Bilbao and the Golden Spike*

A stratigraphic short story of Deep Time in the Basque Country

Wes Gibbons 2018

It is entirely reasonable to suppose that most visitors to the Basque city of Bilbao do not make the trip in order to improve their knowledge of Eocene stratigraphy. This however is a pity that needs to be remedied. The Guggenheim Museum is one thing, but the Global Stratotype Section and Point (GSSP) for the base of the Lutetian Stage is quite another.

This short guide therefore is addressed to those visiting Bilbao who are happy and willing to combine a scenic cliff walk with a trip to the beach and view from a distance a world-famous exposure of rocks formed nearly fifty million years ago. The excursion does not need road transport, instead using the local subway to escape from the city for a few hours, get some exercise, think about deep time, and marvel at the science of stratigraphy and its capacity to invent hard-to-remember names. It would be wrong not to.

Logistics

Allow 3-4 hours return for the excursion: perfect for a sunny morning or afternoon. Buy a Zone 2 single ticket (1.80 euros in 2018) from the Metro station machine and journey north on Line 1 from Bilbao city centre in the direction of Plentzia, alighting at Bidezabal station in the town of Getxo. Turn left (west) out of the station entrance then right (north) at the first roundabout (Angel Etorb). In about 300m fork left into a pedestrianised way (Galea Errepidea) which leads to the paved coastal path and cycleway leading northwest along the clifftop with wide views over Bilbao estuary and harbour. The cliffside route takes an hour or so, passing the Aixerrota Windmill (constructed 1727), Our Lady of Carmen cemetery (1908), Galea Fortess (1742), Galea Lighthouse (1950), and continues to reach an information board (left) where a tarmac lane descends steeply left to Gorrondatxe (a.k.a Aizkorri) beach.

Explanation

Imagine the bottom of the sea not too far from the coast. Rivers will bring in mud and sand particles which eventually settle on the sea bottom under gravity to form layers of wet sediment mixed with the remains of marine animals and plants. These layers with their fossils build up, one after another, drying out and hardening with time to produce a succession of sedimentary rocks that become younger upwards. Each rock layer (or “bed”) will preserve a record of time past. A moment in Earth history. This “moment” might be short (hours) or long (many years), depending on the thickness of the rock layer and the rate at which it was deposited.

The most ancient sedimentary rocks so far known on planet Earth are nearly 4 billion years old. Since at least that time marine sedimentary layers have been deposited on the sea floor, in places accumulating to form sedimentary rock sequences, some of which we can see exposed on the surface of our planet today. The study of these rock layers and what they tell us about Earth history is the science of stratigraphy.

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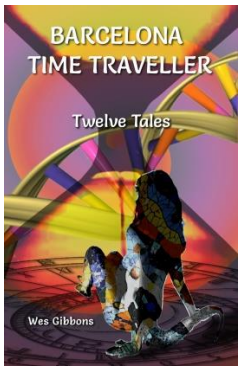
Most of us know at least a few formal stratigraphic terms, sometimes without realising it: “Jurassic” for example. The Jurassic Period is formally defined as having lasted just over 56 million years, from 201.3Ma to 145Ma (Ma = mega-annum = one million years). But to a stratigrapher this is only getting started. The Jurassic is sub-divided into 11 time units called ages, starting with the “Hettangian” and ending with the “Tithonian”. Rock strata deposited during the Tithonian Age are said to belong to the Tithonian Stage. After this we welcome the Cretaceous Period, which has no less than 12 ages, starting with the “Barremian” at 145Ma and ending with the “Maastrichtian” at 66Ma, a moment in time in which we say farewell to the dinosaurs (apart from their only survivors: the birds):

It is early June under a Late Cretaceous sun, just over six hundred and fifty thousand centuries from modern times. Sir Charles Lyell’s “the present is the key to the past” model of slow, non-catastrophic continuity of geological processes on Earth is about to receive an extra-terrestrial surprise as a blinding flash across the Americas heralds the arrival of an asteroid nearly fifteen kilometres in size. Moving obliquely towards the northwest at over twenty kilometres per second it slams into the Gulf of Mexico. In a fraction of a second after impact the bolide has buried itself in the Earth’s crust, generating massive shock waves and sending a spurt of molten and vaporised rock high above the target. Over the next five minutes a vast ejecta curtain of melted rock and shocked rock fragments splashes out sideways from the rapidly excavating crater while high above the impact a huge fireball roils into the stratosphere. Earthquakes reaching unimaginable magnitudes of ten and above are accompanied by mega-tsunami waves that in places rise to over one hundred metres high before crashing down on the Gulf coastline. The oblique northwesterly direction of the Deep Impact focusses the blast wave and heat radiation downrange so that it blowtorches North America.

Meanwhile, in Late Cretaceous Barcelona over five thousand kilometres east of Mexico on the other side of the youthful Atlantic Ocean, the meteoritic monster fireball is too far away to be seen above the horizon. Just over a quarter of an hour after the impact, however, the first tremors ripple through Iberia as the Earth begins to ring like a bell. These earthquakes reaching future Catalonia are not severe, although the dinosaurs definitely notice them and are perturbed. Later in the day the animals are further alarmed by a strange dustiness in the air as the first ejecta fragments reach Europe.



By now a homogeneous veil of peculiar iridium-rich dust and condensing vapour derived from the impacting asteroid and target rocks is engulfing the entire planet and the sky progressively darkens as day turns into twilight. Several hours after impact, a weird sound accompanied by a sudden rush of wind records the arrival in Iberia of the far-travelled air-blast, and the next day brings dampened tsunami waves a few metres high washing up on the eastern Atlantic seaboard.

The sun has disappeared and it becomes terribly cold as the impact aerosols combine with vast amounts of wildfire smoke to prevent heat and light from reaching the Earth’s surface. The situation is made much worse by the fact that the bolide has hit and vaporized a sedimentary succession that happens to contain thick layers of the calcium sulphate evaporite mineral gypsum. Lifted into the stratosphere and condensing as tiny aerosols, these sulphate particles are perniciously persistent, taking months to slowly dilute and rain out. Over these months an impact-generated severe winter grips the biosphere and plants die the world over, followed by the herbivores and carnivores that depend on them as the food chain collapses. A few land animals weighing less than a kilogram or so manage to survive the freezing weather and starvation conditions, mostly sheltering underground and living off whatever non-photosynthetic food source is available. By the time it is all over, around three-quarters of all species on Earth have been wiped out.

It is in this brave new astronomically-cleansed post-Cretaceous world of the Palaeogene Period that the Pyrenean Mountains gradually come into being……

From Barcelona Time Traveller: Creating Catalonia (The Eleventh Tale)

Remarkably, this brief drama in Earth history is recorded in the geological stratigraphic rock record exposed today. For example, near El Kef in Tunisia there is a strange black clay layer half a metre thick and with a peculiar rusty base containing unusual amounts of iridium (derived from the asteroid) and tiny glassy spherules produced by extra-terrestrial bolide impact melting ("microkrystites"). Below this layer are normal Cretaceous rocks belonging to the Maastrichtian Stage, whereas above it lie Palaeogene rock layers belonging to the Danian Stage and suddenly without a *Tyrannosaurus rex* to be found. This El Kef locality is so well-exposed that it has been formally proposed as the world standard for the base of the Danian stage: a **Global Boundary Stratotype Section and Point (GSSP)** where a well exposed rock exposure clearly demonstrates the boundary between two geological stages. More colloquially, such preciously preserved points in the rock record are called "Golden Spikes".

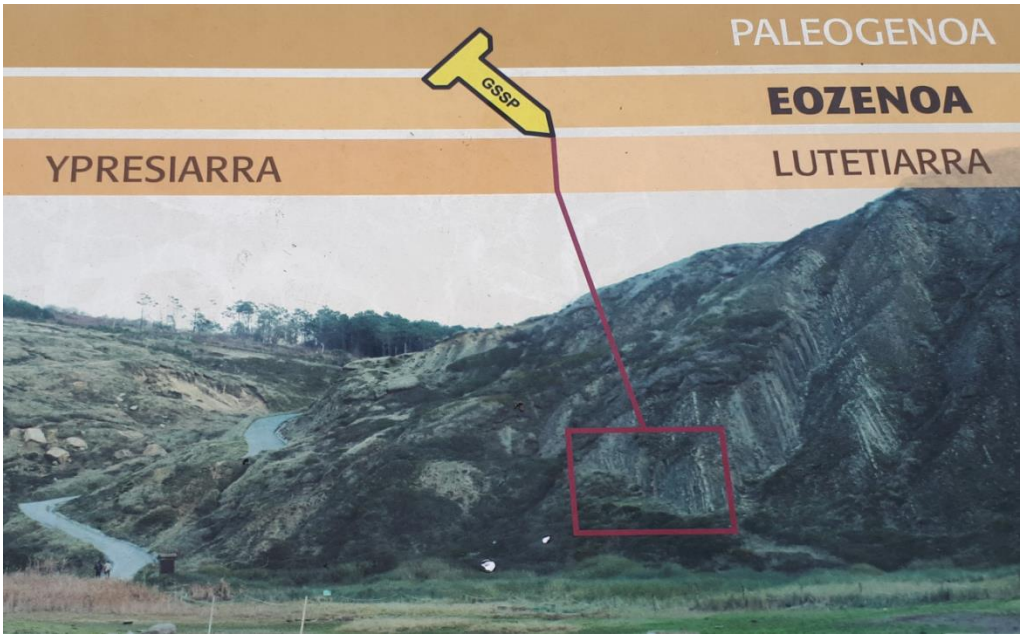
The red line follows the GSSP "Golden Spike" separating the Maastrichtian Stage of the Cretaceous Period (K) from the overlying Danian Stage of the Palaeogene Period (Pg) at Oued Djerfane, west of El Kef in Tunisia. Image from the excellent website of "event stratigrapher" Jan Smit: https://www.geo.vu.nl/~smit/ktboundary/kefgssp.htm

The Palaeogene Period is subdivided into 9 ages, starting with the Danian and ending with the Chattian. But this, Dear Reader, is not enough for post-Cretaceous stratigraphers. For added complexity, sandwiched in between the Palaeogene Period and its 9 ages we have 3 "epochs", namely the Palaeocene (oldest), the Eocene and the Oligocene (youngest). The 9 ages of the Palaeogene are distributed into these three epochs, with the Eocene receiving 4 of them which, from oldest to youngest, are Ypresian, Lutetian, Bartonian and Priabonian:

Finally decelerating at forty-two million years pre-Holocene she has arrived just before the last third of Eocene time is about to begin, in a part referred to by stratigraphers as the Lutetian Age. She recalls the mnemonic she had used to remember the four Eocene Ages from oldest to youngest: "Y Luego Bailamos Pasodobles" (Ypresian, Lutetian, Bartonian, Priabonian). Translating from the Spanish as "And later we dance pasodobles", it has none of the panache of her British husband's preferred alternative, "You Lucky Bastard Priapus!" But at least it is not rude.

From Barcelona Time Traveller: Montserrat (The Ninth Tale)

The layers of sedimentary rock exposed in the cliffs behind Gorrondatxe Beach were deposited on the sea floor during the Eocene Epoch and at one place in the rock succession you can pinpoint the exact boundary between rocks of the Ypresian and Lutetian stages: the Golden Spike. The two photos below (from the information board) show the GSSP Golden Spike as defined by Eustoquio Molina and co-workers in 2011:



For the hardcore stratigrapher the exact definition runs as follows: *The GSSP for the base of the Lutetian Stage (early/middle Eocene boundary) is defined at 167.85 metres in the Gorrondatxe sea-cliff section (NW of Bilbao city, Basque Country, northern Spain; 43º22'46.47" N, 3º00'51.61" W). This dark marly level coincides with the lowest occurrence of the calcareous nannofossil Blackites inflatus (CP12a/b boundary), is in the middle of polarity Chron C21r, and has been interpreted as the maximum flooding surface of a depositional sequence that may be global in extent. The GSSP age is approximately 800 kyr (39 precession cycles) younger than the beginning of polarity Chron C21r, or ~47.8 Ma in the GTS04 time scale* (http://www.stratigraphy.org/GSSP/Lutetian.html). So there.

Tiny fossils in these sediments allow palaeontologists to give this golden spike an age of 47,800,000 years before present (47.8Ma). At that time the sediments were being deposited on the bottom of a marine gulf 1,500 metres deep that opened out west into the widening North Atlantic Ocean. Since then, as a result of earth movements that produced the Pyrenean Mountains, these sedimentary beds have been tilted towards the southwest so that one moves from older to younger rocks as you walk southwest along the beach (left to right in the photos above and below):

…the screws are tightened in Early Eocene time as Africa begins to push harder against Iberia, squeezing, slicing and shortening the rocks to pile up mountains over one kilometre in height. By now the Pyrenean orogen exposed above sea level has grown to over two hundred kilometres long as it extends westward to disappear into the deep marine Basque Basin and the open Atlantic Ocean.

From Barcelona Time Traveller: Creating Catalonia (The Eleventh Tale)

Present day (2018) accessibility of this famous site is denied (hopefully temporarily) by a strip of ecologically protected ground. The white GSSP plaque at the base of the cliffs behind Gorrondaxte Beach can be viewed wistfully only from a distance behind a protected vegetated strip of incalculable ecological value. Compare the photo above with that below. A case of Botanists: 1; Geologists: 0.

The Ypresian sediments below the GSSP can however be enjoyed on the climb back up the access road to the beach, as pictured below:

Layers of sandy sediments deposited by turbid, sediment-laden currents ("turbidites") lie within darker muds mixed with carbonate ("marls") derived from marine organisms. Once deposited in deep, quiet conditions on the ocean floor, the sediments are full of fossilised microscopic-sized sea creatures (forams, ostracods etc) that, combined with magnetostratigraphic data, allow the rocks be assigned an accurate age. Over two kilometres of sedimentary beds accumulated in this marine basin from early Ypresian to late Lutetian time. The entire cliff section here at Gorrondatxe represents something like 5 million years of Earth history in northern Iberia. Finally, place your visit in context by taking a look at where you are on the latest version of the international stratigraphic chart: http://www.stratigraphy.org/index.php/ics-chart-timescale.

Ruminating upon the relevance of the human race to all of this, it is time to make your way back to Bidezabal metro station, perhaps pausing in Getxo for a tapa or two and digesting what you have learnt about Eocene stratigraphy….

Background to Holiday Geology Guides

The author and geologist Wes Gibbons has always had an interest in writing short geoguides aimed at inquisitive tourists, offering them the opportunity to learn about the landscapes and rocks of scenically attractive places. His argument is that there is so much more to know about rocks and Earth history than the superficial descriptions offered by tourist guidebooks, which rarely even scratch the surface of Deep Time.

His first attempt in the geoguide direction produced *The Rocks of Sark* (1975), published jointly with John Renouf of Manche Technical Supplies in Jersey, a venture that taught a youthful Wes to always be the one responsible for the final proof reading. In 1976 Wes moved from Sark to begin a PhD supervised by Greg Power (Portsmouth University) and Tony Reedman (British Geological Survey). Living in a former Post Office in the village of Greatham on the Hampshire-West Sussex border, Wes decided to pass his spare time preparing a guide to the geology of the Weald in southeast England. He sold the idea to the publishers Allen and Unwin who commissioned other authors to develop a mini-series: *The Weald* (1981), *Snowdonia* (1981), *Lake District* (1982), and *Peak District* (1982).

His next field-based guidebook surfaced in 1985, fruit of several years research work in Corsica (*Corsican Geology: a field guidebook* by Gibbons and Horák). Two years later Wes launched the Holiday Geology series, using a simple, inexpensive format later described as "a single A3 laminated sheet …. folded into three and (with).. six portrait panels … filled with a lively mix of colour photos, maps, sections and text" (review by Nigel Woodcock in Geological Magazine, 2000). The first two Holiday Geology guides were *Scenery and Geology around Beer and Seaton* (Gibbons 1987) and *Rocks and Fossils around Lyme Regis* (Gibbons 1988). The Holiday Geology concept attracted the attention of the British Geological Survey who went on to expand the series to over 20 titles.

Following his retirement in 2004 to live in Barcelona with Teresa Moreno, Wes maintained his interest in publishing field guides by writing the text to *Field Excursion from Central Chile to the Atacama Desert* (Gibbons and Moreno 2007), *The Geology of Barcelona: an Urban Excursion Guide* (Gibbons and Moreno 2012), and *Field Geotraverse, Geoparks and Geomuseums* (in central and southwest Japan: Gibbons, Moreno and Kojima 2016). His most recent publishing project, the most ambitious so far aimed at a general readership, has produced the book *Barcelona Time Traveller: Twelve Tales* (2016, Spanish translation 2017: Bimón Press, Barcelona) and the resurgence of the Holiday Geology concept, although this time in virtual format linked to the *Barcelona Time Traveller* webpage.

Wes Gibbons, July 2018

http://barcelonatimetraveller.com/

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