45. A CONTRIBUTION to SOUTH-AMERICAN GEOLOGY. By GEORGE ATTWOOD, Esq., F.G.S., Assoc.Inst.C.E., Mem. Am. Inst. M.E. With an APPENDIX by the Rev. Prof. T. G. BONNEY, M.A., F.R.S., Sec.G.S. (Read June 25, 1879.)

[PLATE XXXIII.]

THE paper which I have the honour to present to the Society, entitled "A Contribution to South-American Geology," refers to a tract of country about 150 miles in length, commencing from a small port called Puerto de Tablas on the Orinoco river in the State of Guayana, Venezuela, and taking a south-easterly direction into the interior as far as the Caratal Gold district, as shown on the Map (Pl. XXXIII.).

Mr. Carlos Seigert, a German surveyor who has spent many years in the country, has lent me his notes in relation to the line of country I have surveyed and described; and his observations confirm the map I have compiled. The elevations marked on the section have been computed by the aneroid and mercurial barometers, and they were carefully checked by the boiling-point test made with Casella's hypsometers, as shown in the following Table (p. 583).

After landing at Puerto de Tablas and climbing up the sandbank, large exposures of weathered rock-masses are seen. It is only after a careful examination that the rock is found to be crystalline and of igneous origin. Parallel lines of alteration are so distinct and so regular on the outer surfaces that, until the weathered portions have been broken off and the unaltered rock exposed, it is not possible that a definite conclusion can be arrived at. The rock presents a highly crystalline appearance, and consists chiefly of felspar, with some quartz and a dark green mineral. It contains 64·83 per cent. silica, and 6·80 per cent. iron = protoxide 8·34 per cent., or peroxide 8·84 per cent. The rock may be called a syenite (with microcline); but until Prof. Bonney kindly examined my microscopic slides I did not feel certain on the point, especially as I found the amount of silica to be unusually large and more than is generally found in syenites.

On the south bank of the Orinoco river the syenite extends some 50 miles east of the port of Las Tablas, and about 90 miles west, as far as the city of Bolivar, near which place a granitoid rock appears, and further west a true granite.

Having left the river, "the road" * takes a south-easterly direction, and passes over about two miles of tableland, the rocks being syenitic and the same as those found at Las Tablas.

An open plain, called by the natives "sabanah," has then to be crossed, and a change in the rocks occurs. The rock is of a greyish-white colour, and consists of felspar, quartz, mica, and a little oxide of iron; it contains 71·50 per cent. silica, and 2·75 per cent. iron = peroxide 3·57 per cent.

* I call "the road" the course taken by myself from the river to the interior.

Table of Latitudes, Longitudes, and Elevations, to accompany Map and Geological Section (Pl. XXXIII.).

Name of Place.	Latitude N.	Longitude W.	Water boils, ° Fahr.	Temp. of Air.	Elevation by Barometers.	Elevation by Hyp- someter.
Chile Mine; Superintendent's House	9 11	61 56	210-05	83	feet.	feet.
Peru Mine; New Shaft	7 11	61 57	210-45	80	1020	1044
Carnal; House of Dr. Rodriguez	7 12	61 55	210-75	84	736	806
Quacipati; small town	7 21	62 01	210-95	84	625	640
Cunuri; farmhouse	7 27	62 06	210-52	91½	515	524
Platanal; farmhouse	7 33	62 08	210-20	91	...	783
Candelaria; farmhouse	7 36	62 19	210-60	78	...	961
*Carichapo del medio; farmhouse	7 39	62 22	210-38	87	...	718
La Florida; farmhouse	7 44	62 27	210-60	93	...	729
Maño Piedra; mountain-pass	7 45	62 29	209-40	90	...	868
Upata; an old Spanish town	7 52	62 34	209-85	80	...	1441
Alta Gracita; village	7 55	62 36	210-10	86	...	1165
Moyori; mountain-pass	8 04	62 35	209-64	91	...	1021
*Las Corales; farmhouse and stopping-place	8 14	62 52	211-90	83	...	1298
Puerto de Tablas; shipping-town, Orinoco river	7 14	61 56	211-00	81	...	552
Callao Mine; Office Callao Company	7 11	61 59	210-75	90	536	502
Potosi; Mining Company's office				84	625	639

* N.B.—The latitudes and longitudes of these places must be taken as approximate, owing to observations not agreeing closely.

The rock may be called a "highly felspathic granite." Leaving the sabanah, which extends about six miles in width, the tropical forest commences and continues until the town of Upata is reached.

About two miles beyond the commencement of the forest a beautiful granitoid rock, full of garnets, takes the place of the felspathic granite. It contains 48·50 per cent. silica, and 11·50 iron=peroxide 14·95 per cent. This rock is found for about 4 miles, and also near a ranch called San Juan. At the crossing of the Upata river rocks of a schistose micaceous character are met with. They are of a white colour with dark specks, and consist of quartz, felspar, and mica. These rocks are then followed to Las Corales (552 feet above sea-level, see Pl. XXXIII.), the road still winding its way through the forest.

At Las Corales a change in the rock is found, and highly felspathic granite again comes in. No change of decided character in the rock is found until the village of Alta Gracita is reached. The rock on the summit of the mountain-pass (of the mountain called Moyori) is found to contain much less mica than at the base of the mountain; but as the rock on the pass is highly weathered, no great attention was paid to the fact. The last-named pass is the highest point in elevation but one found in my section, being 1298 feet above sea-level.

About a quarter of a mile S.E. of Alta Gracita large masses of ferruginous quartzite are met with, and in places they are found to be stratified. *Hæmatite* and magnetic iron-ores of great purity occupy more than two miles in length. In places *pyrrhotite* is met with; the bronze-yellow and copper-red colour on the fresh fracture of the mineral is sufficient to distinguish between it and *pyrite* without the aid of a magnet.

Upon approaching the old Spanish town called Upata, situated on the Upata river (a stream that finds its way into the Orinoco), and 1165 feet above sea-level, a change of rock occurs. The rock is a crystalline one and consists of rather irregularly formed grains of a felspar and a greenish mineral. Prof. Bonney pronounces it to be igneous, and calls it a quartz diorite.

Continuing the journey in a south-easterly direction, the quartz diorite extends about eight miles, when a ferruginous quartzite comes in, and extends for nearly ten miles.

Some stones taken as an average sample were found to contain, by analysis, silica 50 per cent., iron 35·00 per cent.=peroxide 45·50 per cent. For several miles these deposits of *hæmatite* were found stratified, having a S.E. strike and dipping S.W. at an angle of 70°. Large masses of pure magnetic iron-ore were also found; and a large area comprising from seven to eight miles was found composed of the mixed iron-ores.

On approaching the base of the mountain called *Maño Piedra*, the quartzite contains but a small quantity of iron, and finally gives way to a belt of about half a mile in width of quartz breccia made up of very coarse angular fragments. The breccia is then replaced by a beautiful granite consisting of pink quartz, mica, and felspar.

The mountain-pass over Maño Piedra is 1441 feet in height. Granite continues for about five miles, when a dike of basalt about one mile in breadth is found on the S.E. side of the mountain. Near the base of the mountain quartz breccia is again met with, and is about two miles in width, and of a similar character to that found at the N.W. base. A schistose granite is now found consisting of white quartz, felspar, and mica. At the farmhouse of La Florida (see Map) a stratum of slate-rock of a reddish colour, moderately weathered, but much altered, crops up, having an east and west strike, and dipping nearly vertical, but having, if any thing, a slight inclination to the south. Near the above is found a large quartz vein, containing pyrite, which is often decomposed. No minerals of value have been found in it so far. Proceeding still in a S.E. direction, the rock is again found to be granite, but having a schistose character. Large veins of quartz resembling reefs are found about every half-mile, and the quartz fragments are scattered to such a great extent over the hills and valleys that travelling, even on foot or on horseback, becomes tedious as well as dangerous. The country is now more open, very few large trees are met with, and but little vegetation is seen.

Granite still continues.

Upon reaching the Carichapo river close to the farmhouse called Candelaria (see Map and section), a belt of coarse slaty rocks about one mile in thickness is found cropping out, having an E. and W. strike and a slight dip to the S. From Candelaria to a farmhouse called Platanal, a distance of about twenty-four miles, a greyish-white granite prevails, and in it are numerous quartz veins. At present none of them have been found to contain any of the precious metals.

For about one half the latter distance the road goes through the forest. Leaving Platanal (961 feet above sea-level) the greyish-white granite is still found, and continues until the farm of Cunuri is reached.

Cunuri is 783 feet above sea-level, and is distant about twelve miles from Platanal. The road has a gradual descent from the latter place over an open rolling country composed of granite, in which barren quartz veins are numerous. Near Cunuri a small belt of mica-schist is found dipping nearly vertical, and having an E. and W. strike. A small belt of gneiss is now met with. Adjoining it is a narrow belt of quartzite of a highly indurated, saccharoidal character.

From Cunuri to the old Jesuit mission village called Quacipati the same greyish-white granite is the predominant rock; but about a quarter of a mile on the N.W. side of the town granite disappears and a fine-grained gneiss takes its place. It contained silica 72.50 per cent. About one mile to the S.E. of Quacipati, granite reappears and continues to the Yuruari river. The Yuruari is one of the main branches of the Essequibo river, which empties itself into the Atlantic Ocean near Georgetown, Demerara (British Guayana). On each side of the river (Yuruari) is found a stratum of coarse slaty

rocks, highly ferruginous and much altered. The extent of the same is not over a quarter of a mile in width, and then a rock is found with a green and dullish black crystalline mineral, and carrying a small quantity of iron sulphides. It contains 51·15 per cent. silica. The specimens which I was able to collect are considerably weathered, but the characteristic features are those of gabbro. It consists of saussurite and diallage, and is sometimes coarse-grained, fine-grained, or compact. When polished it has both a slaty and a spotted appearance. Prof. Bonney states that the specimen I sent him for examination "has once been a gabbro."

Within one mile of the Potosi Company's office the gabbro gives way to a greenish-coloured rock, very compact and fine-grained, consisting of felspar, augite, and chlorite, and containing small quantities of magnetic iron, also traces of iron and copper sulphides. The rock has been called a diabase.

To show the effect of weathering and the chemical difference produced in the composition of this rock, I have had three complete analyses made from one stone; and as the three different portions analyzed show distinct lines of alteration, and as they are all from one compact stone, the results have proved of interest.

Three analyses made from one piece of diabase rock found at the Potosi Company's Mines (Spanish Guayana, Venezuela, S. A.), to show the difference in chemical composition between the portions weathered and the portion unaltered.

	Unaltered.	Weathered.	Highly Weathered.
Silica	49·57	41·77	43·46
Alumina	15·37	19·34	18·39
Peroxide of iron		13·21	20·43
Protoxide of iron	12·34	4·63	
Protoxide of manganese	traces.	traces.	traces.
Copper	traces.	traces.	traces.
Lime	9·65	4·98	2·37
Magnesia	7·41	5·01	3·46
Potash	0·85	0·69	0·59
Soda	1·99	0·83	0·14
Sulphur	trace.	trace.	trace.
Chlorine	trace.	trace.	trace.
Phosphoric acid	none.	none.	none.
Water (combined)	3·10	7·30	7·95
Water (hygroscopic)	0·17	2·55	3·39
	<hr/> 100·45	<hr/> 100·31	<hr/> 100·18

N.B. The above analyses were made at the Metallurgical Laboratory at the Royal School of Mines, Jermyn Street.

The loss of silica resulting from weathering compared with the stability of alumina shows that silica is much more liable to atmospheric action than alumina.

The iron which exists in rocks contains more oxygen when the rocks have been exposed to the atmosphere, or when they occur near the surface, than when the rocks are found some depth below the surface and sheltered from the weather. The unaltered rock contained 12·34 per cent. of protoxide of iron and no peroxide, whilst the highly weathered contained no protoxide but all peroxide.

Lime shows itself to be readily soluble, the unaltered rock having contained 9·65 per cent. of lime and the highly weathered only 2·37 per cent.

Magnesia also is proved to be readily carried away by the weathering, but not in the same ratio as the lime.

Potash and soda are very sensitive to weathering, but soda much more so than potash.

The quantity of combined as well as the hygroscopic water in the unaltered and the weathered and highly weathered portions proves that rocks contain a larger quantity of water both *combined and uncombined* when they are exposed to the atmosphere than when they are sheltered from its influences.

The diabase rock occupies a large area, and in it are found the gold-producing veins of the Caratal mining-district. The veins are very quartzose and numerous, and all contain gold; but, owing to the present high rate of wages and the great cost of procuring supplies from the Orinoco river, only eight or nine of the richest are now being worked.

The Chile vein is one of the principal ones; and it has been traced about one mile in length. It has a dip of 55° to the south, and an E. and W. strike; it averages in thickness about 4 feet, and is a true fissure vein. The yield of gold at 200 feet in depth gave between five and six ounces of standard gold to the ton (2000 lb.), whilst near the surface it only turned out about one ounce per ton. A large quantity of gold was extracted in the form of nuggets and small grains by washing in wooden bowls (*bateas*) the alluvial soil in the vicinity of the outcrops. The present yield of gold from the Caratal and Las Pastora mining-districts is about 130,000 ounces per annum; but it is rapidly increasing as the country is becoming more populated.

About 30 miles due west from Potosi a new district has lately been opened; large quantities of gold nuggets have been found close to the surface in the alluvial soil, and gold-bearing veins have been discovered near the washings. The rock is diabase and similar to that of the Caratal district.

Conclusion.—It is a remarkable fact that although quartz veins are found in great numbers all the way from the port of Las Tablas to the Caratal mining-district, yet none of them have so far been found to contain the precious metals, *i. e.* in any appreciable quantity, until the diabase is met with.

All the rocks analyzed show a higher percentage of silica than is generally found.

The independent examination made by Prof. Bonney, from *microscopical sections alone*, as to the character of the rocks agrees closely

with the observations made by myself in the field, and also with the analyses previously alluded to.

It is not improbable that many minor details are omitted in my section, considering the difficulties under which the observations were made, my sole object being to explain the general geological features of a comparatively little-known district.

Note on some Rocks from SOUTH AMERICA.

By the Rev. Prof. T. G. BONNEY, M.A., F.R.S., Sec. G.S.

1. (Near Potosi, p. 586.) This rock has been much altered. The following constituents are present:—(a) crystalline grains composed of earthy-looking granules and minute, rather fibrous microliths, showing light colour with the two Nicols, being one of the decomposition pseudomorphs after felspar, often called saussurite; (b) augite and diallage, more or less converted into hornblende and a chloritic mineral; (c) iron peroxide, probably ilmenite; (d) a little apatite. The general aspect of the saussuritic grains suggests that the felspar has been plagioclastic. Of the pyroxenic mineral the greater part is altered, being converted into hornblende with strong dichroism and very characteristic cleavage, associated with which are smaller more fibrous forms, some of which are probably varieties of hornblende, others rather more resemble chlorite. Portions of the diallage and augite remain unchanged in many of the grains; both minerals appear to be present. One or two serpentinous-looking aggregates may possibly replace olivine. We may venture to say that the rock has once been a gabbro, in which the pyroxenic constituent has been almost wholly converted into hornblende, as has not seldom happened*.

2. (Quacipati, p. 585.) The ground-mass of the rock consists chiefly of minute grains of quartz, looking as if fused together. In this are scattered many small grains of epidote and scales of mica. Of the latter there appear to be two kinds—one having its darkest tint an olive-green, rather strongly dichroic; the other nearly colourless, and showing brilliant tints with the two Nicols, rather like paragonite; indeed these two types of mica are common in the granitoid gneiss of the St. Gothard. In this ground-mass are several crystalline grains, not very clearly defined in outline, and containing the epidote and mica-granules. One or two rather resemble kyanite; but, as far as I can make out, they are only felspar, and two or three suggest plagioclase. The rock is a metamorphic one, a kind of fine-grained gneiss.

3. (Cunuri, p. 585.) Consists mainly of hornblende grains rather irregular in form, with characteristic cleavage and strong dichroism; but associated with these, and apparently partially replaced by them, is a mineral which, from absence of dichroism and general aspect, more resembles decomposing augite. There are a good many grains of quartz and some of decomposing felspar. The rock appears to be a hornblende schist with but slight traces of foliation.

* Quart. Journ. Geol. Soc. vol. xxxiii. p. 896.

Fig. 1. Map showing the Course of the Orinoco River from Barracas to the City of Bolivar and the line of section described.

by George Atwood F.G.S 1878.

Line of Section.

Fig. 2. Section from the Port of Las Tablas on the Orinoco River to the Caratal Gold District, S.A.

Horizontal Scale 6 miles 1 Inch.
Vertical Scale 1458 feet 1 Inch.