stone” and your locality.

This text provides a short summary of the theme of each of the six episodes of the video. This should create a focus for viewing and discussing each episode. Also full use should be made of the accompanying booklet: the links between its sections and specific episodes of the video are described and should be a useful reference when it is not convenient to view the video. Reading need not be confined to the booklet: standard textbooks are available from the local or school library and websites should be consulted also. The following GSI websites, [www.gsi.ie](http://www.gsi.ie) and [www.gsiseabed.ie](http://www.gsiseabed.ie), may be useful starting points. In addition, activity tasks have been created for each episode in order to provide discussion of the issues involved as well as their relevance to your specific locality. The Midway Interlude is particularly important in this regard.

## **Episode 1: Layers of Time**

The earth has a history which starts even before there was any life, let alone human beings, and this history is charted through the layers of rock we commonly observe around us. These layers are like the pages of a very extensive history book that reveals a great deal about the origin and evolution of our planet. We learn how its internal forces developed, how its climates and atmosphere evolved, and how life formed and multiplied in scale and complexity both in seas and on land. On its very last page, we see the emergence of humans and the impact they have had on their fragile environment.

Of course, the binding of this history book is long since destroyed, with its pages scattered and jumbled by the earth's forces. This episode describes some of the techniques we use to re-assemble their correct order – including the features of the sediments themselves, the fossils they contain and the radioactivity of the sediments and associated rocks.

**Further reading:** The early sections of the accompanying booklet tend to cover the same ground as this episode. *Introduction* provides a commentary on rocks as a common inheritance of all who ever lived on this island and then discusses the links between its geology and archaeology. *The Earth – one small planet* gives a commentary on the origin and position of our planet in space. It also describes the internal structure, hydrosphere and atmosphere of planet Earth. The section entitled *Time - lots of it* is concerned with how we measure geological time and provides interesting background material on issues such as the role of radioactivity in dating rocks.

## **Reflection and Exploration**

- Describe your nearest countryside as it might have been before there was any life, such as grass or forest – or even flies!
- Discuss a layer of rock (or sand or clay) that you have observed. How do you think it formed?
- Do you think the earth's climate has always been stable? If so, why? Do your parents agree?
- Radioactivity can be used to measure the age of rocks. Can you think of any other uses it has?
- Compare planet Earth with others in the Solar System. With which other planet is it most alike? And unlike?

## **Episode 2: Bends and Breaks**

This episode introduces a brief explanation of how plate tectonics shape the distribution of oceans and continents, mountains and lowlands on our planet. It describes how the opening of new oceans can cause the break up of continents while leading to the formation of mountain chains and indeed new continents. Plate tectonics seemly reflect the internal workings of the earth. This is the essential global context in which is considered the stresses that operate on smaller scales.

Layers of rock are commonly buckled and broken; many examples of folds and faults are shown. There is no doubt that the Earth can wield formidable power. Such features are due to the type of earth pressures that also produce slate from mudstone. We cannot observe these forces at work, but earthquakes are one result with immediate and dramatic effects. It will be no surprise that these are discussed in some detail.

### **Further Reading:**

Take some time with the accompanying booklet at this point, because it illuminates points relating to the workings of the earth and its internal engine – what is formally called plate tectonics. *Continents and Oceans* attempts to characterize the seafloor and explain why it is so different from continental crust. A key feature, concerning the magnetic properties of the ocean floor, is presented as supporting evidence. In *Oceans – where the action is* there is further discussion of ocean spreading with evidence from fossils and magnetism. *Mountains – crumple zones* deals with the driving forces within the earth, which cause the construction of mountain chains in the aftermath of continental collision. The central role of earthquakes and fault lines is treated in *Bends and Breaks – something has got to give*, which describes earthquake zones such as the San Andreas Fault and explains why Ireland has (almost) no earthquakes!

### **Refection and Exploration**

- Can you imagine what the ocean floor looks like? How is its shape different to what you experience on land?
- Are you familiar with any exploration of the seafloor? In the film “Titanic” how was the shipwreck explored?
- Do you know anyone who experienced an earthquake? What did they feel or see?
- Why does Ireland have no serious earthquakes?
- Many rocks suffer stress – they are buckled, broken or have a cleavage. Describe one such rock you have seen.

### **Episode 3: Fire & Brimstone**

This episode concentrates on how the earth's internal energy produces molten rock, or magma, at depth – especially near the margins of plates, where they either separate or collide. When magma makes its way to the surface it is manifested as lava and ashes, the outpourings of volcanoes. Lava chills very quickly and in the case of ocean floor basalt its bubble-shaped masses have glassy rims. But the rock itself also cools quickly and so is always composed of very fine grained crystals which can only be examined with the aid of a microscope. We have no active volcanoes in Ireland, but the traces of ancient ones are obvious in places like Lambay Island, and especially the Antrim basalts. The latter's Giant's Causeway has distinctive vertical columns due to the same rapid cooling.

Granite is a different product of magma. It solidified at depth in the earth's crust, so it cooled more slowly than lava and its coarse-grained crystals can be seen with the naked eye. There is no doubt that it was once liquid because it has trapped fragments of the surrounding rocks – and these latter rocks have been seriously baked by the liquid granite's heat. The mineral andalusite in the mica schists of Killiney Beach is just one expression of this. We see granite at the surface now simply because its overlying rocks have been eroded.

#### **Further Reading:**

Every student will find interesting articles on volcanoes in the local library and on the Internet. The section in the accompanying booklet called *Destruction – Banished ocean floor* will provide an interesting context for such broader reading because it deals with the descent and loss of oceanic crust at collision zones. It also describes the significance on a global scale of the distribution of volcanoes and earthquakes. The nature and origin of granite is discussed in an interesting section called *Granite – a jack of all trades*.

#### **Reflection and Exploration**

- Have you ever visited an area with a volcano? Was it active, dormant or extinct? Explain these terms!
- Find the nearest exposure of volcanic rock to your school (using the GSI 1:100,000 geological map series. Is it composed of lava or ashes (or both)?
- The Antrim coast exposes basalt as flat layers, rather than the cone-shaped hills we often associate with volcanoes. Why is this so?
- Draw a sample sketch of oceanic crust sliding beneath continent at a boundary between two plates. Can you suggest where granite bodies might be found?
- Find a building that uses granite in its construction. Why is granite used so often?

### **Midway Interlude: Examine your locality**

At this point teachers may wish to reflect on the relevance of this video to their own locality or indeed to feature some field study. Young people like to collect stones and become familiar with them.

Local rocks can be collected as beach pebbles. They occur along coastline exposures and cliffs, we can see them exposed in roadcuttings and in quarry faces. They form natural outcrops in all sorts of places, including hilltops and river beds. Wherever you seek out rock samples, take adequate precautions for the health and safety of all participants. Do not collect unnecessarily or in situations where the rock type is special or limited in its distribution. If you are not in a position to explore outdoors do use the Internet or library books to expand your understanding.

You may be able to get geological help locally – from a university department, from field studies or geological associations or from local residents who are professional, amateur or retired geologists.

### **Further Readings:**

The accompanying booklet provides some background on the range of rocks you are likely to encounter. Sedimentary Rocks – Continental Junk deals with the erosion of older rocks and the transport and deposition of the resulting debris –thus starting a new cycle of sedimentation. Thus are built up the various pages of our book (A History Book – loose pages with no numbers?) and the features of these sediments can help us to order the pages. Fossils – evolving life describes examples of fossils of various ages from Ireland and how they indicate the prevailing environment and climate. Igneous Rocks contrasts the different natures and origins of basalt and granite, reflecting their depth of formation and environment where they solidified. Cooked rock – rare, medium and well-done looks at how rocks become baked (metamorphic rock) and describes examples such as schists and gneisses.

### **Reflection and Exploration**

- Where is the most accessible locality in your area for collecting rock samples? Name and describe the most common rock type found there.
- If you look carefully, there may be some interesting fossils or minerals present. Try to identify and describe them.
- Stone and earth materials have many uses! Describe one that is employed in your area.
- Look at the landscape around you and pick an interesting feature (hill, waterfall, sand, boulder clay, etc). Explain how you think it formed.
- There are sedimentary, igneous and metamorphic (baked) rock types. Have you seen or collected an example of each? If you are missing some, where is the nearest area containing them?

## **Episode 4: The Journey**

The sands which make up the quartzite of the Sugarloaf Mountain (Wicklow) flowed off a different continent to that which supplied the sands for the quartzite of Errigal Mountain (Donegal). In fact these sands were once separated by an ocean, one that pre-dated the Atlantic Ocean. As the opposing continents approached and collided, the ocean was gradually obliterated as one continental plate slid beneath the other. The line of collision can be traced from Shannon estuary across the Midlands to the east coast in County Louth. More dramatically, a major mountain chain resulted and its eroded roots can be traced far beyond Ireland, to both the Appalachians and Scandinavia.

At the time of collision, Ireland was in the present-day position of South Africa. Since then it has gradually moved northwards across the tropics to reach its present temperate position. Along the way, Ireland experienced the deserts of the Old Red Sandstone, tropical shallow seas of our limestones, lush swampy vegetation that gave rise to our coalfields, and back to more deserts. Soon afterwards the northward progress was made more complex by the opening of the modern Atlantic Ocean.

### **Further Reading:**

A kaleidoscopic treatment of Ireland's journey across the globe is contained in the accompanying booklet. *There it was – an Irish ocean gone* deals with the ocean that once separated the northern and southern halves of Ireland as well as the evidence that supports the interpretation. *Continents collide in Ireland!* focuses on the deformed rocks of their mountain chains, which are still visible. *The Red Desert* concerns the erosion of these mountains in desert conditions and *Island in the sun* the subsequent deposition of limestones in shallow tropical seas. *Ancient forests – coal to you and me* contains an account of the development of Irish coalfields and *All about again* deals with subsequent desert and shelf sea deposition, giving the younger rocks of the northeast of the island. Various aspects of our four-dimensional journey are contained in *A great journey – we actually got here from there*.

### **Reflection and Exploration**

- When the two halves of Ireland merged, we were on the present-day position of South Africa. What kind of climate would we have had?
- The position of the two parts of Ireland gave rise to a major mountain chain - probably similar in scale to the Alps or Himalayas. Could such mountain building have impacts on the regional climate?
- Before the Atlantic opened, how much closer would we have been to New York? How much shorter would the flight time be for modern aircraft?
- Is there an ideal climate? List the disadvantages (and advantages) of your preferred climate.
- If Ireland keeps moving across the surface of our planet as it has been doing, where are we likely to end up? What would the climate be like?

## **Episode 5: Hard Water**

Water, one way or another, has had an amazing impact on our landscape, weathering and removing its surface and depositing the debris elsewhere. However, it is the solid form of water, ice, that we concentrate upon here. A fall in mean annual temperatures led to the spread southwards of polar ice. Glaciers descended from mountains, gouging out valley sides and scraping rock surfaces as they moved downwards. Today, waterfalls cascade over the steepened valley sides.

At their greatest extent, ice sheets occupied much of the low-lying country and locally exceeded one mile in thickness. The sea level would have been lowered and there may have been a land link to Britain. When the ice melted, the debris it contained was left behind as boulder clay – the basis of our modern agriculture. Where meltwaters flowed off the ice, they carried off the clay particles leaving sand and gravel deposits. As melting was completed and temperatures rose, the first forests and lakes appeared on the landscape. Soon afterwards there is evidence of humans arriving. Some of our earliest settlements were overtaken by bog development – but humans persisted and have had significant impacts themselves on the landscape.

### **Further Reading:**

The story of the Ice Age in Ireland is treated in many standard books of geology and physical geography. It is not surprising then that it receives less coverage in the accompanying booklet. Nevertheless, the account in *Ice cold - almost yesterday* covers the history of Ireland's Ice Age and the effects it has had on the landscape.

### **Reflection and Exploration**

- Boulder clay from the Ice Age is the source of soil in most of our gardens. Is this the case in yours?
- Describe some landscape features you are familiar with that have been affected by the action of ice sheets?
- Where are your nearest sand deposits? Are they in coastal beaches or dunes, river beds, or ridges left from the Ice Age?
- Imagine that sea level dropped by 100 metres during the Ice Age. What effect would that have on the facilities that currently exist in your area?
- Have you ever visited a bog? Describe what you learned about the nature of peat.

## **Episode 6: Heritage**

From the outset, settlers in Ireland used the rock resources around them in order to survive and to develop their communities. The early use of flint for implements is well known. Construction materials for buildings have been quarried throughout our history. More recently we have extracted energy resources from coalfields and peatlands, while the lead veins of Wicklow yielded metal for nineteenth century urban plumbing.

Modern society makes enormous demands on its environment and landscape. At Navan, many miles of underground tunnels have been opened to extract zinc ores from limestone. Elsewhere limestone itself is a feedstock for cement. Gypsum from Kingscourt is mined and processed into plasterboard. 25% of our water supplies comes from underground and requires careful protection.

We need to reflect on what impact our behaviour has on the earth and whether in fact the earth can sustain itself indefinitely into the future. We can extract in a few short years what has taken nature thousands or even millions of years to produce. Can we really sustain this behaviour and still leave a viable legacy to future generations?

### **Further Reading:**

This final episode ranges from the scientific to the philosophical and demands a similar resource from both teacher and pupil. In the accompanying booklet *Rocks and the economy* looks at the nature and origin of valuable resources such as zinc ores and gas deposits. It also describes the variety of rock resources and the necessity to protect groundwater quality. Hydrocarbon resources are described in some detail in *Fossil Fuels*, which appears as an addendum to these notes. The Irish landscape and its shaping by geology is featured in *A beautiful island and a map. The Rock Heritage* emphasizes that every part of that landscape is unique and in part of our natural heritage, a powerful closing statement that is reflected through this series.

### **Reflection and Exploration**

- How many different metals can you identify in, say, your house or car? Find out in which country each is mined.
- What product is extracted from the nearest mine or quarry to you? How important is it to the local economy?
- Bogs hold enormous energy resources and yet they are valuable ecosystems. Should we preserve some or all of them?
- What is the oldest building or human-made structure that you are familiar with? Which quarried materials were used in its construction?
- Which change in behaviour on your part would make the greatest improvement on your environment?

## **Acknowledgements:**

The video "Written in Stone" originated in a six-part television series commissioned by RTE and initially screened in 1995 to celebrate the 150<sup>th</sup> anniversary of the Geological Survey of Ireland (GSI), which also published the accompanying booklet. The video was produced by Emdee Productions and was written and presented by Dr. Padhraig S. Kennan, Department of Geology, University College, Dublin. Dr. Kennan wrote the accompanying booklet as well as the Addendum to these notes entitled "Fossil Fuels".

Following television screening, "Written in Stone" was made available as a six-part video with accompanying booklet. It was recognized that it could be usefully used in secondary schools, especially during the Transition Year. A cluster of hydrocarbons companies, led by Marathon Ireland Ltd, provided sponsorship to make copies available to every secondary school in the country. This school text was produced to accompany the product and was developed by Eddie Mortimer and John O'Donoghue, both of GSI, with enthusiastic assistance from Ms. Joan Brownlee, Association of Geography Teachers in Ireland, and Dr. Bettie Higgs, Dept. of Geology, University College, Cork.

## **ADDENDUM: FOSSIL FUELS**

**Padhraig S. Kennan.**

Way out there beyond the horizon, something stirs. Monstrous floating machines drill into rocks deep below on the floor of the Atlantic. They search for petroleum - oil and gas which, when processed, will make fuel for transport, tar for roads and roofs, plastics, detergents and medicines – and a host of other things besides. Turn on a gas cooker and, in the flames, oxygen from kitchen air releases energy from petroleum gas coming all the way from out to sea off the coast of Cork. In the near future, similar gas may come from the west coast, not only to drive gas cookers, but also the turbines of electricity generating stations converting one form of energy to another. This geological resource brings benefit both to the individual gas-cooker driver and to the national economy.

Petroleum will do all of this for as long as supplies last. It is always worth remembering that no matter how seemingly large or great, nothing on earth lasts forever. The planet is only so large and, so far as is known, only near-surface rocks contain petroleum. The present is - and the future will be – a time of cutting use, conservation, increasingly efficient machines and the winning of additional petroleum supplies from sources previously unprofitable or too difficult to explore. That will be a great challenge in the first century of the next millennium.

It would be all too easy to waste the petroleum resource. Already, many resources, including petroleum, are used at a rate that is out of all proportion to the rate at which the earth can replace them or accommodate the waste produced. Anthropogenic, man-caused (scientists do like to use long words), global warming, if it is a fact, ozone holes and accumulating nuclear waste are symptoms of planetary stress. It tends to be forgotten that every raw material that has been used to fuel just one industrial revolution took millions of years to produce. The earth is a very slow factory. It is also a very slow waste-disposal system. The earth simply does not live in a world of couriers, e-mails, fax machines, mobile phones and just-in-time delivery.

Solar energy is, of course, expected to play a major part in the energy future. That solar energy played a huge part in the energy past might, perhaps, be a surprise. Petroleum is nothing but the solar energy of millions of years of “yesterdays” stored in a convenient ready-to-use form. Since plants first evolved, green leaves have soaked up and used sunlight, and carbon dioxide from the atmosphere, to manufacture carbohydrates - starch and sugars containing carbon, oxygen, hydrogen and nitrogen. The common potato plant is one superb solar-energy conversion machine – solar energy to chips with everything in a few short months.

When the potato or any other vegetable material rots, the complex carbohydrates are broken down into simple chemical mixtures – gases, liquids and solids. Thus, petroleum is born. Retrievable petroleum deposits are formed where the liquid and gaseous materials migrate to collect in large quantities in rock somewhere. The solid fossil fuel, coal, results when much of the rotting material remains where it grew. Coal is just another rock – a carbon rich rock formed from fallen, continental-scale forests buried long ago and compressed deep underground. The oxygen, hydrogen and nitrogen of the original plant tissues have, long since and to one degree or another,

been driven off – contributing to petroleum reserves somewhere else or lost to the atmosphere. Great though it is, the humble potato is not a major contributor to the earth's coal deposits or its petroleum reserves. It is best eaten to release its stored solar energy in another way – leading to another chain of thought.

Getting from plant tissue to an oil field is some journey. That is where rocks play a key role. They are the roads that are travelled. Many rocks are porous – they contain a few percent of holes dispersed throughout which can contain fluids and gases – and often do. However, if these fluids are ever to move and collect in large quantities, the holes must link to one another – the rock must be permeable. As oil and gas move through permeable rock, both tend to move upwards. Water, typically present as well, does likewise. Gravity is the cause. Whether in rocks below ground, or in the gutter at the bus stop, the oil (and gas) always collects on top of the water. There may be nothing to stop petroleum rising all the way to the surface. If it does so, it will quickly evaporate and be lost to the atmosphere. However, moving oil, gas and water often enter geological one-way streets underground and get trapped. There are many dead ends in the earth's crust – places where the history of rock accumulation and the history of rock deformation (folding and faulting) have conspired to create all sorts of natural blockages beyond which upward-moving fluids simply cannot go. In the absence of a reverse gear, a permanent tailback results.

How does all this happen? Everyday experience may provide the answer. How many times, when playing with a bucket and spade on a beach, was a hole dug that slowly filled with water? That water had seeped through porous and permeable sand. It should be no surprise that those who search for oil deposits look for sandstones. Remember times playing football for a school or Sunday-morning team. How many times was the going heavy on a waterlogged pitch? Clay is not very permeable on clay surfaces; rainwater tends to stay where it falls for some time. It should be no surprise to learn that clays – mud rocks – play a key role in trapping oil. In fact, where sands and clays are drawn together, petroleum traps – no less efficient than lobster pots – are in place.

Imagine oil and gas and water migrating upwards through sandy rocks. Imagine an arching cover of clay rocks above. Once inside the arch, there is no escape – the oil is caught between the blocking clay and the water pushing upwards behind. Escape only comes when the searching drill from above breaks through the impermeable cap of clay. However, there is no way of knowing with any certainty on the surface where there is oil underground. Not every lobster pot traps a lobster. It is in hope that the geologist targets the drill at places where permeable and impermeable rocks are drawn together in geological structures that could potentially act as traps or where the geology underground is similar to that in places where oil has been found before. Petroleum traps, though like needles in haystacks to find initially, can be very large structures from which a few percent of pores can deliver millions of barrel-fulls.

But why should there be oil offshore beneath the Atlantic? The answer lies in a history that starts with the initial opening of the Atlantic long ago. In depressions that formed on the margins of the young Atlantic, in the Celtic Sea or, for that matter, in the North Sea between Britain and Europe, sands and clays and other rocks accumulated. Erosion of the nearby landmasses provided the sand and clay. By one route or another, oil and gas accumulated in the relatively young porous and

permeable rocks of these basins. The basins of the North Sea have proved to be extremely rich in oil and gas. The others are exploration targets today in which gas, as we know, has already been found. The older, relatively non-porous rocks of the Irish mainland are unlikely to hold oil or gas in any quantity. It was either never there, or any that was has long since emigrated.

Petroleum is a valuable resource. It is not an inexhaustible resource. Considering the range of uses to which it can be put, it would be easy to argue that it is priceless. It is not just a liquid from a pump with coupons attached. It is the sunlight of countless “yesterdays” packaged in a convenient way. Dwindling supplies will inevitably bring other sources of energy to the fore. Coal, for example, may be burned underground to produce gas. Sands rich in tar, another form of petroleum, exist in huge quantities and will be increasingly exploited. The use of direct solar energy will be commonplace. However, no matter what might be imagined, the solar energy of any one “today” is unlikely ever to sustain the accustomed standard of living – whether that energy is trapped by windmills, falling water, solar panels, plants to burn or yokes bobbing on the waves. The fossil fuels will be important for some time to come.

In the meantime, there is nothing to beat a good potato. I wonder how many the sun could actually grow on earth.