THE FIRST GEOLOGICAL MAP OF PATAGONIA

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ABSTRACT

This contribution analyses the first geological map of Patagonia drawn by Darwin around 1840, and colour-painted by Darwin himself. It had remained unpublished and only a small version in black and white had been printed before. The different units mapped by Darwin are analysed from a modern perspective, and his ability to show a synthesis of the complex geological structure of Patagonia is stressed.

Keywords: *Geological map, Patagonia, Patagonian Shingle, Darwin geologist.*

RESUMEN: *El primer mapa geológico de la Patagonia.* La presente contribución analiza el primer mapa geológico de la Patagonia realizado por Darwin cerca de 1840, pintado en colores por el mismo Darwin, que ha permanecido inédito y del que sólo se conocía una versión de tamaño reducido en blanco y negro. Se analizan las diferentes unidades mapeadas por Darwin desde una perspectiva actual, destacándose su habilidad para mostrar en esa síntesis la compleja estructura de la Patagonia.

Palabras clave: *Mapa geológico, Patagonia, Rodados Patagónicos, Darwin geólogo.*

DARWIN AND THE VOYAGE OF HMS BEAGLE

At the time Charles Darwin set sail on board HMS Beagle on a journey that was to last two years and ended up lasting five, he was not more than an amateur naturalist that had quitted his medical courses and after that abandoned his intention of applying for a position in the Church of England, just to embrace the study of natural history. In those years Charles Lyell (1830-1833) published his theory of gradualism (*the present is the key of the past*) as a counterpart to catastrophism then prevailing in geological thought. During the five years (1831-1835) that his journey on board HMS Beagle lasted - of which three years and one month were spent ashore - Darwin made countless observations on geology and biology and even on the communities that he visited (Fig. 1). These altogether paved the way towards his famous theory on natural selection and the origin of species and the influence that the environment - including its geological constitution and evolution - has on the success and adaptability of species.

Figure 1: Itinerary of HMS Beagle and landings and journeys of Charles Darwin in the interior of South America.

DARWIN'S CONTRIBUTIONS TO GEOLOGICAL KNOWLEDGE

Darwin's contributions to the geological knowledge of South America were recorded in four main papers, i.e., *On the connection of certain volcanic phenomena in South America* (1838), *On the distribution of erratic boulders and on the contemporaneous stratified deposits of South America* (1841), *An account of the fine dust which often falls on vessels in the Atlantic Ocean* (1846a,[Read 4 June 1845), *On the Geology of the Falkland Islands* (1846b), and finally the book *Geological Observations on South America* (1846c) reprinted in 1876 as part of his *Geological observations on the volcanic islands and parts of the South America visited during the voyage of H.M.S. Beagle.* On the other hand, a first unpublished essay of his geological observations was written during his voyage on board H.M.S. Beagle ca. 1834 which is titled *Reflection on reading my geological notes.* In this work Darwin put forward a theory on the geological formation of South America and included his interpretations on the history of life in the continent which, albeit not evolutionist is nevertheless sequential (cf. S. Herbert 1995).

In these works there are numerous and detailed descriptions of geological units. However, figures representing his observations are few and of limited interest. Despite of this, Darwin at some stage of his life as a scientist tried to synthesize in a map the main units that were subject of his work, although such a map was never published.

The Library at Cambridge University keeps an original unpublished map painted with water-colours by Darwin himself. This is the earliest known Regional Geological Map of the Patagonian region of Chile and Argentina (Fig. 2). A black and white version was published by Rhodes (1991, Fig. 3) who stated "*the magnificent structure of this map*" in contrast with the other Darwin's unpublished map of Patagonia which is rather simple (Herbert 1991 and 2005, plate 6). The geological observations were represented on the topography produced by (1826-1830) and published in London by John Murray. The watercolour is from the time of Darwin's voyage on the Beagle or maybe just a few years later, circa 1840. On the back of the map there is an annotation reading "p 94", which suggests that it was drawn for inclusion as an illustration to one of the volumes of the *Geology of the voyage of H.M.S. Beagle* (1846c), but it was never printed.

The only previous regional maps are those published by d'Orbigny (1842) together with the geological sketch of the provinces of Misiones, Corrientes, Entre Ríos, Santa Fe, and Buenos Aires, including northern Patagonia down to Valdés Peninsula.

GEOLOGICAL MAP OF PATAGONIA

The observations by Darwin recorded on the map are mainly referred to coastal areas surveyed by HMS. Beagle (Fig. 2) and involve seven geological units:

1) Granite, Mica slate,
2) Trappean rock and porphyries,
3) Purple porphyries and infra metamorphics,
4) Clay slate,
5) Tertiary [newer - crossed out -] (Pliocene?),
6) Recent,
7) Basaltic lava.

About units 2 and 3 he states *"These two are perhaps very closely allied".*

UNIT 1 (*Granite, Mica slate*). It mainly involves the Cretaceous so-called Coast Batolith that Darwin stated as exposed in Chilean Patagonia south of the Strait of Magellan. It includes outcrops at the notheastern corner of Hoste Island and at the northwestern sector of Navarino Island. In this unit are also included the Mica slates of the southernmost end of the Chonos Archipelago in the Taitao and Tres Montes peninsulas.

In his description of this unit Darwin recorded different lithologies, among which he distinguished - west of the Beagle Channel bifurcation - a complex of gneiss and granitic slates that comprise the Cordillera presently bearing his name (Eastern Metamorphic Complex of Aysen and Magallanes in Chile and Lapataia Formation in Argentina). Towards the northeast he pointed out the predominance of gneiss and granites (Coast Batolith in Chile). Between Cabo Tres Montes and the north of the Chonos Islands the predominant rock is a Mica slate with organic matter (presently Canal King Formation).

UNIT 2 (*Trappean rock and porphyries*). It includes intrusive and extrusive rocks exposed in Hoste and Londonderry Islands (Chile) and also Mesozoic ophiolitic rocks exposed in Wollaston Island.

It comprises Paleogene monzodiorites, diorites and gabros and Mesozoic basaltic lavas of the Hardy Formation, and the Sarmiento and Tortugas ophiolitic complexes in Chile.

In Wollaston Island Darwin described "*greenstones*" with pyrite and epidote with evidence of metamorphism, and basaltic submarine volcanic rocks. In Hardy Peninsula he recorded the pyrite-rich "*trappean and basaltic rocks*", trachytes with columnar jointing, and diorites rocks.

Darwin's precise drawing of the contact between this unit and Unit 1 is especially remarkable when compared to modern maps.

UNIT 3 (*Purple porphyries and infra metamorphics*). This unit was recognized by Darwin on the coast of Santa Cruz. It comprises the volcanic rocks of the Chon Aike Formation, which in this sector represents the easternmost exposures of the Deseado Massif. Darwin described these volcanics as trachytic porphyries. The unit includes the tectonic silicified breccias assigned to the Bahía Laura Group, and exposed at Cabo Blanco. These were erroneously interpreted by Darwin as siliceous sedimentary rocks and compared them to those of the Malvinas Islands.

Off-limits he describes purple to pink, and sometimes laminated, porphyric

Figure 2: Geologic map of Patagonia (Darwin, circa 1840, unpublished).

rocks, which are slightly vesicular with feldspar and quartz crystals. He stated these as the dominant rocks in between Port Santa Elena, Camarones and Malaspina up to the "*Paps of Pineda*" (*sic*).
At Puerto Deseado he records the presence of porphyries up to 40 km west of the coast, covered by Tertiary deposits. He indicates that the composition is similar to that of those described further north and points out the presence of local chert beds.

UNIT 4 (*Clay slate*). According to Darwin's description, it comprises siltstones, feldspar volcanics, graywackes, scarce black limestones with Lower Cretaceous fossil remains, and metamorphic schists. These are the core of the mountain ranges of southern Tierra del Fuego and Navarino Island. He describes slates exposed along the Beagle Channel between its bifurcation and Lemaire Strait, constituting Navarino Island to the south and the eastern sector of Hoste Island and Hardy Peninsula. North of the Beagle Channel this unit runs in a northwestern direction towards Brunswick Peninsula on both coasts of Admiralty Strait, continuing north along the eastern flank of

the Cordillera. Darwin collected fossils from the limestone beds he recorded. These indicate a Cretaceous age.
Darwin stressed the change in the direction of the Cordillera, that north of the Strait of Magellan runs with a N-S orientation changing south of it to a E-W orientation. This unit includes the present Lemaire and Yaghan Formations in Argentina and Cerro Toro, Yaghan and Punta Barrosa Formations in Chile, spanning the Late Jurassic-Cretaceous (see Olivero *et al.* 2009).
Again, we must stress the precision with which Darwin drew the contact between units 2 and 4 in Tierra del Fuego.

UNIT 5 (*Tertiary, Pliocene?*). Darwin includes here the Tertiary units exposed in extra-Andean Patagonia right across to the coast of Santa Cruz. He observes that these overlie porphyries of Unit 3. In the map, he represents this unit in the hills of northern Tierra del Fuego and in the northern areas of Brunswick Peninsula. Darwin's observations on this unit include the identification of several faunal assemblages with abundant *Turritella, Pecten* and *Ostrea*. He called this complex the "*Patagonian Tertiary Formation*" (see Parra and Griffin 2009, Casadío and Griffin 2009).
From a lithologic point of view he recognized the presence of beds with pumiceous siltstone with abundant gypsum, sandstones, and claystones with calcareous concretions. At the headwaters of the Santa Cruz River he observed that the sedimentary rocks are covered by basaltic lavas of unit 7.

UNIT 6 (*Recent*). This unit represents Quaternary deposits that Darwin recognized at the southern end of Santa Cruz between the Río Gallegos and Cabo Vírgenes, in the northeastern coast of Tierra el Fuego, along both coasts of the Strait of Magellan in its northeastern sector, and in the sector between Useless Bay and Bahía San Sebastián. He includes here the "*Rodados Patagónicos*", which he called "*Gravel Formation of Patagonia*". In his description he indicates that not all the gravel beds are from recent times, particularly those of higher tablelands (see discussion in Martínez *et al.* 2009). He recorded interesting observations on the origin and transport mode of the gravels, noting the difficulty in explaining the distribution covering the entire area from the Andes to the coast. He did point out, however, that the present distribution of the gravels was due to marine action.

UNIT 7 (*Basaltic lava*). It represents the basaltic exposures along the middle and upper course of the Río Santa Cruz and the Meseta La Siberia. Darwin placed these outcrops as contemporaneous of the higher sections of the Tertiary formation. In fact, the basalts are of a Pliocene-Quaternary age (see Streling and Malagnino 2009) and include the units presently called Meseta de las Vizcachas Basalt and La Siberia Formation.
In his observations he states that the outcrops predominate on the Northern side of the Río Santa Cruz valley and that they reach the foothills of the Andes. He recorded that the basalts were olivinic and that columnar disjunction was common. He identifies at least three overlying beds. Acknowledging the great extension covered by the exposures he concludes that "*This great deluge of lava is worthy, in its dimensions, of the great continent to which it belongs. The aggregate streams have flowed from the Cordillera to a distance (unparalleled, I believe, in any case yet known) of about 100 geographical miles*" (Darwin 1846, p. 116)

CONCLUSIONS

The brief description presented herein shows one of Darwin's less known facets, i.e., his ability to represent his geological observations in a map. This contrasts Stoddart (1995) who emphasized, when analyzing the geological results of Darwin's voyage on the Beagle, "*the contrast between Darwin's verbal facility in describing landscapes and evoking mood, and his general inability to translate his images into visual representations*".
Lastly, it should be stressed that if it had been published when originally planned, it would have constituted a singular initial contribution to the geological cartography of the South American continent.

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Recibido: 3 de octubre de 2008
Aceptado: 4 de noviembre de 2008