ADDITIONAL NOTICE.

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Notes on the Physical Geography of Paraguay. By KEITH JOHNSTON, Esq.

PARAGUAY may be regarded as a large promontory of the great table-land of Brazil, of about the same extent as England, bordered by the two main tributaries of the Paraná, and abutting in the west and south on the vast sea-like levels of the Chaco and the Pampas, which fill the central region of South America. No part of it, as far as it is known, much exceeds 2200 feet, and none falls beneath a level of about 250 feet above the sea.

Midway in the artificial frontier which separates Paraguay from Brazil on the north, the line of which has been marked from the mouth of the River Apa, in 22°, to the great falls of the Paraná, in 24° s., a broad belt of heights passes across from the Brazilian table-land, maintains a southward direction almost continuously through Paraguay, and forms the water-parting of its interior rivers, terminating at last in a series of bluff heights on the Upper Paraná, where this river, turning westward, separates Paraguay from the Argentine province of Corrientes. This is the main line of height in the country which determines its general form and its slopes.

Taking the southward channel of the River Paraguay as indicating the lowest level of Central South America, the form and elevation of the lands to east and west of the portion of it which bounds the country, afford a strong contrast. On the Paraguayan side, especially towards the north of the Republic, the land (as shown by the barometric heights, table, p. 506) rises from its east bank steadily towards the interior, gaining an average of about 200 feet in the first 50 miles inland, and an equal amount in the second and third of such distances as the base of the central height is approached. Up to this the land swells in gentle undulations, with open, ill-defined valleys: excepting where a few isolated hills are scattered, no prominent ascent is observed. The plateau of Amambaÿ, as the central height is named in the north, has, however, a sharply-defined edge to the westward, which is of considerable height, and in some places is almost precipitously steep. The differences of the elevations of the Laguna de la Reunion (1069 feet), and of the first camp on the plateau (1640 feet), and again of the point called the Mangrullo, above the Yerbal of Chiriguelo (1777 feet), and the Arroyo Claro, at the base of the plateau edge (618 feet), show the amount of the ascent from the river-slope to the highland.

Turning now to the western or Chaco side of the datum line given by the Paraguay River, the land in contrast to that of the eastern bank appears of a uniformly dead level, without a single rise or landmark along its horizon-line.

The view westward across the river from any height on the Paraguayan side always presents the same flat sea-like plain covered with forest, with here and there open patches of grass-land or marshy tracts, or shallow flats of water, glittering in the sun.

Looking eastward towards the valley of the Upper Paraná from the central height of Amambaÿ, the land appears to descend much less rapidly than on the west: broad spurs from the plateau stretch away towards the river, enclosing deeper tributary valleys between them. The whole of this slope of Paraguay has a considerably greater elevation than the western one. The Alto Paraná below the great fall in 24° s. is probably at an elevation of several hundreds

of feet above the corresponding point of the Paraguay River in that latitude, and its valley, unlike that of its great western tributary, being shut in between the heights of Paraguay and those of the southern provinces of Brazil, belongs to the plateau, and not to the plain. The river only escapes from the deep trench which it has cut for itself, where it broadens with less rapid current in turning eastwards to pass by the levels of Southern Paraguay.

The isolated heights of Eastern Paraguay deserve some attention. Throughout those which we have noticed in the north between Concepcion and the plateau the same form and character is observable. The circle of Cerro Corá, the Sarambi or scattered hills, and the hill called Tranquerita, are flat-topped, or gently-rounded masses of red sandstone, rising abruptly from the undulating country which surrounds them, to about 600 feet of relative elevation; fragments apparently of a formerly general elevation which has been swept away. The form of the Tranquerita is specially illustrative of many of the isolated hills of Eastern Paraguay. It is a long, narrow, rectangular block, extending for several miles north to south with perfectly flat, tree-covered top, and with a precipitous cliff extending quite round the upper half of its height.

A more important chain of outlying heights stretches across the south-western angle of the country from the neighbourhood of the capital to near the Alto Paraná. The broad plateau on which Asuncion is situated is a main feature of this series. Its edge skirts or forms the left bank of the river southward from the city for 25 miles, and it extends inland for 40 miles to the village and plain of Paraguari. The greater part of the capital is built immediately on the top of its red sandstone cliff edge, and some of the houses, such as the Cabildo, or old Government-house, are so close to the verge, that a step or two from their doors would lead over the precipice. On an average this Asuncion plateau is about 200 feet in relative height; its surface is undulating, but the borders are marked not less distinctly to north and south than they are towards the river. On the north side a number of rounded, conical hills, such as the cerros of Areguá, Ibitipané, and Pirajú, rise above its level; the south edge is also marked by several prominences, among which the Cerro de dos Cruces at Jaguaron, a mass of red sandstone with flat summit, recalls the form and character of the Tranquerita before mentioned. The Cordillera of Altos rises to a somewhat greater general elevation north-eastward of the Asuncion plateau, and bending round from two prominent hills (the Cerro Costa and Cerro Sto. Tomas) at Paraguari, also abuts on the River Paraguay. Between it and the former heights lies the valley of the Salado, containing the Lake of Ypacarai (12 miles in length). The Cordillera of Altos slopes steeply to the Salado Valley, but on its north-east side falls in a number of spurs and deep-cut valleys to the River Pirebebuy. A spur of this range also stretches out eastward from the angle which is formed by the hills of Paraguari, having a southern slope termed the Costa Pucú (long border), along which runs the main route to Villa Rica. At the pass of Sapucai on this track, a chain breaks off to southward, and connects itself with several irregular masses of height, which occupy the country southward as far as the middle of the River Tebicuary, dividing some of its tributaries from those of the great lagoon of Ypoá.

One of the most remarkable features within this group of heights is the plain of Paraguari, a level grass-land of about 20 miles in extent each way, almost completely shut in by wooded hills on every side, and suggesting the basin of a former lake. The heights previously described close it steeply on the north and east, and on the south there rises a remarkable block of hills called the Cerros of Acaay, with lateral branches towards the villages of Ybicui and Carapegua. The perfectly conical shape of many of the hills which surround this plain is remarkable. Of such the Cerro Costa, Cerro Ybitimi, Tatuqua (the "burrow of the armadillo"), and the tops of the knot of Acaay are good examples; but two hills, of about 600 or 700 feet in relative height,

named the Yarigua-á and Yarigua-mi, which rise isolated like sugar-loaves from the middle of the plain, have this form in greatest perfection.

Nearer the Tebicuary Plain the numberless hill-tops of the department of Caapucu form an almost independent mass, as do also the smaller hills of Quiquio.

Beyond the Tebicuary, in the Missiones, a well-defined plateau, of which the conical Cerro of Sta. Maria, and the chain of Sta. Rosa, are the summits, stretches out from near that river to the border of the Paraná at San Cosmé.

The line of eastern height just described, from Asuncion to the Paraná, shuts off a large south-western angle of level marshland, averaging 50 miles in width, the lowest portion of the country, distinct in character from any other part of the land, and recalling rather the features of the Chaco side of the Paraguay River. The heights descend abruptly into these marshy levels, and the view towards the Paraná, over the Esteros, is rarely broken by the smallest rising ground. Dense growths of reeds 6 or 8 feet high, or shorter grass (*Capii pytá*), or water-plants, appearing in broad, shallow flats of water, are the general covering of the Estero region; but here and there a belt of wood may be seen following the line of firmer ground.

Excepting in the marsh-region of the south-west, and immediately along the borders of the rivers, the soil of Paraguay is dry, porous, and sandy. Where the surface is too closely covered with vegetation to enable its character to be easily observed, the ant-hills (generally 2 or 3 feet in height, sometimes attaining 8 feet), which are dotted about in every landscape in great numbers, are sure indicators of the composition of the soil. They are almost invariably hard and bare hillocks of red sand, sometimes weathered into castellated or chimney-like shapes. But on the borders of the marshes, where they are necessarily built of black alluvial soil, containing a great quantity of vegetable matter, they are soft and crumbling, and at once become covered over with vegetation growing out of them.

Forests.—Lying between the moist tropical climate of the Brazilian "selvas" and the dry region of the vast grass-plains of the Argentine Republic, Paraguay shares the character of each, and enjoys an almost equal amount of forest and pasture-land. Its larger and more continuous forests occupy the eastern watershed of the country, or the slope to the upper Paraná, a region which is so difficult to penetrate on this account, that it has been left, up to the present time, in undisturbed possession of its original Indian peoples. Though numerous tracks lead north and south through the length of the western half of the country, there is not even the smallest wood-path across from east to west in any part, all communication from the more populous western side ceasing before the central heights are reached. In surveying the frontier line, the Limits Commission spent six months in cutting a pathway—long since overgrown again—through the forests of the north-eastern border, to reach the eastern limit on the Paraná.

In the western shed of the country, on the other hand, grass-land, rather than forest, prevails; but everywhere patches of forest, of greater or less extent, are comprised in the landscape. The hills and heights are almost invariably covered to their summits with wood, and belts follow the river courses. Where wood occurs out in the open country, it always takes the form of the compact mass termed an "Isla de Monte," rounded in outline, and very sharply defined from the grass-land—a circumstance which is probably due in the main to the frequent burning of the pastures, when the camp fires spreading out in lines of many miles in length burn all before them up to the edges and round the "islas," the damp close underwood of which they can never penetrate. These masses of forest comprise that infinite variety of splendid timber-woods for which Paraguay has become famous. Here and there the magnificent "lapacho," the oak of Paraguayan woods, is recognised by the pink flowers which cover it completely during some

months of the year. Some of the rising grounds of the Missiones plateau have a different character, being dotted over with thorny bush, and having dwarf "Yataï" palms, the highest of which scarcely surpass 3 feet, scattered through the long grass. These little palms are said to occur in great numbers also in the Argentine province of Corrientes, but are not noticed north of the Missiones. About lat. 26°, the taller palm, called the *Coco* in Paraguay, with feathery head and bunches of grape-like fruit, begins to be common; and this is the palm which is seen most frequently in the neighbourhood of Asuncion. The much more valuable "Carandaÿ" (*Copernicia*), commonly known as the "black" palm, from the colour of its wood, with broad fan-shaped leaf-head, and fine perpendicular stem rising to 40 or 50 feet, does not appear in numbers till after passing some distance north of Asuncion. Great forests of this palm are seen, however, to northward of the 25th parallel, both on the Chaco and Paraguayan sides. Through the operation of some natural law they are planted at regular distances apart, and totally prevent the growth of underwood; so that the whole space in which such a forest appears is perfectly clear of aught else than these upright pillar-stems, and the short, clean grass beneath them. The Carandaÿ palm-forests cease on the western slope of Paraguay, inward from Concepcion (23° N.), at an altitude of about 700 or 800 feet. Large quantities of this palm, which from its durable qualities (in contrast to the "white" wood of the other palms, which quickly rot) is in great demand for roofing-purposes throughout the Plata, are cut and sent down the Paraguay.

The *Pindo*, a palm closely resembling the *Coco* in its feathery head and general appearance, though of somewhat larger growth and darker leaf-colour, is frequently seen scattered among the forests of the centre and north of Paraguay, but does not occur in congregated numbers like the Carandaÿ.

A dwarf variety of the Carandaÿ, a slender, graceful little palm miniaturing its larger sort, scarcely two feet in general height, was frequently seen in ascending to the plateau in the higher slopes, but ceased before the highest levels were attained. The "Yataï-guasú," or large variety of the palm of the Missiones, growing to about 15 feet in height, with a remarkably thick stem, was observed soon after passing inland from Concepcion. Captain Page notes that this palm ('La Plata,' p. 166) is not seen on the banks of the Paraguay south of the Pan de Azucar, a hill near the river, some distance north of the Paraguayan frontier.

The Yerba-maté (*Ilex paraguayensis*), the tea-tree, upon which alone the feeble existence of the Republic now depends, has been frequently described. In size and form this evergreen resembles the orange, but is more delicate in structure. The leaf is oval, less glossy, and more elongated than that of the orange, and may be recognised by its serrated edges. The yerba-tree is scattered all through the forests of Central and Eastern Paraguay, and is nowhere an object of cultivation. In Northern Paraguay it appears to confine itself to the higher grounds; one of the most noted yerbales, that of Chiriguelo, is on the steep slope of the plateau, at an elevation of perhaps 1000 feet above the sea. In the somewhat cooler climate of Southern Paraguay the tree descends to lower levels, as it does in the southern provinces of Brazil, and is more accessible, though the quality of its products appears to diminish in like proportion.

Rivers.—The great enclosing rivers of the country, the Upper Paraná and its tributary, the Paraguay, differ very much in character, besides that the former is estimated to have six times the volume of the latter at their confluence. The Paraná, as we have previously noticed, belongs for the greater part of the distance, in which it forms the limit of the Republic, to the wide eastern table-land of South America. Touching the Paraguayan frontier first where it tumbles over its great fall, the "Sete Quedas," in 24° S., it after-

wards rushes southward between deeply-cut enclosing walls with a rapid eddying stream which only slackens its pace gradually as the river begins to turn westward on leaving the plateau. Along the south of Paraguay it is a magnificent river, varying in width from 1½ to perhaps 3 miles, still moving with a swiftly-flowing current, but presenting no direct obstacle to navigation, excepting in the cataracts which it forms on each side of the long islands of Jacireta and Apipé, enclosed by its branches in the middle of its great westward bend.

The Paraguay, on the other hand, is the great artery of the vast central plain of the continent, which, keeping the perfect level of the Chaco throughout on its right bank, winds along the base of the promontory of the Brazilian plateau which forms the Republic on its left side. With more frequent curves than the Paraná, its current is gentler and more uniform, and its value as a great highway of the continent infinitely greater.

Both have a pretty regular rise and fall throughout the year, varied by minor irregularities of rising and sinking. The Paraná, the upper basin of which in Brazil receives the rains of the Atlantic coast-land, which set in there in October, begins to rise on the borders of Paraguay in December or January, swelling up to an average height of 12 feet above its lowest level in March, and descending irregularly towards its low stage during the rest of the year. The Paraguay, drawing off the floods caused by the rains falling from January till April in its broad shallow basin on the inner borders of Brazil and Bolivia, begins its swelling at Asuncion in February, and continues a gradual rising till June or July, after which it sinks again about 15 feet to its low February level. The two rivers are thus in opposition in their flooding during the greater part of the year at their confluence, the Paraná being full in February and March, while the Paraguay is lowest, and the Paraguay being highest in July and August, when the Paraná is sinking to its deepest ebb. The affluents of both rivers from within the Republic partake of the character of the main stream to which they contribute; thus not one of the rivers flowing east to the Upper Paraná from the central heights of Paraguay is known to be navigable, and all form falls or cataracts in tumbling into its great trench. The rivers of the western slope, on the contrary (excepting the two most northerly, the Apa and Aquidaban), are all navigable for long distances upwards from their mouths in the Paraguay, the Ypané, Jejuy, and the largest interior river, the Tebicuary, especially, affording useful highways to the interior. The hydrography of the marsh-region of the south-west angle of Paraguay presents some remarkable features. Midway between the southern edge of the Asuncion plateau and the lower course of the Tebicuary lies the great lagoon of Ypoá, 20 miles long and on an average 10 miles wide; this is a great patch of perfectly fresh water resting on a bed of clean sand, though surrounded on three sides by great reedy marshes; and so shallow is it, that the winds prevailing from north to south drive its waters for some distance before them when they encroach on one shore and leave the opposite one dry. The chief feeder is the River Canabé, which gathers its supplies in the basin-like plain of Paraguari. Since there is no apparent fall from the plain of Paraguari to the Ypoá levels, and since the Canabé is slow and ditch-like, it is probable that the lagoon is at least 100 feet above the level of the River Paraguay opposite to it. No less than four outlets or marsh-drains are said to connect the Ypoá with the Paraguay westward, and another flows from it to the Tebicuary. The last, the only one which we have actually seen, is a large stream quite equal in apparent volume to the Canabé, and joins the Tebicuary with a good current. The southern "esteros," of which that called "Neembucu," "the endless," is the largest, are none of them stagnant, but drain to the Paraguay and Paraná by more or less definite outlets.

The sharply-marked edge, which the plateau of the Missiones presents in

descending into the level of the marshes, suggests that the Paraná has at one time had its course along its base, and that the levels which extend from these heights to the present channel have been worn down by a gradual sideward movement of the river; indeed, one of the most interesting features of the great rivers of this region is the apparent confirmation they give of Von Baer's disputed law of the mutations of river-channels. "Running water," he says,* "moving from the Equator towards the Pole, carries with it a greater velocity of rotation than that of higher latitudes, and in consequence presses towards the eastern bank," and, conversely, "water moving from the Pole towards the Equator approaches it with a lesser velocity of rotation, and therefore presses towards the west." . . . "In the northern hemisphere, however, for rivers flowing northward the eastern is the right bank, and for those flowing south the western bank is also the *right;* so that this is the one which being attacked becomes steeper and higher, while the left is low and subject to flooding. . . . Should the foregoing explanation prove to be the true one, it follows that in the southern hemisphere the *left* bank should be the higher, the right the lower and flooded one."

If, as some authorities maintain, the operation of this law which clearly evidences itself in the deflection of the winds, is overcome and rendered of no effect in the case of rivers through the restraint imposed on them by clinging close to the earth's surface, the number of examples in which the observed form of meridional river channels agrees with what would result from the working of such a law cannot be regarded as other than most remarkable coincidences. The Volga, with its steep right bank and uniformly flat left shore, from the confluence of the Oka downwards, the Don, Dnieper, Dwina, Mesen, Petchora, Obi, and Indus in the old world—the Mackenzie and the Mississippi, with its frequent "bluffs" on the right and "bottoms" on the left bank in the new, with many others—have been cited as examples, giving proof of sideward movements to the right in the northern hemisphere.

In his voyages up and down the Nile, Dr. Schweinfurth has had frequent opportunity of observing the character of that great meridional river, and gives ample proof of its eastward inclination, citing many towns, which, originally founded as river ports, have been left to decay at considerable distances inward from its western bank, their traffic having passed over to other places of more recent growth and more convenient site.†

Returning to the Paraguay and the Paraná, the evidence of sideward movement to the left which they present, whether from the operation of this law of deflection or from some other cause, is very striking. An explanation of the eastward tendency might perhaps be found in the rule which Dr. Peschel has shown to be of frequent application,‡ that the mountains which have been elevated more recently, or the younger heights, press the courses of rivers towards the base of the older hills. It is generally admitted that the Andes have been rising century after century, and with them, but at a slower rate, the pampas and plains of South America have emerged from the sea, through an upheaving force which dies away towards the Atlantic, or which may cease at the base of the older heights of the Brazilian plateau. From opposite the northern border of Paraguay in 22° s. to 33° s., or for nearly 800 miles, the Paraná and its great tributary have an almost truly meridional direction; on their right banks throughout this great distance, with the exception of two little isolated conical hills on the Chaco bank, a short way above Asuncion, of less than 300 feet in height, there is not the smallest break or rise in the uniform sea-like level of the country which

* 'Kaspische Studien,' viii. (1860).

† "Der Nil u. das Baer'sche Gesetz der Uferbildung."—*Petermann's Mittheilungen*, 1865.

‡ 'Vergleichenden Erdkunde,' 1875, p. 145.

stretches away to the western horizon. On the left bank of the Paraguay, as previously noticed, the country begins to rise at once towards the central heights, or the river skirts the smaller outlying plateaus, and this side almost invariably presents a strong contrast by its height to the levels of the right bank. Humaitá, Pilar, Villeta, Asuncion and Concepcion, some of the largest places in the Republic, are built immediately on the high eastern bank, but the only permanent settlement on the opposite shore for many hundreds of miles is the low-lying and fever-stricken military post of the Villa Occidental.

From the confluence of the Paraguay and Paraná for nearly 400 miles, or from above the town of Corrientes to near Rosario, the left bank of the Paraná is formed by a continuous "barranca" of levelly stratified clay-beds, of from 60 to 160 feet in perpendicular height. The strength and depth of the current whirl and rush along the base of this cliff, eating into its foundations. On the opposite or right bank the river is broken into innumerable "riachos" or shallow, changing branches which wind with sluggish current round the low marshy willow-covered islands which separate them. Looking westward from the height of the barranca at the towns of Corrientes, Bella Vista, La Paz, or Paraná, the same uniform level of the Chaco presents itself without the smallest rise or point to break the line of the horizon, up to which extends a maze of riachos, lagoons, and inundated flats. It is only at Rosario, where the river turns sharply to the east, that there is any definitely marked bank on the western or Chaco side. Frequently during the rising of the Paraná in January and February, we had ocular demonstration of the gradual wearing away of the left bank, as some undermined mass would plunge down into the current, carrying with it a piece of the grass turf of the level top of the cliff; during the night the dull roar of masses of the barranca sliding into the stream might be heard from great distances up or down the river. So great are the changes which are constantly in progress in the channel of the Paraná, that the river pilots assert that its sandbanks shift at every voyage. Keeping Page's Sketch Survey of 1855 in hand while descending, it was evident that very extensive alterations had taken place in the twenty years which have since elapsed, so that many points of the river are now quite unrecognisable from this chart. Among the larger variations since his survey, which also indicate movement towards the left, may be noted the increased width and depth of a channel below the town of Paraná, called the Riacho Paracan. During Page's survey it was noticed that the depth of the then main channel was becoming less, and that a new and deeper channel had broken through a flat which separated the mainland from the island of Paracan. This channel to the left is now of great width, and is apparently the main stream of the river. A more striking change is presented by a reach between 29° 10′ and 29° 20′, not far from Goya, where the river at the time of Page's survey made a curious backward curve, the only one in its remarkably direct course, doubling northward for about 5 miles. This "Vuelta del Norte," as it was called, appears to be now quite abandoned, at all events as the main channel of the Paraná. In watching for it while descending by canoe, we were surprised to find that the current has now taken a more direct passage to the left of the "Vuelta," having widened out a riacho, which, at the time of Page's visit, does not seem to have been of sufficient importance to merit survey.

Climate.—Like other parts of the globe which are situated on the borders of the tropics, and thus lie in a belt of transition between zones of well-marked seasons and climates, the meteorology of Paraguay seems to be chiefly remarkable in the irregularity of occurrence of the various phenomena. Excepting a tolerably gradual and very considerable average variation of temperature from the colder to the warmer months, there are no marked seasonal changes; the temperature from one day to another may vary very considerably according to

the direction of the winds; the winds are subject to the most rapid changes from one quarter to the opposite one; and the rainfall is neither more abundant in the hotter season, as in lands more completely within the tropics, nor greater in winter, as in the countries farther south.

The results of the observations by Mr. Congreve, which accompany these notes, give for the first time, it is believed, a nearly complete record of the meteorology of the capital of Paraguay for one year.

The most trustworthy observations of the meteorology of Asuncion, previously obtained, were those made on board the steamer *Waterwitch*, during the United States Expedition of 1853–56, by Captain Page, when engaged in the survey of the rivers; but from the nature of this voyage, short stays only could be made at any fixed point, and the records at Asuncion are complete only for four months. The averages for these months have been computed from Captain Page's register, as follows:—

Months.	Barometer.	Thermometer.			Prevailing Winds.
		Max.	Min.	Mean.	
October, 1853	29·68	96°	58°	76°	S. and E.N.E.
January, 1854	29·61	95	60	80·3	S. and N.E.
May, ,,	29·75	91	46	71·4	N.E. and S.E.
June, ,,	29·81	90	53	70·6	N.E. and S.E.

M. Martin de Moussy in his great work on the Argentine Republic, indeed gives a summary of the temperature and barometric pressure at Asuncion, in his climatic table (vol. i. p. 348), but this is confessedly only an approximation, not based on any continuous observation.

Since Asuncion is centrally placed in Paraguay, the observations taken there should give a tolerably fair representation of the general climate of the country. The mean barometric readings for the months indicate very distinctly in their gradual rise to the average maximum in the coldest month (July), and their fall to the minimum in the hottest month (Jan.), the close connection between pressure and temperature. The same change is observed in the frequent shiftings of the wind to the prevailing directions of north and south, the barometer invariably rising before the cooler south wind and falling to that from the north. The thermometer columns of Mr. Congreve's Table give an average of 72° Fahr. as the mean annual temperature of Asuncion; an average comparable almost exactly with those of Benguela, in West Africa; of Bona, in Algeria; St. Augustin, in Florida; or Sta. Cruz, in the Canaries. Between the average of the hottest month, January (84°·6), and of the coldest, July (58°·1), there is a mean seasonal change of temperature of 26°·5; but morning temperatures of 46° to 48° are not uncommon in Asuncion in July, and at midday during the hot months the thermometer not infrequently rises two or three degrees above 100° in the shade. The occurrence of white frosts for a few hours of the night in winter over the southern half of Paraguay, shows that the surface temperature of the ground may occasionally for a short time fall to the freezing point.

Scattered observations of temperature which have been made in the interior of the country seem to show, by their being still lower—in comparison with those made simultaneously in the capital—than the increased elevation would warrant, that the temperature of Asuncion, and with it of the banks of the Paraguay, may be abnormally high. Should this ultimately prove to be the

case, the cause is perhaps to be looked for in the heat-conserving power of the great river bringing its volumes of warm water direct from within the tropics, and in greatest quantity during the cooler season of the year.

During 1874 observations for temperature and rainfall were being carried on in Asuncion quite independently of those by Mr. Congreve, by Dr. A. Perini, the results of which were published for 1874 and part of 1875, in the 'Reforma' of Asuncion, in January of the present year. Converting the metric scales in which these observations were made to our own standard, the results are as exhibited in the following Table.

Months.	Thermometer.			Rainfall in Inches.	Number of Storms.	Prevailing Winds.
	Max.	Min.	Mean.			
1874.	°	°	°			
January ..	101	67	83·5	3·34	2	N.N.E.
February ..	100	64	83·	3·93	3	S.W.
March	97	65	82·	3·81	2	N.W.
April	95	60	74·	2·87	4	N.N.W.
May	84	51	67·	4·88	2	S.
June	82	47	66·	6·81	1	S.S.E.
July	86	51	70·	3·15	2	E.
August	92	56	74·	6·93	4	S.E.
September ..	98	59	78·	7·99	6	S.
October ..	102	61	82·5	4·88	3	S.S.W.
November ..	102	68	82·	3·90	1	N.N.E.
December ..	100	64	81·	5·59	2	N.W.
Mean ..	96	59	72·	Total 58·08	32	..
1875.	°	°	°			
January ..	100	67	76·7	2·0	3	N.N.W.
February ..	103	58	83·	3·9	4	N.N.E.
March	95	66	81·	3·5	2	S.S.W.
April	90	56	73·	11·0	4	S.S.W.
May	84	48	69·	8·3	5	S.S.E.
June	76	42	54·	7·0	1	S.
Mean of 6 Months	91	56	72·5	Total 36·	19	..

As far as temperature is concerned, these results agree very satisfactorily with Mr. Congreve's Table; but when the columns indicating the amount of rainfall are compared, they present discrepancies for which it is not easy to account, although the whole amount for the year recorded in each case is not very unequal. To obviate loss from evaporation, Mr. Congreve's gauge (of the pattern recommended in the Royal Geographical Society's 'Hints to Travellers') was emptied frequently; and there is no reason to doubt the accuracy of the record of 18 inches of rain in December, although Dr. Perini has not set down more than 6 inches for that month in his table.

The winds of the valley of the Paraguay incline very much to take the form and direction of the great natural trough of the river. Thus there is a prevalence of northerly or southerly breezes, winds from due east or west being almost unknown; neither of these directions appears to obtain any definite mastery in any month or season, but they interchange continually. The general north and north-easterly winds probably form part of the great returning sweep of the south-easterly trade-winds of the Atlantic, which have become warmed in their passage over the tropical maritime region of Brazil. In the

south winds, especially in the strong cold gusts of south-west wind which blow over the Pampas and take a southerly direction before reaching Paraguay, a branch of the great westerly current of the temperate zone, chilled and dried by its passage over the snowy ridges of the Andes, may, perhaps, be recognised. On an average the difference of temperature between the south and north winds in Paraguay reaches to nearly 10°; but in the case of sudden southerly or northerly storms this difference is greatly exceeded. The south wind is dry, cool, fresh, and invigorating, banishing mosquitoes for a time; a north wind, on the contrary, brings a hot, moist, relaxing atmosphere, and is the signal for the renewal of action of every one of the myriad sorts of insects which join then with the frogs in filling the evening and night air with sound.

From an analysis of Mr. Congreve's register of the weather from January to September, 1874, it appears that out of a total of 72 days on which rain fell during that period, there were 19 days on which the rain occurred with a north or north-east wind, and 15 with that from south or south-east; but that on by far the larger proportion of rainy days, 31 out of the whole number, the wind was variable, and shifted round from one or other of these opposing directions. Thunder and lightning very frequently accompany the more violent changes of the wind; vivid flashes and cannon-like claps of thunder following in quick succession: more frequently still the glare of distant lightning is seen at some point on the horizon. Over the Chaco, especially, dark level banks of cloud lit up now and then by sheet lightning are often seen when the weather in Asuncion is still fine, though this appearance may be regarded as an indication of a change about to take place. Paraguay is free from such excessively violent cyclonic storms as those to which regions in corresponding latitudes of South Africa, coming within the limits of the hurricane-region of the Indian Ocean, are liable; but very powerful wind-storms are by no means rare. Such are the occasional sudden blasts of south wind which generally precede a period of steady breezes from that quarter, and which it cannot be doubted are of the same character and origin as the "Pamperos" which sweep over the Argentine plains, or are probably a continuation of the more extended of these storms.

The approach of these cold blasts is always marked by the appearance of a low, dark arch of condensing cloud in the southern horizon, rapidly spreading upwards towards the zenith. One of these occurred on the 12th of March, while we were going up the Paraguay River, a little below Asuncion. The blackness spread up over the sky in wildly whirling clouds; a gust of chilly wind struck the river below us, lashing it up into waves and spindrift, raising great clouds of sand from a bank on the Paraguayan side, and bending over the palms and other trees of the banks. Quick flashes of forked lightning shot here and there, and the river assumed a strange dark olive-green colour, on which the white waves curled. Striking the barranca, the waves undermined and hurled down great masses of the banks with a roaring sound, which added to the din of the incessant thunder-claps. In the next reach a blast caught the steamer, and whirling her round broadside, drove her hard-and-fast on the bank.

The cause of these "Pampero" winds is probably to be found not so much in an *ascending* current of air over any locally heated region of South America, as in a general rarefaction of the stratum of air lying immediately upon the great plain of the Pampas and the Chaco. This heated stratum in turn raising the superincumbent air, may leave a partial vacuum, into which the heavier, colder air of the great south-westerly current presses to fill it up. If an ascending current were produced, the surrounding air would move inwards, spirally, from all sides, and a cyclonic storm might be the result. It may be remarked that it is quite in accordance with the law of deflection of the winds in the southern hemisphere that the storms of Paraguay coming up from

the south may have had a westerly or south-westerly direction at the place of their origin.

A storm which was experienced on the Cordillera in Northern Paraguay appeared to be of a different class. On the 12th of September, after a week of broken weather, a furious tempest of wind, thunder, lightning, and hail set in suddenly from the *north-east*, the first gust of which threw down the tents and demolished the stone boundary-columns which the Brazilian workmen were building. After about half an hour a lull occurred, and for another short time there was a comparative calm, though lightning continued to flash incessantly. As night closed in the storm set in again with equal violence, but now from the *south-west*. It is likely that this was a circular storm, moving, perhaps, to the south-east; that the north-easterly curve of its spiral path had been first encountered, and afterwards the opposite arc. The effects of this storm were severely felt at the little Brazilian military outpost called the "Colonia Dourados," where it wrecked the greater part of the huts, and carried off completely the roof of the more substantially-built log-house of the Commandante. Dr. Perini's Table shows that the storms of Paraguay are most frequent about the periods of the equinoxes.

Report on the Hypsometrical Observations in Paraguay, of Keith Johnston, Esq., *and* Lieut. C. R. Congreve, R.N. By R. Strachan, Esq., Meteorological Office.

The manuscripts placed in my hands containing observations made in Paraguay (and which are herewith returned) comprise

(1) A Meteorological Register kept at Asuncion, by Lieut. C. R. Congreve, R.N., during the year 1874;
(2) A few observations made with Boiling-point Thermometers in 1874, by Mr. Keith Johnston; and
(3) Barometric and Thermometric Observations made in 1874, by Mr. Keith Johnston, on his journey.

So little is known of the meteorology of Paraguay that even one year's register is of considerable value. I have, therefore, deemed it right to work up the observations so as to make the results available for geographers and meteorologists.

I have compared the simultaneous indications of Captain George's portable barometer with the hypsometers, and the results appear to me to prove that the instruments were practically correct. Mr. Johnston left one of the portable barometers at Asuncion, where it did good service in furnishing observations for the base station as well as in checking those made with the instrument previously in use. The other one he appears to have used very successfully on his journey.

As arranged by Mr. Johnston with Mr. Congreve, the hours of observation at Asuncion were 9 A.M. and 9 P.M. Mr. Johnston himself also adhered to these hours, so that the observations for elevations were simultaneous in all cases.

Appended are the results of the observations made at Asuncion, and a tabulated statement of the corrected data with the elevations deduced therefrom, both in a form suitable for publication.

The details of the calculations are fully given on nine pages of manuscript.