Characteristics of the Activity and the Peculiar Product "SARA-ISI" of the Aso Volcano

By Munetosi Namba

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Abstract

There is a curious stone called "SARA-ISI" among the products from the Volcano Aso. A typical Sara-isi is a somewhat flat rock fragment, the margin of which is rimmed by a projection just like the margin of a dish. Hitherto, the origin of the rim was attributed to the impulsive action which took place when a plastic magma or new magma covered a pre-existing rock dashed against the ash field.

The writer made many year's investigation of the place and manner of existense and the construction of Sara-isi. The results are as follows:—

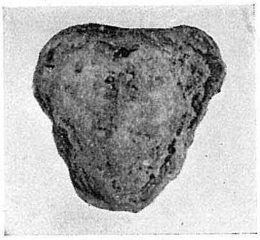
1. The writer discriminated the upper and lower sides of a Sara-isi reasonably.
2. About the genesis of Sara-isi, the writer was obliged to modify previous illustrations, and arrived at the conclusion that the rim of a Sara-isi is a secondary or posterior product which is always growing, and that it is not produced accidentally by the volcanic outburst.
3. The alternative eruptions and states of hot water pool being constantly repeated in the case of Aso account for the special production of Sara-isi. The writer calls shortly such a volcanic activity as "Aso-type."
4. The Naka-dake craters have continued their actions of Aso-type since prehistorical time. Kisima-dake made also the Aso-type volcanic activity in pre-historic ages, and this volcano is younger than volcano Ô-jo-dake.

§ 1. Introduction

Among the various products from volcano Aso, there is a curious kind of stones called "Sara-isi" (meaning dish-stone). Sara-isi is a somewhat flat rock fragment. It was named "Lava-cake" by Prof. Dr. T. Hiki on 1914[1] and commonly has a plate-like suspension along its margin as the eaves of a house, but sometimes two or more parallel suspensions are often produced. These suspensions are commonly called "the rim of Sara-isi" (Fig. 1, 2, 3, 4, 5, 6). Since we have no report about ejecta like Sara-isi except from Aso, we may say surely that they might not exist in other places in Japan and likely not in other countries. If this is so, then this peculiar production of Sara-isi must correspond to the characteristics of the activity of Aso-volcano, and the study of Sara-isi must surely become a key to the

1. Catalogue of Minerals and Rocks from Shimadzu Seisaku-sho Ltd. 1914.

Fig. 1. Sara-isi with one rim.



Lower-side

Upper-side

Fig. 3. Sara-isi of flat type.

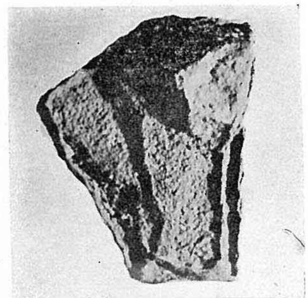
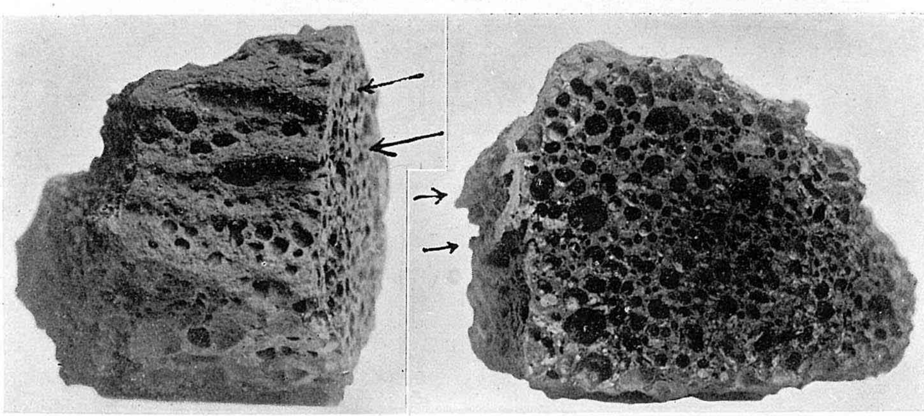


Fig. 2. Sara-isi with two rims.



Side Section

Fig. 4. Sara-isi of irregular type.

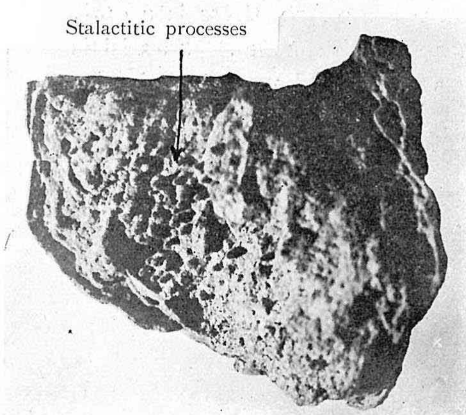
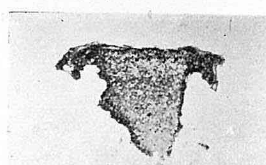
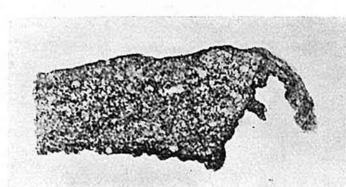


Fig. 5. Sections.

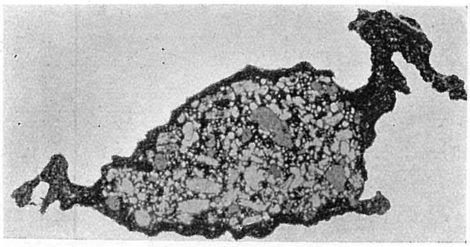


with one rim

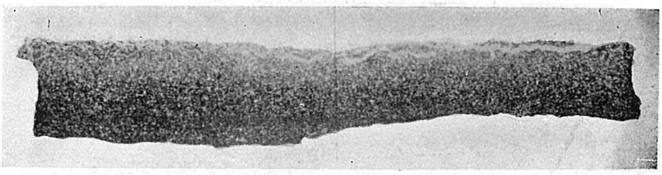


with two rims

Fig. 6. Sections.



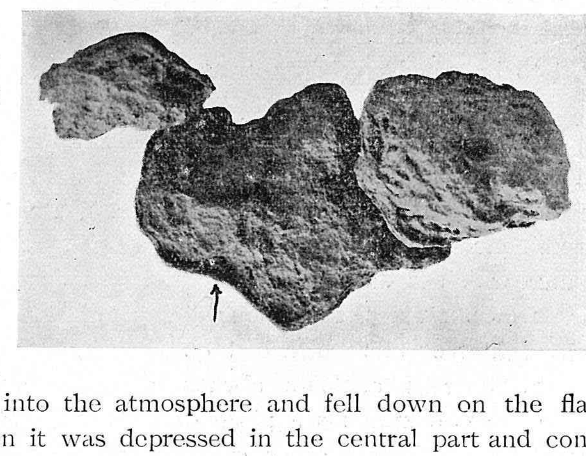
Irregular Sara-isi



Flat Sara-isi

elucidation of the peculiarity of the volcanic activity of Aso. Sara-isi was heretofore collected only at Sara-yama, a part of the ancient encircling crater-rim of Naka-dake (the only one active central cone among the great Aso cones), but the writer, prospecting for several years, discovered Sara-isi not only around the ancient crater of Naka-dake (north, west and south parts), but also in the neighbourhood of the Kisima-dake crater and especially at Ô-jo-dake (both are the central cones of Aso). (Fig. 7, 8, 9). It is generally described in the Japanese text books of geology as a curious kind of volcanic bomb or lapilli.

Fig. 7. Sara-isi from Ô-jo-dake.



Heretofore published opinions about the method of production of Sara-isi may be summarized as follows:—

Mr. Sato[1] and Mr. Igi[2] say that Sara-isi is a volcanic ejectamenta. Some magma once were hurled up into the atmosphere and fell down on the flat and soft ash-field, then it was depressed in the central part and contrarily bent upwards at its margin so that a flat dish-like block of

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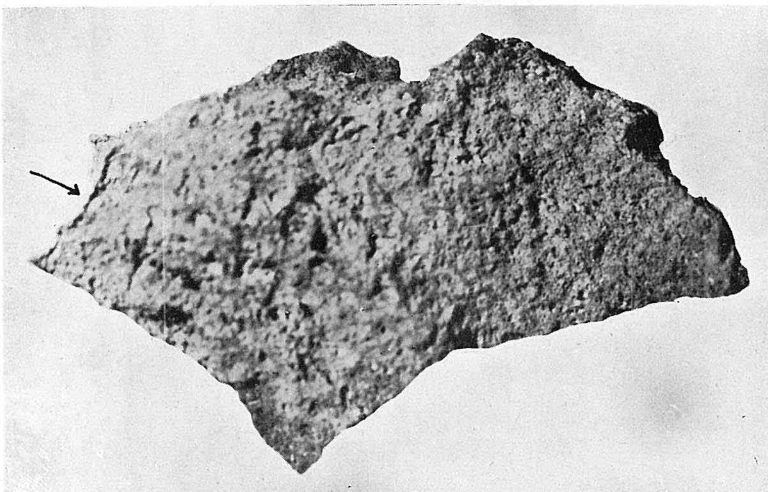
1. 佐藤傳藏:—阿蘇山の皿石, 地質學雜誌 **2**, 356 (1895).
2. 伊木常誠:—阿蘇火山調査報文, 震災豫防調査會報告 **33**, 77 (1901).

lava (Sara-isi) was then formed. Examining its section, therefore, it may be understood that near the surface its structure is compact and rather more homogeneous to the naked eyes than the inner part which is rather roughly granulated . . . . . . etc.

In spite of such illustrations, any one who examines many Sara-isi carefully, will at once find that the central part is not always the

Fig. 8. Sara-isi from Kisima-dake.



newly erupted magma block, but is often the pre-existing rock fragment. This fact shows that some main bodies of Sara-isi cannot be said to be conclusively illustrated in the above mentioned way.

In the next place, Prof. Z. Harada[1] gave his opinion as follows :—

1. The upper surface of each block (he means the outside of the dish in the popular sense) is rough and ragged, while the lower inside of the dish is compact and smooth, and has many wart-like low prominences just like those on the upper surface of a semisolid substance which is dashed on a floor. . . . .

2. Sometimes, the colour differs in different parts of one block, e. g. lighter or more bleached on the upper side than on the lower.

3. Sara-isi encloses always a foreign rock-material, and the enclosure is sometimes a piece of pre-existing rock, in other cases a lapillii ; while in still other cases a fragment of tuff or a lump of

1. Z. Harada :—" Sara-isi " or Dish-Stone of the Volcano-ASO. Proc. of Imp. Academy **3** 539 (1927). 原田準平 :—阿蘇之皿石, 地質學雜誌 **39**, 736 (1927).

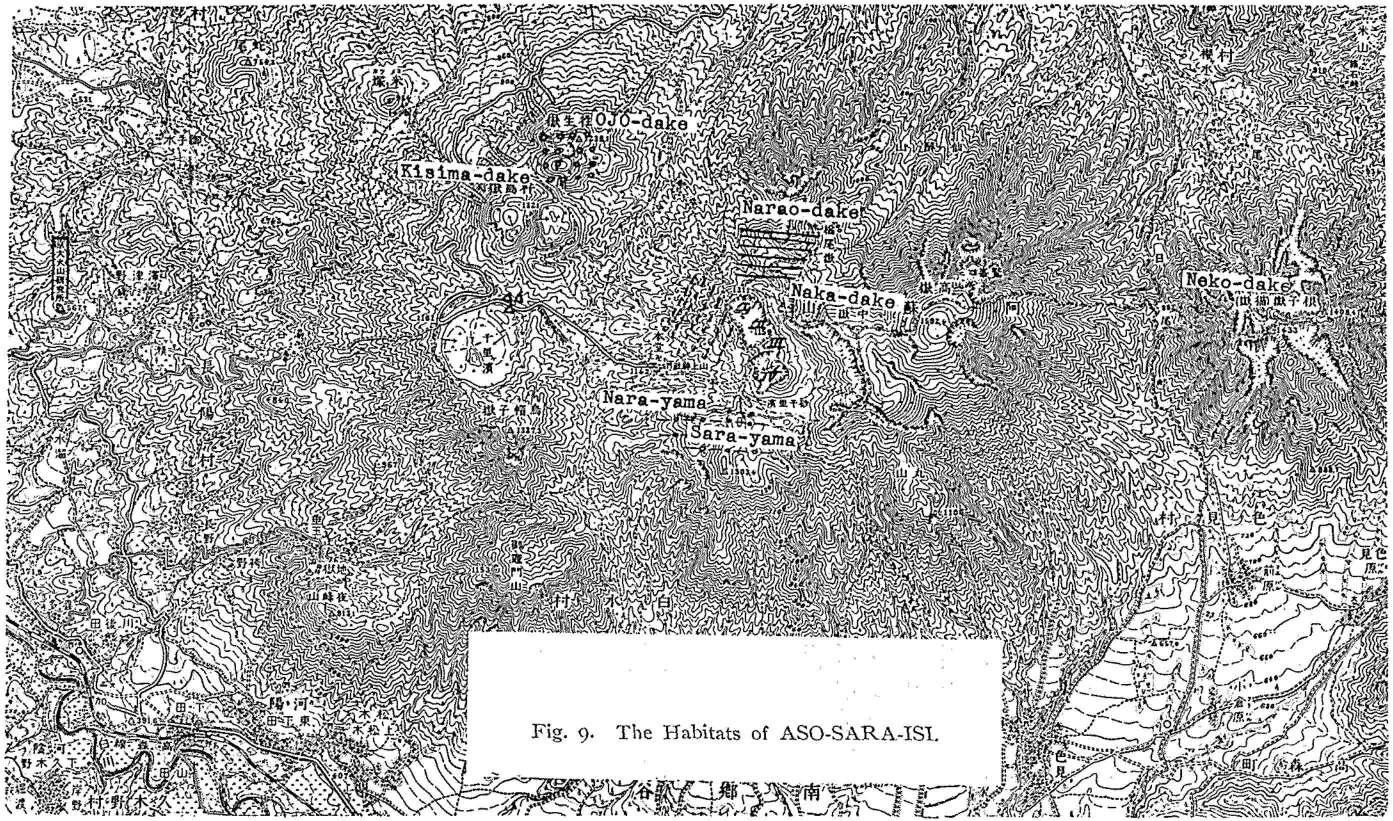


Fig. 9. The Habitats of ASO-SARA-ISI.

volcanic ash. The crust of Sara-isi is thin, usually less than 1 m.m. in thickness, and can be easily taken off in some cases.

4. The crust is thicker on the lower side of each block than on the upper. Some lumps of volcanic ash have the crusts only on the lower side.

5. The rim at the margin of the crust of each block is mostly upward projecting, while sometimes it is projecting on both the upper and lower sides; in other cases it is irregular and discontinuous, and in still other cases the rim turns in the opposite directions at the opposite ends.

6. The crust of Sara-isi is black or dark gray and aphanitic. Under the microscope, it is partly vitreous with a fluxion texture, showing flow-bands around the core, and partly of a vitroclastic tufaceous character, composed of fragmented pieces of pyroxenes and calcic plagioclases with a small quantity of cusp-shaped glass and corroded rock fragments, cemented by brown basic glass.

7. The above facts show that the crust of Sara-isi was formed by mingling of fluidal lava material with fine volcanic ashes, i. e. the crust is made of ash-soaked lava, and that the enclosed blocks of Sara-isi are fragments of pre-existing rocks or lapilli.

8. And a portion of the volcanic vent was disturbed and shattered by explosive action; and disrupted rock fragments thus formed as well as the surfacial volcanic fragmental materials became coated with newly erupted lava mingled with ashes; they were then thrown out and dashed against the surface of the ash-field upon falling. The lava coating on each block was then still in a semifluid state, so that the upward-projecting rim of the crust was produced by the impact action. . . . .

9. But the heat effects on the core rock-fragments are slight. There is, however, no sign of fusion of the enclosure. . . . . . .

Prof. T. Matsumoto,[1] too, seems to adopt No. 7 among the above illustrations. Prof. Harada proceeds further[2]: we can in some measure imagine the volcanic activity of that time by means of the extreme fluidity of the crust lava which perhaps became temporally very great due to some actions during the crystallisation of magma, and by this occasion Sara-isi was then probably produced *extremely accidentally*. . . . .

1. 松本唯一:—大阿蘇の新研究 (1932) p. 36.
2. 原田準平:—或種の火山抛出物と火山活動に就て, 地質學雜誌 34, 208 (1927).

Undoubtedly it can be said that he made a step of progress in the research of Sara-isi, yet his illustrations about the method of formation are not much different from those of Prof. Sato and Igi. One assumes the whole body of Sara-isi being in a plastic state just before falling on the field, and the other assumes the crust only being in a plastic state while its core being the pre-existing rock material. Both adopt in the same manner that a piece of semi-plastic magma falls on the ash field and its margin will be lifted mechanically due to its impact with the ground.

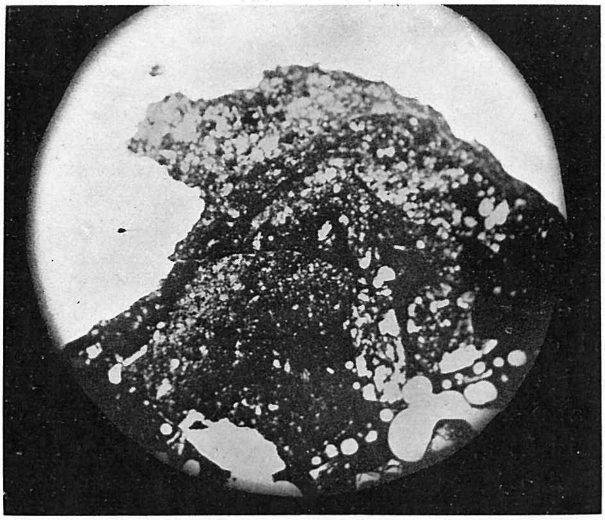
The present writer, however, prospecting the places and manners of existence of Sara-isi during several years, and investigating carefully their structures, found out many facts contradictory to the above illustrations, and wanted a new theory of the origin of Sara-isi. For these reasons we will at first revise and enlarge the investigations on the nature of the Sara-isi itself, and then propose our opinion about the method of its formation based upon many decisive facts newly found. Lastly we will discuss the peculiarity of the volcanic activity of Aso, suggested by the Sara-isi production which is limited to that place. Indeed according to the historical records and our observations during several years it is undoubtedly a fact that, at Naka-dake crater alternative explosions and accumulations of hot water pools are constantly repeated; in other words, it is a notable feature of the action at Aso volcano that both states of an active volcano and a crater lake are often repeated alternately.

Thus we propose to take the mode of volcanic activity with the above feature as a new one named, "the activity of Aso-type." Further, applying our new view of Sara-isi on Naka-dake, Kisima-dake and Ô-jo-dake, we will make an atempt to illustrate the respective peculiarities and the orders of action of those craters.

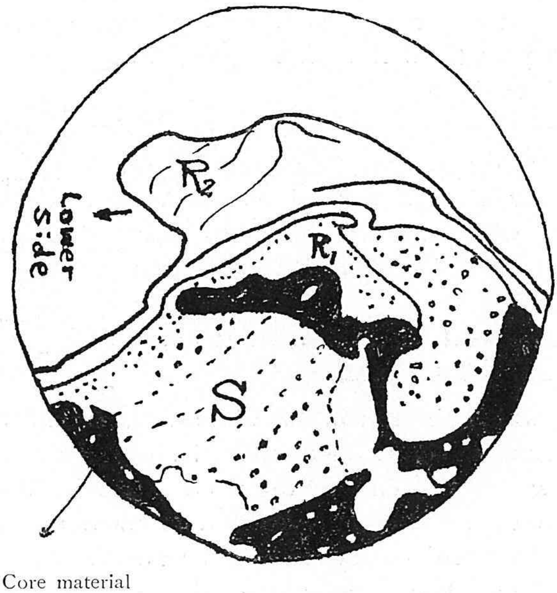
§ 2. Yield Manners and Discrimination of upper and lower Sides of Sara-isi

The sides, towards which the rim of Sara-isi bends, is hitherto called "its upper side" and the other "its lower side." This expression seems to me a view beguiled due to the word "Sara" (dish). As for the scientific research, indeed, the expression must be discriminated carefully by the actual observations of its normal state of existence, because this discrimination may support not a little the view of the formation of Sara-isi. If one carefully observes the yield

Fig. 10. Section of a SARA-ISI to show the growth of a secondary rim toward the earth.



S : — volcanic ash arranged horizontally.
R_1 : — primary rim.
R_2 : — secondary rim.

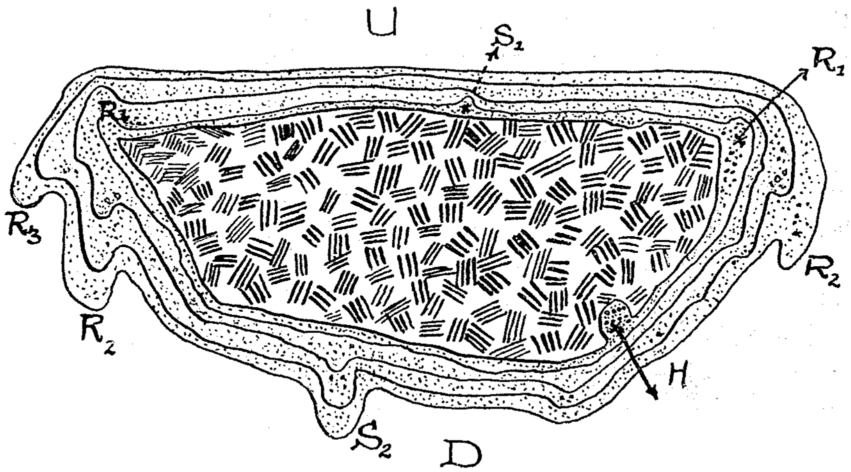


Core material

manner of Sara-isi at the field, he will find that the rim generally suspends down toward the ground except in rare cases in which the original state seems to have been disturbed, and that in those exceptional cases another new rim is growing toward the ground at the margin (Fig. 10).

Sara-isi with a well developed rim can be found more commonly on rather pebbly slopes than on sandy fields, and those lying on geographically old fields have developed better than those on younger fields. By these facts of observation, it seems to me more reasonable to consider that the direction of the main rim should be called "the upper-side (ridge) direction" (Fig. 11). Careless discrimination of the sides, perhaps obliged many of the seniors to attribute the formation of Sara-isi to the falling impact of a pseudo-plastic magma against the ground.

Fig. 11. Schematic representation of a SARA-ISI.



U : — upper side.
R_2 : — main rim.
H : — layer of Yona in a hole.
core material.
tufaceous part.
D : — lower side.
S_2 : — stalactitic process.
R_1, : — primary coagulated part.
coagulated part.
flow band.

§ 3. The Out Side of SARA-ISI

The upper-side of a Sara-isi is dark gray or dark brown and rather smooth, and its protuberances if they exist are dull. The part which is covered by soil or rock fragments, is commonly yellowish brown like the colour of the lower side.

The lower-side, on the contrary, is commonly yellowish brown or white gray and is ragged. The portion which does not directly contact with the ground is comparatively compact and has a colour near that of the upper side, and it must be noticed that there are quite a few stalactitic processes on such a portion. A small Sara-isi (1–2 cm. in diameter) is sometimes smooth on its whole surface, and its rim is not developed enough to discriminate the sides, though even in such a difficult case we will not fail to discriminate, if we carefully examine its colour. There may of course be a complicated Sara-isi whose sides can be discriminated only by a trained man.

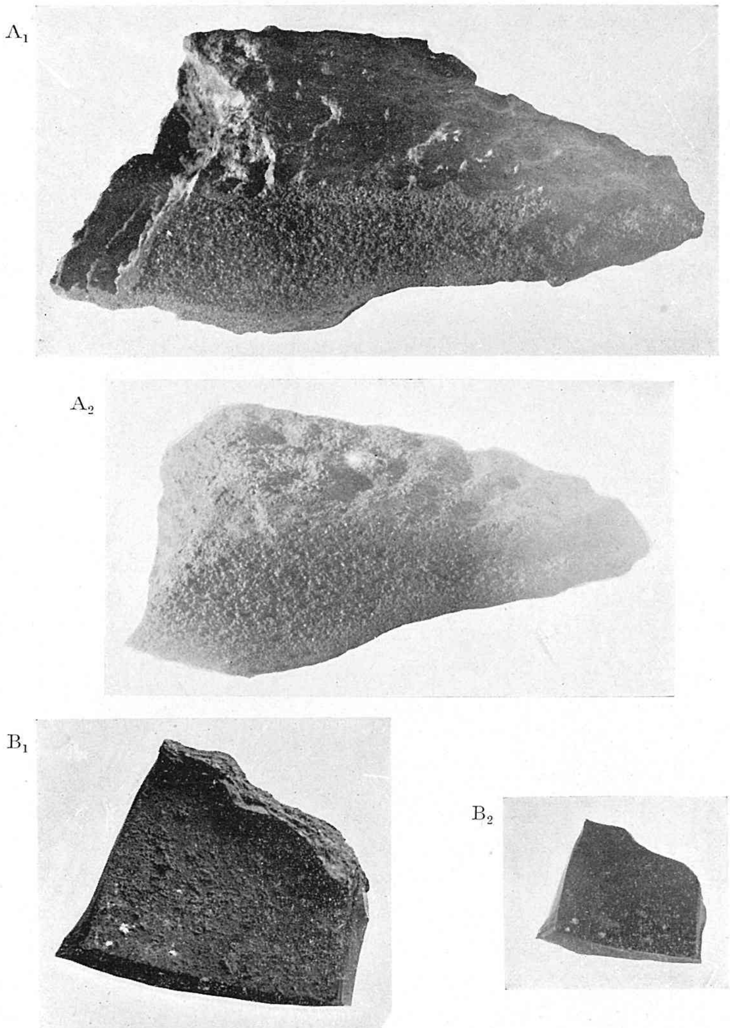
Fig. 1, 2, 3, 4, 5, 6 show both sides of Sara-isi.

Fig. 4 shows the stalactitic processes on the lower side.

§ 4. Sara-isi is Composed of Two Parts

Divide a Sara-isi into two pieces. Observing a part directly by the naked eye or under the microscope, it can easily be recognized that the construction of the core is entirely different from those of the crust and rim (Fig. 5, 6). In the next place when we treat the other part for several hours or more with hot concentrated chloric,

Fig. 12. SARA-ISI under the chemical treatment.



A_1, B_1: — original shape.
A_2, B_2: — after the treatment by NaOH solution.

sulphuric, nitric acid, or even with hot aqua regia, we can not see any mechanical variation as a whole. But if we put a Sara-isi into a hot caustic soda solution (1–5 Normal), there occurs at once the destruction of the rim and crust, but the action will cease in about ten or twenty minutes. Then wash the adhering $Fe(OH)_2$ off the residual solid block with HCl and next with water. Now investigate this solid block macroscopically or microscopically, then we will find surprisingly that the core part in the former piece was unchanged while the crust completely disappeared.

For the sake of convenience, therefore, we will call the residual part " the core of the Sara-isi " and the other collapsed part " the crust or coagulated part," and then a Sara-isi may be discriminated roughly into two main parts — the crust and the core.

Moreover from the above experiment we see that the rim and the stalactitic prominences being undoubtedly to the crust part (Fig. 12).

§ 5. The Crust or Coagulated Part of a SARA-ISI

The crust is the most important part for the investigation of the origin of Sara-isi. It may rather be said that the genesis of Sara-isi can be revealed only by the investigation of the construction of the crust. Following experiments were carried on with such a view in mind.

(1) If a Sara-isi whose enclosure is obviously a vitreous lapillii (Fig. 2) is heated up to about 1100°C in an electric furnace, its crust becomes reddish due to Fe_2O_3, chapped, and somewhat brittle, but original shape is maintained, while the core begins to melt. With such Sara-isi, therefore, it is difficult to conjecture as Prof. Harada did that the crust is composed of a highly fluidal magma. The temperature at which the original shape begins to go out was kindly measured for me by Dr. Akiyoshi Tadokoro, Engineer of Yawata Seitetsu-sho, as :—

crust . . . . 1175–1190°C,
core . . . . 1165°C.

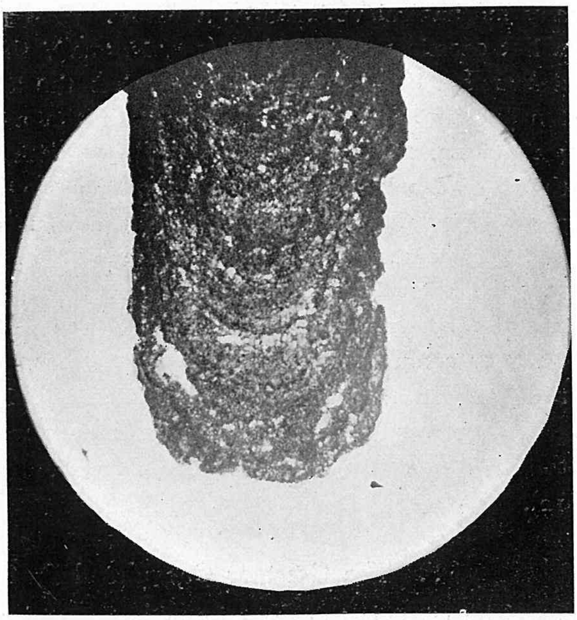
(2) From our witnessing the falling habits of bombs in the cases of recent eruptions of the Aso-volcano and some laboratory experiments we are led to conclude that when a highly plastic matter is dashed down on an ash field, its upper side (the surface which is in contact directly with the atmosphere) is generally more smooth than

its lower side (the surface which is in contact with the ground). Moreover stalactitic prominences are not produced in the upper smooth flat side. These facts will prove that the upper and lower sides of a Sara-isi are scientifically reverse to those of former investigations.

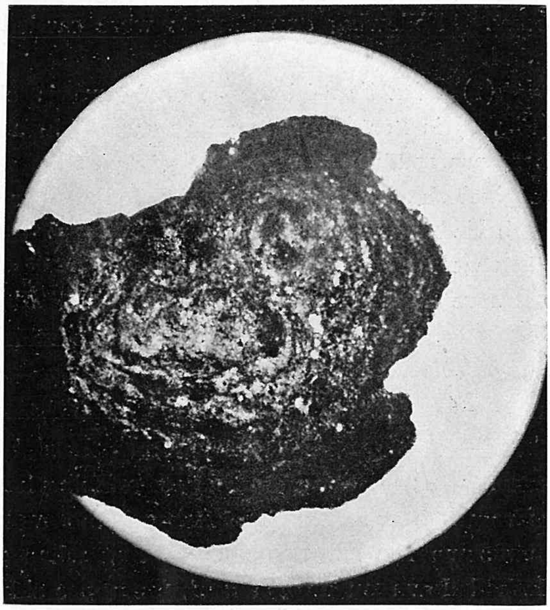
(3) The vertical section of a Sara-isi shows under the microscope some alternative stratum — a rough tufaceous layer and a compact brown fluxion layer (Fig. 5, 6, 10).

One Sara-isi from Sara-yama possesses a crust composed of about twenty layers. Prof. Harada does not point out such alternative stratum. Therefore his illustrations of the method of formation of the crust (due to coating of magma mingled with some Yona) look reasonable, but can not stand in our case. We commonly find

Fig. 13. Section of the lava stalactitic prominences.

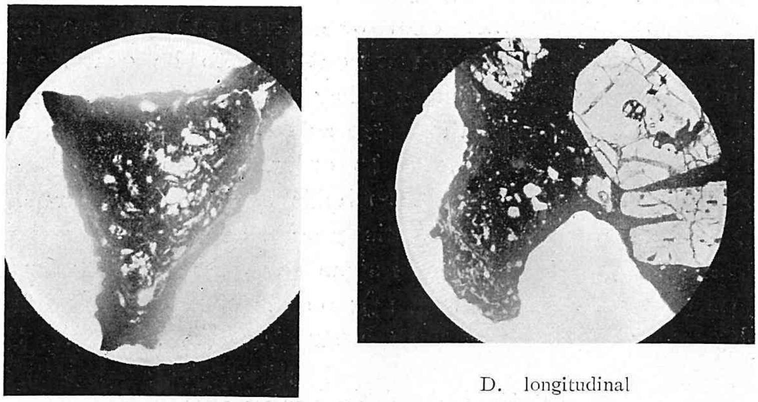


A. longitudinal



B. cross-section

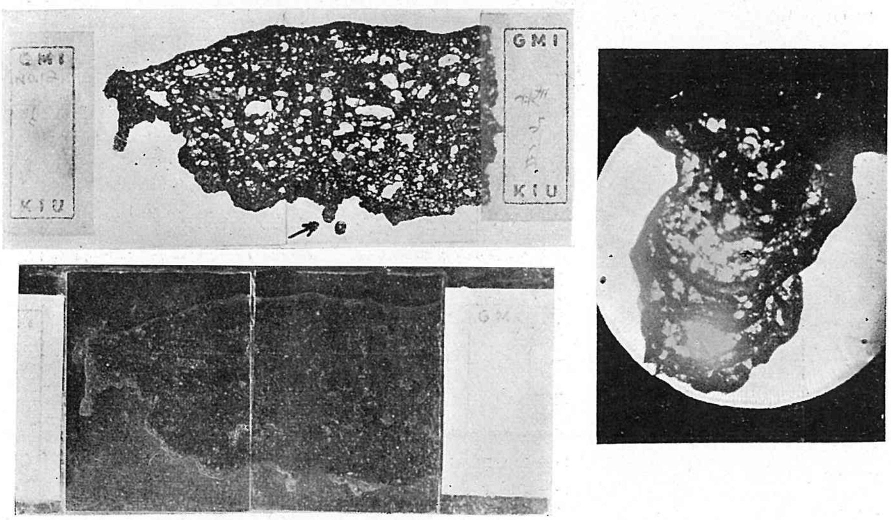
Fig. 13



C. longitudinal

D. longitudinal
(Narao-dake)

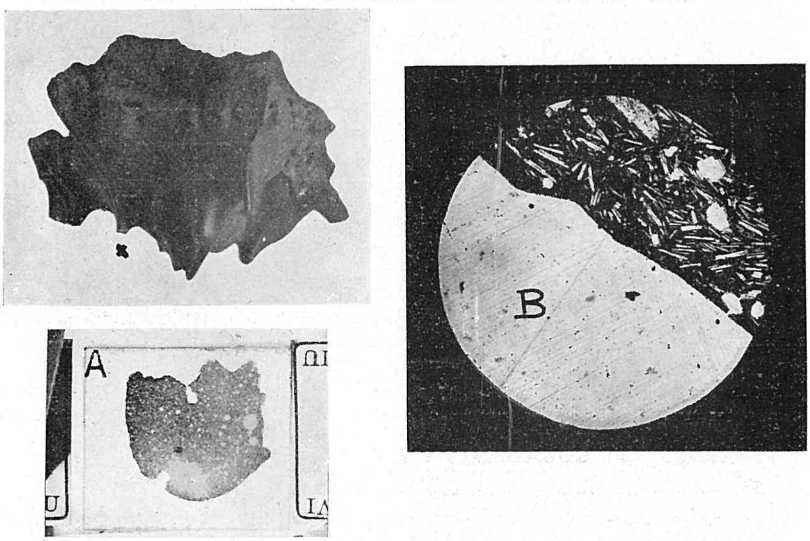
Fig. 14. Section of SARA-ISI and its lava stalactitic process.



some differences between the tufaceous layers, but not among the fluxion layers. The tufaceous layer is composed of fragmental pieces of volcanic ash materials (about 1/10 m.m. in diameter) cemmented with microparticles (less than 1/1000 m.m. ca.) and Fe_2O_3. The volcanic ash is mainly composed of the hitherto known anorthite, augite, volcanic glass, rock, olivine, magnetite etc. When we remove ferric oxides by chloric acid from the section, the brown fluxion layer becomes white (colourless) under a low power microscope. If they were brown glass, such a change could not occur. Under a high power microscope (greater than 800 times ca.) we see crowded amorphous microparticles which we conclude to be quartz particles. Now if we trace the layer under a low power microscope, they form closed curves as shown in the figure schematically (Fig. 12).

Each layer does not disturb its order, though the width is of course not uniform. This relation holds also in the case of poly-rimmed Sara-isi or of the stalactitic prominences. The cross-section of a stalactitic prominence shows some concentric circular structures as those of a stalactite (Fig. 13, 14); on the contrary, a protuberance of the core does not show such a structure (Fig. 13 D). Similar

Fig. 15. Lava stalactite from Mt. Fuji.



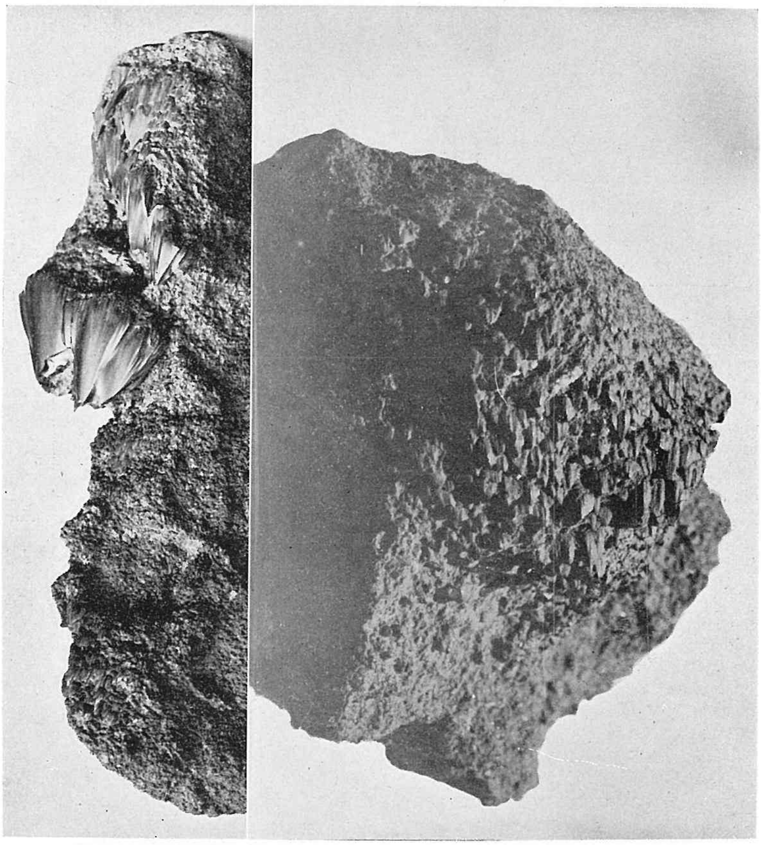
A : — the cross section.
B : — under the microscope.

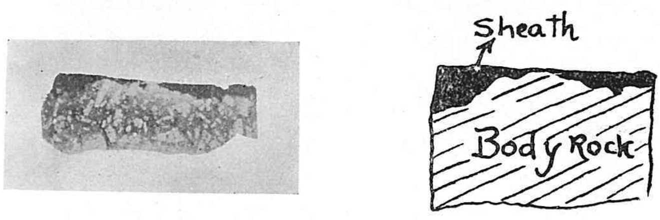
structures can not be found also in the section of a lava stalactite from Mt. Fugi (Fig. 15). These facts also play an important role in the investigation of Sara-isi genesis.

(4) The method of formation of the crust part may inductively be said to be different from that of the core part as already stated above. Now let a rim represent the crust. It can be easily crumbled by NaOH (5N) solution in about twenty minutes; and there remains a residue of chiefly volcanic ash (Yona) and $Fe(OH)_3$, while the filtrate contains SiO_2 (principal part), a few almina and traces of Ca, Na, K

and Mg. But by any acid, HNO_3 (conc.) or aqua regia — cold or hot —, HCl (conc.), H_2SO_4 (conc.), the construction of the rim can not be broken down though the rim is only 0.1 m.m. thick; it only becomes white, Fe_2O_3 being removed. This will show that ferric oxide, calcium carbonate, or sulphate are not the principal cemmenting materials, and that the fluxion layer may originally be white (colourless)

Fig. 16. Tume-isi or Lava-sheath from the New-Crater (1906).





Section of a sheath

but becomes later brown due mainly to Fe_2O_3. The remarkable crumbling phenomena, as with the rim of Sara-isi, does not occur with any products of plastic magma, e. g., Aso-lava, volcanic bombs from the great Aso ancient somma, bombs from Taka-dake, Kisima-dake, Nara-o-dake, old bombs from Naka-dake, new bombs from the fourth crater of Naka-dake, and "Tume-isi" or Lava-sheath (a curious stone from the New-Crater of 1906) (Fig. 16). At my request, various analyses of volcanic products were kindly performed by Mr. T. Kido, formerly chemist of our laboratory, to whom the writer expresses his best thanks here.

Table 1. Chemical Composition of the Rim of Sara-isi (sample from Fig. 2), by T. Kido.

	Soluble part in NaOH(5N-) 5 hours 0.442 gr.	Residue 0.558 gr.	Total 1.000 gr.
SiO_2	37.080%	26.860%	63.940%
Al_2O_3	2.320	8.860	11.180
Fe_2O_3	—	11.660	11.660
CaO	0.800	4.500	5.300
MgO	0.420	—	0.420
SO_4	5.753	0.106	5.859
—	—	—	—
$\frac{SiO_2}{Al_2O_3}$	16.1	3.2	6.2

Table 2. A bomb (Nov. 1929) from the fourth-crater, ASO.

SiO_2	53.8782%
Al_2O_3	16.4302
Fe_2O_3	5.6907
CaO	3.5966
MgO	0.7581
SO_4	0.4142
—	—
$\frac{SiO_2}{Al_2O_3}$	3.3

Table 3. Volcanic ash (1914) from Sakura-jima.

SiO_2	61.4120%
Al_2O_3	18.4321
Fe_2O_3	6.8179
CaO	3.9251
MgO	1.0033
SO_4	0.5342
—	—
$\frac{SiO_2}{Al_2O_3}$	3.3

Table 4. YONA from ASO.

	27–28 Aug. 1929 from 4th crater, lain on our laboratory.	5–8 Nov. 1929 from 4th crater, lain on its rim.	4–8 Sept. 1930 from 1st crater, lain on its rim.	7th Sept. 1932 from 1st crater, lain on its rim.	10th Dec. 1932 from 1st crater, lain on Tochi-no-ki village.
SiO_2	52.28%	57.53%	51.21%	51.77%	54.34%
Al_2O_3	8.23	12.44	8.48	5.92	6.81
Fe_2O_3	9.47	8.74	6.88	11.45	11.13
CaO	6.30	5.56	5.24	5.53	6.02
MgO	0.66	0.65	1.19	1.69	1.54
SO_4	0.33	3.22	0.74	0.95	2.40
—	—	—	—	—	—
$\frac{SiO_2}{Al_2O_3}$	6.9	4.6	6.0	8.8	8.0

Table 5. Glass-cored Sara-isi (Fig. 17).

Wt. of the sample . . . . 3.3432 gr.
Wt. of the core (glass) . . . . . 3.2934 gr.
Then coagulated part . . . . . . 0.0498 gr.

	Soluble part in KOH(5N), 5 hours	Residue
SiO_2	54.4177%	24.8996%
Al_2O_3	0	4.4724
Fe_2O_3	0	11.2353
CaO	0	6.3426
MgO	0	0.9209
SO_4	2.8094	0.3305
—	—	—
$\frac{SiO_2}{Al_2O_3}$	great	5.6

Table 6. Scoriaceous Lapilli (1928) from the Fourth Crater, ASO, by Tsuya.[1]

SiO_2	53.53 wt. %
Al_2O_3	18.67
Fe_2O_3	2.67
FeO	5.93
CaO	9.27
MgO	3.80
—	—
—	—
$\frac{SiO_2}{Al_2O_3}$	3

Table 7. Volcanic Ash (1914) from the volcano Sakurajima accumulated on the play-ground, Kagoshima Normal School.[2]

	By the Geological Survey of Japan	By Eng. Depart. Kyusyu I. Univ.
SiO_2	63.39%	60.38%
Al_2O_3	16.75	18.10
Fe_2O_3	3.100	8.49
FeO	4.00	—
CaO	5.38	6.01
MgO	1.43	3.61
—	—	—
—	—	—
$\frac{SiO_2}{Al_2O_3}$	3.8	3.3

Table 8. The Average Chemical Composition of Igneous Rocks.[3]

	Earth	Japan
SiO_2	59.12	61.92
Al_2O_3	15.34	15.72
Fe_2O_3	3.08	2.07
FeO	3.80	4.41
CaO	5.08	5.16
MgO	3.49	2.47
—	—	—
—	—	—
$\frac{SiO_2}{Al_2O_3}$	4	4

Table 9. Chief Activities of the ASO-crater.

1928. Sept. 6 . . . . during about one week (the 4th. crater).
Dec. 19 . . . . „
1929. Jan. 22 . . . . „
Feb. 20 . . . . „

1. Tsuya:—On the recent ejecta of Volcano ASO, 地質學雜誌, **36**, 17 (1929).
2. 地質學雜誌 **21**, 540 (1914).
3. H. S. Washington a. F. W. Clarke:—Proc. Nat. Acad. Sci. **8**, 108 (1922).

Table 9. (Continued)

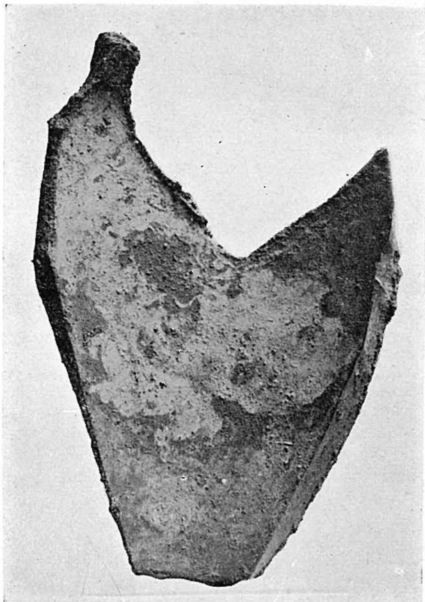
1929. Mar.	6	. . . . during about one week (the 4th. crater)	
	18	,,	
	29	,,	
May	9	,,	
June	22	,,	
July	11	,,	parasitic crater appeared.
	25	,,	
Aug.	24	,,	
Sept.	14	,,	
Oct.	6	,,	
	22	,,	
Nov.	4	,,	after this activity crater pool occurred.
1930. Sept.	4	,,	after this time the crater pool reappeared in the *4th* crater, and its eruption *ceased.*
1932. Sept.	4	. . . . the *1st* crater awakened again after its *long repose* (about 30 years).	
Oct.	10		
Dec.	17		
1933. Feb.	24—Mar. 8, *greatest* explosion during recent years		
May	5		
Sept.	4		
1934. Jan.	3	. . . . now *1st* crater became to be a pool.	

For the bombs, Mr. Kido's results of analysis are sufficiently agreeable with those of Tsuya for scoriaceous lapillii (Table 2, 6), and also with those of the Geological Survey of Japan and the Engineering Department of the Kyusyu Imp. University for the volcanic ash from Sakura-jima (Table 3, 7). All these results give the ratio of SiO_2 to Al_2O_3 as about 3–4, which is coincident with the average for the igneous rocks of all Japan or the earth (Table 8). For the rim of a Sara-isi, however, the ratio of SiO_2 to Al_2O_3 is about 6 as a whole, while in the solute with NaOH (5N) about 16, and in its residue about 3 as those for lapillii (Table 1). This fact seems to me to show that *the rim of a Sara-isi is not a block magma, but a cluster of Yona (volcanic ash).*

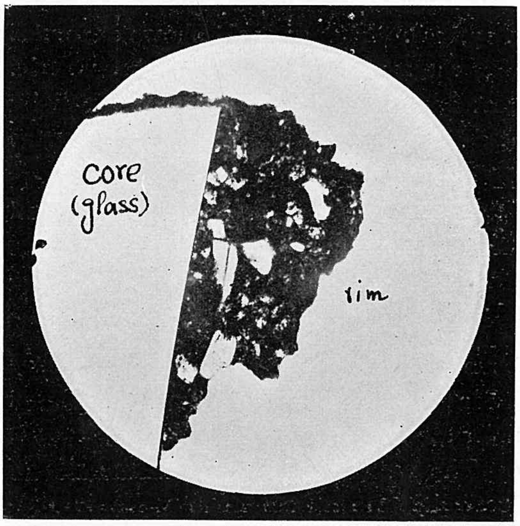
The reader will agree with us on this point, if he looks at the analysis of Yona in Table 4. Especially the ratio in Table 5 is extraordinarily great.

Now, we can see that SiO_2 is found more abundantly in the Yona erupted at the first stage of an eruption than at the last stage. For example, in the Yona of 27–28 Aug. 1929 the ratio of SiO_2 to Al_2O_3 is 6.9 while in that of 4–8 Nov. 1929 is 4.6, which is very near to those of lapillii. Again, in the Yona of 4–8 Sept. 1930 (after about ten months repose) it increases to 6.0. For the sample of the *1st* crater also, the above relations hold obviously; for example, in the Yona on 7 Sept. 1932 (first stage after a long repose of about 30 years) the ratio is 8.8 while in that on 10 Dec. 1932 the ratio decreases to 8.0. The volcanic ash from Sakura-jima may perhaps be newly generated directly from the magma, because its ratio of SiO_2 to Al_2O_3 is very near to that of a lapillii.

Fig. 17. SARA-ISI which enclosed a glass piece.



lower side.



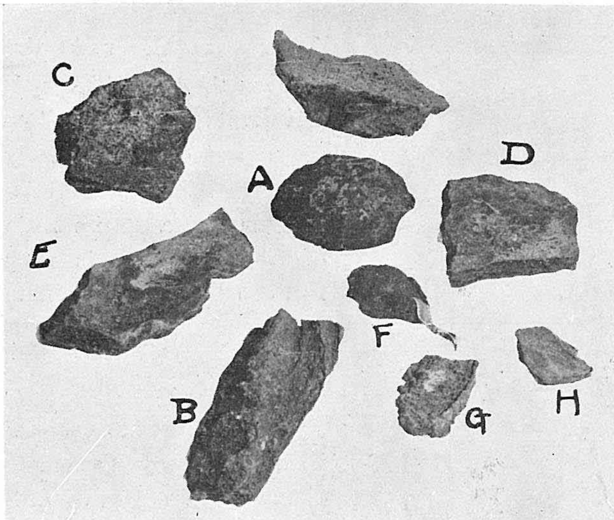
under the microscope.

§ 6. The Core of a SARA-ISI

The core of a Sara-isi is commonly a volcanic ejectamenta as Prof. Harada has already reported (Fig. 1, 2, 3, 4, 5, 6, 7, 8, 10, 18), that is, it may be a magma fragment, a bomb, a lapillii, a tuff or pre-existing rock fragment. For all our efforts we failed to discover a lapillii of " ash mingled magma " which was to be expected from Harada's view. According to our view that the rim is of posterior nature, we may expect the existence of Sara-isi with a core of some artificial substance; and the writer made his utmost efforts to find such a Sara-isi and at last successful results have been obtained.

If we prospect carefully along the flank of the

Fig. 18. Some kinds of SARA-ISI.



A: its core is a spindle bomb.
B: " a twisted bomb.
C: " a massive rock, on whose lower side many lava stalactitic prominences grow.
D: flat one.
E: irregular one.
F: symmetrical one.
G, H: other irregular ones.

ancient crater of Naka-dake we will surprisingly discover many suspensions at the margins of grave stones, stone buddhas, stone monuments, stone lanterns, stone wash basins, etc. (Fig. 19, 20).

These suspensions have a quite similar form and composition as that of a Sara-isi. More decisively we have found a number of Sara-isi whose core are broken pieces of glass bottles or earthen ware. (Fig. 17, 21). Fig. 17, 11B shows examples whose rims are developed along the margin of pieces of a beer bottle. They were collected at the west flank of Naka-dake ancient crater by the writer on 15th Nov. 1931.

Thus, the cores of Sara-isi are not only the ejecta from the crater but the rock fragments from the crater flank as already reported, and more surprisingly some artificial substances also.

§ 7. The Formation-process of the Rim of a SARA-ISI

Many facts described above will entirely refute the customary explanation of the genesis of Sara-isi, and therefore we are obliged to construct a new illustration for the formation-process, basing it upon the facts discovered recently. The writer believes that "the rim of Sara-isi" is not produced directly by the effects of a volcanic outburst, but it is rather a secondary posterior production. Fine pieces of volcanic ash (Yona) are coagulated by colloidal silicic acid on some of the rock fragments of the ground and hardened to form the rim and crust of a Sara-isi. If the writer's view is true, then it must follow :—

i) The core of Sara-isi may not only be such ejectamenta as a volcanic bomb, a pre-existing rock fragment from the crater, or a tufaceous matter, but may also be some foreign fragment carried by nature or a human being. Indeed the same coagulating matter as that of the rim of a Sara-isi will grow on some materials, on whose surface colloidal silicic acid can coagulate.

ii) The crust of Sara-isi will grow with time due to the piling up of colloidal silicic acid. The rim should be usually suspended downwards.

iii) Sara-isi will be produced at the place where colloidal silicic acid and pieces of volcanic ash are supplied, and on condition of the hardening of the colloidal silicic acid by the leaving of its water. Now if we can show that these three circumstances really exist, our view for the genesis of Sara-isi will be readily accepted by the readers, so let us proceed to explain these points by the actual facts taken from the volcano Aso.

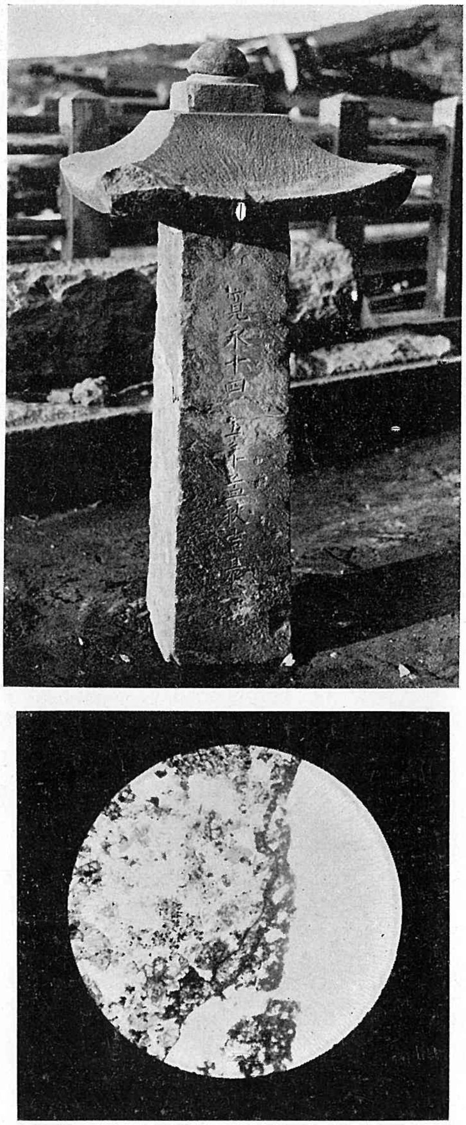
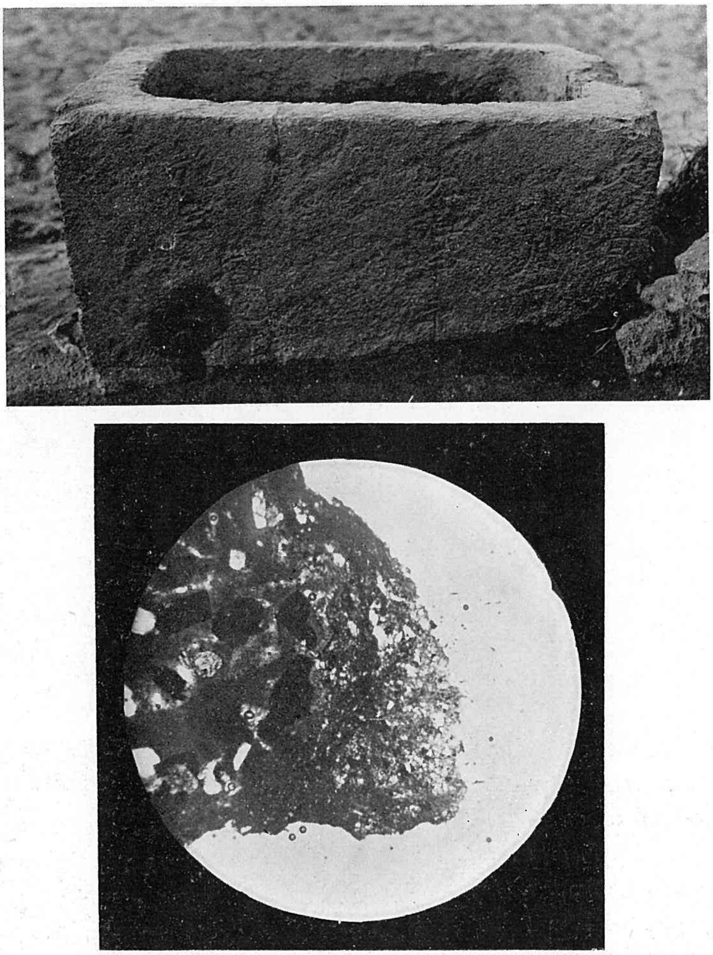


Fig. 19. Stone lantern erected on 1637, and the section of its margin.

I). *The Formation of the rim and crust—Coagulating layer—is not restricted only on the volcanic ejecta.*

Fig. 20. Stone bowl curved on 1807, and the section of its margin.

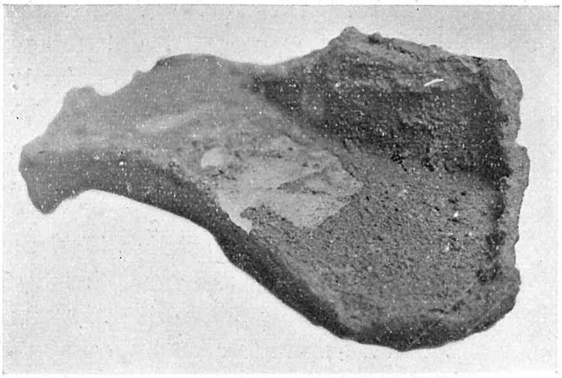


This is verified by facts in § 6. We add here another interesting fact that numerous stalactitic processes are actually developing in some caves under a lava flow and their physical and chemical natures are entirely similar to those of the rim or stalactitic process of a Sara-isi (Fig. 22).

II) *The crust of a Sara-isi may grow with time.*

This will be indicated by the stratification of the rim or crust of a Sara-isi. We will here again add a few new facts. If we examine carefully, we will find that the Sara-isi found at Sara-yama are most developed, those from Sensui-yama come next, and those from the west flank are the most incomplete.

Fig. 21. SARA-ISI which enclosed a stone ware piece.



On the other hand, considered geologically, Sara-yama is the most ancient while the west flank is the newest. Hence the above will show that Sara-isi may grow with time.

Moreover the rims developed at the stone lantern erected in 1637 and at the stone bowl carved in 1807 indicate clear stratifications under a microscope, and we can estimate the rate of growth from the age of their erection. Estimation gives the rate of two fluxional and two tufaceous layers in about 300 years . . . . of course very roughly.

The fluxional layer may be coagulated in a comparatively calm period of the volcano, while the tufaceous layer seems to develope

Fig. 22. Numerous posterior stalactitic (and stalagmitic) processes under a lava flow.

in the active period, accumulating volcanic ash pieces mingled with colloidal silicic acid; thus the above rate might suggest that the activity of Naka-dake prospered and decayed in about 150–160 years (very roughly). This number approximately coincides with that obtained by the statistics of activity in the historical records,[1] and the present time seems to be a comparatively active period.

III) *Production of colloidal silicic acid is possible in the ASO-crater.*

Production of colloidal silicic acid is possible in a crater where hot water stays in its bottom through which sulphuretted gas effuses violently and sulphur or sulphuric acid result. Because it is a well known fact that sulphuric acid becomes neutralized decomposing the volcanic rock or ashes, and colloidal silicic acid can be well produced when the concentration of H ions is suitably decreased. If ashes (Yona) mingled with colloidal silicic acid are blown out from the crater and fall on the rocky ground, then a film is resulted due to the colloidal substances. Moreover, the residual sulphur or sulphuric acid, which were spread out with the above materials, will stick to the rocks and may decompose the rock materials in many years in the same manner as in a hot crater pool. Then if the acid is suitably neutralized, the colloidal silicic acid becomes fixed to the rocks, losing the water in the sun. The stratiform crust may occur only by the pulsating supply of the colloidal silicic acid, i. e. only when both the effusion of volcanic ash and the accumulation of hot water in the crater are repeated alternately. The growth of the crust will depend on the frequency of the repetition of the alternate states of effusion and hot water accumulation in the crater. We here emphasize that these conditions are satisfied by Aso both in the history and also at present as seen in the next chapter.

§ 8. The Characteristics of the ASO-type Activity

If Sara-isi is a special product from volcano Aso, it may inversely be said that the activity of volcano Aso has a certain singularity. And if we find Sara-isi in some other volcano, we may say that the volcano makes activity like that of Aso. We shall now summarize the characteristics of volcano Aso. " Eruptions occur very frequently. During the repose of eruption, colloidal silicic acid is produced in the crater where hot water stays in the basin and sulphuretted gas

1. 震災豫防調査會報告（日本噴火誌下）第87號 p. 28.

effuses through the pool violently. The eruption is rather moderate. If the eruption is very severe, the growth of the crust of Sara-isi must be disturbed by the abundant ejecta . . . Sara-isi must be buried under the abundant Yona. We will call this type of activity shortly "*a volcanic activity of Aso-type.*" The above characteristics were well experienced by the writer during the several years since he began his study on Aso. The volcanic activities of Aso recorded in Japanese history also may be said to show completely the same characteristics. The oldest Aso-activity in the record is written as 延暦十五年秋七月辛亥詔曰比來大宰府言肥後國阿蘇山上有池其名曰神靈池. 水旱經年未嘗增減而今無故涸減二十餘丈云々. (日本後紀).

Since this time, there are numerous records which show that this volcano repeated the bursting out of Yona (霾, volcanic ash) in the active period and the pool-state (神靈池) of Kusui (苦水, active hot water) of the crater in the calm period.

Indeed the repetition of "eruption" and "the presence of hot water" in the crater was surprisingly numerous, and the extraordinary adhesive power of Kusui (苦水) was known already since very long and recorded as "苦水沸騰空中東西洒落其東方者如布延縵廣十許町水色如漿黏著草木雖旬日不消解 (肥後國誌).

Moreover, we can also suppose the existence of the above two phases of action from the etymological meaning of the name of the mountain . . . Aso.

Dr. Tanimoto[1] was said to have solved the word *Aso* as coming from the Ainu language with the meaning "mountain blowing out the fire" as ASAMA-yama. Dr. John Batchelor says that Aso means "a crater"[2] but in other place he says that Aso-yama . . . . 阿蘇山 . . . . Aso-nupuri means "opposite mountain."[3] Dr. T. Oda[4] says that Aso may be an abbreviated word from 阿蘇羅 (violent). For the present Naka-dake also, various different names can be found in the ancient literature, such as:

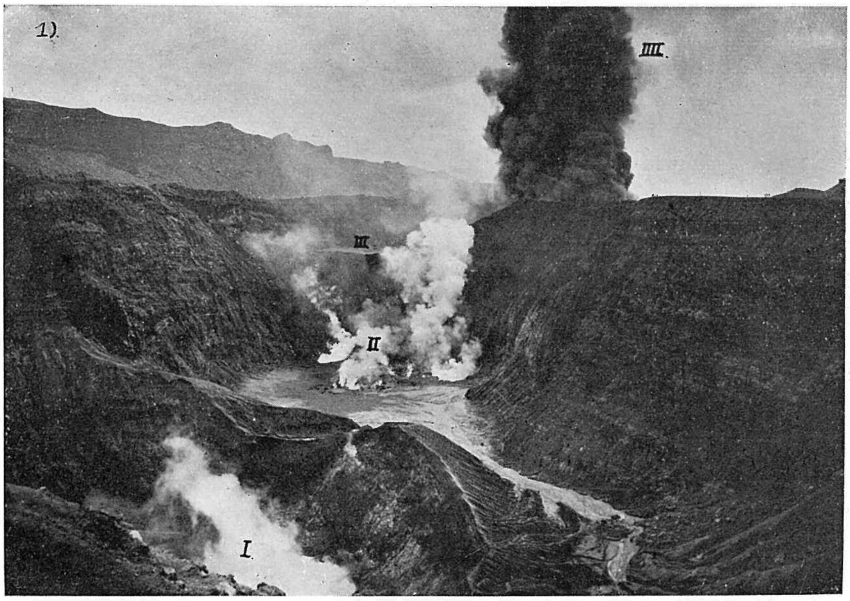
ASO . . . . (阿 蘇 . . . 日本書紀, 阿曾 . . 和名抄, 閼宗 . . 筑紫風土記)
O-take or *Mi*-take . . . (御 嶽 . . . 肥後國誌)
Mae-dake . . . . (前 嶽 . . . 阿蘇郡誌)

1. 阿蘇郡誌 (1926) p. 558.
2. Dr. John Batchelor:—Key to the Study of Ancient Japanese Place Names (1929).
3. " " :—The Pit-Dwellers of Hokkaido and Ainu Place Names considered (1925).
4. 織田得能:—佛教大辭典.

Nara-O-dake . . . . . . (楢尾嶽 . . . 肥後國誌, 阿蘇郡誌)
Nara-yama . . . . (楢 山 . . . 同 上)

These may be grouped into two words :—" ASO-O-MAI " and " NARA." " ASO-O-MAI " means " a place where a firing crater exists " and " NARA " means " a ditch " in the Ainu language. Thus we imagine that the two phases of action (eruption and water-staying)

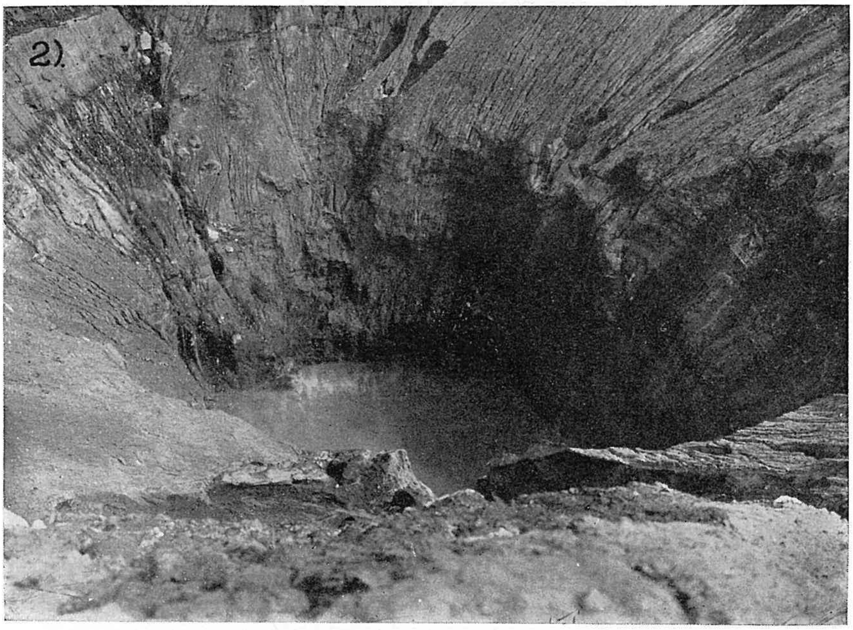
Fig. 23. Photograph of the two phases of action in the ASO-Craters.
1) Photo. on *4th* Nov. 1929.



I & II-Craters :—in state of hot water pool with solfataric action. IIII-Crater :—in explosion.

repeated since prehistorical time so frequently that the ancient people noticed the different phases and named the mountain in two different meaning naturally. If that is the case, the writer can expect some other words of a similar kind which we will speak of here. YONA (霾) (a peculiar word in the district of Aso) seems to be altered from UINA meaning " the volcanic ash," and KU-SUI (苦水) also a word altered from " KUSURI " meaning " the hot spring " in the Ainu language. Neko-dake is the famous cone among the so-called ASO-GO-GAKU (five famous central cones in the great Aso), and has a splendid shape like the teeth of a saw. One of its old names is " HIREME-USI " (肥後國誌). This word seems to me to be altered from "PIRI-EMUSI," which means "a sword shape mountain whose edge is nicked." At the volcanoes Kiri-sima,[1] Asama[2] and others their craters are commonly called "O-KAMA" (the kettle) or "O-HACHI" (the pot) while at the volcano Aso they are called "O-IKE" (the pool). This may perhaps be due to such reasons that the craters of the other volcanoes except Aso were dry and the water

Fig. 23. Photograph of the two phases of action in the Aso-Craters.
2) Photo. on *6th* Oct. 1931.



IIII-Crater:—becoming a hot water pool this time.

was scarcely staying in the basin even during the repose-period.

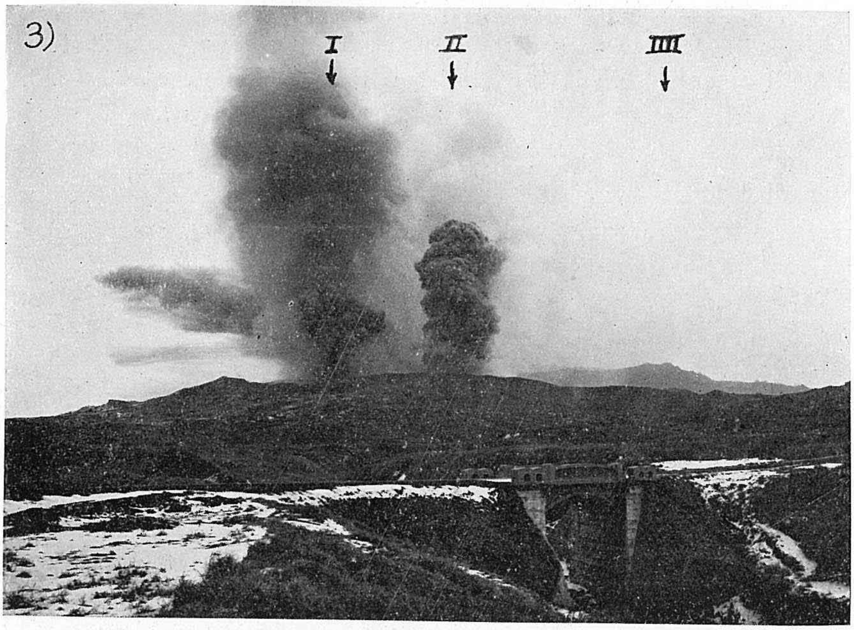
From the above reasoning, the readers may understand that the characteristic activity of Aso has been continued since far remote times, so that Sara-isi may be produced inaccidentally.

We tabulated the chief activities since 1928 in Table 9, and the two phases of activity of the craters *4th* and *1st* are photographed in Fig. 23 (1, 2, 3).

1. This name seems to me to be altered from "Ye-Keure-So-Oma" and "Karuru-Keure-Guru" which mean "a mountain from whose crater the pumices and ashes burst out."

2. This seems to me to be altered from "ASO-Oma" which means "a mountain which has a firing crater." Dr. J. Matsumura considered it to mean "a sparkling crater" in his "An Etymological Vocabulary of the Yamato Language (1921)."

Fig. 23. Photograph of the two phases of action in the Aso-Craters.
3) Photo. on 9h. *2nd.* Mar. 1932.



I & II-Craters :—in explosion. IIII-Crater :– in a hot-water-pool state.

§ 9. Volcano Kisima-dake also had a Period of ASO-type-activity.

From the preceding discussions, we may suppose that a volcanic crater has once at least "activity of Aso-type" if we can find Sara-isi in its surroundings. Now, in the 1/50000 map of Aso issued by our Military Land Survey, the west cone of the ASO-GO-GAKU is named Kisima-dake (Fig. 9). If we search round the circumference of this cone, we can collect Sara-isi at the top of the volcano Ô-jo-dake which is on the NE side of Kisima-dake (Fig. 9) and at a part of the somma of the explosion crater Senri-hama (Fig. 9). The relation of these newly found habitats to Kisima-dake corresponds to that of Sara-yama and others to the Naka-dake craters.

Thus, volcano Kisima-dake must have once had Aso-type activity, and moreover it will be younger than Ô-jo-dake or the Somma of the Senri-hama explosion crater.

This conclusion may be supported etymologically also. According to 肥後國誌, Kishima-dake has many old names such as "Donbendake," "Doben-dake," "Tama-dake," "Suisho-dake," etc. These seem te me to be altered from three words with different meanings. One is "To-Un-Pe" meaning "a mountain which has a pool," and next "To-Oma" meaning "a mountain at which a pool exist," and the last "Shui-sho" meaning "a mountain which has a crater." Namely, this cone has two kinds of names as those of Volcano Naka-dake, indicating two phases of activity peculiar to the Aso-type-activity. As far as we know, there is no literature to determine geologically the order of volcanic repose of the two cones, Kisima-dake and Ô-jo-dake; but fortunately our studies on Sara-isi throw light on this point.

In conclusion the writer wishes to express his sincere thanks to Prof. Dr. T. Nomitsu for his kind instruction and advice throughout the work.