

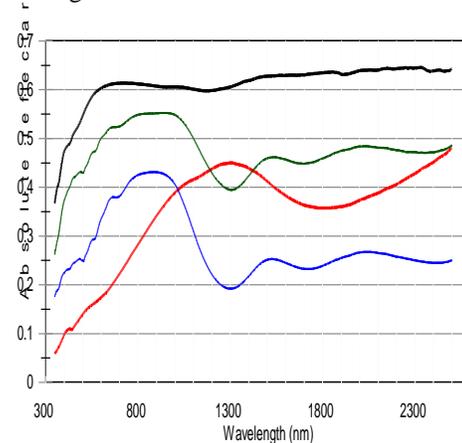
**SPECTRAL REFLECTANCE PROPERTIES OF GARNETS.** Tesia Rhind<sup>1</sup>, E. Cloutis<sup>1</sup>, Paul Mann<sup>1</sup>.  
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**Introduction:** Garnets generally form in high pressure environments, during the crystallization of magma in pegmatite and acidic intrusive rocks, and by regional, plutonic, and contact metamorphism [1]. A knowledge of garnet composition can be used to determine whether kimberlites are diamond-bearing or barren, while determining the presence of garnets can be used to identify areas where deep-seated (lower crust or mantle) materials may be exposed on planetary surfaces. To date, there has been no systematic study of the spectral properties of garnets.

Garnets are silicates with the general formula  $A_3B_2(SiO_4)_3$ , where A is an eight-coordinated (dodecahedral) site normally occupied by divalent cations such as Ca,  $Fe^{2+}$ , Mg, or  $Mn^{2+}$ , and B is a six-coordinated (octahedral) site normally occupied by trivalent cations such as Al,  $Cr^{3+}$ ,  $Fe^{3+}$ ,  $Mn^{3+}$ , Si, Ti,  $V^{3+}$ , or Zr. The tetrahedrally coordinated Si can also be partially substituted by Ti, Al or  $Fe^{3+}$  [1]. Structurally garnets consist of free  $SiO_4$  tetrahedral interconnected by ions of various divalent and trivalent metals [1, 2], and the type of garnet that is formed is determined by the isomorphous substitution of those ions [1, 3]. We are studying the utility of spectral reflectance for garnet identification of the series: pyrope ( $Mg_3Al_2Si_3O_{12}$ ), almandine ( $Fe_3Al_2Si_3O_{12}$ ), grossular ( $Ca_3Al_2Si_3O_{12}$ ) and andradite ( $Ca_3Fe_2Si_3O_{12}$ ). The various cation substitutions in all of these garnets may result in different spectral properties that can be identified and used to determine the presence of various optically-active cations whose spectral properties may vary among different garnet species.

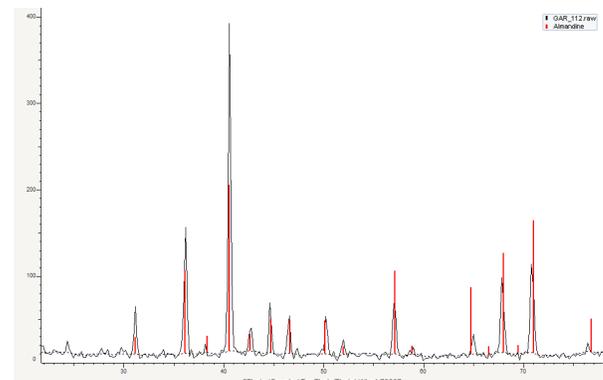
**Experimental Procedure:** All garnet samples were hand crushed and dry sieved to ~45µm particle size. Reflectance spectra were acquired with an ASD Field Spec Pro HR spectrometer (0.35-2.5 µm) with a 50 watt QTH light source with a viewing geometry of  $i=30^\circ$  and  $e=0^\circ$ . Spectra were measured relative to a calibrated Spectralon® standard. X-ray diffraction analysis involved acquiring continuous scan data from  $5^\circ$  to  $80^\circ$   $2\theta$  on a Bruker D8 Advance with a DaVinci automated powder diffractometer. A Bragg-Brentano goniometer with a theta-theta setup was equipped with a  $2.5^\circ$  incident Soller slit, 1.0 mm divergence slit, a 2.0 mm scatter slit, a 0.2 mm receiving slit, a curved secondary graphite monochromator, and a scintillation counter collecting at an increment of  $0.02^\circ$  and integration time of 0.7 seconds per step. The line focus Co X-

ray tube was operated at 40 kV and 40 mA, using a take-off angle of  $6^\circ$ .



**Figure 1:** Example garnet reflectance spectra (<45 µm): GAR102 (grossular) black; GAR141 (andradite) red; GAR112 (almandine) blue; GAR145 (pyrope) green.

**Results:** In Fig. 1 the ASD spectra of the different garnets are clearly exhibiting different spectra, but one thing that is common in the grossulars and andradites are the bands around 440 nm, and the pyropes and almandines both exhibit bands at ~500, 580, and 690nm which we have attributed to spin-forbidden bands of octahedrally bonded  $Fe^{3+}$  [4] [5]. The pyrope and the almandine spectra look very similar, and they both show a unique absorption band around 700nm, which we believe to be due to  $Fe^{2+}$ -  $Fe^{3+}$  charge transfers [4].



**Figure 2:** GAR 112 (Almandine) X-ray diffractometer.  $5^\circ$  to  $80^\circ$  with integration time 0.7 seconds.

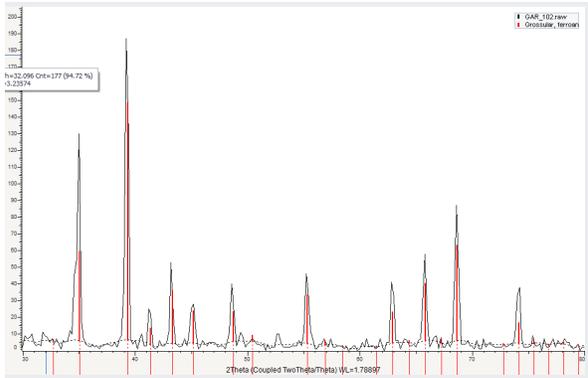


Figure 3: GAR102 (Grossular) X-ray diffractometer. 5° to 80° with integration time 0.7 seconds

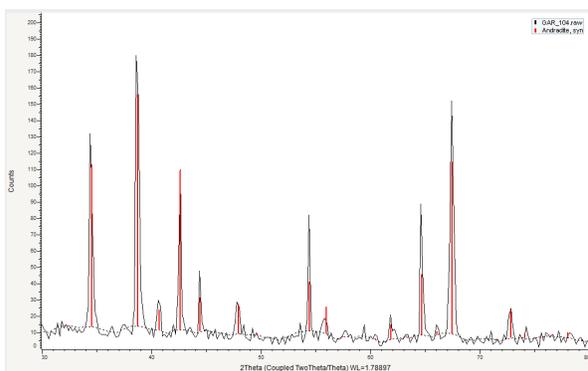


Figure 4 GAR104 (Andradite) X-ray diffractometer. 5° to 80° with integration time 0.7 seconds

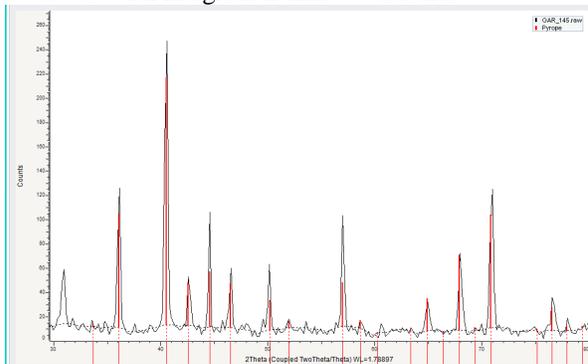


Figure 5: GAR145 (Pyrope) X-ray diffractometer. 5° to 80° with integration time 0.7 seconds

**Discussion:** While the spectra exhibit many similar features, they are all relatively distinguishable from one another, with the possible exception of the almandine and pyrope. X-ray diffractometry is, however, able to recognize the differences in the structure of the garnets.

The divalent metal cations in garnets are found to be predominantly located in the distorted dodecahedral sites [5]. Ferrous iron is the most common element in these garnets that has an unpaired electron, and as such it seems to be common in garnets as a dominant transi-

tion metal as is exhibited by the reflectance spectra in Figure 1.

**Conclusions:** There are clear spectral differences between the different garnets, and while there are other significant absorption bands in many garnets, our preliminary analysis suggests that both ferrous and ferric iron are responsible for most if not all of the absorption bands seen in the reflectance spectra.

**Future Work:** Our analysis of garnet reflectance spectra is ongoing, and more detailed analysis of the compositional, structural, and spectroscopic data for our samples will provide insights into how the presence of iron, its oxidation state, site occupancy, and other transition series elements, affect garnet reflectance spectra. We expect that we will be able to use garnet reflectance spectra to determine these aspects of their compositions and structures.

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**References:** [1] Halder, S.K., and Tisljar, J. (2013) *Introduction to Mineralogy and Petrology*, 59-60. [2] Allen, F.M., and Buseck, P.R. (1988) *American Mineralogist*, 73, 568-584 [3] Grew, E.S. et al. (2013) *American Mineralogist*, 98, 785-811. [4] Manning, P.G. (1967) *Canadian Mineralogist*, 237-250. [5] Deer, W.A., et al. (1962) *Rock-Forming Minerals*, p. 77.