Characterization of Alaskan Jade by XRD, 'mini' XRF, and hand-held XRF

Newberry, R.J.[1] and Burns, E.J.[2]

[1]UAF PO Box 750993, Fairbanks, AK 99775, ffrn@uaf.edu; [2]mathematics consultant, PO Box 82946, Fairbanks, AK 99708
Work Phone: 907-474-6895 Fax: 907-451-5163

Sadly, most gemstone jade is not jadeite; it's very fine-grained tremolite (Ca-Mg amphibole). Jade's extreme tenacity comes from the extremely tiny (50-10 m x 5-1 m needles crystallized in a dense, randomly oriented, interlocking mesh. Jade colors vary from white to very dark green; a perusal of the literature shows no consensus about the origins of the color—variously ascribed to Fe, Co, Ni, Cr and (or) V. The fine grain size of tremolite in jade and the low concentrations (< to <<1000 ppm) of the possible color-causing elements make the electron microprobe a useless tool for pursuing this problem.

Alaskan jade comes exclusively from the SW Brooks Range, where it occurs with serpentinite in isolated fault slivers of uncertain age and parentage. [Jade Mountain, for example, would be better (although less elegantly) described as 'Jade-bearing Serpentinite Mountain'.] Isolated blocks of jade are produced naturally by tumbling downhill followed by extensive stream transport, a process that removes the associated serpentine. Most Alaskan jade is consequently alluvial, and little is know about the actual geologic setting and formation conditions of the jade. Alaskan jade was recognized as the tremolite variety by the late 1800's; virtually nothing else has been published about the jade.

The UAF Museum graciously loaned us a large slab of varicolored Alaskan jade for NON DESTRUCTIVE testing and examination; our goal was to determine the overall composition and likely source of the colors in the slab without resorting to the usual destructive processes required for chemical analysis. We cut 3 tiny pieces off the edge of the slab, but primarily examined the slab using an Innov-X hand-held XRF analyzer. We analyzed >150 spots on the slab, with a sample density of ~ 1 analysis per 0.8 cm^2. We employed a counting time of 50 seconds, later increased to 120 seconds for Cr-poor areas of the slab. We also analyzed 6 mm spots on polished 4 mm thick pieces using a Panalytical Axios wavelength dispersive XRF operating at 60-32 kV and 66-125 Ma.

Based on XRF and XRD, the sample consists almost entirely of amphibole with a composition ~ tremolite: $(Ca_{1.99}Na_{0.1})_2(Mg_{4.6}Fe_{0.36}Mn_{0.03}Al_{0.01})_5(Si_{7.99}Al_{0.01})_8O_{22}(OH)_2$ (average of 23 analyses). The Mg# (atomic Mg/Mg+Fe) of 93-94 is typical of colorless amphibole. The variations in major and most trace element concentrations are quite small (FeO = 3.02-3.18 %, MnO = 0.17-0.22%, V = 6-12 ppm, Zn = 85-120 ppm, Co = 18-20 ppm), however, both Ni (125 - 465 ppm) and Cr (10 – 1550 ppm) show significant variations. We used our 'gridded' analyses of the UAF Museum jade slab to test for relations between composition and color. The average composition of green and white jade differ significantly only in Cr :

color	Cr	+/-	Ni	+/-	% Fe	+/-	% Mn	+/-	Zn	+/-
white	40	30	343	81	1.89	0.04	0.12	0.01	110	11
green	324	167	513	145	1.92	0.06	0.12	0.01	117	19

Further, a sharp break in Cr contents from < 50 to >120 ppm occurs on the slab where white jade turns to green jade.

In sum, the green in Alaskan jade is from Cr—a mere 200 ppm is sufficient. Substitution of Cr^{3+} for Mg^{2+} in the tremolite aught to cause charge imbalance, but there's just barely enough Al present for the paired substitution: $Cr^{3+} + Al^{3+} \rightarrow Mg^{2+} + Si^{4+}$.