THE RELATION BETWEEN COLOUR AND CHEMICAL COMPOSITION IN THE BIOTITES

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Abstract

The results of plotting the analyses of many biotites indicate that the colours of the more common biotites are dependent upon their relative contents of iron, magnesia and titania. Iron is responsible for producing the green colours of biotites, while titania gives the brown and red colours. Magnesia appears to be able to dilute or mask the colour effect produced by titania.

During a study of metamorphic biotites the author was led to certain conclusions as to the relation between the colour and the chemical composition of the biotites. In order to confirm these conclusions, the analyses of as many similar biotites as possible were collected from the literature of the past thirty years and plotted together with the biotites analyzed by the author.

The biotites chosen for this study all contain FeO in excess of Fe_2O_3, while their MnO content is not in excess of 0.50%. In most cases the Cr_2O_3 content has not been reported, but where it is given, as in the case of some of Grout's biotites, it is very small. The oxides used for plotting on the triangular diagram in Fig. 1 are TiO_2, total FeO (Fe_2O_3+FeO all expressed as FeO) and MgO. The percentage values of these oxides will be found in Table 1, together with the pleochroic colour of γ, and the name of the author whose analysis has been used. Several more biotite analyses might have been taken from recent literature were it not for the unfortunate fact that so many authors neglect to state the pleochroic colours with their analyses. Sixteen analyses were carried out on material collected by the author, which, it is hoped, will be published fully later.

According to Heddle's (18) definition of biotite, haughtonite and lepidomelane, the proportion of FeO:Fe_2O_3 in haughtonite is 4:1, in biotite 25:1 and in lepidomelane 1:9. The majority of the micas given in Table 1 vary between haughtonite and true biotite, while those containing large amounts of MgO and low FeO grade towards phlogopites, and those with little or no MgO are siderophyllites.

From the consideration of the triangular plot of the oxides given in Fig. 1 the author was led to the conclusion that the red-brown colour of many of the biotites was due to their high titania content. Some of the brown biotites, however, contain as much or more titania than some of the red-brown ones, but also contain more magnesia. It is therefore suggested that the magnesia has the effect of diluting or masking the colour produced by the titania. In a spectroscopic study of the colour of tourmaline, Warner (19) has found that magnesia has no influence upon the colours produced by iron and manganese in this mineral, but it would appear that in the biotites a high magnesia content has the effect of masking the colour due to titania.

The blue-green biotites described by some authors (see Table 1) owe their colour solely to their iron content, since they have little or no titania. Greenish-brown biotites, on the other hand, may be produced in two different ways. In the case of Woodland's biotite from Hendre, there is a high iron content accompanied by some titania and low magnesia. Greenish-brown biotites at the other end of the field have a low iron content with sometimes an appreciable amount of titania masked by high magnesia. The intensity of colour of these latter biotites is much less than that of the former.

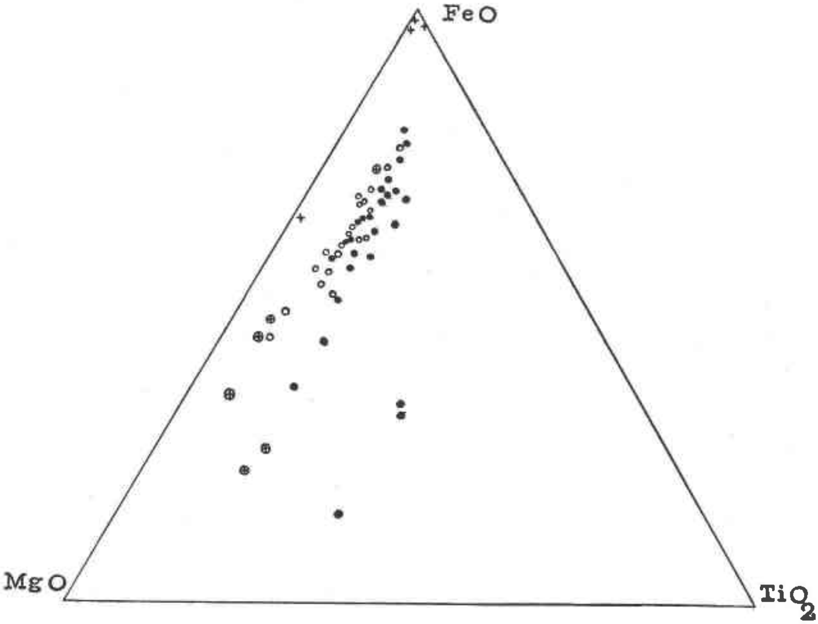

FIG. 1. Triangular plot of total FeO-TiO_2-MgO for the biotites.
+ = green or blue green. ⊕ = brownish green.
○ = brown. ● = red brown or red.

Freudenberg's wodanites and Prider's titano-phlogopite will be seen to occupy positions towards the centre of the diagram in Fig. 1, which they hold by reason of their high content of titania. Beyond a certain amount of titania, the red or red-brown colour will still be maintained even though the magnesia is high.

TABLE 1

No.	Author	Fe_2O_3	FeO	Total FeO	TiO_2	MgO	Colour of γ
1	Nockolds[1]	0.79	20.98	21.69	0.21	0.46	blue-green
2	Harada[2]	1.55	25.50	26.90	—	0.54	green
3	Kranck[3]	9.12	21.62	29.83	tr	0.72	blue-green
4	Phillips[4]	7.37	11.25	17.88	0.23	9.84	blue-green
5	Phillips[4]	1.73	13.23	14.79	1.72	14.93	greenish brown
6	Grout[5]	7.44	7.72	14.42	1.67	16.55	green
7	Brauns[6]	2.02	6.77	8.59	5.14	19.61	greenish brown
8	Kranck[7]	1.46	6.02	7.33	4.90	20.88	greenish brown
9	Hall*	3.33	6.73	9.73	1.66	17.00	brownish green
10	Woodland[8]†	7.24	21.04	27.54	2.85	7.44	brownish green
11	Grout[5]	1.14	23.75	24.78	2.73	6.16	brown
12	Grout[5]	3.03	23.23	25.96	3.32	9.24	brown
13	Grout[5]	4.05	14.80	18.44	2.23	10.21	brown
14	Hess[9]	2.26	14.81	16.84	2.64	8.45	deep brown
15	Seidel[10]	4.88	16.92	21.41	2.63	7.91	brown
16	Seidel[10]	3.96	10.12	13.68	1.95	15.21	brown-yellow
17	Tsuboi[11]	4.49	15.00	19.04	3.29	11.80	dark sepia brown
18	Tsuboi[11]	3.37	20.15	23.18	2.77	7.20	dark brown
19	Tsuboi[12]	2.95	18.87	21.53	3.07	9.52	Vandyke brown
20	Tsuboi[12]	3.00	18.83	21.53	3.15	9.61	Vandyke brown
21	Tsuboi[12]	1.86	26.17	27.84	3.64	5.16	Vandyke brown
22	Seidel[10]	3.03	12.45	15.18	1.86	13.78	yellow brown
23	Deer[13]	3.22	19.94	22.84	3.48	8.23	yellow brown
24	Deer[13]	2.48	19.07	21.30	3.63	11.62	yellow brown
25	Hall*	2.79	14.26	16.77	3.90	11.28	brown
26	Hall	2.59	14.40	16.73	2.95	11.42	brown
27	Hall*	2.79	14.84	17.34	2.20	11.13	brown
28	Hall	2.73	17.08	19.54	3.74	8.70	brown
29	Hall	3.46	16.92	20.04	4.21	8.52	brown with reddish tinge
30	Hall	1.62	16.02	17.48	4.59	12.05	reddish brown
31	Tsuboi[11]	1.00	20.09	21.99	2.52	8.03	brown with reddish tinge
32	Tsuboi[14]	2.10	26.80	28.69	3.33	4.98	mars brown
33	Tsuboi[12]	.77	21.42	22.11	3.28	6.40	madder brown
34	Tsuboi[12]	.69	18.11	18.73	2.99	8.80	etruscan red
35	Tsuboi[12]	.76	18.39	21.48	4.86	11.90	English red
36	Tsuboi[12]	.87	21.10	21.88	3.29	8.71	madder brown
37	Tsuboi[12]	.87	20.88	21.66	3.53	8.08	orange rufous
38	Tsuboi[12]	.27	19.46	19.70	4.07	7.86	burnt orange
39	Tsuboi[12]	.68	16.88	17.49	2.65	9.78	orange rufous
40	Tsuboi[12]	1.05	26.34	27.28	3.79	5.51	madder brown
41	Seidel[10]	4.70	17.09	21.32	3.22	10.00	red brown
42	Chapman[15]	nil	15.52	15.52	5.22	14.23	deep red brown
43	Chapman[15]	8.00	23.54	30.74	2.94	4.97	chestnut brown
44	Deer[13]	2.90	18.30	20.91	3.99	10.42	reddish brown
45	Hall	1.42	19.27	20.55	4.99	9.78	red brown
46	Hall*	1.03	20.56	21.49	3.05	8.62	pale red brown
47	Hall	2.60	19.17	21.51	3.68	6.00	red brown
48	Hall	1.83	21.54	23.19	3.52	6.20	red brown
49	Hall	2.39	20.99	23.14	4.31	6.14	red brown
50	Hall*	3.16	20.34	23.18	4.01	7.34	red brown
51	Hall	1.51	20.53	21.89	5.27	7.28	red brown
52	Hall*	3.05	22.06	24.81	5.40	6.59	red brown
53	Nockolds	1.53	10.97	12.35	5.08	16.87	red brown
54	Freudenberg[16]	1.01	11.09	12.00	12.02	13.11	red brown
55	Freudenberg[16]	3.09	10.63	13.41	12.56	13.80	red brown
56	Prider[17]	2.18	3.73	5.69	12.02	19.66	reddish brown

* Analyst: N. Sahlbom.
† Analyst: A. J. Hall.

It is hardly to be expected that the colour of such a complex system as the biotites could be easily explained by such a simple theory as that given above, but it will be seen from Fig. 1 that the results are sufficiently good to justify the assumption that the theory is fairly correct. In considering the relation of chemical composition to colour in the biotites, it is not the absolute amount of any oxide present which produces the colour effect, but the proportion of that oxide to those of the others present. Thus, red-brown biotites are generally high in titania and iron and low in magnesia, but, if the proportion of titania is sufficiently high, the biotite will still be red-brown even though the magnesia is high and the iron low.

We may draw the further conclusion from the diagram (Fig. 1) that colour is very little real indication of the composition of a biotite. This will become evident if we tabulate the results of Fig. 1 as follows:—

Red-brown biotite=	High TiO_2+high FeO+low MgO
	High TiO_2+low FeO+high MgO
Blue-green biotite=	High FeO$-TiO_2$+low MgO
	$MgO \neq FeO - TiO_2$
Greenish-brown biotite=	High FeO+low TiO_2+low MgO
	Low FeO+TiO_2+high MgO
Brown biotite=	High FeO+low TiO_2+low MgO
	FeO=MgO+low TiO_2

It will be seen that each of the various colour varieties of biotite may be formed in two different ways. It will also appear from the above that the colour effect produced by titania is dominant over that produced by iron unless titania is masked by a large amount of magnesia.

It is rather difficult to discover whether iron present as Fe_2O_3 has any influence on the colour of biotite as distinct from that present as FeO, since no analyses are reported containing Fe_2O_3 only without much FeO or TiO_2. It will be observed, however, that Kranck's siderophyllite contains 9.12% Fe_2O_3 and is still bluish-green. The micas described by Jakob (20) and Magnusson (21) from Långban appear to owe their red-brown colour to their manganese content, since they are high in MnO and low in FeO and TiO_2. These are somewhat exceptional micas, and in general it may be said that biotite does not contain sufficient manganese for this element to have any effect upon the colour, and no doubt the same is also true of chromium.

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