TWO "BALL ANDESITES" FROM JAPAN

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TWO "BALL ANDESITES" FROM JAPAN

By

Sadakatu TANEDA

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Contents

I General Description of the "Ball Andesite"

1) A name "Ball andesite" has been given by the writer[1] to a peculiar andesite which contains many balls surrounded by cracks. Their mineralogical components are the same as those of the rest of the rock. In other words, the rock is composed of many balls and matrix, both of which are of the same andesitic character. On weathering, however, as seen in some variolites, the matrix around the balls alters first, and on further weathering, the weathered matrix falls away, the balls standing out in relief from the matrix as round projections (Fig. 1). In shape the ball is nearly spherical, though sometimes elongated or bent. Sometimes two or three of the balls gather into one, taking the form of cocoon or rosary; and others the irregular aggregates in shape of several balls are not so rarely met with (Fig. 2). The balls range in diameter from over 5 cm to microscopic, though usually from

[1] S. TANEDA; "Ball andesite" from the Ushio Gold Mine, Kagoshima pref., Jour. Geol. Soc. Japan, Vol. LN, No. 635, 1948, pp. 99-100 (in Japanese).
S. TANEDA, N. SAITO and N. KOKURU; "Ball andesite" from Ushio, South Kyushu, Japan, This Memoir, Vol. III, 1949, pp. 63-70.

3 to 1 cm. From megascopic and microscopic observations, it is certain that the balls are not such familiar things as xenolithic blocks, lithophysae, variolite, and the like already described in the literature.

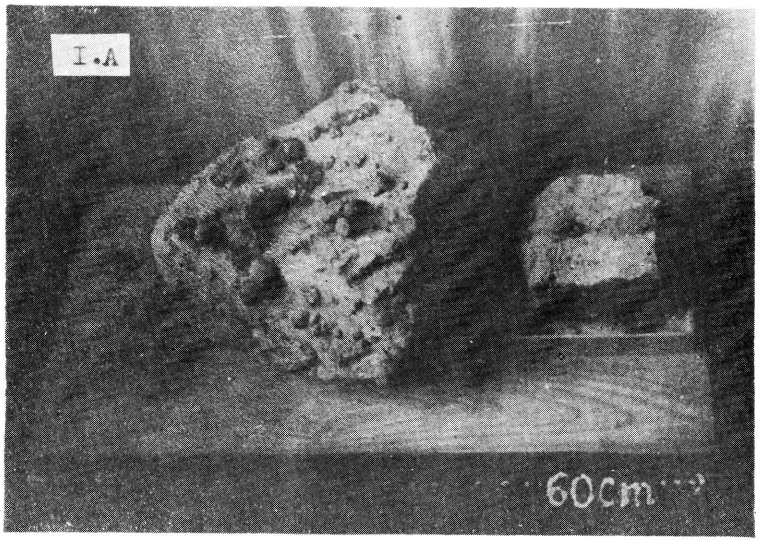


Fig. 1 (I. A)

2) Up to the present time, the ball andesites have been found from only two localities in Japan; one is the **Ushio·Fuke** Gold Mine districts, Kagoshima prefecture,[1] and the another **Himi,** Nagasaki city. In the former locality they occur as a part of lava flow alternating with tuff breccia, which is the mother rock of the gold deposits, while in the latter as a part of massive lava, which is associated with brecciated lava grading into tuff breccia, distributed extensively arouud Nagasaki city.

3) Megascopically both the ball andesites from the two localities just mentioned are almost similar in petrographic characters to each other. They are dark gray with somewhat glassy luster, carrying phenocrysts of white plagioclase (up to 5 mm in length) and sporadic black pyroxenes (usually less than 1 mm), scattering uniformly through a dark gray groundmass.

4) Under the microscope, phenocrysts are zoned plagioclase (bytownite-labradorite), augite and hypersthene with a little magnetite, while the groundmass consists of plagioclase, hypersthene, a small amount of augite, magnetite, and interstital glass.

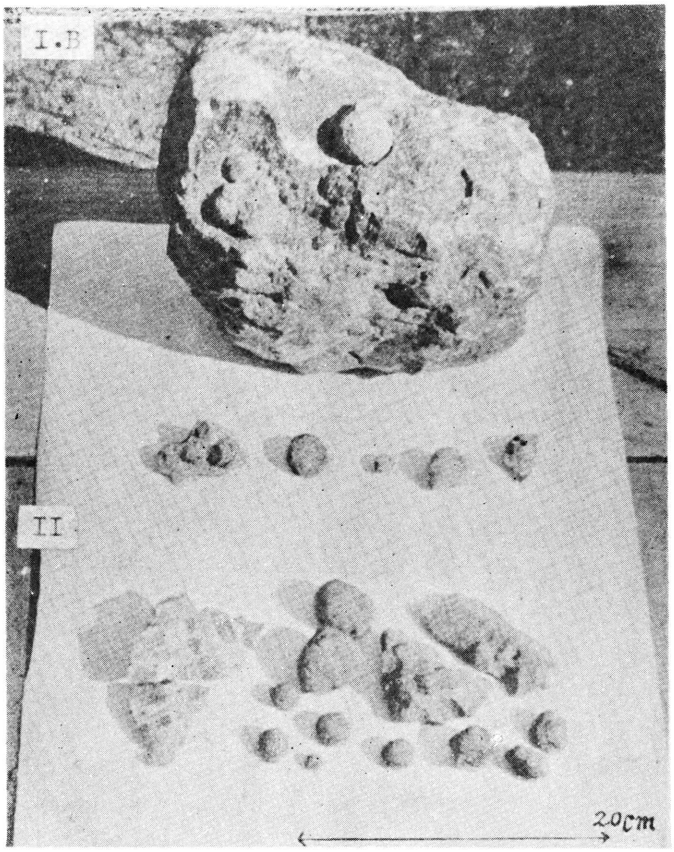


Fig. 1. (I. B & II) Photograph of the "ball andesite"

I. A & B

"Ball andesite" from Ushio, Kagoshima prefecture, Coll. & Photo. S. TANEDA

II. "Ball andesite" from Himi, Nagasaki city, Coll. & Photo. S. TANEDA

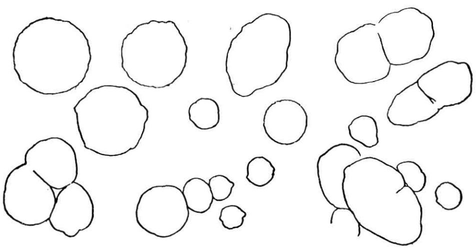


Fig. 2. Megascopical sketches of the balls

Hypersthene shows a zonal structure in both the normal and reverse types, though the latter is rather common.

The intergrowth of augite and hypersthene is not rare, the former being usually grown outside. The zoning of plagioclase is complex, usually of the prominently oscillatory type (Fig. 3).

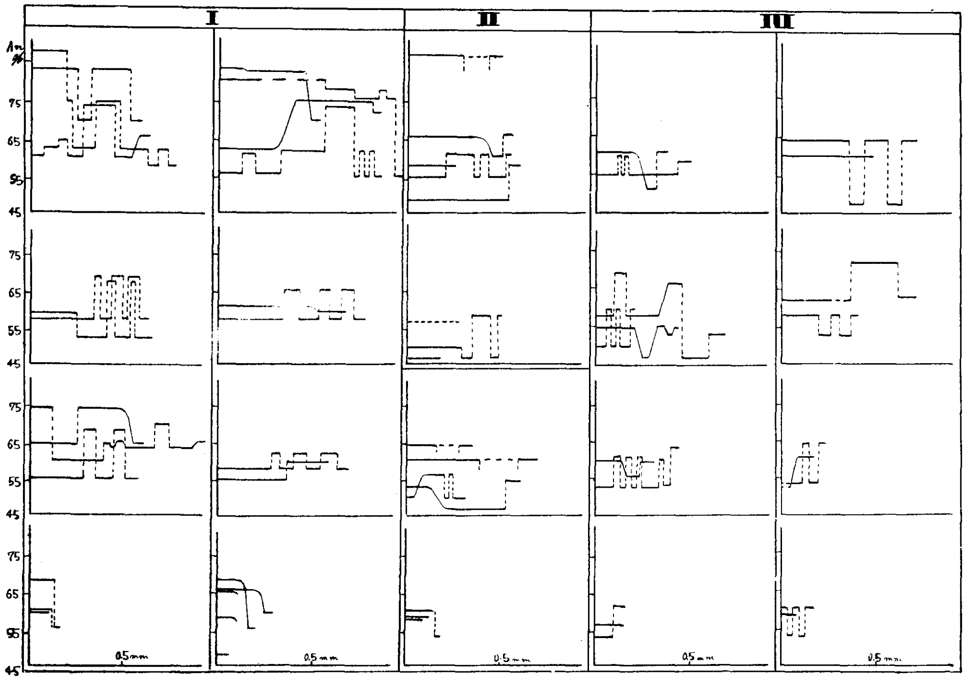


Fig. 3. Modes of variation in An content of zoned plagioclases
I. Ball andesite from Ushio, Kagoshima prefecture, Japan (No. ST. 46083001)
II. Ball andesite from Himi, Nagasaki City, Japan (No. ST. 4683011)
III. Ball andesite from Himi, Nagasaki City, Japan (No. ST. 470702)

Besides the above-mentioned minerals, are met with a few phenocrysts of olivine, and also in only one specimen from Himi phenocrysts of hornblende. The olivine phenocrysts are idiomorphic, some of which are surrounded densely by coronas consisting of granular pyroxenes associated with vermicular magnetite. The hornblende phenocrysts have been opacitized from their margin.

The petrographic characters of the ball is similar in every respects to those of the matrix, except that the groundmass glass of the ball is more or less darker in colour than that of the matrix.

The optical constants of the constituent minerals are given in Tables I A, I B, II and III. As will be seen from the Tables, the modes of zoning of plagioclase and of hypersthene are highly remarked (see also Fig. 3), and the relation in the optical properties and chemical compositions between phenocrysts and the groundmass minerals is significant.*

Table I

Ball andesite from Ushio, Kagoshima Prefecture

(Sample No. 46083001)

(Two-Pyroxene-andesite)

A Matrix

	Phenocryst	Micro-phenocryst	Groundmass
Plagioclase	An 84~55 Zonal structure (ref. Fig. 3)		69-49
	(−) 2V: 56°, 57°, 59°, 59°, 60°,	64°, 64°, 63°,	66°, 68°, 69°,
	61°, 61°, 62°, 66°, 66.5°,		77°, 78°,
Rhombic	68°, 70°,		
Pyroxene	av: 62° (Fs 37.5)	av: 64°	av: 72° (Fs 26.6)
	58° (core) − 68° (margin)		
$\rho > v$	56° 〃 − 65° 〃	(aggregates	
	57° 〃 − 74° 〃	63°, 62.5°,	
	58° 〃 − 69° 〃	62°, 59°,)	
	59° 〃 − 68° 〃		
	60° 〃 − 66° 〃		
	60° 〃 − 69° 〃		
	60° 〃 − 71° 〃		
	av: 59° − 69°		
	β: 1.693 − 1.705 $\pm$ 0.002		
	Fs 32 − 45.5 $\pm$ 0.002		

* Judging from the observed facts hitherto described and other facts that will be pointed out in later sections (II & III), the ball andesites should be considered as the representative of a lava comparatively rich in volatile matters (ref. S. TANEDA; Petrological Studies on the Volcanic Rocks from Japan with Special Reference to the Hornblende Andesite, this Memoir, Vol. II, 1947, pp. 19-62).

Monoclinic Pyroxene $\rho>\nu$	(+) 2V: 46°, 47°, 47°, 48°, 48.5°, 49°, 49°, 49°, 50°, 53°, av: 49° β: 1.7049±0.002 Wo 34.5 En 39 Fs 26.5	(aggregates 51°, 44°,) 51°,	few n. d.

Table I B Ball

	Phenocryst	Micro-Phenocryst	Groundmass
Plagioclase	An 88.5～53 Zonal structure (ref. Fig. 3)		69～56
Rhombic Pyroxene $\rho>\nu$	(−) 2V: 57°, 57°, 57.5°, 58°, 58°, 59°, 59°, 60°, 60°, 61°, 62°, 62°, 63°, 64°, 64°, 66°, 66°, 69°, 76°, av: 62° (Fe 37.5) 58° (core)−68° (margin) 61° 〃 −70° 〃 62° 〃 −76° 〃 60° 〃 −68° 〃 av: 60° 〃 −71° 〃 64° 〃 −56° 〃 β: 1.693—1.705±0.002 Fs 32—45.5±0.002	65°, 66°, 66°, 68°, av: 66°	67°, 70°, 78°, av: 72° (Fs 26.6)
Monoclinic Pyroxene $\rho>\nu$	(+) 2V: 45°, 47°, 48°, 48°, 49°, 50°, 50°, 52°, av: 49° 43° (core)−48° (margin) 50° 〃 −45° 〃 β: 1.703 0.002 Wo 34.5 En 39 Fs 26.5	augite	few n. d.

Table II

Ball andesite From Himi, Nagasaki city (Sample No. 4683011)
(Olivine-bearing two Pyroxene andesite)

		Phenocryst	Micro-Phenocryst	Groundmass
Matrix	Plagioclase	An 60～47 Zonal structute (ref. Fig. 3)	58±	n. d.
	Rhombic Pyroxene $\rho>\nu$	(−) 2V: 58°, 59°, 59°, 60°, 60°, 60.5°, 91°, 60° (core) − 70° (margin) Suddenly 61.5° (core) − 57° (margin) Graduating 61° (core) − 55° (margin) Graduating	56°, 58°, 61.5°,	65°, 67°,
	Monoclinic Pyroxene $\rho>\nu$	(+) 2V: 48°, 50°,	augite	few ?
		Olivine		
Ball	Plagioclase	An 58～48.5 Zonal structure (ref. Fig. 3)	64～47	n. d.
	Rhombic Pyroxene $\rho>\nu$	(−) 2V: 57°, 58°, 60°, 60°, 61°, 61°, 61.5°, 62°, Zoned crystals n. d.,	59°, 61°, 67°, aggregnte augite 58°, 60°, 62°,	63°, 64°, 64°≦, 64°,
	Monoclinic Pyroxene $\rho>\nu$	(−) 2V: 48,5°,	augite	few ?
		Olivine		

Table III

Ball andesite from Himi, Nagasaki city (Sample No. 470702)
(Olivine-and Hornblende-bearing two pyroxene andesite)

		Phenocryst	Micro-Phenocryst	Groundmass
Matrix	Plagioclase	An 72−47 Zonal structure (ref. Fig. 3)	60−53	60−53
Matrix	Rhombic Pyroxene $\rho > \nu$	(−) 2V : 57.5°, 59.5°, 60°, 61°, 63°, 54° (core)−59° (margin) 57° (core)−61° (margin) 58° (core)−55° (margin)	60°, 63°,	62°, 64° ≦,
Matrix	Monoclinic Pyroxene $\sigma > \nu$	(−) 2V : 48°, 51°,	augite	few ?
Matrix		Olivine Hornblende		
Ball	Plagioclase	An 68−47 Zonal structure (ref. Fig. 3)	61−53	n. d.
Ball	Rhombic Pyroxene	(−) 2V : 55.5°, 57°, 57.5°,		
Ball	Pyroxene $\rho > \nu$	57.5°, 58.5°, 53° (core)−58° (margin) 57° (core)−54° (margin)	n. d.	n. d.
Ball	Monclinic Pyroxene $\rho > \nu$	(−) 2V : 47.5°, 49°, 49°,	augite	few ?
Ball		Hornblende Olivine		

II Some Microscopic Features

In thin sections are observed some remarkable features which will be briefly noted as follows:

1) Shape of the ball: The shape of the ball is neither a simple sphere nor an ellipsoid, but its surface is uneven or wavy due to abundant minute depression in juxtaposition, making apexes among them, and at places these apexes are stout enough to show outward convexity (Figs. 4, 5, and 6).

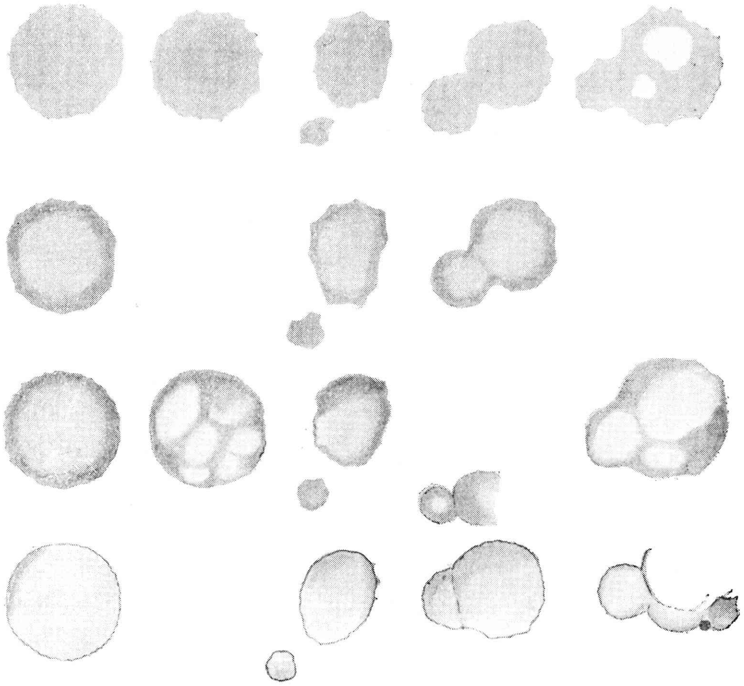


Fig. 4. Schematic sketches showing the shape and the depth of colour of the balls, the latter due to the dark glass of the groundmass.

The lowest balls, surrounded by the brown film, may represent the crack filled up with brown material (cross section)

2) Boundary between the ball and the matrix: The boundary is sometimes clear without any filling substances, but sometimes it is seen as a crack runs across a single crystal—this crystal lies in part in the ball and in part in the matrix.

Since the groundmass glass of the ball, as already mentioned

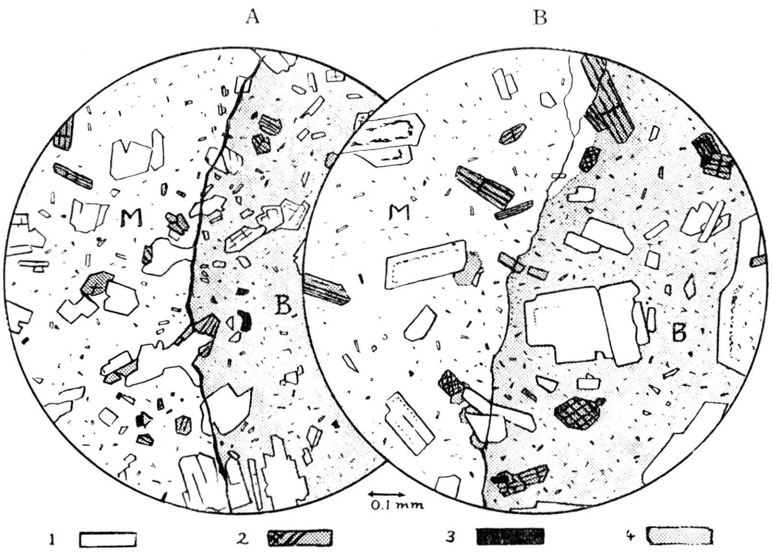


Fig. 5. Microscopic sketches of the ball-andesite, especially showing the features along the boundary between ball (B) and matix (M)
1. Plagioclase 2. Pyroxene 3. Magnetite
4. Dark area in the matrix (M)

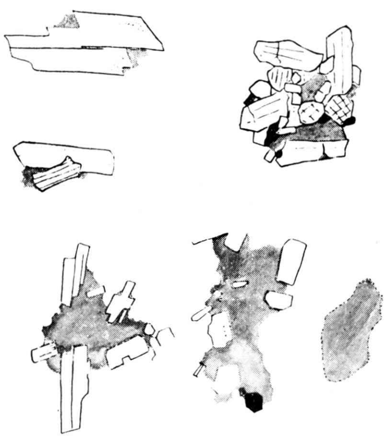


Fig. 6. Microscopic sketches of the dark patches

(I. 4), is more or less darker in colour than that of the matrix, the ball may be called a "dark body". Strictly speaking, the cracks around the balls do not completely surround the entire "dark body" (Fig. 5 B).

3) Depth of colour of the ball: The colour of the ball is due to the presence of the dark glass in the groundmass. In the case where the boundary between the ball and the matrix is shown as a crack filled up with brown materials, the colour of the groundmass glass of the ball is not so dark as in the case where the boundary is clear.

In some instances the depth of colour is not uniform even in a single ball. Sometimes the centre is lighter while the margin darker, the change being gradual in usual. In cases a single ball contains two or more light coloured centres.

The schematic sketches showing the shape and the depth of colour of the ball are shown in Fig. 4.

4) Texture: In texture the ball and the matrix are uniform and continuous, that is the fluidal arrangement of the constituent minerals is neither disturbed nor cut at the periphery of the ball, but continuous throughout both the ball and the matrix. There are many crystals (phenocrysts, microphenocrysts, and crystals of the groundmass) which are laid across the boundary (Fig. 5 B).

5) Dark patches in the matrix: In the matrix, not uncommonly are found small patches where the groundmass glass is darker in colour. Though they are apparently irregular in shape, their outlines are composed of many little inward convex surfaces as seen in the outline of the ball. It should be noted that these patches develop at the indented parts of a crystal or of crystal aggregates (Fig. 6).

Such dark patches may be the embryos of the balls, either perfect or imperfect in shape.

III Chemical Characteristics

The chemical analyses of the ball andesite from Ushio, Kagoshima prefecture, were performed in the Chemical Laboratory of the Asahi Kasei Co., Nobeoka city, and in the Chemical Department, Kyushu University. The results are given in Table IV.* From the results we can see the following characteristics:

1) So far as the main constituents are concerned, the ball andesite belongs to the ordinary, but not abnormal, variety of andesite from Japan.

* S. Taneda, N. Saito and N. Kokubu; loc. cit.

Table IV
Chemical Composition*

	(1)	(2)	(3)
SiO_2	58.60%	57.18%	58.44%
Al_2O_3	19.68	17.04	18.94
Fe_2O_3	4.89	6.64	4.17
FeO	3.01	2.92	3.50
MgO	3.96	4.13	4.10
CaO	5.78	6.33	6.06
Na_2O	2.90	1.75	2.31
K_2O	2.08	0.17	2.18
$H_2O(+)$	n. d.	1.00	n. d.
$H_2O(-)$	n. d.	1.19	n. d.
TiO_2	n. d.	0.49	n. d.
Cl	0.16	1.98	0.52
NH_3(as N)	0.0033	0.0064	0.0026
	101.06	100.82	101.22
$-O=Cl$	0 07	0.89	0.23
Total	100.99%	99.93%	100.99%

(1) ball
(2) brown material at the boundary
containing a part of (1) and (2) as impurities
(3) matrix

The main chemical constituents of (1) and (3) were determined in the chemical Laboratory of the Asahi Kasei Co., Nobeoka city, Japan

* cited from the writer's previous paper (This Memoirs, vol. III, No. 2, 1949, p. 67)

2) With regard to their main constituents in particular, the three different facies—the ball, matrix and brown material filling up the crack between the ball and the matrix—show no remarkable difference, although such ratios as Fe_2O_3/FeO and Na_2O/K_2O are somewhat higher in the brown material.

3) As for the minor constituents, however, it is clear that

several components such as chlorine and ammonia are highly concentrated in the brown material. This high concentration of volatile matters in the brown materials seems to be very suggestive for the formation of the ball.

IV Origin of the Balls

The characteristic features of the ball andesites so far described lead the writer to make the following conclusive remarks as to the origin of the balls:

1) It is thought that the ball andesite was derived from a magma relatively rich in the volatile matters, though the rock is not unusual with regard to the main chemical constituents.

2) The peculiar ball structure may be the characteristic feature of a lava, representing the action of volatile matters.

3) Though the process of the formation of the peculiar structure is entirely unknown at present, it is postulated that the volatile matters might have become more and more active as the crystallization of the magma advanced; and that, when the crystallization of the groundmass which started at numerous points and advanced in all directions, the volatile matters which remained in the magma without entering into the early crystallizing minerals might have been pushed aside, gathering toward some certain parts favourable for their concentration—especially favourable parts were the indented parts of a crystal or of crystal aggregates.

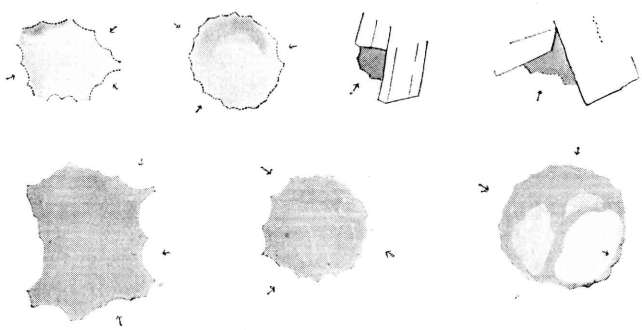


Fig. 7. Diagramins explaining the manner of concentration of volatile matters

Now such an area where the volatile matters were concentrated in a way just mentioned will be called the "accumulator of volatile matters" or in short "accumulator" (Fig. 7). The "accumulator" is more or less darker in colour than the rest owing to the abundance of the extremely minute, dusty iron ores and others, which might have been transported by gaseous transfer. Under some condition, though still difficult to explain, the "accumlator" might have a tendency to take the shape of sphere. In places, the centres of crystallization might have been enclosed in such "accumulator", within which on the other hand new centres sprung up, making varied forms of the "accumulator" as shown in Fig. 4. In such cases, it may be possible to take the shape composed of many little spherical, outward convex surfaces (Figs. 7 and 4).

At a certain, perhaps the latest, stage the crack took place, nearly enveloping the "accumulator". Even at such latest stage the volatile constituents will emit to the crack to concentrate there, if they are active. Thus the formation of ball andesite was completed.

In conclusion it is thought that one of the necessary conditions, though still precisely unknown, may be a sufficiently quiet state of effusive magma during its latest stage of consolidation.

V Appendix: On the "Striped pattern" in Volcanic Rocks

During the investigation of the "ball andesite", was found an interesting specimen concerning what has been known as "streak"

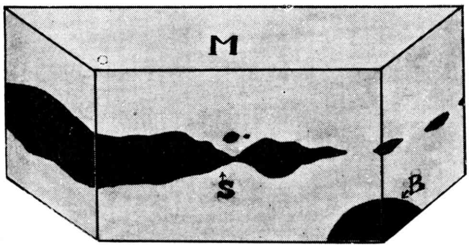


Fig. 8. Schematic sketch showing the shape of a dark streak in the two pyroxene andesite from Ushio
Black: S streak, B ball Gray (M): matrix

in volcanic rocks. Near the ball andesite locality at Ushio was found one block of two-pyroxene andesite which has an interesting "striped pattern" (minute banded structure) along with several balls as shown in Fig. 8. The dark streak varies in width, swelling and shrinking alternately; and at its end it passes into a row of balls. The balls in such a row, with somewhat varied diame-

Table V

Andesite with a dark streak from Ushio

		Phenocryst	Micro-Phenocryst	Groundmass
Rest	Rhombic Pyroxene $\rho > \nu$	(−)2V: 52°, 53°, 57°, 58°, 58°, 58.5°, 58.5°, 59°, 59°, 60°, 60°, 62°, 62°, 64°, 65°, av: 59° (Fs 42.5)	58°, 61°, 65°, av: 62° (Fs 37.5)	
	Monoclinic Pyroxene $\rho > \nu$	(+)2V: 49°, 48°, 50°, 51°, av: 50°,		Pigeonite & Pigeonitic augite
	Plagioclase	An 89—50.5— (±5) Zonal structure (ref. Fig. 9)		60—(±5)
Dark Streak	Rhombic Pyroxene $\rho > \nu$	(−)2V: 52°, 58°, 58°, 58°, 58.5°, 59°, 59°, 59°, 59.5°, 61°, 62°, av: 59°. (Fs 42.5)	61≦°, 62°, 63°, 63°, 64°, av: 62° (Fs 37.5) 64°(incl. of pl.)	
	Monoclinic Pyroxene $\rho > \nu$	(+)2V: 47°, 47.5°, 49°, 50°, 50°, 51°, 52°, 52°, av: 50°. 46.5° (core)—54° (margin)		Pigeonite & Pigeonitic augite
	Plagioclase	An 89—47 (±5) Zonal structure (ref. Fig. 9)		

ter, are elongated at first in the direction of the streak, but by and by approach in shape a sphere.

Under the microscope the surface of the streak is found to be composed of many minute spherical surfaces, in the same manner as seen in the ball already mentioned.

The dark streak and the other part are of nearly the same petrographic character, except the depth of colour of the groundmass: the former is darker than the latter. The optical constants of the principal constituent minerals are given in Table V and the variation in An component of zoned plagioclase is shown in Fig. 9.

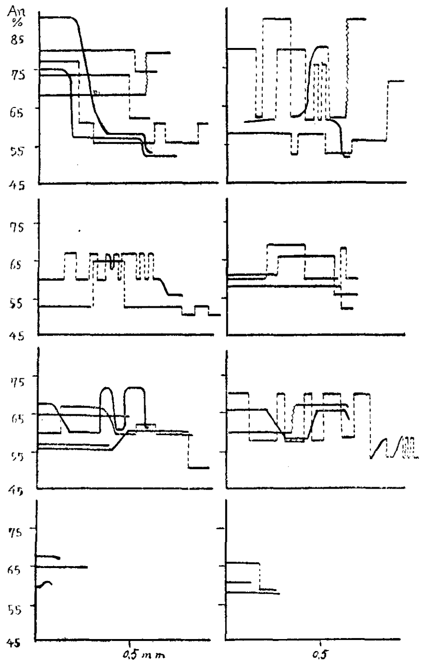
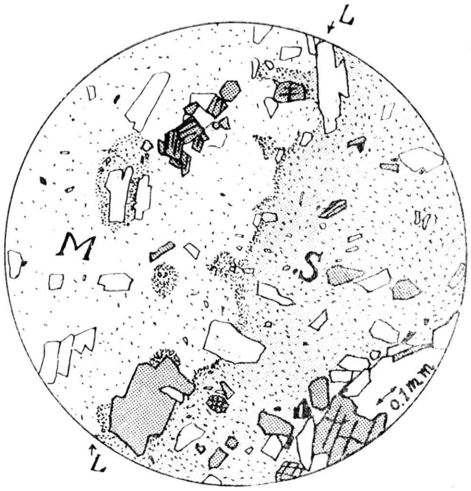


Fig. 9. Mode of variation in An content of zoned plagioclase in the dark streak (Right) and Matrix (Left)

Generally speaking, it may be well to mention that these characters of the streak are so conspicuously alike those of the ball near the streak that the characteristic features of the "striped andesite" should be comparable with those of the "ball andesite". Thus the streak in question may be a variety of the "accumulator of volatile matters"; and at least some, though not all, of the "striped pattern" which are not uncommonly met with in volcanic rocks might be produced in a way appreciably like that of the ball andesite, although it is not always asserted.



plagioclase
pyroxene
magnetite

S dark streak
M matrix

Fig. 10. Microgram showing the boundary (L L) of the streak (S) and the matrix (M).

At present it cannot be decided whether (1) any one of the ball and streak is produced first and changed later to another, or (2) both of them are produced almost simultaneously under some different conditions in the same cooling magma; but it may be also possible that both (1) and (2) will happen in some instances.

Fugitive Matters at the Deuteric Stage of Magma

The characteristic of the brown matterial at the boundary between the ball and matrix in chemical composition, that several components such as chlorine and ammonia are highly concentrated and such ratios as Fe_2O_3/FeO, Na_2O/K_2O are higher, may be very suggestive for the study of the fugitive matters at the deuteric stage of magma.

Acknowledgement

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