

and so on through the remainder of that month and January ensuing.

This was not stated to be unusually severe. It is strange that the agars and many species of cactus should be able to resist this cold. They do not indeed thrive, but they live, only of course in consequence of the extreme dryness of the ground at that season.

A few years before, the water, trickling down the sides of the shaft of Concepcion, froze to the depth of seventy varas (thirty fathom). The shaft is in a very sheltered situation, but as its mouth is far below the level of the general drainage shaft, close by it, the cold air enters by Concepcion, and after circulating through the working, issues warmed through the tiro general as through a chimney.

The condition of countries situate as a portion of Sonora and California is, between the summer and the winter rains, is worthy of some consideration. Having seen only this one, I shall limit my observations to it.

The whole of the rain in Mexico may be said to fall in the summer months; occasional and usually slight showers fall in winter, but are pretty much limited to particular districts, as Xalapa, &c. In California Alta, on the contrary, it rains only in the winter, with a similar exception in favour of Monterey, where there are sometimes, but rarely, slight showers in summer. The summer rains reach the lower part of Sonora, where, however, they are scanty and irregular; and from Pitis, northward, across the sands, it rarely rains at all; as is also the case in the northern portions of Lower California, where the summer rains scarcely prevail to the north of Loretto, the capital.

I am sorry to be obliged to content myself with offering the Society so desultory and imperfect a sketch as this; but I have many claims on my time, the most urgent of which is the preparation of a work in some detail on the entire subject of California. Whatever is here defective will there, I hope, be found supplied.

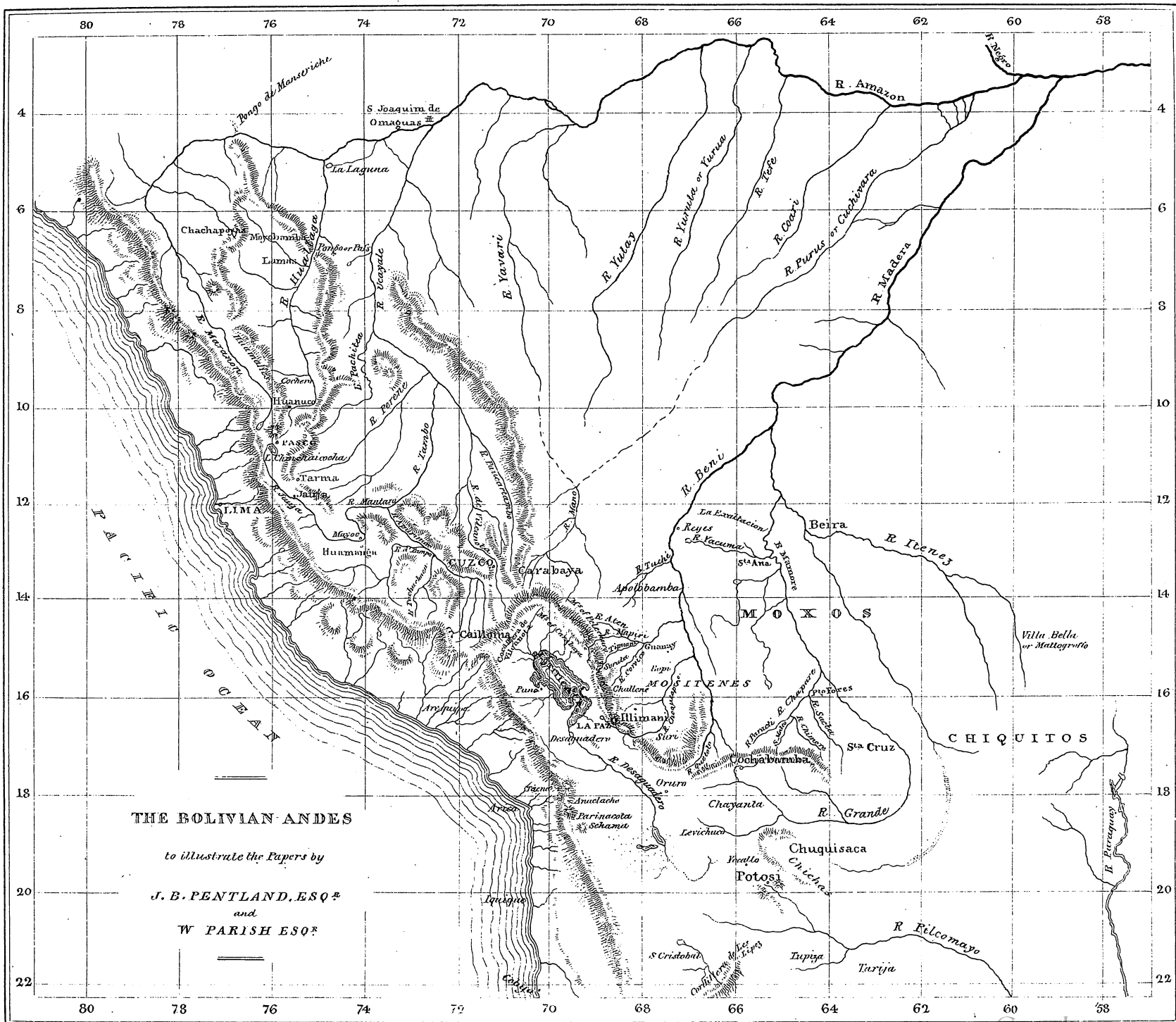
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V.—*On the General Outline and Physical Configuration of the Bolivian Andes; with Observations on the Line of Perpetual Snow upon the Andes, between 15° and 20° South Latitude.* By J. B. Pentland, Esq. Communicated by Woodbine Parish, Esq. Read March 23, 1835.\*

BARON HUMBOLDT, in the interesting notes to the third volume of his "Relation Historique," has so accurately sketched the general outline of the Peruvian Andes, situated between the four-

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\* This paper was written in 1830, and was intended as an introduction to a geological description of that part of the Andes of Peru.



**THE BOLIVIAN ANDES**

*to illustrate the Papers by*

**J. B. PENTLAND, ESQ<sup>r</sup>**

and

**W. PARISH, ESQ<sup>r</sup>**



teenth and twentieth parallels of south latitude, as to render it unnecessary for me to enter into any detail respecting the physical configuration of that portion of the chain. I shall only therefore observe, for the information of those who may not have perused Baron Humboldt's work, and by way of confirming his description by what has fallen under my own notice, that the great chain of Andes, which appears to form a single and undivided ridge from the most southern extremity of the American continent to the neighbourhood of the tropic of Capricorn, separates into two great longitudinal ridges in the vicinity of the celebrated city of Potosi (lat.  $19^{\circ} 35'$ ). These ridges, which, viewed on a large scale, may be said to be parallel to each other, bound the immense inter-alpine valley of Desaguadero, including the great mediterranean Lake of Titicaca, the islands and shores of which may be considered the birth-place of Peruvian civilization; and re-unite at the northern extremity of this great basin, to form again an undivided ridge in the Andes of Vilcañota and Cusco. The westernmost of the longitudinal ridges above-mentioned runs parallel with the shores of the Pacific Ocean, and is distinguished in the Alto-Peruvian provinces by the denomination of Cordillera of the Coast; whilst the eastern ridge, or that of the interior, is known by the general name of Cordillera, and in its northern prolongation, of Cordillera Real. I mention these local designations of the two great divisions of the Andes of Bolivia, as in the course of this paper I may have occasion to employ them, for the sake of brevity or otherwise.

In a mountain system, formed on the gigantic scale of the Andes, it is difficult to fix the geographical position of each bifurcation, and consequently to state with accuracy the exact parallel of latitude where the Cordillera separates into the two longitudinal ridges of the Bolivian Andes. Yet the western ridge, or Cordillera of the Coast, may be said to detach itself from that of the interior, in lat.  $20^{\circ}$  S., in the mountains of Lipez and Chichas; and the road from Attacamá (lat.  $23^{\circ} 22'$ ), and from the port of Cobija (lat.  $22^{\circ} 23'$ ), to Oruro (lat.  $17^{\circ} 58'$ ) and La Paz (lat.  $16^{\circ} 30'$ ), crosses the western Cordillera near its southern extremity, where some snowy peaks rise upon it, the elevation of which can fall little below 18,000 British feet.\* At the period of my journey (1827) little was known of the topography of this part of the chain, owing to the aridity and uninhabited state of the countries bordering on it; but since then, the establishment of Cobija as a free port, and now the great emporium of the foreign trade to the Bolivian provinces, and the con-

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\* The principal nevados of this part of the chain, and which are known to the inhabitants of the interior of Bolivia by the names of nevados of Esmoraca and Lipez, rise considerably above the limit of perpetual snow.

sequent constant communications from thence with the interior, have rendered the examination of this portion of the Andes more easy, though still it is but very little known to the naturalist and geographer.

I shall now, however, proceed to notice different parts of each of these two Cordilleras, founded on my own observations. Between the parallels of  $19^{\circ} 20'$  and  $18^{\circ}$ , the western Cordillera attains a very great elevation, and offers several snow-capped peaks, well known to navigators who sail from Cobija to Arica. The most southern group of these peaks consists of four majestic nevados, known to the aboriginal inhabitants of the neighbouring provinces of the interior by the names of Gualatieri or Sehama, Chungara, Parinacota, and Anaclache; and may be seen from the valley of the Desaguadero on the one side, and from the shores of the Pacific on the other, towering over the port of Iquique (lat.  $20^{\circ} 13'$ ). The nevado of Gualatieri or Sehama, which appeared to me to be the most elevated of the four, rises from an extensive table-land of new red sandstone, above the alpine village of Cosapa, in the Bolivian province of Carangas—five leagues distant from Turco—in the form of one of the most regular truncated cones I have seen in the Andes, enveloped to its base in perpetual snow. Masses of ashes and of vapour are seen to issue from its summit at intervals, so as to leave no doubt of its being a volcano in activity. From a trigonometrical measurement, executed at a considerable distance from this cone, its highest point appeared to me elevated 4800 feet above the snow line in the month of March; and as I have elsewhere shown that this line seldom descends lower than 17,100 feet in this parallel in South America, we may reasonably conclude that the volcano of Gualatieri rises to an absolute elevation of 22,000 feet.

North of Gualatieri are seen to rise two magnificent nevados, which, owing to their similarity of form and their contiguity to each other, are known to the Creole inhabitants by the name of Melizzos or Twins, whilst they are called Chungara and Parinacota by the Indian population. The most southern of these two nevados forms a very perfect truncated cone, whilst the most northern rather resembles a dome or bell (*campana*). There is little doubt that both are of igneous origin; and judging from the similarity of its shape to that of other active volcanic vents in the Andes, and also from its position, there is every reason to believe that the volcano of Chungara possesses an extensive crater at its summit, and is still in activity, although I was unable to discover, from the Indians who inhabit the neighbourhood in the summer season, that it had been seen to emit either ashes or vapour. The bell-shaped configuration of Parinacota, on the other hand, renders it probable, that like Chimborago and the nevado of Chuqui-

bamba (of which I shall hereafter speak), it has been formed by one great trachytic elevation. The nevado of Anaclache is certainly less elevated than any of the three preceding, and did not appear to me to exceed 18,500 feet. It forms a ragged ridge of considerable length in the direction of the axis of the Cordillera, and, like similar mountains in the vicinity of Arequipa, appeared to me to be also of trachytic origin.

Continuing to follow the western Cordillera in a northerly direction, we discovered several snow-capped peaks between the parallels of  $18^{\circ} 51'$  and  $17^{\circ} 30'$  S.; and the centre of this group may be fixed near the Indian hamlet of Tacora (lat.  $17^{\circ} 50'$ ), and the Gualillas Pass, a col or passage of the western Cordillera, which attains a elevation of 14,830 feet, where it is crossed by the great commercial road leading from the port of Arica to La Paz, and the interior of Bolivia. The nevados seen from the roads of Arica, and from Tacna, belong to this group. The nevado of Chipicani\* (at the south-western base of which the hamlet of Tacora is situated) consists of a broken-down crater, with an active solfatara in its interior, emitting quantities of aqueous and acid vapours, which by their condensation give rise to the Rio Azufrado, a considerable torrent that derives its name from the large quantity of sulphates of iron and of alumina which its waters contain in solution. The nevado of Chipicani rises to an elevation of 16,998 feet, which may be considered as the mean height of the snow-capped mountains that belong to this group of nevados.

I regret not having in my possession any precise data on the configuration or elevation of the western Cordillera, between the parallels of Ancomarca (lat.  $17^{\circ} 32'$ ) and of Arequipa (lat.  $16^{\circ} 24'$ ). Between the city of Moquegua (lat.  $17^{\circ} 42'$ ), situated on its westerly declivity, and the village of Santiago de Machaca, on its eastern, the Cordillera of the Coast is traversed by a road that leads from the maritime province of Moquegua into the interior of Bolivia, along which are transported the brandies, cottons, and other articles which the districts bordering on the ocean furnish to the inhabitants of the Alto-Peruvian provinces of La Paz, Oruro, and Potosi. An elevated cone-shaped nevado is discovered from several

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\* In the interesting description of his journey from Arica to Puno, Dr. Meyen has applied this name to a peak, still belonging to the same group of nevados, different from that here described. The mountain of Chipicani of Meyen is situated near the post-house of Ancomarca (lat.  $17^{\circ} 32'$  S.), the torrent of Utchosoma which flows past this, having its source in the snow or glaciers on its south-eastern declivity. In this arid region of the Andes, where there scarcely exists any fixed population, the nomade aborigines met by the traveller frequently apply the same appellation to different peaks, and *vice versá*; so that it is impossible to arrive at the true Indian name of each remarkable eminence: hence the difference between Dr. Meyen's and my statements as regards the nevado of Chipicani. And I may here state once for all, that the same doubt attaches to the names given to many other mountains mentioned in this paper.—Vide *Meyen Reise um die Erde*, vol. 1.

points between Puno ( $15^{\circ} 50'$  S.) and the village of Désaquadero, ( $16^{\circ} 38'$  S.), situated on the declivity of the western Cordillera, towards the basin of the lake Titicaca, and in a south-west direction. The clouded state of the atmosphere in the season of the rains, when I visited this part of Peru, only permitted me to obtain a few transient glimpses of it, and I was consequently unable to observe its exact bearings, angles of elevation, &c.; it appeared to me, however, to enter far beyond the limit of perpetual snow.\*

In  $16^{\circ} 24'$  S., towering over the populous city of Arequipa, the capital of southern Peru, rise three snow-capped mountains, nearly of equal height, viz. Pichu-Pichu, the volcano of Arequipa or Guagua-Putina, and Chacani. The first and third of these mountains form two elongated serrated ridges, † whilst the second presents a very regular volcanic cone, truncated at its summit, and rising to an elevation of 18,300 feet above the level of the Pacific. This volcano has a deep crater, from which ashes and vapour are constantly seen to issue. The three nevados of Arequipa, like most of the mountains of igneous origin in the western Cordillera, are placed near its maritime declivity; but about ten leagues from the same point, in a S.E. direction, and consequently farther removed from the borders of the sea, is situated the volcano of Uvinas, now extinct, but which, in the sixteenth century, produced an eruption, that spread desolation and aridity for many leagues around. The volcano of Uvinas has since ceased to burn, and at present offers a very extensive though shallow crater, where the aborigines of the surrounding country collect small masses of alum, which they use as a mordent in dyeing their coarse woollen tissues. The volcano of Arequipa, and the adjoining ridges of Pichu-Pichu and Chacani, if they do not rise above the limit of perpetual snow, approach very nearly to it. When I visited Arequipa, during the spring months (October and November) of 1826, all three were deeply capped with snow; but I was assured by residents in that city, that after very warm summers the summit of the volcano is sometimes seen without a trace of its icy hood, and that the nevado of Chacani is at times deprived of its snow during the autumnal months. As to the volcano of Uvinas it little exceeds 16,000 feet in elevation.

On the prolongation of the western Cordillera, north of Arequipa, rise the nevados of Ambato, and Corpuna; and about

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\* This is probably the mountain seen by Meyen between the villages of Pisacoma and Marocollo, to which he has given the name of Volcan Viejo, and which he considers as attaining an elevation between 19,000 and 20,000 feet.

† The mountains of Pichu-Pichu and Chacani, are composed of trachytic rocks, and have probably formed a portion of the walls of a very extensive elevation crater, in the midst of which the more recent eruption cone of Guagua-Putina, the modern volcano of Arequipa, has been raised.

twenty miles from the same city the colossal nevado of Chuquibamba, so called from a large village situated at its base. The nevado of Chuquibamba has the form of a dome, and when seen from the plain presents, under certain points of view, a striking resemblance to Chimborazo, as delineated in Baron Humboldt's 'Vues des Cordillères;' it appears to be formed like this latter giant of the Columbian Andes, of one simultaneously uplifted mass of trachyte, which has pierced and reposes upon the subjacent secondary strata (new red-sandstone, with saliferous and gypseous marls). The dome of Chuquibamba rises to an elevation of 21,000 feet, deduced from a measurement I made of that portion of its summit which rises above the limit of perpetual snow, assuming this latter line at 17,200, in the parallel of  $16^{\circ}$ .

Between the latitude of Arequipa ( $16^{\circ} 24'$ ) and that of Lima ( $12^{\circ} 3'$ ) I have not visited any part of the Peruvian Andes, so that I am ignorant of their configuration and elevation beyond the nevado of Chuquibamba. But I have been informed by travellers that the portion of the chain which is traversed by the road from Arequipa to Cusco (lat.  $13^{\circ} 42'$ ) presents numerous nevados, equalling in magnitude and elevation that of Chuquibamba.

Having thus passed in review the principal mountains of the western Cordillera, in an extent of nearly  $5^{\circ}$  of latitude, it remains for me to add a few remarks on its breadth and general configuration.

As I have already noticed, its most elevated points consist either of volcanoes still in activity or of mountains of igneous origin: they are situated, with a single exception (the extinct crater of Uvinas), close upon the maritime declivity of the Cordillera, and consequently at an inconsiderable distance, not exceeding sixty miles, from the nearest shores of the ocean. The western declivity consequently of this Cordillera is extremely precipitate and abrupt from this circumstance: so much so indeed; that the traveller in many places finds himself transported, in a few hours, from the fertile valleys bordering on the Pacific, to the arid regions of the Cordillera at an elevation exceeding 15,000 feet. On the eastern side of the Cordillera of the Coast the declivity is less rapid, since it is there skirted by a valley which itself is elevated 13,000 feet; and thus, from its loftiest passes, the descent to the valley of the Desaguadero, or to the shores of the great lake of Titicaca, does not exceed 4000 feet.

I have endeavoured to deduce the maximum breadth of the western Cordillera from my astronomical observations made on either declivity, the most modern maps being extremely defective as regards the geography of the Alto-Peruvian provinces, the position of their towns, and the delineation of the mountain chains by which they are traversed. In the parallel of  $16^{\circ} 24'$  S. I find



that the western Cordillera intercepts a space equal to  $2^{\circ} 1'$  in longitude, that is, between the city of Arequipa and the western shores of the lake of Titicaca, not far from the large village of Juli (lat.  $16^{\circ} 11'$ ). I am aware, however, that this determination on a single parallel cannot be considered as giving the real width of the chain, since its direction forms an angle with that of the Cordillera. A line passing from Arequipa to Puno ( $16^{\circ} 24'$  to  $15^{\circ} 50'$ ) will perhaps represent the real breadth of this Cordillera more exactly, as being nearly perpendicular to its axis (which runs from about S.S.E. to N.N.W.); and here the intercepted space occupies an extent of  $1^{\circ} 32'$ , or about eighty-eight miles, the longitude of Arequipa being  $71^{\circ} 54'$  and that of Puno  $70^{\circ} 22'$  west of Greenwich. We may therefore conclude that the western Cordillera occupies in breadth a space of nearly one hundred English miles; and we shall see hereafter the immense breadth which the two Cordilleras united occupy.

The Eastern Cordillera, which may be called also the Bolivian, since the greater part of its extent is comprised within the political limits of the Republic of Bolivia,\* detaches itself as a separate chain in the 20 par. of lat. south of Porco ( $19^{\circ} 50'$ ) and of Potosi ( $19^{\circ} 35'$ ). The metalliferous mountains which surround the former town may be considered as constituting its southern extremity; and the celebrated mountain or cerro of Potosi also belongs to it. The mean elevation of this metalliferous group does not exceed 16,000 feet, which is nearly that of the mountain of Potosi (16,040 feet); none of its peaks consequently rise within the limits of perpetual snow.

Between the parallels of Potosi (lat.  $19^{\circ} 35'$ ) and that of  $16^{\circ} 50'$  no part of the Bolivian Cordillera attains an elevation of 17,000 feet, none being enveloped in snow during the entire year, until it reaches the latitude of  $16^{\circ} 40'$ ,† where the gigantic mass of Illimani suddenly rises, forming the southern extremity of the great Bolivian snowy range. Between Potosi and Illimani the Eastern Cordillera presents numerous passes or cols, some of which equal in height those of the Western Cordillera.‡

The nevado of Illimani § is situated in lat.  $16^{\circ} 40'$ . Its form is

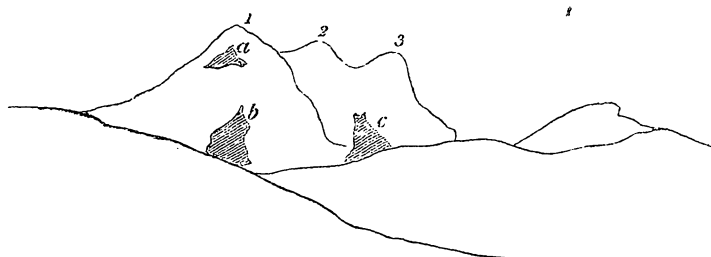
\* The Republic of Bolivia, founded in 1825, embraces those provinces of Alto-Peru which, under the dominion of Spain, formed the Presidency or Audiencia of Charcas,—viz. La Paz, Oruro, Cochabamba, La Plata or Chuquisaca, Santa Cruz de la Sierra, with the Missions of Moxos and Chiquitos, Potosi, and Tarija.

† This position has been deduced from bearings observed at La Paz and La Ventilla, on the road to Potosi, the geographical situation of which had been previously ascertained by direct astronomical observations.

‡ The most remarkable of these passes, are that of Livichuco, which is traversed by the road from Oruro to Chuquisaca; and that of Challa between Oruro and Cochabamba.

§ Illimani, or Yllimani, appears to derive its name from its icy covering, *lli*, in the Ymarra dialect of the aborigines, signifying snow.

that of a serrated ridge, elongated in the direction of the axis of the chain upon which it rises, offering four principal peaks to the observer, when seen from its western side. From the city of La Paz (lat.  $16^{\circ} 30'$ ) distant about thirty miles, it presents itself with the imposing grandeur of Montblanc when seen from Salanches, or of Monte Rosa from the subjacent valley of Macugnaga.



[Outline of Illimani, seen from the valley of La Paz.\*]

The elevation of this giant of the Bolivian Cordillera is 24,200 feet, and the lowest glaciers on its northern declivity, the only part of it I could visit, do not descend below 16,500.

North of Illimani, but separated from it by the deep valley of Totoropampa and Totoral, which forms one of the most frequented communications between La Paz and the province of Yungas, celebrated for its rich plantations of coca (*Erythroxylon coca*), is situated the Nevado of Tres Cruces, towering over the Indian hamlet of Totoropampa; and from this point (lat.  $16^{\circ} 35'$ ) the Bolivian Cordillera may be said to form an almost continuous line of snowy mountains, to its junction with the Western Cordillera in the Andes of Vilcafiota.† It is to this portion of the Andes that appears to have been more particularly applied the denomination of Cordillera Real, doubtless from its great elevation, its imposing grandeur, and the considerable extent in which it is discovered from the subjacent (comparatively) low country. From the shores of the lake of Titicaca the Bolivian Cordillera presents an almost continuous line of nevados from Illimani on the south, to those of San Juan del Oro, and of Vilcafiota on the north. The most elevated pinnacles of this snow-capped range tower over the large Indian village of Sorata, in the province of Larecaja, and hence are known among the Creole inhabitants by the name of Nevado

\* In this outline the 4th peak is not visible, being hidden by the northern (1); the part of the mountain embraced is entirely enveloped in snow, except the patches *a*, *b*, *c*, formed by prominent masses of rock.

† The view of this portion of the Bolivian Cordilleras is particularly magnificent from one of the islands in the lake of Titicaca (Isla de Coata, lat.  $16^{\circ} 3'$ ), from which the whole snowy ridge is seen, with the immense expanse of the subjacent lake in the foreground.

di Sorata, and by the aborigines, who use the Ymarra idiom, by the several names of Ancomani, Itampu, and Illhampu; the most elevated attains the immense height of 25,250 feet, being situated in lat.  $16^{\circ} 10'$ , as deduced from bearings taken from the shores of the lake of Titicaca. And although, as just observed, the Bolivian Cordillera, north of Illimani, may be considered as one continuous line of snowy peaks, there are some which deserve to be cited from their especial elevation, as, for example, the Nevado de Cacaca, north of La Paz; the Nevado de Mezada, so called from its flat summit resembling a table; and north of the gigantic Nevado of Sorata, that which towers over the Indian village of Yani. I possess no positive data on the Bolivian Cordillera beyond the point where it is traversed, in a most remarkable manner, between the villages of Ananea and Consata ( $16^{\circ}$ ), by the river Mapiiri, one of the largest affluents of the great river Beni; but it appears certain, as already noticed, that it continues to form an almost continued line of Nevados, until its junction with the Western Cordillera in the Andes of San Juan del Oro, and of Vilcañota.

When seen from its western declivity, the Bolivian Cordillera offers a succession of sharp, ragged peaks, and serrated ridges; a configuration which contrasts with the conical and bell-shaped summits of the Cordillera of the coast, and results from their different geological composition.

I have already stated, that the greater number of the passes or cols by which the Eastern Cordillera is traversed, south of the parallel of Illimani, are situated at elevations exceeding 14,000 feet. In this portion of the chain no part of it indeed descends to my knowledge below this level; and the rivers, consequently, that rise on its western side empty themselves into the Desaguadero. Arrived, however, at the snowy portion of the range, things become completely changed, and the torrents, which there descend from either declivity of it empty themselves invariably into the affluents of the Amazon, those on the west side crossing the chain of the Bolivian Cordillera; whence it arises that the snowy Cordillera is traversed north of  $16^{\circ} 50'$  of latitude by many deep valleys, and offers many passes at elevations greatly inferior to what might at first view be expected from the excessive mean elevation of its highest summits. This very curious fact of rivers escaping through such an immense mountain-mass as the Bolivian Cordillera is perhaps one of the most important points connected with the physical geography of this portion of the Andes, and deserves to be noticed at greater length.

The annexed map of this portion of the Andes, destined to show the affluents of the Rio Beni which have their source in the department of La Paz, has been reduced from several MS. maps

made by the missionaries which I have consulted; as well as from my own observations; and will render clear the remarkable geographical fact to which I have above alluded.

It will be seen, that all the rivers descending from the western side of the snowy Cordillera empty themselves into two great channels, the Rio Mapiri on the north, and the Rio Chuqueapo, or river of La Paz, on the south. The Mapiri, a very considerable stream, traverses the central ridge of the Bolivian Cordillera north of the Nevado of Yani, between the villages of Ananea and Consata; and, after a very tortuous course, joins the rivers Tipuani, Challana, and Coroico, which descend from the eastern declivity of the same Cordillera, and form by their junction the Rio Caca. The Rio Chuqueapo\* rises among the glaciers that cover the nevados north of La Paz; whence it passes through that city, and, running parallel to the Bolivian Cordillera receives all the rivers that descend from its western declivity as far south as  $16^{\circ} 55'$ , the point where it runs through the chain to enter the province of Yungas, constituting one of the highest branches of the great river Beni; and thus it may be considered, not only the source of this latter, but also of the Madeira and Amazon, if we adopt as the source of these great rivers the affluent the most distant from their mouths. I have not been able to ascertain the exact elevation of the two remarkable gorges or chasms through which the Mapiri and Chuqueapo traverse the chain; but from the nature of the vegetation on the banks of the latter at this point (*Bananas, Grenadillas, &c.*), it does not probably exceed 6000 feet; and thus we have a valley 18,000 feet lower than the neighbouring peaks (those of Illimani), which almost overhang it, perhaps the greatest difference that has been observed in the level of the most elevated points, and of the adjoining valleys of any mountain system yet examined.

The declivity of the Bolivian Cordillera is rapid on either side; but particularly so on the eastern. On the western it presents short transverse valleys, which only in its southern portion open into the great basin of the Desaguadero. On the eastern side it sends off many lateral and transverse ridges, which, for the sake of brevity, I shall designate with Baron Humboldt by the name of the Contrefort of Cochabamba. The mass of hilly or mountainous

\* *Chuqueapo*, the name of La Paz in the Ymarra dialect of the aborigines, signifies field of gold. The word Chuque is frequently met with in names of places in the Bolivian Cordillera, Chuque-camata, Chuque-saca, &c.

† I am aware that this point may be disputed by those accustomed to pin their faith to the erroneous compilations of Olmedilla de la Cruz, the Padre Sobreviela, and their copyists; but I possess the proof that the Rio Beni (which with the Mamore and Ytenes form the Madeira) is formed by the union of two great streams; the Mapiri or Caca on the north, and the Chuqueapo on the south, both of which rise on the west declivity of the Bolivian Cordillera, and unite the waters of that majestic chain in its highest portion between  $16^{\circ} 55'$  and  $15^{\circ} 40'$ .

country which forms the whole of the Bolivian provinces of Cochabamba, and of Chuquisaca, and a part of those of Potosi and of Santa Cruz de la Sierra, consists of lateral or transverse ridges, which the Bolivian Cordillera sends off from its eastern side, and which only terminate in the extensive plains of Chiquitos and Paraguay. The most remarkable, for extent and elevation, of these transverse ridges, is that which bounds on the north the rich valley in which the city of Cochabamba (lat.  $17^{\circ} 23'$ ) is situated; and which, detaching itself from the Cordillera nearly in lat.  $17^{\circ} 10'$  south, rises above the limit of perpetual snow, near Cochabamba, in the pointed Nevado di Tinaira; whence it becomes gradually lower, forming the territory of the Yuracariæ Indians, and finally terminating on, or near, the banks of the Rio Guapãi or Grande, within a few leagues of the town of Santa Cruz de la Sierra.

Having thus sketched the great mountain-features of the Bolivian territory, it remains for me to say a few words on the extensive inter-alpine valley that separates the two Cordilleras, embracing the Valley of the Desaguadero and the celebrated Lake of Titicaca, thus forming one continuous basin. The limits of this great mountain depression are the parallel of Lampa in  $15^{\circ} 5'$  on the north, and that of Condorcondo in  $19^{\circ} 30'$  on the south. Its width varies considerably in its different parts. In the parallel of Puno (lat.  $15^{\circ} 50'$ ) it exceeds sixty miles, and in lat.  $16^{\circ} 50'$  it is still wider; but from this point to its southern termination it gradually narrows, so as in the parallel of Oruro ( $17^{\circ} 58'$ ) not to exceed thirty-five miles. From a calculation which I have made, the superficial extent of this immense basin, including that occupied by the lake, exceeds 16,000 square miles (geographical), and the lake at the present day covers between a fourth and fifth of that area. I say at the present day, for it appears that its extent has diminished even within the historical period of this continent; since a writer,\* soon after the conquest of Peru by the Spaniards, describing the gigantic Peruvian monuments of Tiaguanaco (lat.  $16^{\circ} 34'$ ), says, that the waters of the lake washed their walls, whereas these ruins are now elevated many feet above the level of the lake, and are at a considerable distance from it. I shall have occasion, however, elsewhere to enter on this subject more at length.

The valley of the Desaguadero is necessarily in the direction of the two chains that inclose it. In its southern portion it runs nearly parallel to the meridian; but north of lat.  $17^{\circ}$  it forms an angle of almost  $35^{\circ}$  with that line, running very nearly north-west by north and south-east by south. It is entirely bounded by mountains, having no outlet towards the sea; and the rivers which descend into it are either lost in the sandy soil, or empty them-

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\* Garcilaso de la Vega, *Commentarios Reales*.

selves into the lake of Titicaca at its northern extremity. This celebrated lake, the most extensive fresh water accumulation in the South American continent, occupies an area of almost 4000 geographical square miles, and forms the northern extremity of the great inter-alpine depression in the Bolivian Cordilleras. From a very extensive and accurate series of barometrical observations made on its shores, its waters in the dry or winter season are situated 12,795 British feet above those of the Pacific Ocean, an elevation superior to that of the highest summits of the Pyrenees. Owing to the total want of boats at the period of my journey, other than the rude canoes of the natives, I was not enabled to obtain deeper soundings than 120 fathoms; but from the precipitous cliffs which in many parts of it form the shores, and its islands, I am persuaded that its depth in the central portion is considerably greater. The lake of Titicaca receives numerous streams at its northern extremity, but by no means so great a mass of water as might be expected from the height of the Andes that surround it; arising from the *divortia aquarum* of the Western Cordillera\* being situated little distant from the shores of the lake, so that the greater part of its waters run towards the Pacific, while on its eastern side the lake is bordered by a low secondary ridge of red sandstone, which prevents the torrents descending from the Eastern Cordillera reaching it, and causes them to form the Mapiri and Chuqueapo, running to the Amazon. The principal streams that supply the lake of Titicaca are those which on its northern side form the rivers of Asangaro, descending from the Cordillera of Crucero and San Juan del Oro, and that of Lagunillas, which rises in a chain of small lakes in the Western Cordillera. Its only outlet is the River Desaguadero, which issues from its south-western extremity in lat. 16° 38' 10" south, and is an inconsiderable stream when compared to the immense extent of the lake from which it issues; † an anomaly which may be easily explained by the great amount of spontaneous evaporation to which its surface is exposed in an extremely dry and rarefied atmosphere, owing to its excessive elevation.

The lake of Titicaca contains numerous small islands; that from which it has taken its name, and which is situated at the south-east extremity, being the largest and most celebrated, tradition having

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\* I found the width of the river Desaguadero, in the beginning of the rainy season, and close to its origin in the lake, to be forty-six yards; its course was scarcely two miles an hour, but its depth considerable.

† Most map-makers have placed the Bolivian Cordillera to the west of the sources of the Mapiri and Chuqueapo, acting no doubt on the old notion that none but great mountain-chains form *divortia aquarum*; and thus, in the best maps of Peru, the sources of the Mapiri, Beni, and the towns of Sorata, La Paz, are placed on the eastern declivity of the Bolivian Cordillera, whilst they are really situated on the western side of that ridge.

there placed the miraculous appearance of Manco-Capac, the first Inca of the last Peruvian dynasty of sovereigns, where he laid the foundation of those extraordinary theocratic-political institutions which enabled his successors to found the most extensive empire in the annals of American history, and to bring about a degree of civilization among their subjects so superior to that of the other barbarous nations of the American world, as to enable the Peruvian Incas in the twelfth generation of their dynasty to extend their conquests from Cundinamarca, and the equinoctial regions of Quito, to the centre of Chili. The island of Titicaca still contains numerous Peruvian ruins, of which I shall speak in another place.

To complete the description of the mountains of Bolivia, it is necessary to say a few words on a system of elevations which exists between the two great Cordilleras, connecting them in some degree, and crossing the great inter-alpine depression which I have just described. This chain detaches itself from the western Cordillera in lat.  $16^{\circ} 38'$ , where the river Desaguadero emerges from the lake of Titicaca,\* and flows in a gorge through this intermediate chain, which, for the sake of brevity, I shall call that of Pacajes, from the province of which it constitutes the greater part. It thence runs in a south-east direction, passing near the far-famed Peruvian ruins of Tiaguanaco (lat.  $16^{\circ} 34'$ ), to Corocoro and Belen, lat.  $17^{\circ} 18'$ , near which it ceases to form a continuous chain, being succeeded by a series of insulated conical groups, which form the mining districts of Laurani, La Silla, and Oruro (lat.  $17^{\circ} 58'$ ), each of these groups rising like so many islands in the midst of the great plain of the Desaguadero. South of the metalliferous group of Oruro is situated the mountain of Poopo, separated by a valley, through which the river of Sorasora runs to empty itself into the Desaguadero; and this mountain of Poopo is directly connected with the eastern or Bolivian Cordillera. The direction of the chain of Pacajes is nearly north-west by west, no part of it reaching the region of perpetual snow, the most elevated point I have visited being situated between Corocoro and La Paz, where a conical mountain, formed of highly inclined strata of the new red sandstone series, rises to an elevation of 15,100 feet. We may, therefore, consider the intermediate chain of Pacajes as forming a kind of connecting link between the two great Cordilleras, although raised perhaps at a later period; a view which is confirmed by its geological structure.

In concluding this article, it may not be uninteresting to inquire what may be the mean breadth of the Andean chain within the

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\* From the erroneous drawing of every map of Peru hitherto published, the Desaguadero is represented as flowing into the lake of Titicaca, whilst the contrary is the case; an error caused by map-makers being at a loss to dispose of its waters otherwise, and being ignorant that they are dissipated by spontaneous evaporation.

geographical limits here contemplated—*i.e.* between the fourteenth and twentieth parallels of south latitude, where this gigantic range attains a greater transversal development than in any other part of its course. As the incorrect maps hitherto published of this country can afford no data to arrive at even an approximative result, I shall be obliged to employ my own astronomical observations, which are unfortunately too few to fix with certainty this important point of the physical geography of South America. In the parallel of  $16^{\circ} 30'$  the direction of the chain of the Andes is inclined about  $35^{\circ}$  to the meridian; and here I determined, at the maritime base of the Western Cordillera, the longitude of Arequipa,  $71^{\circ} 54'$ , and on the eastern base of the Bolivian Cordillera, that of Chullumani, situated near the foot of Illimani,  $67^{\circ} 40'$ ; the intercepted space being, consequently,  $4^{\circ} 14'$ , or  $243\frac{1}{2}$  miles. On the parallel of  $17^{\circ} 25'$  to  $18^{\circ}$ , I determined the longitude of Tacna at the west base of the Cordillera of the coast, and of the city of Cochabamba on the east foot of the Bolivian Cordillera,  $70^{\circ} 12'$ , and  $65^{\circ} 52'$ , the direction of the Cordilleras on this parallel being inclined about  $20^{\circ}$  to the meridian; the intercepted longitude is, consequently,  $4^{\circ} 20'$ , or  $228\frac{1}{2}$  miles. Finally, in the parallels of  $19^{\circ}$  and  $20^{\circ}$ , I determined the longitude of Tarapaca and Chuquisaca,  $69^{\circ} 27'$ ,  $64^{\circ} 26'$  (lat.  $20^{\circ} 6'$  and  $19^{\circ} 3'$ ), the direction of the Cordillera being the same as in the parallel of  $17^{\circ} 18'$ , so that the intercepted line is nearly at right angles with the axis of the chain, and the distance 284 miles. Reducing, then, these different distances to lines forming right angles with the direction of the chain in the different parallels, we shall obtain for its breadth

Between $16^{\circ}$ and $17^{\circ}$ South latitude, geographical miles	199.5
„ $17^{\circ}$ and $18^{\circ}$ . . . . .	214.5
„ $18^{\circ}$ and $19^{\circ}$ . . . . .	266.0
„ $19^{\circ}$ and $20^{\circ}$ . . . . .	266.0

The above numbers express the breadth of the Andes, taken from the extreme base of each of the central chains only, or of the two Cordilleras, with the intermediate valley of the Desaguadero; and, as I have already stated, it will be found much greater than that of any other part of the chain. But if, instead of taking the breadth of the two principal ridges, we adopt, for the width of the chain, the extreme points of the lateral ridges which rise from either side of the Andes, we shall find that in the parallels of  $17^{\circ} 25'$ , in which the town of Santa Cruz de la Sierra, at the eastern extremity of the Contrefort of Cochabamba is situated,—the mountainous ridges which rise from the two Cordilleras, and these two Cordilleras themselves united, occupy an extent of  $8^{\circ} 40'$  in arc, or 500 geographical miles.

I shall conclude this notice by a few observations upon the limit



of perpetual snow on the Andes comprised between the  $15^{\circ}$  and  $20^{\circ}$  of south latitude.

In a paper, inserted by M. Arago, in the 'Annuaire du Bureau des Longitudes,' for 1829, founded on notes which I communicated to him, and in a correspondence with Baron Humboldt, which appeared in the 'Hertha' for the same year, I have shown that 5200 metres, or 17,100 English feet nearly, may be assumed as the mean elevation of the inferior limit of perpetual snow in those parts of the Andes between the 14th and 20th parallels of south latitude, which I had occasion to visit during my journey in Upper Peru. And I shall now endeavour to establish this anomalous fact, anomalous in so far as it is in opposition to all pre-conceived opinions respecting the distribution of heat in South America, by adducing the principal examples upon which it is founded, and which I trust will suffice to render it evident to the most sceptical.

The first point I shall cite, and of which I have had occasion to speak in my preceding observations, is the volcano of Arequipa (lat.  $16^{\circ} 20'$ ), which, according to my observations, attains an elevation of 18,300 feet.\* Its apex is in general covered with snow for about 500 feet below its summit, at all seasons; but this sometimes disappears entirely during the autumnal months. The circumstance of this mountain being an active volcano may render it improper for determining the limit of perpetual snow, but as the volcanic action is of a very limited nature, confined to the emission of clouds of aqueous vapour, and perhaps of ashes at remote intervals, it cannot be supposed to exercise any great influence in modifying the temperature of the surface of the cone; besides, on the adjoining mountains of Pichu-Pichu and Chacani the snow line is on the same level as on the volcano, and disappears under the same atmospheric circumstances. We may, however, adopt 17,200 feet as the inferior limit of the perpetual snow on that mountain, and in the early part of the summer season (October and November).

In my letter to M. Arago I have also cited the mountain of Inkocajo, situated near the centre of the Western Cordillera, in lat.  $15^{\circ} 58'$ , and near the sources of the river of the same name, which passes through the city of Arequipa. Here the lowest patches of snow, and those placed only in the ravines, were 1300 feet higher than the pass of Los Altos de Toledo, or at an absolute elevation of 16,850, whilst the great mass of snow covering the summit was fully 250 feet higher up. This was in the middle of October, and consequently at the close of the spring.

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\* There is a measurement of this mountain, by a Mr. Curzon, in Shillebeer's Voyage, who states it to be 2775 toises, or 16,650 feet.

I have only had occasion to determine the height of the snow line on a single nevado in the southern prolongation of the Western Cordillera,—viz. the extinct volcano of Chipicani, which towers over the village of Tacora (lat.  $17^{\circ} 50'$ ). On the 9th of March, corresponding in the southern hemisphere to our autumn, I found the barometer at mid-day to mark 18,158 inches, th. at. (Fahr.) being at  $61^{\circ} 7'$ , which gives 14,255 feet for the height of the station. From this point I measured a base line, and by means of angles taken with a good sextant and mercurial horizon I found the elevation of the snow-line to be 2500 feet higher; whilst on the northern side of the mountain, that exposed to the more continued action of the solar rays, the same line was 390 feet more elevated than on its south declivity; adopting, therefore, a mean of these two determinations, we shall have for the height of the inferior limit of snow, at the close of the summer, and in lat.  $17^{\circ} 48'$ , 5181 metres = 16,945 feet. It is on this determination that are partly founded the heights which I have assigned to the nevados of Gualatieri, Sehamá, Parinacota, &c., the elevation of the summits of which I had only occasion to determine above the snow-line. The nevado of Chipicani is situated in lat.  $17^{\circ} 48'$ , as results from bearings carried on from Ancomarca and Palca, the latitude of both which places was deduced from good meridian altitudes of a *Lyræ*.

On the Eastern Cordillera I shall cite two direct observations only, made on the gigantic Illimani, and on the south-east declivity of the neighbouring nevado de Tres Cruces. At the former station, close to the lowest patch of snow I could discover, and my observation was made in the month of December, the barometer stood at 16,477 inches th. at. (Fahr.)  $49^{\circ} 3'$ , which, compared with the mean of my observations made at the same hour, and at La Paz during several successive days (19,507 inches, Fahr.  $62^{\circ} 6'$ ), gives 16,865 feet, for the height of my station.

In speaking of Illimani, I have stated that its lowest glaciers, or snow collected in the ravines, did not descend below 16,340 feet. The lake of Illimani is itself placed at an elevation of 15,950 feet, and although at the time I visited it a good deal of rain had fallen in the subjacent valleys, and that snow lay in the more elevated situations, not a particle of either snow or ice was to be seen within 350 feet of its level.

The nevado de Tres Cruces rises at a short distance from the northern base of Illimani, and is only separated from it by the deep valley of Totoral and Totoropampa; here I reached the snow-line during the same journey, and found my barometer to mark 16,347 inches, Fahr.  $41^{\circ} 5'$ , whence the elevation of my station was 17,090 feet.

South of the 18th parallel of latitude I have not been able to

determine the inferior limit of the snow-line on any mountain, the season having prevented my examining the numerous nevados of the provinces of Carangas, Atacama, and Lipez. The only snowy mountain south of this parallel, where I am aware that any observations have been made, is the nevado of Chorolque, in lat.  $21^{\circ} 30'$ , not far from Tupisa (lat.  $21^{\circ} 28'$ ), the capital of the Bolivian province of Cinti; and on which Dr. Redhead, a gentleman well versed in meteorological studies, writes to me that the snow-line descends, in the month of March, as low as 15,120 feet. I entertain very great doubts, however, as to the accuracy of this observation, since, in the mountains of Porco, and on the Cerro of Potosi (lat.  $19^{\circ} 50'$  and  $19^{\circ} 36'$ ), not a particle of snow was to be seen in the month of December, and these mountains attain an elevation of 16,000 feet; it is difficult, therefore, to suppose a sudden depression of nearly 900 feet in the limit of perpetual snow, in an extent so trifling as eighty or ninety miles. Besides this, Dr. Redhead estimates the total elevation of Chorolque at only 16,548 feet—an altitude too small, evidently, since the whole of the snowy portion of the pyramid of Chorolque is visible from Bartolo, a village north-east of Potosi, itself elevated 11,100 feet, and distant, in a straight line, from Chorolque at least 115 geographical miles.

Recapitulating, therefore, the preceding observations, we shall obtain for the mean elevation of the inferior limit of perpetual snow—

On the Volcano of Arequipa,	lat. $16^{\circ} 20'$	Elev. 17,200 feet.
Nevado of Inkocajo	15 58	„ 16,850
„ Chipicani	17 48	„ 16,946
„ Illimani	16 42	„ 16,865
„ Tres Cruces	16 30	„ 17,090
Mean elevation of the snow-line	.....	16,990

In corroboration of this important fact, that the inferior limit of perpetual snow is here much higher than in the prolongation of the chain in the same latitude in the northern hemisphere, and even than in its equatorial regions, I shall cite some points, the most elevated I have had occasion to visit, where not a particle of permanent snow was to be seen:—

1. Cerro di Potosi, the summit of the celebrated metalliferous mountain, in lat.  $19^{\circ} 36'$ ; its elevation being 16,037 feet.

2. Mountain of Porco, lat.  $19^{\circ} 45'$ ; elevation 15,913 feet.

3. Mountain of La Galofa, on the northern declivity of Illimani, lat.  $16^{\circ} 42'$ ; elevation 16,250 feet.

[These three localities present elevations superior to that of the inferior limit of the snow-line under the equator, which descends to 15,748 feet; and the mountains of Potosi and Porco attain, within a few feet, the level of the highest peak of Pichincha (the Rucu Pichincha), elevation 15,925 feet, which is covered at all seasons with its icy coating.]

4.	Passage of Chullunquani,	lat. 17° 18'	Elev. 15,610 feet.
5.	„ Las Gualillas	17 50	„ 14,830
6.	„ Los Altos di Toledo	16 2	„ 15,528
7.	„ Paquani	16 33	„ 15,226
8.	„ Leñas	19 16	„ 14,203
9.	„ { La Compuerta, or } Lagunillas }	15 52	„ 15,613

Of these six passes, four exceed the height of the inferior limit of perpetual snow on the Mexican prolongation of the Andes, which Baron Humboldt fixes at 4600 metres = 15,092 feet. And as no fact is better calculated to convey an idea of the height of the Peruvian Andes than the excessive elevation of its mountain-passes—for it is evident that man will always seek the least elevated and dangerous passages in his migrations—I annex a list of the different passes most remarkable for their elevation:—

*Western Cordillera.*

1.	Altos de los Huessos, at the foot of the volcano of Arequipa	} lat. 16° 21'	Elev. 13,573 feet.
2.	Altos de Toledo		
3.	Pass of Lagunillas (the Divortia Auarum)	} 15 22	„ 15,613
4.	Pass of Las Gualillas		
5.	„ Las Gualillas (another)	17 43	„ 14,200
6.	„ Chullunquani	17 18	„ 15,610
			Mean 14,892

*Eastern Cordillera.*

7.	Pass of Pacuani	lat. 16 33	Elev. 15,226
8.	„ Challa	17 40	„ 14,700
9.	„ Tolapalca	19 0	„ 14,075
10.	„ Leñas	19 45	„ 14,210
11.	„ Condur Pacheta	18 0	„ 13,950
12.	Pass between the mountain of Potosi and of Huayna Potosi	} 19 36	„ 14,370

At first sight it would appear from this list, that the depressions or passes in the Western Cordillera are more elevated than in the Eastern (which would be the contrary of the highest peaks); but it is to be remarked, that the passes in the former have been chosen in the most elevated portion of the ridge, their mean position corresponding to lat. 16° 52' S.; whereas, with the exception of No. 7, all the passes of the Bolivian Cordillera are situated in that portion of its extent where no part of it reaches 17,500 feet; and are in latitudes more removed from the equator, viz., in a mean latitude of 18° 26'. One of the highest passes in the Bolivian Cordillera is that crossed by the road from Sorata to the great auriferous valley of Tipuani, at the foot of the nevado of Sorata. I have not been able to ascertain its exact elevation,



and 15° S. lat., some of which—those of Huaylillas, the Toldo di Nevé (seen from Lima), and the nevado of La Viuda (seen from Huanuco)—attain a considerable elevation.

Between the parallels of 21° 30' and 33° S., we do not possess a measurement of any part of the Andean chain. I have already mentioned that Dr. Redhead had determined the height of the nevado of Chorolque, situated in the former parallel; but that some doubt hangs over the determination of that observer. The Andes of Chili offer, consequently, the most unknown part of the chain.

In lat. 33° and 34°, the Chilian Cordillera is traversed by two remarkable passes—that of the Cumbre on the north, and of the Portillo on the south—between which rises the mountain of Tupungato, which towers over the capital of Chili, and which, covered at all seasons with snow, attains an elevation of 15,500 feet. The Tupungato and volcano of Penqueñes, situated near the Portillo pass, which latter rises, according to Dr. Gillies,\* as high as 15,000 feet, and is covered with snow, appear to be the highest points of the Andes, between 33° and 35° S.: the most elevated passes of the same part of the chain being La Cumbre, or culminating point of the road between Mendoza and Santiago de Chili, which is 12,454 feet.† In his Paper on the volcano of Penqueñes, above referred to, Dr. Gillies furnishes us with the elevation of that volcano, 15,000 feet; and of two passes at its base, on either side of the longitudinal valley of Tunyan (a kind of diminutive basin of the Desaguadero), elevated 14,365 and 13,210 feet. South of this point numerous passes cross the Chilian Andes—that of Las Damas, north of an active volcano, probably the Descabezado, and the pass Del Planchon (less elevated than the Cumbre and Portillo, since vegetation extends to its summit), and which serves as a constant communication between the Indian territory in the Buenos-Ayorean province of Mendoza and the Chilian towns of Talca, San Fernando, and Curico. From these measurements of the passes, we may conclude that the mean elevation of the Andes diminishes very gradually, as far south as the 35th parallel of latitude.

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\* Vide *Edinburgh Journal of Nat. and Geog. Science*, Aug. 1830.

† To arrive at this determination, I have employed the barometrical observations of Dr. Gillies, and have re-calculated those of Miers and Bauza, applying corrections which these authors had neglected, and connecting their observations with others made at Santiago and Mendoza.

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