GEOLOGY OF NORTHERN MEXICO,

by R. H. Burrows.

The mining districts adjacent to the line of the Kansas City, Mexico & Orient railway, taking in a strip about 70 miles in width by 400 in length, extend from Presidio del Norte on the Rio Grande, to Topolobampo on the Gulf of California. The territory in question may be most conveniently subdivided into three regions, namely, the Eastern, Sierra, and Western. These subdivisions may be fairly well defined. They differ from each other essentially in physiographic features, climate, geology, and character of mineral deposits. Beginning at the Gulf of California, the Western region may be considered to extend from the Coast to the western base of the Sierra Madre, a distance of about 150 kilometers (96 miles). Continuing eastward from this line, the Sierra region will be assumed to extend to the line of the Mexican Central railway. From this line, the Eastern region extends to the Rio Grande. The Eastern region, which is especially discussed in this paper, is characterized by an almost even distribution of mountain and plain, the mountains consisting of isolated peaks or ranges of small extent, while in the Sierra the mountains predominate, running in more or less extended ranges, until the continuous chain of the Sierra Madre is reached. The almost level surface of the Western region is interrupted only by the narrow range of hills that crosses the Fuerte river at San Blas, the plain being bounded on the west by the San Blas range that fronts the Gulf of California.

The general geology of the three regions is different. The Eastern region is mainly underlaid by sedimentary rocks. The Sierra province is almost entirely covered by late eruptives. The Western region differs from both in the constitution of its bedrock, which is principally granite, and older than the others. The difference in altitude, and the great difference in the quantity of rainfall in the three regions, gives each a different climate, causing

an essentially different flora, with corresponding variety in agricultural conditions. The extensive plains of the Eastern province, with their deep, rich soil, are, through lack of moisture, of little utility except for grazing. On the contrary, through the constancy of the summer rains, and the persistence of the streams in the Sierra and Western regions, crops may be raised wherever sufficient soil can be found to cover the seed.

EASTERN REGION.

The general character of the Eastern region is that of regularly alternating mountain and plain, the latter remarkably level, with an average altitude of 4000 ft. above sea-level. The mountains rise abruptly to additional heigths of 500 to 2500 ft. The region is traversed by the river Conchos, which, running at almost right angles to the mountain chains, has cut through some of them near their points of greatest elevation. The eccentric course of this river is a most striking phenomenon, and difficult to account for. Instead of choosing the easier course through the plains, it has cut through the rocky strata of the ranges, at practically their central points. The proper course for the stream would seem to be a continuation of the San Pedro river near its junction with the Conchos. Following that course it would have passed to the south, avoiding the high ranges, finding an easy path across the north end of the Chilicote plain, and thence through the Puerto del Gato straight to the Rio Grande. Instead of that it goes out of its way to plunge into the heart of the mountains, preferring a tortuous course through a dark rocky enclosure, rather than the straight path through the open freedom of the plain. In passing through the mountain ranges, the river has carved deep canyons, impassable at many points, some of them not far inferior to the barrancas of the Sierra Madre in their abruptness. Entering the region from the southwest, the river turns around the Sierra San Diego, and running northward through the plain, for about 20 miles between two mountain ranges, makes a right angle to cut through the Sierra del Morrion. It then traverses another narrow plain, plunging again into the Sierra de Santo Domingo, from which it emerges into a long valley, in which are some of the most fertile lands of the region. After meandering through this valley the river cuts across the range at Las Vigas to enter the valley of San Pedro, leaving it through the San Pedro range to emerge into the valley of Cuchillo Parado. To escape from this

valley, the river breaks directly through the high range of Cuchillo Parado in a series of picturesque canyons, from which it finally debouches into the valley of the Rio Grande. As a source of water supply in its lower reaches, the Conchos river is exceedingly erratic. With its headwaters reaching to the summit, and draining about 400 kilometers (250 miles) along the eastern slope of the Sierra Madre, it is influenced by the summer rains of the Sierra region, becoming a mighty river at times. During the dry season the irrigation ditches take practically all of the water except the underflow, so that it is possible to cross in many places dry shod. It is a great pity that the enormous quantities of water now going to waste in the rainy season cannot be deflected to the plains that lie on either side. These, if watered, would prove one of the great sources of wealth in the Republic.

A good idea of the topography of the Eastern region may be obtained by traveling eastward from the City of Chihuahua over the K. C. M. & O. railway. The manner in which the road winds around the bases of the mountain ranges, passing from one valley to another, demonstrates the interrupted character of the ranges and the way the plains are linked. Few of the ranges exceed 20 miles in length, their axes having a general northwest direction, corresponding to folds and faults that are probably contemporary with the elevation of the central plateau. The breaks in the continuity of the ranges are mostly due to variations in the intensity of the folding, and sometimes to faults, an example of the latter occurring at the break in the Sierra de Aldama, where the Chuviscar river enters the Aldama plain. That part of the range lying north of the river, has been raised several thousand feet. The most extensive mountain chain is that of Cuchillo Parado, about 70 miles in length, forming in its continuity a notable exception to the other elevated portions of the region. Owing its origin to a great fold, which is traceable northwestward in somewhat interrupted series of ranges almost to El Paso, it determines in a great measure the course of the Rio Grande for a considerable distance, the river following approximately parallel to the axis of the fold.

By reason of the isolated character of the mountains, the plains run together at numerous points, forming continuous stretches of practically level ground. Good wagon roads are the rule, and the entire region is comparatively accessible. Although relatively narrow, some of the plains extend for immense distances, demonstrat-

ing the great uniformity of the earth-movement which gave rise to the peculiar topography. Considered as topographic units, the plains are remarkable. The plain of Aldama, from 20 to 30 kilometers in width, extends from the Sierra de Naica on the south, without interruption northward, passing the international boundary and stretching into Arizona, a distance of about 500 miles. South of the Conchos river, the Chilicote plain, 75 miles wide, extends southward into the neighboring State of Coahuila, a distance of fully 275 miles. Dotted here and there over its surface, small ranges and lone peaks give the effect of an archipelago of rocky islands emerging from the ocean. Across the northern end of this plain lies the old road from Presidio del Norte, which constituted one of the principal throughfares between Mexico and the United States for the caravans of merchandise, before the advent or the railroads. It is still the highroad of communication that connects Ojinaga and other settlements of the Rio Grande with the interior of the Republic. As the distance between watering places is often 50 miles, this plain has claimed a number of victims. Heavily laden, slow-traveling wagons go provided with barrels, lashed one on each side, carrying two days' supply for man and beast.

Although the ter n 'desert' is frequently applied to these plains, conjuring up visions of the sandy Sahara, the only feature that renders them deserving of the epithet is the lack of water, there being no sandy wastes and few rocky barrens. Vegetation is by no means scanty, grass growing thickly all over the plains and mountains, with patches of mesquite and other brush at intervals. The atmosphere is dry and the rainfall light. Numerous attempts have been made to procure water by digging wells and although the ground beneath is moist, most attempts have resulted in failure.

The bedrock of the Eastern region is composed mainly of marine sedimentary beds, that have been subjected to extreme folding by a force that seems to have operated uniformly along the entire Gulf slope, the disturbance in this section being the expression of the forces, that raised the Sierra Madre Oriental, and which probably began with the post-Laramie movement that elevated the Rocky mountain chain. In the region under consideration, the folds formed parallel elevations with intervening valleys, their axes having a general northwest direction. The uplifted ridges constituted barriers, which, retaining the drainage of the region, formed a pa-

rallel system of long narrow lakes, that extended north and south for hundreds of miles, and well back toward the Sierra Madre on the west. These lakes subsisted a sufficient period to allow deposition of immense beds of gravel, attaining a thickness of several hundred feet. Minor earth-movements during the latter period of the existence of the lakes, culminated in opening passages for the water through the mountain barriers, finally draining the lakes and determining the present water-courses.

Small areas of igneous rocks are scattered over the region, increasing in extent as the Sierra is approached; these igneous rocks form outliers of the tuffs and lava that make up the Sierra Madre. The lower sedimentary rocks of the region, that is, the rocks between and including the Boquilla slates and the Aurora limestones, probably extended westward to a shore-line about the centre of the Sierra Madre: the continent at that period stretching away to the west. After the deposition of the Aurora formation, the sea became rapidly shallower, as attested by the large amount of fossil wood and remains of land animals found in the Ojinaga beds. The shore receded nearly to the line now marked by the Rio Grande. Owing to the depth of gravel and silt, the bedrock is concealed to a great extent in the valleys and plains, though well exposed in the mountain ranges, especially along the Conchos river. The formations in these latter localities have been thoroughly dissected, offering good opportunities for their examination, although even at these points the excessive crumpling of the strata frequently obscures the relations of the beds.

The accompanying plan and section, although incomplete, will illustrate to some extent the geological sequence and conditions of the Eastern region. The names given to the formations are arbitrary, the writer's familiarity with the geology of the Mexican border being insufficient to permit the correlation of the formations with recognized horizons. The following detailed description is more for the purpose of setting forth the economic importance of the beds, than of a complete geological discussion. The formations will be regarded in the order of their succession, beginning with those apparently oldest.

BOQUILLA STATES.

These are probably the oldest sedimentaries exposed in the region, the only locality where they were observed being in the gorge

of the Conchos river, just above the Boquilla, near Santo Domingo. In this locality the slates are about 1000 ft. thick, forming the core of the Santo Domingo range, and extending both north and south of the Conchos. Their extent northward was not determined, but they were traced south almost to Coyamito mountain, a distance of 6 miles. The amount of distortion precluded following any well defined strike or dip. Neither could any well marked contact be found between it and the overlying beds, the two rocks being perhaps unconformable. The rock is a clay slate, extremely fissile, and having a tendency to break into small wedge-shaped fragments. Neither organic remains nor any other evidence to indicate the age of the beds could be found, except their inferior position, which, taken together with their probable unconformability, suggests the possibility of a pre-Cretaceous origin.

The only sign of mineralization consists of small veins of quartz, the thickest of which was less than an inch wide, containing no metallic minerals, in spite of the fact that the overlying formations are rich in metallic deposits. It is evident that the texture of the rocks prevented their fissuring to a sufficient extent for the admission of mineral solutions.

PLOMOSAS FORMATION.

Above the Boquilla slates, sloping from the Santo Domingo range eastward toward the plain, may be seen a system of beds consisting mainly of limestones and shales, with a layer of congiomerate near the centre and quartzite at the base, having an aggregate thickness near Plomosas, of about 1150 ft. These beds extend along the eastern base of the Santo Domingo range, showing plainly at some points, and at others disappearing under the alluvium of the plain. Although the outcrop is interrupted south of Plomosas, it is probable that the limestones of the Cerro de Coyamito, south of the Conchos river, belong to these beds. No organic remains were noticed in this formation. Embracing the zinc and lead deposits of Las Plomosas and the copper prospects of Coyamito, this formation is of considerable economic importance, having produced and still yielding large quantities of ore. Referring to the sketch, and beginning at the base of the range where the beds emerge from the plain, there occurs 160 ft. of shale containing three interbedded layers of limestone, the latter with small deposits of lead and zinc, which lie practically parallel to the planes of bedding. The next in

succession is a bed of massive limestone 450 ft. thick, in which the large orebodies are found, occurring as irregular deposits nearly parallel to the planes of bedding, and also in short fissures striking across the stratification. Under the massive limestone, layers of shale, aggregating 180 ft. in thickness, are followed by 80 ft. of conglomerate, both of the latter, so far as known, being barren of ore. Under the conglomerate comes 200 ft. of limestone, which is remarkable as containing iron and copper ores to the exclusion of lead and zinc.

This is in contradistinction to the upper limestones, which contain lead and zinc, but no copper. At the base of the formation is seen a bed of quartzite 100 ft. thick, much shattered in places, and showing a network of quartz veinlets with an occasional trace of copper. All mining in the vicinity has practically been confined to the exploitation of the lead and zinc ores in the heavy bedded limestones near the centre of the formation, the copper prospects having received much less attention than they really merit, according to their surface-indications. South of the Conchos river, about 18 kilometers from Las Plomosas, the Plomosas formation again appears in the Cerro de Coyamito, where the beds are seen to dip toward the west. Small quantities of lead and zinc are found here, but the principal mineralization seems to consist of bodies of iron gossan containing traces of copper. These deposits occur in the central body of limestones, parallel to their bedding-planes, and are traceable at least two miles, varying from one foot to a hundred in width.

ORE DEPOSITS OF LAS PLOMOSAS.

Just how long the mines of Las Plomosas have been worked is not of record, but it is likely they have been operated in a desultory way for a hundred years or more. Lead was the sole object of value in these mines in earlier times. The zinc being useless was left in the mine. The high price of zinc during the last few years, drew attention to the district, resulting in the re-opening of the old mines as well as the discovery of numerous orebodies hitherto unknown. The camp being situated within five miles of Picachos station, on the Orient railway, with which it is connected by a wagon road, makes it easily accessible. The mineral in the shape of smithsonite, has been admitted into the United States free of duty, to which circumstance alone is due the profitable exploitation of the

ores. The lead and zinc minerals exist almost separately in the ore-cavities, passing from one mineral to the other so abruptly as to make a fairly clean extraction of the different ores. The extent of purity attained in the mining of the zinc may be understood when it is known that a great deal of the carbonate ore assays 50% Zn in large shipments. The purer ore is generally of a honey-yellow color, and aside from its weight, has at first sight more the appearance of a limestone concretion than that of a metallic mineral, the successive layers of the deposit being clearly distinct, and in some cases so thin that 16 layers to the inch may be counted.

The conditions of mineralization at the Juarez mine exemplify the type of ore deposit in the district, and merit description for this reason. This mine is on a short fissure of varying width, running obliquely across the limestones. The stopes showed, first, a deposit of calcite and iron oxide on the walls; next to the iron oxide, and extending from both sides toward the centre, were well defined streaks of smithsonite. Exemplifying the last phase of deposition, was a core of lead carbonate occupying the centre of the cavity. The separation between the lead-ore and the zinc was fairly well defined; that between the zinc and iron not quite so well defined, but still enough so to permit mining the ore comparatively clean. In one of the stopes, the lead ore had been taken out by the old miners, thus leaving the zinc exposed on either wall, so that the present operators had only to strip off the clean zinc ore. This was an extremely cheap method of mining, and, as one of the miners remarked, it was little short of finding the ore piled up on the roadside.

From the evidences which exist in the neighborhood, it is probable that these deposits have been formed from the decomposition of mixed sulphides of lead, zinc, and iron, and the successive redeposition of these minerals in the shape of oxides and carbonates. Small stringers of mixed galena, blende, and pyrite are found by cross-cutting the limestones, these stringers having retained their normal constitution through some condition which has prevented access of atmospheric water or other decomposing agency. It is, therefore, likely that these streaks represent the primary mineralization. Additional evidence may be cited in the occurrence of native sulphur crystallized within the body of the calcite which forms the gangue of the deposits, this sulphur most probably having been derived from the decomposition of the original sulphides.

LAS VIGAS FORMATION.

Between the Plomosas and Las Vigas formations, several hundred feet of rocks occur, which at all points examined were so covered with gravel and soil, that their nature could not be determined. It is probable, however, that they are the continuation upward of the shales seen at the summit of the Plomosas formation. The Las Vigas formation, through the hardness of the sandstones which constitute its most prominent feature, outcrops as a distinct ridge, traversing the country for miles. It may be seen in the long ridge traceable from Chorreras on the south to Las Trancas on the north, a distance of over ten miles, and at Cuchillo Parado for an even greater distance. The locality of Las Vigas, which has been described by Walter Harvey Weed, is, perhaps, the most familiarly known along the various outcrops of this formation. This fact has promoted the selection of that name to facilitate description. The conditions at Chorreras, however, although practically the same as at Las Vigas, are more familiar to the writer, and will be taken as a basis for description.

At Chorreras, the formation has a thickness of about 2000 ft., and consists of gray calcareous sandstone and shale in alternate beds, the latter rock predominating. Topographically, the formation is characterized by a succession of ridges with intervening hollows, the ridges forming the outcrops of the sandstones, the hollows indicating the position of the shales. The base of the formation as seen at Cuchillo Parado and Chorreras, is represented by a bed of arenaceous limestone, about 250 ft. thick, the next in succession being beds of calcareous sandstone, aggregating a thickness of 700 ft. In these latter are found the principal copper deposits belonging to the formation. Next occurs 240 ft. of black shale, followed by thin sandstones, which alternate with shales to an additional thickness of 750 ft., where it passes into the shales and gypsum of the Cuchillo formation. With the exception of a few obscure remains, resembling plant stems, no fossils were found. In spite of the extreme aridity of the region, this formation yields water plentifully at sligth depths, most of the shafts that have been sunk revealing water in abundance. As a rule this water contains iron sulphate and free acid in solution. Water for domestic purposes is derived from springs in the neighboring formations.

The first mining of copper from this formation, so far as

known, dates back to the year 1870, at which time the mines of Santa Sofia and Santa Cristina were actively worked, the ore, consisting of oxides and carbonates, being reduced on the spot in adobe furnaces with charcoal as fuel. As the workings penetrated the sulphide zone, operations were suspended, until the establishment of railroads and smelters in the Republic encouraged the re-opening of the old mines. As this involved a wagon haul of 75 miles to the Mexican Central, together with a costly railroad transportation to the smelter at Aguascalientes, this period of activity was short lived, and the mines again became dormant until the commencement of work on the Kansas City, Mexico & Orient railway drew attention to the mineral resources of eastern Chihuahua. About this time the Santa Cristina mine was acquired by the Hathaway Brothers, who began sorting the old dump, shipping the product to Aldama by wagon, and thence by railroad to the smelters, making a profit in a few months of $10,000 mex. that amount representing the purchase price of the mine.

The orebodies are parallel to the bedding of the formacion, occupying and adjacent to narrow fissures, made by the slipping of the sandstones on each other or on the shales. This movement must have been due to the excessive bending of the strata in the vicinity, causing the different beds to slip on each other as sheets of paper are seen to do under similar conditions. Evidences of such movement are conspicuous throughout the formation, although perhaps less so at points where extensive mineralization has caused partial disintegration of the adjacent rocks. The ores are exclusively copper, and consist of narrow streaks of solid mineral filling the cavities between the sandstone and shale. There is also impregnation of the adjacent rocks to some distance from the plane of movement, the workable ore varying from a few inches to 8 ft. in width. The shoots of ore are fairly constant, that of Santa Cristina, which extends into the Justicia claim, being little less than a thousand feet in length. The ores at and near the surface, consist of carbonates and copper oxides, the carbonate stains coloring the rocks for a considerable distance from the veins. As permanent water-level is soon reached, the oxidized ores do not persist to any great depth, chalcopyrite taking their place. Gray copper was observed at the mine of La Lágrima, three miles north of Santa Cristina, and it is worthy of note that this mineral assayed much higher in silver than either the chalcopyrite or the oxidized ores, the gray copper carry-

ing an average of 40 oz, per ton, while the latter seldom contain one-quarter of that amount. The gray copper is evidently a secondary mineral here, as it is seen to pass into chalcopyrite near the bottom of the mine, although the lowest working is only 60 ft. below surface.

The most striking phenomenon seen in the Las Vigas copper deposits, is their general distribution along the sandstone outcrops. Probably a length of 20 miles along the edge of the beds was passed over, and at every point where the sandstone horizon was visible, *considerable copper ore was encountered. This at times would* be represented by a mere stain of green carbonate, but the continuity of mineralization was unbroken, showing clearly that the mineral was not limited to any local impregnation as is the case in so many ore deposits. The outcrops of the copper sandstones are found distributed over an area 50 miles long by 12 miles wide, equal to 600 square miles. The mineralization of this formation over such an extensive area is hardly paralleled by the Kupferschiefer of the Mansfeld district in Prussian Saxony. Eruptive agencies, which are generally coupled with the impregnation of metalliferous beds, are nowhere in evidence in the district covered by the Las Vigas formation. Whether the copper may have been originally disseminated through the body of the formation, and subsequently concentrated near the planes of movement, or whether the mineral was introduced into the fissures after the crumpling and slipping of the strata, is a matter of speculation, although the latter hypothesis seems the more probable. Assuming the latter case, the conduits which connected the present mineral-bearing strata with the source of the copper solutions, must have been numerous and widely distributed, as it is hardly possible that the mineralization could have spread over such a wide area from any single source of supply. Directly bearing upon this latter consideration, it may be stated as probable that the copper noticed in the Plomosas formation at Coyamito and Las Plomosas, has been derived from the same source and deposited at the same time as that of the Las Vigas formation.

CUCHILLO FORMATION.

What is undoubtedly the best section of this formation to be seen, is near Cuchillo Parado, on the road from the river to the Aurora mine, where the formation follows a depression in the Cuchillo Parado range. This range is formed by two parallel ridges, the

westernmost of which constitutes the outcrop of the Las Vigas sandstones; the other forming the summit of the range, and consisting of the Aurora limestones. Between these two ridges and running throughout the entire length of the range, a considerable depression exists, which is occupied by the beds of the Cuchillo formation, including a thickness of about 2000 ft. The lower 1500 ft. of the formation is an almost pure gypsum, which at the surface breaks into a white sugary mass. A few thin beds of limestone course through the centre of the gypsum, showing quantities of fossil shells. The summit of the formation consists of alternate beds of gypsum and limestone, the latter becoming thicker as they approach the top, gradually passing into the massive limestones of the Aurora formation. At Chorreras the Cuchillo formation consists almost entirely of clays, gypsum being practically absent. South from Rancho Viejo the ravines which cut through the mesas expose the same formation, consisting here of gypsum and clays, about equally distributed.

At Cuchillo Parado the lower part of the Cuchillo formation contains salt, which leaches out and is carried to the river, where the evaporation of pools often leaves crusts 2 in. thick. The exploitation of salt at this place was at one time an industry that furnished employment for several hundred people, but since the advent of the railroads the salt business has dwindled to almost nothing. Four miles south of the Santa Cristina mine, the Cuchillo formation has been borken through by an intrusion of granite; the clays having been converted into slates and the limestones into marble. These rocks being harder than the surrounding formation rise several hundred feet, in sharp contrast to the continuation of the beds east and west. To the west of the intrusion, a number of small veins have been formed in the metamorphic rocks, in which extremely rich bunches of lead-silver ores have been found near the surface, generally, however, changing into low-grade galena and blende as depth is attained. Perhaps a resource of greater value than either of the above mentioned minerals, is the great quantity of gypsum at Cuchillo Parado, which may become valuable as soon as the opening of railroads affords cheaper transportation.

AURORA FORMATION.

The name of Aurora formation was adopted on account of the magnificent exposure of these rocks near the Aurora mine in the

Cuchillo Parado range of which it forms the culminating ridge. The formation as seen at the Aurora mine dips steeply to the east, becoming flatter as it is followed south to the edge of the Chilicote plain, where it then becomes flat and constitutes the bedrock of the plain. West of the Chilicote plain, the formation appears in the Chorreras range, dipping about 50° to the southwest. From here the limestones swing around to the north, crossing the Conchos river at Soldado and continue northward, forming the Sierra del Morrion and the hills around the Hormigas ranch. The outcrop in the Sierra del Morrion is practically vertical, the beds flattening slightly at the base of the mountains, dipping under the valley of Dolores to the west, and rising farther west to form the Sierra de Santa Eulalia, in which occur the famous mineral deposits. North of the Santa Eulalia range the relations of the limestones are rather obscure, but they are seen again north of Aldama, where they rise in the Sierra de La Peña Blanca, outcropping in a bold escarpment facing the east. Dipping to the westward at La Peña Blanca, the formation re-appears in the vicinity of Terrazas and constitutes the matrix of the lead and copper deposits of that camp. West of Santa Eulalia and Terrazas, the limestones almost entirely disappear under the eruptive rocks, and are only seen at infrequent intervals, where the combined forces of upheaval and erosion bring limited areas to the surface. One of these small areas is exemplified in the camp of Minillas, 10 miles northwest of the city of Chihuahua, where the limestone fissures contain lead-silver ores. On the west side of the valley of Cuchillo Parado, the limestones dip into the San Pedro mountains, and rise again farther west near Las Vigas, the syncline being occupied by the valley of San Pedro. North of Las Vigas, the Coyame mountains are built up of this formation, which also contains great caves, said to rival those in Kentucky. The formation is nearly pure limestone, in thick layers; the entire thickness of the beds varying from 600 to 1500 ft., thicker in the western part of the region than in the eastern. At a few points, notably in the Chorreras range, numerous nodules of flint and iron ore were observed. Fossils are plentiful, but generally so firmly imbedded in the limestone matrix that it is difficult to obtain good specimens. A few fragments of ammonities were found near the base of the beds at Chorreras and several specimens of echinoids at Cuchillo Parado; the majority of fossil organism, however, are bivalves. This formation is probably identical with the Edwards limestone

of the Texas Lower Cretaceous, as suggested by Robert T. Hill in articles of Santa Eulalia and Sierra Almoloya.

The Aurora formation contains the most important mineral deposits found in the entire region. Santa Eulalia, Naica, Sierra Almoloya, Terrazas, Minillas, and Cuchillo Parado, all lead-silver producers, with some zinc; Jimenez and Terrazas, producing copper and silver, are all contained within these rocks. So much has been written regarding the mineral deposits of Santa Eulalia, and the opportunities afforded the writer in that locality were so limited, that no attempt will be made to enlarge on what has already been so well described. Having occasion, however, to wander over a good part of the camp for the purpose of determining the boundaries of several mining claims, the opportunity was improved to the extent of making approximate sketch of the surface geology, which is herewith submitted. The Sierra Santa Eulalia lies near the eastern edge of the territory deluged by the igneous material which practically covers the country from this line westward to the western flank of the Sierra Madre. The east side of the Santa Eulalia range shows an appreciable thinning of the eruptive rocks to an edge and they disappear a few miles east of the range. It is observable also that the underlying rock is limestone, the surface of which, prior to the effusion of eruptive material, was extensively eroded, although the bedding remained practically horizontal. This is clearly shown at the head of the gulch near the Vergara shaft, where the edges of several hundred feet of limestones have been uncovered by the erosion of the tuffs, showing the existence of an ancient hollow. The limestone must have subsisted for a long time as a land surface, the hollows now filled with eruptive material representing ancient water courses, the debris of which may be seen in the profusion of water-worn limestone boulders that lie on the limestone surface of the San Antonio Chico and other claim in that locality. Over this surface, volcanic outbursts spread an enormous cap of fragmental material filling the depressions and covering the limestones until the later beds of tuff show a uniform bedding independent of the former topography. At the Picacho Robinson and the Cerro de la Campana, the tuffs are probably over a thousand feet in thickness, the greater part of which, however, in the gulch near Santa Eulalia village, has been removed by erosion. A flow of lava 20 to 50 ft. thick then covered the tuffs, this lava showing as a fringe of massive rock running around the hills to the north and south of the gulch of San-

ta Eulalia. On the top of the massive rock tuffs were again deposited constituting the highest formation in the district, most of which has been eroded.

During the period of eruptive activity, eastern Chihuahua consisted of a uniform plain surface, sloping gently toward the east, broken at intervals by local eruptions of igneous material, such as that of Sierra Rica. Subsequent to this ensued the folding which formed the Santa Eulalia and other parallel ranges. The same forces that elevated the district contributed to the formation of the ore deposits; the activity of the ore-forming elements probably having their inception with the first orogenic movement. The elevation of the range exposed it again to the ravages of the elements, which have disintegrated and swept away a large part of the overlying igneous rocks, again laying bare the limestone, and carving out new canyons, often a thousand feet in depth.

At Terrazas, 25 miles north of the city of Chihuahua, the same formation encloses deposits of copper and silver-bearing lead. An intrusion of eruptive rock near the centre of the mineralized area, divides it into two distinctive portions, the southernmost of which contains only copper-silver ores, while that on the north produces only those of lead-silver, the copper and lead being nowhere associated within the district. The two parts of the district also differ from each other, in the fact that the copper mines are dry, while the lead mines are extremely wet. At one of the latter mines, at the time of my visit, it was impossible to make headway against the water with a pump throwing 1500 gal. per minute from a depth of only about 200 ft. The ore being soft, the miners were provided with extra long shovels, working with the water up to their chins and reaching as deep as possible after the ore. Diving suits were not provided, consequently production had to stop until the mine could be equipped with more effective pumping appliance. The copper ores, consisting of carbonates and oxides, are reduced on the spot. The lead ores were shipped to Torreon and El Paso. The ores consist of cave-filling and metasomatic replacements in the limestone. In the eastern part of the region, near Cuchillo Parado, the Aurora mine is found in the same formation. The deposit follows approximately the bedding of the limestones, being seen to cut diagonally across some of the layers near the surface. Limited in its lateral extent, as far as could be seen, the Aurora deposit occupies a cavity which might have been the conduit of a hot spring.

The outcrop is mainly iron oxide, which changes into a silicious lead carbonate within a few feet of the surface. The carbonate becomes purer as the deposit is followed into the ground, the lower workings at the time of my visit, showing ore 19 ft. wide, that averaged 40% lead with 4 oz. silver per ton. A striking feature of the deposit was the occurrence of pockets of wulfenite along the foot-wall containing from a hundred pounds to a ton of the mineral, the greater part of which consisted of beautiful crystal aggregations. In sinking a winze 160 ft., about 25 tons of this mineral had been extracted. The development of this district is retarded by difficulties of transportation; the completion of Kansas City, Mexico & Orient, however, will bring the railroad line within 30 miles of the district and enable the mines to be operated at a profit.

Before dismissing the subject of the ore deposits of the Aurora formation, mention should be made of the influence of the Chorreras granite at its contact with the limestone. This intrusion, which has been mentioned as interrupting the Cuchillo formation, came up directly under the Aurora limestones, the contact between these and the granite showing for a distance of about two miles. The mineralization on the line of contact was represented by bodies of almost pure crystallized hematite. One such mass was over 400 ft. in length by 30 width. The limestone within a distance of about 300 ft. of the granite has been metamorphosed into marbles of different shades of color, while the contact displays the usual phenomena of green and brown garnet with more or less epidote. Amphibole of the variety called 'mountain leather,' is also found in the vicinity, and has been turned to practical use by a Mexican mine-owner near-by for the lining of a primitive smelting furnace, which is still being used in the reduction of silver ores.

A fact not generally recognized is that all the important springs of water wherever found in eastern Chihuahua, break out of the Aurora limestones. The oases of Coyame and Chorreras are fed from these sources, and the lesser springs of Hormigas, Chupadero, and others are in the same formation. Most of these springs exhibit a steady flow independent of the change of seasons. This suggests the possibility of reclaiming parts of the region now uninhabitable, by the development of artesian water. The Chilicote plain, for instance, toward which the limestone dips on all sides, might, instead of being a synonym for drought and starvation, be made to blossom, if the indicated artesian water should be developed. While

the limestones, however, furnish channels and reservoirs for the circulation and impounding of water, their cavernous nature in other cases has drained the formation, leaving it almost dry. This is exemplified in the Potosí mine at Santa Eulalia, where shafts and bore-holes have penetrated to a depth of 2100 ft. without finding water. The reverse condition is found at Terrazas, where at a depth of 200 ft. it was practically impossible to exhaust the water.

OJINAGA FORMATION.

This includes the latest sedimentaries of the region, and is limited to the area of the Ojinaga basin, the soft character of the rocks being responsible for the modified topography of the basin, as compared with the outcrops of the surrounding formations, which rise in rugged mountain forms. Comprehending at least 2000 ft. of beds of different character, this formation probably includes the Washita division of the Lower Cretaceous, together with later beds, which may belong to the Upper Cretaceous. The marked unconformability which is generally understood to exist between the Upper and Lower Cretaceous was nowhere observed. Detailed study of these beds will no doubt succeed in connecting them with known formations lying to the northeast. The base of the Ojinaga beds, lying directly on the Aurora formation, is composed of thin-bedded gray limestones, which pass into a succession of shales having a total thickness of about700 ft. Succeeding the shales, is a sandstone forming a prominent ridge and nearly a hundred feet thick. It contains fossil wood and other fragments of plant remains. The material between this sandstone and the summit of the beds consists of about a thousand feet of alternating clays and sandstones, the latter in thin beds, and not to be confounded with the massive one which lies near the centre of the series. The clays at two distinct horizons were seen to contain large fossil bones. A thin layer of sandstone lying 250 ft. above the massive sandstone, contains an abundance of small shells ressembling Turritella. About 400 ft. higher in the series, a layer of clay 20 ft. thick was found, which contained numerous limestone nodules, in some places almost entirely made up of shells of Exogyra. Fifty feet above this shell-layer another bed of clay showed numerous ammonites and nautili, many being extremely good specimens. This series of beds has attracted attention during the last three years as a possible source of oil, drilling for which is in progress at the present time. Cement mate-

rials occur in abundance within the formation. A slight amount of prospecting has been done for coal, but the largest seam found so far is less than a foot in thickness.

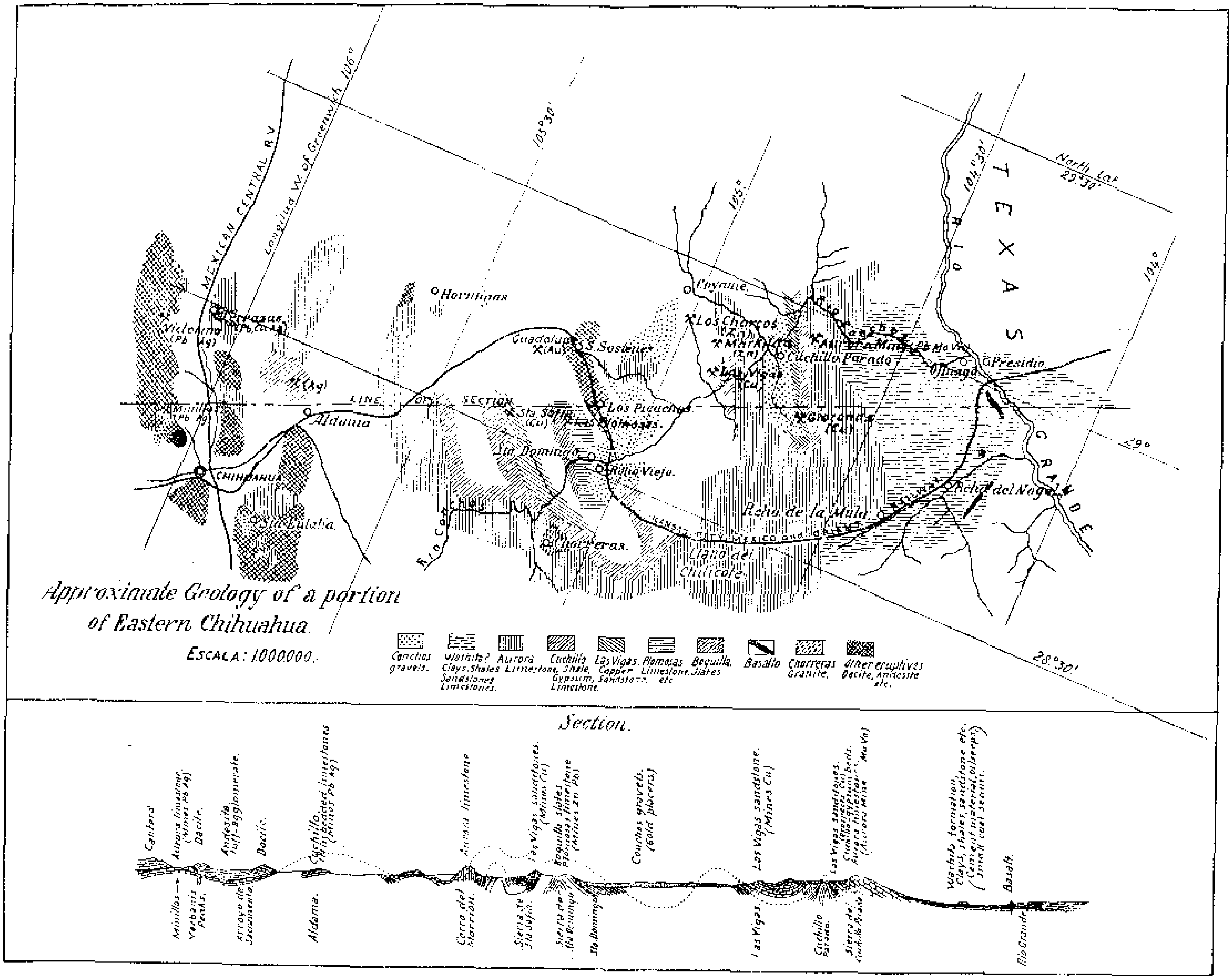
CONCHOS GRAVELS.

Occupying areas much greater than those indicated on the map, and representing accumulations of debris resulting from the erosion of the surrounding country, these gravels were carried into the lakes and there subjected to sorting and re-distribution, the gravels being found in fairly uniform beds, in which the boulders seldom exceed a foot in diameter. Calcareous waters percolating through the gravels have cemented them into a material resistant to erosion, as shown by the banks of the Conchos river, where abrupt escarpments, nearly 200 ft. in height, consist entirely of the cemented gravel. Near the village of Santo Domingo, at a point where the cemented gravels have been disintegrated, small placers have been worked by the natives for a long time; probably for the last hundred years. A few years ago an American company subscribed a large capital for the systematic exploitation of the gravel, establishing a powerful pumping plant in connection with a steam-shovel for handling the material on a large scale. The steam-shovel, however, was insufficient to cope with cemented gravel, and the enterprise has lain idle for some time, but is expected to start again on an area of disintegrated material that has been proved by late prospecting.

Eruptive rocks are of minor importance in the region of eastern Chihuahua, and are not found to any great extent until the line of the Mexican Central railway is approached, where the outlying edge of the Sierra province is reached. Near Hormigas, directly west of the ranch house, a line of low hills between Hormigas and the Aldama plain is composed of andesite tuff-breccia, the same character of rocks also forming the hills around the Guadalupe placer. At Santa Eulalia the Aurora limestone has been covered with a considerable thickness of tuffs, as described in a former paragraph. Dikes of eruptive rock are common in the eastern and western part of the region, but in the central part are only seen in the Santo Domingo range. They occur in the Boquilla as an andesitic intrusion over 400 ft. thick, and continuing northward in the shape of a dike for nearly five miles. This andesite is in marked contrast with the dike-rocks near the Rio Grande, which are uniformly ba-

saltic, and those of the western part, which are dacites or rhyolites. The Cerro del Coronel and Nombre de Dios near the city of Chihuahua are mainly composed of a thick sheet of dacite dipping to the west. A thin sheet of this material may be seen interbedded with the fragmental rocks in the hills overlooking Santa Eulalia, probably representing the edge of the lava flows eastward. The southern extension of the Santa Eulalia range is entirely composed of massive eruptives, mostly dacite. Near the Rio Grande, numerous dikes of basalt, which can be traced for miles, break through the sedimentaries. About five miles northeast of the Nogal ranch a basaltic cone rises through the Ojinaga beds, the latter dipping away in all directions from the cone.

In striking contrast to all other eruptives of the region, the intrusion of granite on the Chorreras ranch is interesting. This has been spoken of before in connection with its effect on the Cuchillo and Aurora formations; the sedimentary rocks having been metamorphosed to a considerable distance from the granite. The granitic facies is best observed near the centre of the mass, the structure becoming porphyritic as the edge is approached. The few small veins of silver-bearing galena west of the granite area, and the bodies of iron ore lying between the granite and the marble of the Aurora beds, doubtless owe their origin to this intrusion.


Approximate Geology of a portion
of Eastern Chihuahua.
ESCALA: 1000000.
MEXICAN CENTRAL RY
Longitud W. of Greenwich 106°
105°30'
105°
104°30'
104°
North Lat 29°30'
29°
28°30'
TEXAS
RIO GRANDE
LINE OF SECTION
Hornillos
Chihuahua
Aldama
Sta. Eulalia
Sta. Domingo
Los Picachos
Las Plomosas
S. Sostenes
Guadalupe (Au)
Sta. Sofia (Cu)
Charreras.
Rancho Viejo.
Coyame.
Los Charcos (Zn)
Las Vigas (Cu)
Cuchillo Parado
Ojinaga
Presidio
Rancho de la Mula
Rancho del Nogal
Llano del Chilicote
Conchos gravels.
Washita? Clays, Shales Sandstones Limestones.
Aurora Limestone.
Cuchillo Shale, Gypsum, Limestone.
Las Vigas. Copper Sandstone.
Plomosas Limestone, etc.
Bequilla. Slates
Basalto
Charreras Granite.
Other eruptives Dacite, Andesite etc.
Section.
Conchos gravels. (Gold placers)
Las Vigas sandstone. (Mines Cu)
Basalt.
Aldama.
Cerro del Morrion.
Las Vigas.
Cuchillo Parado.
Rio Grande