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On the Meteorites which have been found in the Desert of Atacama and its neighbourhood.

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(*With a Map of the District, Plate* X.)

[Read March 12th and May 7th, 1889.]

1. THE immediate object of the present paper is to place on record the history and characters of several Atacama meteorites of which no description has yet been published; but incidentally it is convenient at the same time to consider the relationship of these masses to others from the same region, which either have been already described, or at least are stated to be preserved in one or more of the known Meteorite-Collections.

2. The term "Desert of Atacama" is generally applied to that part of western South America which lies between the towns of Copiapo and Cobija, about 330 miles distant from each other, and which extends inland as far as the Indian hamlet of Antofagasta, about 180 miles from

the coast. The Atacama meteorites preserved in the Collections have been found at several places widely separated throughout the Desert.

3. A critical examination of the descriptive literature, and a comparison of the manuscript and printed meteorite-lists, which have been placed at my service, lead to the conclusion that all the meteoritic fragments from Atacama now preserved in the known Collections belong to one or other of at most thirteen meteorites, which, for reasons given below, are referred to in this paper under the following names :—

1. *Lutschaunig;* a chondritic stone, in which only small grains of nickel-iron are visible:

2. *Vaca Muerta;* one of the links between the Irons and the Stones, consisting essentially of nickel-iron and stony matter, both in large proportion:

3. *Imilac;* a sponge-shaped nickel-iron, of which the cavities are filled almost solely by olivine:

4. *Copiapo;* though largely of nickel-iron, characterised by the presence of irregularly disposed angular enclosures, chiefly of troilite and silicates:

5. *Mejillones*, 6. *Polanco*, 7. *Mount Hicks*, 8. *Varas*, 9. *Cachiyuyal*, 10. *Ilimaë*, 11. *Juncal*, 12. *Barranca Blanca*, 13. *Joel;* all consisting essentially of nickel-iron.

4. Three of these meteorites, *Mejillones*, *Polanco*, and *Mount Hicks*, were all found within a few leagues of the Bay of Mejillones; *Varas* and *Imilac* were found nearly a hundred miles away, and about forty miles apart; *Vaca Muerta*, *Cachiyuyal*, *Copiapo* and *Lutschaunig*, and probably also *Ilimaë*, came from a more southern part of the Desert, while *Barranca Blanca* and *Juncal* were brought from the south-east: *Joel* was discovered in an unmentioned part of the Desert.

5. But terrestrial proximity of itself affords no certain proof that different meteoritic fragments have belonged to a single celestial mass or group, and are the residues of a single meteor. On the other hand, we are confronted by the fact that since the year 1751 only nine falls of meteoric iron on the whole of the earth's surface have been chronicled; whence it seems beyond belief that several distinct falls of meteoric iron can have taken place in so limited a region as the Desert of Atacama, unless we can suppose that the dates of fall have been distributed over many centuries. Not a single meteoritic fall of any kind is known to have been actually observed in the Desert.

6. Various facts are suggestive of such a multiplicity of falls; indeed, relying upon the experience afforded by actual observation, we can

scarcely doubt that several distinct meteors are represented in the Desert; and, this once granted, an assertion of simultaneity of fall of two or more masses on the purely geographical ground that they have been found in the Desert can be allowed no great weight.

7. Meteorites of quite distinct types have been brought from the Desert: and though many small and large showers of stones have been observed in various parts of the world during the present century, in every case the individuals which have fallen simultaneously have been found to belong to a common type. *Lutschaunig*, for example, belongs to the more frequent kind of meteorite, the chondritic, of which many falls have been actually observed; but it is entirely different in its characters from the other Atacama meteorites. *Imilac*, again, belongs to an extremely rare type; so rare indeed, that no actual fall of such a meteorite has yet been observed. *Vaca Muerta*, too, has characters which distinguish it from all other known falls.

8. But argument founded on difference of type must be cautiously used. Owing to the composite structure of meteorites various parts of the same mass present different characters; and where the structure is a coarse one there may be a difficulty in recognising two fragments as having originally belonged to a single specimen. In the case of the Irons the difficulty is perhaps greater than in that of the Stones, for as far as we have yet discovered there is generally little more than the figures developed by etching which can be used for their differentiation. If allowance be not made for possible differences in the parts of a large mass, or in the individuals of a meteoritic shower, it may thus be wrongly inferred that specimens due to a single meteor belong to different falls. A good illustration of this difficulty is presented by the masses which have been named Jewell Hill and Duel Hill respectively, the former known since 1854 and the latter since 1873. These are placed in two widely different groups by Brezina, than whom we can wish for no better judge of their structure as revealed by etching. Yet it now appears that the difference of locality is merely one of spelling, and the two masses were found only a mile apart: it is impossible to believe that they can have been projected against the same part of the same hill at different times; and such being the case we can scarcely rely upon the etching figures as a certain method of distinction.

9. The wide extent of space over which the Atacama masses have been found is also suggestive of the occurrence of several distinct falls.

(*a*.) Of the nine observed falls of *Meteoric Iron* seven have each yielded only a single mass. At Agram two masses fell, and were only about a

mile apart; two fell at Braunau also, and were likewise in close proximity. There is thus no recorded instance of an observed shower of meteoric iron. The most convincing proof of the actuality of such showers is furnished by the masses which have been found in the Valley of Toluca in Mexico: their existence had been chronicled as early as the year 1784, yet in 1856 it was still possible to find as many as 69. When etched they show the Widmanstätten figures in a most excellent way, and in their characters they are typical meteorites. Belonging, as they do, to a single type, they lead to the conviction that they are the result of a single shower. But the region over which the distribution took place is not large: the length of it is said to have been only about 14 miles.

(*b.*) *Siderolites*, single or multiple, have also been rarely seen to fall. The largest and most widely spread fall yet observed has been that of Estherville. In that case the largest masses were found within 4 miles of each other; while a number of smaller ones, estimated at about 5,000, were picked up not far away in a region about eight miles long and half-a-mile wide.

(*c.*) Of the fall of small and large showers of *Meteoric Stones* we have by this time a large series of observations; and we may assert that the extent of space over which the individuals of a single fall are scattered rarely exceeds ten miles. As far as I have been able to ascertain the greatest observed separation is not more than 16 miles.

The extent of surface over which fragments have been picked up after some of the best known and widely spread falls is given in the following list:—

Limerick,	3 miles long.
Mocs,	3 miles by 0·6 miles.
Butsura,	3 miles by 2 miles.
Pultusk,	5 miles by 1 mile.
L'Aigle,	6 miles by 2·5 miles.
Barbotan,	6 miles long.
West Liberty,	7 miles by 4 miles.
Stannern,	8 miles by 3 miles.
Knyahinya,	9 miles by 3 miles.
Weston,	10 miles long.
Hessle,	10 miles by 3 miles.
New Concord,	10 miles by 3 miles,
Castalia,	10 miles by 3 miles.
Khairpur,	16 miles by 3 miles.

In three other cases, *Macao*, *Cold Bokkeveldt*, and *Pillistfer*, it is true that a wider spread has been chronicled, but on examination the accuracy of the original statement is disproved:—

1. The *Macao* stones were said, on the authority of a letter of M. Berthou,[1] to have been scattered over a region more than 10 leagues in radius. According to later inquiry, Berthou's statement was made on hear-say-evidence, and the maximum length of the space was only 14 miles.[2]

2. Stones of the *Cold Bokkeveldt* fall were said, on the authority of a letter of Mr. Jerram,[3] dated January 29th, 1839, to have been picked up over a distance of 150 miles. This statement was made on insufficient grounds; for in a detailed authoritative account[4] signed on December 7th, 1839, by Sir Thomas Maclear, the Royal Astronomer at the Cape, it is definitely stated that stones were picked up only in a zone 16 miles long and 1 mile wide. Dr. Treuter says that "the *sensation* was felt simultaneously over an extent of upwards of 150 miles."[5]

3. Stones of the *Pillistfer* fall were reported to have been found 55 miles apart.[6] Later it was shown that a confusion had arisen between the apparent fall of the meteor and the actual fall of the stones; in fact the stones were found comparatively near together, being within an area 8 miles long by 2¼ miles broad.[7]

10. So far we have had under consideration only those Atacama specimens which are known to have been preserved; but it is important to get a correct idea of the approximate number of the separate masses which have been actually met with in the Desert, whether they have been preserved or not: if the observed masses have been numerous and in close proximity to each other over the whole Desert, the argument for the actual fall of one or more enormous widely spread showers, either of meteoric iron or of meteorites of various types, will obviously be strengthened. The general impression, howsoever produced, is that the separate masses scattered throughout the Desert are beyond number.

11. That this impression is one of long persistence is illustrated by the following statement made by M. Darlu of Valparaiso, which was brought before the French Academy of Sciences 44 years ago:[8]—

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[1] *Comptes Rendus*, 1837, vol. 5, p. 211.
[2] Partsch. *Die Meteoriten zu Wien*, 1843, p. 83.
[3] *Philos. Magaz.*, 1839, ser. 3, vol. 14, p. 392.
[4] *Amer. Jour. Sc.*, 1841, ser. 1, vol. 40, p. 199.
[5] *Philosophical Transactions*, 1840, vol. 130, p. 181.
[6] *Pogg. Ann.*, 1864, vol. 122, p. 323.
[7] *Archiv. für die Naturk. Liv-., Ehst-, u. Kurlands*, 1864, ser. 1, vol. 3, p. 446.
[8] *Comptes Rendus*, 1845, vol. 20, p. 1720.

"For the last two years I have made observations of shooting stars during the nights of November 11th to November 15th, without remarking a greater number than at other times. I was led to make these observations by the fact that in the Desert of Atacama, which begins at Copiapo, meteorites are met with at every step. I have heard also, from one who is worthy of trust, that in the Argentine Republic, near Santiago del Estero, there is—so to say—a forest of enormous meteorites, the iron of which is employed by the inhabitants."

12. As Darlu's statement is probably one of the sources from which the idea as to the immensity of the number of masses has been directly or indirectly derived, it is well to test its general accuracy as far as is in our power.

As regards the second part of the statement, we have very satisfactory information from persons who have actually visited the Santiago del Estero locality with the special purpose of seeing the specimens. The odd term *forest* was doubtlessly understood by Darlu himself as indicative of infinity of number: as a matter of fact, probably not more than five masses had been seen.

Owing to the Indian assertions of the occurrence of native iron in the Gran Chaco, Don Rubin de Celis left Santiago del Estero in 1783 under orders from the Spanish Government to report on the advisability of founding a colony and working the supposed mine.[1] He was guided to the place, which was known to the natives under the name of Otumpa, and there saw a crest of metallic iron projecting from the ground: he found, however, on examination that it was the crest, not of a vein, but of an isolated mass, the weight of which he estimated at 30,000 lbs. This was the only specimen seen by Rubin de Celis himself, but he adds:

"It is an undoubted fact that in these immense forests there exists a mass of pure iron, in the shape of a tree with branches. Many of the Indians have seen it, and the inhabitants of the colony of Avipones are acquainted with the spot where it lies. A distinguished European of Salta has touched it. The body of this tree extends upon the ground in the direction from E. to W., having left behind to the E. a part which lies in the direction from N. to S.; and it is from this that the pieces of metal may have been taken with a chisel."

Avipones (Abipones) is shown in the maps as being in the province of Santiago, on the south-western border of the Gran Chaco.

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[1] *Philosophical Transactions*, 1788, vol. 78, part 1, pp. 37, 182.

Writing later, Redhead,[1] who had better opportunities than Darlu for getting accurate information, says as follows :—

"The native iron found in Santiago is not a single mass, as has been said: there are several, and the most recent accounts describe them as huge trunks with deep roots (I use the expression of the natives) supposed to communicate with each other."

Sir Woodbine Parish,[2] the British Consul-General in the Province of Buenos Ayres and its Dependencies, further tells us that at the time of the Struggle for Independence, when the coast was blockaded by Spanish cruisers, and ordinary iron among other necessaries could no longer be obtained, the existence of native iron in the Gran Chaco was remembered, and the Government of Buenos Ayres decided to send in search of it. One mass, weighing 1,400 lbs., was actually transported at great expense to the Capital, a distance of more than a thousand miles: owing to the raising of the blockade, the mass, instead of being worked in the arsenal, as had been intended, was presented by the Government to Sir Woodbine Parish as a curiosity: by him it was afterwards given to the British Museum through Sir Humphrey Davy as President of the Royal Society.

The official charged with the transport of the iron from the Gran Chaco made sketches of *three* masses, but the sketches have not been preserved: one of the masses may possibly have been that described by Rubin de Celis, and thus too heavy for removal.

Only one conclusion can be arrived at—namely, that not more than four or five large masses were really known to have been seen in the so-called Santiago del Estero locality at the time of Darlu's statement, and that the odd term "forest," understood by Darlu to refer to number, was merely a free translation of the native statement that there were "several masses having the shape of huge trunks with deep roots."

13. We may safely infer that the first part of Darlu's statement is similarly exaggerated. Up to that time the only meteoric iron got from Atacama was the sponge-shaped nickel-iron enclosing stony matter in its cavities: this was known at least as early as 1822, but until the journey of Professor Philippi in 1854 the locality in which it was found had never been described, probably never even visited by a European. The iron was stated in 1827,[3] on Indian authority, to be plentifully scattered over a

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[1] *Buenos Ayres and the Provinces of the Rio de la Plata, by Sir Woodbine Parish*: London, 1839, p. 259.

[2] *Ibid.*, p. 257.

[3] *Trans. Roy. Soc. Edinb.*, 1831, vol. 11, p. 223.

district 3 or 4 leagues in length in the neighbourhood of the town of *San Pedro de Atacama* (sometimes abbreviated to *Atacama*). As it is malleable, and when polished has a silvery appearance, the iron was worked by the Indians into various useful and ornamental forms—spurs, stirrups, spear-heads and knives: the rough specimens, too, were eagerly inquired after from far and wide, and were obtained through the inhabitants of San Pedro. In this way the specimens first sent to Great Britain by Sir Woodbine Parish in 1827 were got by him while in residence at Buenos Ayres. It was doubtless this plentiful occurrence of meteoric iron, though only of one rare type, and over a limited area, that gave rise to the statement of Darlu that meteorites are found at every step in the Desert. As a matter of fact almost the whole of the Desert itself was at that time untrodden and unexplored.

Mr. George Hicks, one of the earliest explorers of the district of the 23° and 24° parallels, to whose generosity the British Museum owes *Mount Hicks*, *Varas*, and by far the largest known mass of *Imilac*, informed me in 1882 that masses of iron of the Imilac type had often been met with during recent explorations of the Desert, but that he had never heard of two being found near together. That meteoric iron of the Imilac type is far from plentiful in the northern part of the Desert is shown by the fact that Hicks, though much interested in the occurrence, never found a specimen himself, and only acquired his first specimen of any type of meteorite after years of persevering inquiry from the Indians, though he had been told that masses consisting wholly of meteoric iron are often found. This will be discussed later in the paper.

14. A brief survey of the physical features and climate of the Desert, and of the history of its exploration, throws light on various points of interest.[1]

The Desert is far from being the ideal vast plain of mobile sand: indeed, in most parts there is little sand at all. The coast is extremely wild and mountainous, rising 2,000 to 4,000 feet direct from the sea: there are very few bays or landing-places. At the time of Philippi's visit (1853-4) the total number of dwellers on the coast between Caldera and Cobija was only 150 to 200, while the interior was virtually uninhabited. At only few places on the coast is there any beach, so that the Desert cannot be traversed by a route near the sea-level. Between the sea and the Alta Cordillera (Andes), about 90 miles distant, is an

[1] *Peterm. Mittheil.* 1856, p. 52; 1860, p. 369; 1860, Ergänz. 2; 1864, p. 86; 1876, p. 321; 1879, p. 301; 1880, p. 267. *Quart. Journ. Geol. Soc., London*, 1861, vol. 17, part 1, Proceedings, p. 7. *Jour. Roy. Geograph. Soc., London*; 1851, vol. 21, p. 126; 1861, vol. 31, p. 155; 1877, vol. 47, p. 250. *Ann. d. Mines*, 1846, ser. 4, vol. 9, p. 365. *U. S. Naval Astron. Exped. to the Southern Hemisphere*; 1855, vol. 1, p. 243.

elevated table-land rising gradually towards the east, and containing many depressions in which there are dried-up salt-pools. The climate is extremely dry: when Philippi arrived at the town of San Pedro there had been no rain for a year and a half; and he was told that a good storm of rain, lasting for a few hours, only occurs at intervals of 20 or 30 years. The air of the Desert is so clear that he found, as a result of experience, that a distance which appeared equivalent to a four hours' journey really meant at least a couple of days of hard travelling.

Harding states, as an illustration of the dryness of the air, that a page of ordinary note-paper, if doubled over and pressed with a paper-knife, will break in two when opened out.

Hence there is an almost complete absence of drinkable water, and the Desert was uninhabited, being crossed only by Indians travelling from San Pedro to Copiapo or from the inland Antofagasta to the coast at Paposo. Their tracks lay between widely separated wells: only an occasional mine-seeker or guanaco-hunter ventured away from the lines of traffic, and then at no small risk to his life. Mr. Hicks, who has followed the old and long untrodden desert-tracks for hundreds of miles, says that every now and then a mound of stones is met with, on each side of which there are lines of small stones indicating the direction of the next mound; from each mound another is invariably visible, though often as far distant as the eye can reach: by following the directions thus given the traveller is sure sooner or later to find water. The character of the track from San Pedro to Copiapo will be appreciated from the fact that in one part the track attains a height of 13,000 feet above the sea-level: during his thirteen days' journey along this dreary route Philippi was cheered by no intervening house or tree.

Such a condition of affairs is of itself quite sufficient to disprove the accuracy of Darlu's statement: the "San Pedro" specimens were themselves only found because they were in the neighbourhood of one of the best watering places in the Desert.

15. In so dry a climate a mass of meteoric iron of moderate size will endure for countless ages before completely rusting away. Of this satisfactory evidence is afforded by the big "San Pedro" specimen, weighing 450 lbs., now in the British Museum: even its olivine, though the mass was found so lately as the year 1877, is in excellent condition; in fact in much better condition than that of the specimens which were brought from the same part of the Desert half a century before.

16. It is obvious that the first exploration of such a district must inevitably lead to the discovery of meteoritic masses which may have been

long in process of accumulation, and that the discovery of even a large number of distinct types of meteorite could afford no proof that the region had been exceptionally favoured by meteoritic falls. Most of the masses projected into any part of Europe during the same period will have been found and destroyed long before the assertions of the fall from the sky of heavy masses of stone or iron received any credit. Further, in our part of the world, where iron extracted from ores is plentiful, a farmer is far from being violently excited by the discovery of a mass of iron during the ploughing of his field: indeed, the observer of the actual fall of a meteorite at High Possil, near Glasgow, on April 5th, 1804, after looking at the stone threw the fragments away as of no further interest to anybody; it was only by means of a search lasting for several days that a portion of the original mass was eventually recovered. The case is different with the traveller in a region like the Desert of Atacama: it needs no argument to convince him that isolated masses of iron found there can have come from no terrestrial iron-furnace, and such a mass is thus more likely to be picked up and preserved,—especially when mistaken, as is so frequently the case, for silver.

It need only be added in this respect that the fall of meteorites has been recorded again and again throughout historical times; the fact that their fall is not a feature only of our own epoch has been recently proved by the discovery of a mass of meteoric iron in the tertiary lignite of the Wolfsegg Mines, Upper Austria, under such circumstances that its fall can only have taken place before the end of the tertiary period.

17. It is well known that very few meteoric stones, as distinct from meteoric irons, have been found at any part of the earth's surface unless the actual fall has chanced to be observed: this is partly due to the speedy disintegration of a meteoric stone on exposure to ordinary atmospheric influences, and partly to the fact that a meteoric stone is less easily distinguished than a meteoric iron from terrestrial products.

It might, however, have been supposed that in the dry air of the Desert of Atacama even meteoric stones would be very lasting. The incorrectness of this idea is proved by the character of the surface of the Desert; for the ground is largely strewed with angular rock-fragments, so much so that it is necessary for the guanaco-hunters to protect their feet from being cut by the sharp edges of the stones. The angular fragments result from the fracture of the rocks through the rapid and continual variations of temperature to which they are subjected, owing to the absence of vegetation and the extreme dryness of the air. A meteoric stone would soon be broken up and become indistinguishable to the naked eye from its immediate neighbours.

18. Since Philippi's journey vast changes have been brought about within the northern portion of the Desert through the discoveries of silver ores and nitrate of sodium within its borders. The Bay of Mejillones, where there is a rich deposit of guano, was found to be one of the finest and safest on the west coast of South America, being fully protected from the south-west winds; and in spite of the absence of fresh water and vegetation it began to assume importance as a place whence the mines, started at Sierra Gorda and Caracoles, could be most easily reached. In 1871 the first twenty miles of a projected railway from the coast to the centre of Bolivia were laid down, and by the following year Mejillones had upwards of 2,000 inhabitants. Shortly afterwards the railway scheme fell through, owing to lack of money, and the population speedily dwindled down again to 300. At the same time, there was founded a new town, Antofagasta, on the south of the headland of Mejillones, which soon became the most flourishing-place on the Atacama coast, owing to its proximity to large nitrate-deposits, to which a railway was immediately laid down; the line has now been extended through Calama and Jarapura as far as Huanchaca. In 1874 as many as 114 calls were made at Antofagasta by sailing vessels and 385 by steamers, and at the census of 1875 there were no less than 5,384 inhabitants. The most striking change, however, is shown in the very centre of this part of the Desert, at Caracoles, a district totally unknown to us before the discovery of its silver ores on March 22nd, 1870. This silver district is about 24 miles long and 9 miles wide, and contains numerous mines now in working order, each having its neighbouring village. By 1875 the most important of these, Placilla, 8,900 feet above the sea-level, had become a town with streets of stone buildings, 2,000 inhabitants, and even a Chilian vice-consulate! On the northern border of the Desert the old village of Chiu-chiu has about 800 inhabitants, and that of Calama about 1,000 to 1,200: these villages are on the roads from Cobija to Potosi and Salta. The exact frontiers of Peru, Bolivia, and Chili, previous to these changes had been a matter of little concern, but the discovery of the mineral riches of the Desert led to a prolonged and destructive war. In this war Chili was victorious; and by the truce, signed on 4th April 1884, acquired, among other concessions, temporary possession of Atacama.

19. Since the journey made by Philippi, and more especially since the discovery of silver ores at Caracoles, a large extent of the Desert has been more or less closely examined, and other meteorites than that of "San Pedro de Atacama" have been added to the Collections. Still the meteorites which have become known to Science are far from being extraordi-

narily numerous: at the most thirteen are now represented in the known Meteorite-Collections, and even this number may be reducible through two or more of the irons having been parts of a single fall. Quite as many have been brought from the States of North and South Carolina, which have together a total area much smaller than that of the Desert of Atacama.

It is not unworthy of notice that nearly all the Atacama masses of known locality have been found on or near the desert-tracks; in a certain measure this is due to the country having been there most easily explored, but in some cases it is doubtless a result either of loss during transport or of rejection of the specimens after discovery that they contained no silver.

In the accompanying account of the Atacama meteorites which are preserved in the Collections, the details of each are only so far given as is requisite for the recognition of the individuality; but to aid in a proper appreciation of the evidence which relates to the asserted wide spreading of the Atacama falls, it has been deemed necessary, in the more critical cases, to discuss with some minuteness both the history of the discovery of the various fragments and the geographical relationship of their sites. The relative positions of all the places mentioned in this account, as far as they can be traced, are shown in the accompanying diagrammatic map (Plate X.); it is founded on a map constructed by Brackebusch,[1] and that again depends for its Chilian details on the maps of Pissis and Villenueva; the longitudes and latitudes of many places given in Brackebusch's map differ very considerably from those assigned in the other maps which have been quoted.

1. The Lutschaunig Stone.

(*Desert of Atacama.*)

Lutschaunig is a chondritic meteorite: it will be described in a separate paper.

2. Vaca Muerta.

(*Taltal: Sierra de Chaco: Chili: Janacera Pass: Jarquera Pass: Mejillones.*)

This meteorite[2] was first mentioned in a letter, dated 17th August

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[1] *Mapa del Interior de la Republica Argentina*, 1885.

[2] *Comptes Rendus*, 1862, vol. 55, p. 873. *Ber. Ak. Berlin*, 1863, p. 30. *Anal. Univ. d. Chile*, 1864, vol. 25, p. 290. *Comptes Rendus*, 1864, vol. 58, p. 551. *Ann. d. Mines*, 1864, ser. 6, vol. 5, p. 431. *Comptes Rendus*, 1872, vol. 75, p. 1547; 1875, vol. 81, p. 599. *Mineralojia, por Domeyko*, 3rd ed., 1879, p. 135. *Sitz. Ak. Wien*, 1884, vol. 88, part 1, p. 351.

1861, written by an old pupil, Leonidas Garcia, when sending two specimens of it from (Coquimbo or) Copiapo to Professor Domeyko at Santiago. The place where the masses were found was described by Garcia, on the authority of José Diaz Gana as a *llanura* (vast plain); there were some hillocks at a little distance away, but so far that it was impossible to suppose that the stones could have rolled down from them; nor were other similar masses, or any metallic veins, discoverable elsewhere in the neighbourhood. The specification of the locality itself was wanting in precision: it was first understood by Garcia to be "near to Taltal, and ten leagues to the south-east of the silver-mine called *Isla*," and this information was given to him by Gana. In a second letter written by Garcia, and supposed by him to contain more precise information, the place was said to be "forty leagues north-east of Taltal, in front of the Sierra de Chaco, to arrive at which the road is taken which passes through the valley of Cachiyuyal." Later still (1875) Domeyko states that the first mine-seeker could only say that the place was "enormously in front of the Sierra de Chaco, although far from the Cordillera, at forty leagues to the north-east of Taltal," and he adds:—"I have lately chanced to learn that the mine-seekers call the place Quebrada de Vaca Muerta; it is a dozen leagues from the small bay (coast) of Guanillo (Guanilla, Huanilla);" he states between parentheses that Guanillo is in 25° south latitude. It is necessary, in the first place, to discover whether the two specifications of the locality adopted by Domeyko are consistent with each other, and how far they agree with the statements in the original letters.

Garcia and Domeyko write throughout as if the two specifications only differ in precision; but it will be seen on consideration that such is not the case. Domeyko understood by Chaco the watering place of that name, 8,778 feet above the sea-level, on the road from Copiapo to San Pedro de Atacama, for he mentions that it is marked on Philippi's map as being nearly under the same meridian as Imilac, though more than a degree of latitude further to the south. It is less easy to discover what locality is signified by Quebrada de Vaca Muerta. On a detailed map[1] of the Desert, founded on an official survey, the only Guanillo mentioned is $2\frac{1}{2}°$ north of the assigned latitude. Philippi's map,[2] however, shows a Quebrada Guanillo terminating at the coast in the latitude mentioned by Domeyko, and a later map[3] shows a Cape Guanilla (*sic*) at the same part

[1] *Carta del Desierto de Atacama: basada en los estudios del ingeniero Don Augusto Villanueva G. i otros viajeros. Segunda edicion para la Oficina Hidrográfica.*

[2] *Peterm. Mittheil.*, 1856, plate 3.

[3] *Ibid.*, 1879, plate 16.

of the coast. There can thus be no doubt that this was the small bay (coast) of Guanillo intended by Domeyko: yet it is difficult to understand why Paposo, which is situated on the coast at this point, was not itself selected to aid in the specification. Paposo had been said by Domeyko himself (1846) to be a small village, nearly half-way between Copiapo and Cobija, containing about a hundred inhabitants; according to Bollaert, writing in 1851, it was the principal *rendezvous* of the native fishermen of the coast for the purpose of barter; according to Philippi, it was at the time of his visit (1853) a single but long farm, with some rough pasture, extending for miles along the coast. One of the few tracks across the Desert ended at Paposo, being used by Indians travelling between the inland Antofagasta, on the eastern part of the Andes, and the coast. As the place was well known and its name was to be found on all the maps, we might have expected Paposo, and not Guanillo, to have been mentioned by Domeyko in his indication of this part of the coast. However that may be explained, it is quite clear that a point "twelve leagues from the coast in latitude 25° S." must be at least a hundred miles away from the watering place Chaco. The two specifications are in fact hopelessly inconsistent with each other: by no stretch of inaccuracy could a place a hundred miles distant from Chaco be described as "in front of" or even as "enormously in front of" Sierra de Chaco: even if Chaco had been visible at such a distance it would not have had much chance of being selected as a landmark.

Before proceeding further we must ascertain more precisely where Domeyko considered the Quebrada de Vaca Muerta to be. On no map published before Domeyko's statements does there appear to be marked any Vaca Muerta at all, but he was probably under the impression that it was a lateral ravine entered from the line of traffic between Paposo and Cachinal de la Sierra. In the detailed map, kindly sent me by Mr. Hicks, there is shown a hill called *Toro* (Bull) about the stated distance from the coast, and it would not have been surprising if the mine-seekers had actually placed a *Vaca Muerta* (Dead Cow) in its neighbourhood: from Taltal the foot of this hill may, now at least, be reached by a cart-road which winds round the watering place of Cachiyuyal: its distance from Taltal by such a route, and its distance from the coast at Paposo, would accord as satisfactorily with the "forty leagues" and "dozen leagues" of the later statements as do other estimated and actual distances in the Desert: we have only to take into account the fact that where there are no milestones the actual length of an estimated league must depend largely on the difficulty of the road.

In this tortuous way it is possible to imagine that a place "twelve leagues from the coast of Guanillo" might be described as "forty leagues north-east of Taltal on a road which passes through Cachiyuyal"; but still such a place is not in front of the Sierra de Chaco. Nor is there to be found on the maps any silver-mine called Isla, which this locality could be "ten leagues to the south-east of."

Hence it is clear that we must either renounce one or other of the original statements or interpret them in another way; remembering that as Professor Domeyko was located at Santiago, not very far distant, he may have had access to information from travellers and to maps not referred to by him in his memoir, and that any geographical suggestions of his are not to be lightly put aside.

We may first point out that if the original statement of Gana be true, the masses were found on a *llanura* (level plain); and this conflicts with the later statement that the locality is a *quebrada* (ravine).

Is there any *à priori* reason why doubt should be cast on Garcia's first account of Gana's statement, namely, that they were found near to Taltal, "about ten leagues to the south-east of the silver-mine called Isla"? José Diaz Gana, the authority for the original statement, was one of the ablest of mine-seekers, and was afterwards the discoverer of the rich silver-district of Caracoles.[1] It is almost certain, indeed, that Gana himself was the actual finder of the meteorite during one of his mine-seeking expeditions; and, according to Garcia, he had read Philippi's statements relative to the "San Pedro" iron, and had himself recognised the meteoric origin of the "Sierra de Chaco" masses before giving his information. Such a man would be at once familiar with the region and mentally capable of giving precise information as to the site.

Doubtless a false locality is sometimes assigned to a mineral with a view to the temporary concealment of the true one; but in this case it is scarcely conceivable that Gana could have considered such concealment as necessitated by his interests: probably he secured in the first instance as much as his mule or mules could carry; and he would feel that in any case no verbal description of the locality could enable a rival to anticipate him in the re-discovery of the place where the other masses were still lying; probably too he had muleteers with him who would render his keeping of the secret a useless task. In fact, Domeyko said in 1864 that as much as two hundredweight of the meteorite was known by him to be in the hands of collectors.

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[1] *Peterm. Mittheil.*, 1876, p. 322.

In a large map of the Argentine Republic[1] lately prepared by Professor Brackebusch of Cordova, there is given more or less detail of the neighbouring Desert of Atacama. In it there is marked a mine *Isla* only seven leagues distant by road from Taltal: and on the south of the mine is shown a large plain, Llano de Vaca Muerta. From the proximity to Taltal it seems certain that this must be the Isla signified by Gana; and if we accept as *bonâ fide* the information supplied by him, the true locality must have been ten leagues south-east of the mine, and thus about latitude 26° S. and longitude 70° West of Greenwich: the masses being found partly buried in the plain not very far away from some hillocks. A second Cachiyuyal, apparently a mountain, is situated in this part of the Desert. Philippi travelled in this neighbourhood when going from Cachinal de la Costa to Taltal, and describes it as a most sterile table-land, about 2,000 feet above the sea-level. This locality agrees perfectly with the indications given by Garcia in his first letter: it only remains to show how the other specifications may have arisen.

Gana, who probably gave his statement orally, is recorded by Garcia in the first letter to have said that the masses had been found in a large plain of the Desert, but near some hillocks: in saying that they were found *en frente de la sierra del chaco*, he would be merely expressing the same fact in different words, and would intend *chaco* to have its literal meaning, *desert*: by a mistake the words *sierra del chaco* were thought to be *Sierra de Chaco*, and taken to refer to the watering-place; and as Chaco is about ten leagues E.S.E of another *Isla*, such an interpretation agreed very fairly with the first specification: the "40 leagues north-east of Taltal" and the route by the valley of Cachiyuyal correspond with the position given to Chaco on Philippi's map, and are not definitely stated by Garcia to have been given by Gana; but they may have been added by Garcia merely to define the position of the watering-place Chaco relative to Taltal, after his inference that the masses had been found there. That Chaco was not the true locality is suggested by the fact that there is no mention on the maps of the existence of any mine at the corresponding Isla: nor does the configuration of the country as shown on the maps suggest a large plain terminated by low hills such as is described by Gana. Again, Chaco as a watering-place must have been so well known, being marked on all the maps, that only confusion could be produced by the mention of the comparatively little known Isla in its specification.

That Domeyko had doubts as to the locality even a year after Garcia's letter is shown by a letter, written and signed by himself, sent at the same

[1] *Mapa del Interior de la Republica Argentina*, 1885.

time with a specimen of the meteorite to the British Museum. This letter, which is written in French and is dated 26th October 1862, after stating that the meteorite had been found a year before, says :—

"There is not yet complete certainty as to the locality, but all the information I have been able to gather agrees in specifying a plateau situated at about *fifteen* (quinzaine) leagues from the coast, in front of the Sierra de Chaco, to the north-east of the port of Taltal, at more than a degree of latitude to the south of Imilac, and almost under the same meridian."

Here we have almost absolute proof that the "forty leagues from Taltal" was only a late interposition, resulting from the misinterpretation of Chaco: "about fifteen leagues from the coast" agrees well with "about ten leagues to the south-east of the silver-mine called Isla;" for, as already stated, the mine Isla is only about seven leagues by road from Taltal: the stated longitude and latitude are not likely to have been astronomically determined by Gana, and they are doubtless suggested by Philippi's map: later maps make Chaco to be almost due east, and not north-east of Taltal. It is impossible to resist the conviction that the "fifteen leagues" was altered to "forty leagues," after discovery from the map that Chaco was about the latter distance from the coast. To this it may be objected that the letter sent to the British Museum in 1862 is possibly less accurate than the published letters: but it must be remembered that although the letters from Garcia were written in 1861, they were not published till 1864, either at Santiago or at Paris. The alteration of the *fifteen* to *forty* might thus have been made by Domeyko as editor of the letters, in order to remove what he considered a mere numerical error: that the letters have been actually "edited" is obvious on comparison of the French and Spanish versions of the memoir. It is not unworthy of remark that in the French version, doubtlessly written but not revised in the printing by Domeyko himself, the words *sierra del Chaco* appear in place of Sierra de Chaco: before *proper* names the definite article is omitted in Spanish. Although in the same sentence *Cachiyuyal* is misprinted as Lachiyuyal, the substitution of *del* for *de* is scarcely of the accidental kind to be accepted as an error of printing: still in the "1862 letter" and in the Spanish paper of 1864 the words appear as *Sierra de Chaco*. That Gana actually said *sierra del chaco* is rendered more probable by the fact that, as shown in Plate X., the definite article is often used with compound proper names made up of common terms like *chaco*, *sierra* and *costa*.

The greater part of the statement attributed in 1875 by Domeyko to

the first mine-seeker who found the masses, namely, that "they were found enormously in front of the Sierra de Chaco, although far from the Cordillera," does not appear in the letters as published by Domeyko in 1864: if the sentence is an accurate repetition of the original statement, the Cordillera meant is probably not the Alta Cordillera (Andes), as understood by Domeyko, but the Cordillera de la Costa (the coast-range).

We have seen that two places bearing the name Guanillo or Huanillo (*i.e.* little palm) are given on the maps: the signification of the word was sufficient to suggest that the name might not be an uncommon one; and a search, for some time fruitless, was made for a map showing a third Guanillo, of which the position might accord more satisfactorily with the published statement of the locality of the masses. Since the above argument was written such a map has been found at the London office of the Taltal Railway Company: on this map, which is on a large scale and had been constructed by their engineer for the use of the Directors, is given a Bahia de Huanillos in latitude 25° 45′ S.; and in the immediate neighbourhood of the bay is marked a silver-mine called Vaca Muerta. The validity of the argument is thus almost beyond doubt. We have now a satisfactory explanation of the difficulty already mentioned, as to why Guanillo, rather than the better known Paposo, was used by Domeyko in defining a point of the coast in 25° south latitude. The Bay of Guanillo will have been mentioned by Domeyko's informant, and as we have just seen is really fifty miles south of Paposo: but the only place of similar name given in the maps, available for Domeyko, was Punta (Cape) Guanilla, close to Paposo, in 25° south latitude, and was therefore adopted by him as the one signified, notwithstanding the probability that Paposo itself would in such case have been selected by his informant.

The masses were in great abundance dispersed over a small area without order or definite direction: it was estimated that a ton (20 quintals) could easily have been collected: at the time of the publication of the first paper by Domeyko, at least two hundredweight (2 quintals) was known by him to be in the hands of collectors. The largest masses were partially embedded in the ground. Many of them were whole stones: the largest in the possession of Domeyko weighed more than 20 kilograms; some weighed only a few grams. Other specimens were evidently fragmentary, and had perhaps been broken for convenience of carriage. The density varies from 4·10 to 5·64, according to the proportion of the iron. Detailed descriptions of the mineralogical structure will be found in the memoirs cited above.

(*a.*) *Chili.*

A complete stone, which weighed originally 1,530 grams, and had been brought from Chili, was acquired for the British Museum in 1879, and entered provisionally under the name of *Chili* in the meteorite-list. The similarity to Vaca Muerta is so great, that having regard to the number and weight of the masses found at that locality, the name provisionally assigned to the specimen will be now changed to *Vaca Muerta*.

(*b.*) *Janacera Pass.*

In 1864 Professor Joy[1] carefully analysed and described a meteoritic fragment weighing 1,784 grams, which had been found on a mountain-pass about 50 miles from Copiapo by a native of the Argentine Republic: it had been presented by its finder to Mr. J. Brower, and by him had been brought to New York. In the same year Professor Lawrence Smith,[2] who had also received a bit of Brower's specimen, confirmed the description given by Joy, but pointed out the close similarity to the meteorite from Vaca Muerta which had then been just described under the name of Sierro de Chaco: he added that the name of the mountain-pass was given as Janacera, and that it had been suggested to him by Gillis, who had travelled much in Chili, that Jarquera, not Janacera, was really intended, for no Janacera Pass was known.

Of the accuracy of this suggestion we can after consideration have no doubt. There are only four or five passes over the Andes[3] used by travellers from Copiapo, and in the case of three of them the first fifty or sixty miles, namely, as far as Las Juntas, is along the Valley of Copiapo. At Las Juntas the Valley of Copiapo resolves itself into three, and one of them is followed for some distance for the ascent of the Come Caballo or Barranca Blanca passes. In this valley the first and almost the only inhabited place is a farm called Jorquera[4] or Jarquera, nearly seven leagues beyond Las Juntas, at a height of 6,406 feet above the sea-level: hence, though in its successive parts it is known as Rio del Pan, Rio del Cachita, Rio Turbio and Rio Figueroa, the whole valley, even as far as the Come Caballo pass, 14,522 feet above the sea-level, is known under the general name of Rio Jorquera or Jarquera. Further we may notice that a written label "Jarquera" may easily be misread as "Janacera:" it is only necessary to transform "rqu" into "nac;"—a

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[1] *Amer. Jour. Sc.*, 1864, ser. 2, vol. 37, p. 243.

[2] *Ibid.*, 1864, ser. 2, vol. 38, p. 386.

[3] *Petrm. Mittheil.*, 1860, p. 369.

[4] *Ann. d. Mines*, 1846, ser. 4, vol. 9, p. 421.

roundhand *r* is easily mistaken for *n*, an *a* for *q*, and even the conversion of *u* into *c* is far from impracticable.

We may thus, in the first place, infer with almost absolute certainty that the Brower fragment was actually picked up in the first part of the Jarquera valley before 1864, by some one travelling from Copiapo into the Argentine Republic by way of either the Come Caballo or the Barranca Blanca pass.

It still remains to determine whether the specimen represents a distinct meteorite—or is a far-off outlier of the Vaca Muerta fall—or finally, is merely a fragment of the Vaca Muerta fall which has been transported to the Jarquera valley from the spot where it was first found. All the evidence points unmistakeably to the accuracy of the latter explanation. The greater part of the Jarquera specimen (1,520 grams) is now in the Vienna Museum, and the suggestion made by Lawrence Smith of an identity of mineralogical characters with the Vaca Muerta meteorite is accepted as correct. An inspection of the small fragment now in the Ludlam Collection of Meteorites at the Museum of Practical Geology leads to the same conclusion. In such case we cannot doubt that both are likewise parts of one fall; for it is quite incredible that two meteorites, mineralogically identical, and yet different from all others, can have fallen on different dates at places only a hundred miles apart, have both been undiscovered for years, and then have chanced to be found about the same time, one of them far off in the Desert, and the other shortly afterwards on a line of traffic across the mountains, starting from the very place, Copiapo, to which at least two hundredweight of the first are known to have been transported before the second was found. It is evident that there was a demand for specimens; and we may reasonably conclude that many of the masses and fragments would be sent overland by way of the Come Caballo and Barranca Blanca passes. A statement of Philippi's experience with mules in the Desert of Atacama[1] sufficiently explains the rest:—

"There is much trouble with the mules: every moment the load keeps getting too much to one side or the other; and if it be not immediately put right, the mule runs, leaps and kicks, until the whole load is strewed on the ground. Some of the mules sought to get rid of the unwelcome load from the very beginning of our journey: they set off in full career and rushed round continually in circles until everything was spilled. After eight days they began to tame down. What the poor creatures have to suffer on the journey is proved by the skeletons which lie everywhere on the road."

[1] *Peterm. Mittheil.*, 1856, p. 62.

A distance of fifty miles from Copiapo is well within the eight-day limit.

(*c.*) *Mejillones.*

Some large meteoritic fragments in the British Museum Collection, without any more precise definition of locality than that they came from the Desert of Atacama, were provisionally entered in the list under the name of *Mejillones*. This name was assigned after discovery from examination of a polished face that they were doubtless mineralogically identical with a specimen (brought to the Museum for inspection), which was accompanied by a label bearing the following inscription :—

" Olivine meteor (Pallasite). This meteor was found by Indians near Meyellones in the Desert of Atacama, Bolivia, South America. The olivine is seen in right rectangular prisms, otherwise sprinkled everywhere with the iron."

But as they differ no more from the original specimen of Vaca Muerta, sent to the Museum by Domeyko, than fragments of any coarse-structured rock might be expected to, they may more legitimately be ascribed to the Vaca Muerta locality.

Looking to the weight of the Vaca Muerta fragments said by Domeyko to have been in the hands of the collectors before 1864, we must further infer that the information on the above label is not sufficiently authenticated to enable us to say that the fall was widely spread : all the reliable evidence in fact tends to prove the contrary. The specimen to which the above label belonged was probably itself a Vaca Muerta one acquired at Mejillones, the label merely repeating inaccurate information supplied to the purchaser.

3. Imilac.

(*Atacama : San Pedro de Atacama ; Toconao : Peine : Huanaquero : Potosi : Twenty leagues north-east of Toconao ; Campo de Pucará : Caracoles.*)

The sponge-shaped nickel-iron, with its numerous olivine-filled cavities, being at once of so definite and so rare a meteoritic type, there can be no difficulty in inferring that all which has been brought from a region of small area is the product of a single meteor. There however remains some doubt as to whether all the South American fragments of iron of this type have been found in the immediate neighbourhood of Imilac : to render a decision more possible as to the wide spreading or otherwise of the individuals of the fall, it is necessary to bring together for ready comparison the various statements which have been made relative to the discovery in South America of meteoritic fragments belonging to this type.

In a paper, read on February 4, 1828, Allan[1] gave the following account furnished by Dr. Redhead, who had been living in the Upper Provinces of Rio de la Plata since the beginning of the century :—

"The specimens were taken from a heap of the same nature, esteemed at about 3 cwt. They existed at the mouth of a vein of solid iron, half a yard wide, situated at the foot of a mountain. The opposite plain is strewed with similar fragments. The Indian who brought these calls them "Reventazones," supposing them to be produced by explosions from the mines. He had been charged to bring a piece of the vein itself, and some of the rock in which it is embedded; but this he says he could not effect for want of tools. He therefore contented himself with picking up some pieces that were at the foot of the hill, where the mouth of the vein opens. If it be true, as, from the probity of the Indian, who is well known from previous information and from general report, we must believe it to be true, that the metal is in a vein, it ought to be considered as the first phenomenon of this nature that has occurred."

In the same paper is quoted a letter, dated April 1827, from Sir Woodbine Parish, in which it is stated :—

"The account given by Dr. Redhead has since been fully confirmed by other accounts from different persons. The iron is found in the province of Atacama in Peru, at a distance of about twenty leagues from the port of Cobija, in large masses embedded in a mountain, in the neighbourhood of the village of San Pedro, and scattered over the plains at the foot of the mountain in question for a distance of three or four leagues, in fragments similar to that sent herewith, but some of them of considerable magnitude."

Further details were given in a work published by Sir Woodbine Parish[2] in 1839 :—

"The iron is found scattered in large quantities over a plain at the foot of a mountain a little to the south-west of a small Indian village called Toconao, ten leagues from San Pedro, the capital of Atacama, and about eighty from Cobija, on the coast. The tradition there is, that the fragments have been thrown out by some volcanic explosion from the side of the neighbouring mountain, in which the people of Toconao say there is a large vein of pure iron. The Indian who collected the specimens which I sent to this country was employed to search for mines; and the nature of his occupation rendered it requisite for him to be particular in

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[1] *Trans. Roy. Soc. Edinb.*, 1831, vol. 11, p. 223.

[2] *Buenos Ayres and the Provinces of the Rio de la Plata: London*, 1839, p. 260.

his observations. Further inquiries were subsequently made, the result of which corroborated his testimony. The magistrate of Toconao, who had been at the place, stated that the fragments had issued from a cavity of about fifteen feet diameter, which, from the nature of the soil, was filling up. This is sandy, and for three leagues round there is neither wood nor water nor pasture of any kind. Several persons in San Pedro, and amongst others one named Gonzales, who had likewise seen the cavity, gave a similar account."

So far there is only mention of a single not very well-defined place: the statement of Darlu, published in 1845, which has been already considered, should doubtless be taken to refer only to the fragments from the same neighbourhood.

In a letter written by Reid[1] of Valparaiso to Bonar of Ratisbon, published in 1851, is a description of a journey from Cobija to Tucuman from which the following is extracted:—

"Not far from the same place (Cobija) are the so famous meteorlithes [stones supposed to have fallen from the air] which you will receive at the same time with the mummies. It is my opinion that they are not meteorlithes, but are of volcanic origin. The first was found about 50 years ago. They lie on the road by which the Indians carried the Peruvian bark to Copiapo in Chili. At first they were thought to be silver, and the Indians made themselves spurs of them. Those which have not already been collected are covered over by the drifting sand, and one must dig in order to get at them. With little trouble we may convince ourselves that a volcanic eruption once took place here, for the direction of a distinct vein can easily be followed. I have my compass with me, and find that these stones contain a large quantity of iron. The stones appear in about 23° 30′ south latitude, and between 45 and 50 Spanish leagues distant from the coast."

As Dr. Reid made no visit to the place itself, and is merely quoting the accounts of the Indians, his statement must refer still to the same locality as before, as the internal evidence indeed suggests. The date of discovery given by him is quoted in various meteorite-lists, but it is evidently given without any attempt at precision, or the direct authority of the discoverer.

In the same year (1851) were published the results of the inquiries made by Bollaert,[2] whose attempts to reach the locality itself proved futile. He says:—

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[1] *Chambers' Journal*, March 8, 1851.

[2] *Jour. Roy. Geograph. Soc. London*, 1851, vol. 21, p. 128.

"I had so far back as 1826 obtained a specimen of this iron, which I had no doubt was of meteoric origin; and whilst travelling as far south as Mani, in the province of Tarapaca, in 1827 I learnt that there were two "iron mines," one called Peino, the other Huanaquero, in the Desert of Atacama, and that they were called "*reventasones*" or burstings. This word fortified me in the belief that they were deposits of meteoric iron, more particularly as I subsequently learnt that a person named Alejandro Chaves had heard a great noise in the vicinity of Peine in 1821, and that shortly afterwards large masses of iron were found scattered about the plain; also that an Indian, named Matico, and who lived near Huanaquero, knew the exact spot of the *reventason* there. The route to one of the iron-mines was given me, and I was informed that iron was found in abundance in a mountain. This I suppose to be at Toconao. It was this information that prompted me to essay crossing the Desert, when at Cachinal, in search of Huanaquero and Peine, in which I did not succeed. At Copiapo I got only little information on the matter; but at Coquimbo Monsieur C. Lambert corroborated much of what I had been informed in Peru, and mentioned to me that, in 1822, when he was on his journey from San Pedro to Copiapo, and wished to be taken to the *reventasones*, the people of that part of the country would not show him the spots, supposing them to be silver. He afterwards procured some specimens from one or other of the *reventasones* which proved to be meteoric iron: one of these he sent to England, and it is now in the British Museum, with a larger one presented by Sir Woodbine Parish. I have entered rather fully into this matter, as the positions have not as yet been visited by any scientific explorer, and the more so as it has been the subject of correspondence between Sir Woodbine Parish and Humboldt: the former having been informed that the Toconao deposit had been found existing as a vein."

The date of Lambert's journey fixes the fact that the discovery was already made in 1822, though at that time the fragments were still regarded by the Indians as containing silver. As earthquakes are frequent and active volcanoes exist in the vicinity, the noise heard by Chaves in 1821 very probably had no relation to the fall of the meteorite.

The existence of other localities of this sponge-shaped meteoric iron was carefully inquired into by Philippi[1] from the inhabitants of San Pedro, Toconao, Peine, and other villages: he never heard of more than one place of find, and became certain that a second did not exist.

[1] *Neues Jahrb. f. Miner.*, 1855, p. 8.

After meeting with great difficulty in securing a guide for the journey from San Pedro to Copiapo, Philippi had the good fortune to meet with Chaile himself, one of the original finders of the iron, and is thus able to give a satisfactory explanation of the origin of the various names which have been mentioned in connection with the specimens. *Huanaquero*, one of the assigned localities, is merely a watering-place a few leagues from Pajonal, where José Maria Chaile, who called himself "Proprietor of the mine of Imilac," had always a couple of cows at pasture in summer: *Peine* is the village where he generally lived: *Toconao* is mentioned because it is an important neighbouring village; it is the next village after passing San Pedro on the road from Cobija to the province of Salta, and had a certain importance, since after it was left there was a six days' journey across the Andes before dwellings were again met with (at Molinos). As the history of the find was furnished to Philippi by Chaile, who acted as his guide to the place, it is as far as possible free from the inaccuracies with which tradition is almost of necessity affected.

The locality was visited by Philippi and Döll in February 1854. The iron had been discovered 30 or 40 years before by two Indians from Peine, José Maria Chaile and Matias Mariano Ramos, when hunting the guanaco: mistaking the iron for silver Chaile speedily removed two big pieces, each 120 to 150 lbs. weight, making a mule-load. These treasures he buried in the neighbourhood of the watering-place Pajonal, concealing them so successfully that he was afterwards unable to re-discover them. When the news of the find leaked out, some of the curious made expeditions to the spot, while others acquired specimens through persons in the town of San Pedro, who themselves got them from the inhabitants of Peine. As already mentioned, some of the iron was worked into spurs and other articles in the smithies of San Pedro, and doubtless such of the bigger masses as could be found were carried away at that time.

Imilac, near which the specimens were actually found is not a village: it is one of the few places where water is found on the road from San Pedro to Copiapo. It is a small depression, estimated roughly by Philippi as 8,600 feet above the sea-level: in this depression is a small dried-up salt-lake on the banks of which are two holes full of moderately sweet water: there is thus some vegetation, though insufficient for a caravan of twelve mules.

Philippi continues his account as follows:[1]—

[1] *U.S. Naval Astron. Exped. to the Southern Hemisphere*: 1855, vol. 2, p. 287. *Peterm. Mitthel.*, 1856, p. 64.

"In order to reach it, on leaving the water-holes of Imilac we turned to the south-west, entering a little valley with an eastern aperture, whose very gentle slopes are scarcely more than 110 to 120 feet high. After half an hour's travel the first small specimen of iron was found, and ten minutes later we reached the principal place from whence it has been obtained. At the bottom of the valley a hole eighteen to twenty feet deep has been excavated by Indians, who expected to encounter a vein of iron; and in several directions from this principal one, at distances from ten to twenty paces, there are other apertures and piles of rubbish two to three feet high, indicating beyond doubt the places from which the largest and heaviest pieces of this greatly-sought substance had been extracted. At San Pedro I heard it said that there was still a large mass buried in the surface; and one Manuel Plaza told me, at Peine, that a very big specimen was rolled to the bottom of the valley; but I saw nothing of either. I remember reading, in a manual of mineralogy, that a stone weighing three hundred pounds had been obtained from here: but it must be a mistake, because masses of that weight cannot be carried by mules, and they afford the only mode of transport in the Desert.

"Arriving at the spot, we began to search for specimens. Nothing was found at the bottom of the valley or on the northern slope; but in a search of more than an hour on the southern declivity, and at an elevation of seventeen to twenty-eight feet above the bottom of the valley, I found a very great number of small fragments, within a space from sixty to eighty paces long by twenty paces broad.

"The surface has been formed from the decomposition of certain classes of porphyritic rocks, and is composed of a loose clayey earth mixed with an infinity of little stones, from the size of a walnut to that of an apple, and does not differ essentially from the greater portion of the Desert. The porphyry may be termed granitic or syenitic, because, in a whitish, crystalline, felspathic component, of which the oxide of iron on the surface becomes reddish, we find disseminated grains of hyaline quartz, slightly inclined to grey, which are of the size of hempseed. Small black spots, more or less dendritic, appear to arise from manganese; but in some cases they are positively known to be amphibole. It is very rare to find any specimens containing small spots of white mica; they form the transition to granite, and are more granular. Some of these stones have their surfaces covered with a black crust, which appears to be principally formed of the hydrated oxide of iron. The most remarkable thing is, that all of them have their angles very sharp, proving that they have not been rolled from afar, but were formed on the same spot by natural fracture of the rock.

"The specimens I collected weigh three pounds less three drachms, and number 673; so that the mean weight of each is twenty-three grains—the largest weighing two ounces, and the smallest less than one grain. We may suppose that my companion, Don Guillermo Döll, obtained the same number, José Maria Chaile as many, and it is probable that one half remained unseen. Therefore the total number of pieces in that locality exceeded 3,000, without enumerating the many large stones carried away during the last thirty or forty years, and which there is no possible mode of estimating."

Although in Philippi's account we have no mention of a plain or plains opposite to the mountain, there can be absolutely no doubt that the locality described is identical with the one mentioned by Dr. Redhead and Sir Woodbine Parish, and that there is, as far as we have yet mentioned, no evidence of a widespread fall. The largest preserved mass then known was one in the possession of Professor Domeyko at Santiago, and weighed more than 50 lbs.

About the year 1877, owing to the persevering inquiries of Mr. George Hicks, there was found near Imilac a specimen weighing 450 lbs., and thus far bigger than any previously known. Mr. Hicks presented it to the British Museum in 1879; and after a visit to the Museum in 1882 sent a letter containing the following interesting details relative to the discovery and the district:—

"By way of reference I accompany this letter with a new map of the district of Atacama; in it are embodied my own observations, particularly between the 23° and 24° parallels of S. latitude, which I was one of the early explorers of, and which on account of the great wealth of nitrate of soda and of silver, subsequently discovered, excited the envy of the Republics of Peru, Bolivia and Chili, finally resulting in the present disastrous war. In consequence of the entire absence of fresh water or any kind of vegetation, the tract of country lying between the Serrania de Sarapana and the coast had scarcely ever been trodden previously to 1867; but the district of Atacama lying to the east of those mountains has been explored and reported on by Professor Philippi, who in his memoir on the Desert of Atacama refers to the frequent splinters of aerolite scattered over that region. I had frequently been shown specimens of the shower to which he referred, all of which closely resemble the large specimen now in your collection, and also several small specimens that I saw there which must I think have been brought from the Desert of Atacama. For years I was anxious to obtain a specimen; and when the important silver-region of Caracoles was discovered, in the

centre of the district to which I refer, explorers came in from all parts and the country was most closely examined; the explorers often found small specimens but never anything approaching a deposit, or ever that I have heard of, two pieces near together; the pieces found were eagerly inquired after, and I failed to obtain a sample notwithstanding a liberal offer for a piece weighing about 20 lbs. which was purchased for the Museum at Santiago. In my frequent attempts to obtain a specimen, I offered a reward to some Indians employed in bringing sheep from the Argentine Republic to the coast at Antofagasta; they for years assured me that they had searched in vain; but finally, about 1877, an old Indian rode down to inform me that he had found a very large one near Imilac. He said it was very heavy, and could not be lifted by less than four men, and that it lay in a ravine half buried in the sand. He managed to break off a few bits of the specimen which convinced me that it was an aerolite: as it was too heavy for a mule-load it was necessary to send a cart, which rendered the task of getting it to the coast over a distance of 150 miles of desert very difficult and expensive. At a point on the Serrania de Sarapana marked A on the map (Plate X.), the open Desert ends, and roads had to be made for the cart to pass, but at Imilac and also at Cuevitas 70 miles from the coast drinkable water exists; so I despatched an expedition of four men and a cart with four mules, and in about ten days had the satisfaction of receiving the aerolite safe at Antofagasta: I had been searching for a specimen for at least four years. Its discovery caused great interest on the coast, and I had offers for it for the Museums of Limá and Santiago, but from the first destined it for the British Museum.

"Now although it is my opinion that this is no other than part of the great shower of aerolites which fell at some distant time over this part of the earth, for in no other way could one imagine so many pieces of so rare a substance being scattered so indiscriminately over such a large space as these are in the Desert of Atacama, it must still be borne in mind that the locality in which it is found is highly volcanic, many of the mountains along the range lying at the east of the great dry salt lake of Atacama being still active volcanoes; the Redonda Volcan and Socomba, only about 25 miles from the spot where this specimen was found, are also at times active. The mountain called Llullaillaco, about 50 miles south, although formerly considered an extinct volcano was, strangely enough, seen by Professor Pissis, when employed in determining the boundary-line between Chili and Bolivia on May 5th, 1879, two days before the great earthquake, sending forth volumes of smoke: the whole region is in fact of a highly volcanic character."

The only accounts suggestive of a wide-spreading of the Imilac fall have been the following :—

(*a.*) *Potosi.*

"H. M. Juben, a lieutenant in the French navy, among other minerals which had been presented to him, brought from Peru a piece of meteoric iron found near Potosi in Bolivia: it is now deposited in the Museum at Angers."[1]

As the accompanying description is identical with that of Imilac, we may point out that Juben makes no claim to be the finder of the specimen, and that, as has been already pointed out, Imilac specimens are known to have been in the hands of very distant collectors long before 1839. The road from Cobija to Potosi passes through Chiu-chiu, and the Juben specimen might have been taken to Potosi after being acquired either at Chiu-chiu or at San Pedro. The mineralogical identity of Potosi and Imilac was asserted by Partsch.[2] In a letter lately sent by Mr. Hicks he writes as follows in answer to my inquiries :—"I have often heard of the Potosi aerolite, and General Jofré, Prefect of Antofagasta, had a small piece (about 8 oz.) which he told me came from there : it was exactly like the Imilac aerolite : he had seen the large lump, weighing a ton or more, of the same class, with olivinoid, somewhere near Potosi."

At first sight this seems conclusive of the existence near Potosi of a large mass belonging to the Imilac type : but it is still possible that the Jofré fragment came from Imilac itself, and was never part of a large Potosi mass ; in which case there would remain a doubt as to the identity of the mineralogical characters of the Imilac and Potosi specimens.

(*b.*) *Twenty leagues north-east of Toconao.*

J. J. Von Tschudi of Jakobshof,[3] in a letter to Haidinger, dated October 9th, 1859, wrote as follows :—

"There is still a mass of meteoric iron, weighing about a ton, lying 20 leagues north-east of Toconao : fragments of it in my possession are perfectly like that from Imilac about 50 leagues further south, where, as Philippi has shown, the iron is no longer found. The locality mentioned by me is only known to a few persons : I have seen very fine stirrups and spurs which have been made from this iron."

Tschudi does not say that he himself had seen the mass ; and having a wrong impression that specimens could no longer be got from

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[1] *Phil. Mag.*, 1839, ser. 3, vol. 14, p. 394.

[2] *Die Meteoriten zu Wien*, 1843, p. 86.

[3] *Sitz. Ak. Wien*, 1864, vol. 49, part 2, p. 494.

Imilac, may have been more ready to credit an Indian report to the effect that the fragments offered to him came from a new locality: big specimens were by that date rarely found, and if one had again been discovered near Imilac the Indian might be anxious to conceal the true locality.

Tschudi travelled from Salta through Toconao and San Pedro de Atacama to Cobija in the summer of 1858:[1] his statement may be merely a repetition of one made by some Indian when offering him fragments at the time of his passing through Toconao or San Pedro.

Mr. Hicks writes to say that he has heard of such a mass, but cannot be certain either of its existence or its composition.

A place twenty leagues north-east of Toconao will be within the State of Potosi, though not near the town of that name: hence having regard to the stated weights it is conceivable that the reports of Tschudi and Hicks have had a common origin. Further information, however, must be awaited, before the existence of a large meteoritic mass of the Imilac type in the neighbourhood of Potosi is accepted as proven.

(*c.*) *Campo de Pucará.*

In the Exhibition held at Buenos Ayres in 1882 was shown a specimen said to have been found in 1879 at Campo de Pucará in the Cordillera of Catamarca.[2] According to Cohen,[3] who has carefully described a fragment of it, the meteorite cannot be distinguished mineralogically from Imilac, and he discusses the question as to whether it is a widely separated individual of the Imilac fall or the residue of another meteor.

The two instances of other widely-spread falls adduced by Cohen are unsatisfactory: the one *Vaca Muerta*, has already been controverted in the course of this paper; the other, *Coahuila*, may be discussed in a similar way.

Nor on the other hand do the falls mentioned by Cohen of two very similar stones, the one, *Klein-menow*, in the Old World, the other, *Wisconsin*, in the New, afford any weighty proof that the Imilac and Campo de Pucará fragments have been the result of separate meteors; for of course the sole difficulty is due, not merely to the two fragments being similar, but to the fact that similar fragments of a very rare type have been brought from places only 200 miles apart, a distance too small for separate falls and too large for a single fall to be the probable explanation.

We here suggest that, like the *Potosi* specimen of M. Juben, it is merely

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[1] *Peterm. Mittheil.*, 1860, *Ergänz.* 2.
[2] *Abhandl. h. vom Naturw. Vereine zu Bremen*, 1886, vol. 9, p. 359.
[3] *Neues Jahrb. f. Min.*, 1887, vol. 2, p. 45.

a fragment carried away from the vicinity of Imilac, and we may follow the line of argument adopted both in that case and in the consideration of the meteoritic fragment brought from the Jarquera valley :—

Specimens of the Imilac iron were certainly carried across the Andes, for those sent to the British Museum by Sir Woodbine Parish in 1827 were carried overland to Buenos Ayres, and would be brought by way of the town of Cordova, which is the centre of traffic between the Upper Provinces and Buenos Ayres ; from the latter place Cordova was distant 172 leagues by post-road. There is considerable traffic between Campo de Pucará and Chili.[1] Campo de Pucará is one of the most important pasturages of the chiefly sterile province of Catamarca : cattle-farming is done on a large scale, and good butter and cheese are made. From this and similar high valleys live stock after fattening is sent to Chili, being shod with iron for the crossing of the Andes. The line of traffic between Cobija and Cordova passes through Campo de Pucará : a detailed map and a minute description of the route have been given by Tschudi. It is thus quite possible that the specimen was one from Imilac, which had either been dropped during transport, or had been preserved by a dweller at Campo de Pucará. The difficulties of the route are such that it would not have been surprising if the whole track had been strewed with baggage, left behind after the collapse or disappearance of the mules, and neglected by subsequent travellers. A two hours' descent, immediately after crossing the Campo de Pucará, is thus described by Tschudi:—"During the extremely precipitate descent I could easily understand the mishap of the North American traveller whom we had just met, and who had told us of the fall of one of his mules over a precipice. It was with anxiety that I gazed on the mules as they came down the rocks far above us : in the more difficult parts their loads fell forward over their necks, and every moment I stood in dread of seeing them topple over their heads." Burmeister,[2] describing the passage of the Andes made during his journey from Catamarca to Copiapo, says :—" The cloudless and extremely dry wind, which is generally blowing violently from the west over the top of the Cordilleras, permits of objects being seen clearly at a great distance : it dries up everything organic immediately, and in a few hours mummifies the carcases of the fallen mules, which indicate the track, lying as they frequently do at short distances from each other, and yielding the only variety to be met with in this monotonous waste." Gillis, describing

[1] Burmeister. *Description Physique de la République Argentine*, 1876, vol. 1, p. 343.

[2] *Peterm. Mittheil.*, 1860, p. 373.

another route across the Andes by way of the Portillo pass, says that merchandise is never risked over it, except for about two months in the summer.

We have as yet no statement of the weight of the Campo de Pucará specimen, but the fragments sent over to Europe have been so small that it is not rash to infer that the original had a weight well within that of a possible mule-load: at Göttingen there is a fragment weighing 352 grams, at Paris and Vienna there are 8 and 5 grams respectively.

(*d.*) *Caracoles.*

It is mentioned in the above letter of Mr. Hicks that small specimens similar to those of the Imilac locality had been often found by the explorers during the examination of the country subsequent to 1870, when the silver-riches of Caracoles were discovered, but that he had never heard of two being found near together. The letter gives no information as to the distance from Imilac at which specimens had been found.

Domeyko,[1] in 1879, said that a mass belonging to the Imilac type had been recently found in the neighbourhood of Caracoles, and that he owed a fragment of the mass to the kindness of Uldaricio Prado: a piece weighing 42 grams is in the Paris Museum, and is said to have been found in 1877. It is far from certain that Imilac itself would not come within the "neighbourhood" of the Caracoles district, as understood by Prado. A road now runs straight from Placilla to the southern extremity of the great dried salt-lake of Atacama, which is quite near to the original site.

Mr. Hicks tells me that the *Caracoles* specimen mentioned by Domeyko must be identical with the big mass found at Imilac in 1877 and sent to the British Museum: no other specimen of importance could have been found without his hearing of it. That Mr. Hicks is right in the suggestion is confirmed by the fact that Domeyko, in the edition of his Mineralogy published in 1879, made no mention at all of a large mass having been found at Imilac and taken to Antofagasta in the year 1877. He knew of the existence of the mass; for, as stated in the above letter, offers were made for the specimen for the Museums of Limá and Santiago, the latter of which was in Domeyko's own charge. Although he heard of the mass itself, he had probably only a vague idea of its size, and merely obtained with a fragment from Prado indirect information as to where the mass itself had been found. May not Prado have got his fragment from the men who were transporting the large mass to Antofagasta?

[1] *Mineralojia, por Domeyko*, 3rd ed. 1879, p. 129.

Summing up, we may say that there is really no satisfactory evidence of an extraordinary spreading of the Imilac fall, and that every fragment known to be preserved has very possibly been found in the immediate neighbourhood of Imilac itself. The specimens which would indicate an extraordinary spreading of the shower are probably either mythical, or have been actually carried from Imilac.

For information as to the chemical composition and the structure of the Imilac meteorite we may refer to the following literature in addition to that already cited :—Rumler ; *Pogg. Ann.* 1840, vol. 49, p. 591 : Schmid ; *Pogg. Ann.* 1851, vol. 84, p. 501 : von Kobell ; *Corresp. Bl. zool. min. Vereines in Regensburg*, 1851, p. 112 : Field ; *Quart. Jour. Chem. Soc.*, 1856, vol. 9, p. 143 : Frapolli ; *Jahrb. f. Mineral.* 1857, p. 264 : Reichenbach ; *Pogg. Ann.* 1861, vol. 114, p. 104 : Meunier ; *Comptes Rendus*, 1872, vol. 75, p. 588 ; 1882, vol. 95, p. 1384.

4. Copiapo.

(*Sierra de Deesa : Atacama : Chili.*)

(*a.*) A specimen of nickel-iron remarkable for its irregularly disposed angular enclosures, chiefly of troilite and silicates, was described and figured under the name of *Copiapo* by Haidinger[1] in 1864 : it had been sent in November 1863 to the Vienna Museum by Dr. Speyer, of Cassel, who had received it along with some silver-ores from one of the partners in a rich silver-mine near Copiapo. The specimen had thus presumably been found somewhere in the southern part of the Desert of Atacama. When cut it weighed 1242·5 grams.

(*b.*) A fragment, 2·4 grams in weight, presenting, though small, a similarity to the above, was purchased for the British Museum in 1866 from Landauer, of Frankfort-on-Main : it was labelled "Meteor-Copiapo-Chili" : it is so similar to another small specimen received from the Paris Museum in 1867 with the label "Sierra de Deesa" that it is impossible to doubt that both are fragments of one mass.

(*c.*) In 1868 there were described, by Daubrée,[2] two specimens, weighing 800 and 1305 grams respectively, both of them presenting characters which are extremely rare, and are identical with those of the iron called *Copiapo :* the specimens which had been sent by Domeyko were supposed by Daubrée to have been found in the Cordillera de Deesa, near Santiago.

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[1] *Sitzungsb. Ak. Wien*, 1864, vol. 49, part 2, p. 490.

[2] *Comptes Rendus*, 1868, vol. 66, p. 571.

The distance from Copiapo to Santiago being upwards of 450 miles, this seemed to be another illustration of the occurrence of widely-spread falls. There are now 13,990 grams of this meteorite in the Paris Collection, and 840 grams at Dresden.

A comparison of the accounts given by Domeyko[1] and Daubrée conclusively proves, however, that a wrong locality has been unluckily assigned to the so-called "Sierra de Deesa" specimens. Two meteoric irons were sent simultaneously by Domeyko to Daubrée; one of them had been found in the "Cordillère de Deesa" (Dehesa) "near Santiago;" the other was from "an unindicated locality in Chili." Identical descriptions and identical analyses are published by Domeyko and Daubrée for each of these irons, but the description and analysis given by Domeyko for the Deesa iron are assigned by Daubrée to the iron of unindicated locality, and *vice versâ*. There has evidently been an interchange of labels, either at Santiago or Paris; and in that case we must adopt as correct the localities assigned by Domeyko, from whom the specimens and the analyses had been derived. We may add that La Dehesa is shown in the maps as being 10′ N.N.E. of Santiago.

Upwards of 7 kilograms of the iron had been originally received by Domeyko in a lot of Chilian minerals sent to him by Señor Ludéve.

(*d.*) A fragment, weighing 818 grams, which presents identical characters, was acquired for the British Museum from M. Bertrand, of Paris, in 1872. It was approximately half of a specimen, which had belonged to an important series of Chilian minerals collected by a medical gentleman, Dr. Thomas, who had long lived in Chili. According to Bertrand, the iron was said to have been brought from the Desert of Atacama. After the death of Dr. Thomas, the second half of the specimen was also acquired by M. Bertrand, and was eventually sold by him in one piece, but he does not remember the name of the purchaser.

There can be little doubt that all these specimens are the products of a single fall, and it is likely also that they have been parts of a single find: in any case there is absolutely no evidence of a wide spreading of the fall. A single name for these fragments of meteoric iron can lead to no confusion of specimens, and, however trivial, would be acceptable, so long as it suggests only what is not untrue. The generally accepted name at present is *Sierra de Deesa;* but after the above statement only confusion would result from its further retention, and reversion is here made to *Copiapo*, the name originally given by Haidinger.

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[1] *Mineralojia, por Domeyko:* 3rd ed. 1879, p. 132.

5. Mejillones.

A mass of iron, so big that a cart would be requisite for its carriage to the port, was found about 3 or 4 leagues from the Bay of Mejillones by Captain Francesco Vidal Gormaz, a distinguished Chilian naval officer and explorer. Only a fragment was detached at the time and carried to Santiago, but measures were taken for the transport thither of the original mass: half of the fragment, weighing 164 grams, was sent to the Paris Collection by Domeyko, by whom a description of the iron was published in 1875,[1] shortly after its discovery. Daubrée adds that a polished face yields no Widmanstätten figures on etching, but reveals a confused crystallisation suggestive of the *moiré métallique*.

Domeyko's analysis gave :—

Iron	...	...	95·4
Nickel	...	...	3·8
Cobalt	...	...	0·1
Schreibersite		...	0·9
			100·2

6. The Polanco Iron.

According to Domeyko[2] (1879) a mass of meteoric iron, found about 12 leagues to the south of the town of Mejillones, was recently exhibited by Señor Polanco at the International Exhibition at Santiago. No description of the iron has yet been published.

7. Mount Hicks.

(*Mantos Blancos.*)

This mass of iron, weighing 10·3 kilograms, was presented to the British Museum by Mr. George Hicks in the year 1879. It had been found by one of his workmen, about three years before, on the south-eastern side of Mount Hicks, a mountain so named after Mr. Hicks himself as one of the earliest explorers of the district. This mountain is close to the Antofagasta Railway, about 40 miles from the town; it is skirted on the railway-side by Mantos Blancos: the latter name is as yet

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[1] *Comptes Rendus*, 1875, vol. 81, p. 597. *Mineralojia, por Domeyko*, 3rd ed. 1879, p. 131.

[2] *Mineralojia, por Domeyko*: 3rd ed. 1879, p. 137.

more frequent than that of Mount Hicks on the maps. A detailed map and description of the immediate neighbourhood of the railway has been given by Harding:[1] in that map the mountain is given as in latitude 23°23′ South, longitude 70°5′ West of Greenwich. Like Juncal and Youndegin, this meteorite is a portion of a shell; it is rudely triangular in outline, each side being about 210 mm. long; the thickness of the shell at one side reaches 60 mm. On the convex side there are numerous pittings, about 5 mm. in diameter, having sharp rims: on the concave side are large depressions, one reaching 50 mm. in diameter; the latter are very similar to the concavities of Youndegin.

As in Juncal and Ilimaë, linear ridges have resulted during the slow atmospheric erosion of the mass.

The iron during cutting was found to be moderately soft: in the section, which is about 80 mm. by 80 mm., there are several small spots of troilite. On the etched surface the kamacite is seen to be in narrow bands; for each of two sets the average width of the bands is 0·25 mm., for a third set it is 0·75 mm.; the bands are long, straight-edged, and sometimes closely grouped. The plessite is plentiful and well distributed.

Relative to a solution of copper sulphate, the iron is active.

Relative to water at 4°, and allowing for displaced air, the specific gravity at 15° C. of a thin slice without visible enclosures and weighing 5·6064 grams, was determined to be 7·904 (uncorrected 7·92).

On analysis of the slice by the methods already described,[2] the following numbers were obtained:—

Iron	90·77
Nickel	8·83
Cobalt	0·55
Copper	trace
Phosphorus	0·10
	100·25

8. Varas.

A mass weighing nearly 1470 grams, also presented to the British Museum by Mr. Hicks, was found about 1875 by a miner when exploring near Serrania de Varas; the spot is marked by Mr. Hicks on his map as

[1] *Jour. Roy. Geograph. Soc. London*, 1877, vol. 47, p. 250.

[2] *Mineralogical Magazine*, 1887, vol. 7, p. 124.

being 24°33′ S., 69°4′ W. of Greenwich. On one side it is only slightly convex, on the other it is nearly an obtuse cone; the base of the cone has an average diameter of about 90 mm., and approximates to a triangle with convex sides and rounded corners. The conical side is covered with shallow pittings of small diameter; the other side is more smooth. None of the original crust was found to be present, and the rust-coating is thin. The iron is soft and malleable. No enclosures were passed through in making the section, which is bounded by an ellipse with axes of 57 mm. and 30 mm. in length.

Relative to a solution of copper sulphate, the iron is active.

The Widmanstätten figures produced by etching are very distinct: the kamacite bands are very narrow (generally 0·25 mm. for one set in the section, 0·50 for another set), sometimes following one another in quick succession; their edges are nearly rectilinear : the plessite is dark in colour, fairly plentiful in parts, and is generally free from the "combs" mentioned by Reichenbach.

Relative to water at 4°, and allowing for displaced air, the specific gravity at 17° C. of a thin slice, without visible enclosures, and weighing 5·0024 grams, was determined to be 7·863 (uncorrected 7·88).

On analysis of the slice by the methods already described, the following numbers were obtained:—

Iron	91·28
Nickel	8·00
Cobalt	0·44
Copper	trace
Phosphorus	0·05
	99·77

9. Cachiyuyal.

A small mass of iron, weighing 2550 grams, was found at the end of 1874 about a score of leagues from the coast and somewhere near Cachiyuyal. The Cachiyuyal referred to is probably the more northern one, on the road to Cachinal de la Sierra. The entire mass was placed in the Santiago Museum; a small piece weighing 350 grams, detached for the purpose of analysis, was eventually sent by Domeyko to the Paris Collection.

The form of the mass is very irregular, and its whole surface is covered with furrows like those visible on Juncal.[1]

[1] *Comptes Rendus*, 1868, vol. 66, p. 570.

Daubrée says that no Widmanstätten figures are developed on this iron by etching; this is an unexpected result, having regard to the furrows consequent on atmospheric action.

Domeyko's analysis gave—[1]

Iron	93·72
Nickel	4·87
Cobalt	0·39
Schreibersite	0·40
Silicates	0·50
	99·88

A cast, just received with the label *Cachiyuyal* from the Vienna Museum, corresponds to a mass of meteoric iron weighing about 37 kilograms; its original must therefore be distinct from the mass above mentioned.

10. Ilimaë.

A mass of meteoric iron, brought to Heidelberg by Herm. Schneider, a student from Valparaiso, was acquired for the Vienna Museum in 1870 by Professor Tschermak, by whom it was figured and minutely described.[2] The only information as to its locality was given on a label which stated that it was found about 26° S. latitude, and 70° W. longitude: whether the longitude is measured from Greenwich or Paris seems to be uncertain: in a Chilian map drawn by Domeyko the latter meridian is chosen. If the meridian is that of Greenwich, the locality must be approximately the same as that of the Vaca Muerta masses, and very near to Cachiyuyal. The name Ilimaë, given by Schneider as that of the locality, is shown on none of the maps: indeed it is far from impossible that the name is a mere misspelling of Imilac, which is itself another version (used by Domeyko) of *Imilac*, long the only known locality for the Atacama iron: in such case the name may have no relation to the true locality.

The iron weighed 51·7 kilograms; it shows none of the original exterior, is somewhat convex on one side, and concave on the other; it is covered with more or less spherical depressions, about 3 or 4 centimeters in diameter on the former side and 1 centimeter on the latter. The atmospheric erosion has revealed the octahedral structure, as in the case of Juncal.

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[1] *Comptes Rendus*, 1875, vol. 81, p. 597. *Mineralojia, por Domeyko*, 3rd ed. 1879, p. 131.

[2] *Denk. Ak. Wien.* 1872, vol. 31, part 1, p. 187. *Sitz. Ak. Wien.* 1871, vol. 63, part 2, p. 323.

When the iron was cut troilite-lamellæ parallel to the faces of the cube were met with. An etched surface shows excellent figures on etching, and has an orientated sheen.

Ludwig's analysis gave—

Iron	91·53
Nickel	7·14
Cobalt	0·41
Copper	trace
Phosphorus ...	0·44
	99·52

11. Juncal.

A large mass, weighing 104 kilograms, was found in 1866 by Lisaras Fonseca near the watershed on the western side of the Alta Cordillera of the Andes, between Rio Juncal and the dried up Salinas de Pedernal, which are near to the open pasturages of Leoncita (Leoncilla) and La Ola, about 50 leagues in direct line north of Paypote.[1] Leoncito (Leoncita) and La Ola are on a road which skirts the Salinas de Pedernal, and is used by travellers from Copiapo to the inland Antofagasta: the meteorite seems, however, to have been found on the other side of the Salinas de Pedernal, nearer the road which passes through Juncal towards San Pedro de Atacama. Fonseca had been on an unsuccessful expedition in search of mines, and had already lost 11 out of his 25 mules, while the rest could scarcely walk: the big black block was only a small distance from the road and arrested his attention. Thinking it was silver he determined to take it to Copiapo, and luckily one of his mules was still equal to the load. It was only on his arrival at the metallurgical establishment that he learned its true nature. Fonseca's opinion was that the mass had been carried so far by miners from the other side of the Andes, and then abandoned with the intention of removing it later. It was presented by the Government of Chili to the Paris Collection. The surface is almost completely covered with concavities of various sizes: there are also sinuous furrows due to slow atmospheric erosion, which has at the same time brought out evidence of the octahedral structure.

The Widmanstätten figures are excellently shown on etching a polished face.

[1] *Comptes Rendus*, 1868, vol. 66, p. 569; 1875, vol. 81, p. 599. *Mineralojia, por Domeyko:* 3rd ed. 1879, p. 129. *Denk. Ak. Wien.* 1882, vol. 43, part 2, p. 13.

At one part of the mass is a cavity visibly due to the disappearance of troilite.

The specific gravity is 7·697 at 9°·5 C.

Damour's analysis gave :—

Iron	92·03
Nickel	7·00
Cobalt	0·62
Phosphorus ...	0·21
	99·86

12. Barranca Blanca.

(*San Francisco Pass.*)

This mass of meteoric iron, weighing 11·3 kilograms, was purchased for the British Museum in 1867 from Señor Bustos : it had been found in 1855 by a muleteer, Vincenti Avila, close to "Barranca Blanca, a refuge from the terrible tempests of the Andes, between Copiapo and Catamarca." Burmeister, in his description of a journey made from Catamarca to Copiapo in 1860, says that there is a shelter for the night at Arroyo Blanco, quite close to Barranca Blanca : a map of the route showing both these names accompanies his paper. Since 1860 a *casucha*, or substantial house, has been built there by the Argentine Government for the use of travellers.[1] From this account of the discovery it is very possible that the mass had been dropped during transport across the Andes from Copiapo : sentences of Philippi and Burmeister indicating such a possibility have already been quoted (pp. 242, 253).

The mass is somewhat flattened in shape, being 220 and 230 mm. long in two directions, and having only a maximum thickness of 80 mm. On both sides there are large concavities, some of them 60 mm. in diameter, and, with the exception of part of one side, which is more smooth, the whole is covered with smaller pits, generally about 3 mm. in diameter and having sharp rims : the smoother side is doubtless that on which the mass has been lying, and the pits on the other parts are due to a prolonged atmospheric exposure. In the polished section, which has a maximum length and breadth of 150 and 65 millimeters, several scores of troilite-spots, having a maximum length of 3 mm., were visible. When treated with bromine-water no Widmanstätten figures were revealed : but all over

[1] Burmeister. *République Argentine*, 1876, vol. 1, p. 366.

the section were seen small closed angular curves formed by a bright substance resembling tænite.

Relative to a solution of copper sulphate the iron is active.

Relative to water at 4°, and allowing for displaced air, the specific gravity at 20° C. of a slice weighing 5·6209 grams and containing visible enclosures of troilite was determined to be 7·823 (uncorrected 7·85).

On analysis of this slice by the methods already described the following numbers were obtained :—

Iron	91·50
Nickel	8·01
Cobalt	0·65
Copper	trace
Phosphorus ...	0·15
Sulphur	0·13
Insoluble residue	0·03
	100·47

The minute residue (1·6 milligrams) insoluble in *aqua regia* consists partly of richly facetted crystals of chromite, and partly of grains of a colourless transparent birefractive substance with the density and certain other characters of asmanite (or tridymite): the chromite is sometimes intergrown with or enclosed by the asmanite.

13. The Joel Iron.

(*Atacama.*)

A mass of iron, weighing 1300 grams, found in the year 1858 in some unspecified locality in the Desert of Atacama, was presented to the British Museum in 1863 by Mr. Lewis Joel, the British Vice-Consul at Cobija. This mass is likewise somewhat concavo-convex in form. Although the meteorite is small, its surface has large deep concavities, one of them 40 mm. in diameter, such as are shown by Ilimaë: the large concavities are covered with small shallow pittings 1 or 2 mm. in diameter.

Relative to a solution of copper sulphate the iron is active.

Immediately after polishing, and before it had been subjected to the action of an etching liquid, a face showed very distinctly the lines of octahedral structure. In the section, which is 67 mm. long, and varies from 23 to 50 mm. in width, narrow elongated inclusions of troilite reaching 5 mm. in length are visible, and after the etching of the face

are seen to be almost wholly in the kamacite and parallel to its edges. The kamacite bands are broad: three forming a triangle were in one average case 1·2, 1·0, 1·0 mm. wide respectively; they have a more or less undulating outline, and occasionally run uninterrupted for a distance of 20 mm., though generally not so far.

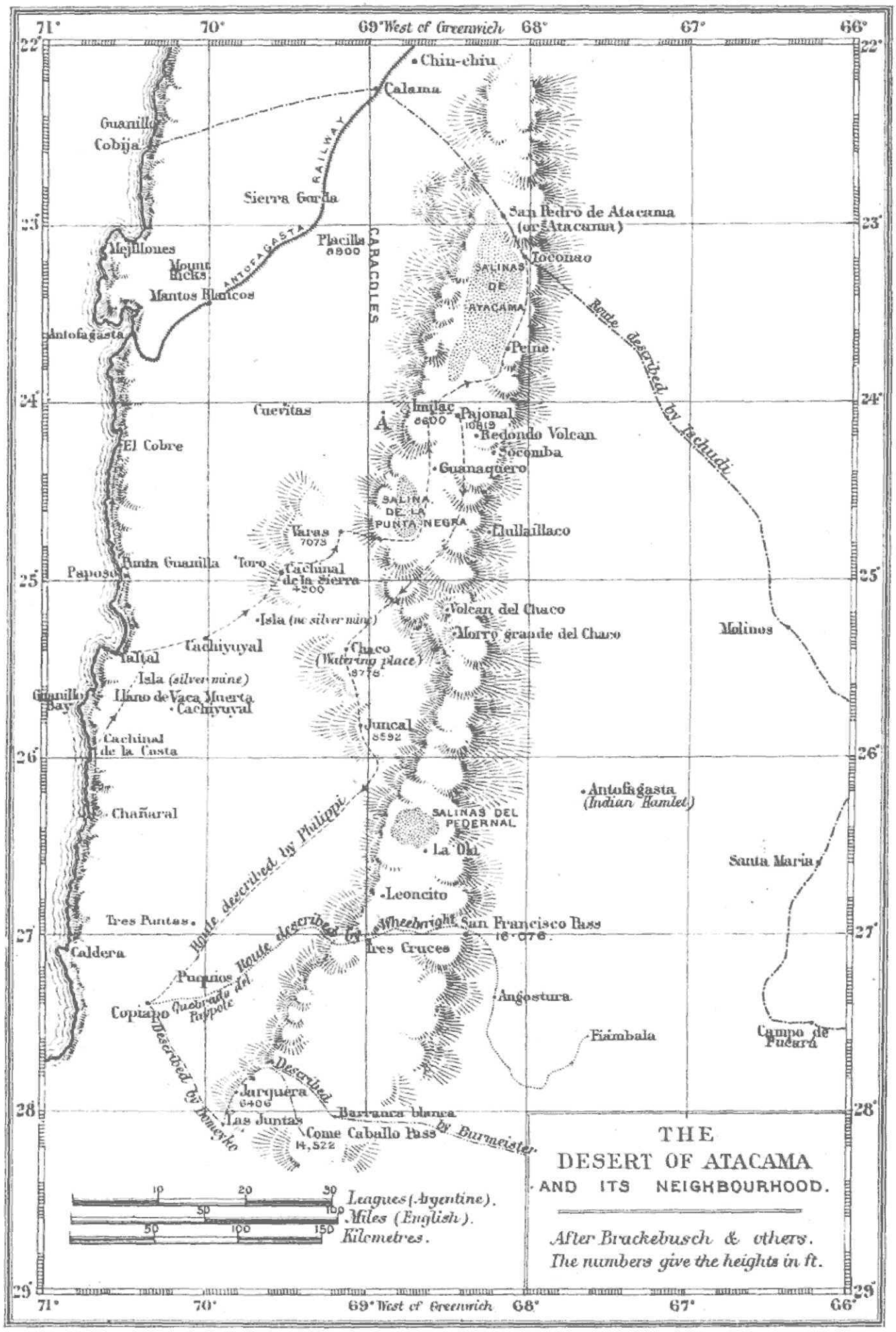
The plessite is plentiful, and forms large fields, containing numerous ridges [" combs " of Reichenbach].

Relative to water at 4°, and allowing for displaced air, the specific gravity at 15½° C. of two portions of one slice, without visible enclosures, and weighing 3·7207 and 1·6577 grams, were determined to be respectively 7·863 and 7·958 (uncorrected 7·88 and 7·97). These two portions of one slice differ in specific gravity more than is the case with many distinct meteoric irons, and show once more that the specific gravity of a small piece may have no discriminating value.

On analysis of these slices by the methods already described, the following numbers were obtained:—

Iron	90·45
Nickel	8·80
Cobalt	0·54
Copper	trace
Phosphorus	0·26
Graphitic Carbon ...	trace
	100·05

In concluding this account of the meteorites which have been found in the Desert of Atacama, we may assert: (1) that the peculiarities of the Desert are entirely terrestrial, not celestial; (2) that there is nothing extraordinary in the number of the meteorites which have fallen in the region; and (3) that the discoveries of meteorites in the Desert fail to prove the occurrence of widely spread meteoritic showers.



Mintern Bros. lith.