

GEOLOGY.

The geology of Mexico has been but imperfectly studied. In the higher ranges the prevailing formations are granite, which seem also to form the foundations of the plateaus, above which rise the traps, basalts, mineral-bearing porphyries, and more recent lavas. Hence, Lyell's theory that Mexico consisted originally of granite ranges with intervening valleys subsequently filled up to the level of the plateaus by subterranean eruptions. Igneous rocks of every geologic epoch certainly form to a large extent the superstructure of the central plateau. But the Mexican table-land seems to consist mainly of metamorphic formations which have been partly upheaved, partly interpenetrated, and overlaid by igneous masses of all epochs, and which are chiefly represented by shales, greywacke, greenstones, silicious schists, and especially unfossiliferous limestones. All these formations are alike remarkable for the abundance and variety of their metalliferous ores, such as silver, silver glance, copper, and gold. Gneiss and micaceous schists prevail in Oaxaca and on all the southern slopes facing both oceans. But the highest ranges are formed mainly of plutonic and volcanic rocks, such as granites, syenites, diorites, mineral-bearing trachytes, basalts, porphyries, obsidian, pearlstone, sulphur, pumice, lavas, tufa, and other recent volcanic discharges. Obsidian (*itzli*) was the chief material formerly used by the natives in the manufacture of their cutting implements, as shown by the quarries of the Cerro de las Navajas (Knife Cliff), near Real del Monte and Pachuca in the State of Hidalgo. Vast deposits of pumice and the purest sulphur are found at Huichapam and in many of the craters. But immeasurably the most valuable rocks are the argentiferous porphyries and schists of the central plateau and of Sinaloa, unless they are destined to be rivalled by the auriferous deposits of Sonora. Horizontal and stratified rocks, of extremely limited extent in the south, are largely developed in the northern states, and chalk becomes very prevalent towards the Rio Grande and Rio Gila valleys. To this chalk and to the sandstones are probably due the sandy plains which cover vast tracts in North Mexico, stretching thence far into New Mexico and Texas. Here the Bolson de Mapimi, a vast rocky wilderness inhabited until recently by wild tribes, occupies a space of perhaps 50,000 square miles in Coahuila and parts of the surrounding States.

None of the horizontal layers seem to be very rich in ores, which are mainly found in the metamorphic, palæozoic, and hypogene rocks of Durango, Chihuahua, and the south. Apart from Sinaloa and Sonora, which are now known to contain vast stores of the precious metals, nearly all the historical mines lie on the south central plateau at elevations of from 5500 to 9500 feet. A line drawn from the capital to Guanajuato, and thence northwards to the mining town of Guadalupe

y Calvo of Chihuahua, and southwards to Oaxaca, thus cutting the main axis of upheaval at an angle of 45° , will intersect probably the richest known argentiferous region in the whole world.

Of other minerals the most important are copper, found in a pure state near the city of Guanajuato, and associated with gold in Chihuahua, Sonora, Guerrero, Jalisco, Michoacan, and elsewhere; iron in immense masses in Michoacan and Jalisco, and in Durango, where the Cerro del Mercado is a solid mountain of magnetic iron ore; lead associated with silver, chiefly in Oaxaca; tin in Michoacan and Jalisco; sulphur in many craters; platinum, recently found in Hidalgo; cinnabar, also recently found in Morelos and Guerrero; "steppe salt" in the sandy districts of the north; "bitter salt" at Tepeyac and many other places; coal at various points; bismuth in many parts; marble, alabaster, gypsum, and rock-salt in great abundance throughout the plateaus and the sierras.

MINING.

Mexico is, perhaps, the richest mining country in the world, and the production of silver—notwithstanding the imperfect methods and other drawbacks with which it has contended—represents over one-third of the product of the world, according to official statistics. Almost all the mountains of Mexico are of the metalliferous character, but those which seem richest in mining deposits are the western cordillera, extending from the State of Oaxaca to Sonora, a distance of about 1600 miles from northwest to southeast.

Humboldt gave as his opinion that Mexico would be "the treasure house of the world." Subsequent history has, in a great measure, confirmed the opinion of the great savant of his time. Still a more conservative authority has quite lately asserted that only one-tenth of the mining resources of Mexico is known. This last estimate, I am sure, is inside rather than outside of the facts. Mexico has always been considered the great silver producer, and, considering her area, and taking the century as a measure, she is the greatest silver producer of the world.

Silver.—The central group of mines in the three mining districts of Guanajuato, Zacatecas, and Catorce, in the States of Guanajuato, Zacatecas and San Luis Potosi, which have yielded more than half of all the silver heretofore found in Mexico, lies between 21° and $24^\circ 30' N.$, within an area of about 13,000 square miles. Here the Veta Madre lode of Guanajuato alone produced \$252,000,000 between 1556 and 1803.

In the beginning of this century Humboldt found two Guanajuato mines—the famous "Conde de Valenciana" and the "Marques de Rayas"—producing annually 550,000 marks, 4,400,000 ounces, of silver,

one-seventh or one-eighth of the entire American output. From January 1, 1787, to June 11, 1791, the Valenciana yielded 13,896,416 ounces of silver, its ore averaging a little over 100 ounces to the ton. Though flooded, this fine old mine is still far from exhausted.

Gold occurs chiefly, not on the plateau in association with silver, but on the slopes facing the Pacific, and apparently in greatest abundance in Sonora, near the auriferous region of Lower California. The production would have been larger if an improved process of reducing the metals had been used, but during the whole colonial period and up to the present time, we have used the patio system, which consists in grinding the ore, stirring it until it is reduced to a fine dust and mixing it then with salt and copper amalgam; after the paste dries somewhat, salt is added in proportion to the amount of silver supposed to be in the ore; the material is then mixed with shovels and trodden by mules, and, after a day or two, another mixture of copper, vitriol, and salt is added; after that it is mixed and trodden again; then quicksilver is finally added, and then more mixing and treading. This process is repeated from five to fifteen times until the silver and quicksilver unite to form an amalgam, which is gathered into bags, and that requires about forty days. Most of the quicksilver is squeezed out and the rest is evaporated and run off into tubs. This method saves 50 or 60 per cent. of rich ore and, besides being very long, is rather imperfect, as it leaves a great deal of silver in the ore, and only rich ores could be treated by it; but it was on the whole the easiest and cheapest.

Some of the old mines were worked until finally they became so deep that, with the methods then used, as buckets were employed instead of pumps, and steam had not been employed as power, it was impossible to drain them. Naturally in a deep mine the water flows in from springs, and the deeper a mine becomes the more water it has. These mines were worked until it was seen that it was impossible to drain them, and then they were abandoned, even though they were rich in metals. During our war of independence almost all the mines were abandoned for the want of guarantee to life and property, and the mining industry, therefore, declined considerably; but recently the old mines have been worked again and the production of silver has increased very considerably.¹

¹ Mr. J. A. R. Waters of the firm of Waters Bros., Mining Engineers of the City of Mexico, said of his visit to the Jesus Maria District of the State of Chihuahua, where he went to examine the mine worked by the Pinos Altos Co., as follows:

"The district is very thoroughly mineralized and is pierced by veins more frequently than any district I ever saw. The general formation is very similar to that of Cripple Creek, with the exception that it is not traversed by the great porphyry dikes that occur there and in other parts of Colorado. The country formation is largely braccia. The ore is generally free milling, and is treated with stamps and pan amalgamation, the finer ores being treated with Huntington mills. There is little waste of values."

Real del Monte Company.—It would be interesting to refer briefly to the ups and downs of one of the mining enterprises of Mexico—the Real del Monte—as a typical case which exemplifies what has happened with many other of our mines, namely, that sometimes they yield large profits, and soon afterwards they cause tremendous losses. The Real del Monte is located about three miles from Pachuca, a large mining centre and the capital of the State of Hidalgo, distant about sixty miles southeast of the City of Mexico.

In 1739, a Biscayan, by the name of Don Pedro Jose Romero de Terreros, came from Santander and settled in Queretaro. He acquired a fortune of \$60,000 in a small store in 1749, closed up his affairs, and started to return to his native land. On reaching Pachuca he met an old mining friend, Don Jose Alejandro Bustamante, who called his attention to the Real del Monte. In company with Bustamante he staked out the Biscaina, Santa Brigida, and Guadalupe mines and began to get the water out, but they soon exhausted their united funds. However, they succeeded in raising money in the City of Mexico on hard terms and drained their properties by a tunnel, which started at Moran, on the northern slope of the mountains, and, running 9000 feet through hard porphyry rock, struck the vein at a depth of 600 feet. This was accomplished a few years later in 1759. Bustamante by this time had died, but Terreros continued the work. On striking the vein he drained it, and in 1760 began the erection of the Hacienda de Regla, to work the rich ore he was taking out. He took out \$15,000,000 at a small cost, repaid his advances, built and presented to the King of Spain a man-of-war and 4700 bars of silver, for which he was created Conde de Regla. He lived in grand style in the City of Mexico, and built a palatial residence on Cadena Street.

He died in 1781, and was succeeded by his son, the second Conde, who from 1774 to 1783 struggled with the water, which, as depth was attained, was very severe; according to Ward, twenty-eight horse-whims were employed in the drainage at great expense and unsuccessfully. However, they had gotten down to 324 feet below the Moran adit on the Biscaina vein in the Guadalupe and Santa Teresa shafts. The production was \$400,000 per year, drainage costing \$250,000 per year, and sinking was abandoned, and the work was confined to drifting above water level.

From 1801 to 1809, \$300,000 per year was taken out, but the cost of extraction was severe. Humboldt visited the property, and in 1810 the war of independence broke out, and all operations were suspended. Meanwhile the water rose and the Moran tunnel caved in, and so allowed the water to rise to an enormous height, and the district went to rack and ruin.

In 1822 the Conde's administrator, Don Ignacio Castelazo, made a

report, and by his Italian mining friend, Rivafinoli, sent it to the Conde, who was living in England.

That country was only too anxious to reap for themselves some of the spoils that Spain had gleaned from Mexican mines. Here was their opportunity, many became interested, and the celebrated mining expert of that day, Mr. John Taylor, the founder of the present London firm now so heavily interested in South Africa, Taylor Bros., was sent to make an examination, and in 1824 the English Real del Monte Company was formed on the following terms:—The company leased the mines and haciendas for twenty-one years: 1st. The capital invested was to be returned from the products of the mines with interest; 2d. The Conde was then to have one-half of the remaining proceeds yearly; 3d. Meanwhile he was to receive \$16,000 per year as an advance against his portion or anticipated profits. In case of failure of this third clause the lease would be cancelled and everything revert to the Conde. As the outlay amounted to over \$5,000,000 and no profit ensued, it amounted to a rent of \$16,000 per year.

In 1824 Captain Vetch, of the Royal Engineers, was sent out as manager. He brought three ships filled with one thousand tons of machinery, pumps, etc., and after untold trials in transportation and erection, finally got them to their destination. All this was done by English engineers, machinists, miners, and workmen, nearly all Cornishmen, under the direction of Colonel Colquhoun, a Peninsular veteran, who finally died of yellow fever with over fifty of his men. After unheard-of troubles they got everything by 1826 safely landed in the Real del Monte. The magnitude of the task may be understood when the almost roadless condition of the country is considered, and the bringing up of the machinery from the coast was a splendid example of British tenacity and pluck.

Captain Vetch had now cleaned out the Moran adit and the Dolores shaft, and the machinery was at once erected. The stock now rose from \$500 to \$8000 per share. The Conde had, in the meanwhile, borrowed money from the company and made the twenty-one-year lease perpetual, the annual rent of \$16,000 remaining in force.

By 1829 Captain Vetch had grappled with the water question, and with an annual cost of \$30,000 had accomplished what the first Count had paid \$250,000 for, and extracted metal 324 feet below the Moran adit.

Captain Tindall, R. E., succeeded Captain Vetch, and a new shaft (1830) was commenced on the Santa Teresa and called the Terreros shaft. It was 1140 feet to the vein and was started at four points, and was connected in 1834 by drifts run from several levels, and then raised and sunk on. The work came out as true as if it had been done from the surface, thanks to the correctness of the plans of the English mine surveyors.

A 54-inch engine was erected, and with it they sank to 720 feet below the Moran adit. At this point water overpowered them. This was in 1838, and Captain John Rule, who had succeeded Captain Tindall, put in a 75-inch engine at Dolores, and removed the 54-inch one to Acosta. Captain Rule enjoyed a salary of £10,000 per year, and all other payments were in proportion. He struck two bunches of rich ore, one on the Santa Brigida, near Acosta, and the other on La Biscains, near Dolores. From these two and one at Torreros they had produced \$10,481,475 at a cost of \$15,381,633 or nearly \$5,000,000 loss in twenty-three years. By 1846 the stock had fallen to \$12.50 from \$8000 a share.

In 1848, Mr. J. H. Buchan arrived, representing the English stockholders. He found water in the mines and increasing; a heavy debt of \$5,000,000, bearing a tremendous interest; no money on hand and no ore. So in October, 1848, by order of the bondholders he turned over the business to a Mexican company—the present one—composed of Manuel Escandon, Antonio and Nicanor Beistegui, Mr. Mackintosh, and others for the paltry sum of \$130,000. The haciendas, stock, and ores on hand were worth millions, but the English company could not dispose of them.

This was the end of the famous English Real del Monte Company. Their Mexican successors reduced expenses, completed the adit from Omotitlan commenced by the first Conde, which, running 13,500 feet, cut the mines 1110 deeper and struck immediately the *bonanza* in the Rosario, which tradition says had previously been discovered and covered up by Captain Rule.

New Mines, Topia.—We have now a great many districts that were not known by the Spaniards and have recently been discovered. Notable among them is the Sierra Mojada district in the State of Coahuila. The State of Durango has, on the west slope of the Sierra Madre mountains, the mining camps of Topia, Sianori, Birimoa, Gusanillas, Canelas, Ventanos, El Pando, Rodeo, and San Fernando; and with the exception of San Fernando they are close together, a square, one of whose sides is forty miles, would almost cover them all. This section has all the elements to form the basis of a great mining and smelting centre, as is evident by the great deposits of galena in the Topia district; in fact, this is the only place on the coast where lead ore is found in abundance; and smelting, if done at all, must rely on Topia for its supply of lead ores. In no other part of Mexico are lead ores so cheap, because of the fact that to realize on them at all they must be transported on mule-back to Culiacan in the State of Sinaloa, a distance of 106 miles, at a rate of \$26.40 silver per ton, and from there by rail to Altata, a distance of thirty-nine miles; and from Altata by steamer to San Francisco, or to Guaymas, and thence by rail to the

smelters in the United States, very much at the same cost. La Liona mine of this district is a very rich mine, its vein being almost vertical, and is tapped from both sides of the mountain, with tunnels at right angles to the vein. Where the tunnels intersect the vein, the vein is driven on in both directions from the tunnels; stopes are opened, and chutes for ore are put in every seventy-five feet. The vertical distance between the tunnels is 125 metres. This mine can easily produce one thousand tons per month of clean galena, and would produce that much metal if there was a market for it.

There are other mines as large and perhaps better than La Liona, as, for instance, La Madrugada mine, formerly owned by Santa Fé Railroad employees, but now controlled by Mr. Charles Miller, of Franklin, Pa., connected with the Standard Oil Company. Topia is a great dry-ore camp as well. One thousand tons of dry ores can easily be mined there per month, were there a market for them, such as a commercial smelter located centrally to treat the ores of this and adjoining districts. Such smelter would have the advantage of an inexhaustible supply of good water the year round, fine iron ore, and limestone for fluxes.

At Topia there are four mills for the treatment of zincy ores, and dry ores assaying below one hundred ounces silver per ton. The lixiviation process by hyposulphite of soda is employed in the four mills or haciendas, two of them employ occasionally the patio process as well. Two of the mills and two mines are lighted by electricity; the dynamo that furnishes light for one of the mills and both of the mines is driven by water power. Below the mills operated by water power, there is sufficient fall and sufficient water to furnish the power to operate compressed-air drills in all the large mines.

The other mining camps of this district, although not so well developed as Topia, are also in process of development and in a very good condition. Velardeña is also in the State of Durango, but on the other or eastern side of the mountains, and is located in a comparatively new district, where the previous owners had failed. Mr. James F. Mathews purchased the Velardeña property, erected a smelter after the International Railroad Company had extended their main line from Torreon to the city of Durango, passing near the mine, and from the beginning has run five of the six furnaces almost continuously. During 1896 the Velardeña smelter smelted on an average 175 tons of ore per day.

Li Hung Chang and the Mexican Silver Mines.—When Li Hung Chang, the Chinese Viceroy, was in Washington, in August, 1896, he inquired of me about the production of the Mexican mines, and I, trying to be conservative, informed him that they produced about \$50,000,000 a year. He then inquired how long they would continue yielding that amount. I answered that it was uncertain, but that, judging from present appearances, it could safely be said that it might be for one

hundred years. This seemed incredible to him, and he said that I had been so long absent from Mexico—for he had previously asked me how long I had been in this country—I could not know the real wealth and abundance of our mines, and he was very positive that I had made a mistake. He assured me that the silver mines in China yielded occasionally something, but soon were exhausted, and it was impossible to get any silver out of them, and judging the Mexican silver mines from those he had seen at home, he was, of course, incredulous as to their yield.

Some years ago, and when the Mexican mines only yielded about \$20,000,000 a year, I predicted that their annual yield would reach \$100,000,000, and that prediction is about being verified, as the present product exceeds \$60,000,000.

Gold.—Gold was used freely in Mexico before the Spanish conquest, and history teaches us how Cortez induced Montezuma to deliver to him his gold treasury.

As soon as Mexico was conquered, Bernal Diaz del Castillo, one of the cotemporary historians, tells us that Cortez inquired very carefully about the place where the Indians obtained their gold, whether there were placers, mines, or washings, and his agents were taken to some localities in the State of Oaxaca, where they were told was the gold supply, but, whether the Indians concealed the real location of the gold deposits, or for other reasons, the Spaniards did not obtain much gold. I have known recently of unavailing efforts having been made of persons from the United States who have tried to ascertain the localities where the Indians obtained their gold, that is—the places which were shown to Cortez in Oaxaca as gold deposits.

There is a river in the State of Guerrero which flows over a country with hills abundant in gold formation, which carries nuggets that the natives find without any difficulty, and it is called for that reason the Gold River. That river passes over some mountains where gold is found, and then comes to a place where a natural dam is formed, and the gold carried by the washings in the rainy season sinks when reaching that place, and every indication shows that there must be a very large deposit of gold there. A military engineer suggested, the last time I was Secretary of the Treasury in Mexico, that the bed of the river be changed by the Mexican Government, a work which did not present serious obstacles, and thus allow excavations to be made and the gold deposits found. It was thought advisable to make some preliminary examinations in the way of boring, and for that purpose the necessary orders were issued to send soldiers there, but I understand the project was given up and nothing was accomplished. I have no doubt that at some future time that matter will be taken up, and a great deal of gold will be found there.

Our production of gold has so far been comparatively small, because the mining and reduction of gold are more difficult and expensive than the same operations in silver, and our gold production has really been the amount of gold which has been found in our silver. For many years, when the amount was small, it was not separated, and for that reason old Mexican dollars have in China greater value than newly coined ones; but recent improvements have made it easy and cheap to make the separation of the two metals. Now that gold has risen so much in value, its mining is beginning to be developed in Mexico on a comparatively large scale, and I have no doubt that before long Mexico will be one of the largest gold producers of the world.

Mexico is an undeveloped country, in fact there are parts of Mexico as unknown as was Central Africa a few years back. From the Sonora gold district, south, on the west side of the Sierra Madre, to the State of Oaxaca, there is a gold belt as rich as California, Alaska, and South Africa combined. It is known that in the State of Sinaloa there are gold placers and gold washings, and that they are also found in every State from there south on the line of this belt.¹

The gold output of Sonora, now beginning to attract attention, is only the first contribution of Mexico to the world's stock of the yellow metal. The west side of the Sierra Madre has a belt rich in gold, and when the world discovers this fact capital will flock to Mexico to dig it out, and Mexico will become one of the first gold producers of the world, as she has been in silver.

Specimens of "float" rich in gold have been brought from the State of Guerrero. These indications of gold have not been followed up, because no one has been progressive enough to advance the means necessary to prospect this belt. To prospect in a country where often water fit to drink must be carried, where food for man and beast must be carried, and where in many places roads must be cut with machete and axe, cannot be done without the spending of money in outfit and expenses.

The principal gold-producing States will be Sonora, Sinaloa, Guerrero, and Oaxaca, but in all of them gold-mining is yet in its beginning.

¹ I take from a report of Mr. Cramer, a mining engineer sent to Mexico by the Geological Society of Washington, D. C., as Commissioner to explore the gold fields of that Republic, the following, which refers to only one of the many new gold fields that are being found there:

"There exists an extensive 'gold placer' situated about thirty miles from Durango in the mountain devoid of vegetation; the rock that is found in greater quantities is porphyry. I estimate that one ton of ore will yield at least \$50 of gold.

"Gold is found all over the mountain, though in such imperceptible filaments that it is hard to recognize it with the naked eye; however, every piece of stone contains the same proportion of gold."

Coinage of the Precious Metals.—Mexico has produced about one-half of the silver supply of the world. In the statistical portion of this paper I shall give full details of the production of gold and silver in Mexico, coinage, etc., and here I will only append the total coinage of gold, silver, copper, and nickel according to official statistics of the Mexican Government, which is the following:

COINAGE OF MEXICO FROM THE ESTABLISHMENT OF THE MINTS IN 1537 TO THE END OF THE FISCAL YEAR OF 1896.

COLONIAL EPOCH.	GOLD.	SILVER.	COPPER.	NICKEL.	TOTAL.
Unmilled coin from 1537 to 1731.....	\$ 8,497,950 00	\$ 752,067,456 54	\$ 200,000 00	.....	\$ 760,765,406 54
Pillar coin 1732 to 1771.....	19,889,014 00	441,629,211 45	.....	.....	461,518,225 45
Bust coin 1772 to 1821.....	40,391,447 00	888,563,989 45	342,893 37	.....	929,298,329 82
INDEPENDENCE.	\$ 68,778,411 00	\$ 2,082,260,657 44	\$ 542,893 37	.....	\$ 2,151,581,961 81
Iturbide's Imperial Bust from 1822 to 1823.....	\$ 557,392 00	\$ 18,575,569 69	.....	.....	\$ 19,132,961 69
Republic from 1824 to June 30, 1896.....	55,748,559 50	1,247,289,651 59	\$6,511,350 36	\$4,000,000	1,313,549,561 45
	\$ 56,305,951 50	\$ 1,265,865,221 28	\$ 6,511,350 36	\$ 4,000,000	\$ 1,332,682,523 14
Total coinage from 1537 to June 30, 1896.....	\$ 125,084,362 50	\$ 3,348,125,878 72	\$ 7,054,243 73	\$ 4,000,000	\$ 3,484,264,484 95

SUMMARY.

Colonial Epoch.....1537 to 1821.....	\$2,151,581,961 81
Independence.....1821 to 1896.....	1,332,682,523 14
Total.....	\$3,484,264,484 95

Iron.—Iron, the most useful of all the metals, is found in such vast abundance in Mexico that, could it be even partially utilized, that Republic would become one of the wealthiest of modern communities. One of the largest mines was discovered by Gines Vazquez del Mercado, in Durango, in 1562, and its appellation of "*Cerro del Mercado*" still preserves his name. The hill, which is 4800 feet long by 1100 feet in width and 640 feet in height, is almost a solid mass of mineral, averaging about seventy per cent. of metal and from which could be extracted more than 300,000,000 tons of solid ore; this only to the level of the plain, beneath which it probably extends to an unknown depth.

The iron is also magnetic to a high degree and its power is greater when the grain is fine. This may delay fusion, but the result is an excellent wrought iron, with none of the inconveniences caused by earthy substances mixed with the iron. I have no doubt that when the coal mines are developed the iron industry will make great strides and that we will be able to manufacture most of at least the low grades of the iron goods required for our consumption. In several other places besides our Iron Mountain we have iron with very little phosphorus, which makes first-class steel and is as good as the best produced in Cuba or Spain.