CHARLES DARWIN AND THE FIRST SCIENTIFIC OBSERVATIONS ON THE PATAGONIAN SHINGLE FORMATION (*RODADOS PATAGÓNICOS*)

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ABSTRACT

The *Rodados Patagónicos* is one of the most intriguing lithostratigraphic units in the Late Cenozoic of Patagonia. Charles Darwin named these gravels as the "*Patagonian Shingle Formation*", when he discovered them during his trip to Patagonia on board HMS Beagle in 1832. According to the prevailing paradigm of the time, he assigned these deposits to a giant transgression during the Great Universal Déluge epoch, considering that their formation was related to wave action along the beach in ancient times. The name of *Rodados Patagónicos*, as they are generally known in the Argentine geological literature, is usually confusing since it has been applied to a wide number of geological units of multiple origin and age. Many authors have discussed the nature and origin of these gravels, considering them to have been formed by piedmont, alluvial, colluvial, glaciofluvial, and/or marine processes. Today, it is accepted that the term *Rodados Patagónicos* includes gravel deposits of varied nature and age, perhaps with a prevalence of piedmont genesis in northern Patagonia and glaciofluvial dynamics in southern Patagonia and Tierra del Fuego.

Keywords: *Charles Darwin, Patagonian Shingle Formation, Late Cenozoic, Patagonia, Tierra del Fuego.*

RESUMEN: *Charles Darwin y las primeras observaciones científicas sobre los Rodados Patagónicos.* Los *Rodados Patagónicos* son algunas de las unidades litoestratigráficas más sorprendentes del Cenozoico tardío de Patagonia. Charles Darwin dio a estas gravas el nombre de *Patagonian Shingle Formation*, cuando las descubrió durante su viaje a Patagonia en el HMS Beagle en 1832. De acuerdo con los paradigmas dominantes de la época, asignó estos depósitos a una transgresión gigantesca durante el "Gran Diluvio Universal", considerando que su formación estaba relacionada a la acción del oleaje a lo largo de la playa en tiempos antiguos. El nombre de *Rodados Patagónicos*, como generalmente se los conoce en la literatura geológica argentina, es usualmente confuso, ya que ha sido aplicado a un amplio número de unidades geológicas, de múltiple origen y edad. Muchos autores han discutido la naturaleza y génesis de estas gravas, considerándolas como formadas por procesos diversos, ya sea pedemontanos, aluviales, coluviales, glaciofluviales, y/o marinos. En la actualidad, se acepta que el término *Rodados Patagónicos* incluye a depósitos de grava de naturaleza y edad muy variadas, quizás con una predominancia de aquellos de génesis pedemontana en Patagonia septentrional y debidos a la dinámica glaciofluvial en Patagonia austral y Tierra del Fuego.

Palabras clave: *Charles Darwin, Rodados Patagónicos, Cenozoico tardío, Patagonia, Tierra del Fuego.*

INTRODUCTION

The outstanding work of Charles Darwin in the biological sciences has concealed his significant contributions to geology and other earth sciences. Perhaps because of this reason, the great influence of his findings in South American earth sciences is seldom appraised in the literature beyond his biological theories. The publication of *The Origin of Species* (Darwin 1859) was the onset of a period in which there were so many radical changes in the structure of western knowledge that it can be considered an authentic scientific revolution. However, the strengthening of this new paradigm on the origin and evolution of living beings was accompanied, and mostly complemented, by the formulation of new approaches to the great geological dilemmas of the times. By then, the paramount work of Charles Lyell (1830-1833) represented the gradualist principles within the geological sciences, which appeared as a reaction and antipode position against the catastrophist theories, that postulated that natural history was, essentially, a succession of universal cataclysm that had dramatically modeled the surface of the Earth, generating mass extinctions and the rise of new species different to the previously existing ones. Darwin's work, basically of a gradualist nature, fired catastrophism the final blow. Almost at the same time that Darwin was traveling on board HMS Beagle, the last steps towards the presentation of the *Glacial Theory* were being fulfilled in central Europe (Louis Agassiz, in 1837; Agassiz 1840, in Imbrie and Imbrie 1979), which would deeply modify the ideas about the origin and evolution of the landscape in the northern hemisphere and, as it happened later on, on the understanding of the global climate system. This new theory did not adjust to Bible principles that underpinned the *Great Universal Déluge* as the main cause of most of the present landscape features, and strongly supported by the aforementioned catastrophist conception. The first volume of Lyell's *Principles of Geology* was published in 1830, only one year before Darwin set out on his 5-year voyage to the Southern Hemisphere. This volume, and the second one that he received when HMS Beagle was in Buenos Aires in 1832, became the conceptual platform from which Darwin made his observations and formulated his principal hypotheses on the geological sciences in general and of South American geology in particular.

It is frequently believed that Darwin's main contributions to earth sciences are his works on plutonic and metamorphic rocks and his ideas on the origin of the volcanic islands and reef barriers. In this article, we want to emphasize the thoughts dedicated by this great scientist to one of the more interesting and intriguing geological units, not only of those days but even today, as are the so called *Rodados Patagónicos*. For a review of Darwin's work as a Quaternary geologist and as a glaciologist see Rabassa (1995).

The discussion of Darwin's process of identification, description and interpretation of the *Rodados Patagónicos*, which are ubiquitous over most of the surface of Argentine Patagonia (Fig. 1), reveals once again his scientific talent and pioneer activity in the area and also allows recognition of relevant aspects of the historical-scientific background in which such process occurred.

CHARLES DARWIN AND THE "DISCOVERY" OF THE *RODADOS PATAGÓNICOS*

The voyage of the HMS Beagle took place between 1831 and 1836. The first opportunity in which Charles Darwin identified gravel deposits that are today known as *Rodados Patagónicos* was in 1833, during his expedition to the surroundings of the present city of Bahía Blanca, southern Buenos Aires province (Fig. 1). There, he observed a layer that was less than a meter thick, composed of small pebbles, essentially porphyritic rocks, that were lying on top of the "Pampean beds" and that were the base over which the frequent large dunes in the area are deposited (Darwin 1846). Starting here, and later during different landings as they sailed southwards, such as San Antonio, the mouth of Río Chubut, Puerto Deseado, San Jorge Gulf and the mouth of Río Santa Cruz (Fig. 1), Darwin described the outcrops at the scarps of tablelands and terraces stretching along the sea. At the same time, he began working on the hypothesis that these gravels were the product of alluvial accumulation at the foot of the Andean Cordillera and later spread out by wave action during a marine transgression. He verified the vast continuity of these gravel beds he named as the "*Gravel Formation*" or "*Patagonian Shingle Formation*", concluding that they represented one of the main physical features of this region. The term "shingle" referred to the gravels which are the result of wave action on the cliffs along many sectors of the British coasts (Fig. 2). To Darwin's eyes, the vast expanse of the Patagonian gravel beds was awesome and astounding, in comparison to what he had seen in Europe before, to a point that he considered that these units were the largest ones of this kind in the entire world. He assumed that a clear evidence of the marine origin (in fact, submarine for him) of these strata was the frequent finding of Recent marine shells scattered on top and even within these terraces. Although several authors later discarded this genetic interpretation, it was Feruglio (1950) who confirmed that the shells had been accumulated by human action and they were actually archaeological sites. There are other elements that contributed to Darwin's choice of his marine (submarine) process interpretation. Firstly, the great widening of the Río Santa Cruz valley nearby its sources at Lago Argentino (Fig. 1), more than 300 km from the Atlantic coast, was wrongly interpreted as an ancient estuary. This large landform is today known to have been generated due to recurrent Pleistocene glaciation and the action of glaciofluvial streams (Mercer 1976, Clapperton 1993, Schellmann 1998, among others). It is also accepted today that the building up of the extensive, step-like terraces and/or tablelands of the region is also due to the same glaciofluvial processes. However, Darwin linked these landforms to the impact of Atlantic Ocean transgressions that reached locations very close to the Andean Cordillera. Besides, he also considered that it was very likely that Patagonia would have been crossed by many sea passages in the past, similar to the present Magellan Straits (Fig. 1), which connected both oceans. It should be considered that almost simultaneously with Darwin's pioneer scientific observations in Patagonia (1833-1834), the ideas that led Louis Agassiz to postulate his *Glacial Theory* in 1837, were growing steadily. For an ample discussion of this epistemological process, see Imbrie and Imbrie (1979). Concerning Darwin's geological background, it was probably not conceivable that glaciers would have had in the recent geological past a larger extent that today. Even less conceivable was that areas which are ice free today and very far from the glacier boundaries could have been covered by large ice masses in the past; a feature that has been shown was a distinctive characteristic of Patagonia (Caldenius 1932, Feruglio 1950, Clapperton 1993, Coronato *et al.* 2004, Rabassa 2008). Darwin focused his geological analysis accepting Lyell's statements as a foundation, albeit in a critical manner, as Lyell was still supporting the hypothesis of a large flooding -a phenomenon of Biblical roots- which had had a key role in the origin of many features of the Earth's surface. It is interesting to

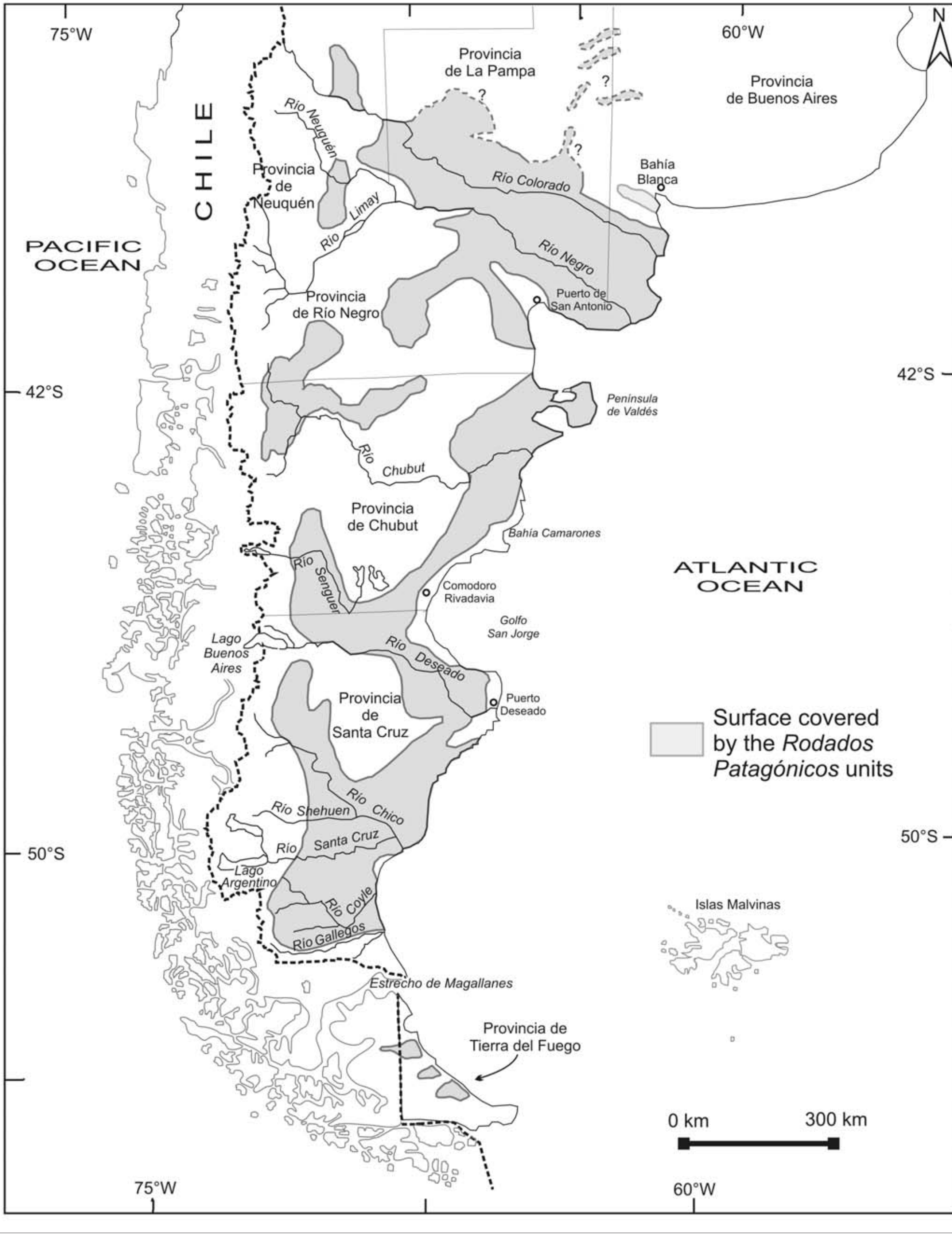

Figure 1: Location map of Patagonia and Tierra del Fuego showing the areas covered by the *Rodados Patagónicos* (modified from Clapperton 1993).

consider that in those years Lyell believed that the erratic boulders, today accepted as essentially of strict glacial origin, had been transported through usually very long distances by icebergs generated by such flooding, to be later abandoned on land as the sea withdrew. This interpretation, which Lyell abandoned a few years later, was very influential on Darwin's intellectual work. The large boulders of foreign rocks (of Andean origin) that are lying on or partially buried in the gravel beds along extra-Andean areas of southernmost Patagonia (Darwin 1848), were thus of marine origin for Darwin, becoming so another strong line of reasoning in favor of a similar or identical origin for the *Shingle Formation*.

Figure 2: Beach gravel deposits (*shingle beach*) in a classical locality along the English coast, representing the kind of deposits that Darwin had seen before starting his voyage on board HMS Beagle. Darwin's home memories about these kind of deposits lead him to interpret the gravel deposits that he found everywhere along the Patagonian coasts and rivers as "shingle formations", thus giving support to the original, historical name of these units. Reproduced with permission of www.beenthere- donethat.org.uk, copyright © by Barry Samuels.

THE SEDIMENTARY MATERIALS THAT HAVE BEEN NAMED AS *RODADOS PATAGÓNICOS*

Previous works

After Darwin's early contributions there were several authors that documented the existence of these characteristic gravel and sand beds in Patagonia (Table 1). Doering (1882) named them as *Piso Tehuelche* and in a pioneer manner interpreted them as of glaciofluvial origin in a moment in which the *Glacial Theory* was well accepted by the scientific community. This author correlated them with the lower section of the Pampean sediments, based on the occurrence of calcareous duricrusts locally known as *tosca,* and assigned them an Early Pliocene age. Carlos Ameghino (1890) was the first geologist to discard a single origin for these materials and he differentiated between the marine deposits forming the high terraces and the low terrace sedimentary beds, referring the first ones as the *Formación Araucanense*, deposited in successive epochs since the Early Miocene. Mercerat (1893) studied these accumulations in the southernmost part of Patagonia between the Río Santa Cruz and the Magellan Straits. He named them as *Rodados Tehuelches* and assigned them a marine origin and a pre-Pliocene age. Hatcher (1897) also considered them of marine origin and attributed them to a sea transgression that would have covered all of Extra-Andean Patagonia during the Pliocene, reinstating the Darwinian name of *Shingle Formation*. Nordenskjöld (1897), who was strongly influenced by the recently introduced *Glacial Theory* and his wide knowledge of the glacial landscapes in Scandinavia and northern Europe, correctly proposed a glaciofluvial origin for the gravel deposits in southern Santa Cruz province and the Magellan Straits, but he did not discuss the origin of similar units farther north. Florentino Ameghino (1906) returned to the topic from a regional perspective, insisting that it was not appropriate to assign a unique origin to all gravel deposits and that they could have a different genesis according to their location.

The first author to relate the *Rodados Patagónicos* to the development of the glacial periods in the Patagonian Andes was Rovereto (1912), who recognized a link to four hypothetical glaciations according to the Alpine scheme then in use. According to him these glaciations were related to different marine terraces with a mollusk fauna quite similar to the present one, as suggested by his studies along the Atlantic coast.

Keidel (1917) disagreed with the hypotheses of the previous workers, postulating that the gravels that cover much of the tablelands and terraces of northwestern Patagonia represented alluvial *bajadas* built by fluvial streams coming from the Andes, during the Pliocene and the Quaternary, in response to regional uplift events. Keidel was the first to note the unconformity between the gravels and the underlying Late Tertiary marine and continental sedimentary rocks. Later, Bonarelli and Nágera (1922) returned to the ideas about the marine origin of the gravels and assumed that the so-called *Rodados Tehuelches* of the highest terraces were at least of Pliocene age, which had been dispersed later by the action of marine waters pertaining to a transgression that reached the foothill of the Andes. These later were the source of the fluvial deposits of the lower terraces, carved after successive episodes of river base drop.

Windhausen (1931) suggested that the higher beds were deposited in an alluvial manner over a rather flat relief with a very gentle slope, whereas the topographically lower, terraced gravels were the consequence of glaciofluvial deposition in different stages of uplift that occurred during the Quaternary. Based on the ideas of Rovereto (1912), Frenguelli (1931) distinguished the *Tehuelchiano* beds, composed of three orders of marine terraces and other continental ones corresponding to the *Post-Tehuelchiano*, formed by low terrace gravels, of postglacial age.

Caldenius (1932, 1940) assigned a fluvial

TABLE 1: Summary table of the main contributions to the knowledge on the *Rodados Patagónicos*, since the first descriptions (Darwin 1848) up to the end of the 20th century. The great historical controversy -which still persists- may be identified, concerning the genesis and age of these units.

Author	Proposed denomination	Geographical distribution	Depositional environment	Age
Darwin (1846)	"Gravel Formation" or "Shingle Formation"	Throughout Patagonia	Fluvial, piedmont and marine	Not specified
Moreno (1876)	No specific new name given	Throughout Patagonia	Glacial and glaciofluvial	Not specified
Doering (1882)	"Piso Tehuelche"	Northern Patagonia	Glaciofluvial	Early Pliocene
Ameghino (1890)	"Formación Araucanense"	Throughout Patagonia	Marine	Since Early Miocene
Mercerat (1893)	"Rodados Tehuelches"	Southern Santa Cruz province	Marine	pre-Pliocene
Hatcher (1897)	"Shingle Formation"	Throughout Patagonia	Marine	Pliocene
Nordenskjöld (1897)	No specific new name given	Southern Santa Cruz province	Glaciofluvial	Quaternary glaciations
Ameghino (1906)	No specific new name given	Throughout Patagonia	Poligenetic	Not specified
Rovereto (1912)	No specific new name given	Northern Patagonia	Glacial	Quaternary glaciations
Kiedel (1917, 1919)	No specific new name given	Northeastern Patagonia	Fluvial, piedmont	Not specified
Bonarelli and Nágera (1922)	No specific new name given	Southern Patagonia	Marine	Not specified
Windhausen (1931)	No specific name given	Throughout Patagonia	Fluvial, piedmont and glaciofluvial	Quaternary
Frenguelli (1931)	"Estrato Tehuelchiano" and "Post-Tehuelchiano"	Throughout Patagonia	Marine and continental	Post-glacial
Caldenius (1932, 1940)	"Rodados Patagónicos", "Patagonian Gravels"	Throughout Patagonia	Fluvial, glaciofluvial y solifluxión	Pre-glacial and during Quaternary glaciations
Groeber (1936)	"Rodados Patagónicos"	Throughout Patagonia	Fluvial, piedmont	Not specified
Feruglio (1949-1950)	"Rodados Patagónicos"	Central and southern Patagonia	Glaciofluvial, fluvial	Since the Pliocene
Frenguelli (1957)	"Rodados Patagónicos"	Throughout Patagonia	Glaciofluvial, fluvial	Since the Pliocene
Fidalgo and Riggi (1965, 1970)	"Rodados Patagónicos"	Northern and central Patagonia	Fluvial, piedmont, glaciofluvial	Pre-glacial and during Quaternary glaciations
Mercer (1976)	"Patagonian Gravels"	Southern Patagonia	Glaciofluvial	Since the Miocene
González Díaz and Malagnino (1984) and Malagnino (1989)	"Rodados Patagónicos"	Northern Patagonia	Piedmont (the older ones), glaciofluvial (the younger ones)	Quaternary glaciations
Clapperton (1993) Lapido and Pereyra (1999)	"Rodados Patagónicos"	Throughout Patagonia	Fluvial, piedmont (northern Patagonia), glaciofluvial (central and southern Patagonia)	Since the Miocene

and glaciofluvial origin to the *Rodados Tehuelches*, originally deposited in the shape of piedmont glaciofluvial cones and he suggested that these units had undergone certain amount of reworking due to solifluction processes. Likewise, he recognized the existence of higher level gravel beds and of an older age than even the oldest glaciations, which he named as *Initioglacial*.

Groeber (1936) proposed a mixed alluvial and colluvial origin for these gravels. Feruglio (1950) recognized the existing relation among the fluvial terraces of the different fluvial systems of the southernmost Patagonian *meseta*, in the valleys of the Chubut, Deseado, Shehuen, Coyle, Santa Cruz and Gallegos rivers (Fig. 1). The great dimensions of the terraces, the thickness of their alluvial mantles and the marked relief that separated them justified his interpretation linked to the glacial and interglacial periods that affected the mountain ice sheet of the Patagonian Andes since the Pliocene, and to a lesser extent, to phases of tectonic uplift. On these terraces Feruglio (1950) identified moraine deposits and glaciofluvial gravels of varied lithology, but mostly of eruptive rocks. Frenguelli (1957) agreed in general terms with Feruglio's (1950) interpretations.

The first really rigorous systematic and solid studies on the gravels were done by Fidalgo and Riggi (1965, 1970), who based their interpretations upon geomorphological and sedimentological observations in the surroundings of Lago Buenos Aires (Santa Cruz province; Fig. 1). In agreement with Caldenius (1932), they classified these materials into two large groups: (a) those of fluvial and piedmont origin (*Rodados Patagónicos*, *sensu stricto*), located at higher altitude and covering the tablelands and pediments, and (b) those that form the glaciofluvial plains that are found within the valleys or depressions around the *mesetas* and therefore of younger age. According to Fidalgo and Riggi (1965, 1970), all other deposits of more restricted extent as those building up the flanking pediments should also be considered as *Rodados Patagónicos*, a proposal that Clapperton (1993) considered as of little value.

The development of absolute dating and the consequent confirmation of the occurrence of glaciations older than the Pleistocene in Santa Cruz province allowed Mercer (1976) to identify accumulations of glaciofluvial origin, referring them to the *Rodados Patagónicos*, with an age equivalent or even older than that of those of piedmont origin that had been mentioned as the oldest by some authors. González Díaz and Malagnino (1984) and Malagnino (1989) centered their observations in northern Patagonia and they concurred in assigning a polygenetic character to the *Rodados Patagónicos* at these latitudes, proposing an essentially glaciofluvial origin for the younger ones, and broadly a piedmont genesis, possibly associated to tectonic pulses for the older ones. Clapperton (1993) and later Lapido and Pereyra (1999), reviving the essentials of Ameghino's (1906) hypothesis, proposed classifying the deposits in (a) those located in northern Patagonia, between the Negro and Colorado rivers (Fig. 1), to which they assigned a dominantly piedmont origin and (b) the gravels of southern Patagonia, in the provinces of Chubut and Santa Cruz, which were interpreted as of predominantly glaciofluvial nature. During the second half of the 20th century the geological surveys of Extra-Andean Patagonia became more frequent and many authors have proposed a series of lithostratigraphic units corresponding to the *Rodados Patagónicos*. Among many others should be mentioned the contributions of Volkheimer (1963, 1964, 1965 a and b, 1973), Cortelezzi *et al.* (1965, 1968), González (1971, 1978), Coira (1979), Fidalgo and Rabassa (1984), Page (1987), Cortés (1987), González Díaz (1993a, b and c), Panza (1994a, 1994b), Panza and Irigoyen (1994) and more recently, Strelin *et al.* (1999), Caminos (2001), González Díaz and Tejedo (2002), Pereyra *et al.* (2002) and Leanza and Hugo (1997, 2005). Meglioli (1992) mapped as *Patagonian Gravels* -without distinguishing about their genesis- the plains located along the southern margin of the Río Gallegos, the Río Chico de Santa Cruz basin and several basins in Tierra del Fuego Island (Fig. 1). The slender relief of these gravelly plains, undifferentiated from a genetic point of view, is interrupted by the Quaternary volcanic cones that form the Pali-Aike volcanic field. The glaciofluvial gravels from the Pleistocene glacial advances are distributed according to the moraine morphology, either in frontal or marginal position. Although Meglioli (1992) did not present details of the location of each one of the glaciofluvial terraces, he defined their spatial setting and assigned them to the Cabo Vírgenes, Punta Delgada, Primera Angostura and Segunda Angostura glaciations, or the Post-GGP I, II and III glaciations and Last Glacial Maximum, according to Coronato *et al.* (2004) in the Magellan Straits, Skyring and Otway sounds ice lobes (Fig. 1). In high topographic positions, Meglioli (1992) identified a thin gravel bed that is part of the Sierra de los Frailes Drift, corresponding to the Great Patagonian Glaciation (GPG, according to Coronato *et al.* 2004), whose age was established in ca. 1 Ma (Ton That *et al.* 1999, Rabassa 2008). Meglioli (1992) defined several units of rounded and subrounded gravels of similar origin in Tierra del Fuego and named them as *Rodados Fueguinos*, thus recognizing that this type of unit is also present in the southernmost end of the continent.

Finally, the work of Panza (2002) provided an integrated view of the Cenozoic gravels within the province of Santa Cruz, whereas Martínez and Coronato (2008) extended this analysis to the rest of Patagonia.

CHARACTERIZATION OF THE *RODADOS PATAGÓNICOS*

The *Rodados Patagónicos* are accumulations of gravelly clasts (Figs. 3 and 4), cemented or not, substantially rounded, with pebbles and cobbles as the dominant size fractions, in a sandy or silty/clayish matrix, of highly variable lithology, although with a certain predominance of basic and mesosilicic volcanics and acid plutonic rocks. They range between the Andean Cordillera and the Atlantic Ocean coast, and from the northern flank of the Río Colorado valley to the island of Tierra del Fuego (Fig. 1). They tend to form horizontal to subhorizontal mantles of varied extension and thickness, which are located in different topographical positions, usually showing an east-west dominant gradient, and the genesis of which may be variable according to the considered unit or geographical area. They were generated at some time during the Late Cenozoic. They may be forming different landforms or their relicts, such as inactive flood plains, alluvial terraces, alluvial fans, *bajadas*, pediment covers, proglacial plains and structural plains covers (Fig. 5). Hence, the great diversity of the many variables that play a part in the definition of these units (Table 2), i.e. (a) sedimentological / petrological (composition, grain size, shape, selection, among other parameters), (b) spatial (shape, elevation, slope, size, extent, thickness of the beds), (c) chronological (tentatively between the Late Miocene and the Holocene) and (d) genetic (fluvial, piedmont, glaciofluvial, periglacial, among other possible environments).

It is clear then that the concept of *Rodados Patagónicos* is ample enough, and thus ambiguous, so as to hamper its use in a regional stratigraphic sense. However, it may have a useful practical application as a generic term in those cases - not infrequent-, in which it would be impossible or unnecessary to establish the age and/or genesis of these gravel layers. As suggested by Lapido and Pereyra (1999) the lack of chronostratigra-

Figure 3: A *Rodados Patagónicos* outcrop in the area of Lago Argentino, Río Santa Cruz valley, Province of Santa Cruz. Photograph by A. Coronato, 2006.

Figure 4: Outcrop of the *Rodados Patagónicos* in the tablelands of Central Chubut Province. Photograph by O.A. Martínez, 2007.

phic studies and of absolute datings in the different Quaternary units of the region renders any predetermined time framework and/or geographical location pattern of these deposits only tentative and incomplete. When the gravel mantles are grouped more or less in a parallel manner with respect to the present drainage networks, they might be genetically related to fluvial valley processes. This possible genesis should be considered as the result of both climatic fluctuations (glacial and interglacial periods) and base level modifications in response to Late Cenozoic tectonic and epeirogenic uplift (Strelin *et al.* 1999). Besides, it seems relevant to consider that major piedmont aggradation events should have followed and, in some cases, even coincided at the regional level with those of glaciofluvial nature, at least since the late Miocene (Martínez and Coronato 2008). The general idea of advocating an older age for the piedmont deposits in relation to those formed by glaciofluvial action (Fidalgo and Riggi 1965, 1970) seems inconvenient at least, considering the complexity in the tectonic and climatic evolution of such extensive a region as Patagonia (Lapido and Pereyra 1999).

J.L. Panza (pers. comm., while acting as a reviewer of an earlier version of this manuscript) did not agree with some of our conclusions. He considered that most of, if not all, those deposits assigned to the *Rodados Patagónicos* of ages older than 1.2-1.0 Ma in the Province of Santa Cruz are not related to glaciofluvial proceses or genetically or timely associated to the major Patagonian glaciations, being much older than these. He understands that there is no synchronism bet-

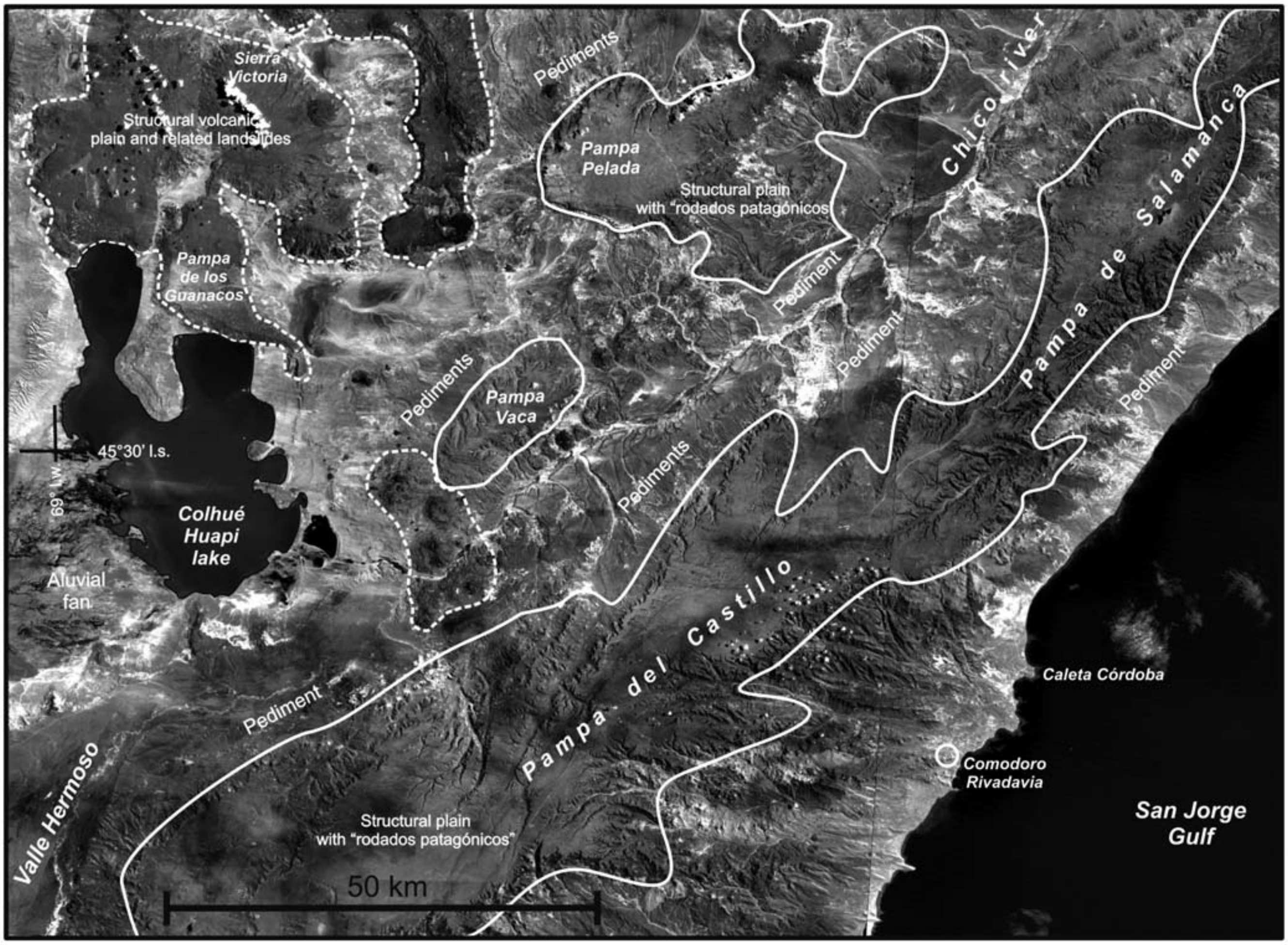

Figure 5: Structural terraces and other landforms covered by the *Rodados Patagónicos* in southeastern Chubut Province, mapped on a Landsat satellite image (from Martínez and Coronato 2008).

TABLE 2: Genetic classification and general sedimentological characterization of the *Rodados Patagónicos* (modified from Martínez and Coronato 2008).

Genesis	Areal Extent[1]	Latitudinal location	Age distribution	Lithology	Slope of the original surface	Elevation
Fluvial valley processes	Local, regional and extra-regional	Throughout Patagonia	Since the Late Miocene	Variable	Highly variable, very gentle, according to local conditions	Variable
Glaciofluvial processes	Extra-regional and regional	Throughout Patagonia, predominant in southern Patagonia	Glacial periods between Pliocene and Early Pleistocene	Clasts of Andean volcanics and metamorphic rocks	Very gentle	Variable, lowering with younger ages
Piedmont processes	Extra-regional	With better development in Northern Patagonia	Miocene to Early Pleistocene	Clasts of Andean volcanics and metamorphic rocks	Very gentle	Variable, loweirng with younger ages
	Local, occasionally regional	Throughout Patagonia	Miocene to Early Pleistocene	Variable, coming from local mountain ranges	Moderate to strong	Variable, lowering with younger ages
"In situ"[2], due to bedrock weathering	Local	Cited in Central Patagonia	Since the Pliocene	Same as bedrock	Horizontal to sub-horizontal	Usually above the present fluvial valleys

[1] Three levels or cathegories are recognized: 1) those of local extent, when the depositis do not extend more than a few km from the source area, being this the mountain front (piedmont) or a moraine arc (glaciofluvial); 2) those of regional extent, considering for this purpose three main regions (or longitudinal stripes), a- western or Andean, b- central or Extra-Andean and c- eastern or coastal; 3) those of extra-regional extent, when the areal extent covers more than one region.

[2] The authors of the present paper have considered appropriate to include this type corresponding to some gravel accumulations (González, 1978) in whose genesis superficial runoff would have not taken part of.

ween the main aggradational events and those of glaciofluvial nature, particularly in Northern Patagonia. He also considers inappropriate our discussion of the relative ages of piedmont and glaciofluvial deposits.

J.L. Panza's comments are very valuable and worthy. However, we would like to state that we have never denied the fluvial/aggradational/piedmont origin for some of the *Rodados Patagónicos* units. Moreover, we have clearly maintained (see for instance Tables 1 and 2) that this genesis is one of the possible major sources for these units. Our intention has been just to make noticeable that some of the accumulations of *Rodados Patagónicos*, and particularly those of Early Pleistocene and older ages (Rabassa *et al.* 2005), may have been generated by glaciofluvial action during very ancient glaciations, older than the Great Patagonian Glaciation, even though these glacial events were growing small, isolated ice caps before the Patagonian Mountain Ice Sheet finally developed around ca. 1.2 Ma (Rabassa 2008). Though on-going and future research will undoubtedly elucidate this puzzle, the scale and complexity of this problem has kept this discussion open for over a century and obviously it will probably remain so for a long time.

FINAL REMARKS

This article intends to give renewed importance to the historic role that the work of Charles Darwin on the *Rodados Patagónicos* had at his time, precisely in a profoundly revolutionary moment within the earth sciences, when new ideas were thriving and new paradigms were precipitously put forward. The Darwinian production concerning the *Rodados Patagónicos* compels us to recognize the enormous merits of this author as an intuitive geologist of great intellectual audacity and who conceived science, as many other naturalists of those times, as an essentially integral and multidisciplinary activity. Thus, Darwin achieved a prominent position in this discipline in Argentina, perhaps unintentionally, since his most insightful interests were in the fields of biology and anthropology. Nevertheless he is widely recognized in the earth sciences particularly as a petrologist (some of the first descriptions of plutonic and metamorphic rocks), sedimentologist (pioneer reconnaissance of old sedimentary rocks and modern sediments), geomorphologist (identification and characterization of terraces, tablelands, dunes, estuaries, moraines, erratic boulders, etc.), stratigrapher (a visionary definition of the Pampean units), paleontologist (transcendental discoveries of relevant localities for Tertiary and Pleistocene fossil mammals in the Pampean region) and glaciologist (innovative observations of the Patagonian and Fuegian glaciers).

Darwin was one of the most important geologists and geomorphologists of the 19th century, very far ahead of his time, and his forerunner ideas needed over a century to be revised, incorporated, confirmed, or dismissed. Even today we continue revisiting his ideas and still work pursuing the search of valuable, ground-breaking concepts which may still be hidden within his unforgettable writings.

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