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Niobian titanite and eudialyte from the Ilomba nepheline syenite complex, north Malawi

DURING a chemical and mineralogical study of the Ilomba nepheline syenite complex, northern Malawi, titanites have been found which contain up to 11% by weight of Nb_2O_5. Bloomfield *et al.* (1981) described titanite separated from aegirine pegmatite at Ilomba with 3.22% Nb_2O_5, which they considered to be the highest values of niobium recorded for this mineral. As discussed by Deer *et al.* (1982), the position of Nb in titanite is uncertain but the chemical data presented here indicate that it must replace titanium in the octahedral sites, and thus plays a similar role to the tantalum in a tantalum-rich variety of titanite described by Clark (1974).

The specimen containing the titanite was collected by Bloomfield from southwest of the summit of Ilomba and is now in the collection of the Natural History Museum, London—number BM 1987, P6(75). The rock is a foliated nepheline syenite comprising perthite, nepheline and agerine with accessory titanite, eudialyte, zircon, pyrochlore and carbonate. The titanites occur as abundant but small (generally <0.1 mm), discrete crystals.

Analyses were made using a Cambridge Instruments Microscan 9 wavelength-dispersive microanalyser operated at 20 kV with a specimen current of 25 nA. A selection of analyses is given in Table 1. Nb_2O_5 values vary from 1.9% to 11.12% by weight, with all the lower values found

Table 1
Analyses of niobian titanite

SiO_2	29.04	29.12	29.03	28.77
TiO_2	29.51	27.15	26.28	32.17
ZrO_2	1.42	1.58	1.65	1.58
Nb_2O_5	7.84	9.91	11.12	5.88
Ta_2O_5	0.15	0.17	0	0.24
Al_2O_5	0.37	0.39	0.35	0.22
Fe_2O_3	2.86	3.16	3.12	2.60
MnO	0.11	0.08	0.14	0.14
CaO	26.15	25.33	24.72	26.79
SrO	0.13	0.20	0.16	0.14
Na_2O	0.71	1.07	1.29	0.89
F	0.40	0.24	0.45	0.25
	98.69	98.40	98.33	99.67
O=F	0.17	0.10	0.19	0.10
Total	98.52	98.30	98.14	99.57

Numbers of ions on the basis of 5 oxygens

Si	0.997	1.000	1.007	1.007	1.009	1.009	0.976	0.985
Al	0.003		-		-		0.009	
Al	0.012		0.016		0.014		-	
Fe^{3+}	0.074		0.082		0.082		0.066	
Ti	0.762	0.995	0.706	0.988	0.687	0.986	0.821	1.005
Nb	0.122		0.155		0.175		0.090	
Ta	0.001		0.002		0.000		0.002	
Zr	0.024		0.027		0.028		0.026	
Mn	0.003		0.002		0.004		0.004	
Na	0.047	1.015	0.072	1.017	0.087	1.015	0.059	1.040
Ca	0.962		0.939		0.921		0.974	
Sr	0.003		0.004		0.003		0.003	
F	0.043		0.026		0.049		0.027	

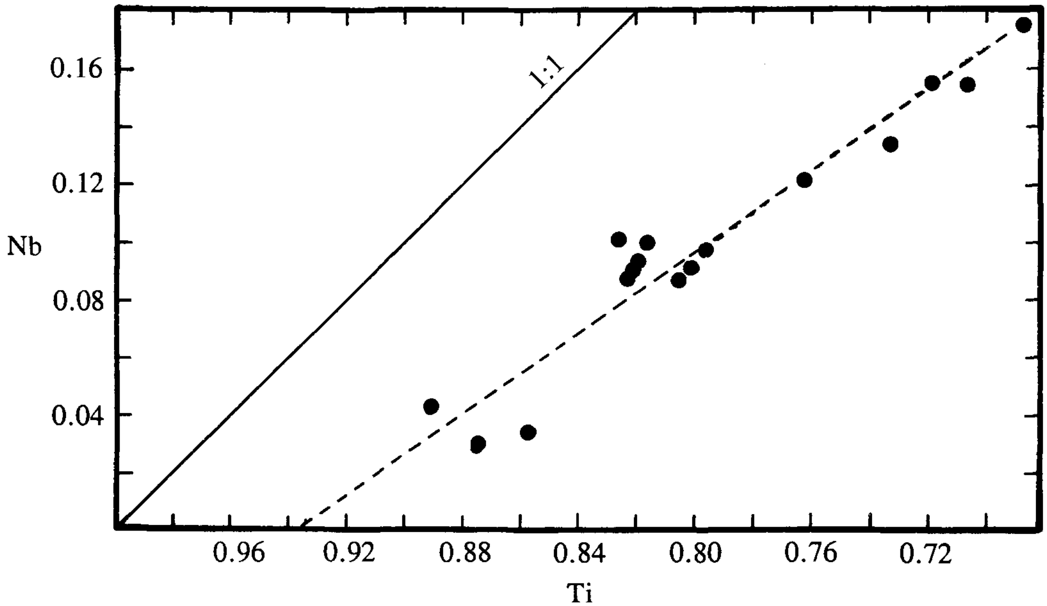

FIG. 1. Plot of Nb against Ti (atoms) for Nb-rich titanite. A strong correlation is apparent. The Nb must occupy the octahedral sites, although there is not sufficient Nb to account for all the deficiency in Ti.

in the cores of crystals and the higher ones close to crystal margins. Tenors of zirconium are also consistently high with values up to 2.67%, while iron, calculated as Fe_2O_3, is always >1% and may be >2.5%. There is a strong correlation between niobium and titanium, illustrated by Fig. 1, indicating that the niobium must be occupying the octahedral sites. Although the titanium clearly decreases as niobium increases there is insufficient niobium alone to fill the octahedral sites, and even after the addition of aluminium and iron this site is still apparently not fully occupied. Although the position of Zr is considered to be uncertain (Deer *et al.*, 1982) its assignment to the *Y* position, as followed by Sahama (1946), results in a better balance. Following Clark (1974) Ta is also assigned to the *Y* position.

The presence of such an abundance of Nb in the Ilomba titanite must reflect a high Nb activity in the primary melt, and this is also indicated by the presence of pyrochlore and eudialyte which is unusual in containing >3.5% Nb_2O_5. An analysis of the eudialyte is given in Table 2.

This unusual Nb-rich magmatic environment is reflected in the whole-rock chemistry of the sodalite and nepheline syenites in which Nb/Ta ratios vary from 40 to 60, compared with Nb/Ta ratios of 15–20 typical of most igneous rocks (Woolley *et al.*, in prep.). Such ratios are more typical of carbonatites and given the nearby presence of the Nachendezwaya carbonatite complex in Tanzania may suggest a linkage between these intrusions.

Table 2
Analysis of niobium-bearing eudialyte

SiO_2	48.34	Number of ions on the basis of 19 oxygens		
TiO_2	0.02			
ZrO_2	11.42			
Nb_2O_5	3.56	Si	6.288	
FeO*	1.75			
MnO	6.50	Ti	0.002	0.726
CaO	15.04	Zr	0.724	
Na_2O	8.80			
Y_2O_3	0.54	Nb	0.209	
La_2O_3	0.74	Fe^{2+}	0.190	1.115
Ce_2O_3	0.64	Mn	0.716	
Pr_2O_3	<0.15			
Nd_2O_3	<0.12	Na	2.219	
Sm_2O_3	0.07	Y	0.037	
Gd_2O_3	<0.15	La	0.036	4.418
ThO_2	<0.1	Ce	0.030	
UO_2	<0.1	Sm	0.000	
Cl	2.02	Ca	2.096	
	99.44			
		Cl	0.363	
O=Cl	0.44			
Total	99.00			

* all iron determined as FeO.

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