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Author(s)	MUKAE, Michitoshi
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A Trial for the Rapid Determination of Volcanic Rocks

The relation of the refractive indices of melted rock-glasses to their chemical compositions

By

Michitoshi MUKAE

with 2 Text-figures

ABSTRACT It becomes evident that the refractive indices of artificially prepared rock-glasses easily by melting in the flame of oxygen-gas have an intimate relation to their chemical compositions, being clearly shown on certain smooth curves. As to some of the Tertiary calc-alkalic rocks obtained from the San-in district, is their interrelation inspected practically in the present paper. The method hereunder referred to may be utilizable to determine rapidly a large number of volcanic rocks such as tuffs or tuff-breccias.

CONTENTS

I. INTRODUCTION

Volcanics such as tuffs or tuff-breccias play sometimes an important rôle as the key-beds in correlating the strata, but the determination of a large number of volcanics for this purpose is in trouble, because there are many diffiiculties in preparing thin sections of volcanics for the microscopic study, while on the other hand it is also laboursome and much expensive both in time and in cost to analyse chemically numerous specimens of them.

Various interrelations concerning both physical and chemical properties of natural glasses, previously given by some investigators are sometimes of uncertainty and ambiguity with respect to their refractive indices, especially when discussed on the ground-masses or the natural glasses accompanying a large quantity of phenocrysts. Basing on the chemical and physical relationships of artificially meltd rock-glasses including every sort of constituents, it seems in consequence theoretically more suitable to presume the petrographic characters of volcanics. The author tried to melt rocks by the

flame of oxygen-gas in this paper.

II. PREVIOUS WORKS

By Tilley (1922) and George (1924), the physical and chemical relations of natural glasses, as were shown in some diagrams, were previously indicated to have been very clear and intimate. But, as pointed out by Dr. Kawano (1950) in his paper recently, the chemical compositions and the refractive indices of natural glasses seem sometimes indifferent with each other. In the data for the chemical compositions together with the refractive indices of a large number of ash stone and pumice around the Bay of Kagosima, given by Dr. Yamaguchi (1938a, b), their relationship was not referred to. His data have been examined by the author, but their relation in this case seems to be obscure, since the refractive indices of the natural glasses only have been measured in spite of almost always accompanying more or less amounts of phenocrysts.

It thus follows that some difficulty to attain the determinative results for the petrographic features of volcanics by simply measuring the refractive indices of the natural glasses is, in part, ascribable to the neglect for the coexisting phenocrysts. From these inspections, it is theoretically assumed that the refractive index of a natural glass representing a part of residual liquid of magma may have different values owing to the quantity of phenocrysts or to the difference of succeeding process of fractional crystalization. Unfortunately, no paper referring to this subject has been found by the author.

III. MELTING PROCEDURE

In this study, the procedure to melt the pulverized specimens of rocks in question directly by the flame of oxygen-gas was put into operation. As the burner for melting, an ordinary handburner used by the glassman is most convenient. Town-gas and oxygen derived from bombe were used for heating fuel and the samples were supported on the flat planes of some waste rock blocks.

Each specimen was powdered to about 200 mesh in such size as preferable for the chemical analyses. On the start, somewhat weak flame must be slowly approached to the small volume of the powder set on the sample holder. At first, a glassy film is appeared on the surface of powder. Afterwards, with supplying more oxygen, the temperature of the flame becomes over 1600°C. The specimen, though is easily melted, must be in the similar condition continuously melted in more a few minutes in order to make a homogeneous glass.

IV. Data of Some Tertiary Volcanic Rocks from the San-in District

In this paper were examined 32 specimens collected from the San-in district in the western Japan. The data for their chemical compositions and the refractive indices of the glass melted by this method are presented in Table 1. In Table 2 are described their localities. Within them, 24 specimens from No. 1 to 24 belong geologically to the same calc-Alkalic rock series of Tertiary in the San-in district. From the results

Table 1. The Refractive Indices and the Chemical Compositions.

No.	1	2	3	4	5	6	7
Ref.- indices of glass.	1.588 ±0.002	1.585 ±0.001	1.572 ±0.003	1.558 ±0.002	1.558 ±0.002	1.547 ±0.002	1.545 ±0.002
SiO_2	50.00	50.32	52.85	55.09	55.35	58.51	59.41
Al_2O_3	14.73	17.22	15.60	18.14	17.81	16.11	15.69
Fe_2O_3	5.20	4.32	4.43	6.59	5.58	1.85	2.99
FeO	7.49	5.44	4.02	2.38	3.57	5.01	4.72
MnO	n.d.	0.37	1.03	1.21	0.53	0.24	n.d.
MgO	4.31	4.55	3.22	2.89	2.33	2.98	3.17
CaO	10.06	9.40	11.08	7.33	7.81	8.51	7.50
Na_2O	1.71	4.52	2.24	2.66	3.48	1.94	2.06
K_2O	2.02	0.94	1.84	1.14	0.85	1.75	0.93
TiO_2	0.41	0.58	1.05	0.65	0.43	0.77	0.94
P_2O_5	n.d.	0.49	n.d.	n.d.	0.18	n.d.	n.d.
H_2O+	0.70	2.42	0.97	1.92	0.69	0.29	0.81
H_2O-	2.53		1.50	0.58	1.45	1.49	1.03
Total	99.16	100.57	99.83	100.58	100.06	99.45	99.25
Total Fe_2O_3	13.52	10.36	8.89	9.23	9.54	7.41	8.23
Total alkali	3.73	5.46	4.08	3.80	4.33	3.69	2.99

No.	8	9	10	11	12	13	14
Ref. -indices of glass.	1.537 ±0.002	1.534 ±0.001	1.526 ±0.002	1.523 0.002	1.523 ±0.003	1.518 ±0.002	1.514 ±0.001
SiO_2	59.83	66.13	65.65	59.48	65.25	68.26	70.74
Al_2O_3	17.37	14.88	11.75	15.99	12.88	12.40	13.99
Fe_2O_3	2.98	3.83	5.68	3.15	5.87	2.97	1.44
FeO	3.71	2.84	2.75	2.40	2.88	3.02	1.86
MnO	0.63	1.40	0.21	1.91	n.d.	0.35	0.23
MgO	1.62	0.48	1.33	1.47	4.64	3.40	0.41
CaO	7.33	3.39	4.71	2.56	1.56	1.03	1.97
Na_2O	4.20	3.30	3.10	6.35	2.46	2.93	4.25
K_2O	1.72	1.99	1.60	2.44	1.91	2.27	2.44
TiO_2	0.21	0.55	1.05	2.19	0.59	1.30	0.35
P_2O_5	0.35	n.d.	n.d.	0.46	n.d.	n.d.	n.d.
H_2O+	0.53	0.80	0.71	1.70	0.56	0.88	1.05
H_2O-	0.47	0.44	1.19		0.82	0.57	0.46
Total	100.95	100.03	99.73	100.10	99.42	99.38	99.19
Total Fe_2O_3	7.10	6.98	8.73	5.81	9.07	6.32	3.50
Total alkali	5.92	5.29	4.70	8.79	4.37	5.20	6.69

TABLE 1. (*continued*)

No	15	16	17	18	19	20
Ref.- indices of glass	1.513 ±0.001	1.498 ±0.002	1.498 ±0.002	1.497 ±0.002	1.492 ±0.002	1.489 ±0.002
SiO_2	64.98	70.14	74.94	71.32	71.98	71.69
Al_2O_3	14.88	16.36	11.02	14.66	14.42	13.11
Fe_2O_3	1.88	1.67	1.10	2.37	1.06	0.85
FeO	2.15	0.22	0.83	0.12	0.16	0.49
MnO	1.68	n.d.	0.63	n.d.	n.d.	n.d.
MgO	0.93	0.09	0.32	0.12	0.16	0.12
CaO	5.42	1.36	2.20	0.73	0.16	0.06
Na_2O	4.21	6.14	5.76	6.04	5.65	4.01
K_2O	0.94	1.05	1.11	1.08	2.30	4.12
TiO_2	1.83	n.d.	0.84	n.d.	n.d.	n.d.
P_2O_5	0.45	n.d.	0.19	n.d.	n.d.	n.d.
H_2O+ H_2O-	0.58	2.79	0.83	3.28	1.34	1.95
Total	99.93	99.82	99.77	99.72	100.23	99.40
Total Fe_2O_3	4.26	1.91	2.02	2.49	1.24	1.39
Total alkali	5.15	7.19	6.87	7.12	7.95	8.13

No.	21	22	23	24	25	26
Ref.- indices of glass	1.487 ±0.002	1.487 ±0.002	1.487 ±0.002	1.485 ±0.002	1.582 ±0.002	1.560 ±0.002
SiO_2	75.43	75.60	76.63	75.30	48.04	51.82
Al_2O_3	13.09	13.35	12.65	14.46	16.97	17.33
Fe_2O_3	1.57	0.59	0.66	0.89	4.47	7.70
FeO	0.29	0.15	0.19	0.15	4.51	1.91
MnO	n.d.	n.d.	n.d.	n.d.	0.30	0.27
MgO	0.11	0.20	0.17	0.11	7.59	3.51
CaO	0.12	0.18	0.12	0.32	7.40	6.67
Na_2O	4.73	4.31	3.93	5.40	5.36	5.50
K_2O	4.02	4.07	4.04	1.80	1.63	2.76
TiO_2	n.d.	n.d.	n.d.	n.d.	0.51	0.41
P_2O_5	n.d.	n.d.	n.d.	n.d.	0.49	0.71
H_2O+ H_2O-	0.98	0.90	1.75	1.85	1.01 1.47	0.31 1.74
Total	100.34	99.35	100.14	100.28	99.75	100.64
Total Fe_2O_3	1.89	0.76	0.87	1.06	9.48	9.82
Total alkali	8.75	8.38	7.97	7.20	6.99	8.26

TABLE 1. (*continued*)

No.	Ref.-indices of glass	SiO_2	No.	Ref.- indices of glass	SiO_2
27	1.582	50.71	30	1.493	74.24
28	1.498	71.84	31	1.492	76.20
29	1.497	74.00	32	1.487	75.82

obtained for 24 specimens, the diagrams of relation between the chemical compositions and the refractive indices are drawn on Fig. 1 and 2. Indices of 2 specimens of No. 25 and 26 belonging to the alkaline rock series of the Circum Japan Sea in the same district are measured to compare with the former. The other 6 specimens from 27 to 32, belonging to the former rock-series too, are examined to test whether or not their data are in good accordance with the standard SiO_2-index curve. The refractive indices were measured ordinarily with the usual immersion oil method through the electric light at the room temperature. The chemical compositions of the rocks were gravimetrically analysed. Five specimens such as No. 5, 8, 11, 16 and 18 of 32 were chemically analysed by Mr. Y. Nagaoka, and the other specimens by the author.

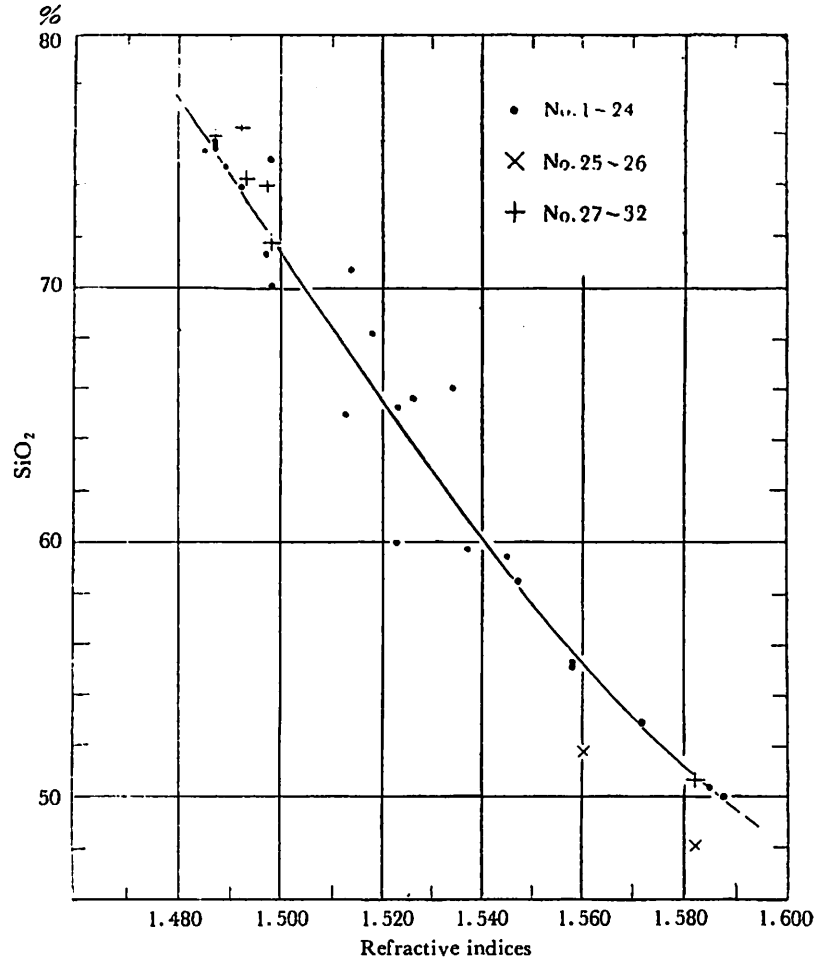

FIG. 1. The relation of the refractive indices to SiO_2

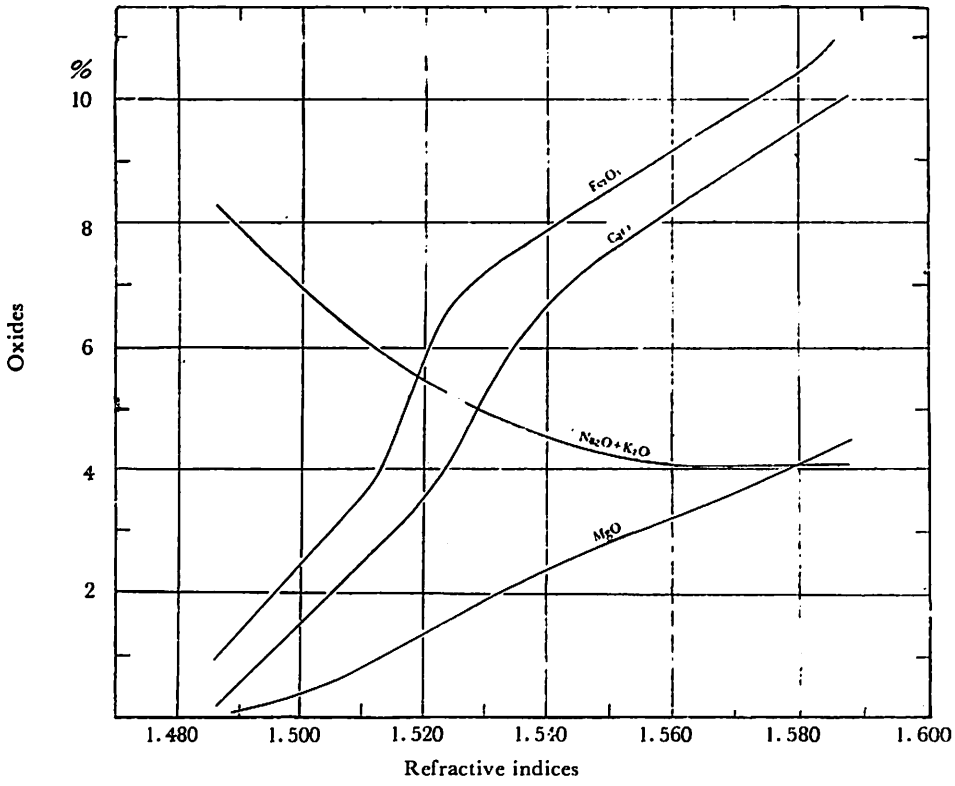

FIG. 2 The interrelations of The Refractive indices to some oxides

TABLE 2. THE LOCALITIES OF SPECIMENS

All specimens were collected from Shimane prefecture in the San-in district, western Japan.

1. Two pyroxene basalt; Kanetsuki, Hiebara-mura, Hikawa-gun.
2. Olivine bearing augite basalt; Atodani, Mitoya-chō, Iishi-gun.
3. Augite basalt; Yoshino, Kubota-mura, Hikawa-gun.
4. Augite basaltic andesite; Onya, Hata-mura, Iishi-gun.
5. Two pyroxene andesite; Kakeya-chō, Iishi-gun.
6. Two pyroxene andesite; Yahatabara, Kubota-mura, Hikawa-gun.
7. Two pyroxene andesite; Kentabara, Asayama-mura, Hikawa-gun.
8. Augite andesite; Yaeyama, Hata-mura, Iishi-gun.
9. Augite dacite; Maeneba, Hiebara-mura, Hikawa-gun.
10. Augite leucoandesite; Sugezawa, Oda, Kiku-mura, Hikawa-gun.
11. Two pyroxene andesite; Higashiiwasaka, Yagumo-mura, Yatsuka-gun.
12. Dacite; Mimigu, Asayama-mura, Hikawa-gun.
13. Dacite; Maki, Asayama-mura, Hikawa-gun.
14. Rhyodacite; Yaedaki, Hata-mura, Iishi-gun.
15. Dacitic andesite; Isotake, Isotake-mura, Nima-gun.
16. Rhyolite; Yamakuraji, Shizuma-mura, Nima-gun.
17. Rhyolite; Jitōsho, Isotake-mura, Nima-gun.

18. Rhyolite-breccia; Ōtoshi, Kawashimo-chō, Izumo-shi.
19. Rhyolite; Sarugahana, Shimoubeo, Mihonoseki-chō, Yatsuka-gun.
20. Rhyolite; Nima-chō, Nima-gun.
21. Rhyolite; ditto.
22. Rhyolite; ditto.
23. Rhyolite; ditto.
24. Rhyolite; Sarugahana, Shimoubeo, Mihonoseki-chō, Yatsuka-gun.
25. Olivine trachybasalt; Koshiwara, Matsue-shi.
26. Olivine augite basaltic andesite; Ichinari, Matsue-shi.
27. Basaltic tuff-breccia; Higashisusa-mura, Hikawa-gun.
28. Rhyolite tuff-breccia; Hōmanzan, Yagumo-mura, Yatsuka-gun.
29. Rhyolite tuff-breccia; Yamakuraji, Shizuma-mura, Nima-gun.
30. Rholite tuff; Bessho, Yagumo-mura, Yatsuka-gun.
31. Rhyolite tuff; Shimoubeo, Mihonoseki-chō, Yatsuka-gun.
32. Rhyolite tuff;Nima-chō, Nima-gun.

V. Consideration of the Results

From the diagrams of Fig. 1 and 2, their relations in question are considered as follows:
1) The values of the refractive indices of melted rock-glasses are reverse to the contents of SiO_2 and this relationship constructs a most smooth relation curve, apparently being linear.
2) Those are parallel to each contents of MgO, CaO and total Fe_2O_3 and their interrelation is nearly intimate with each other.
3) Those are reverse to the contents of total alkali and their interrelation is about close.
4) Because of the unsignificant relation of indices to the contents of Al_2O_3, it is not presented on the graph.
5) All the refractive indices of 3 specimens of basalt are over 1. 57.
6) Among 6 specimens of two pyroxene andesite, those for 5 ones range in 1.57 to 1.53, but the index of the remainder is little smaller, 1.523.
7) Among 6 specimens of dacitic andesite and dacite, those for 5 ones range in 1.53 to 1.51, but the index of the remainder is little larger 1.534.
8) Those for 9 rhyolites are all under 1.50.

Then the points representing the other 6 specimens from No. 27 to 32, measured to discuss the standard SiO_2-index curve of Fig. 1, fall closely near the curve. On the other hand, the points of 2 specimens of the alkaline rock, though the number studied may be too few, fall somewhat far from the curve and their values of indices seem to be smaller against those of the corresponding rocks of the calc-alkalic rock series. Therefore, it may be concluded that the relation curves for different rock-series are accountably different from each other.

VI. Summary

As the relation curves have been drawn from the results for 24 specimens, they may

be statistically insufficient. So the data of a large number of specimens separated to each rock-series must be added in the future. But from the present results, it can be recognized clearly that the refractive indices of rock-glasses melted artificially and the values of silica contents relate most intimately. Therefore, petrographic characters of certain volcanics belonging to the calc-alkalic series are able to be determined roughly but rapidly by using the silica-index relation curve of Fig. 1. Furthermore, the melting procedure using the flame of oxygen-gas is very simple and not expensive, so it can be easily utilized by everyone.

VII. ACKNOWLEDGMENTS

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