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Optical, X-ray, and chemical analysis of four eudialytes from Alaska

FOUR eudialyte samples from Alaska were studied to determine their optical, X-ray, and chemical properties. These data are useful in helping to document the overall correlation between optical properties and crystal chemistry of the chemically complicated eudialyte group. No definite correlations could be found, although an overall trend does exist. This is probably the result of the complicated chemistry and chemical substitutions that occur in this mineral group (Johnson *et al.*, 1990). Positive eudialytes have lower refractive indices than negative eudialytes, sometime referred to as 'eucolite' (a variety name only, which should not be considered a separate mineral, E. H. Nickel, IMA, pers. comm., 1991). ω increases at a faster rate than ε; thus, for a change in optic sign, ω and ε must become equal, resulting in near-isotropic eudialytes. This has been observed and is called 'mesoeudialyte'. Recently, Pol'shin *et al.* (1991) also attempted to determine the crystal chemical reasons for positive and negative eudialytes by correlating them to the spectroscopic behaviour of Fe^{2+}.

Three of the eudialyte samples are from the north-central Alaska Range; the other is from southeast Alaska, about 1400 km away (Fig. 1). Of the three Alaska Range samples, two are from the Middle Fork plutonic complex (MFPC) and is one from the Windy Fork plutonic complex, which is about 8 km southeast of the MFPC. Both of these localities are associated with silica-saturated plutons, whereas the fourth sample, from Prince of Wales Island, is from a silica-undersaturated pluton.

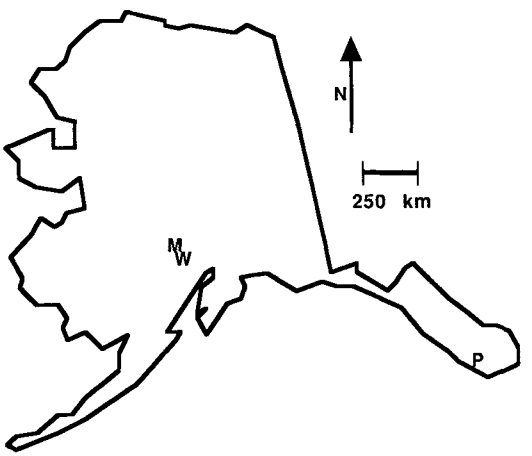

FIG. 1. Map of Alaska showing location of eudialyte samples. 'M' is the Middle Fork plutonic complex, 'W' is the Windy Fork pluton, only 8 km southeast of the Middle Fork, and 'P' is the Prince of Wales Island pluton in southeast Alaska.

Middle Fork Plutonic Complex. The early Tertiary (57 m.y.) MFPC consists of coeval syenite, peralkaline alkali feldspar granite, metaluminous granite, diorite, and gabbro, hosted by thinly bedded Palaeozoic calc-phyllites and marbles (Solie, 1988; Solie and Sinha, 1988; Gilbert *et al.*, 1989). The eudialyte-bearing specimen was found in talus in the contact zone between cogenetic fayalite–hedenbergite–syenite and peralkaline alkali feldspar granite near the southern

Table 1: Optical, X-ray, and chemical data for eudialyte

	Middle Fork(B)*	Middle Fork(P)*	Prince of Wales	Windy Fork
SiO_2	50.1	51.9	50.9	51.9
TiO_2	0.15	0.78	0.93	0.56
Al_2O_3	0.53	0.16	0.12	0.08
FeO	6.9	6.5	6.5	6.5
MnO	1.5	0.84	0.64	0.24
MgO	0.01	0.03	0.01	0.06
CaO	8.7	11.7	12.0	12.8
Na_2O	15.5	13.6	14.0	14.6
K_2O	0.43	0.84	0.77	0.37
ZrO_2	11.0	10.1	9.9	10.5
Y_2O_3	1.4	0.4	0.62	0
Ce_2O_3	0.3	0.2	0	0
Cl	2.17	2.52	2.55	2.62
$-O=Cl_2$	0.48	0.56	0.56	0.58
Total	98.2	99.0	98.4	99.7
ω	1.6057(2)	1.6061(1)	1.6032(2)	1.6062(2)
ε	1.6083(2)	1.6099(2)	1.6066(2)	1.6138(3)
a(Å)	14.2429(5)	14.2473(4)	14.2421(6)	14.2459(3)
c(Å)	30.031(1)	30.043(1)	30.051(3)	30.023(1)

* (B) refers to the brown samples and (P) refers to the pink samples of eudialyte from the Middle Fork pluton.

margin of the plutonic complex. Metasedimentary host-rock comprises part of the specimen and suggests that the eudialyte is in a dyke which intruded the country rock near the southern contact of the MFPC. There is little or no quartz in the sample, implying a closer genetic relationship with syenite than with adjacent peralkaline granite. Two distinct populations of eudialyte were separated from the sample based upon colour differences (pink and brown). In addition to about 5 percent eudialyte, the mineralogy includes alkali feldspar (some with microcline twinning), clinopyroxene, aenigmatite, minor plagioclase, and carbonate.

Windy Fork pluton. The peralkaline Windy Fork pluton and the MFPC are hosted by the same Palaeozoic metasedimentary sequence. Although the Windy Fork alkali feldspar granite is mineralogically and compositionally similar to the peralkaline alkali feldspar granite of the MFPC, the Windy Fork granite is younger (about 30 m.y.; Reed and Lanphere, 1972). The eudialyte-bearing sample is from a vertical dyke, 25–30 cm wide, which cross-cuts host rock foliation, tens of metres from the pluton margin. A K–Ar age determination on aegirine–augite from this dyke yielded a result of 23.5 m.y. (Gilbert *et al.*, 1989). The dyke contains up to 10% eudialyte which is distributed irregularly in clumps and bands parallel to dyke margins. Other minerals include quartz, perthitic alkali feldspar, bright green to olive green pleochroic blades of aegirine–augite, and minor orange–red aenigmatite.

Prince of Wales Island. The eudialyte-bearing sample is from the head of Dora Bay in the southeastern part of Prince of Wales Island. The sample is from a eudialyte-bearing phase within hornblende syenite (M. A. Wiltse, pers. comm., 1988). The syenite is mapped as Mesozoic and/or Palaeozoic nepheline–eudialyte-bearing syenite and associated pegmatite, hosted by pre–middle Ordovician/Precambrian greenschists, quartz-

sericite schists, and marbles of the Wales group (Eberlein *et al.*, 1983). The specimen contains eudialyte, alkali feldspar, plagioclase, nepheline, hornblende with blue–green, olive green, and brown pleochroism, clinopyroxene with bright to pale green pleochroism, orange–brown biotite, and fluorite.

Optical analysis. The refractive indices and optical orientations were determined for each sample by spindle stage methods (Table 1). A single crystal was mounted on an X-ray goniometer head, and the *c* axis of the crystal was oriented normal to the rotation axis of the spindle stage axis. The goniometer head was then transferred to a precession camera and the quality of the crystal assured. Next, the goniometer head and crystal combination was transferred back to the microscope and the double-variation method was used to determine ω and ε precisely (Bloss, 1981; Su *et al.*, 1987).

X-ray analysis. Cell parameters were determined with a back-reflection Weissenberg camera (Table 1). One back-reflection Weissenberg photograph was taken for each crystal. The rotation axis was either **a** or **b**, so (0*kl*) or (*h*0*l*) reflections could be indexed. For each crystal, approximately 60 spots were indexed and 2θ values were measured for $CuK\alpha_1$, $CuK\alpha_2$, and $CuK\beta$. The resultant 2θ values and reflection indices were submitted to the least-squares program of Burnham (1962, 1965).

Chemical analysis. The eudialyte crystals were analysed on the University of Idaho's ARL EMX-SEM electron microprobe (Table 1). Standards used were albite for Na and Si, biotite for Al, Ti, Mg, K, and Cl, zircon for Zr, anorthite for Ca, spessartine for Mn, olivine for Fe, and *REE* glass #3 for Ce and Y (Drake and Weill, 1972). La, Nb, and Sr were all below detection limits Operating conditions were 15 kV and 0.1 μA. The data were reduced using the method of Bence and Albee (1968).

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A Rb-Sr isochron from a single biotite crystal

MINERAL constituents of a single rock sample can be used to date its crystallization, or recrystallization, i.e. 'the internal isochron method'. These authors wondered if there could be enough variation in Rb and Sr in a single biotite crystal to enable Rb-Sr isochron calculations. Therefore a biotite megacryst from an undeformed granite pegmatite near Burås in the Proterozoic Bamble Sector, South Norway (e.g. Verschure, 1985), was investigated.

The Burås pegmatite is emplaced in a discordant metagabbro of supposedly Sveconorwegian (Grenvillian) age in Sveconorwegian upper amphibolite facies setting about 5 km outside the orthopyroxene-in isograde (Starmer, 1985*a*,*b*; Theulings, 1988; de Haas *et al.*, 1992; Nijland *et al.*, 1993). In the Bamble Sector similar pegmatites are widespread and probably cogenetic, e.g. the Gloserheia (Baadsgaard *et al.*, 1984) and the Auselmyra pegmatites (Neumann, 1960), respectively 1 km S and 14 km NE of the Burås occurrence.

The biotite megacryst measures 40 × 25 × 10 cm. Petrographical observation of the biotite showed no traces of chloritization or intercalations of Ca-bearing silicates (e.g. epidote, prehnite, pumpellyite, hydrogarnet). However, some thin quartz intercalations, tiny ilmenite flakes or symplectitic quartz-ilmenite intergrowths do occur.

A prism measuring 3 × 3 × 10 cm was sawn from the crystal and split into 7 slices, each approximately 1.4 cm thick. The slices 91 Bam $108A_1$ through $108A_7$ were powdered and subjected to standard techniques for the analysis of Rb and Sr and major elements (Verschure *et al.*, 1987). The analytical accuracy is considered to be within 0.5% for isotope dilution of Rb and Sr and 0.005% for $^{87}Sr/^{86}Sr$. The errors quoted for the isochron ages and intercepts are 2σ inclusive a correction for the MSWD. The ages are based upon the IUGS decay constant of ^{87}Rb ($\lambda^{87}Rb = 1.42 \times 10^{-10}a^{-1}$).

The variation in the analysed major elements of the biotite crystal is restricted (Table 1) and does not show any relationship with the vertical outlines. The variation in Rb and in Sr however, showing no relationship with the vertical outlines of the biotite crystal, was enough to warrant isotope analyses for a possible isochron calculation. The average K/Rb ratio of 105 excludes severe Rb depletion.

The results of the Rb–Sr determinations are given in Table 2 and presented in Fig. 1. Regression of the Rb-Sr data of all slices yields an errorchron (MSWD = 2.9) of 987 ± 62 Ma with initial $^{87}Sr/^{86}Sr = 1.00 \pm 0.513$. If slice A_1 is omitted, the data of the remaining slices define an isochron (MSWD = 1.1) of 976 ± 37 Ma with initial $^{87}Sr/^{86}Sr = 1.141 \pm 0.312$. These ages are