

III. "Notes on the Microscopic Structure of some Rocks from the Andes of Ecuador, collected by Edward Whymper, No. II. Antisana." By Professor T. G. BONNEY, D.Sc., F.R.S. Received February 29, 1884.

Antisana is a much loftier and grander mountain than Pichincha, for its summit rises to an elevation of about 19,000 feet above the sea,\* and the upper part of the mountain (some 4,000 feet) is covered with snow and glaciers. The crevasses on the latter are described by Mr. Whymper as being of an enormous size, probably the largest he had ever seen, and on his first attempt to ascend the peak he was prevented from reaching the summit by chasms and cliffs of ice, among which his party, in consequence of the mists, had become entangled. A second attempt proved successful, but the snowy summit of Antisana is evidently not one likely to be reached by unpractised mountaineers.

The mountain is situated slightly to the south of the equator, to the east-south-east of the city of Quito, and nearly due east of the town of Machachi. "The extent of ground covered by Antisana," according to Mr. Whymper, "is, perhaps, as great as that covered by any of the Ecuadorian Andes, and more than is occupied by most of them. From north to south it extends over more than 20 miles of country, and not much, if at all, less from east to west. From most points of view at a distance, the mountain in form appears more like a ridge than a single summit. A close approach on the western side shows that this appearance is somewhat misleading, and that Antisana has two principal summits, the larger and higher being an immense snowy flat-topped boss, and the second (not less than 1,500 feet lower than the other) a sharp peak, which is probably at all times completely inaccessible."

The lowest point to which the glaciers extend on the western side is 15,294 feet; on the northern and southern they descend to about the same level; but Mr. Whymper is not able to say how far they come down on the eastern side. "In that direction the most notable feature of the mountain is a very extensive shoulder running out from near the summit, at a height of about 17,000 feet above the sea, in an east-north-east direction. It is singularly level and unbroken in outline, and is entirely obscured by a snow-covered glacier, suggesting by its form that there is an old flow of lava concealed beneath.

"There is no trace of a crater anywhere near the summit upon any side, but the snow covering the flat-topped boss, forming the higher

\* Whymper, *merc. bar.*, 19,335 feet; Reiss and Stübel,  $\Delta$ , 18,885 feet. It is thus about third or fourth in order of elevation among the summits of Ecuador, being about as high as Cayambe, but lower than either Cotopaxi or Chimborazo.

point, may possibly fill and hide a crater. The diameter of the nearly level area which forms the summit is about equal to that of the lip of the crater of Cotopaxi. It is also certain that there is no open crater on any part of the western slopes of the mountain." Of the remainder Mr. Whympers says: "I speak with less confidence of the northern and southern sides, as I have not seen completely round them, and of the eastern side I can only speak of the parts not more than 1,000 feet below the summit. Upon my first and unsuccessful attempt to ascend the mountain we were stopped for a considerable time (by the difficulties encountered) at a height of somewhat more than 17,000 feet above the sea, and, whilst waiting, we noticed several puffs of strongly sulphurous vapour. We did not, however, observe either upon the summit, or when viewing it from a distance, anything of the nature of an eruption, or learn from the persons living in the vicinity of the mountain that any eruption had occurred to their knowledge."

Mr. Whympers's collection from Antisana consists, as in the case of Pichincha, of a series of ten specimens obtained in Quito, and fourteen collected by himself. Four of the latter shall be described first, as they come from the lower part of the mountain, from a spot called Antisanilla, which however is 12,340 feet above the sea. Here a *hacienda* abuts against a great lava stream which has descended from the mountain, and is the one most familiar to the natives of the district. Mr. Whympers remarks that it was the only large stream of lava which he observed on the western side of the mountain running on towards the west: "Its full extent I do not know, owing to mist. We coasted its southern side for 5 or 6 miles on the way to the Hacienda of Antisana (13,300 feet), and the small Hacienda of Antisanilla, an appendage of the large establishment, is built by the side of the lava stream, which was by various persons several times termed in my hearing the lava of Antisanilla. The surface of the stream was extremely rugged and well-nigh inaccessible."

From this lava Mr. Whympers collected specimens: the one selected for microscopic examination is a black sub-vitreous rock, containing small crystals of white felspar, whose diameter is commonly not more than 0.125 inch. The general aspect of the specimen shows it to be one of the darker varieties of andesite, a member of the group of rocks that have been variously named melaphyre, pitchstone-porphyr, &c.

The crystals belonging to the earlier stages of consolidation which are included in the slide are rather small, no one of the felspars exceeding 0.1 inch, and only one or two approaching this size. They are plagioclastic, but as the majority have broken away in grinding the slide, one cannot venture to give a more definite name. The crystals of pyroxenic minerals are yet smaller; most of the latter occurring either in small scattered crystals about 0.006 inch long, of rather

elongated form or in small granules. Owing to the smallness and rather indefinite character of the pyroxenic constituents it is difficult to speak very positively about them; augite, however, is certainly present, and possibly hypersthene. Minute crystals and grains of an iron oxide, probably magnetite, as we might expect from the colour of the rock, are rather abundant. The ground-mass appears to consist of a clear glass, faintly tinged with brown, and densely crowded with microliths. These are lath-like crystallites of felspar, generally not exceeding 0·005 inch long, not seldom composed of two or three individuals, and belonites, of a very faint green tinge, not exceeding about 0·001 inch by 0·0002 inch, probably hornblende. The evidence as to the felspar is conflicting; probably both oligoclase and labradorite are present, but my observations tend to the conclusion that the latter is the more abundant species. The rock on the whole agrees best with augite-andesite. Its specific gravity, determined for me by Mr. J. J. H. Teall, is 2·656.

A second specimen from the same locality resembles the former in structure, but is of a dull india-red colour. It is so evidently the same rock, differently coloured by conversion of the black oxide of iron into the red oxide, that I have deemed it needless to examine its microscopic structure. The two other specimens are simply scoriaceous varieties of the latter rock.

It is difficult to fix the precise localities of most of the specimens obtained by Mr. Whymper from the collector at Quito, as the places mentioned on the labels are not known to the former, and in most cases, he thinks, are of no more general acceptation than the names attached by Alpine herdsmen to the crags and pinnacles in the vicinity of their châteaux. All, he believes, are from the south-western or western side of the mountain and from localities whose height above the sea is not likely to exceed about 13,000 feet. Three are probably derived from some one subsidiary crater on the south-western flank of Antisana, named Guagra-ialina, though there is a slight variation in the spelling. The first of these is labelled *Corriente de lava de Guagrahialina volcan, Lado S.O.O. Antisana*. It is a dark grey rock, of scoriaceous aspect, with many small vesicles, usually less than 0·1 inch in diameter, and several specks of whitish felspar. It resembles some of the dark grey lavas of Auvergne, and, like them, is no doubt an augite-andesite. As the specimen presents no features of special interest, I have not examined it with the microscope. The next is simply labelled *Antisana, Guagrayalina volcan*. It is a compact dull grey rock, with a slight purplish tinge, containing occasional crystals of glassy felspar, sometimes rather more than 0·1 inch in length. These, on examination with the microscope, prove to be a plagioclastic felspar, but there is so much variation in the extinction angles that it is impossible to decide upon the species. They con-

tain, in variable amount, cavities with bubbles, brown glass enclosures, and other microliths, some being elongated prisms which may be apatite; but probably more than one mineral is present. There are also some small fairly well-defined crystals of augite, but I have not succeeded in identifying any hypersthene. A remnant of a glassy base appears to be present in the ground-mass, but it is so crowded with felspar microliths, and with granules of iron peroxide and of augite, as to be with difficulty distinguished. The felspar microliths are lath-shaped; they are a plagioclase; but, as in the case of the larger crystals, it is probable that more than one species is represented. The rock is an augite-andesite, and its general aspect reminds me of some of the porphyrites of the Cheviots (*e.g.*, a hypersthene-andesite from Coquet, near Windy Haugh). The third specimen, labelled *Guagra-ialina volcan, lado S.O. del Antisana*, is a rather duller coloured, less markedly porphyritic rock than the last, having some minute vesicles. The microscopic structure does not differ materially from that of the last described. Possibly a little hypersthene is present, but this is not conspicuous; thus the rock is an augite-andesite, and all these specimens may have come from different parts of the same flow or from a closely related series of flows.

From *Quebrada de Urcucuy* come two specimens of pitchstone. One, labelled *entre Tablarumi y Urcucuiloma*, is a dark greenish-grey rock, traversed by numerous cracks; its fracture is very irregular, and it exhibits the resinous lustre characteristic of pitchstone. A few minute scattered crystals or grains of a glassy felspar are visible, and there is a very faint indication of a fluidal structure. When examined microscopically, the rock exhibits as a base a clear and colourless glass. In this are scattered a large number of microlithic enclosures together with some scattered crystals of larger size. The general parallelism of the longer diameters of both of these, and the occasional filamentous streaks of an aggregated grey dust render the fluidal structure more conspicuous microscopically than macroscopically. The great majority of these microliths are little prisms or columns, usually about 0·001 inch long, and commonly about one-sixth of this in breadth. They are almost colourless, but appear to have a slightly green tinge. I think it probable that, like the belonites in the Arran pitchstones, to which they present some resemblance, they are hornblende. Besides these, we find opacite, with occasionally a fleck of brown mica or felspar crystals of small size. The "dusty" bands are found to resolve themselves, when viewed with a quarter-inch objective, into streams of microliths, like to, but perhaps slightly smaller in size than, those described above. Among the larger crystals are felspar: of this mineral orthoclase and a plagioclase are present. Some of the crystals are rather broken or rounded in outline, but others have well-defined external angles; the

latter are generally smaller and clearer, containing a few belonites, and but little else. The former are often "dirty," containing glass enclosures, cavities, and various microliths, as if belonging to an earlier stage of consolidation. Besides these are several crystals of brown mica and a few of hornblende, well defined, together with scattered grains of magnetite. The cracks are marked by a pale green staining, and there are no indications of a perlitic structure.

The other specimen of pitchstone labelled *entre Tablarumi y Chacana* is of nearly the same colour as the last described, but contains many rounded whitish spots, roughly about  $\frac{1}{10}$  to  $\frac{1}{8}$  inch diameter, which are seen on examination to be spherulites; a portion of the specimen is vesicular. The description given of the base of the last specimen will serve for this, except that there is little indication of a fluidal structure. There are a few scattered crystals of felspar, brown mica, and hornblende. The spherulites are rather peculiar, they have a rather irregular bluntly lobed outline, are nearly opaque, but exhibit a faintly fibrous structure, something like that of groups of blunt-pointed camel's hair brushes. So far as can be ascertained, they consist of a brown glass traversed by belonites of a paler mineral, and trichites of a darker one, but it is very difficult to determine their exact structure. They generally enclose a small crystal of hornblende or felspar, in one case both are present, but not centrally disposed. Without chemical analysis one cannot decide whether these two rocks are glassy forms of the rhyolites or of the dacites, but I should be disposed to class them with the latter.\*

A third specimen from *Quebrada de Urcucuy*, labelled in addition *Entre Tablarumi y Urcucuy*, is a crumbling pale cream-coloured rock, which, on closer examination, gives indications of having been glassy and of a somewhat perlitic structure. This is confirmed by microscopic examination, though the nature of the rock has prevented the preparation of a good slide. It is evidently a decomposed perlitic pitchstone, and very probably when in a fresh condition was nearly related to the two others from this neighbourhood.†

From the south western side is a specimen labelled *Quebrada azufre grande, S.O.* Reiss and Stübel, as Mr. Whymper informs me, mention a "*Quebrada azufre grande*," giving a measurement *Parte inferior de la Loma al lado derecho de la Quebrada, &c.*, 4,040 mètres (13,255 feet). The name signifies "Great Sulphur" ravine. This

\* Since the reading of this paper Mr. J. J. H. Teall, F.G.S., has kindly determined for me the specific gravity and silica percentage of the former of the two pitchstones. S.g.=2.337; SiO<sub>2</sub>=72.99, the loss on ignition being 1.15. These determinations fully confirm the microscopic analysis.

† A spherulitic pitchstone from Antisana is described by Vom Rath, "Verh. Nat. Ver. Preuss. Rheinl.," Folg. 4, Bd. 1; "Sitzungsb.," pp. 173, 174 (1874).

altitude is a little lower than the Hacienda of Antisana\* (13,300 feet), and so, if the indication of direction be correctly given, cannot be so near as it to the summit.

The specimen is a rather compact cream-coloured rock, at first sight not unlike one of the South Tyrol dolomites, but slightly vesicular in places, and spotted here and there with pale yellow sulphur. It is evidently a volcanic rock from the vicinity of fumaroles which deposit sulphur, and presents the usual aspect of a trachyte which has been thus treated. From the appearance of the rock, and a certain resemblance to one of those described, from Quebrada de Urcucuy, I should think it probable it had once been a pitchstone.

A specimen is labelled *Del Nevado Pic O, principio del Arenal*; the "snowy peak" and the "sandy plain" of Antisana are localities unknown to Mr. Whymper. The rock is subvitreous, dark in colour with slightly redder streaks, and numerous scattered crystals of white felspar, commonly not more than about 0.1 inch long, but now and then twice or thrice as large. In the earliest stage of consolidation are (1) plagioclase felspar (probably in part at least labradorite), sometimes irregular in external form, often crowded with glass cavities, having fixed brownish bubbles, with microliths of augite (?), and with opacite; (2) augite; (3) very characteristic crystals of hypersthene; (4) granules of iron oxide and a few scales of iron glance. The rock has a glassy base, but this is crowded with lath-shaped felspar microliths (plagioclase), and in most parts is rendered almost opaque by dusty opacite and ferrite, the redder streaks being the more transparent parts, in which a glass, now clear, now brown, may be distinguished. The rock is a hyperstheniferous augite-andesite.

The locality of the next specimen, labelled *Cuspide del Achupallas Lado O. del Antisana*, is also unknown to Mr. Whymper. The rock has a deader lustre, and more scoriaceous aspect than the last described, and contains greater crystals of whitish felspar, their diameter being sometimes fully 0.3 inch. Under the microscope the larger of these are seen to contain glass enclosures and other microliths, and are probably labradorite; the smaller, which are more lath-shaped, agree better in their extinctions with oligoclase. There is a fair amount of well characterised brown mica and of hornblende, both brown and pale green varieties, with some granules of the latter or possibly of augite, and some grains of iron oxide. There is a clear glassy base,

\* Reputed to be the highest farm in Ecuador. "It is situated on the western slopes of Antisana, in a cheerless situation, without a tree in sight, and is enveloped in fog the greater part of the year. The lower slopes of Antisana are of immense length and very devoid of character on this side. The upper 4,000 feet of the western side of Antisana is almost entirely covered by glacier. The nearest to the *hacienda* ends at an elevation of 15,295 feet." (E. W.)

but it is crowded with microliths of felspar, of a pyroxenic mineral, of brown mica, ferrite, &c. The rock is thus a mica-hornblende-andesite. The last specimen is labelled *Cuspide del chusa longo*. It is a dark grey vesicular rock, the proportion of solid to cavity being about two to one. The cavities commonly are not more than 0·2 inch in longest diameter, irregular in form, slightly drawn out in one direction, and coated with brown iron oxide. The rock is compact in structure, with a general resemblance to the matrix of the last described, but contains only very minute crystals of whitish felspar, rather irregular in form, and hardly more than 0·05 inch in diameter. It is no doubt an andesite, and is not unlike some of the scoriaceous varieties of that rock which are obtained from the Auvergne volcanoes. I have not thought it necessary to examine it with the microscope.

The remaining ten specimens brought back by Mr. Whymper are all representative of the highest part of Antisana. They were collected from the upper part of a moraine, by the side of which he encamped for the night, at an elevation of about 16,000 feet above the sea, or 3,300 below the actual summit. The materials of this moraine are derived from several rather small crags of rock which here and there crop out from the snowy slopes above. None of them were touched by Mr. Whymper during his ascent on the following day, for they are not numerous and are generally in inaccessible positions. He was careful to bring a specimen of every marked variety which caught his eye, so that the series is probably a fair representation of the rocks which constitute the Peak of Antisana.

Of these specimens (1) and (2) are vesicular rocks of a dull reddish colour, no doubt scoriaceous forms of a rock closely allied in composition to (4) and other dark varieties described below. (3) is a tuff, consisting of a fine yellowish paste, in which are numerous fragments up to the size of a small nut of a slightly vesicular, subvitreous, blackish rock, evidently closely allied to the next mentioned. (4) is a blackish subvitreous rock, containing glassy-looking felspar crystals up to about 0·2 inch diameter. A few minute vesicles are present. The microscopic description is given below. (5.) A very similar rock, a little lighter in colour, also described more fully below. (6.) Closely allied to the last, but paler, probably a little more decomposed. (7.) A dark compact rock, with some small crystals of felspar; very like the specimen from Antisanilla. (8.) A compact blackish rock, mottled with small spots of dull gray, in the inner part of which a small vesicle may be seen; a very few crystals of felspar, not exceeding 0·1 inch diameter, are visible; its microscopic structure is described below. (9.) A rather vitreous, slightly vesicular, rock, a fluidal structure being indicated by reddish and blackish layers, containing crystals of a whitish felspar, rarely exceeding 0·1 inch in diameter. The microscopic structure is described below. (10.) A large fragment

of dull reddish-gray not very vesicular scoria, probably lithologically in close alliance with (1) and (2).

The following is a description of the microscopic structure of No. (4). In the earlier stage of consolidation are (*a*) felspar crystals, probably in great part labradorite. The enclosures are frequently variable in nature, quantity, and arrangement. Sometimes their disposition is zonal and external, sometimes it is central. Among these enclosures are pale green belonites (? hornblende), colourless belonites, pieces of brown glass, often abundant, containing gas cavities and crystallites of magnetite, cavities containing bubbles, which occupy one-sixth or one-seventh of the whole space. The exteriors of the crystals are frequently broken-looking or corroded. (*b*) A pyroxenic constituent, of which some is certainly augite, but a part (the smaller) probably hypersthene. The former rather frequently contains enclosures; among them are magnetite and grains of a slightly irregular oval outline, sometimes nearly 0.003 inch diameter, occasionally associated with gas cavities (? felspar). (*c*) Grains of iron oxide, probably magnetite. The part of later consolidation is a pale brownish glass, speckled with opacite and crowded with acicular microliths, six or seven times as long as broad, which generally do not exceed 0.001 inch long. These are colourless and probably to a large extent felspar. No. (5) differs from the last rock but little in its microscopic structure; it has a rather clearer ground-mass and perhaps not quite so many granules of black iron oxide. The crystals of felspar are similar, but there is also a large number of well-formed lath-shaped crystals, measuring in longer diameter above 0.01 inch. Two varieties of augite, a greenish and a brownish, are present, together with a little of the greenish mineral which, as it has an orthorhombic extinction, I refer to hypersthene. Microscopic examination of (8) shows it to be not materially different from (4), except for the presence of the more decomposed spots, mentioned above. The glassy base is perhaps a shade more colourless. Both augite and hypersthene are present. No. (9.) In the first stage of consolidation we have rather numerous felspar crystals, with the usual variable enclosures—glass cavities with fixed bubbles, microliths, nearly all of which exhibit the characteristic twinning of plagioclase, though one or two show Carlsbad twinning and may be orthoclase. The former usually extinguish at moderately large angles, ranging from rather less than  $10^\circ$  to more than  $20^\circ$  with the twin-plane. In one, where the twinning is sharply defined, the extinctions are  $21^\circ$  and  $30^\circ$  respectively on either side of the twin-plane. It is therefore probable that these crystals are neither albite nor oligoclase. The pyroxenic constituent appears, as above, to be of more than one kind. The most abundant is a brownish, rather dichroic mineral, black bordered, and sometimes rather “dirty,” owing to inclusions. In colour and general aspect it more resembles



hornblende, but the angles of cleavage (which, however, is in no case very well defined) and of extinction make it more probable that the mineral is augite. There are two or three crystals of a slightly greenish colour, which show the characteristic form and cleavage of augite, and one which in all respects better agrees with hypersthene. The ground-mass consists of fairly numerous, lath-shaped crystallites of a plagioclastic felspar, prisms of augite (?), often darkened with ferrite, granules of opacite and ferrite, and possibly in some cases flakes of mica. These are scattered in what may be a glassy base, but it is so densely crowded with extremely minute acicular crystallites (colourless, probably felspar), and with a minute dust (ferrite in the browner streaks, opacite in the darker) that, as the slide is rather thicker than usual, I cannot be quite sure. Although, to the unaided eye, and even when examined with low powers, this rock appears to differ considerably from (5) and (8), yet with high powers the resemblance becomes much closer, so that we may, I think, confidently refer it to the same group, and regard it as merely a more slaggy variety.

It follows, then, from the above examination that the rocks which form the actual peak of Antisana are augite-andesites, containing at any rate occasionally hypersthene, and to the same group belongs, though perhaps it is slightly more basic, the rock of the great lava stream which has descended to Antisanilla, while the pitchstones of Quebrada de Urcucuy must be representatives of a group with a higher percentage of silica, *i.e.*, rhyolites or dacites, probably the former.

IV. "The Variation of Stability with Draught of Water in Ships." By F. ELGAR, Professor of Naval Architecture in the University of Glasgow. Communicated by Professor Sir WILLIAM THOMSON, F.R.S. Received March 6, 1884.

(Abstract.)

Of all the properties possessed by a ship none is more vital to her safety and efficiency than that of stability. At the same time none is dependent for its existence and amount upon so many or such diverse and variable circumstances as it. The stability of a ship, both as regards moment and range, is affected not only by the position of her centre of gravity, which largely depends upon stowage, but also by draught of water. If the centre of gravity be kept fixed in position at various draughts of water, the stability will still vary very considerably with the draught, and often in a manner that contains elements of danger.

The usual practice in investigating a ship's stability is to calculate a curve of metacentres, and one or more curves of stability at certain