# DARWIN AT PUENTE DEL INCA: OBSERVATIONS ON THE FORMATION OF THE INCA'S BRIDGE AND MOUNTAIN BUILDING

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**ABSTRACT**

The analyses of the observations of Charles Darwin at Puente del Inca, during his second journey across the High Andes drew attention on two different aspects of the geological characteristics of this classic area. Most of his descriptions on the characteristics and the origin of the natural bridge were not published, mainly due to his poor impression of Puente del Inca. However, the application of the uniformitarian principles shows that it was formed as an ice bridge associated with snow and debris avalanches later on cemented by the minerals precipitated by the adjacent hot-water springs. Darwin's observations on the complex structural section at Puente del Inca, together with his findings of shallow water marine fossil mollusks in the thick stratigraphic column of the area interfingered with volcanic rocks, led him to speculate on several geological processes. Based on his geological observations, Darwin argued on the mountain uplift, the subsidence of the marine bottom, the episodic lateral growth of the cordillera, and their association with earthquakes and volcanic activity, which was an important advance in the uniformitarian hypothesis of mountain uplift proposed by Charles Lyell. Darwin was able to recognize the episodic nature of mountain uplift, and based on these premises he concluded that the Andes were still undergoing uplift. Taken as a whole, his ideas anticipated in many years some of the premises of the geosynclinal theory, and current hypothesis on foreland migration of the fold and thrust belts.

Keywords: *Andes, Subsidence, Volcanism, Mountain uplift, Lateral growth, Ice-bridge.*

**RESUMEN:** *Darwin en Puente del Inca: observaciones sobre la formación de Puente del Inca y el levantamiento de las montañas.* El análisis de las observaciones geológicas realizadas por Charles Darwin en Puente del Inca, durante su segundo cruce de la alta cordillera de los Andes, atrajo la atención a dos diferentes aspectos de las características geológicas de esta clásica área. La mayor parte de sus descripciones sobre las características y el origen de este puente natural no fueron publicadas, principalmente debido a su pobre impresión sobre el Puente del Inca. Sin embargo, la aplicación de principios uniformitaristas muestra que fue formado como un puente de hielo asociado con avalanchas de nieve y detritos y posteriormente cementado por los minerales precipitados por las termas adyacentes de agua caliente. Las observaciones de la compleja sección estructural en las vecindades de Puente del Inca, junto con sus hallazgos de moluscos marinos fósiles de aguas someras en la potente columna estratigráfica del área intercalada con rocas volcánicas, lo condujeron a especular sobre diversos procesos geológicos. Basado en sus observaciones geológicas, Darwin argumentó sobre el levantamiento de las montañas, la subsidencia de los fondos marinos, el crecimiento lateral y episódico de la cordillera, y su asociación con terremotos y actividad volcánica, que fue un importante avance en las hipótesis uniformitaristas de levantamiento de montañas propuestas por Charles Lyell. Darwin fue capaz de reconocer la naturaleza episódica del levantamiento de montañas, y basado en estas premisas, concluyó que los Andes estaban todavía creciendo.Tomadas en conjunto, sus ideas se anticiparon en varios años a algunas de las premisas de la teoría geosinclinal y las hipótesis actuales de la migración de las fajas plegadas y corridas.

Palabras clave: *Andes, Subsidencia, Volcanismo, Levantamiento de montañas, Crecimiento lateral, Puente de hielo.*

## INTRODUCTION

It is well established in the biological science community that Darwin's theory on the evolution of the species is a milestone in the comprehension of Life, and that this theory started to develop in Darwin's mind during his research and observations in South America and later consolidated after his return to Britain. However, his important ideas on the formation of the mountains and his hypothesis on the origin of the Puente del Inca are not well known (Inca's Bridge, see Figs. 1 and 2). It is well documented that he considered himself a geologist, receiving in his early days a strong influence of the uniformitarian ideas of Charles Lyell (Judd 1909). It is also important to state that after his Beagle journeys around the world, he contributed to improve and exerted a strong influence on Lyell's ideas. When we read that in 1838 he chose to characterize himself this way: "*I a geologist*" (Herbert 2005, p. 2), it should not come as a surprise that his monumental contribution - as stated in his *Geological Observations in South America* (Darwin 1846) - to the evolution of the Patagonian Coast and the High Andes is still a milestone in the comprehension of the geological history of these regions.

There are several contributions highlighting his geological thoughts, his ideas on mountain building, and his geological descriptions of the many different geological environments visited (see for example Judd 1909, Rhodes 1991, Herbert 2005, and references therein). In the present contribution I examine only his observations and his thoughts - first in the origin of the bridge, and later on his ideas on the uplift and deformation of the Andes - gained during his excursion to the Puente del Inca region.

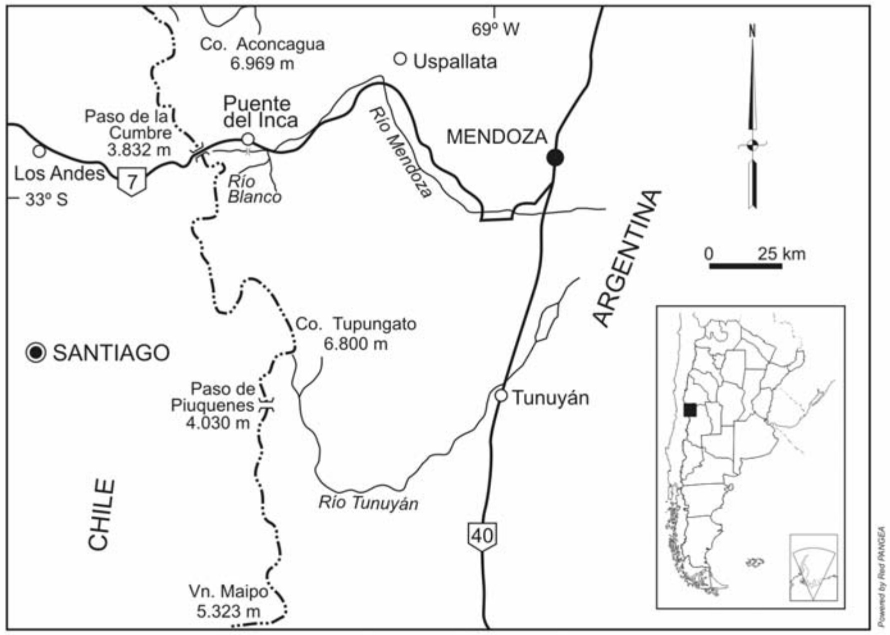


**Figure 1:** Location map of Puente del Inca in the High Andes of Mendoza.

## ORIGIN OF PUENTE DEL INCA

### The pioneer observations

The first mention of the natural bridge in the headwaters of Río Mendoza is attributed to Alonso de Ovalle in 1646. This natural bridge later drew the attention of several 19th Century travelers, who in their reports described what began to be called the Puente del Inca (Inca's Bridge). The earliest description was by Schmidtmeyer in 1820 to 1821, although the illustration was drafted by A. Aglio, a lithographer that had never seen the bridge. In spite of his unrealistic representation, the two major springs are depicted in the southern part of the valley (Fig. 3a, after Schmidtmeyer 1824). The second description was by John Miers in 1826, and he again related the bridge to the two thermal springs and presented the first analyses of the composition and temperature of the hot water (Fig. 3b). Darwin had a copy of Miers' (1826) book in the library of the Beagle, and followed his trail on his way back to Chile. Another picture of the bridge was published in a later edition of Darwin's Voyage (Darwin 1890, Fig. 4).

New samples of the thermal springs were obtained by another British traveler, Charles Brandt in 1827, and the chemical analyses were done by the famous physicist and chemist of that time Michael Faraday (Brandt 1827), whose results were analyzed by Darwin (1846).

However the first geologic description and hypothesis on the origin of the bridge were proposed by Darwin, in spite of the poor impression that the bridge produced on him: "*When one hears of a Natural bridge, one pictures to oneself some deep & narrow ravine across which a bold mass of rocks has fallen, or a great archway excavated. Instead*

**Figure 2:** Present view to the southeast of Puente del Inca, High Andes of Mendoza. Note the thermal springs developed on the southern side where the ruins of the old hotel bath are preserved (photo by Marcelo G. Armentano).

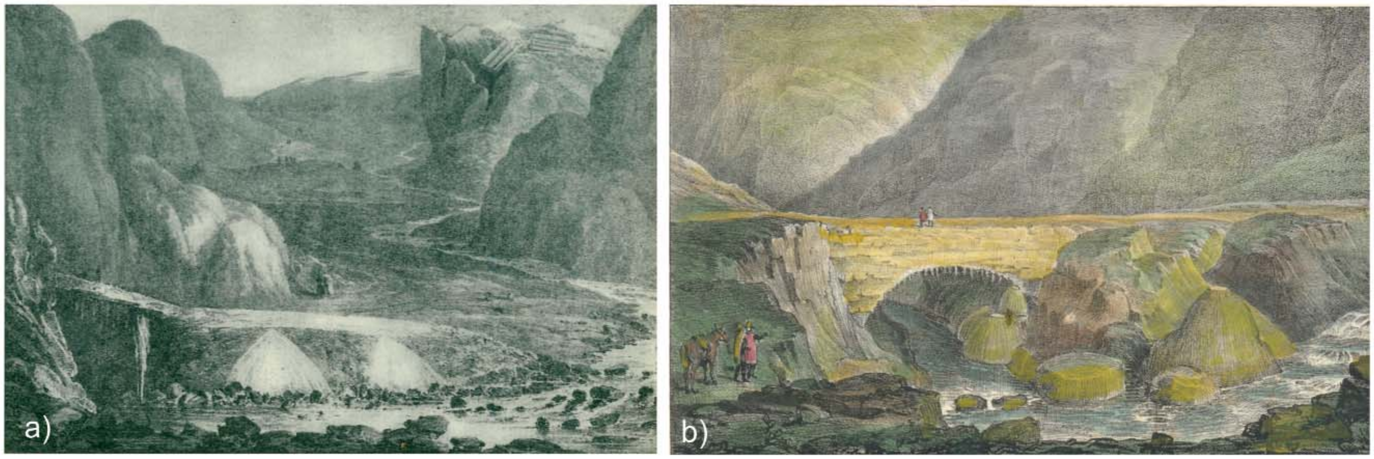


**Figure 3:** a) First picture of Puente del Inca. Note the two thermal springs on the southern side of the valley as depicted by the lithographer A. Aglio (after Schmidtmeyer 1824); b) Puente del Inca and hot mineral springs described by Miers (1826). Note the ravines developed behind the thermal springs where nowadays are the ruins of the hotel baths (compare with Fig. 2).

*of all this the Incas bridge is a miserable object*" Darwin's Diary of the Beagle (1831-1835) reproduced by Keynes (2001).

In his original field notebook he depicted a pencil sketch (Figs. 5a and b) and described "*Incas bridge irregular hilly plain of valley filled up with pebbles & detritus a fan of ferruginous cellular Tufa covering a part: the river having cut as far as (x). continued to scoop out to the Southward; rubbish (B) fell down from plain I supported circled [page 202a] (m) whilst river, continued forming arch. - the oblique junction is very evident (horizontal & confined) plain generally horizontal gravel this not so; hence rubbish: - My hypothesis of Tufa is that it was deposited after valleys excavated & just before sea retired; matter before that generally deposited - hence Tufa from these Springs extends above ... in the slope, above their level: Springs hot - violent emission of gaz: Concretions, where water drips*" (Darwin field notebook, pages 201-202a).

The most complete description is preserved in the Diary of the Beagle (1831-1836) where he described "*the bottom of the valley is nearly even & composed of a mass of Alluvium; on one side are several hot mineral springs, & these have deposited over tha pebbles* [page 554] *a considerable thickness of hard stratified Tufa; The river running in a narrow channel, scooped out an archway beneath the hard Tufa; soil & stones falling down from the opposite side at last met the overhanging part & formed a bridge. The oblique (D) junction of the stratified (A) rock & a confused mass is very distinct & this latter is different from the general character of the plain (B).- This Inca's bridge is truly a sight not worth seeing*" (Darwin's The Diary of the Beagle 1831-1836, pages 553-554, see Fig. 6).

Later on in Darwin's Journal of Researches he said "*April 4th.- ...when one hears of a natural Bridge, one pictures to oneself some deep and narrow ravine, across which a bold mass of rock has fallen; or a great arch hollowed out like the vault of a cavern. Instead of this, the Incas Bridge consists of a crust of stratified shingle,*[page 335] *cemented together by the deposits of the neighbouring hot springs. It appears, as if the stream had scooped out a channel on one side, leaving an overhanging ledge, which was met by earth and stones falling down from the opposite cliff. Certainly an oblique junction, as would happen in such a case, was very distinct on one side. The Bridge of the Incas is by no means worthy of the great monarchs whose name it bears*" (Darwin 1845, p. 334-335).

In his geological observations he quoted "*at this place* (Puente del Inca)*, there are some hot and cold springs, the warmest having a temperature, according to Lieut. Brand (Travels, p. 240), of 91°; they emit much gas. According to Mr. Brande, of the Royal Institution, ten cubical inches contain forty-five grains of solid matter, consisting chiefly of salt, gypsum, carbonate of lime, and oxide of iron. The water is charged with carbonic acid and sulphuretted hydrogen. These springs deposit much tufa in the form of spherical balls. They burst forth, as do those of Cauquenes, and probably those of Villa Vicencio, on a line of elevation*" (Darwin 1846, p. 190).

As a common factor in all these descriptions it is clear that Darwin recognized that the river first excavated its channel, and later the thermal springs cemented the gravels. He also recognized that the bridge gravels where some kind of stratified crust in contrast with the northern side, where colluvial debris was falling from a disorganized deposit. He identified the obliquity between the river valley and the bridge, interpreting a younger age for the bridge. He accepted that concretions were formed were water drips, explaining the long stalactites descending from the roof of the bridge. He considered the origin of the bridge so simple that "*this Inca's bridge is truly a sight not worth seeing*". His sketches were not published until recently (Keynes 2001), and therefore his detailed descriptions were ignored in subsequent publications.

## Modern proposals on the origin

Most of the subsequent visitors recognized - as Darwin did - the natural origin of Puente del Inca, with the only exception of Christiano Junior (1902). This author claimed that perhaps it was an old Inca bridge built with wood and rattan (*bejuco*, a climbing wild plant used by the Incas to make ropes), that after several centuries was cemented by the thermal springs and thus obtaining its present shape.

Schiller (1907) described the deposits involved in the formation of the bridge, although his hypothesis on its origin is known from other people's references (see Sekelj 1947, Monteverde 1947). His hypothesis was that a crust growth from the thermal springs reached the opposite margin of the valley by means of slow lateral precipitation, a criteria accepted by Reichert (1924, 1929, p. 51).

The bridge was again studied by Kittl (1941), who improved Darwin's original hypothesis. He postulated that the river was deflected southwards, increasing the incision that favored the slumps from the southern margin, later on cemented by the thermal springs. This proposal was refined by Monteverde (1967), who also supported the excavation of the river, but did not accept the lateral growth. He postulated that the gravels of the bridge were prior to its formation and were preserved from glacial erosion. He claimed that the excavation was enhanced by lateral erosion coming from the northern side, which deflected the river valley southwards. See the analyses of Ramos (1993) for further details in these hypotheses.

## Present knowledge

To analyze the origin of Puente del Inca it is necessary to refer to the original ideas of Darwin and to apply Lyell's (1835) classical concept: "*the present is the key of the past*". From time to time, abundant and frequent snowfall during the winter is followed by the ENSO (El Niño Southern Oscillation) over the high subtropical Andes (Compagnucci and Vargas 1998). This abundant and frequent winter snowfall produces numerous ice bridges that last until the following summer, and sometimes even for two or three years. I had the opportunity to observe several ice bridges along the Horcones, Las Cuevas and Blanco rivers in the vicinities of the Puente del Inca

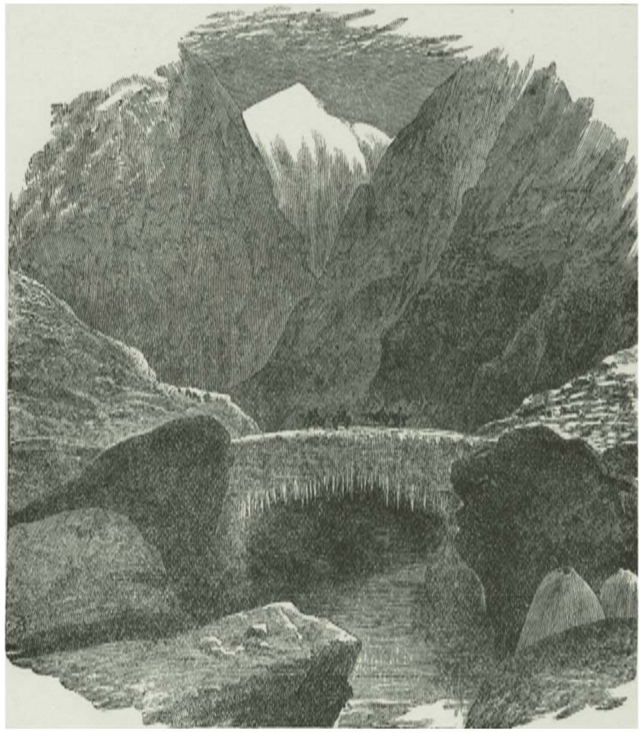

**Figure 4:** Puente del Inca as illustrated in a new edition of Darwin's Voyage (Darwin 1890).

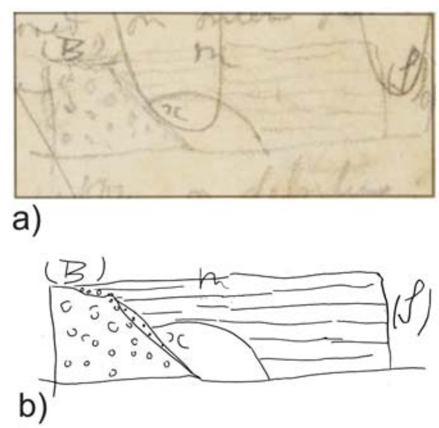


**Figure 5:** Puente del Inca after Darwin: a) Reproduction of Darwin's pencil sketch from his field notebook, April 5th, 1835 (with the permission of English Heritage); b) Trace of the author from the original sketch (see explanation on the text).

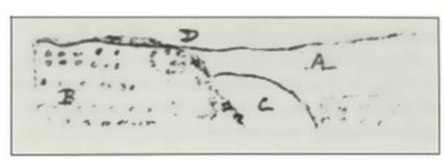

**Figure 6:** Puente del Inca after Darwin: Small sketch in the margin with letter A, B, C, and D drawing in his Diary of the Beagle (1831-1836).

region in the summer of 1983. The avalanches reached the opposite side of the valley producing a run-up (see Fig. 7). Thawing concentrated the gravels of the avalanche in the upper surface, and these gravels are supported in a mud matrix. This process hardens the gravel conglomerate and allows crossing these temporary bridges even with loaded mules. If that happens near a thermal spring, cementation of the gravels with precipitation of sulphates and carbonates would be possible, as observed in Puente del Inca.

Puente del Inca is the only natural bridge of its type presently standing, but collapsed bridges have been observed in the headwaters of Río Plomo. In the sources of Río Morado de Las Toscas, a river that joins the southern margin of the Río Plomo one kilometer upstream of the Refugio Las Toscas, Padva (2000) described travertines and other deposits associated with thermal springs. There is evidence in these deposits that the travertines reached the opposite margin, but they are now collapsed.

It is interpreted that during the last glaciation the headwaters of the Río Mendoza valley were covered by snow avalanches developing a series of ice bridges as the ones depicted in figure 7. After thawing, only those with an extra hardening were preserved, as the one cemented by thermal spring waters. Figure 8 illustrates the different stages in the development of Puente del Inca.

As established by Rubio *et al.* (1993), the precipitation of carbonates and sulphates is controlled by the presence of cyanobacteria. These blue-green algae produce thin layers of carbonates coating the surface. The hot water flux is linked to the amount of seasonal rainfall in the region, which controls the temperature and the concentration of the spring waters.

During the dry seasons, fluvial and aeolian erosion dominate over carbonate and sulphate precipitation, thus drying and cracking the bridge. These periods alternate with more humid ones that produce an intense coating of the bridge structure. A delicate equilibrium between erosion and precipitation, sometimes modified by anthropic activity, preserved the bridge until nowadays.

In spite of Darwin's negative impression of Puente del Inca, the comprehension of its genesis is another good example that the "*the present is a key of the past*". No doubt that if Darwin would have seen an ice bridge he would have not hesitated in applying the uniformitarian ideas he defended - alongside Lyell - to understand the processes that formed the bridge.


**Figure 7:** a) Ice bridge in the Río Blanco, a few kilometers south of Puente del Inca as seen in the summer of 1983. An avalanche during a hard winter remains for one or two years. Note the concentration of the gravel covering the ice and the run-up formed by the avalanche on the right side of the bridge; b) Partially collapsed ice bridge located upstream of Puente del Inca in the Río Cuevas, during the same field season.

## ANDES MOUNTAIN BUILDING

There is no doubt on the importance that the journey across the Andes had for Darwin's geological thought. He stated in a letter to her sister: "*I returned a week ago from my excursion across the Andes to Mendoza. Since leaving England I have never made so successful a journey...how deeply I have enjoyed it; it was something more than enjoyment; I cannot express the delight which I felt at such a famous winding-up of all my geology in South America. I literally could hardly sleep at nights for thinking over my day's work. The scenery was so new, and so majestic; everything at an elevation of 12,000 feet bears so different an aspect from that in the lower country...* ***To a geologist,*** *also, there are such manifest proofs of excessive violence; the strata of the highest pinnacles are tossed about like the crust of a broken pie*" (Burkhardt and Smith 1985).

Darwin's observations on the geology around the Puente del Inca region, when he examined the Mesozoic sections at both sides of the valley (Fig. 9) coming back to Valaparaíso, were important in several aspects of the development of his ideas on mountain building. In this area the complexity of the structure competes in impressiveness with the extraordinary exposures of the marine sequences interfingered with volcanic rocks. The stratigraphic sequence is repeated by a series of thrusts from Puente del Inca up to the drainage divide along the present border with Chile. Figure 10 shows Darwin's interpretation and the present understanding of that structure. Note how Darwin was aware of the complex structure of Río Horcones and the fine details in the classical Puente del Inca Section. He described in detail the anticline and the fault of Los Horcones as follows: "*A little further on, the north and south valley of Horcones enters at right angles our line of section; its western side is bounded by a hill of gypseous strata [F], dipping westward at about 45°, and its eastern side by a mountain of similar strata [G] inclined westward at 70°, and superimposed by an oblique fault on another mass of the same strata [H], also inclined westward, but at an angle of only about 30°: the complicated relation of these three masses [F, G, H] is explained by the structure of a great mountain-range lying some way to the north, in which a regular anticlinal axis (represented in the section by dotted lines) is seen, with the strata on its eastern side again bending up and forming a distinct uniclinal axis, of which the beds marked [H] form the lower part*"(Darwin 1846, p. 189). This is the overturned faulted anticline nowadays recognized in Los Horcones valley as shown in figure 10b. The observation of these sections influenced his geological thoughts in several central facts. I would like to emphasize the followings aspects.

### Evidence of uplift

As Charles Lyell, Darwin was impressed by the localized uplift denoted by the evidence of variation of sea level through time. The example of the Temple of Serapis near Naples that was the frontispiece illustration of the "*Principles of Geology*" was clearly showing uplifts in the order of tens of meters, only affecting a small portion of the coast. But if we compare these small variations with what he was seeing during his journeys across the Andes - where marine "*shells that once were crawling in the bottom of the sea*" are now standing over 10,000 feet above sea level - we can understand his exciting comments. Puente del Inca was a key area for this observation by him.

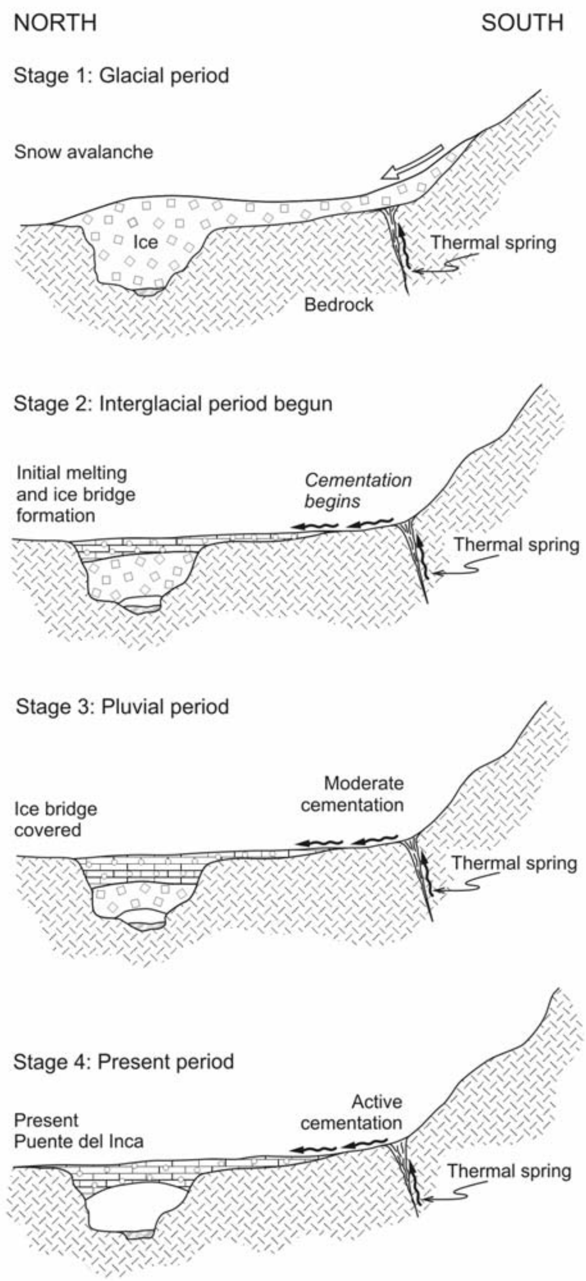


**Figure 8:** Schematic evolution of Puente del Inca based on Ramos (1993) and Aguirre-Urreta and Ramos (1996). Note that when the avalanche is compacted and melting starts, the pebbles are concentrated in the upper part, where they are slowly cemented by the products of the thermal spring. Compare stage 2 and 3 with the ice bridges of figure 7.

During his examination of the sedimentary and volcanic sequences he found remains of fossil shells in his level No. 3 a few hundred meters to the southeast of the bridge (see location (I-3) in Fig. 9), almost 3,000 meters above sea level (Darwin 1846). Some specimens fallen from the outcrop were identified as *Gryphea*, a typical benthic mollusk of Jurassic - Cretaceous age. He associated this uplift to some sort of injection of the volcanic rocks. The observation of fossiliferous strata interfingered with the volcanic sills, interpreted as evidence of submarine volcanism, matched early 19th Century ideas on mountain building. Darwin's paper "*On the connexion of certain volcanic phaenomena, and on the formation of mountain-chains and volcanoes, as the effects of continental elevations*" (Darwin 1838) read in the Geological Society on the 7th of March, produced a deep impact in the members of the society. As already established by Rhodes (1991), he favored the slow formation of the mountain chains, based on the relation between the small elevations

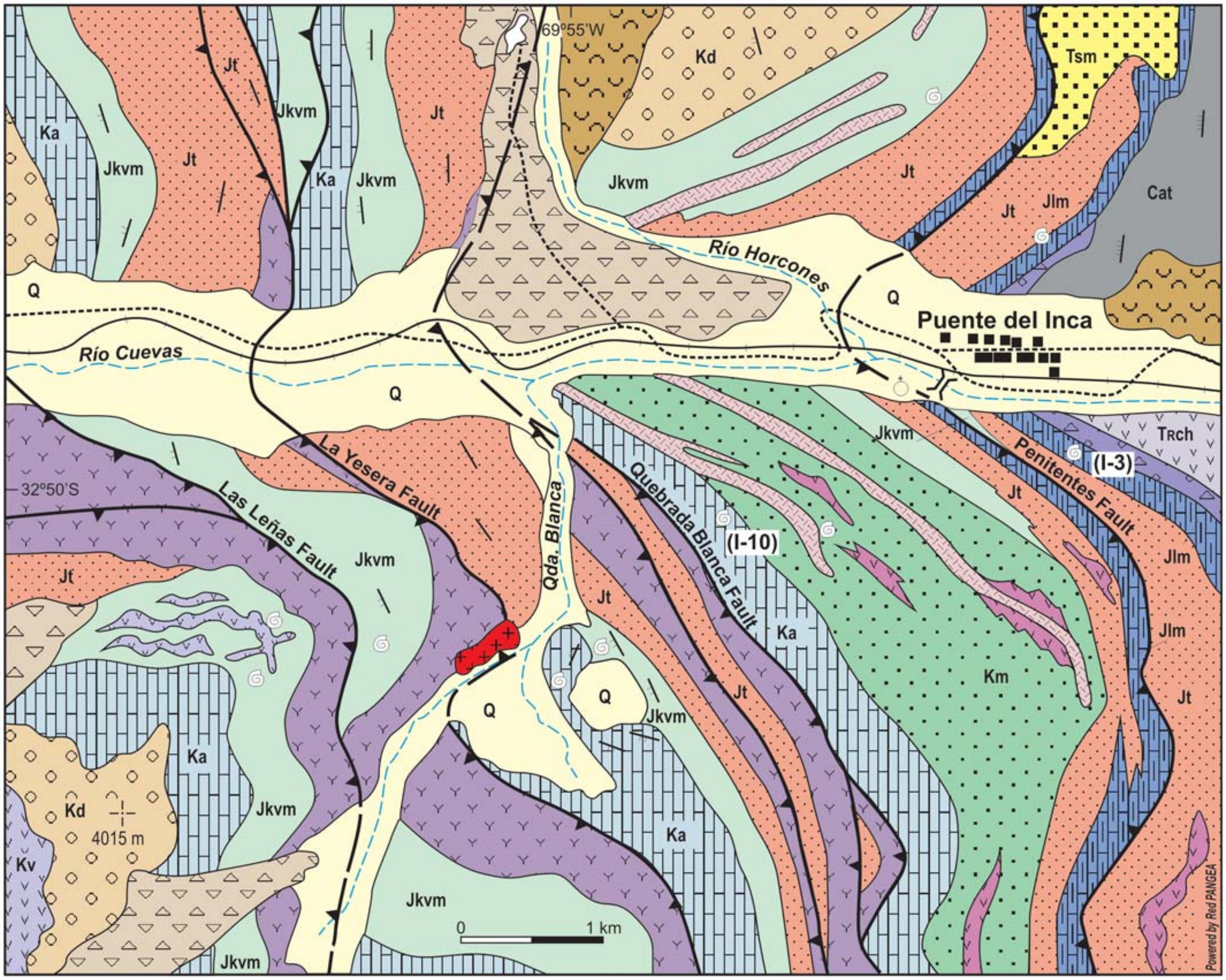


**Figure 9:** Geologic map of Puente del Inca (after Ramos 1988 and Cegarra and Ramos 1996) with indication of some fossil localities (I-3, I-10) described in the text. Legend: Cat: Carboniferous slates; Trch: Triassic Choiyoi volcanics; *Jurassic:* Jlm: La Manga Formation carbonates where level No. 3 was described; Y: Auquilco Gypsum; Jt: Tordillo Formation redbeds; JKvm: Vaca Muerta Formation black shales; *Cretaceous:* Km: Mulichinco Formation redbeds; Ka: Agrio Formation limestones and sandstones; Kd and Kv: red sandstones and volcanic rocks; Most of these rocks are interfingered with volcanic flows and sills; Tsm: synorogenic Miocene deposits; Q: Quaternary Alluvium.

in the order of a few meters produced by his observed earthquake displacements of Concepción, and the supposed subsequent volcanic activity in the Osorno volcano. A few months later in the Presidential Address of 1839 Whewell - then the President of the Society - expressed the antagonism between the Uniformitarians and the dominant Catastrophists views of society at that moment. Darwin's ideas quoting that "*the formation of mountain chains and volcanoes, which he* (Darwin) *conceives to be the effect of gradual, small, and occasional elevation of continental masses*" contrast with the paroxysmal turbulence accepted in the current theories of that epoch (Whewell 1839, Rhodes 1991).

## Evidence of subsidence

Another important contribution of Darwin derived from his observations in the Puente del Inca region was his analysis of the sea bottom subsidence. He claimed that "*the fossils … from the limestone-layers in the whitish siliceous sandstone, are now covered … by strata, from 5,000 to 6,000 feet in thickness. Professor E. Forbes thinks that these shells probably lived at a depth of … 180 to 240 feet; … in this case, as in that of the Puente del Inca, we may safely conclude that the bottom of the sea on which the shells lived, subsided, so as to receive the superincumbent submarine strata: and this subsidence must have taken place during the existence of these shells; … The conclusion of a great subsidence during the existence of these cretaceo-oolitic fossils, may, I believe, be extended to other districts*" (Darwin 1846).

His reasoning on an active subsidence anticipated James Hall's similar ideas of 1857, who proposed - based on the subsidence inferred for the Appalachians' during Paleozoic times - that the great sediment load caused crustal failure and downwarp, opening the way to geosyncli-

ne theory (Hall 1857).
Darwin used as reference the stratigraphic thickness between the first fossil bed at (I-3), and the youngest one located at (I-10) (see location in Fig. 9). The presence of several packages with similar fossil shells from the top to the bottom of the marine sequence was for Darwin clear evidence of a great subsidence. When combined with the observation of the thick conglomerates of the Tunuyán Formation these packages indicated to him a second, and more recent period of subsidence. This perception of renewed subsidence and subsequent uplift was the embryonic stage of his global mountain uplift hypotheses later discussed.

**Evidence of lateral growth**

As quoted by Giambiagi *et al.* (2009) clast provenance analyses of the synorogenic conglomerates of Miocene age provided the key for Darwin's claim for an episodic and lateral migration of the mountain uplift. The finding of the succession of marine fossils derived from the Cordillera Principal at the base, and clasts from the high grade metamorphic basement of Cordillera Frontal above in the sequence, clearly indicated to him the lateral and episodic growth of the Andes. This concept was analyzed in the same region many years later by Polanski (1964, 1972), who also arrived at the same conclusions about the foreland migration of the uplift during Andean deformation. This notion is part of the ideas about fold and thrust belt deformation as inferred in modern plate tectonics.

**Association with volcanoes**

In 1838 Darwin read at a meeting of the Geological Society perhaps the most important of all his geological papers, relating deformation, earthquakes, and mountain uplifts. After describing the great earthquakes which he had experienced in South America, and the evidence of their connection with volcanic outbursts, he proceeded to show that earthquakes originated in fractures, gradually formed in the earth's crust, and were accompanied by movements of the land on either side of the fracture (Darwin 1838, 1846). In conclusion he boldly advanced the view "*that continental elevations, and the action of volcanoes, are phenomena now in progress, caused by some great but slow change in the interior of the earth; and, therefore, that it might be anticipated, that the formation of mountain chains is likewise in progress: and at a rate which may be judged of by either actions, but most clearly by the growth of volcanoes.*" (Darwin 1838, pages 654-660).

## CONCLUDING REMARKS

The region of Puente del Inca was very important in Darwin's geological observations and considerably contributed to his post-fieldtrip interpretations of the collected data. His work there can be summarized under two different aspects, i.e., the origin of the Puente del Inca and his contributions to mountain building.

**a) Puente del Inca**
Although Darwin was not impressed at all with the natural bridge of Puente del Inca, he spent some time analyzing its origin. For him this had been a simple process associated with lateral growth and cementation aided by hot-spring water. Most of his observations were left unpublished in his field notebook and in his Diary of the Beagle (1831-1836). His basic ideas were right, but because they remained unpublished they were not considered for many years by later authors that hypothesized on the genesis of the bridge. The origin of the bridge is simple to understand when Darwin's ideas on uniformitarian processes are combined with actual observations of hard winters with exceptional snowfall, such as in those seasons preceding the El Niño Southern Oscillation. The sequence of processes involved in the formation of the bridge is straightforward, if classical uniformitarian concepts are applied. First it was formed as an ice bridge, probably during the last maximum glacial; the ice was covered by avalanches debris from the adjacent slope; then during thawing the bridge was supported by the mud matrix of the conglomerates, which subsequently were cemented by the minerals of the hot-thermal springs.

**b) Mountain building**
The observations that led Darwin to infer gradual, small, and episodic mountain uplift combined with periods of important subsidence, together with the perception of lateral growth of a mountain chain to the foreland, are the base of modern concepts in orogeny. The evidence connecting episodic earthquakes and volcanic activity, partially seen by Darwin, but also mentioned to him by some other witnesses, were complementary to understand the processes associated with the uplift of the Andes. However, the notion that the uplift was produced by a succession of earthquakes, an active process still ongoing, was the clue for the comprehension that the Andes are still undergoing uplifting, and one of the best examples of application of uniformitarian ideas in tectonics. It is easy to understand the satisfaction of Charles Lyell with the new evidence drawn from Darwin's observations, and the close friendship developed by these two scientists in the Geological Society, that at that time was dominated by Catastrophists. There is no doubt now that Darwin's and Lyell's ideas slowly pervaded the geological community, and that in those early years Darwin was a geologist trained mainly by several years of fieldwork and observations obtained during his research in Argentina, where the Andes played a central role in his hypotheses.

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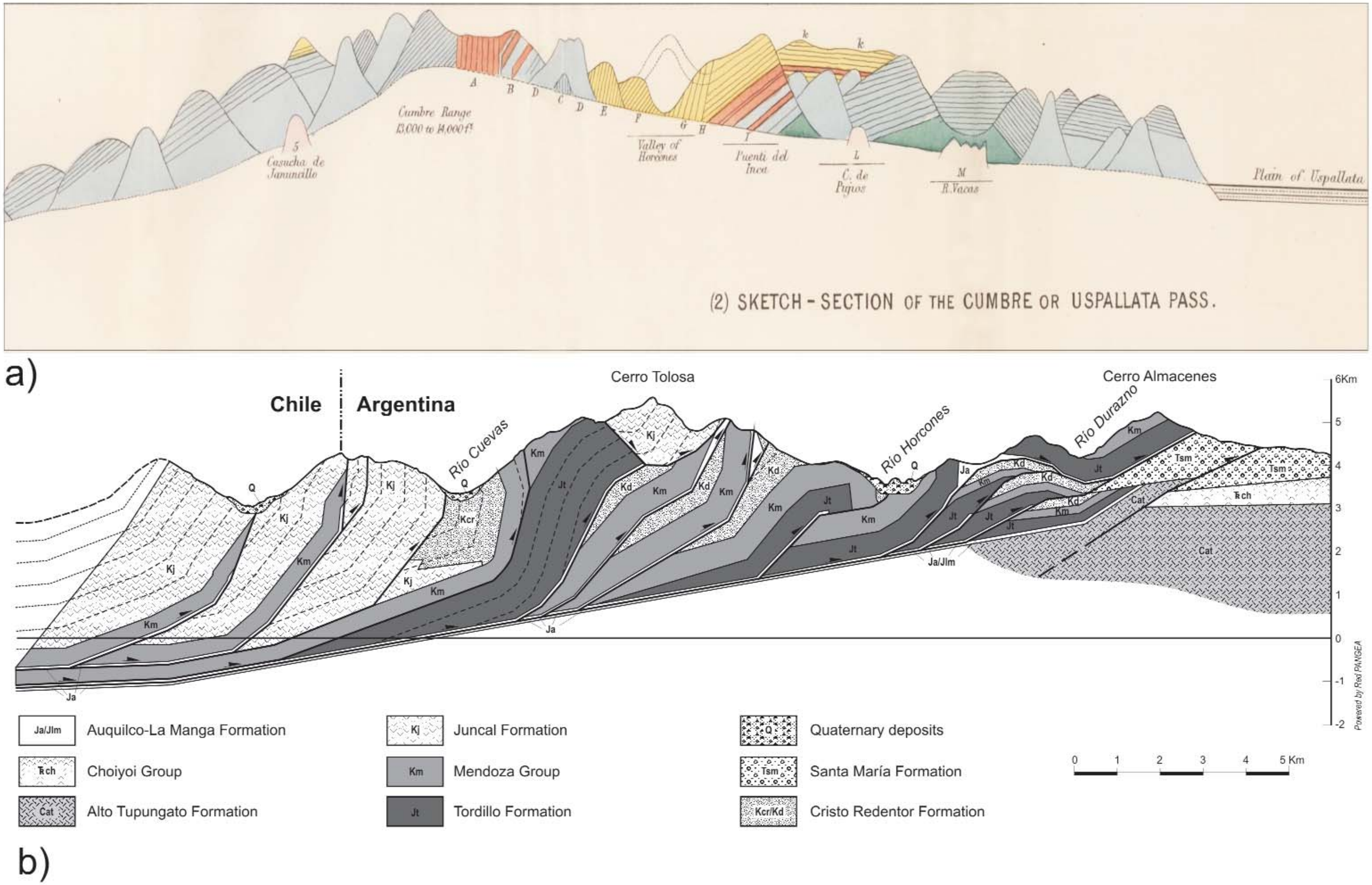


**Figure 10:** a) Classical structural cross-section of the Cumbre Pass to the Uspallata valley drawn by Darwin (1846); b) Present interpretation of the structure based on Cegarra and Ramos (1996). Cerro Almacenes correlates with k k in Darwin's cross section.

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