ART. XX.—*On the Silver Mines of Santa Eulalia, State of Chihuahua, Mexico*; by JAMES P. KIMBALL, Ph.D.

THE silver mines of Santa Eulalia were among the earliest mineral discoveries of the Spaniards in Northern Mexico. Don Jesus Inocente Irigoyen of Cusihuiriachic, a good antiquarian authority, states that the year of discovery was 1591. The only available official register of their performance, however, goes back no further than 1705, but mentions their discovery in 1703—twelve years after the city of Chihuahua was founded, according to the date given by Dr. Wislizenus. From 1705 to 1737, they produced 6,583,500 marcs, or an average of 1,938,903 dollars of silver per annum. Up to 1791, during a period of eighty-six years, their acknowledged production of silver, of which the *quinto*, or king's fifth, was paid to the royal exchequer, was 11,903,126 marcs, or nearly *one hundred and twelve millions of dollars*, and their entire production from one-fifth to one-third more. At this period the district had a population of 6000, and supported sixty-three reduction establishments with one hundred and eighty-eight smelting furnaces of

the type known as the Mexican *horno*, and sixty-five cupelling furnaces; while a number of similar establishments in the city of Chihuahua were also kept running on ores from this district. The depredations of the savages, which until comparatively quite recently have always seriously interfered with industrial pursuits in Northern Mexico, became so grievous during the last five years of the past century that the district was gradually abandoned.* Indian hostilities were soon followed by political troubles, including the war with Spain and the proscription of the Spaniards. During the present century, operations at the hands of the Mexicans have never been fully resumed. Yet shallow workings have continued to furnish ores to a small number of furnaces, which to a considerable extent have also made use of the débris of former operations. At present ten blast furnaces, each of a capacity of 2500 to 3000 lbs. of ore per day, are in operation, their small supply of ore being drawn from the older as well as the newer mines. The fresh ore from the mines as charged to the furnace, is eked out with the settlings of the old slag heaps, and coarse refuse from old workings, extracted from the dry bed of the creek which in time of rain courses through the mining village of Santa Eulalia. As in old times, for the sake of mutual protection, the reduction works of the district are still all collected here, along with the dwellings of the miners and smelters, who number with their families some 700. Recollections with the old, and traditions with the young, still fill the minds of the dwellers in this narrow valley with dread of the Apache, who even now is occasionally found lurking among these mountains, and of whose hiding all have been taught to be wary when moving about alone.

The village of Santa Eulalia is fifteen miles east of the city of Chihuahua, across the expansive champaign valley of Tabalopa. This city, the capital and social center of the state of the same name, and containing some 20,000 inhabitants, attained its importance mainly through the silver industry of Santa Eulalia, in the period of whose prosperity it had a population of 70,000. Chihuahua afforded—what have ever been lacking at Sta. Eulalia—water and space for the dressing and reduction of ores; and to the city therefore was brought and smelted a large portion of them. Immense heaps of slag, twenty in number, on the outskirts, attest the extent of work done there during the last century, while the imposing, and in some respects admirable, cathedral of the city is a monument to the mines of Santa Eulalia, it having been built out of a fund raised by the tax of one real per marc of silver coined,

* Manuscripts and certificates in No. 65, folio 26, state archives. See also Ward's Mexico, 1st edit., vol. ii, p. 129, (2d edit., i, p. 454).

and which, continued for sixty-two years, ending in 1789, amounted to 800,000 dollars.*

The Sta. Eulalia mountains are a portion of a long range trending N.E.—S.W., one of a system of parallel ranges, which, separated by champaign valleys or valley-plains, characterize the topography of the sloping margin of the Grand Sierras, and as much at least of the state of Chihuahua as lies north of the 28th parallel, and east of Concepcion—beyond which limits my experience does not extend. The range lies between the broad and fertile valley of the Conchos on the east, and the narrower valley-plain of Tabalopa on the west. Access to the village and mines of Sta. Eulalia is from the latter. The village lies two-and-a-half miles from the plain up the mountain stream of the same name, at the foot of the higher hills, in which, at distances of two to five miles, the mines are situated, and which are crossed only by bridle-paths.† The mining ground is embraced within the area of an uplift of the Cretaceous fossiliferous limestone, imparting toward the center of it gentle quaquaversal dips. This is a prolongation of the narrow continuous elevation of this formation, reaching to the Rio Grande in an axis parallel to the Conchos river, and a part of the same formation which in Texas comes to the surface in the Rio Grande basin, at least, between the 28th and 31st parallels, except in mountainous localities, or in the case of stratigraphical depressions, where an upper and metamorphosed member of the same formation (a porphyritic quartzite) known in Mexico as *cantera*, caps the summits.‡ In Mexico, under similar conditions of superposition of the latter, the

* State archives. Ward erroneously states this tax to have been collected during nine years pending the last *bonanza*, ii, p. 581. (2nd edit., p. 305).

Accustomed, as of late, we have become to the far higher returns of not larger groups of silver mines, it is easy to pass over the full significance of the comparatively low figures of early operations in northern Mexico, unless we are mindful that it is to the availableness of mechanical appliances, that our great production of silver is more to be ascribed than to the number or superiority of recent discoveries. What account of the Comstock lode by this time should we have were its mines, as in the case of those of northern Mexico during the period of their activity, without other than the rudest iron or steel implements, without powder, except in rare cases of a foreign stinted supply, with only the *adobe horno* for smelting, and the little *cazo* for amalgamation; and continually harrassed by Indians? Although supplies are no longer quite out of reach, the mines to-day are worse off than during the last century, for most of them have reached a point where have become necessary mechanical appliances, with which the Mexicans are entirely unacquainted. They continue to suffer the want of what *adobe*, raw-hide, and wood will not supply, following the practice of the Spaniards, which in their hands has rather retrograded than advanced. The silver industry of Chihuahua at present amounts to little more than cleaning up the rubbish of former workings.

† For a popular and graphic account of this picturesque mining district, see an article by Gen. Lew. Wallace in Harper's Monthly, Nov., 1867.

‡ See notes on the Geology of Western Texas and Chihuahua, by the writer, this Jour., xlviii, p. 378.

Cretaceous fossiliferous limestone, with local lithological differences, is the prevailing formation of the Rio Grande and Conchos basins, where, as seems likewise to be the case in Texas, within the development of the cantera it sustains throughout a metalliferous character. The mineral deposits of Sierra Rica, Cuchillo Parado, the Chupaderos, and the Chorreras in Chihuahua are all contained in it. In the Santa Eulalia mountains is its most westerly development in any great prominence above the valley plains, though seventy-five miles still further west, a limestone is said to form the low base of the Sierra de Magistral, where it is likewise metalliferous, and where, going west, it is last seen. In the Santa Eulalia mountains, the same as in other localities named, the *cantera* caps the higher elevations. This name is applied in Northern Mexico to the bleached portion of an essentially alumino-siliceous rock, generally more or less metamorphosed and ferruginous, and occurring in a great variety of colors.* As elsewhere explained, it is to the disintegration of this rock that the accumulation of soil in the valleys is due, as well as their peculiar conformation.†

Allowing for erosion, the mines of Santa Eulalia may strictly be said to be grouped in a single great boss of the Cretaceous limestone strata, gullied or scored by water-courses which impart to all portions of it a rugged and precipitous configuration. There, as elsewhere throughout the development of the fossiliferous limestone, the water-courses have cut bold, almost perpendicular, escarpments in which the stratification is very plainly marked. In this district the dips are from 5° to 15°, and from a point near the Vieja mine are quaquaversal. The ravine, Arroyo de Dolores, which takes its name from the old mine of Dolores, at its head, has been cut through the crest of the limestone uplift, and thus exhibits in steep mural escarpments a partial thickness of the formation of 400 to 500 feet. Its true thickness, however, has never been revealed. The oldest and most extensive mines are in this ravine, including the deep ones of Dolores, Vieja, Aguada, and the shallow or cavernous workings of Parcionera, San José and San Matias. The distance of Arroyo de Dolores from the village is some three miles, horizontal, from four to five topographical.

As the limestone uplift or boss expires, the summit cantera, a few remnants of which cap the limestone hills, sets in, and within a couple of miles, becomes the main formation, and forms the body of the range. No limestone appears in the Puerto de Dolores, seven miles to the north, where the San Diego and Chihuahua road crosses the Sta. Eulalia range; and in the village of Sta. Eulalia, it has already declined below the surface. The overlying cantera presents a greater development

* This Journal, xcviii, p. 380. † Ibid, p. 381.

in the surrounding hills, which rise to the height of some 800 feet above the plain.

A curious lithological phenomenon, though in a less conspicuous way not uncommon in other localities which I visited in Chihuahua, is a formation of conglomerate which is found on all the slopes of the district, and which incases the lower and middle portions of the hills like a shell.* This has evidently been formed by carbonated calcareo-magnesian infiltrations, springing from the summit cantera; and, penetrating the fine and coarse detritus of the surface alike, have cemented it, and thus produced all the gradations from a fine friable sandstone to a coarse breccia. The village rests upon it. In the main street it is distinctly bedded, and cleaved by joints. Nowhere is it found entering into the interior structure of the hills, and no traces of it are found in steep places. Yet cursory observation might dispose the traveler to assume the main body of the mountains to be made up of this formation.

The mineral deposits of Santa Eulalia are unique. The only instance of a vein formation brought to my notice in the region is in the Santo Domingo mine. All the rest of the deposits are more or less irregular, and in a variety of modes of occurrence, are contained in the nearly horizontal fossiliferous strata (Cretaceous). All the strata above water level are exceedingly cavernous. In nearly all of the workings, caves, entirely shut off from the surface have been encountered. Some of these are of enormous size. The great cave of the Parcionera and San José mines, is said to be large enough to hold the cathedral of Chihuahua. Though unable to explore its height, or to illumine its roof, I am disposed to believe this. Drusy cavities or vugs of all sizes, are the smaller exhibitions of the same prevailing cavernous character. These latter yield excellent pockets of ore. Rich *bonanzas* have been got from chambers in the walls of the large caves. The ores which are mainly the chlorid and sulphids of silver, argentiferous galena and salts of lead, together with, (though of rarer occurrence,) the chloro-bromid (embolite) and iodid (iodyrite) of silver, are very ferruginous, to which circumstance they owe their friable character, and also, to a considerable degree, the spaces in which they have been deposited. Courses of ore are always marked by ferruginous stains, which, properly considered, are segregations of mineral matter, sometimes following cleavages and joints, and sometimes planes of bedding, and, again, sometimes reticulating solid beds, and in all these modes of occurrence, without order or defined limits. A bed, or a number of beds, of the limestone, in places may be thoroughly webbed with such segregations of so decided a character as to

* This Jour., xlviii, p. 382.

impart a concretionary appearance, or, as if limestone breccia were cemented by ferruginous ore. In such places the beds, are *not* brecciated, but thus strikingly indicate the energy of disintegrating and segregating action under the decomposition or oxydation of iron salts (probably proto-carbonate) originally contained in the limestone, together with diffused salts of silver. These ferruginous portions always afford good mining ground. As some of them are very extensive, and as their distribution is irregular, their excavation results in large and rambling chambers, generally ranging through a number of the heavy beds of limestone. Such chambers are often continuous with natural caverns, together forming underground spaces scarcely less imposing than the most noted caves that excite the wonder of tourists.

The mines of Santa Eulalia are scattered all over the great limestone uplift, and along the deep ravines which have scored it. All are comprised within an area of some five square miles. In the hillsides they consist mostly of horizontal workings, and occupy different strata from top to bottom. Shafts and deep workings, which are few and ancient, are located both in the hills and ravines. Accessibility of the mines is determined by the topographical configuration of the mining ground, the primary form of which, before modified by erosion, it is important to keep in view. As they are reached from the village by three different trails, I will describe them in as many separate groups, as follows: the *Santo Domingo group*, comprising the workings in the same cañon as the Santo Domingo mine, and of which this mine is the principal; the *Dolores group*, or those in the cañon, at the head of which is the old Dolores shaft; and the *Guadalupe group*, comprising the workings on the summit and S. W. flank of the limestone ridge, which forms the divide between the Dolores Cañon on the northwest, and on the southeast—the waters of the *arroyo* in which is the village of Santa Eulalia.

Santo Domingo Group.—The Santo Domingo and neighboring mines are two miles north of the village, up near the head of a deep ravine, in both sides of which, at different elevations, they have their entrances. As this locality is about one-and-a-half miles to the southeast of the axis of the boss, the dip of the formation is seen rapidly declining in the ravine toward its mouth, and the overlying cantera is thus brought down so as to form the body of the hills. The limestone altogether disappears from above the bed of the ravine within a few hundred yards south of the Santo Domingo mine, where the cantera sets in and forms the surface. The town is really on the horizon of this formation, though the surface is immediately overspread by the cemented rubble above described. The hills on either

side of the defile in which the village is situated, rising as they do some 700 feet above it, are both topographically and stratigraphically the, highest elevations in the district. They are made up wholly of cantera distinctly and nearly horizontally stratified, and in different zones weathering with a variety of colors. They have mesa tops, and present to the broad valley-plain of Tabalopa bold escarpments flanked by low foot-hills.

The *Santo Domingo*, old and present, are deep workings entering the limestone boss on the west side of the ravine. The old mine, now abandoned and dismantled, consisted of a shaft located so high on the hillside that it must have pierced one hundred feet of cantera before striking the limestone. The present mine is some 500 yards further up the ravine, and, at an elevation above its bottom of some 120 feet, goes down in a bed of fossiliferous limestone some 30 feet from the top of the formation, the division being plainly indicated by a ledge of cantera above the entrance of the mine. Its depth is about 400 feet. This is reached by an irregular descent, the only thoroughfare, in which passage is laboriously effected partly by means of ladders, and partly by footholds in the rock. This main-way occupies a vertical crevice in the limestone, or a series of cavernous partings more or less filled out with workable ores. The widest portions are some 12 feet, the most contracted, not more than six inches. Many of the former are of the nature of drusy cavities lined with quartz and gypsum. The narrower portions have generally yielded paying ore of a decomposed and ferruginous character. The vertical crevice, which has been followed westerly into the hill has been pretty thoroughly wrought. The most extensive workings, however, follow rich partings between planes in the limestone beds, thus giving rise to lateral excavations opening into the main-way. Rich pockets of galena are found both in the crevice and in the horizontal deposits, and these seem to be increasing in depth. Indeed it is chiefly for galena and other plumbiferous ores (*plomosos*), that this mine is at present wrought; and it appears that its ores of all grades (*ayudas*) have always been prized less for their argentiferous qualities, than for the property of facilitating the smelting of the more refactory ores (*resecos*) of the district.*

* Although over 300 feet below the bed of the ravine, which is dry except in the rainy season, there is no water, or even sensible moisture in the bottom of the mine; and though the deepest mine at present wrought in the region, it is, like all the others, without mechanical appliances of any sort. The ore is spalled underground and brought to the surface on the backs of men and boys whose burdens vary from 100 to 125 lbs., and who make during the day five trips to the bottom. The mine is so excessively warm and badly ventilated as to be almost suffocating; while its passages are so worn and polished by the hands and feet of the miners as to afford the most precarious footing. The carriers (*tenateros*) are surprisingly muscular, nimble and sure of foot, running with swiftness up and down the single

The other workings of this group are on the east side, and further toward the head of the ravine, occupying different beds in the limestone and pursuing productive courses of ore. The principal are *Chiquihuite*, *Rosario*, *Gertrudis* and *S. Lazaro.*

DOLORES GROUP.—The cañon of Dolores is a deep gorge cutting almost perpendicularly the axis of the limestone uplift or boss. The cliffs thus formed, expose on either side a perfect section of bare limestone strata. Its course is very nearly westward, and its head opposite and very near that of the Santo Domingo arroyo. Together the two water-courses describe a triangle, and as they border the mining area impart this shape to it. A lofty ridge capped with the summit cantera divides the two waters. Owing to the comparatively rapid declination of the limestone strata in this direction, the workings toward the head of the cañon are by means of shafts going down just above its dry bed. They are the Tiro Dolores, present Dolores, the "Gauo" (Aguado) and the Vieja shaft.

The *Tiro Dolores* is a vertical shaft starting in the cemented rubble, but soon striking the fossiliferous limestone which, from 200 to 300 yds. below, is uncovered in the bed of the cañon. The shaft is 327 ft. vertical—at which depth a slanting passage, now flooded with rain-water, carries it some 100 feet deeper.

The *Aguado*, like the Dolores, is now inaccessible. It is an irregular sinking of about the same age and depth as the latter, and communicates with it by deep workings. Its mouth is near the top of the limestone formation.

The *Dolores*, present working, is a sinking of the same description as the Aguado, with the lower workings of which, and thereby with those of the older Dolores, it connects. The upper and more accessible workings are still wrought in a small way for plumbiferous ores. The *Vieja*, some 200 yards still further down the arroyo is also an irregular sinking carried to the depth of about 165 ft. It still affords desirable silver ores.

All these mines were formerly diligently wrought—the shafts by means of horse-whims. From a watch-tower on the highest point overlooking the whole district, timely warning of the approach of the savages could be given. Ruins of stone dwellings built strong for defense, indicate a former settled establishment in the bottom of the defile, which, as in the case of all the others in the region, contains water only during rains. The water in the mines appears to have got in from the surface, no percolation being sensible even in the deepest.

In the immediate vicinity of these old workings, near the

notched stem of a ladder, and the shelving, slippery rocks in lieu of steps, but laboring for breath, and their bare bodies bathed in perspiration. No laborers in the world have a more arduous task. The cost of raising the ore in this manner is 25 cents per 350 lbs. This could be greatly reduced, and the mine improved by an opening from the ravine.

head of the arroyo, the dip of the limestone beds to the southeast is near 45°. The vertical axis of the boss is in the eroded neighborhood of the Vieja, at the confluence of another arroyo from the southwest. From this point in every other direction the dips (quaquaversal) are gentle, coming down gradually to not more than five degrees. But the steeper dips toward the outside of the limestone boss have brought up a great thickness of this formation (400 ft.) above the arroyo, and thus west of the Vieja the same strata are above its bed, as could only be entered by shafts east of this point. This is an explanation of the fact that below the Vieja all the workings are above the bed of the ravine, their openings being in the bluffs. These workings are all approximately horizontal: that is, they follow the stratification which on either side being slightly inclined *from* the ravine, gives them all something of a descent *into* the body of the hills.

The *San José* enters the south bluff a quarter of a mile below the Vieja, some 30 ft. above the bed of the arroyo. Its workings extend to several beds, the excavation of which has caused great chambers, while a number of natural caves also have been opened. The ores here are mainly diffused through the limestone strata in ferruginous and the more decomposed portions. They are also found in courses leading from stratum to stratum, but never in the form of a vein.

The *Parcionera* opens near the San José some 70 feet higher up the bluff—its workings, however, descending so as to connect with those of the latter, and thus excavating several beds. It may be described as a series of caverns, both natural and artificial, the largest in the district. It is here that is to be seen the immense one already mentioned. The openings extend about 500 yds. into the hill, in which distance they fall some 150 ft. The pursuit of courses of ore whither they might lead, has caused very irregular passages. The ores of the mine are highly prized, and at the time of my visit were being extracted by twenty miners for the supply of the furnaces of Don Emanuel Escobar. The ores then coming out were plumbiferous. Their mode of deposit does not differ from that of the San José ores.

The *San Matias* is in the north bluff, directly opposite to the San José and Parcionera, and going in on the same level. It is one of the more cavernous, as well as one of the largest and oldest, mines in the district, having been wrought southeastward so as to connect by descending passages with the workings of the Vieja, a quarter of a mile off. It is still wrought by Mateos & Co. Its ores are excessively ferruginous (*colorados*), their color being that of red hematite. According to the owner they are now yielding 12 ounces to the carga ($103 to the ton.)

Several openings in the north bluff have been made at higher levels. One, the *Cuartillera*, is at the height of some 300 feet above the bottom of the cañon. It furnishes a non-ferruginous ore of a drab color.

GUADALUPE GROUP.—It is convenient thus to designate the numerous workings in the same hill with the Parcionera, situated, topographically speaking, some above these mines, and some on the opposite north and west sides, wherever the surface is not too steep to afford easy access.

The *Guadalupe* mine is directly over the Parcionera and San José, and opens from the plateau which marks the top of the limestone formation. Its workings progress southeasterly, descending through several very ferruginous beds in which silver ores seem to be concentrated in "pockets"—the average ferruginous courses being filled with segregated quartz, and generally barren. A drusy cavity is said to have been struck here in 1865 which gave in one day sulphids of silver worth $5000; and five months afterwards another, yielding $1200.

The *Aragon* is a similar working in still higher limestone strata, and very near the junction of this formation with the cantera, here a buff, porphyroidal quartzite, a fine outlier of which rises some 150 ft. above the limestone plateau. Both this mine and the Guadalupe steadily yield plumbiferous ores, carrying, mostly in an invisible form, chlorid, bromid and sulphids of silver.

The other mines of this group are all on the left flank of the limestone ridge. They are the Santa Rita, San Francisco, Purisima, Negrita Grande, Negrita Chiquita, and the Carmen.

The *Santa Rita*, one of the oldest and more reputable mines, is a shelving excavation, starting in fossiliferous limestone, some 350 ft. above the bed of the Dolores arroyo. A large burrow of ferruginous material indicates the extent of former workings. The main opening is said to be asphyxiated, and is now closed, though containing, according to all accounts, ores running as high as four marcs to the carga ($250 to the ton).

The *Purisima*, occupies nearly the same level as the Santa Rita, going down some 60 ft. in heavy bedded limestone, fossiliferous at the surface. The fossils, as usual in this locality, are a coral, *Radiolites*, and fragmentary *Pecten* and *Inoceramus*. The mine, though now vacant, was worked three years ago, and is said to have proved satisfactory.

The *San Francisco* is a sloping excavation in the hillside, and some 100 ft. lower in the limestone than the Santa Rita. The workable portions of the limestone beds closely resemble those of the workings in the Dolores arroyo. The mine is now supplying highly prized ores to the Chihuahua Company's hacienda.

The *Negrita Grande* is an old, now inaccessible, shaft, more

than 250 ft. deep, which depth about corresponds to the level of the arroyo immediately below the mouth of the mine, and from which it would be practicable to reach its workings. The shaft was formerly worked by horse-whims (*malacates*)—probably by the distinguished Bustamente who is reputed to have had a *bonanza* from it of $60,000, said to have been in the form of concentrated chlorid of silver.

The *Negrita Chiquita* is a newer open working, now operated by Don Jesus Mateos, and occupying strata but a little lower than the mouth of the shaft of the *Negrita Grande*. The *Carmen* occupies beds somewhat higher, and is a similar cavernous excavation.

It will be understood that notwithstanding wide differences in topographical level, all the workings above mentioned are embraced within the same set of beds whose combined thickness does not exceed 450 ft.; that the shaft workings at the head of Arroyo de Dolores, the mines of the Santo Domingo arroyo, and the workings on the top of the plateau forming the surface of the limestone uplift, *all have their entrance at about the same stratigraphical horizon; that is, near the top of the limestone.* And it is to be borne in mind that stratigraphically the lowest workings are *not* those which topographically are the lowest, but the San José and San Matias instead of the Dolores, Vieja and the Aguado.

Notwithstanding the number and size of the excavations in the mining ground of Sta. Eulalia, and the large returns which these have afforded, its future prospects seem scarcely impaired by the achievements of the past. By the modern scale of minral industry, these might pass for only a thorough exploration—in its assurances worth all that it has yielded. The location of the mines has been determined by the accidents of the surface rather than by promising outcrops—a foothold upon the surface seeming to have been all that was necessary. Besides the great amount of unbroken ground left in and amidst the established mines, a large body of the limestone strata remains untouched, especially to the north of the Dolores arroyo, where the inner ends of the workings, proceeding from the bluff on that side, show no deterioration or diminution of the ores. It is not venturing too much to predict that the past record of Sta. Eulalia will be far surpassed at some future time by its development prosecuted by an enlightened practice.

Yield.—Extracted according to the judgment of the miners who are very expert in the detection of familiar ores, the ores after being spalled, run from 4 to 6 oz. to the carga ($34·46 to $51.60 per ton of 2000 lbs.) Four-ounce ores are abundant in all of the mines, but scarcely pay for working by the present smelting practice. By care in selection, this grade is easily

brought up to five and six ounces to the carga. This is the lowest working yield of all the smelting operations—the average being something above this. Don Jesus Mateos, one of the most experienced operators in the district, by using a mixture of the 12 oz. ores from the San Matias and 6 oz. ores of the San José, obtains never less than 6 oz. to the carga, generally as high as 8 oz., and sometimes 9 and even 10 oz.

Cost of ore.—The cost of ore delivered at the mouth of the mine varies according to the expense of raising. At the Parcionera, which may be taken as the type of horizontal or sloping workings, this cost, which includes all mining expenses, is stated at $1.50 per carga. At the Santo Domingo, the cost is greater on account of the laborious raising. The ores are delivered at the furnace for 20 to 37½ cents per carga, the donkey-load being one carga (300 lbs.)

Reduction.—The furnace employed in the district is the common Mexican *adobe horno*, a blast-furnace 47 inches high, 18 in. wide at the top, slightly tapering toward the bottom, and 16 in. across. The blast is supplied by hand bellows, the nozzle of which is in the back, 8 in. from the bottom. In the better constructed establishment of the Chihuahua Co. the bellows are set in motion by mules. The charge of the furnace varies according to the notion of the smelter as to the requirements of the different ores. Mateos uses 75 lbs. of spalled ore to 20 lbs. of litharge, and 12 to 25 lbs. of old slag (*grasa*) by way of flux. The charge of litharge varies with the ore. Plumbiferous ores, like those of Santo Domingo, Santa Gertrudis, Dolores and San Antonio, give an excess of litharge, and hence are in especial favor for mixture; while the excess of litharge obtained is sold out of the district at the rate of 8 to 16 dollars per carga ($2.67½ to 5.32½ per cwt.) The cupellation is done in the ordinary *adobe vaso*, one serving three blast furnaces, or treating 20 cargas of argentiferous lead per week.

Fuel.—The question of fuel is one of paramount importance to the industry of the district. The *mesquite* root is the only indigenous fuel of the immediate section of country, forest trees being entirely unknown east of the humid belt, 50 miles to the west of Sta. Eulalia, except the cotton wood (*alamo*) which is cultivated for shade. Yet nothing could excel this root as a fuel, either as it comes from the ground, or after conversion into charcoal. A single shrub generally gives near a cord of heavy root. In the neighborhood of Sta. Eulalia, the *mesquite* has long been exhausted by the draft upon it from there, and from the city of Chihuahua. Oak charcoal is brought 30 leagues to Sta. Eulalia from Mapula, and sold at the rate of 75 cents to one dollar per quintal (100 lbs.)—the lower price prevailing whenever the roads are favorable. Oak wood is likewise brought thither, and

sold at the rate of one dollar (copper) per carga (80 sticks, 28 by 4 in.). The same prices prevail in the city of Chihuahua. Mes quite charcoal from the east side of the Sta. Eulalia Mts. is delivered at the village for $1 to $1.50 (copper) per quintal. These prices, already high, would doubtless steadily advance under a larger and more pressing demand, such as would be created by an extensive smelting industry depending upon a *certain* supply and *limited* price of fuel, without control over either.*

With a cheaper mode of reduction, the cost of production would be very considerably lessened by rendering available ores which, though cheaply and largely broken, are now rejected —ores yielding as high as $34 to the ton. This condition, rather than the introduction of mechanical appliances, would necessarily bring this cost below the cost of extraction of silver ores from expensive workings in Nevada, though now far exceeding that of most of the deep mines of the Comstock lode. But the cost of reduction is even more excessive and out of proportion to the value of the ores. Though the Mexican smelting practice is attended with a smaller loss of silver, the fact that Nevada ores returning no more than $15 per ton can be worked by amalgamation with some profit, more than offsets the loss of 20 to 25 per cent to which all are subjected, as a large and regular business generally depends upon the availableness of the ores of low grade—always predominating in extensive deposits. Yet the Mexican furnace by no means extracts the whole of the silver as may be seen by picking up from any ancient or fresh slag heap fragments containing numerous globules of argentif-

* Expressing in familiar units the above rates imparted to me by Don Jesus Mateos, we have in a form for comparison with working results elsewhere obtained by different modes of reduction the following exhibit:

Cost of Production.

Cost of ore at mouth of mine, per ton, at $1.50 per carga,	$10.00.	
Transportation to furnace, " " 0·37½ "	2 62½.	
		12.62½

Cost of Reduction.

Charcoal in blast furnace, per ton of ore, at $1 per quintal,	$10.62½	
Wood " *vaso*, cupelling, " " " $1 per carga,	2·66⅔	
2 Smelters at $1. per diem, / 1 Refiner at 1. " / 6 Helpers at 0.37½ " } Labor,	4.92	
Litharge, repairs, etc.,	1.00	19.21½
Total cost of production and reduction,		$31.84

Having adopted the mean of variable rates, no allowance is made for the discount of copper currency (at the time of my visit, in the winter of 1869—33⅓ per cent; but now much greater) in which are stated the prices of fuel, especially as the above exhibit bears out the representation of Don Jesus; namely—that in the failure of the 50 cargas of ore smelted weekly by one furnace to yield a total of thirty marcs of silver, that is (taxes paid) $32 per ton, loss is incurred.

erous lead, and otherwise indicating imperfect reduction. Fuel is far more costly at Virginia, Neveda, than anywhere in Chihuahua, but this difference follows from the higher price of labor there—the supply of fuel really being greater than at Santa Eulalia.*

Thus will be seen the mistake of treating the ores of Santa Eulalia by a practice which is so costly as to render unavailable the great bulk of them, and to absorb almost the whole value of even the choice ores in their reduction, when by a cheaper practice the whole run of the ores could be treated with profit, and the industry improved and expanded in all respects. I allude to amalgamation as practiced in Mexico itself, and which the climate, labor and facilities of the country especially favor. In 1846, it was estimated by Mr. John Phillips, seven-eighths of the silver produced in Mexico was obtained by amalgamation.

The lack of surface for *patios* at Sta. Eulalia, together with the scantiness of water, are circumstances sufficient to account for the prevalence there of smelting, notwithstanding the ores are of a nature to yield readily to patio amalgamation. That these difficulties have never been surmounted is to be ascribed to the isolated condition of this section of country, and its lack of facilities for extralimitary supplies. In the last century, during the period of its prosperity, as I learn from a manuscript in the state archives, amalgamation both by *patio* and *cazo*, was carried on at Sta. Eulalia and Chihuahua to the extent of keeping in operation in the two places 72 drag-mills (*tahones*), and 6 stamp-mills (*morteros de agua y caballerias*). The reduction works, just erected, of the new Chihuahua Co. have not in the least departed from ancient models. Nor would a change of practice be warranted by anything short of an extensive undertaking. In view of the scarcity of water and fuel at Santa Eulalia, it must be seen that present operations without modification can scarcely be extended beyond their present scope. As long as they are thus limited, they are favored by the choice of ores, and by cheap labor. By dispensing with mechanical appliances for dressing ores any considerable outlay is avoided.

The silver deposits of Santa Eulalia, however, are so superior and extensive as to warrant their extraction and reduction on a

* Notwithstanding the rates of labor in Nevada are more than treble those of Santa Eulalia, the ores of the Comstock lode are extracted for a half to a third less, and reduced for less than a half cheaper—their average yield ranging in different mines from $28 to $43. To properly contrast the wide difference between the economical conditions of the industry taken as a whole in the two localities of Sta. Eulalia and Virginia City, it is necessary to consider that of the latter as involving an immense outlay for milling and deep mining, altogether beyond the requirements of the former locality. It is also obvious that a high cost of fuel would, the same as at Santa Eulalia, preclude the practicability of working by smelting any but *selected* ores, and thus confine the Comstock industry within comparatively narrow limits.

large scale. This will be practicable by having recourse to the facilities afforded by one or both of the two plains on either side of the Sta. Eulalia mountains.

West of the mountains, superior facilities for the dressing of ores, and for patios, are to be had at Tabalopa on the Sacramento river, at the distance of some eight miles from the mouth of the Arroyo Dolores. Ores could be delivered at this point by wagon at near the same rate that they are now freighted on mules over the mountains to Santa Eulalia. This way out to the plain would be by the ravine, and thence the whole way to Tabalopa by a down grade.

Having extended my observations but a little way east of this gorge, I am not prepared to determine the question of an exit on that side of the Sta. Eulalia range. Should it be found practicable to cheaply deliver ores in the Conchos valley, this side would, on the whole, present superior conditions for reduction works, provided a good water supply can be had, which is probable, as the plain is already thoroughly irrigated. Fuel (mesquite) is far more abundant here than on the Chihuahua side, and the position is nearer by two days to all supplies drawn from Texas.

New York, Jan. 1, 1870.