

K-poor titanian fluor-richterite from near Nullagine, Western Australia

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ABSTRACT

Strongly zoned amphibole formed of titanian fluor-richterite cores with 2.24% TiO₂ and margins of titanian ferro-richterite with 6.65% TiO₂ is described from a basaltic andesite. The cores are richer in F, Al, Mg, and Ca than the edges, which are richer in OH, Ti, Fe, Na, and K. Similar sodic-calcic amphiboles are widely known to appear in lamproites, but typically they contain 5% or more K₂O, whereas the present sample reaches a maximum of 1.18% K₂O at the margin. As is characteristic of titanian potassium richterite, there is Ti in tetrahedral coordination and a pink to yellow pleochroism. Ba, Sr, Li, B, Cl, Be, Nb, La, Ce, Pr, Y, V, and Zr contents are given. Zoned augite with Ca₄₂Mg₄₂Fe₁₆ cores and Ca₄₃Mg₃₅Fe₂₂ rims is also present, plus chloritic material and feldspar.

INTRODUCTION

In a lava flow of basalt or basaltic andesite near Wild Dog Well, on the Roy Hill (no. SF-12) 1:250 000 sheet of the Geological Survey of Western Australia, about 25 km southwest of Nullagine (119°47' E, 22°8' S), a strongly yellow to pink amphibole has been discovered that is related to the titanian potassium richterite common in lamproites, but with much lower K than previously known for titanian richterite or ferro-richterite.

MINERALS

The rock is a fine-grained aggregate (grain size <0.1 mm) of (1) 40% euhedral to subhedral colorless augite, (2) 40% green (or, where oxidized, brown) fine-grained composite Fe-rich chloritic material, possibly an alteration product of glass and phenocrysts, and often amorphous and turbid, (3) 15% a solid solution of sodium potassium feldspar in composite grains that show plumose extinction, (4) 5% amphibole with the characteristic yellow-reddish pink pleochroism of titanian potassium richterite, and (5) accessory carbonate, apatite, opaque patches of Mg-poor ilmenite and rare ferro-actinolite. The chemical analysis of the rock (Table 1) corresponds to basaltic andesite according to the IUGS classification (Le Maitre, 1989).

The augite is zoned with cores higher in Al, Mg, and Cr and margins richer in Ti, Fe, and Na (Table 1), which makes it significantly different from normal lamproite diopside (Mitchell and Bergman, 1991).

The amphibole, which is usually interstitial or occasionally poikilitic, has pale cores, dark pink to pale red

rims (α very pale pink, almost colorless; β yellow; γ pink to pale red, especially at the margins of grains). The centers of the grains are titanian fluor-richterite (Leake, 1978) and rich in F, Al, Mg, Ca, and Cr, whereas the margins are titanian ferro-richterite and richer in OH, Ti, Fe, Na, K, and possibly Mn (Table 1). The maximum K₂O reaches 1.18 wt% at the edge of some grains; most of the amphibole has about 1 wt% K₂O. As there is a great deal of irregular variation due to the zoning, Table 1 includes the core and edge of one typical grain (AM1), the average of 50 apparent cores (AM-Av. C), and the composition of the margin of the grain richest in Ti (AM-Ex. E), together with an analysis of a minute grain of ferro-actinolite (Fe-Act) at the edge of one titanian ferro-richterite.

It is notable that, apart from F and K, which do not usually enter pyroxene, the zoning (Al, Ti, Fe, Mg, Cr, and Na) in the pyroxene matches that in the amphibole. This, together with the lack of replacement of augite by amphibole, suggests that both minerals formed in equilibrium with a cooling fractionating magma or fluid system. Although the compositional variation of amphibole zoning is always the same, the edges of grains vary widely in composition; hence crystal growth must have ceased at varying stages during fractionation.

The F distribution is particularly irregular, but F is certainly lower in the edges than in the cores of the grains. This is consistent with the findings of Della Ventura et al. (1993) that the Ti content of titanian potassium richterite is positively correlated with the OH content and negatively correlated to the F content. No attempt has been made to calculate Fe₂O₃, as none of the present methods is very reliable.

TABLE 1. Chemical analyses of pyroxenes, amphiboles, and rock WA 4918

| | PX-C | PX-E | AM1-C | AM1-E | AM-Av. C | AM-Ex. E | Fe-Act | ROCK |
|--------------------------------|--------------|-------|-------------------------|-------|----------|----------|---------------|----------|
| SiO ₂ | 52.06 | 51.89 | 50.94 | 50.74 | 50.98 | 50.50 | 50.25 | 51.80 |
| Al ₂ O ₃ | 0.87 | 0.52 | 2.08 | 0.99 | 2.08 | 1.07 | 1.24 | 8.35 |
| TiO ₂ | 0.39 | 0.75 | 2.72 | 5.44 | 2.24 | 6.65 | 0.03 | 1.18 |
| Fe ₂ O ₃ | | | | | | | | |
| FeO* | 9.92 | 12.98 | 12.94 | 18.63 | 11.55 | 18.13 | 21.65 | 14.80 |
| MnO | 0.20 | 0.21 | 0.16 | 0.17 | 0.15 | 0.15 | 0.37 | 0.20 |
| MgO | 14.89 | 11.70 | 14.65 | 9.29 | 15.98 | 8.99 | 9.43 | 7.27 |
| CaO | 20.66 | 20.48 | 6.98 | 4.36 | 7.20 | 4.29 | 12.04 | 8.93 |
| Na ₂ O | 0.41 | 0.96 | 6.00 | 7.15 | 6.25 | 7.03 | 0.21 | 2.28 |
| K ₂ O | 0.00 | 0.00 | 0.97 | 1.09 | 0.95 | 1.18 | 0.08 | 1.19 |
| P ₂ O ₅ | | | | | | | | 0.20 |
| Cr ₂ O ₃ | 0.15 | 0.03 | 0.03 | 0.00 | 0.03 | 0.00 | 0.00 | 0.01 |
| H ₂ O | | | 0.20 | 0.80 | 0.20 | 0.80 | | |
| F | | | 3.38 | 0.63 | 2.93 | 0.00 | | |
| Cl | | | 0.00 | 0.00 | 0.00 | 0.00 | | |
| O = F | | | -1.42 | -0.26 | -1.23 | 0.00 | | |
| Total | 99.55 | 99.53 | 99.63 | 99.03 | 99.31 | 98.79 | 95.30 | 100.35** |
| | Ions per 6 O | | Ions per 24 (O,OH,F,Cl) | | | | Ions per 23 O | |
| Si | 1.96 | 1.98 | 7.54 | 7.77 | 7.53 | 7.75 | 7.79 | |
| ⁽⁴⁾ Al | 0.04 | 0.02 | 0.36 | 0.17 | 0.36 | 0.19 | 0.21 | |
| ⁽⁶⁾ Al | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | |
| Ti | 0.01 | 0.02 | 0.30 | 0.62 | 0.25 | 0.76 | 0.00 | |
| Cr | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| Fe ³ | | | | | | | | |
| Fe ² | 0.31 | 0.41 | 1.60 | 2.38 | 1.47 | 2.32 | 2.81 | |
| Mn | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.05 | |
| Mg | 0.83 | 0.66 | 3.23 | 2.12 | 3.51 | 2.06 | 2.18 | |
| Ca | 0.83 | 0.84 | 1.10 | 0.72 | 1.14 | 0.70 | 2.00 | |
| Na | 0.03 | 0.07 | 1.72 | 2.12 | 1.79 | 2.09 | 0.06 | |
| K | 0.00 | 0.00 | 0.19 | 0.21 | 0.18 | 0.23 | 0.02 | |
| OH | | | 0.20 | 0.80 | 0.20 | 0.82 | | |
| F | | | 1.58 | 0.63 | 1.37 | 0.00 | | |
| Cl | | | 0.00 | 0.00 | 0.00 | 0.00 | | |
| O | | | 22.22 | 22.89 | 22.44 | 23.18 | 23.00 | |
| | At% | | | | | | | |
| Ca | 42 | 43 | T 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | |
| Fe | 16 | 22 | C 5.05 | 5.08 | 5.14 | 5.10 | 5.06 | |
| Mg | 42 | 35 | B 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | |
| Mg' | 0.72 | 0.61 | A 1.01 | 1.05 | 1.11 | 1.02 | 0.08 | |
| | | | 0.66 | 0.47 | 0.71 | 0.47 | 0.43 | |

Note: Mg' = Mg/(Mg + Fe + Mn); PX = pyroxene; AM = amphibole; C = center; E = edge; Av. = average; Ex. = extreme; Fe-Act = ferro-actinolite. Rock analysis by XRF by Analabs, Welshpool, Western Australia. H₂O, in amphiboles by ion probe, is only approximate ($\pm 30\%$). PX-C and PX-E each an average of 15 analyses; AM-Av. C of 50 analyses and the remaining mineral analyses are each an average of six analyses. T = total tetrahedral site cations, C = total octahedral site cations, B = total M4 site cations, and A = total A site cations.

* Total Fe as FeO.

** Includes 0.01% BaO, loss on ignition 3.41%.

DISCUSSION

Mitchell (1985) and Mitchell and Bergman (1991) have reviewed the mineral assemblages of lamproites, in which titanian potassium richterite often occurs. The present sample is unusual in the extent of the Ca, Fe, Na, and Ti enrichment, combined with the relative paucity of K. The usual trend (Mitchell, 1985) in lamproites from West Kimberley, Western Australia, is for Na, Fe, and Ti enrichment with K and Mg decreasing outwards, whereas the present samples (although invariably much richer in Na than K) show increasing K from center to margin. As is typical for titanian potassium richterite, there is insufficient Si + Al to fill the tetrahedral sites, and Ti⁴⁺ must occur in tetrahedral sites, as shown by Oberti et al. (1992) and recently confirmed by Della Ventura et al. (1993).

Again, as in typical titanian potassium richterite, the A and B sites are filled or even slightly exceed 3.00 ions. None of the present analyses is alkali amphibole, a clear distinction from the K-poor amphiboles of the Pendennis minette (Hall, 1982) and the Mount Bayliss lamproite (Mitchell and Bergman, 1991). Venturelli et al. (1991) claimed titanian potassium richterite from the Jumilla lamproite, Spain, had the lowest known K-Na ratio (of 0.29), but the present samples are about three times lower at 0.09–0.10. Prider's (1939) original analyses of titanian potassium richterite (which he called magnophorite) show significant Ba and Sr, "Sr-rich potassic richterite" has been described by Mottana and Griffin (1986), and strontium richterite has been synthesized and described by Della Ventura and Robert (1990). Ion microprobe analysis of

the cores of the present amphibole using NBS-610 glass as a standard show about 10 ppm Ba, 60 ppm Sr, 1 ppm Li, 2 ppm B, 2 ppm Be, 8 ppm Y, 30 ppm Nb, 21 ppm La, 53 ppm Ce, and 7 ppm Pr; Zr and V were not detected on the electron microprobe.

Titanian richterite is not necessarily K-rich, but it still has the characteristic yellow to pink pleochroism of the more common K-rich variety.

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