CHARLES DARWIN AND THE OLDEST GLACIAL EVENTS IN PATAGONIA: THE ERRATIC BLOCKS OF THE RÍO SANTA CRUZ VALLEY

Jorge STRELIN[1] and Eduardo MALAGNINO[2]

[1] Instituto Antártico Argentino, Universidad Nacional de Córdoba, Departamento de Geología Básica, Facultad de Ciencias Exactas Físicas y Naturales, Universidad Nacional de Córdoba, E-mail: jstrelin@yahoo.com.ar
[2] Departamento de Ciencias Geológicas, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires.

ABSTRACT

Although the depositational environment assigned by Darwin to the large erratic blocks and gravels in the Río Santa Cruz valley has been reinterpreted, his geomorphological and stratigraphic observations are still in force. The large erratic blocks he described as crowning the Condor Cliff terrace and spread at the bottom of the valley just east of this locality (Sites 2 and 3), are now interpreted as indicators of the maximum glacial expansion in Patagonia. Similar blocks, though of a different lithology, accumulated over a lower terrace located up-valley (Site 4), are now linked to moraines and glacifluvial terraces of the Penultimate Glaciation. Finally, in addition to the erratic block discovered by Darwin in the lower Río Santa Cruz valley (Site 1), there are others - recently discovered - which probably account for a catastrophic event ascribed to a big glacier-lake outburst during the last interglacial.

Keywords: *Patagonia, Glaciations, Moraines, Erratic blocks, Darwin.*

RESUMEN: *Charles Darwin y las glaciaciones más antiguas de Patagonia: los bloques erráticos del alto valle del Río Santa Cruz.* No obstante haber sido reinterpretado el ambiente depositacional asignado por Darwin a los grandes bloques erráticos y rodados del valle del río Santa Cruz, siguen vigentes sus observaciones geomorfológicas y estratigráficas. Los grandes bloques erráticos que describe coronando la terraza de Condor Cliff y dispersos en el fondo del valle inmediatamente al este de esta localidad (Sitios 2 y 3), son interpretados ahora como indicadores de la máxima expansión glaciaria de la Patagonia. Bloques similares, aunque de dispar litología, acumulados sobre una terraza más baja situada río arriba (Sitio 4), se vinculan actualmente a morenas y terrazas glacifluviales de la Penúltima Glaciación. Finalmente, al bloque errático descubierto por Darwin en el tramo inferior del valle del río Santa Cruz (Sitio 1), se le suman otros -de reciente descubrimiento- que probablemente den cuenta de un evento catastrófico atribuible al vaciamiento de un gran lago glaciar durante el último interglaciar.

Palabras clave: *Patagonia, Glaciaciones, Morenas, Bloques erráticos, Darwin.*

INTRODUCTION

Although Charles Darwin was a naturalist with a remarkably penetrating, ingenious and broad mind in the field of biology, the not so well-known geologist in Darwin -eclipsed by the former- did not lag far behind. Many of the observations that he made and the geological theories he formulated when still a youth during his scientific voyage to South America and the Pacific Ocean are still current and go beyond pure historical interest.

As an example of his innovative theories, it is worth mentioning one which arose from his published observations on coral reefs (Darwin 1842a), which made him famous among geologists. It was only a century later, with the help of modern technology, that his deductions on the great oceanic subsidence could be proved. This work, together with his one on volcanoes (Darwin 1844) and South American Geology (Darwin 1846), make up Darwin's most prolific geological period - from 1841 to 1846.

During his journey on board the HMS Beagle, in his own words "*one of the most important events*" in his life, was when he reached the valley of the Río Santa Cruz. It was here, in 1834 and when only 26 years old, that he made observations of great scientific value.

Darwin (1842b) was the first one to describe and discuss the origin of the extensive gravel and shingle layers scattered with erratic blocks, occasionally connected with till deposits, which he discovered during the Beagle's itinerary along the coasts of Patagonia, Tierra del Fuego and Chiloé Island. His interest in these deposits was not fortuitous. Charles Lyell, one of the foremost geologists at the time, had not only sent him a copy of the first edition of his *Principles of Geology* but had also asked him to pay special attention to the presence of erratic blocks in these regions.

By the end of the 18th century, Cuvier's catastrophism theory had been dogmatically accepted by geologists. The first one to seriously oppose it was von Hoff (1834). However, it was Charles Lyell who, following Hoff's steps, introduced

actualism in geology. In his *Principles of Geology* (Lyell 1830), together with his revolutionary contributions to this science and loyal to his uniformitarian ideas, Lyell suggested that the big erratic blocks found in the Northern European plains had been transported there by icebergs in shallow seas and had accumulated on the bottom jointly with non-stratified gravel of chaotic grain sizes which he called till. Just before Darwin's work on gravel beds and erratic blocks in Patagonia was published, Lyell (1840) discussed the origin of this type of erratic blocks in Northern Europe in clear criticism of the neocatastrophic theory proposed by Agassiz (1840), according to which extensive land-grounded ice sheets acted as gatherers of erratic blocks.

After his journey to Patagonia and strongly influenced by Lyell (1830-1833), Darwin wrote to his cousin and friend Darwin Fox (July 1835) from Lima, "*I have become an enthusiast of Mr. Lyell's ideas and I have tried to explain them in my geological work in South America*". Twelve years after Lyell's work, Darwin (1842b) also supported a glaciomarine origin for the extensive gravel deposits and erratic blocks he had discovered in the southern part of South America.

Darwin obtained the most complete vision of the geomorphology and stratigraphy of gravel beds and erratic blocks when, together with FitzRoy, he traveled up the valley of the Río Santa Cruz. During this journey, which took place between April 3rd and May 8th, 1834, he focused his descriptions on four sites (Fig. 1). He established the geographic location of these sites by indicating their distance from the Atlantic Ocean and the Andes Mountains in geographical miles.

Herein we will see how, 166 years later, Darwin's observations of those sites are still in force and play a key role in the interpretation of the oldest glacial events in Patagonia.

DESCRIPTION OF THE SITES

Site 1 - The Lower Río Santa Cruz Valley

The first isolated erratic block which drew young Darwin's attention as he traveled up the Río Santa Cruz was partially buried in the alluvial plain of the river, 57 miles (105 km) away from the Atlantic Ocean and 110 miles (204 km) from the Cordillera (Site 1 - Fig. 1). However, as he could not find any other similar blocks nearby, he did not consider it important and only described it as a feldspathic rock of about 0.70 m diameter.

This feature was pointed out again by Moreno (1879) 45 years later. He also mentioned erratic blocks in the lower valley of the Río Santa Cruz and particularly described a 1m² block partially buried in thin gravel, two thirds from the top of a terrace level (elevation 40 m a.s.l., i.e., 30 m above the river level) and 6 miles (11 km) away from Isla Pavón.

Our recent observations have allowed the discovery of numerous blocks at several locations close to this site. One example are the large erratic blocks, partially buried in alluvium, that can be found on the northern side of the Río Santa Cruz valley, on a terrace at an elevation of 65 and 70 m a.s.l. (40 m above the river valley), 50 miles (91 km) away from the Atlantic Ocean (19 miles - 35 km - from Isla Pavón). The most outstanding are samples 6LA1 of andesitic composition, striated, 1.70 m maximum diameter (Fig. 2) and sample 6LA2 of basaltic composition, 0.80 m maximum diameter. There is also a series of blocks between 1.00 and 0.80 m diameter, partly disaggregated in situ, of rhyodacitic and basaltic composition. East-west oriented fluvial bars, ten to twenty meters long and around 1 to 2 m high, can be observed on the surface of this terrace. Seven erratic boulders up to 1.2 m long have been found to the east of this locality (written communication from Mr. Segovia), at the bottom of a depression which lies partly below sea level. Another block was identified at the foot of a terrace (elevation 40 m a.s.l.) located on the northern margin of the river, near the point mentioned by Moreno (1879) (written communication from Mr. Segovia).

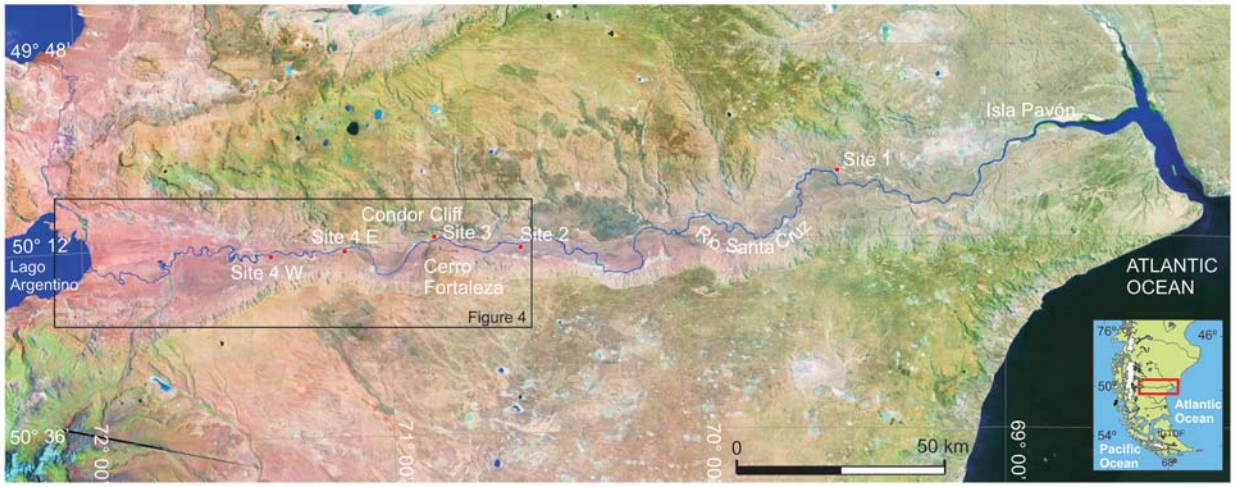

Figure 1: Satellite image of the Río Santa Cruz Valley showing the sites described by Darwin (1842b).

Site 2 - The Middle Río Santa Cruz Valley

Darwin (1842b) mentioned the reappearance of erratic blocks 100 miles (185 km) away from the Atlantic Ocean and 67 miles (124 km) away from the Cordillera (Site 2 - Fig. 1), a presence that is continuous and gradually increasing towards the Cordillera.

According to our observations, the erratic blocks reappear on the southern side of the valley, 7.8 miles (13 km) east of the point indicated by Darwin. They are partly buried and partly lying on the fluvial terrace at an elevation of 200 m.a.s.l., approximately 100 m above the current river bed. The erratic blocks, which can reach 0.90 m in diameter, are partially weathered and mostly of basaltic and rhyodacitic composition, accompanied by smaller blocks (0.20 - 0.25 m in diameter), some of which seem to be noticeably faceted.

Figure 2: Erratic block located 15 km downstream of Site 1, at the top of a 65 m. a.s.l. high terrace.

Site 3.- Condor Cliff

It was here, at the narrowest point of the Río Santa Cruz valley, where Darwin (1842b) described and sketched in more detail (Fig. 3a) the morphologic and stratigraphic characteristics of the gravel beds and erratic blocks in Patagonia. Following Darwin's description, the site is located 112 miles (207 km) from the Atlantic Ocean and 55 miles (102 Km) from the Cordillera (Site 3 - Fig. 1). Site 3 was plotted on figure 1 using the intersection of the river with the meridian of 70°50' W, also provided by Darwin (1842b). The distance that we measured following the river track from this geodetic point to the Atlantic Ocean is 116 miles (215 km), only 4 miles longer than the distance measured by Darwin.

Darwin's (1842b) observations include a stratigraphic section of the outcrop on the northern side of the valley, which ends at the top of a terrace (at an elevation of 425 m a.s.l.) covered by erratic blocks (Fig. 3a). The covered base of this outcrop begins at an elevation of 90 m a.s.l. with 180 m of small round pebbles composed of clay-slate, feldspathic rock and quartzose chlorite schist. The grain size decreases towards the upper half where thin layers of a variety of colours can be seen. Overlying these are 100 m of basaltic lava which are in turn overlain by 65 m of rounded, coarsely stratified gravel, similar in composition to the underlying gravel but also including basaltic pebbles. Spread over this surface are large blocks, in one case up to 20 m diameter and sticking out 1.8 m above the gravel bed, a block of quartzose chlorite schist of 4.5 x 4.5 m and 1.5 m high, and numerous blocks which range from 0.60 to 1.20 square meters. Darwin (1842 b) mentioned that the top of this sequence is part of a high gravely terrace which reaches 425 m a.s.l. at Condor Cliff, climbing up to 900 m a.s.l. towards the Cordillera, which again does not exceed 2000 m a.s.l. Towards the Atlantic shore this gravel layer, descends slowly down to an elevation of only 245 m a.s.l. This low inclination of the terrace, the absence of mounds and ridges, and the angularity of the boulders lead Darwin (1842b) to postulate a glaciomarine (ice-drifted) origin for this accumulation.

One hundred and three years after Darwin's observations, Mercer *et al.* (1975), in a study of the oldest glaciation in the basins of Lago Argentino and Lago

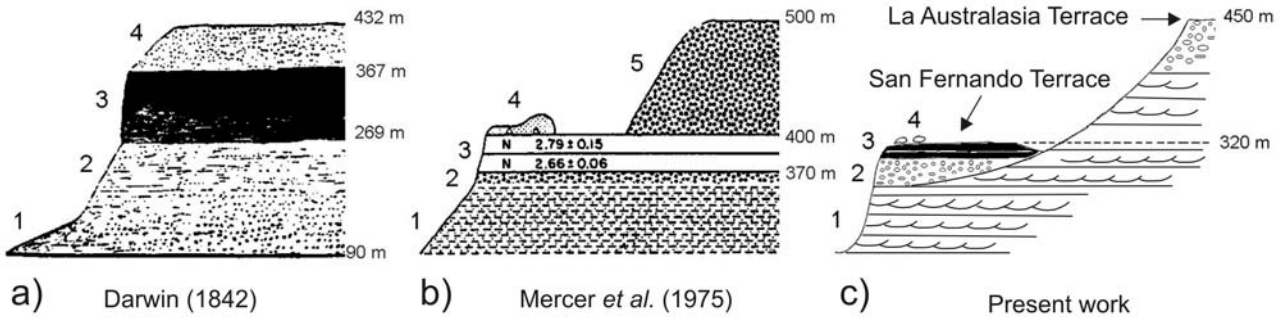

Figure 3: Condor Cliff according to (a) Darwin's interpretation (1842b), (b) Mercer *et al.* (1975) and (c) the proposal in this paper. 1) Santa Cruz Formation 2) San Fernando Terrace alluvium (Strelin *et al.* 1999) 3) Condor Cliff Basalts 4) Erratic blocks of the Estancia La Fructuosa Moraine (Strelin1995) 5) post Pliocene gravel strata (Mercer *et al.* 1975)

Viedma, drew a new stratigraphic section at Condor Cliff, near the site described by Darwin (1842b). Comparing both sections, it is possible to observe that they only differ in the position of the erratic blocks. According to Mercer *et al.* (1975) they are located right over the Pliocene basalts (Fig. 3b) while Darwin (1842b), as we have seen, described them as crowning 65 m of gravel. In agreement with Darwin (1842b), Mercer *et al.* (1975) intercalated the exposures of Pliocene basalt on the northern side of Condor Cliff within two layers of gravel. The 100 m thickness Darwin described for the basalt bed is probably an overestimation caused by basaltic landslides covering part of the northern side of the valley.

Mercer *et al.* (1975) indicated the presence of calcinated gravels at the base of the lava flows corresponding to an alluvial cycle (glaciofluvial) prior to the cycle which accumulated the 100 m of gravel which cover the same flows. By means of radiometric dating they determined a Pliocene age for such lava flows (2.92 ± 0.07 Ma; 2.79 ± 0.15 Ma; and 2.66 ± 0.06 Ma). According to these authors the basal gravel bed reaches a thickness of 30 m and rests on the Santa Cruz Formation. The 180 m of basal gravel associated with thinner stratified levels described by Darwin (1842b) are probably part of the fluvial facies and tuffaceous levels of the Santa Cruz Formation and the psephitic layer described by Mercer *et al.* (1975).

Our observations (Strelin *et al.* 1999) agree with Mercer *et al.*'s (1975) in the sense that the erratic blocks, together with some moraine residue, rest directly on the basaltic flows. The allochthonous blocks found reach up to 3 m in diameter (Fig. 5a) and are mainly of an acidic volcanic nature (rhyodacitic), although some are pelitic and occasionally striated. Autochthonous blocks of basaltic composition are also common. However, we disagree with Darwin (1842b) and Mercer *et al.* (1975) regarding the stratigraphic relationship between the lava layers and the gravel beds. We have been able to demonstrate that the Condor Cliff basalts are not intercalated between the layers of gravel and that instead they flowed down valleys incised in a terrace level (elevation 500m) which we call La Australasia terrace (Strelin *et al.* 1999). La Australasia terrace (Figs. 3c and 6) is carved into the Santa Cruz Formation and crowned by gravel. Our conclusion differs from Darwin's proposal (1842b) and Mercer *et al.* (1975) who considered that the gravel was deposited on the basalts (Fig. 3a and b). The mistake in the interpretation is probably due to the presence of talus deposits formed by gravel which cover the contacts between the lava flows and the base of the Australasia terrace. The basalt channel over a lower terraced level called San Fernando Terrace (Strelin *et al.* 1999), which at Condor Cliff can reach an elevation between 350 and 400 m a.s.l. This terraced level is also carved into the Santa Cruz Formation and crowned by gravel which appears to be calcinated when covered by basaltic flows. Lava windows are common in this volcanic environment showing intact gravel outcrops with a maximum thickness of 20 metres. In addition to gravel deposits, the sections in the aggraded levels of the San Fernando Terrace show laminated sand beds, tuffaceous and diamictitic levels which include sometimes faceted blocks of up to 0.40 m diameter (Fig. 5b)

Site 4.- Upper Río Santa Cruz Valley

Upstream from Condor Cliff, the valley expands into an extensive amphitheatre, which Darwin explained as an ancient estuary of a post Pliocene sea and whose mouth opened towards the west, stressing the marine origin of this section of the valley with the finding of marine shells. The site Darwin (1842b) described is located along a section of the valley located between 127 and 137 miles (235 to 254 km) from the Atlantic coast and 30 - 40 miles (56 - 74 km) from the Cordillera (between sites 4W and 4E, Fig. 1). Both the valley floor (elevation 135 m) and an intermediate terrace (elevation 240 m) are covered with erratic blocks of granitic, sienitic and conglomeratic composition, while no blocks of basaltic composition have been found. In his description, Darwin (1842b) reveals that there is an important difference in the composition of these erratic blocks and those which lie on the upper terrace at Condor Cliff (San Fernando Terrace, Strelin *et al.* 1999), which he considered evidence of the occurrence of different glaciomarine episodes.

Our study (Fig. 4) reveals that the intermediate terrace level that Darwin (1842b) mentions when he described this section of the valley matches the moraine and glacifluvial deposits of the Penultimate Glaciation termed Arroyo Verde (Strelin and Malagnino 1996). The moraine deposits are buried by their own glaciofluvial deposits and the whole set reaches an elevation of 250 m a.s.l., 100 m above the river. The inner slopes of these moraines and glaciofluvial deposits, left behind by ice during the glacial retreat, were modified by an ancient glacial lake (PLA, figure 4). The most prominent lacustrine forms are the paleo-beach levels, bars, spits, lagoons and deltaic deposits. The lithology of the largest erratic blocks which cover the moraine tops is more varied than that of the oldest moraines, and as Darwin (1842b) indicated, blocks of granitic composition appear and basaltic blocks are absent. This particular feature is a result of the level of erosion of the Cordilleran valleys, which reached the granitic substratum (e.g. Fiordo Mayo, Cerro Murallón) in the Cordilleran source area. On the other hand, the decrease in the number of basaltic blocks is related to the decrease of basaltic outcrops upstream. The continental sedimentary sequences of the Santa Cruz Formation crop out along the southern side of the valley, while along the northern side - besides the continental deposits - there are outcrops of marine origin which belong to the Monte León Formation (Patagonian-Patagoniense), with a high content of marine shells, espe-

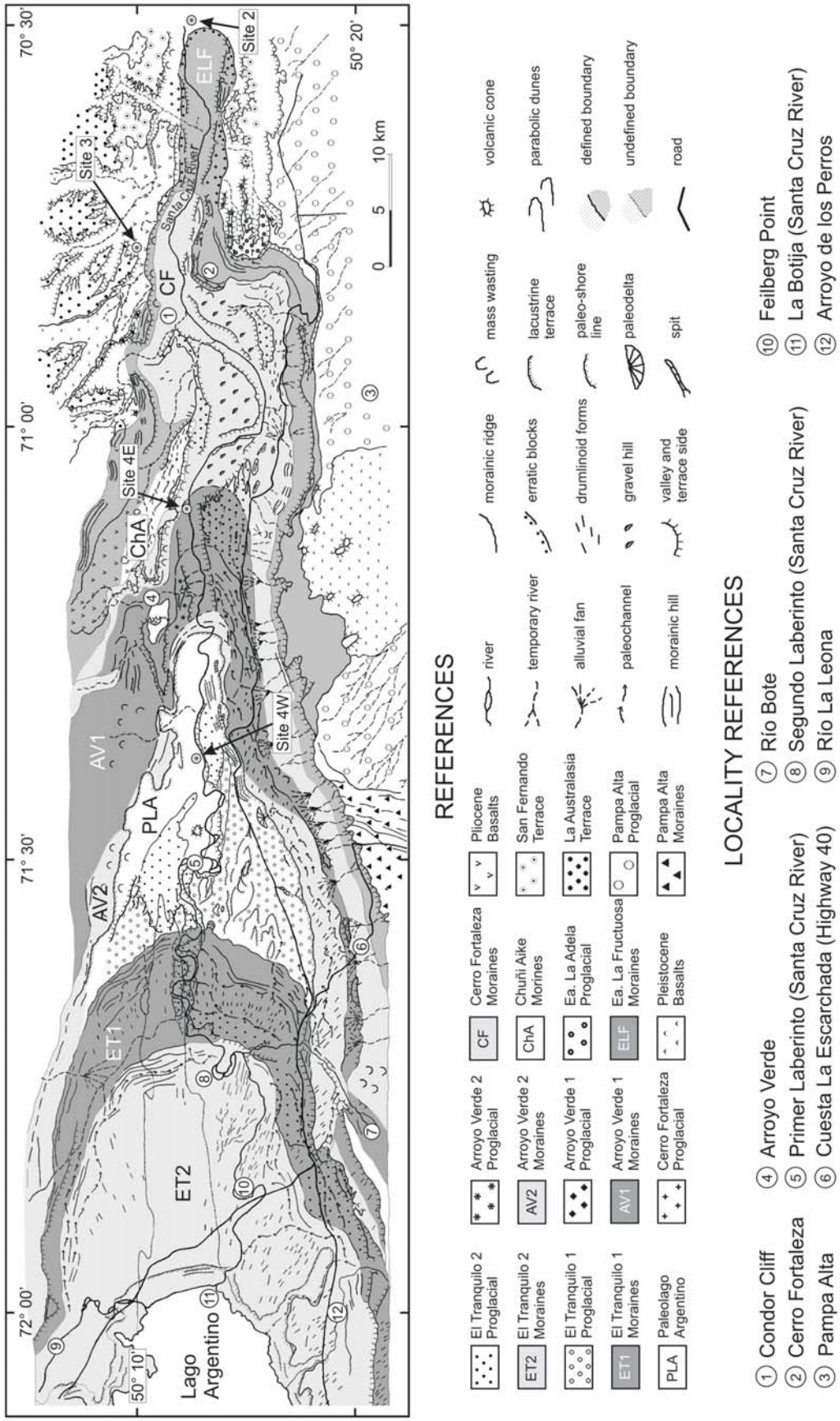

Figure 4: Distribution of the geomorphic units in the Upper Río Santa Cruz Valley region (after Strelin and Malagnino 1996) and Darwin's visited site location.

Figure 5: a) Rhyodacitic erratic block located at the top of Condor Cliff; b) Diamictitic level underlying the Condor Cliff lava flows, top of San Fernando Terrace.

cially oysters and pectinids.

DISCUSSION AND CONCLUSIONS

Darwin (1842b) incorrectly interpreted the depositional environment of the gravel and erratic blocks which cover the Patagonian plateaus, largely influenced by Lyell's (1830) ideas. Nevertheless, his data allowed the determination -with considerable accuracy- of the extent of the maximum expansion of the glacial advances in the Río Santa Cruz valley. The erratic blocks and moraine remnants deposited to the east and at the foot of Condor Cliff narrow (Sites 2 and 3 respectively, Fig. 4) correspond to these extended glacial advances.

Caldenius (1932) and Feruglio (1950) underestimated these observations and did not take into account the location of the erratic blocks mentioned by Darwin (1842b) in Site 2. Therefore, they situated the maximum glacial expansion of the Lago Argentino Basin further up-valley (Caldenius 1932) and at Condor Cliff narrow (Feruglio 1950).

Caldenius (1932), for example, considered the *Per Dusen Moraines* as the oldest (initial glacial) and most expanded system in the Río Santa Cruz valley, with its closure situated at 71º W. Feruglio (1950), on the other hand, referred -in a footnote- to the great erratic blocks at the closure of Cerro Fortaleza (Figs. 4 and 6) as indicators of the maximum glacial expansion in the Río Santa Cruz valley (internal moraines) but, unlike Caldenius, he

Figure 6: Relief model of the Condor Cliff narrow, showing the basaltic flows channeled on the San Fernando Terrace, between the relicts of the Australasian Terrace.

did not consider them indicators of the oldest glaciation.

Likewise, Mercer *et al.* (1975) thought the glacial advance reached the narrow of Condor Cliff twice. During the first advance of his *Most Extensive Glaciation* (Mercer *et al.* 1975) the glacier would have gone beyond the narrow depositing the big erratic blocks which lie on the basaltic cliffs (Figs. 3b and 5a). These blocks would correspond to those mentioned by Darwin (1842b) at the top of his section. During the next advance, the glacier would have deposited the moraines which lie over the western slope of Cerro Fortaleza, at the foot of the basaltic cliffs (Mercer *et al.* 1975).

We agree with Feruglio (1950) in considering that the erratic blocks at Condor Cliff are not the signs of the oldest glaciation in this region (Strelin 1995 and Strelin *et al.* 1999). Prior to the incision of the valley of the Río Santa Cruz through which the second Patagonian glaciation later channeled (Estancia La Fructuosa Glaciation, Strelin 1995 and Strelin *et al.* 1999), the Andean glaciers first irrupted in ample lobes along the foothill belt of the Cordilleran front leaving upon their retreat the moraine arches corresponding to the Pampa Alta Glaciation (Strelin 1995) and the glaciofluvial deposits associated and defined as Pampa Alta Proglacial (Strelin 1995). These morphological units make up the top of the plateau at Pampa Alta, located south of the upper valley of the Río Santa Cruz (Fig. 4). Evidence of this first foothill glaciation is also present at other localities in the Patagonian Andes. In the Lago Buenos Aires basin for example, Malagnino (1995) identified the Chipanque Moraines, as a set of three systems made up of 27 belts located on the Guenguel Plateau at an elevation of 900 meters. These were deposited by a glaciation (Chipanque Glaciation, Malagnino 1995) which had not been identified before in the Lago Buenos Aires basin. With this discovery it was possible to raise to six the number of glaciations in this area of the Patagonian Andes and its foothills.

After the Pampa Alta Glaciation and before the maximum glacial expansion in the Río Santa Cruz valley (Estancia La Fructuosa Glaciation, Strelin 1995) there was a long interglacial period during which the course of the Río Santa Cruz was formed, producing a deep *canyon* which was later partially filled with basaltic lava flows during the Late Pliocene.

We have been able to demonstrate that the referred basaltic volcanism took place at two different eruptive periods: *i.e.*, before and after the accumulation of the moraines which cover the terrace at Condor Cliff (Strelin *et al.* 1999). The terrace level on which the lava flows are channeled coincides with the ancient tributary valleys of the ancestral Río Santa Cruz, the valley floors of which formed the current San Fernando Terrace (Strelin *et al.* 1999). The entrenchment of the tributary valleys, adjusted to the old base level of the Río Santa Cruz, continued until it reached an elevation of 200 -250 m a.s.l. (75 -135 m above the current level of Río Santa Cruz). This can be verified right in front of Condor Cliff at the foot of Cerro Fortaleza, along the southern margin of the narrow, where 12 basaltic lava flows with a total thickness of 100 m lie (through pillow lavas and palagonite tuffs) over the layers of the Santa Cruz Formation.

To the west of the Condor Cliff narrow the valley opens into an amphitheatre which Darwin (1842b), as previously mentioned, interpreted as a terraced paleo-estuary (intermediate terrace, elevation 240 m a.s.l.) opening towards the Cordillera. He described it as abundant in erratic blocks with a different composi-

tion from those on the upper terrace of Condor Cliff and belonging to a different glaciomarine event from that which deposited the blocks on the upper terrace. Darwin (1842b) thought to confirm the marine environment with the finding of shells on the valley floor (elevation 135 m a.s.l.). This interpretation strongly contrasts with ours at first sight because we consider that Darwin's intermediate terrace is part of the moraine and glaciofluvial deposits formed by the glacial tongue which channeled through the Río Santa Cruz valley during the Penultimate Glaciation (Arroyo Verde Glaciation, Strelin and Malagnino 1996). However, if we analyze the landscape features in detail we will see that Darwin (1842b) did not let his imagination run away. On the one hand, there is the fact -well-established by Darwin- of a different glacial event based on the different composition of the erratic blocks. On the other hand, we can justify his interpretation of the existence of a paleo-estuary (paleo-fjord) in the upper valley of Rio Santa Cruz if we consider the morphological similarities between this valley and other glacial valleys, totally or partially flooded by the sea, visited by Darwin during his voyage to the southern seas (Strait of Magellan, Otway and Skyring Fjords, San Sebastián Bay, Inútil (*Useless*) Bay, Beagle Channel, etc). The morphological similarity with flooded valleys is even more noticeable if we consider that the section of the valley Darwin (1842b) examined was reshaped by an ancient lake as shown by the lacustrine paleo-forms (raised beaches, bars, spits, lagoons and deltas, in figure 4) hanging at elevations of up to 250 m a.s.l. (100 m above the valley floor). This lake formed as a result of a moraine damming (Arroyo Verde moraines, Strelin and Malagnino 1996) during the glacial retreat which took place in the Paleo-Lago Argentino Interglacial (Strelin and Malagnino 1996). As regards the marine shells Darwin discovered in this section of the valley, Feruglio (1950) suggests that they may have been abandoned there by natives. We consider, however, that it is more likely that Darwin (1842b) found reworked oyster and pectinid shells coming from the coquina exposures of the Monte Leon Formation located near this site. It is worth mentioning that the surfacing of Monte Leon Formation in this part of the valley is a feature which has yet not been clearly explained.

Finally, the origin of the erratic blocks (Fig. 2) found in the lower valley of the Río Santa Cruz (Site 1, Fig. 1) has not been elucidated yet. Darwin (1842b) was sensitive to this enigma, which he tried to solve when he suggested that they could have been accumulated after rafting over fluvial ice. At present we consider this feasible and furthermore that it could have been after the catastrophic draining of the ancient Arroyo Verde moraine-dammed glacier-lake (Strelin and Malagnino 1996).

ACKNOWLEDGMENTS

We are especially grateful to Marcos Mozetic, Eduardo Olivero, and Michael Kaplan for their suggestions and for improving the english of this paper. Also we thank very much Beatriz Aguirre-Urreta for inviting us to participate in this special issue dedicated to Charles Darwin.

WORKS CITED IN THE TEXT

Agassiz, L. 1840. Études sur les glaciers. Jent et Gassmann Libraires, 346 p., Neuchâtel.

Darwin, C. 1842a. The structure and distribution of coral reefs. Being the first part of the geology of the voyage of the Beagle, under the command of Capt. Fitzroy, R.N. during the years 1832 to 1836. Smith Elder and Co. 214 p., London.

Darwin, C. 1842b. On the distribution of erratic boulders and on the contemporaneous unstratified deposits of South America. Transactions Geological Society London 6: 415-431.

Darwin, C. 1844. Geological Observations on The Volcanic Island, visited during the Voyage of H. M. S. Beagle. The Geology of the Voyage of the Beagle, Part 2, Smith Elder and Co. 172 p., London.

Darwin, C. 1846. Geological observations on South America. Being the third part of the geology of the voyage of the Beagle, under the command of Capt. Fitzroy, R.N. during the years 1832 to 1836. Smith Elder and Co. 280 p., London.

Feruglio, E. 1950. Descripción Geológica de la Patagonia. Yacimientos Petroliferos Fiscales 3, 431 p., Buenos Aires.

Hoff, K.E.A. von 1834. Geschichte der durch Ueberlieferung nachgewiesenen natürlichen Veränderungen der Erdoberfläche, 1-4, Perthes, 2086 p., Gotha.

Lyell, C. 1830-33. Principles of Geology. John Mu-rray, Albemarle-Street, (1830) 1, 511 p.; (1832) 2, 330 p.; (1833) 3, 109 p., London.

Lyell, C. 1840. On the Boulder Formation, or drift and associated freshwater deposits composing the mud-cliffs of Eastern Norfolk. The London and Edinburgh Philosophical Magazine and Journal of Science, Third Series 16(104): 345-380.

Malagnino, E.C. 1995. The discovery of the oldest extra-Andean glaciation in the Lago Buenos Aires Basin, Argentina. A.A. Balkema, Quaternary of South America and Antartic Peninsula 9: 69-83, Rotterdam.

Mercer, J.H., Fleck, R.J., Mankinen, E.A. and Sander, W. 1975. Southern Patagonia: Glacial Events Between 4 m.y. and 1 m.y. Ago. In Suggate, R.P. and Creswell, M.M. (eds.) Quaternary Studies, The Royal Society of New Zealand, 223-230, Wellington.

Strelin, J.A. 1995. New evidences on the relationships between the oldest estra-andean glaciations in the the Santa Cruz River area. A.A. Balkema, Quaternary of South America and Antarctic Peninsula 9: 105-116, Rotterdam.

Strelin, J.A. and Malagnino, E.C. 1996. Glaciaciones Pleistocenas del Lago Argentino y Alto Valle del Río Santa Cruz. 13° Congreso Geológico Argentino, Actas 4: 311-326.

Strelin, J., Re, G., Keller, R. and Malagnino E. 1999. New evidences concerning the Plio-Pleistocene landscape evolution of southern Santa Cruz region. Journal of South American Earth Sciences 12: 333-341.

Recibido: 19 de septiembre de 2008
Aceptado: 29 de octubre de 2008