Franco Urbani P.

Venezuela—The Guayana Highlands

Gold Deposits of the State of Bolivar

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The third article of a series on Venezuela.

Introduction

All the known major gold deposits of Venezuela are located in the Yuruari-Cuyuni Basin and they include auriferous quartz veins, eluvials, and alluvials. The northern part of the basin, from Ciudad Bolivar to El Callao mining region, is easily accessible and for that reason is better known and more developed than the others; it has yielded about 80% of all the gold produced to date. Ciudad Bolivar is the gateway to all the goldfields and the principal means of communication with the interior from this town have already been described (Map No. 3).[1]

The history of the development of the gold-mining industry has already been briefly mentioned in the first article.[2] After the first recorded production in 1829 there is no official record available of mining operations between 1830 and 1857, owing to civil strife and the destruction of part of the archives. In addition, the Federal Government from 1864 to 1884 yielded its powers of granting mining concessions to the individual States and as a result much useful statistical and legal information has been lost.

The mining law in force up to 1854 had been that of Spain, with slight modifications made by Simon Bolivar in 1829 at Quito, whilst he was president of Gran Columbia. It was following this period, from 1859 to 1889, that many large concessions were granted to foreigners, mainly North Americans, English, and Dutch, but little work was done on the majority of these properties, some of which are even held to-day by other companies, through legal transfers, as entirely virgin properties. This state of affairs is possible, because, according to the Constitution of Venezuela, no law can be retro-active and the conditions under which these original titles were granted were so liberal that no conditions were imposed regarding exploitation.

History

The first recorded recovery of gold, in 1829, amounted to 15,112 oz. and was obtained from the banks of the Yuruari River, near Tupuquen, an old Catholic (Capuchin) mission station, four miles east of the town of El Callao. Many foreigners were working in this region, including negros from British Guiana, Germans, Frenchmen, and Brazilians. It was one of the latter, Pedro Joaquin Ayres by name, who in 1842 first made public the discovery of these auriferous alluvials, but little notice was taken of his report. However, in 1849 two Venezuelan miners, Andrés Morales and Pedro Monasterio, again made it known that in the region of Anacupai (Nacupay) there was much gold in the bed of this creek, which is a tributary of the Yuruari River. Dr. Luis Plassard, a medico, and at that time French consul in Ciudad Bolivar, also made a trip to these alluvial workings in 1849 to check on these reports and was so impressed with what he saw that on his return he applied for concessions.

By 1857, when Michelena Rojas, on behalf of the Government, visited the small miners' camps at Tupuquen, Nacupay, and Caratal, he found some 400 men at work. The biggest nugget found up to that date weighed 250 oz. and many others up to 20 oz. were reported. Exploration and mining activities were extended from the Yuruari River into every creek and tributary and in 1859 the Corina lode and others were found near the mouth of the Nacupay Creek. The discovery of the famous El Callao lode soon followed and before 1880 most of the major lodes of the El Callao area had been discovered and concessions taken out. The first primitive stamp mill was erected in the Nacupay valley, at Buen Retiro, in 1869, and the mill of the Panama company started working later the same year. The first mill of the Callao company was erected in 1871 and gradually increased its production after overcoming what appeared at that time to be insuperable difficulties. In 1875 the first dividend was paid and this company continued to pay big dividends every year until 1890.

During this period Venezuela's gold production was equivalent to 3·42% of the world's total, but following the closing of the

[1] The Mining Magazine, Sept., 1945, p. 139.
[2] *Ibid.*, July, 1945.

Callao group of mines it dropped considerably and it was not until 1926 that any marked recovery was recorded.

Many of the earlier companies experienced financial difficulties, some had insufficient capital, others wasted their cash resources on surface works, but the major part was often swallowed up in the cost of transporting heavy machinery from Ciudad Bolivar to the mines. Others had poor development results, as ore assaying less than 25 or 30 dwt./ton did not pay expenses at that time. As a result of a few high-grade lodes being worked out a 20-year boom was followed by a period of lode mining depression, which lasted from 1890 to 1925.

Exploration work from 1870 to 1900 resulted in the discovery of gold deposits in other areas—*viz.*, Botanamo (1877); La Cicapra (1878); El Dorado and Alto Cuyuni (1888/1904), and El Manteco (1888). However, outside of the El Callao area most of the mining work consisted in the recovery of alluvial gold from the numerous streams and creeks by washing the gravels in bateas and sluices.

Eventually the two major companies now operating in the Callao area between them acquired most of the concessions covering the known lodes and to-day they are producing run-of-mine ore varying from 11 to 17 dwt./ton from the ore-bodies nearest their treatment plants. If they are to continue operating their mills at maximum capacity it will be necessary for them to develop some of their now dormant and almost virgin properties, as the producing mines show signs of exhaustion in the lowest levels.

Production

Data on the production of gold are not complete, but the figures in Table 25 include official returns and an estimate of the probable production for those years for which no returns are available, or are incomplete.

Table 25

Year or Period.	*Gold Produced.* (oz.)
1829	15,112
1857	14,511
1830–1856	399,568 [1]
1858–1865	120,000 [1]
1866–1869	104,809
1870–1944	4,888,488
Total Gold Produced, 1829–1944	5,542,488 oz.

[1] Estimated.

From 1829 to 1869 practically all the gold produced in Venezuela came from the alluvial deposits of the Yuruari River and its tributaries and amounted to about 654,000 oz.

A certain amount of clandestine alluvial mining has been carried on during the past 120 years in the south-eastern part of Venezuela close to the British Guiana boundary and also more recently in the Gran Sabana area close to the frontier with Brazil. If these are taken into account the total production of gold in Venezuela since 1829 is probably in excess of 6,000,000 oz.

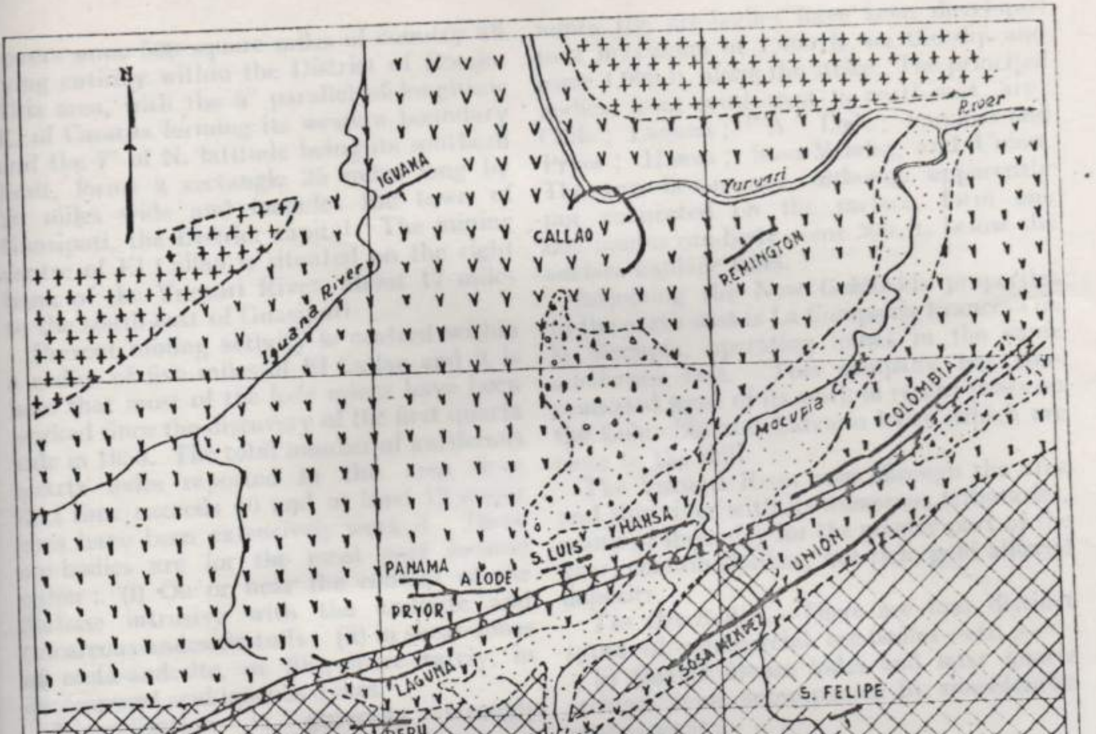
Over 40 auriferous quartz ore-bodies are known in the El Callao area and the total production from those that have been worked between 1870 and 1944 has been 4,500,000 tons of ore for a recovery of 3,900,000 oz. of gold, equivalent to an average grade of 17·3 dwt./ton. Of this total the Old Callao mine contributed 706,272 tons of ore which yielded 1,443,106 oz. of gold. It is, therefore, evident that even excluding this once famous mine the average grade of 12·9 dwt./ton for all the other ore-bodies is still high and constitutes one good reason why more attention should be directed to gold-mining possibilities in this region of Venezuela in the immediate future.

Climate and Health

The climate in the region north of the latitude of El Dorado is healthy and Europeans with reasonable care remain many years without having any serious illness. South of El Dorado the country is much more thickly wooded and malaria and beriberi are fairly common amongst the small, scattered, native population.

Labour, whilst not plentiful, has been sufficient and is recruited principally from the vicinity of the towns of Upata, Guasipati, El Palmar, and Cudad Bolivar.

Fruit and vegetables can be grown in this region, but it is difficult to find anyone sufficiently interested, or experienced, to maintain gardens large enough to supply local needs. South of El Dorado supplies must be transported by launch or dug-out canoe and all foodstuffs must be brought in from Ciudad Bolivar, El Callao, or Tumeremo. Field work, especially prospecting and sampling, can only be done in this region uninterruptedly during the dry season, which lasts from September to April, but in the northern part of the area, from El Dorado to Ciudad Bolivar, exploratory work may conveniently be done throughout the year.



GEOLOGICAL SKETCH MAP OF EL CALLAO REGION
STATE OF BOLIVAR-VENEZUELA
BASED ON THE WORK OF Dr. M. MACLAREN & Dr. W. S. McCANN

Regional Geology

Between Ciudad Bolivar and Guasipati the road traverses the granite-gneiss of the Archaean Complex, into which a younger granite has been intruded. The latter is seen in occasional low flat-topped hills and numerous outcrops of quartz are found in this granite, or at the contact of it with the older granite-gneiss. The northern part of this area is one of undulating open *sabanas*, topographically somewhat like the *llanos* north of the Orinoco River, on which grow a coarse grass and stunted *chaparro* (scrub-oak) trees. However, soon after leaving Guasipati and proceeding in a south-easterly direction towards El Callao there is a marked change in the vegetation and closer inspection reveals that the acid igneous rocks have given way to basic igneous rocks. The latter extend south and east to the borders of the Gran Sabana and into British Guiana and north-west to beyond the Caroni River. These basic igneous rocks of the Pastora Series form part of a greenstone complex and include andesites, tuffs, diabase, gabbro, and chlorite-schist. Intruded into these are dykes of aplite, quartz-porphyry, granite-porphyry, and pegmatites.

The greenstones have a fairly uniform appearance in the field and locally all these basic rocks are called *piedra azul* (blue stone).

The oldest members of the Pastora Series appear to have been an andesitic lava and thin beds of calcareous tuff. These andesites and andesitic-tuffs have been intruded by a diabase, which considerably altered the andesites and the pyroclastic sediments and also created zones of weakness and fracture. A grey biotite-granite intrudes the greenstone complex, forming a large boss underlying the whole area and outcropping only in the region between Guasipati and Ciudad Bolivar and in the extreme east and south-east parts of the basin. A much later age of intrusives is represented by gabbro, dykes of younger diabase, and numerous smaller dykes of acid igneous rocks—such as, aplites and granite-porphyries—that are seen in the region of El Peru, Botanamo, and El Dorado.

Andesite.—The unaltered andesite is a fine-grained, green-coloured rock containing principally hornblende and plagioclase felspar. The former is often altered to chlorite and the latter to kaolin. In may places close to the ore-bodies the andesite is bleached and contains secondary pyrite. Above the water-table it is often much decomposed and forms a red ferruginous clay—called locally *cascajo*—which may extend to 200 ft. below the surface. A very calcic type of andesite, containing an unusually high percentage of CaO and exhibiting pillow or ellipsoidal structure and sometimes amygdaloidal cavities containing calcite, is also common in the El Peru—Caratal area. Where this andesite is very decomposed, as on the Union mine, the pillow structure is very evident. A quartzose-andesite grading into a quartzose-andesite-schist is seen in the region of, and in, the Union and Sosa-Mendez mines. It is usually fine-grained and of a dark-green colour, but where the quantity of quartz present is high, as at the Mocupia mine, it has the appearance of a dacite and the colour is a greyish-green or a bleached dirty white.

Diabase.—There are two ages of diabase intrusions. The older diabase covers a wide area in the form of a sill and is clearly exposed south of the Salto and Chile mine. Its texture varies from a fine- to medium-grained rock which consists principally of hornblende, plagioclase felspar, and quartz. The colour is generally greenish-grey, but varies with the degree of weathering and nearness to the contact with other rocks.

Younger Diabase.—This age of diabase is represented in the El Callao area by a prominent dyke, varying in width from 125 ft. to 160 ft., which traverses the Callao mining district with an average strike N. 70° E. and has been identified over a length of about four miles. At its contact with the andesites it has a chilled margin of very fine-grained black rock containing principally augite and biotite-mica. Towards the centre of the dyke the texture varies from medium to coarse grain and the rock contains mainly hornblende, augite, plagioclase felspar, and some magnetite.

The basic rocks are often covered by a capping of laterite of varying thickness called locally *moco de hierro*, resulting from the weathering of these outcrops. This laterite varies from a brown to a red colour and consists of angular fragments of quartz, ferruginous clay, crystals of magnetite, ilmenite, and pisolitic grains or concretions of limonite. This laterite usually contains some gold and samples taken on San Luis hill and near the Mocupia mine have given values ranging from 2·00 dwt. to 8 dwt./ton.

Gabbro.—There is a large outcrop of gabbro on the hill opposite the town of El Callao on the north side of the Yuruari river and another on Monte Sacro hill west of this town. It varies in texture but is generally medium-grained and contains augite, another pyroxene, and decomposed plagioclase felspar. The intrusion of these gabbros caused tilting of the meta-andesites and tuffs south of El Callao and Monte Sacro.

Auriferous Areas

For descriptive purposes this auriferous basin within the State of Bolivar has been divided into six mining regions (Map No. 4).[1]

(I) *El Callao Region*

This is the most important of the gold-mining fields in Venezuela, although it is the smallest of the areas to be described ; it

[1] THE MINING MAGAZINE, Sept., 1945, p. 145.

covers some 500 square miles of country all lying entirely within the District of Roscio. This area, with the 5° parallel of longitude E. of Caracas forming its western boundary and the 7° of N. latitude being its southern limit, forms a rectangle 25 miles long by 20 miles wide and includes the town of Guasipati, the District capital. The mining centre of El Callao is situated on the right bank of the Yuruari River, about 17 miles to the south-east of Guasipati.

Present mining activity is centred within a radius of five miles of El Callao and it is here that most of the lode mines have been worked since the discovery of the first quartz lode in 1853. The total number of auriferous quartz lodes reported in this area since that time exceeds 40 and at least 12 major ones have been extensively worked. These ore-bodies are for the most part located either: (i) On or near the contact of the diabase intrusive with the andesite and calcareous-andesitic-tuffs; (ii) in shear-zones of meta-andesite, or (iii), more rarely, in decomposed acid igneous dykes.

Mineralization is generally strongly developed where:—

(i) Earth movements have taken place either parallel to the original fissures (veins) causing zones of fracturing along the walls, or

(ii) where an intrusion or faulting has caused buckling, fracturing, and folding of the schists, or

(iii) where there are sudden changes in dip or strike.

There is marked secondary enrichment in the zone of oxidation of these lodes and the ore occurs in shoots and lenses of greatly varying extent The lenses pinch out and make again both horizontally and vertically, but, with the exception of those in the New Chile mine, do not overlap. There is little post-mineral faulting and generally the amount of displacement is small, but enough to cause inconvenience in development and stope-preparation work.

Space does not permit a description of all the auriferous quartz deposits in the area south of El Callao, but some notes regarding their main features may be of interest. El Peru mining camp is 3¼ miles south-east of El Callao and here are located the local headquarters of the New Goldfields of Venezuela Company's operations (Map No. 5). In recent years it has been developing and mining several ore-bodies in a shear zone of varying width and some four miles long, with a general strike of N. 60° E. In individual mines the ore-bodies have been developed to a maximum of 1,400 ft. on the dip and some 4,000 ft. along the strike. The principal bodies, from south-west to north-east, are: Chile; Laguna; "A" Lode; Panama and Pryor; Hanza; Sosa-Mendez, and Union. The two last-named, although apparently not connected on the surface, form one continuous ore-body some 300 ft. below the surface haulage level.

Adjoining the New Goldfields properties to the north-east is La Compañia Francesa de la Mocupia, operating mines in the same auriferous belt. This company has concentrated most of its work in recent years on the Columbia and Calvario lodes, which are close to the mill.

The Yuruari River runs through the area and this river with its numerous tributaries, many of them dry for the greater part of the year, contain shallow, but rich, gold alluvial deposits.

The Ore-Bodies.—There are four distinct types of commercial ore-bodies—*viz.*:—

(i) Quartz fissure lodes and later quartz stringer veins accompanied by considerable replacement;

(ii) quartz-vein dykes;

(iii) lenticular quartz ore-bodies, and

(iv) mineralized acid igneous dykes.

The first type includes the Laguna mine ore-body, which so far has proved to be the largest in this district. It has been developed over a strike distance of about 3,000 ft. and on the dip for 1,400 ft. Production from this mine to date has exceeded 1,000,000 tons of ore, averaging approximately 10 dwt./ton. The strike of the lode follows the form of a flattened arc and varies from N. 58° W., west of the main entrance adit, to N. 73° E. on the east side of it. The dip is generally to the south, but in the most easterly section of the mine it is reversed for a short distance. The lode was originally a quartz-filled fissure with quartz veinlets spreading out into smaller cracks and fissures in the walls. A greater percentage of free gold is found in the quartz vein than in the stringer veins of the quartzose-schist. The replacement ore consists of auriferous pyrite which, where the pyrite is fine grained, often contains values higher than those found in the primary quartz veins. A diabase dyke (younger diabase, Map No. 5) intersects the lode at an oblique angle at the western end of the mine and near this contact there has been considerable enrichment of the quartz in the form of coarse native gold. As the workings deepen this enriched zone extends for a greater length along the strike north-west of the dyke.

The altered aplite dyke which runs parallel to the lode in the central part of the mine has been intersected by this diabase and considerable quantities of free gold occur near this contact also.

The dip of the lode varies in various parts of the mine between 38° and 70° south, with occasional rolls which are often the seat of local enrichment. The lode width also varies considerably and ranges from 3·5 ft. to over 20 ft. and high-grade ore-shoots vary in strike length from 85 ft. to 700 ft.

Below the Datum Level the lode has been displaced by a series of north-dipping strike faults, which have caused displacement of the lode to an increasing extent in depth.

The Union and Sosa-Mendez mines, which were originally two separate properties worked on extensions of the same ore-body, have somewhat similar features to the Laguna mine, but the mineralized shear zone has been subjected to more extensive hydrothermal metamorphism and sulphide replacement of the quartzose-andesite-schist.

In the Union mine section the ore-body is located in a wide shear zone and in the upper levels there are four distinct zones of mineralization, parallel to one another in strike, which are tending to coalesce in depth to form one major lode. Running through the centre of this shear zone is a pre-mineral thrust fault, dipping from 48° to 56° south, parallel to the schistosity, and carrying a thick, greenish-blue, clay gouge, which is not mineralized.

The western end of the mine is much less affected by metamorphism than the eastern and in the latter mineralization is spread over a wider area of the shear zone. The ore occurs in large lenses in which the highest values are concentrated near the centre and gradually fall off towards the perimeter. They represent quartz-auriferous pyrite replacements in the andesite-schists. Oxidation has persisted to a maximum depth of 200 ft. below the surface and has resulted in considerable secondary enrichment of the original low-grade sulphide ore, especially in the foot-wall side of the shear zone. The oxidized portions of the ore-bodies contain principally drusy and sugary quartz, free gold, iron oxides (limonite and magnetite), and kaolin.

In the zone of oxidation of the Union and Sosa-Mendez mines, but particularly of the former, there are a number of flat-dipping faults, which appear to be pre-mineral, and often the ore-lenses end abruptly on these faults. Hydrothermal metamorphism is extensive, especially in the eastern part of the mine, where silicification, sericitization, and propylitization are clearly manifested. Amongst replacement minerals are sericite mica, calcite and ankerite, and flint-like quartz and jasperoid quartz are also common in the quartzose-andesite-schist. Sericitizations, and to a lesser extent, chloritization, have been extensive, especially within the mineralized portions of the shear zone. The hornblende andesite has been bleached and silicified and considerable chlorite and pyrite are present as alteration products. The Sosa-Mendez mine has a similar type of lode to the Union mine in depth, but near the surface a more massive quartz ore-body containing a considerable amount of kaolin, iron oxides, and psilomelanite. Free gold was often visible in the quartz, but when accompanied by psilomelanite it was not amalgamable.

The total length of mineralized shear in these two mines exceeds 4,000 ft. and development extends to about 600 ft. vertically below the highest outcrop level.

The ore to date produced from the Union-Sosa-Mendez mines totals approximately 750,000 tons and it will probably eventually exceed the Laguna mine in tonnage, although not in grade.

The quartz-vein dyke type of ore-body is represented by the Old Chile, Peru, Old Callao, and Columbia (Mocupia) mines, which have proved to be the richest in the State of Bolivar. Their combined output (including the Old and New Chile mines) totals more than 1,500,000 tons of ore, with a gold content averaging 30 dwt./ton. These ore-bodies generally have clean-cut walls and the mineralization consists mainly of free gold in the quartz. In the deeper levels the amount of auriferous pyrite present tends to increase somewhat and is located mainly on the foot-wall of the lode.

The Old Chile lode was worked on a strike length of about 1,500 ft. to 1,600 ft. to a depth along the dip of 800 ft. to 900 ft. and varied in width from 3 ft. to 5 ft.

The new Columbia mine of the Compañia Francesa de la Mocupia has been developed only for a strike length of 900 ft. to 1,000 ft., between two oblique faults, although high-grade ore has been proved in the faulted portions of the lode by diamond drilling. The

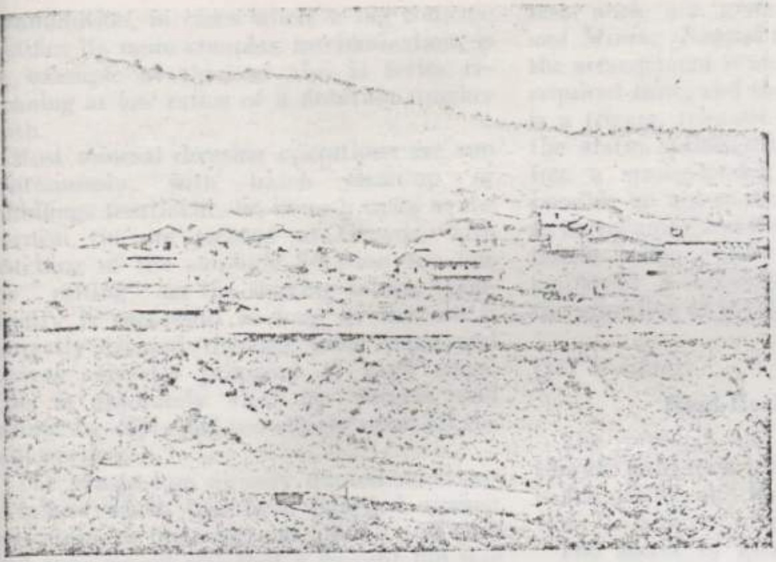


Fig. 6.—Mill, Stores, and Workshops of New Goldfields of Venezuela.

same diabase dyke that cuts obliquely across the Laguna lode also intersects this one at 230 ft. below the surface, but has a strike parallel to the lode. This intrusive has caused a vertical displacement of the lode north of the dyke and also considerable enrichment and widening of the quartz-filled fissure on the hanging-wall side below the dyke. The foot-wall of the lode has been altered in places to a dacite and close to the dyke it contains angular fragments of dacite and bleached andesite. The lode dips south and flattens below the dyke from 37° to 12° and then steepens again to 27°, but generally it is flatter than any other lode in the district. In this mine volcanic tuffs are clearly seen, both above the diabase dyke and below it. Layers and bedding planes are clearly defined and bands of green and yellowish calc-sinter can be distinguished, although most of the original sediments have been silicified.

The old section of this property was worked to the west of the present mine down to the level where the diabase dyke intersected it and where it was thought at that time that the lode ended. In an attempt to determine whether the lode existed to the south some diamond drill-holes were badly placed and penetrated only the diabase dyke, which is practically vertical and from 160 ft. to 180 ft. wide in this section, and the property was then abandoned for many years. Post-war development should enable this property to work the western extension of this rich lode below the dyke and the ore reserve should be at least equal to that below the dyke within the present mine limits.

The ore produced from all sections of the Columbia (Mocupia) mine totals over 480,000 tons of an average grade of 13·6 dwt./ton and at the present time (March, 1945) the run of mine grade is 16 dwt./ton, with current output running about 2,000 tons per mensem.

Lenticular Ore-Bodies.—This type is really a subdivision of the quartz-vein dyke class of ore-bodies, but differs to the extent that these are quartz-filled fissures, which were formed as the result of lateral earth movements along the irregular contact of the diabase with the andesite. The principal ore-body of this type in the Callao region is that of the New Chile mine. Here the original quartz filling of the fissures has been heavily shattered and crushed by later movements along the planes of the vein, accompanied by silica and auriferous solutions depositing gold in the minute cracks of the first- and second-generation quartz. The length of the ore zone is about 2,200 ft. and the strike averages N. 80° E., while the dip is very uniform and averages 45° south.

The total production of all sections of the Chile mine has been approximately 360,000 tons of ore, averaging over 30 dwt./ton.

Mineralized Acid Igneous Dykes.—These are not common in the El Callao region, but the Calvario mine is definitely of this type and probably the southern portion of the San Felipe mine is another, but the weathering of the last-named ore-body has been so intense that it is impossible to determine the nature of the original rock, other than it appears to have been an acid igneous intrusion. The Calvario lode had a total length of about 800 ft., a strike of N. 46° E., and a dip of N. 45° W. The eastern half alone contained payable values in gold and these persisted only to the water level of the mine. The gold occurred in a very fine state of division in a decomposed quartz-porphyry dyke varying in width up to a maximum of 4·5 ft. The felspathic minerals were completely kaolinized and the country rock in the vicinity of the dyke was also weathered to a soft, ferruginous, red clay.

Production from the eastern section of the Calvario mine was around 30,000 tons of ore, averaging 12·0 dwt./ton, and that of San Felipe about 27,000 tons of 9·0 dwt./ton.

(To be concluded.)

Ore-Dressing Notes

(23) *Flow-Sheets.*

Batch to Continuous

Formulation of the ore-dressing flow-sheet usually starts with batch tests, going on with a miniature continuous processing in which the difficulties arising between successive stages of batch treatment are adjusted and times, qualities, and costs of process reactions are studied. Finally comes the settled operational flow-sheet. From study of the batch tests the metallurgical consultant is able to predict with fair accuracy the grinding capacity needed for a specified daily tonnage and the conditioning times, pulp densities, fouling rectification, etc., requisite for optimum recovery. The old adage—" a chain is no stronger than its weakest link "—applies to continuous processing. Any neglected point, or unbalanced section of the circuit, will react on the general efficiency.

A symposium on continuous processing in the heavy chemical industry,[1] although going beyond the specialized requirements of the ore-dresser, is of interest, as it weighs the rival claims of the batch and continuous system of treatment from both economic and technical viewpoints. " Batch " treatment refers to any operation which can be considered by itself as applied to a definite quantity of material. A continuous process is—

> Ore in which all process variables remain constant with time at a given point in the flow-path, but vary with distance along the path. This definition applies not only to complete processes but also to the individual steps of the process, such as chemical changes, physical changes, and the transfer of materials and of heat.

[1] *Chem. Met. Eng.*, May, 1945.

Thus the segregation of an accumulated fraction of the ore for special batch treatment does not alter the general continuity of a flow-sheet. Continuity can be concurrent, in which case the whole process is moving in one direction, or counter-current (in part), as where gold pulps are treated in a reversed flow of cyanide to strip them of residual values. At one treatment extreme is all-batching, in which the material is transferred in a series of processing steps through successive chemical and physical environments. Intermediate is the semi-continuity of successive batching arrangements connected by transfer arrangements and surge bins or tanks, capable of adjusting any excess or deficiency between steps by providing reservoir accommodation. Next comes the kind of processing in which the batching steps merge and overlap, while additives enter normal to the main flow and an arrangement of this sort is typical in mineral dressing. Point-to-point surges and starvations are taken up as the need arises by manual or automatic adjustments of the controls.

In the experimental work from which the flow-sheet will be evolved it is possible to apply mechanical, thermal, and chemical energy with fair precision and to obtain a good empirical picture of the factors at work. By its nature a continuous flow must fail to receive the same intimate mixing and tight control and must therefore be somewhat less efficient for the same quantity and time. This applies chiefly to small tonnages. As it becomes possible to break down a given " batching process " into sub-batches, and to incorporate this into the continuous flow-sheet, the efficiency of continuous processing is improved toward optimum batching standards. Multi-stage comminution, in cases where a big tonnage justifies its more complex mechanization, is an example of this, as also is series re-cleaning at low ratios of a flotation rougher froth.

Most mineral dressing operations are run continuously, with batch clean-up or middlings treatment, or, in such cases as the Cornish tin ore treated at Geevor, with batching of the sulphide flotation too fine for "rafting" on the shaking tables. Continuity is successful so long as the ore is correctly treated through each stage and arrives correctly prepared at each stage. This is absolutely vital for success and cannot be impressed too clearly upon all the mill workers.

The symposium already quoted mentions a failure which had been guarded against by automatic metering and mixing. All that had gone wrong was that a reagent bin was empty while the worker in charge lay peacefully asleep on a pile of bags. In another case, where size was an important process factor, a screen was alternatively starved and swamped with feed until bridging of the feed to it was corrected by the installation of an electric vibrator. In a third case any failure of a fine screen, which could have upset the graded product, was avoided by double decking, using a slightly larger mesh and stouter wire on the lower deck. Thus any oversize coming from the lower deck indicated screen failure and by providing a balanced hopper it was possible to give automatic warning when this happened.

Batch tests in the laboratory must be supplemented by re-cycling tests when there exists a possibility of fouling. This is particularly important in cyanidation, where a trace of impurity in the passing stream of ore, too insignificant to give warning in a single extraction test, might well be dissolved and retained by the cyanide and so built up to the point where it interfered seriously with dissolution of the gold or its re-precipitation. Every ingredient of the pulp must be considered in this connexion—ore, water, mill-linings, and ball alloys included. Even the wood from underground which escapes sorting can become a source of trouble once it has been floured in the grinding section.

(24) *Control.*

A Home-Made Timer

Particulars of a simple arrangement for switching off power in connexion with test work are given in the *Engineering and Mining Journal* for May. The basis of the arrangement is an alarm clock, set to the required time, and the actuating mechanism is a trigger, released as the winding key of the alarm spring rotates. The trigger can free a spring-loaded switch, thus making possible an automatic timing of such things as barrel amalgamation, screening, or cyanide bottle tests. One form of arrangement employed a break-back mousetrap, using the vibration of the alarm bell to spring it.

(25) *Washing.*

Hard-Rock Phosphate

The problem of dealing with clay in Florida hard-rock phosphate washing plants is formidable and has received much attention. In a recent article[1] T. D. Felton says: "The secret of good log washing lies in maintaining a heavy bed of material in the logs and at the same time introducing sufficient water to carry away the disintegrated clay or slime. With a fluctuating feed it is impossible to do this unless you have variable speed or adjustable pitch, preferably both. We can vary the speed of our logs from 20 r.p.m. to 35 r.p.m. When the feed slackens or stops . . . 20 r.p.m. will hold the bed for about 15 minutes and when we get adjustable pitch . . . 20 r.p.m. will not make the log discharge at all." The plant has two sets of duplex log-washers in series and these are now being equipped with adjustable pitch. Another novel feature of the plant is the automatic control of the 20-ft. hydro-separator. As load increases the thrust on the rakes is balanced by increased compression of a heavy spring, an indicator showing the amount of compression, as is customary with mechanisms of the thickener type. In this phosphate plant there is further control. As the spring moves three mercury switches are activated, the first at 50% load, the second at 75%, and the third full load. These vary the resistance in the motor pumping the underflow and render operation automatic.

(26) *Grinding.*

The Closed Circuit (2)

When the grinding circuit is closed by a screen there must inevitably be a tendency for near-mesh particles to increase. As the

[1] *Eng. Min. Journ.*, May, 1945.

Venezuela—The Guayana Highlands

Gold Deposits of the State of Bolivar

By John C. Davey, A.C.S.M., M.Inst.M.M.

(*Concluded from the November issue, p. 282.*)

(II) *La Cicapra Region*

This old alluvial mining centre was discovered in 1878 and is located some 20 miles west of Guasipati, although the distance by road is double this figure. It may be reached by a branch road, which leaves the Guri-Guasipati highway at La Pastora and follows a south-easterly direction for about 12 miles. The Cicapra field covers an area of 2,450 square miles with the town of Upata (capital of Piar district) forming the north-west corner of a rectangle some 70 miles in length by 35 in width.

The north-east section of this rectangle, which includes the area between the main highway from Upata to Guasipati and the Imataca Range, contains no known mineral deposits. However, in the southern half of this rectangle, from 15 miles north-west of Quebrada de Oro to Avechica, there is a number of old mining properties on which little or no work has ever been done. The quartz veins are found in chlorite-schists and values in the outcrops range from 5 dwt./ton to 1 oz./ton. All the old workings that are accessible show that mining ceased at a very shallow level and the deepest pit known is not more than 120 ft. below the surface.

Most of these quartz outcrops carry considerable free gold, but this soon gives way to an auriferous pyrite and mining work was generally stopped at this level. This is given as the reason for the abandonment of lode mining in this region, as at that time cyanidation was unknown and the recovery by the amalgamation process was small and completely inadequate to pay operating expenses.

This field was noted in the past for its rich alluvial deposits and one report, written in its heyday, stated that the gold recovered indicated values running as high as one ounce of gold for every three cubic yards of gravel treated. In 1880 some 3,000 miners were employed in panning for gold in the various creeks of the Cicapra River, but there has been very little activity in this region in recent years. Between 1878 and 1900 more than 3,000,000 bolivares worth of gold was recovered and in 1938 and 1939 the official records show a production of 3,300 oz. and 5,000 oz. of gold respectively.

(III) *El Manteco Region*

The straight-line distance from Guasipati almost due west to El Manteco is 50 miles, but by the unkept dirt road it is 68 miles. Taking the western limit of La Cicapra rectangle as its eastern boundary the Manteco rectangle extends some 40 miles further west to include the San Luis de Caroni mine and a number of alluvial deposits making a total of 2,800 square miles of fairly open country.

The old San Luis de Caroni property has at least three lodes, which were worked some 40 years ago for a period of three years, after which the mine remained abandoned until 1944, when a Venezuelan syndicate reopened it. A mill with ten heads of stamps was erected close to No. 2 lode and water for treatment purposes was pumped from the Caroni River, which lies about three miles to the west.

The amount of ore crushed is not known, but judging by the shallowness and limited lateral extent of the workings it was small. The quartz outcrops were very rich and contained visible gold, but little is known of the values at the bottom of the mine, some 120 ft. below the surface. Of the three lodes worked, No. 1 pinched out at a very shallow depth ; No. 2 varied in width from 3 ft. to 4 ft. and carried values up to 12 dwt./ton, according to a report made by one of the first operators. No. 3 lode is the strongest, strikes E.–W., and dips about 50° south. The reported width is 3 ft. to 4 ft. and values range from 10 to 18 dwt./ton. The mine was abandoned before the workings reached water-level and recent work has been confined to sections of the lode above the bottom of the mine.

Some 12 miles south-west of El Manteco, beyond the Cerro Azul, are some quartz-vein outcrops in schists containing visible gold. These have been worked by local people to the extent of breaking the high-grade quartz from the outcrops and then following the lode down to water-level. The pits in the Quebrada Mapuey are all very shallow and in some cases have been filled with debris. About 20 miles north of El Manteco is the old Mapurite mine, on which some work was done in 1920, but on which no information is available other than that a five-stamp mill was erected to treat the ore by crushing and amalgamation. The lode is located close to the outcrops of the younger granite intrusive and does not appear to be of major importance.

There are some auriferous alluvial deposits in this area, but probably most of them are too small to warrant treatment by machinery.

(IV) *Botanamo Region*

The Botanamo region covers an area of 2,500 square miles and extends westwards from the Venezuela—British Guiana border to a north–south line seven miles east of the town of Tumeremo and also extends north from the 7° parallel of latitude to the foot of the Sierra de Imataca. Communications east of Tumeremo are by river or by a rough truck road and the fact that this town is on the highway from Ciudad Bolivar and possesses an airfield makes it the logical headquarters for work in this area.

Several mining companies have operated quartz mines in this region, of which the best known is the Botanamo, some 2·5 miles north of the mouth of the river of that name. The mill, with a capacity of 50 to 60 tons per diem, treated some 175,000 tons of ore and recovered about 148,000 oz. of gold before ceasing operations in 1936. The ore-bodies were fissure veins containing quartz, native gold, auriferous iron-pyrite, and a little tetrahedrite. The country-rock consists of foliated sericite-schists resulting from the alteration of quartz-porphyry dykes. A fine-grained diabase is exposed in the banks of the Botanamo River near the mine and granite-porphyry dykes also outcrop east of it. Gold values were very irregular and generally the highest grade occurred in the veins, where they were crushed and faulted. Acid igneous intrusions are more common here and closer to the ore-bodies than in any other area except that of El Dorado (Upper Cuyuni).

Other quartz-lode properties in this region include the Nuevo Callao (20-stamp mill), Inflexible, and Orion. None of these has been worked to more than 200 ft. below the surface, although the Botanamo mine bottomed at 850 ft. Vuelvan Caras, the only mine now working in this region, is situated 42 miles south-east of Tumeremo and only 12 miles from the British Guiana border. Trucks are able to reach this property in the dry season only and for the greater part of the year the journey must be made on mule back from Botanamo and takes about 13 hours. The region is thickly wooded and the high overhanging trees prevent the road from drying until long after the rains have ceased. A landing field for aeroplanes, with a runway 2,300 ft. long, has been made by this mining syndicate, but up to the present it has not been used. The area is healthy and free from mosquitoes, although the elevation is not more than 600 ft. above sea-level. The gold is found native in a very fine state of division in a drusy quartz occurring in narrow veins in a calcareous chlorite-schist. On the hanging-wall side of the lode this gives way to a quartzose-schist and andesite. Outcrops of a weathered granite intrusive are also found in close proximity to the ore-body.

Since the commencement of operations in 1939 about 25,000 oz. of gold have been recovered. For more than two years the ore was crushed in a primitive stamp mill, but in 1942 a new mill building was erected and ten heads of Californian stamps installed. During the first year of operation of this plant 8,544 tons of ore was treated for a recovery of 7,376 oz. of bullion. This indicates a rapid falling off in values, as the outcrop workings often yielded up to 12 oz. per ton.

In this mine, as at Botanamo, the best values have been found near a fault, where the lode had been twisted and crushed. The lode strikes N. 30° W., dips S. 85° W., and

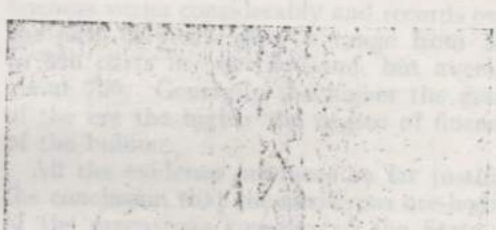


Fig. 7.—Prospect Pit, Mocupia.

varies from 3 ft. to 6 ft. in width. Recently work in this property has been mainly confined to attempts to locate the faulted portion of the lode. No mining has been done below the zone of oxidation, as this will require rock-drills and additional machinery that are not available at the present time.

In addition to these quartz vein deposits and others not mentioned the area possesses a number of alluvial deposits. The following rivers are known to be auriferous, although little work has yet been done to prove their extent—*viz.*, Guarampin, Morajuana, Matupo, and Cuyuni. Probably on account of the remoteness of this area and the fact that before 1939 no mining work of note had been done east of Botanamo, it is little known and has not attracted local miners.

(V) *El Dorado*

The mining region of El Dorado, including the Alto Cuyuni, is the largest in the auriferous basin and covers an area of 3,500 square miles. It roughly extends from 5° to 6° of longitude (east of Caracas) and from 6° to 7° N. latitude. The highway from Ciudad Bolivar passes through Tumeremo and ends at El Dorado. The whole area is thickly wooded and is traversed by innumerable streams, all of which are considered to be auriferous.

Owing to the lack of road communications south of El Dorado very little quartz-lode mining has been attempted. However, the little underground mining that has been done has proved the lodes to be extremely high grade. The Amarilla property lies on the river of the same name, some 80 miles south of the town of El Dorado. This distance may be covered in a dug-out canoe with an outboard motor in about 22 hours. The mine is at an altitude of about 450 ft. and although the atmosphere is humid the maximum day temperature rarely exceeds 95° F.

The rocks outcropping in the area include andesite, pegmatite, dacite, quartzose-schist, and sericite and chlorite-schists. The principal quartz vein is found in the chlorite-schist and strikes roughly north-west–south-east and dips S. 60° W. The outcrop has been traced for a considerable distance and has been developed to a depth of about 150 ft. below the surface in the zone of oxidation.

A small mill was erected to treat this ore by amalgamation and between July, 1936, and December, 1937, some 5,000 tons were treated giving 4,600 oz. of gold. The quartz is glassy, often dark grey in colour, and contains visible gold and some auriferous pyrite. Limonite and psilomelanite often coat the quartz and the latter may have affected mill recovery adversely. Probably not more than 8,000 tons have been extracted from this mine since it was discovered in 1920, but records are fragmentary.

Another quartz lode of the same type was uncovered some years ago about 5 miles from Puerto Sor Teresita, but there is no information available regarding the extent of the development work done here. The whole area is noted for its rich gold alluvials and it was a major producing field for many years, although, with one exception, all the gold was recovered by washing the gravels in bateas or sluices. One dredge has worked in this area since 1916 and between that year and 1938 it recovered 106,700 oz. of gold. This dredge has buckets of 2·5 cu. ft. capacity, close-connected, and was manufactured in San Francisco (California). The auriferous gravel (*formacion*) here is thin, but the overburden rarely exceeds 15 ft. and values in the region of the Corocoro and Foco creeks have ranged from 0·25 dwt. to 1·0 dwt./cu. yd. In the course of working these shallow alluvials the outcrops of quartz veins have been uncovered, some being as much as 3·5 ft. wide and containing high gold values.

The principal rivers of this area unite near El Dorado, so that this town forms a hub, or centre, from which these auriferous alluvial deposits may be visited. The Rio Yuruari coming from the north joins the Cuyuni flowing from the south opposite this town, at which point the Cuyuni swings sharply east. The Rio Yuruan describes a wide arc proceeding due north from its source in the Serrania de Lema and then swings east to join the Yuruari, a short distance from El Dorado. The basins of each of these rivers contain innumerable tributary creeks and streams, practically all of which contain auriferous sands. Systematic sampling and prospecting anywhere within a radius of 35 miles of El Dorado should prove a number of valuable alluvial properties, which cannot be economically worked by the local miners because of the depth of the gravels and of the river. The alluvials are of two classes—those of old rivers and those of young rivers. The latter are of small volume and because of their shallow depth are worked by the local miners. The former have much more economic value but are too deep to be worked by the primitive means available to the local miners.

Eluvial deposits also cover a large surface area, but the gold in the form of coarse gold nuggets is found in a superficial layer rarely more than 24-in. thick and frequently only 8 or 9 in. thick.

(VI) *Tumeremo*

This is a relatively unimportant mining area, although it covers about 1,000 square miles of territory between the El Callao and Botanamo areas already described and extends from 7° N. latitude to the foothills of the Imataca Range, forming a belt 20 miles wide—the Yuruari River being its western limit. There are a few small quartz lode mines in the area that have been worked by hand to very shallow depths. The quartz is hard and vitreous and contains free gold and very little pyrite. The country rock is diabase and meta-andesite, which is much less decomposed than in the El Callao area.

Several auriferous alluvials are known in this region, but they are mostly small in areal extent and volume.

Mineralogy of the Ore-Bodies

The major constituent of the ore-bodies is quartz, which is generally fractured and in the zone of oxidation is fragmentary, drusy, and covered with iron oxides, particularly limonite. In some mines (Sosa-Mendez, Hanza, Columbia, Vuelvan Caras, etc,) manganese dioxide, in the form of psilomelanite, is common in the zone of oxidation, coating the quartz and often forming botryoidal masses. Chemical analysis has shown some of these occurrences to contain high gol' values which could not be recovered by amalgamation.

The quartz occurs as a crystalline, milky white, banded variety or as a dark-grey type, sometimes with a ribbony structure formed by shearing. Brecciated grey quartz cemented by white quartz and limonite is also found in the mines of El Callao area. Occasionally the quartz is pink in colour, as at Lo Increible mine, and it then contains very little mineralization other than native gold. Two ages of quartz can be distinguished in some of the ore-bodies and also two ages of mineralization. Native gold of the second age of mineralization is younger than the pyrite. The ore minerals are native gold and auriferous pyrite. The latter varies in quantity from about 1% to 6% and the gold content also varies within very wide limits. Generally the smaller the crystals of pyrite the higher the gold content and the higher the degree of fineness (purity) of the gold recovered. Secondary pyrite also contains some gold and a number of samples of specially-selected pyrite crystals varying in size from $\frac{1}{8}$ in. to $\frac{17}{32}$ in. were assayed and found to contain 5·40 dwt./ton. The discovery of large nuggets of gold in the eluvials is a common occurrence and after heavy rains men, boys, and even women search in the gutters and alongside the dirt roads for nuggets that are often uncovered by the sudden heavy rains during May, June, and July.

Other metallic minerals occasionally found in the ore-bodies, usually when close to the intrusive younger diabase dyke in the mines in the Callao area, are galena, sphalerite, chalcopyrite, and pyrrhotite. At the Columbia mine (Mocupia), on the first level south of the dyke, considerable quantities of lodestone and tremolite were found close to the contact of the diabase with the ore-body and another crystalline, waxy, yellow mineral not yet identified.

Gangue minerals also include calcite, ankerite, hæmatite, sericite, and chlorite. Pseudomorphs of magnetite after pyrite are fairly common in the zone of oxidation at the Union and Mocupia mines.

There are no silver minerals known in this region and the amount of silver found in the gold bullion produced is with one or two exceptions extremely small. The bullion fineness varies considerably and records over the past 18 years show a range from 557 to 896 parts in one thousand, but average about 750. Generally the higher the grade of the ore the higher the degree of fineness of the bullion.

All the evidence produced so far justifies the conclusion that the auriferous ore-bodies of the greenstone complex in the State of Bolivar belong to the mesothermal class. Owing to the long period of erosion in this region the lodes do not extend far below the present surface, but the erosion of the outcrops of these quartz ore-bodies has resulted in the formation of numerous rich placers containing coarse gold.

Stratigraphy

The geological history of this auriferous region is still far from clear and unfortunately no one has yet studied in detail the rocks of the greenstone complex and the adjacent granites both in the field and in the laboratory. From field observations the following appears to have been the sequence of events :—

After a long period of erosion of the Archean complex there followed the local extrusion of andesitic lavas along the general N.E.–S.W. line of weakness of the basement granite-gneiss complex. These andesites are often calcic and also exhibit pillow structure and probably represent a subaqueous extrusion in a local basin. The occurrence of arkosic-conglomerates and calcareous-schists and shales near the base of this series also indicate the presence of lake or marine conditions at, or before, the time of the extrusion of the andesitic flows. There followed a period of deposition of calcareous tuffs and more arkosic sediments terminated by the intrusion of the older diabase in the form of an extensive sill. This was succeeded by the intrusion of the younger granites, now exposed only in the northern part of this area, between Guasipati and Ciudad Bolivar. This intrusion caused fracturing, folding, and metamorphism of the andesites and the calcareous-andesitic tuffs. As a later phase of this acid intrusion the fissures created were filled with quartz containing relatively small amounts of gold. These quartz-filled fissures are represented by the numerous outcrops of quartz in the sabanas north of Guasipati that frequently contain up to 1·5 dwt./ton of gold.

Metamorphism of the andesites resulted in their local silicification and conversion to quartzose-andesite-schists as exemplified in the Union and Sosa-Mendez mines etc. A further period of erosion was succeeded by intrusion of gabbros and dykes of diabase causing additional local metamorphism and fol .ng.

These basic igneous intrusions were succeeded by acid intrusions in the form of granite-porphyries, aplites, quartz-porphyries, pegmatites, and siliceous gold-bearing solutions. Finally there was another period of basic intrusions represented in the El Peru-Caratal mining area by the N.E.–S.W. trending diabase dyke already described and others north of the Yuruari River. In many respects this area has geological features almost identical with those of some of the gold-mining districts in North-Western Ontario and Quebec (Canada) and it is believed that the greenstone complex of the Pastora Series in which the principal Venezuelan gold deposits are located is of Pre-Cambrian age.

Notes

The following notes may be of use to those contemplating mining work in the State of Bolivar :—

(1) Exploration should be confined to the greenstone complex.

(2) Since the ore-bodies are apparently of limited depth as a result of a long period of erosion the outcrops on high hills should receive attention in preference to those in low-lying areas, other factors being equal.

(3) No single lode or vein is likely to yield a big tonnage of ore and for that reason new companies in this field should avoid ambitious programmes until sufficient development work has been done to enable a reasonable estimate to be made of the extent of the ore-body.

(4) Frequently more than one lode or vein may be found within a small radius and simultaneous prospection and development of two or three ore-bodies may radically change the outlook for a new property.

(5) Values are often much higher in the zone of oxidation than in the sulphide zone. Cases are known of values dropping from $\frac{1}{2}$ to $\frac{1}{10}$, as the zone of oxidation is left and the sulphide zone is entered, within a vertical distance of 150 ft. Such being the case development work should be extended into the sulphide zone as early as possible, especially in the smaller mines.

(6) Quartz outcrops usually contain visible or free gold but are patchy. The same applies to the majority of ore-bodies underground and close channel sampling is essential if a reliable average value is to be obtained. Professor Truscott's frequency *plus* assay method of calculating ore reserves could be usefully employed in Venezuela.

(7) Most of the lenticular ore-bodies have high gold values in the centre and diminish towards the outer limits of the lense and for that reason development work in drives should not be stopped as soon as values fall below the pay limit or the ore-body tapers to a stringer. Often if this narrow stringer, or a gouge, is followed another lense will be encountered within a relatively short distance.

(8) Because of the frequent lenticular nature of the ore-bodies and their occasional occurrence in wide shear zones small diamond drills should be used to test both the foot-walls and hanging-wall for parallel or new ore-bodies.

Gold Alluvials and Eluvials

(1) Most of the auriferous alluvial deposits worked by Venezuelan miners are of relatively small yardage and unsuited to dredging operations.

(2) The alluvial gold is generally coarse and of a high degree of purity (fineness).

(3) Large boulders are few and the beds of the streams are fairly even and the bedrock soft to medium hard.

(4) The gold alluvials near the headwaters of many of the rivers have been worked by local miners because their operations are limited to depths not exceeding 20 ft. The deeper alluvials, which exist in the lower reaches of the principal rivers and major tributaries, have in many cases never been sampled. In the region of El Dorado there are distinct possibilities of locating deposits large enough for dredging, but in the past no one has carried out a systematic sampling campaign over large areas either by pitting or Banka drilling.

(5) Eluvial deposits are common and in them are found large nuggets and coarse gold. These have been worked since pre-Columbian times and even at the present time a considerable amount of gold is produced each year from this type of deposit. In alluvial sampling possible eluvial deposits should not be overlooked.

(6) Stream gradients are generally small and the rivers follow a very serpentinous course and for that reason old terraces may exist, or the alluvial deposit extend over a much greater area than appears possible by present surface indications.

(7) Aerial photographs of these regions often disclose old river courses when they are not apparent from inspection on the ground.

Conclusion

To sum up, it may be said that of the six auriferous regions mentioned at least three—*viz.*, El Callao, Botanamo, and El Dorado—merit systematic prospection. Of these three the El Callao region, though the most favourably situated, offers only limited scope for future development in lode mining. Several very good prospects exist, but the best appear to be in the possession of the companies now operating in this region. The Botanamo area contains several lodes which might possibly supply enough commercial ore for a central mill of medium capacity. In addition there are some auriferous alluvials which merit investigation. However, the region with the greatest possibilities for development in practically virgin ground is that of El Dorado (Alto Cuyuni).

Some Details of Diamond-Drilling Equipment

By S. V. Griffith, A.C.S.M., M.Inst.M.M.

A guide to specialized machinery for the mining engineer.

Introduction

Many engineers appear to be under the impression that anything to do with diamond-drilling equipment is more or less in the nature of a closed book and therefore best left to experts to deal with. While it is true that the actual diamond-drilling operation is very skilled, the equipment used is extremely simple to anyone the least bit mechanically-minded. In the writer's experience the "swivel head" and the designation of the various sizes of rods and casings appear to be the biggest bugbears; a description of these items, together with some generalities, therefore, form the basis of this article and refer chiefly to the type of machines used in America, particularly in the Far North.

The lighter diamond drills referred to are powered by a 12-h.p. Wisconsin, 4-cylinder, air-cooled motor of the automobile type, while the heavier machines are fitted with a 30-h.p. Ford, water-cooled engine, the whole outfit being supported on an iron framework on skids for ease of transport. Power is imparted to the tail shaft by the ordinary standard car transmission, which in turn drives the main shaft by means of a quadruple chain on low-gear sprockets. The main shaft transmits power to the crown gear, which meshes with the bevel gear of the swivel head drive-sleeve.

Swivel Head or Feed-Screw Assembly

The detailed description of the operation of the feed-screw assembly which follows