ART. XII.—*On the occurrence of Monazite as an accessory Element in Rocks;* by ORVILLE A. DERBY.

SOME five or six years ago Mr. John Gordon, an American mining engineer now engaged in commerce in Rio de Janeiro, brought to my attention a peculiar heavy yellow sand which had been sent to him from the province of Bahia under the supposition that it was tin sand. This on examination proved to be monazite with the composition, according to an analysis by Prof. Henri Gorceix of the Ouro Preto Mining School (*Comptes Rendus*, 1885): Phosphoric acid 28·7 per cent, oxide of cerium 31·3 per cent, oxides of didymium and lanthanum (?) 39·9 = 99·9. Inquiries instituted by Mr. Gordon and myself in regard to the locality and mode of occurrence of this sand revealed the fact that it occurs in considerable patches on the sea beach near the little town of Alcobaça in the southern part of the province of Bahia, where it seems to have been accumulated by natural concentration through wave action.

Attention having been thus drawn to this mineral, Prof. Gorceix has since detected yellow grains in the diamond sands of several localities of the provinces of Minas Geraes and Bahia which from giving the didymium lines in the hand spectroscope have been referred to monazite, and I have myself identified it by the same process in gold sands from several points in the provinces of Minas, Rio de Janeiro and São Paulo. The wide distribution of the mineral in the sea and river-sands of Brazil was thus established, but under circumstances that gave no clue to its origin.

Recently Mr Gordon informed me that in examining with a lens the sands of the beaches about Rio de Janeiro he found always yellow grains similar in appearance to the Bahia monazite and that on concentrating the sands in a copper miner's pan, he obtained a small quantity of white and yellow sand that

hung to the bottom of the pan behind the black iron minerals. Under the microscope the white grains show the characteristic form of zircon while the yellow ones, aside from their physical resemblance to the Bahia mineral, give like that, the didymium band in the hand spectroscope and the microchemical tests for phosphoric acid and cerium, so that their identity with monazite seems clearly established.

As gneiss is the only rock that is at all abundant about Rio de Janeiro, it was natural to suppose that the mineral so widely distributed in the sands might have come from that rock. About the same time Prince Pedro Augusto de Saxe Coburg Gotha discovered in an apatite-bearing streak of the gneiss of the Serra de Tijuca a minute yellow crystal with the physical aspect of monazite, but too small for chemical tests. This suggested the idea that, notwithstanding the small proportion of the mineral and the microscopic size of the grains, it was not altogether hopeless to look for it in the rock itself, while Mr. Gordon's method of concentration by panning was naturally suggested as the simplest and readiest mode of investigating the question. Under Mr. Gordon's instruction I soon acquired sufficient facility in the use of the pan to make a satisfactory concentration and with his aid some scores of tests have been made of the rocks in the vicinity of Rio and from about a dozen points in the provinces of Rio de Janeiro, Minas Geraes and São Paulo. Where decomposed rock was obtainable the tests were made on this by washing a quantity equal to a heaped double handful, care being taken to obtain material decomposed *in situ* and carefully freed from any extraneous wash. Where decomposed material was not at hand pieces of sound rock were ground in a mortar, a fragment the size of the fist or even smaller proving sufficient for a satisfactory test.

All the tests made on gneiss, granite and syenite have given, in addition to zircon, a greater or less quantity of microscopic crystals of a heavy yellow mineral apparently identical with the Bahia monazite. As no crystallographic study could be made, the identification has been based on the general appearance of the grains, their high specific gravity, and microchemical tests for phosphoric acid and cerium. In some few cases the yellow grains are lighter in color and duller in luster than the Bahia mineral, but as they give the phosphoric acid and cerium reactions they are presumed to represent a variety of monazite, or perhaps some other cerium-bearing phosphate. Their high specific gravity is proved by their behavior in the pan where they remain with the zircon, behind the other minerals, so that, after extracting the magnetite with a magnet, it is possible by careful manipulation to obtain these two min-

erals nearly free from titaniferous iron and garnet when these are present. The separation of the zircon is presumably favored by the minute size of the grains and by their prismatic form as it remains behind minerals as heavy or even heavier than itself when, as is generally the case, these are in larger grains. The yellow mineral, however, is frequently in as large grains as the titaniferous iron and of a similar rounded form and appears to hang back in virtue of its greater specific gravity. A few tests were made with fused chloride of lead (sp. gr. 5), which on cooling showed the yellow grains at the bottom of the ingot while the zircon and titaniferous iron were near the top. A number of the samples were tested with the hand spectroscope giving the didymium band, but owing to the difficulty of bringing together a sufficient number of such minute grains to give a perfectly satisfactory test, this means of identification was abandoned in favor of microchemical processes. All of the samples have been tested by treatment with sulphuric acid and molybdate of ammonia. In some cases crystals appeared in the sulphuric and oxalic acid solutions, along with those referred to cerium, which probably represent some other elements. It is possible that a more complete chemical and crystallogical study of the yellow grains of these residues may prove some of them to belong to minerals other than monazite, but in the impossibility of making such investigations here, they are all referred provisionally to that species. Samples of rock and residue from the granite of the Serra do Tijuca in the outskirts of Rio de Janeiro, in which the yellow grains are particularly abundant, have been placed in the hands of Prof. George H. Williams of Baltimore, in the hope that he may find them of sufficient interest to make such studies as, from the lack of appliances and the necessary training, are out of the question here.

The gneisses examined were obtained from a score or more points in and about the city of Rio, including porphyritic, granulitic and schistose varieties; from Kilometer 78 (ascent of the Serra do Mar), on the Dom Pedro II. railroad, and the station of Barra do Piraley on the same line; the station of Socego on the União Mineira railroad in the province of Minas Geraes; and the towns of Cutia, Piedade, Santos and Iguape in the province of São Paulo representing an extension of about 300 miles along the axis of the great gneiss region of the maritime group of mountains of Brazil. In every case zircon and the yellow mineral were found there, proving to be the most constant accessories since; of the ordinary accessory elements, garnet, rutile and the iron minerals, magnetite and ilmenite—the first two were frequently absent, while rarely only one of the iron minerals seemed to be pres-

ent. Rutile appears to be a comparatively rare element in these gneisses since the transparent red titaniferous grains referred to it were found only in two or three places in peculiar highly micaceous schistose layers, unusually rich in iron minerals. If, as is possible, these grains belong to some other mineral, then rutile is entirely lacking in the rocks examined. The gneiss from Socego and Cutia contains an abundance of sillimanite. All the gneisses examined belong to the class of biotite gneiss, except that from Santos which contains both muscovite and biotite and in this the yellow grains are rare in comparison with the zircon. No opportunity for examining a purely muscovite gneiss has yet been afforded. The relative proportions of zircon and the yellow mineral vary considerably in these tests, sometimes the one sometimes the other predominating. In the rock from Socego and from Kil. 78 D. Pedro II. railroad, the yellow mineral is particularly abundant.

A small number of granites have been examined with a similar result, that is to say, all of them give zircon with a heavy phosphate which in most cases appears to be identical with the Bahia monazite. The greater number of tests have been made on fine-grained biotite granites which give residues identical in appearance with those from the gneiss. The two specimens of muscovite granite examined from the station of Caieiras on the São Paulo railroad and from Sorocaba in the province of São Paulo gave a small quantity of lusterless whitish grains, quite different in appearance from those which we had become accustomed to refer to monazite, but on subjecting them to microchemical tests these also proved to be cerium-bearing phosphates. Yellow grains of the ordinary aspect are quite abundant in the small dykes of biotite granite in the gneiss about Rio and also in the larger masses of the Serra de Tijuca near Rio and at Pridade in the province of São Paulo, where Mr. Henry Bauer has kindly made a test for me. It is also abundant in uncommonly brilliant and perfect crystals in a small dyke in the gneiss of the Serra de Tingua, a peak of the Serra do Mar range near Rio. They are rare, in comparison with the zircon, in the large dykes near Campo Grande on the Santa Cruz branch of the Dom Pedro II. railroad, and near Bassa do Pirahy on the main line of the same roads, and in a small dyke at a place called Boa Vista on the Ribeira river in the Iguape region. It is interesting to note that the first two of these rocks carry cerium as a silicate in the form of orthite. The Tijuca granite is one of the richest rocks yet examined in the yellow mineral and a rough quantitative test was made on it as follows: A quantity of the rock disintegrated but not completely decomposed was dried in the sun and ground in a mortar to pass through a sieve

containing ·45 holes to the linear inch. As the decayed feldspar and mica, which may be presumed to carry the rarer and first formed minerals of this rock, went much finer than this, it was assumed that all of these were set free. From 1906 grams of the ground rock 0·557 grams or 0·029 per cent of residue consisting mainly of the yellow grains were obtained. As the small quantity of zircon and ilmenite in this residue is, probably, but little if any in excess of the loss in washing, the proportion of the yellow mineral can be safely put down as from 0·02–0·03 per cent of the entire mass of this rock.

A red syenite from the Serra do Stauba in the province of Bahia gave the yellow mineral in comparatively large grains, but these were few in number in comparison with the zircon. A mass of clay from the station of Sān Joās on the Sorocaba railroad in the province of São Paulo which is presumed to represent the syenitic rock of the vicinity, but which may be from gneiss, gave, with abundant zircons, a mineral giving the same reactions as those from the other rocks but lighter in color and duller in aspect than is usual.

The basic eruptives thus far examined, representing diabase, quartz-diorite mica-diorite and minette have afforded no trace of the yellow mineral.

It should be mentioned that in all these tests care has been taken to select samples representing the principal mass of the rock free from veins and mineral aggregates. In the course of these investigations grains which appear to represent several other rare minerals have been met with, but these have not yet been fully examined.

Since the above was written, a test has been made on a rock richer in monazite than any hitherto examined. This is a fine grained granitite exposed in a large dyke in the road from Engenho Noro to Jacarepagua in the outskirts of Rio de Janeiro. After thorough drying in the sun 3002 grams of the clay resulting from the decomposition of the rock was washed and the residue cleaned by the use of a heavy solution (sp. gr. 3·5), and of the electro-magnet. The residue weighing 2·24 grams, or 0·0746 per cent of the entire mass, consists principally of monazite in exceedingly fine grains with a small amount of zircon and a much smaller amount of other impurities that could not be completely separated without loss of material. The mixed monazite and zircon can safely be put down as 0·07 per cent of the rock.

In a recent excursion to the Argentine Republic Mr. Gordon obtained residues of zircon and monazite from the riversands at Buenos Ayres and from gneiss and granite decomposed *in situ* at Cordoba.