THE ANDES OF THE NORTH-WEST ARGENTINE

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THE ANDES OF THE NORTH-WEST ARGENTINE: *A paper read at the Evening Meeting of the Society on 16 April 1934, by*

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LAST September, proceeding from Mendoza for a journey to Uspallata, in the Andes, I arrived after a rather rough drive through the wild gorge called "Quebrada de Toro," at the top of the Paramillos, a high plateau near to 3000 metres. The ragged snow-capped peaks of the Cordillera de Tigre rose boldly to 5000–6000 metres above the desert landscape, with its occasional patches of dry grass and naked hills of yellow and pink rocks. Looking at the outcrops, I remarked some reddish places, and stopping I could easily identify remains of trees preserved in the sandstones. At this very place, as tells a modest plate with an inscription placed on a rock, Charles Darwin stopped a century ago, while he was crossing the mountains on horseback, and he noticed the fossil trees. I confess I was deeply impressed by this reminder, and I ask for permission to begin this lecture by a salute to the great British naturalist.

Since the time of Charles Darwin's journey much has changed: travelling in South America has become a good deal easier; you may cross the Andes not only on horseback in summer, but also by motor, if you are accustomed to the worst roads; you have the Transandine railway, operating once a week all the year round; you can use the regular air service of the American Line. And I can say that every mode of travelling has its advantage, for I used them all, and some others, for my study of South American physiography.

I am afraid this subject may be taken as a rather dry one, but it gives an opportunity of contemplating such picturesque landscapes that I hope you will not regret following me on the wild paths of north-western Argentina.

Geographical aspects

Argentina is known as the country of the Pampas, that is to say, immense treeless plains; but it is also the country of high summits. The Andes are among the boldest mountains on earth. It is on their crest (when there is a crest) that the frontier with Chile is established from north to south for more than 3000 kilometres. To the south, where the continent becomes narrower, the chain of the Andes is comparatively low and narrow, few summits rising

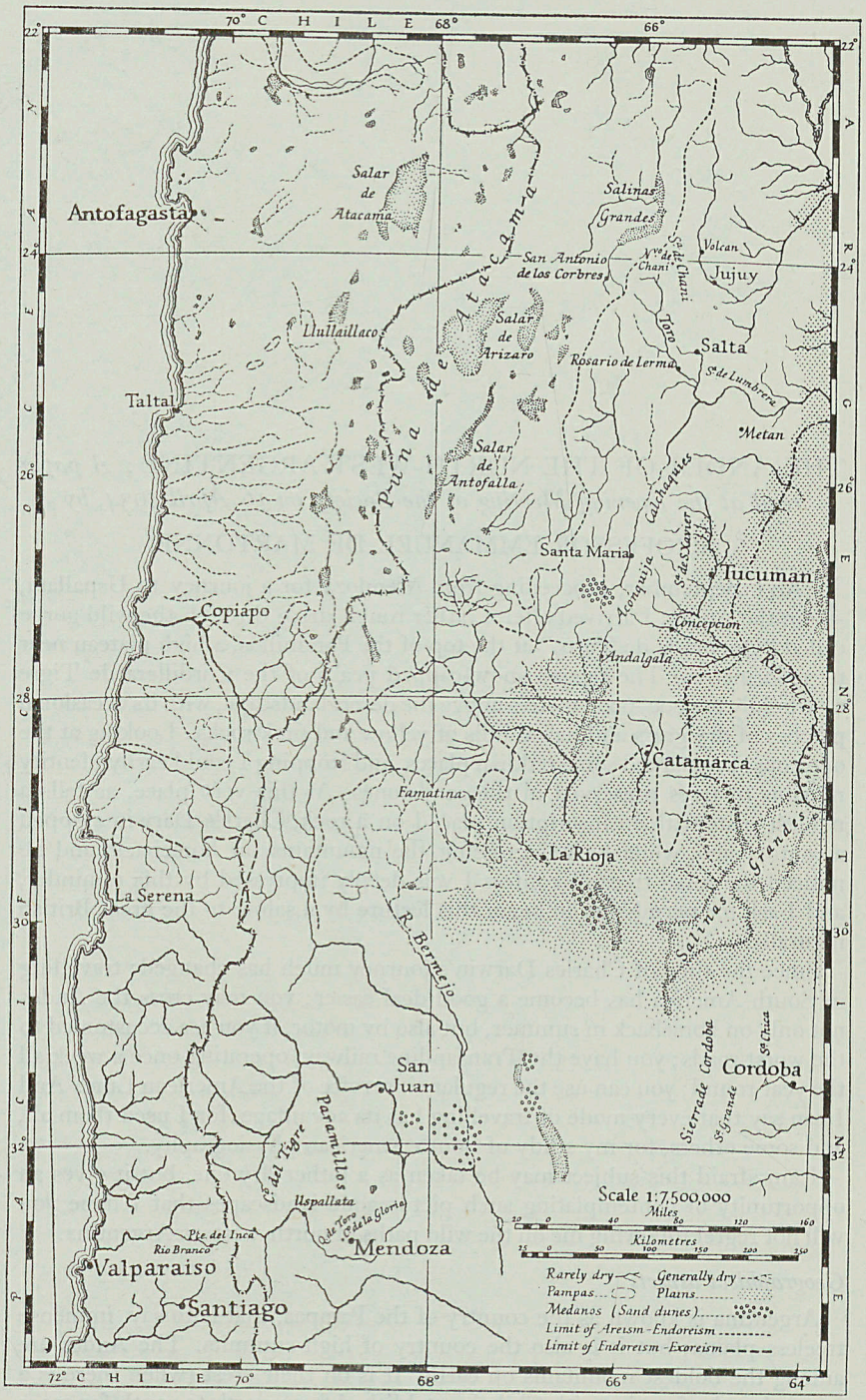


Fig. 1. Hydrography in the region of the areic diagonal, north-west Argentine

above 3000 metres (and being almost exclusively volcanoes). To the north, on the contrary, the chain becomes higher and larger, and although its greater height and its greater extent are encountered in Bolivia, you still find in north-western Argentina, near the Bolivian border, one of the most impressive blocks of mountains; for you have to ride, or to drive, or to fly, as you like, over 400 kilometres of high plateaux rising to 3600 metres, with peaks of 6000 metres, in order to pass from Salta, near the border of the Chaco plain in Argentina, to Antofagasta on the Chilean shore of the Pacific.

Now, if we go a little more to the south, as far as Cordoba, we see that the contact of the mountain with the eastern plains is not so well defined as near Salta. It seems as if the huge mass of the Andes would split into a series of small blocks, which become lower to the south and depart more and more from the trend of the high summits, while intermontane belts of plains appear, growing in extent to merge finally in the immense plain of the Pampas. What I shall call the Andes of north-western Argentine begin at the Bolivian frontier and extend as far to the south as these Subandine Sierras, that is to say, near to Cordoba. It is an extremely interesting country, not only for the geologist and the geographer, but for the historian or the sociologist, and even for the tourist.

It is there that you reach the very heart of old Argentina. The peopling of he Pampa is a recent thing. Even in pre-Spanish times the open plains, with their rough climate, were without any permanent dwelling, while Indian tribes were numerous in the *bolsons* or intermontane basins of north-western Argentina. All the Indian antiquities you find in the beautiful Museum of La Plata come from the north-western provinces. It is also in Jujuy, Salta, and Catamarca that you can buy those brilliant-coloured carpets, these finely engraved *bumbillas*, and other nice things that Europeans like to take home.

Anybody who has travelled through the Pampa understands why Buenos Aires was abandoned after its first foundation by the Spanish. The *pampero* is a terrible wind, which makes the thermometer drop 20° centigrade in a few hours. The *bolsons* of the north-western provinces are sheltered corners, a little hot and dry, but where the mountains give water for irrigation. The gardens of Salta, Tucuman, or Mendoza look little paradises, while in the parks of Buenos Aires, for the establishment of which millions have been spent, even eucalyptus trees do not grow well.

Buenos Aires is the most stupendous city, for the brilliant aspect of its centre near the port, and the extraordinarily rapid growth of the lonely suburbs; there is nothing old in it, and even the historic *Cabildo* has been cut by the opening of the *Diagonal Sud*. You must go to Cordoba, Salta, and Jujuy if you want to see something of the old colonial architecture, houses with wooden columns at the corners, patios with flowers, churches with ornaments in Jesuit style. It is in a church of Jujuy that you can see the curious wood carving in which the angels, the saints, and even Christ have been represented by the naïve sculptor with faces of Indian types.

Any geographer travelling in that country cannot fail to be impressed by the boldness of the relief, which shows unusual aspects to the West-European scientist, by the violent contrasts of altitudes and the similarly violent contrasts of climates. Extremes of low and high, dry and wet, cold and hot so close

together that you can hardly imagine it. Erosion by rivers and weathering are working with energy such as is rarely experienced even in the Alps. But the most curious feature is the aridity of the mountains as a whole.

I trust I do not promise too much if I say that I will introduce you to a country where some of the general rules of physical geography seem to be contradicted by nature; where you will see mountains which are drier than the surrounding plains, and where climbing brings one into relatively warmer and drier places. In the contemplation of this paradox we are confronted with a more general problem, covering most of western South America, which seems to be one of the most curious pieces of country on the face of the Earth, for it is the only continent where a track of deserts is able to cross diagonally a great chain of high mountains from border to border.

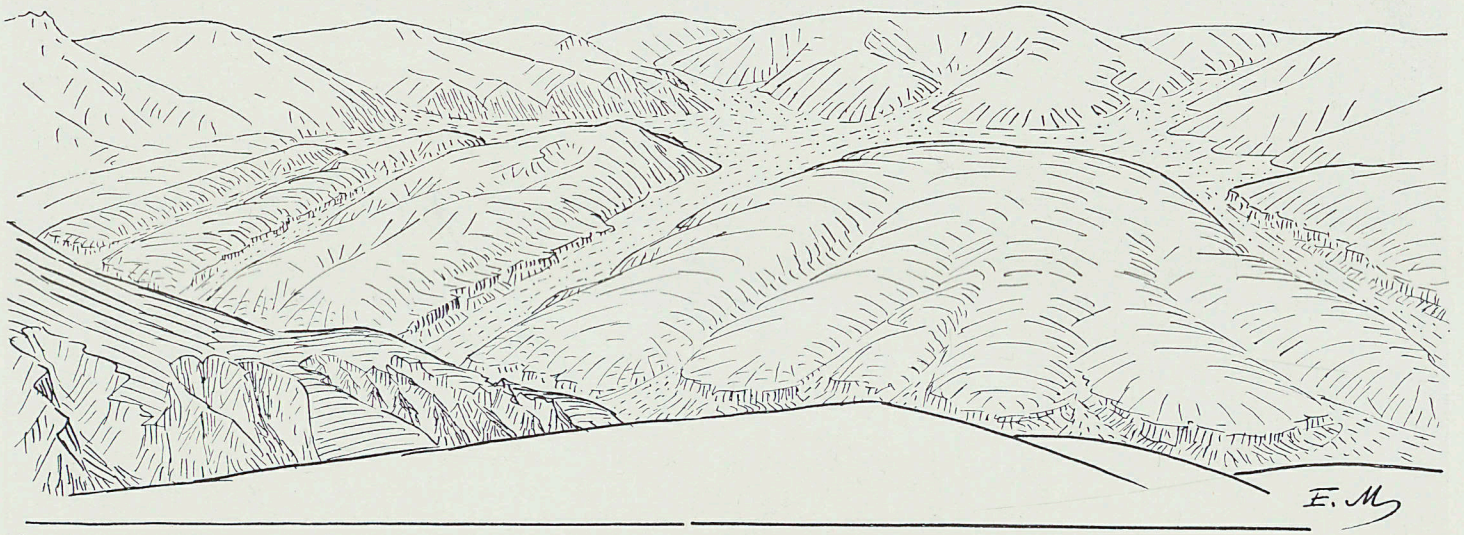
Contrasts in the landscape

One of the most interesting places to visit in north-western Argentina is the vicinity of Tucuman. Starting from Buenos Aires, you may notice that the true Pampa does not extend farther to the north than the latitude of Cordoba. The *Monte* is a sort of forest, thorny bushes or small trees with small or evergreen leaves, mixed with cactus and cereus, which cover most of the plain as far as Bolivia. On approaching Tucuman, cultivated fields and numerous villages are seen. This is the most important sugar-belt of Argentina, and the fine town of Tucuman would certainly not have such well-tended avenues and such beautiful gardens without the benefits of the sugar-cane in the preceding years. You will not be surprised to hear that there is at present a serious drop in these benefits. Some of the *Ingenios*, as they call the sugar factories, are closed, and the cultivation of the cane is replaced by that of vegetables for the great city of Buenos Aires, especially in the *Falda*, that is to say, the belt of alluvial fans at the very foot of the mountain which can be easily irrigated and where frost is practically unknown. I found there, near the little town of Concepcion, on the border of the splendid tropical forest of Alpachili, not only some German colonists, but a Frenchman, recently established and cultivating mostly potatoes.

There are still many *Ingenios* at work, and the cane-fields extend as high as possible up the lower slopes of the mountain, which rise very abruptly, covered with a dense tropical forest. I must say that this is the most beautiful forest I have seen in tropical Argentina; it does indeed lack palm trees, but the great "Laurels" (*Nectandra porphyria*), some 100 feet high, are covered with creepers and epiphytes with red, violet, or yellow flowers.

We see that contact of the mountain with the plain is affected by a humid belt where there are running rivers all the year. The total amount of rain is over 1200 millimetres, and irrigation is necessary only for a rapid growth of vegetables in the dry and rather mild winter season. It is the same all along the border, up to the Bolivian frontier. But the towns of Salta and Jujuy are in a more arid landscape than Tucuman, for they do not lie like the latter at the contact with the great plain but in mountain basins, 1200–1300 metres above the sea, west of such sub-Andine Sierras as the Sierra de Lumbrera or the Sierra de Metan, which are nearly as humid and densely wooded as the Sierra of Tucuman.

Terrace of Pueblo de Pucara near Tilcara (25 miles north of Volcan); on the opposite slope stream issuing from old terraces, with two confluent alluvial cones; cereus in foreground



Sketch by Professor de Martonne of typical country above the "meseta" level (c. 3000 metres) between the Puna de Atacama and the Sierra de Chañi

The fact is that humidity is the privilege of a very narrow belt of front ranges. The mountain proper is dry if not desert. This is true of the whole of north-western Argentina, with the one exception of the sub-Andine Sierras. And the best place to get a strong impression of this contrast is Tucuman, for in no other place does the mountain rise so rapidly, reaching in a few kilometres to an altitude of nearly 5000 metres above the sea. This makes condensation more effective on the lower slopes and prevents every bit of humid air from touching the first depressions west of the high summits. Crossing by aeroplane above these bold mountains affords the best opportunity. I fear the photographs I managed to take on this trip were not all of the best, but the impressions which the passage left on me are some of the most vivid which I have ever experienced as a traveller.

As soon as we leave the ground, we have an interesting view of the system of agriculture of the sugar-belt, every *Ingenio* being the centre of a village. In a few minutes we are near the first ridge, the Sierra de San Xavier, covered with a luxuriant forest, and are now flying over its rounded top, where no forest is seen, but only gardens and bungalows. This is the summer resort of planters, and clearing has done something for the disappearance of the trees, but not all. Then I have been on foot over the ridge, where nothing grows but those patches of dry grass.

The summits of the Cumbres Calchaquies and the high Aconquija are in full view. From 2000 up to 4000 and 5000 metres they are completely bare; outcropping rocks are seldom to be seen, and slopes ascending in ledges lead to rounded crests, where you hardly find in mid-winter (which is the dry season) any patches of snow. We should have to fly a little more to the south over the high Aconquija itself, to see the mountains carved in glacial amphitheatres which bear *névés* if not small glaciers, as I was able to remark on a journey from Concepcion to Andalgala.

The flight now brings us over the Tafi valley. It is a dry country, where agriculture is conducted with the help of irrigation, while the cattle spread over the grassy slopes. These slopes look like immense talus of debris descending from the top of the mountain. Only in few ravines can you see running water apparently fed by small snow patches.

The valley ends in a large amphitheatre with slopes so graded that you would think you were flying over a plain. But this is a gap. Suddenly the ground breaks in precipitous slopes, and the view extends over the *bolson* of Santa Maria. We are flying over a true desert. Badlands, salt-grounds everywhere, and to the south the white belt of the " campo de arenal " (sand-dunes).

It is hard to believe that this trip takes only an hour, even with a small aeroplane of low speed. There are certainly other places where great contrasts of climate and landscape may be observed by crossing a mountain. I remember the clouds hanging over the Bay of San Francisco, clinging to the western front of the Sierra Nevada of California, and the bright sunshine on the desert plains of the Great Basin. I have experienced too the heavy rains and the humid atmosphere of the coast of Asturia in northern Spain and the sunny steppe landscape of the plains of León and Old Castile. But in both cases, as in many similar, we start from the seaboard itself and we have to travel some 100

kilometres to find dryness in an enclosed depression; while in north-western Argentina we are far from the sea and are carried by a flight of only 100 kilometres from the dense tropical forest to the desert. But the most striking fact in this case is that dryness is not limited to some valley behind the humid front range; it is the whole of the mountain mass which is the domain of aridity. As you penetrate it, ascending by the wild *quebradas*, you see a more and more brilliant sun, and more and more desert landscapes.

In the little town of Jujuy or in the city of Salta, for example, you are in an intermontane basin, but not far from the humid border. While torrential rains pour for months during the summer, the sky remains blue for long months in the winter; but sometimes the clouds override the front range and proceed as if they would catch the high Sierras, that ordinarily rise with their bare rounded slopes so monotonous and so sunbeaten that they seem to float like a dream above the whole landscape. Such clouds however must not prevent you from starting for a trip in the mountains. Going up a few kilometres you get the sun, and the temperature seems to rise as you are ascending. Walking on the stony slopes, among the big *Cereus*, which are called "Cardon," in the midday is a rather hot experience; but the best zone to be sunbaked is between 2500 and 3000 metres. Only in the main valleys can you see water flowing in the midst of a vast plain of boulders, and in many places white patches of salt-ground are shining.

As you go farther up to 3500–4000 metres the *Cereus* become smaller and smaller, and finally disappear. A dry steppe of hard bushes, leaving more and more bare ground, extends on the slopes. We are in the Puma de Atacama, a rolling upland of some 3500 metres mean elevation, mainly composed of old rocks (palaeozoic and even crystalline) with lava flows and volcanoes rising to 5000 metres. You encounter the last stream near San Antonio, at a height of 3800 metres. It is fed by hot springs, but gets lost some miles away. Even the valleys disappear, and between the heights of the land are enclosed basins (the *bolsons*). Immense slopes of stony soil descending from the summits lead to the flat centre, the *Salar*, a plain of salt loam, sometimes white and hard, sometimes brownish-red and looking as if ploughed. One hardly understands why a railway should be built to reach this wild region as far as San Antonio de los Cobres. The capital of the *Territorio de los Andes* is a most lonely place at 3800 metres, where life awakes only on the arrival of the weekly train. Mining people, hunters and guards, mostly Indians or half-breeds, but Europeans also, meet at the Bazar, where you can buy many things and have a good drink, and hear curious stories of pioneer life in the Puna.

Driving farther away you will see rather primitive mines of copper with some silver and gold and the exploitation of the borate salts in the great Salars that extend over hundreds of square miles. The more you go to the west approaching the Chilean frontier, the more arid and desert grows the landscape.

Now it is clear that the Andes of north-western Argentina are a huge block of mountains, which, instead of being more humid than the plains, as is the rule, are much drier. Meteorological statistics enable us to draw a cross-section (Fig. 2) of the amount of rain which, instead of running parallel to the section of the relief, runs mostly inverse to it. But the curious landscapes of north-western Argentina are not only due to an abnormal distribution of

humidity, and the physiographer cannot fail to consider the work of tectonic process which is responsible for the general features of the relief, as well as the sculpture and degradation by erosion.

Turning to the last subject, we are again faced with unusual facts. It is not in the humid front ranges that the mountains seem to be more strongly attacked, that the slopes are more rapidly carved, that more debris is carried down to the valley bottoms, but in the intermontane drier basins, as the plain of Salta, and farther up in the region of the wild *quebradas* where we noticed the increasing aridity, between 1500 and 3000 metres. I know that bare and dry soil is more exposed to weathering and torrential action. I have seen the Badlands of the western United States, as well as the terrible torrents of Ubaye in the Alps of Southern France; I travelled through the high plateaux of Algeria and the border of Sahara; but I did not expect what my eyes have seen while visiting the *quebradas* north and west from Jujuy and Salta. This is the land of bare strongly dissected slopes, with rock pinnacles and organ-

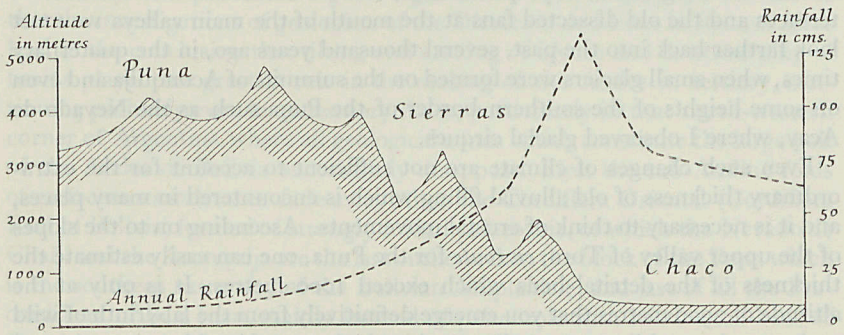


Fig. 2

like cliffs, the varied colours of which, white and brown, red and violet and green, are vivified by the dryness of the atmosphere.

From every ravine pours a stream of pebbles and boulders which spreads in an alluvial fan with a slope of 15 degrees. Every tributary valley terminates with such a fan, ten times as large as you would expect from the catchment area. The main river cuts into the front of these fans producing cliffs 30 to 50 metres high. Ravines are carved in them, and from each pours a new stream of boulders, making a new fan. Many times I saw three formations of fans imbedded one in another. Sometimes the last was growing so rapidly that the remnants of older dissected fans were drowned.

The most conspicuous case is that of the *Volcan*, which blocks the Quebrada de Huamaca. Going up from Jujuy, you see the huge mass of this fan rising so high above the valley bottom that you think you are approaching a mountain pass. On the other side remnants of a lake are evident, a true plain of comparatively fine alluvial deposits with swamps and meadows and fields which do not need irrigation. The river has cut a deep wild gorge, biting even into the rock of the left valley slope. The name of *Volcan* may be due to the fact that the whole mass of the fan moves like a lava-flow after heavy rain in the summer.

At the mouth of every great valley entering an intermontane basin, like the plain of Jujuy or Salta, there is a staircase of four or five terraces, the highest of which are the remnants of alluvial fans standing some 200 metres above the river. The lower terraces can be traced farther up into the *quebradas*, ascending with a slope of 2 to 3 per cent. But as a rule the bottom of every valley is a large plain of boulders, sometimes a kilometre broad, ascending rapidly. It is evident that every stream is overloaded with debris coming from the slopes and from the tributary valleys. You may see at a confluence rock islands rising abruptly from the alluvial plain which means the burying of a crest formerly sculptured by erosion.

It is rare indeed to see such a severe conflict of degradation and aggradation. The more violent the erosion on the slope, the more rapid is the accumulation on the valley bottom; but as the alluvial fill grows, drowning the relief, erosion has again the advantage. Everything tells a long story of alternating decay and accentuation of the relief. Slight changes in the climate may be responsible for the building of the superposed fans, but to understand the staircase of terraces and the old dissected fans at the mouth of the main valleys we must look farther back into the past, several thousand years ago, in the quaternary times, when small glaciers were formed on the summits of Aconquija and even on some heights of the southern border of the Puna such as the Nevado de Acay, where I observed glacial cirques.

Even such changes of climate are not sufficient to account for the extraordinary thickness of old alluvial filling which is encountered in many places, and it is necessary to think of crustal movements. Ascending on to the slopes of the upper valley of Toro, *en route* for the Puna, one can easily estimate the thickness of the detrital beds which exceed 1000 metres. It is only at the altitude of 2900 metres that you emerge definitively from the labyrinth of wild ravines and crumbling crests, all carved in the layers of boulders, gravels, and sands, arriving at a sort of vast terrace, which is properly called *meseta*. Nobody would imagine that the whole detrital deposit was formed in quaternary times; there is certainly much of Pliocene, if not of older ages. In some places the beds appear tilted. Even near the valley bottom there are ridges of upturned sandstones or conglomerates, the pebbles of which are as fresh as those of the alluvial fans.

An extremely interesting point of view is found a little above the *meseta* from which I got rather poor photographs and a better sketch (facing p. 5). One sees how the detrital beds extend between the western front of the Sierra de Chañi and the eastern border of the Puna, being slightly bent in the form of a syncline. This is an old tertiary *bolson*, incorporated in the mountain by the growth of the Andes and dissected by erosion. The physiographer remarks a true *cuesta* facing the Sierra de Chañi with consequent valleys and a subsequent depression; and all these forms of erosion, developed under more humid climatic conditions, appear half drowned in the flow of detrital material which is now continuously descending from the Sierra, spreading all over the subsequent depression and breaking through the gates of the consequent valleys down to the main valley bottom.

Now these remarkable features are not a local case; the torrential zone of the *quebradas*, described in the vicinity of Salta and Jujuy, may be found also as

far as San Juan de Mendoza. If time allowed I could show many pictures of the same facts. I will only remind you of these *Cerros* made of almost vertical beds of coarse conglomerates, half drowned in the slope of coalescent fans which descend from the front-range as the Cerro de la Gloria itself in Mendoza, and of the intermontane basin of Uspallata with its staircase of terraces and its upturned beds of tertiary conglomerates overriden by mesozoic strata.

The story of the Andes of north-western Argentina is that of a mountain which seems to have been demolished while it was growing and is formed for a great part by its own debris. And this story could be traced all through tertiary times, probably as far as the cretaceous itself; for the front ranges or sub-Andine Sierras which block the basins of Salta and Jujuy are mainly formed of cretaceous strata of detrital origin.

Such a geological story involves not only changes in climate, with alternating humidity and dryness, but repeated phases of tectonic disturbance, which may have prevented a good organization of hydrography. The fact is that the investigations of geologists of the Direccion de Minas in Buenos Aires lead to the conclusion that tilting and arching of blocks and downwarping of basins played the greatest role in the making of the Andes in tertiary, continuing probably even in quaternary times, particularly in that north-western corner of Argentina where all geological zones which constitute the large belt of the Andes of Bolivia successively disappear. First the sub-Andine folds of cretaceous sandstones fade away; then the Cordillera Oriental (Cordillera Real of Bolivia) formed of strongly folded palaeozoic, of which the Nevado de Chañi and the Aconquija are the last outliers, then the block of the Puna which is the southern extremity of the Bolivian Altiplanicie, and last of all the Precordillera of San Juan, mainly formed of palaeozoic with continental beds of Gondwana and old eruptives. To the south of Mendoza nothing remains but the Cordillera occidental, the only zone which reminds us of the alpine mountains of Europe, being formed of strongly folded marine mesozoic strata, but with such important series of volcanic rocks that the physiography is very different from that of the Alps.

Such a dissociation of a complex system of mountains cannot be produced at once. There has been repeated tilting and downwarping of blocks. This affords the best opportunity for rejuvenated local erosion and for local accumulation, preventing the organization of the drainage even where climate would not make it completely impossible. But the lack of sufficient rain still appears as the main fact that controls the physiography; and while it is good to think of the antiquity of dryness and the geological conditions correlated with it, we have to deal more especially with the present.

Areism

Now what we actually observe can be summarized as follows: Crossing from east to west we meet, after the humid front range, a zone of particularly violent erosion and powerful accumulation, where more debris is coming down the slopes than the streams flowing in the *quebradas* can carry to the plains; and later, in the Puna and its southern border, a zone where there are no streams and no valleys, but enclosed basins with Salars. North-western Argentina is

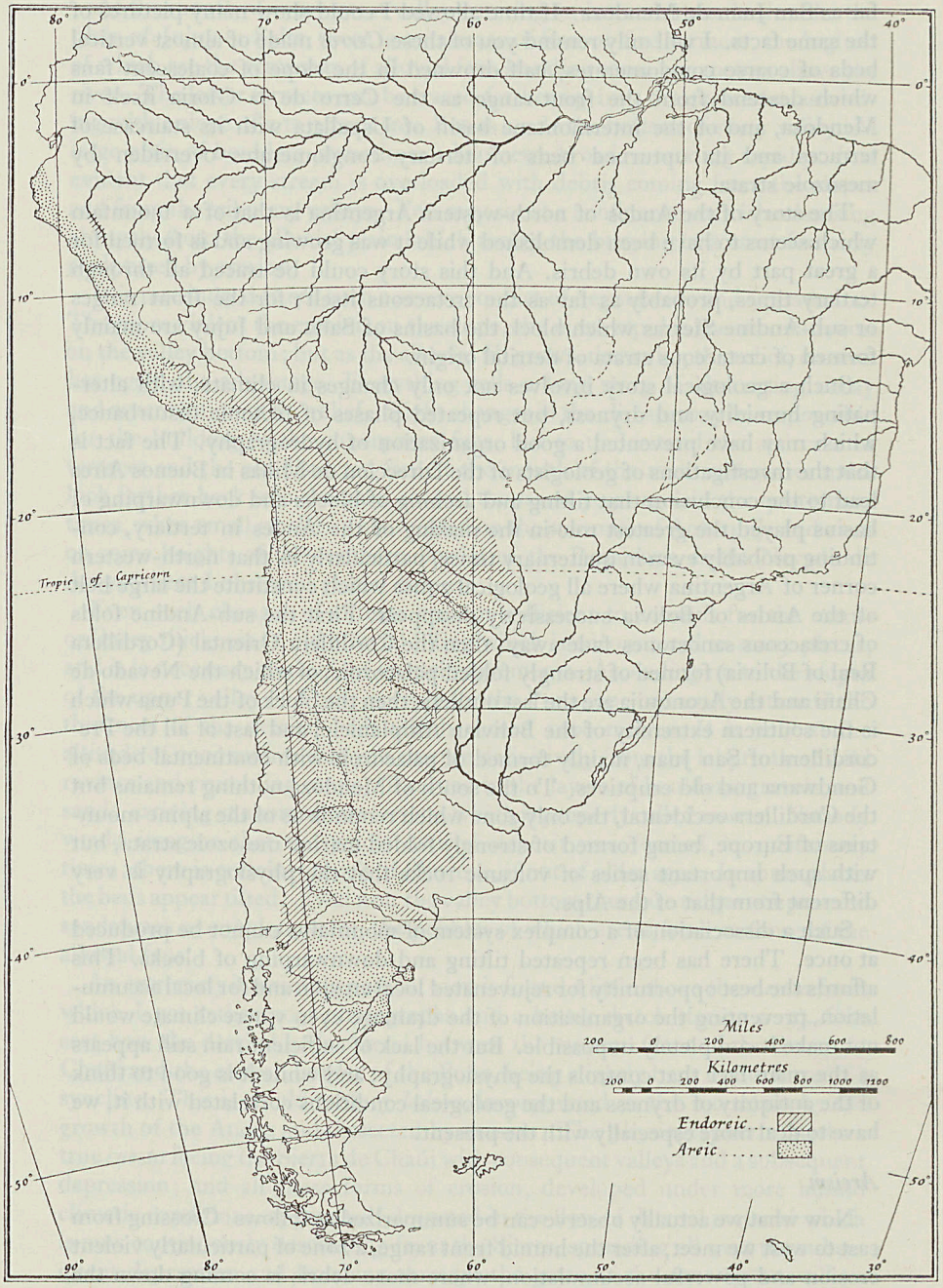


Fig. 3. Endoreic and areic regions in South America

one of these regions from which no water reaches the ocean and no debris is carried as far as the seashore.

I confess that this is the very reason why I was so anxious to visit it. I had already seen similar countries—Mexico and the western United States, Algeria, Morocco, Egypt. Some geographers who are present may remember that I presented to the International Congress of Geography in Cairo a world map, produced with the assistance of L. Aufrère, showing the extent of the regions which I called *endoreic* in general, and particularly *areic* when the climate prevents any through-flowing stream. The same colleagues know that the map was improved as much as possible when it was distributed on the occasion of the International Geographical Congress in Cambridge, as a special publication of the International Geographical Union, when Sir Charles Close was acting as Secretary of the organization.

One of the interesting features shown by this map was the great extent of endoreic and even areic regions, a much greater one than was expected. It was pointed out that these regions are ordinarily disposed in belts, according to the zones of climates; that the tropical belt, which is the most developed, begins on the western shore of each continental mass, extending more or less to the east, while the less developed belt of the temperate zone is found only in the interior; that both belts may be in contact in the centre of a great continent, as is seen in Eurasia; but that the general trend of the areic zones remains from west to east, and that it never crosses from ocean to ocean. To this general rule there is only one exception, and that is found in South America, where the areic belt runs along the meridian, beginning near the Equator, crossing diagonally the whole continent from Pacific to Atlantic, and crossing in the same way, without any respect to the relief, this huge track of mountains which is called the Andes. And this extraordinary cross-line occurs in north-western Argentina. (See Fig. 3.)

But these conclusions were derived only from the study of existing maps and rather poor maps, I must say. You will understand that I could not miss the first opportunity of testing them in the country. I had to cover as much ground as possible in a short time, using every mode of locomotion. The automobile, on what is called a road in north-western Argentina, proved the most tiring, and I took much advantage of the aeroplane. Now I can say I have seen with my own eyes and I am able to trace more exactly on a map of larger scale the dry belt crossing from the Chilean shore of the Pacific to the great plain of Argentina, from which it continues to the south as far as the Atlantic in Patagonia.

It seems hardly necessary to remind you of the desert character of northern Chile, where I had a very interesting flight over the nitrate belt, starting from Antofagasta. But I insist on the complete aridity of the western Cordillera, where volcanic summits like Llullaillaco, rising to 6600 metres at the frontier with Argentina, hardly show any patches of snow. We have seen what is the Puna de Atacama, and I have shown enough pictures of the torrential zones of the *quebradas*. You remember that a narrow belt of forest extends in the front ranges bordering the Chaco plain. But to the south of Tucuman, even this humid zone disappears, while the high crest of Aconquija merges into low summits, which finally are lost in the plains. A large gap of dry ground with

salt soil (the *Salinas grandes*) must be crossed to reach the highest of the Pampean Sierras, the Sierra de Cordoba.

A few pictures will be sufficient to show that this massif, although so much celebrated in Argentina, actually marks a corner of the dry belt. To the citizens of Buenos Aires, who do not know anything but the Pampa, the surroundings of Cordoba may appear as the most pleasant and refreshing place, with so many summer resorts and beautiful irrigated gardens; but on the front range itself (the Sierra Chica) you do not find anything like the luxuriant forest of Tucuman, only the thorny bushes of the *Monte* with cereus and cactus; and as soon as you enter the Sierra Grande all trees disappear and the granite plateau of the Pampa de Achala recalls the border of the Puna de Atacama.

West and north-west of the Sierra de Cordoba dryness prevails throughout. This is the region of low half-enclosed *bolsons* and high block mountains, where the strong cohesion of all the structural zones, which make the greatness of the Andes, is lost, as was previously shown. And while the *Nevados* afford some water for irrigation, thus enabling the development of small centres on the border of each *bolson*, not a single stream can be formed and everywhere appear *Salinas* and *Medanos*. We understand how the dry belt terminates the cross-line of the Andes arriving at the eastern plains.

The fact is exactly corroborated by the map of what I called the Index of Aridity (which is a function of temperature and precipitation). By plotting all the available meteorological records in Argentina, Chile, and Peru, I got a very interesting map of this climatological Index. The lowest values actually cross the Andes from Antofagasta to Catamarca. (See Fig. 4.)

To the north of this line a narrow humid fringe is found in the eastern front range; it grows larger and larger as it approaches the Equator, but the whole mass of the mountain still remains arid in Peru. To the south of this line the conditions are exactly inverse. The greatest aridity is found in the front range of the Pre-cordillera of San Juan, while the Chilean front can no longer be considered as dry at the latitude of Santiago, and becomes more and more humid going farther to the south.

Anybody who crosses by the Transandine railway from Mendoza to Santiago or Valparaiso cannot fail to remark the strong contrast, which is more accentuated in winter. The first snow is encountered near Puente del Inca, on the upper Rio Mendoza above 2600 metres, where an hotel has been built for winter sport. The pass itself at 3200 metres is completely blocked, and the train runs in long sheds before entering the tunnel. The rapid descent on the Chilean slope recalls alpine scenery: hanging valleys buried in snow which hardly allows a view of the glaciers, repeated steps in the valley and wild gorges cut in rock-bars; the last snow-patch is found on the valley bottom near Rio Branco at 1500 metres.

I think it is clear why the Andes of north-western Argentina are a dry range, the only one in the world where dryness prevails from border to border. The diagonal of aridity is found near the tropic, where dryness is common on the western shore of each continent, and it reaches the eastern plains at the place where the humid belt of the eastern ranges disappears, while the western front is not yet exposed to the moisture-laden westerlies.

This is not only a very peculiar physical feature; it may be quoted as interest-

Between Volcan and Tilcara

Looking over great alluvial cone near Pueblo de Pucara, with front dissected into terraces and ravines; old ravined terraces with pyramids in middle distance; summit of (?) tertiary embankment in background

ing even for the economist and the historian. It is amazing to hear of the ancient commercial relations between northern Chile and the towns of north-western Argentina. Caravans of mules and large herds of cattle used to cross 400 kilometres of high mountains from Salta to Antofagasta. Nobody would have

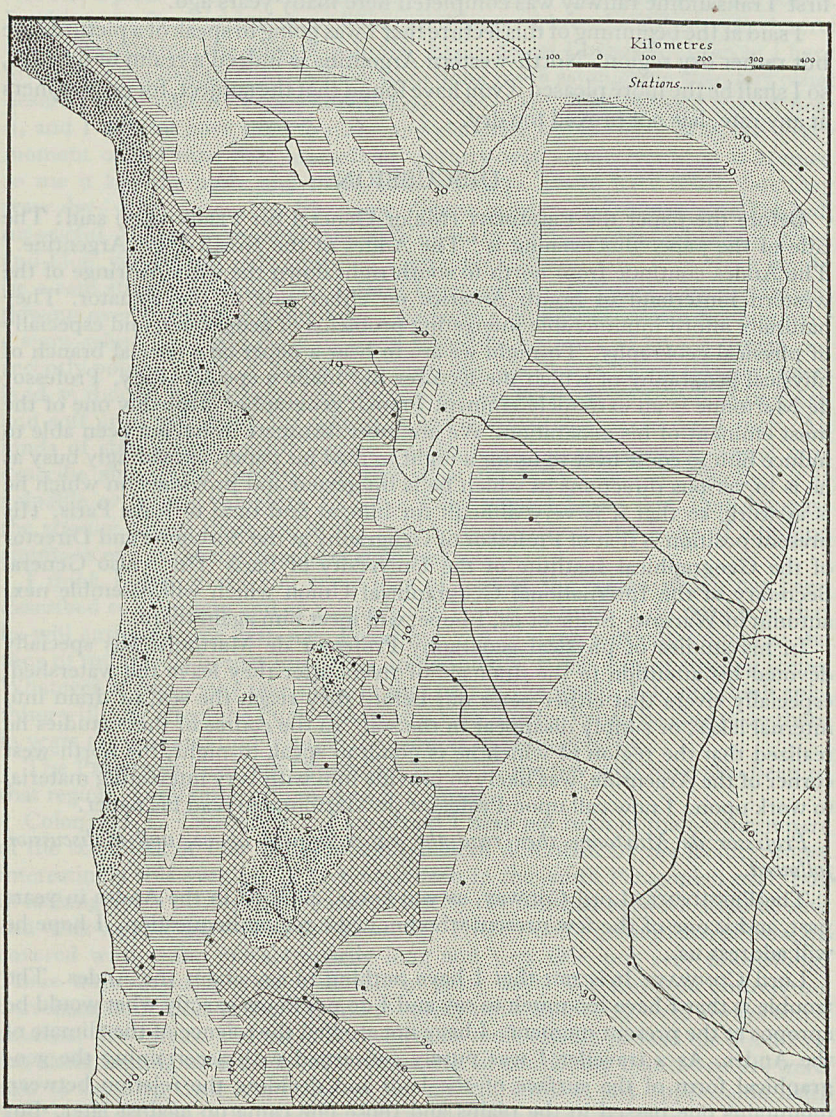


Fig. 4. Index of Aridity, northern Argentine

thought of such a journey if dryness had not prevented snow cover. It is for the purpose of continuing this tradition that a railway is being built at great expense, starting from Rosario de Lerma, near Salta, and at present reaching only San Antonio de los Cobres, in the high Puna de Atacama. Between

Mendoza and Santiago crossing is much easier, for the mountain is narrower and the snow accumulated by winter storms on the Chilean slopes melts away in the dry summer. This helps one to understand how the plains of Mendoza were a part of the Chilean province before the independence, and how the first Transandine railway was completed here many years ago.

I said at the beginning of this lecture that I was going to speak of a picturesque but rather dry region. North-western Argentina is indeed a realm of dryness, so I shall be the more pleased if you have found that the subject, for geographers at any rate, has not proved too dry.

DISCUSSION

Before the paper the PRESIDENT (Major-General Sir PERCY COX) said: The title of the paper this evening is "The Andes of the North-West Argentine." The Andes continue from north to south right down the western fringe of the western hinterland of South America on either side of the Equator. They naturally afford innumerable interesting problems of geography, and especially of physical geography. To-night we are to hear a paper on a special branch of physical geography of which the lecturer has made a special study. Professor de Martonne is an extremely eminent French geographer, probably one of the most eminent of his generation. We are most fortunate in having been able to induce him to come over to us for a night to read his paper, exceedingly busy as he is in various directions in which he is interested and problems on which he is at work, so that it is very difficult for him to find time to leave Paris. His present position is that of Professor of Geography at the Sorbonne and Director of the Geographical Institute of the University of Paris. He is also General Secretary of the International Geographical Union which will assemble next autumn in Warsaw. Some of us, I hope, will meet him again there.

In his studies of physical geography Professor de Martonne has specially devoted his attention to the drainage of rivers after they leave the watershed, especially rivers that either peter out before they reach the sea, or drain into internal lakes, or simply disappear in the soil. In the course of these studies he realized that the region of which he is going to speak to-night, the north-west corner of the Argentine, was likely to provide him with very interesting material to work upon. I now call upon Professor de Martonne to read his paper.

Professor de Martonne then read the paper printed above, and a discussion followed.

The PRESIDENT: Lord Conway, as you know, climbed in the Andes in years past, and is one of the few present who know the region in question. I hope he will address us.

Lord CONWAY: It is not that I have nothing to say about the Andes. The trouble is that I have too much to say and I do not know exactly what would be apropos at the present moment. I have not studied the science of the climate of the Andes. As a traveller I was purely concerned with ascertaining the geographical form of the surface of the land and deciding the relation between mountains one passed in the plains and those one came up against later. But as I look back to the period of that journey, now thirty-four years ago, there are certain pictures that arise in my memory as characteristic of other scenes: there are certain strongly characteristic views. Apart from the snow mountains, the climate and so on, which are much the same whether in the Himalayas, the Andes, or the Alps, there was a region through which I passed in Southern Peru and Northern Chile which struck me as one of the most astounding looking

places in the world. I have never seen anything like it. At one time I was much interested in astronomy and used to look through a large telescope turned on to the surface of the moon. Thus I became familiar with the lunar landscape, with Copernicus and all its peaks. The piece of South America to which I am referring was like a piece of the lunar landscape—like nothing one had seen in the world. I refer to the Puna of Atacama. I love all deserts. I love the Sahara; the deserts of South America; the deserts of India. Every desert I have ever been in I have loved, but the desert of Atacama is something more astonishing than any other desert I have visited. I only spent three days there. The railroad passed near it, and I did not have time to make any elaborate examination of it, but every moment of the time that marvellous country was within my view it seemed to me it became more and more extraordinary. There were lakes, but they were dry—they were white like snow. There were salt lakes, dry, uninhabited, un-useful. There were mountain cliffs of every kind of colour—brilliant green and blue, yellow and red; stratified, incredible colours. And then there would be a rare stream flowing from I don't know whence to I don't know whither, flowing over one of the white lakes; perhaps a blood-red stream flowing over a snow-white lake; and close by there would be a stream of lava, a stream not recently poured forth: it might have been any age, but it lay on this dry desert land as though it had been recently poured out on it. It appeared to be fresh and soft until you came up against it and discovered it to be hard rock. All kinds of strange and weird images rise in my memory which I cannot now describe and which belonged to that most marvellous region. Whether it is valuable or utterly valueless, I do not know; but I know this, that amongst the strange scenes there are in the world the scenery of the Puna of Atacama counts as one of the most striking and most wonderful.

I think I have given you some idea of part of the region which has been described so minutely and so scientifically by our lecturer. I do not know that he will entirely agree with me. Possibly I was in some particular mood at the time of my travels in that Puna, but, undoubtedly, it was a most striking scene. Whatever changes may take place in that part of the world, I do not think anything will ever affect the Puna of Atacama very much. I shall be able to go there in years to come and find it much the same as in years gone by.

The PRESIDENT: Colonel Crosthwait is one of the few who have also been to that region. I call upon him to say a few words.

Colonel H. L. CROSTHWAIT: I am afraid I have not been in the northern part of the cordillera of Los Andes which has been described by the lecturer most interestingly this evening. I have only been in the south Patagonian part, but in looking at his photographs I was struck by the contrast between what he saw and what we saw when down in the south. There we saw great plains of pampas covered with grass, extraordinarily long and very dry, but very nourishing. There were no aeroplanes or motors in those days. We travelled entirely on horseback with mule transport, and for every mule load there were always three animals. We carried no forage, but while one mule carried its load the other two ran along feeding on the way. The grass was so nourishing that the mules were able to keep up their condition on the march, without any appreciable halt. That is the difference that particularly struck me between the country I travelled over and that which Professor de Martonne has shown us.

Then there was something peculiar about the Santa Cruz river. To the south of the river there were no armadillos; but on crossing to the north one finds them. It appears that the river has stopped the progress of the little animal: it is a good example of the spread of animal life being arrested by a natural feature.

We visited the famous Cave of the Mylodon, where the remains of the Giant Sloth were found. From the freshness of these remains it was thought that the animal might possibly not be extinct. So some enterprising newspaper got up an expedition, led by Mr. Hesketh Pritchard, to search for it in the recesses of Patagonia, but without any result. It certainly was remarkable how well preserved the skin of the sloth was and what a quantity of it there was lying about in the cave. A model of this cave used to be in the South Kensington Museum.

The PRESIDENT: Is there any one else who has experience of that country and would like to address us? No? In that case it remains for me to ask you to thank the lecturer. He has been describing to us a most unusual piece of country. terribly inhospitable to look at on the screen. I am afraid it will be some years before photography can reproduce the colours that Lord Conway was so impressed with in those landscapes. The fields of giant cacti were especially interesting. You will realize that only intense enthusiasm could have induced Professor de Martonne, ordinarily working fourteen hours a day in Europe at his profession, to make that journey to the Andes to verify his belief that certain problems with which his studies confronted him would be found well represented there. His achievement in diagnosing and proving on the ground the existence of that dry belt running diagonally from north-west to south-east right across the mountain range was a truly remarkable one. I should imagine that as a feature of physical geography the phenomenon is probably unique.

I do not feel able, and I doubt if we here who are plain geographers are able, to go deeply to-night into the scientific aspects of the problems on which Professor de Martonne has discoursed to us and of which that region presents so many examples. He has made them his own special study and we are fortunate in having heard him to-night explain the satisfactory way in which his theories have worked out in practice in the Andes. I will now ask you to join with me in thanking him very much for coming over to England to read his paper to us and in expressing the hope that he will have equal success in the further researches in physical geography on which he is engaged.

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