Hydrothermal Formation of Unakite in the Blue Ridge Mountains, Virginia: A Geochemical Analysis

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Abstract

Unakite is a rare, altered granitoid consisting chiefly of epidote, orthoclase feldspar, and quartz. It was classified in 1874 by F. H. Bradley and given the name unakite for its location in the Unaka Mountain Range, North Carolina. Unakite has gone largely unstudied for the past one hundred years despite being a globally occurring rock-type present in Fennoscandia and the Indian subcontinent, as well as the Blue Ridge Mountains of Virginia. This work elucidates some of the complications associated with unakite, epidote minerals, and the associated interactions between them.

Electron probe microanalysis (EPMA) and laser ablation inductively coupled mass spectrometry (LA-ICP-MS) techniques were applied to samples of unakite and its associated lithologies in order to gain chemical data. These data were analyzed to produce ratios of elements deemed to be significant to understanding the differences in how these rocks were affected differentially by the same processes or by different processes through different time periods.

Hydrothermal alteration is certainly at play here, with the epidote exhibiting sparry vugs (a low temperature hydrothermal texture) and chemical signatures being exchanged between rock types during variations in their alteration. Highly weathered charnockites can exhibit chemical signatures that are found in the unweathered country rock, but not in the overlying basalt, etc. Determination of the differences between these chemical signals, and how they relate to the spatial field relations is crucial for understanding the chemical, physical, and lithologic parameters in the formation of this rare but beautiful stone.

Geologic Setting

Unakite is a rare, altered granitoid consisting chiefly of epidote, orthoclase feldspar, and quartz with other minor minerals. It was first described by Bradley (1874), who proposed the name unakite because of its locality in the Unaka Mountains between Tennessee and North Carolina (Bradley 1874). Although unakite has been described in various locations including Virginia (Phalen 1904), Finland (Barth 1938), and India (Sen 1958) since its classification in the late eighteen hundreds, this visually striking pink-and-green rock has gone largely unstudied; the last and only major paper published on the subject was by Phalen (1904).

Unakite is found in the hydrometamorphically-altered granites and granodiorites of its localities. Originally, the country rock of the unakite was described variously as a hypersthene-akerite (Phalen 1904) and a quartz-bearing hypersthene-syenite (Watson 1906, Watson & Cline 1916). In the nineteen thirties however, Anne Jonas suggested that the lack of significant quartz content of the country rock was more characteristic of a hypersthene-granodiorite (Jonas 1935). Most of literature on the subject approaches the matter from this perspective until modern times, when the term charnockite is used (Tollo et al. 2004). Invariably though, the rocks are a described as a plutonic, pyroxene-bearing granofels. This paper will refer to the country rock as charnockite.

The mineralogy of the charnockite is described containing primarily quartz, feldspar, and orthopyroxene (hypersthene) (Jonas 1935, Bartholomew 1977, Furcron 1934), with hornblende, augite, and/or biotite featured almost as prominently (Watson & Cline 1916, Furcron 1934) as the pyroxene. Textures range from massive with a granitic texture to foliated; the aforementioned mineral assemblages vary little between the two textures (Jonas 1935, Santosh & Rajesh 2012), with myrmekitic and perthitic textures being observed in thin section (Watson & Cline 1916, Jonas 1935). The charnockites are often bleached a light gray due to retrograde recrystallization of the primary plagioclase and lesser alkali feldspar (Tollo et al. 2004).

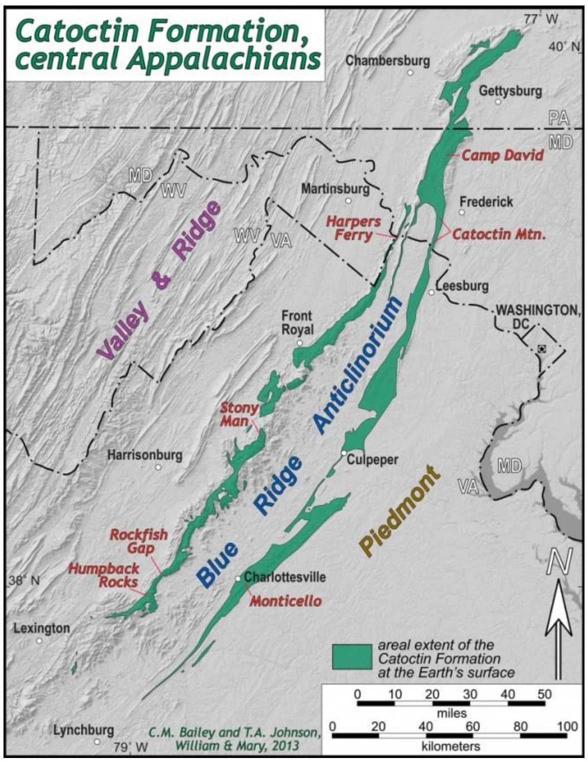


Figure 1. Location of the Blue Ridge anticlinorium.

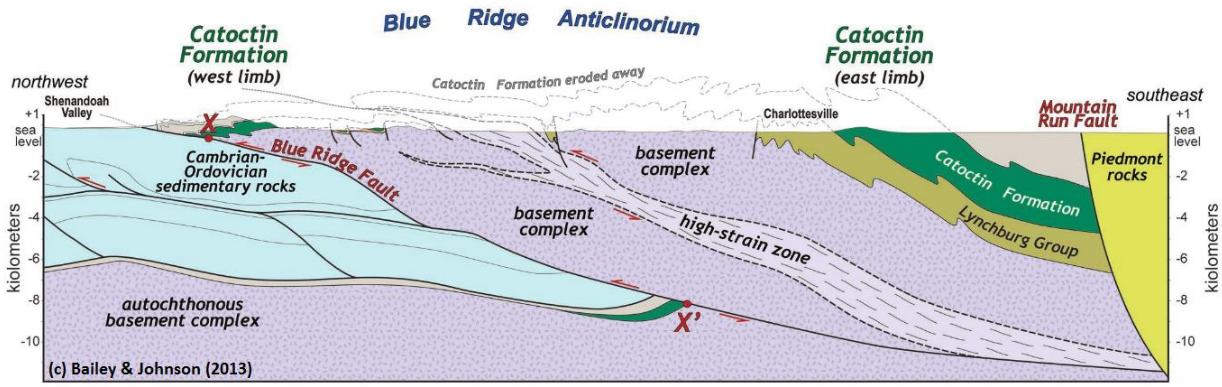


Figure 2. Cross-section of the Blue Ridge anticlinorium.

The Blue Ridge Mountains of Virginia are a Grenvillian-age suite of rocks (Hughes et al. 1997) comprising the Pedlar Massif (containing the charnockite basement) to the northwest and the Lovingston Massif to the southeast. Charnockite is present in both massifs, and is overlain unconformably by the Neoproterozoic Catoctin Basalt Formation in much of the outcrops. The overwhelming consensus is that the charnockite basement is much older than the Catoctin basalts, with the charnockite dated to 1021 ± 36 Ma (Pettingill et al. 1984) and the Catoctin dated from 700 ± 30 Ma (Pettingill et al. 1984) to 570 ± 20 Ma (Southworth et al. 2009).

The Catoctin Formation has been thrust some 100 km northwest to its present location (Bailey & Johnson 2013) and eroded, leaving us with the Blue Ridge anticlinorium visible in figure 1. This event has turned the majority of the remaining Catoctin into what is known as greenstone (an epidotic, greenschist facies). Commonly, the basalt is amygdulic, with quartz-epidote filling in the amygdules. The anticlinorium is split by the Rockfish Valley fault that lies between the Pedlar and Lovingston Massifs (Pettingill et al. 1984).

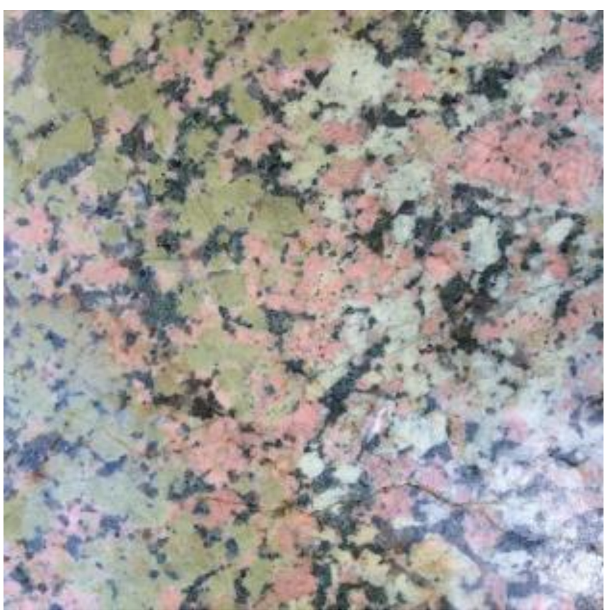


Figure 3. Polished unakite cross-section

The prevalent theory is that the alteration of the charnockite is believed to have come from the hydrothermal fluid of the Catoctin basalt flows (Phalen 1904, Cloos c. 1930), which is consistent with the unwavering observation that the epidote in the unakite is entirely secondary (Bradley 1874, Phalen 1904, Watson 1906, Jonas 1935).

The unakite itself is believed to have formed by the replacement of plagioclase and ferromagnesian minerals with epidote, leaving the quartz and potassium feldspar relatively untouched (Bradley 1874, Phalen 1904, Watson & Cline 1916). The unakite is absent any of the ferromagnesian minerals of its country rock, including biotite, pyroxene, and hornblende (Watson 1904). Because all of these minerals are present in the unaltered country rock, it is suggested that they are consumed to form the epidote. The following mechanisms have been proposed for the production of epidote from phases in the host granite:

- Bradley (1874): Mica (granite)/hornblende (syenite) → epidote
- Watson (1904): Biotite and/or feldspar → epidote
- Phalen (1904): Pyroxene + feldspar → epidote
- Watson (1906): Pyroxene + feldspar → epidote
- Watson & Cline (1916):
    - NC: Biotite → epidote
    - VA: Pyroxene + hornblende → epidote

In some cases, the altered feldspar is solely plagioclase, but in others it is both plagioclase and orthoclase (Watson 1906). Additional alteration textures are those of myrmekite and perthite, just like the charnockite. Myrmekite is an alteration texture in which "wormy" growths of quartz are found in plagioclase. In the country rock this texture is unaltered, but in the unakite the plagioclase has been altered to epidote (Jonas 1935). The perthite texture, consisting of plagioclase lamellae in host potassium feldspar, is also visible unaltered in the host rock, with the alteration of the lamellae into epidote apparent in the unakite.

Epidosite is a quartz-epidote rock believed to be a product of extreme epidotization in which even the orthoclase has been epidotized (Phalen 1904, Jonas 1935). It contains the accessory minerals zircon, apatite, and ilmenite. The titanoferromagnesian phases in the epidosite mirror closely those found in the unakite, which are distinctly different than those in the charnockite (Watson & Cline 1916). This is suggestive of charnockite → unakite → epidosite.

Broader Implications

In the Blue Ridge unakite often occurs as linear or planar features, apparently through joints or faults within the host rock. These alteration zones vary in width from a couple meters to a couple dozen centimeters. The degree of alteration in the larger zones is typically gradational, but in some of the narrower bands the alteration has gone to completion from contact to contact. This research focused on the gradational changes found in order to asses to variances in alteration found along the contact. Following this, my primary hypothesis is that the concentrations of (fluid mobile) LILEs and REEs will increase with distance from the alteration contact between the charnockite and the unakite.

It could be that the unakitic alteration only occurs in these zones because a more easily altered igneous intrusion with a similar texture (giving the appearance of altered charnockite) intruded there, or perhaps there was a change in the mineralogy or porosity due to localized shear stress. In an attempt to constrain differing petrologies and fluid flow pervasivity, my second hypothesis is that the chemical composition of the epidote is the same in the Catoctin, the unakite, and the charnockite. If the host bulk rock composition does not exert considerable control on the formation of epidote, a regional fluid flow should emplace identical epidote everywhere.

Because unakite occurs in relatively small scale zones, its study could serve as a helpful analog for other understanding larger scale alterations that are too difficult to sample the entire gradational distance. The planar features indicate that faulting may constrain the alteration, and so can provide valuable insight as to how tectonism and fluid flow are related. The unakite found at the field site is very close to a suite of faults known as the Tye River Fault Zone.

A better understanding of the formation of this unakite will enable us to understand the geology and geochemistry of fluid-rock interactions. Since there are many examples worldwide of fluid-rock interaction encompassing a huge variety of rock types it is odd that unakite is rather rare. Whether it is a result of protolith control, metamorphic conditions, or unusual fluid composition is unclear. Hydrothermal element mobility and the subsequent concentration of industrially important minerals in such processes means that further understanding of rock-fluid interactions may lead to a fuller understanding of the concentration mechanisms of ore minerals. Indeed in the Blue Ridge, an old copper mine lies just east of the Rose River headwaters, and tin lodes are found exclusively in the charnockites (Koschmann 1942). The hydrothermal alteration of charnockite into unakite could lead to insights into the formation of these ore deposits

Field Site and Methodology

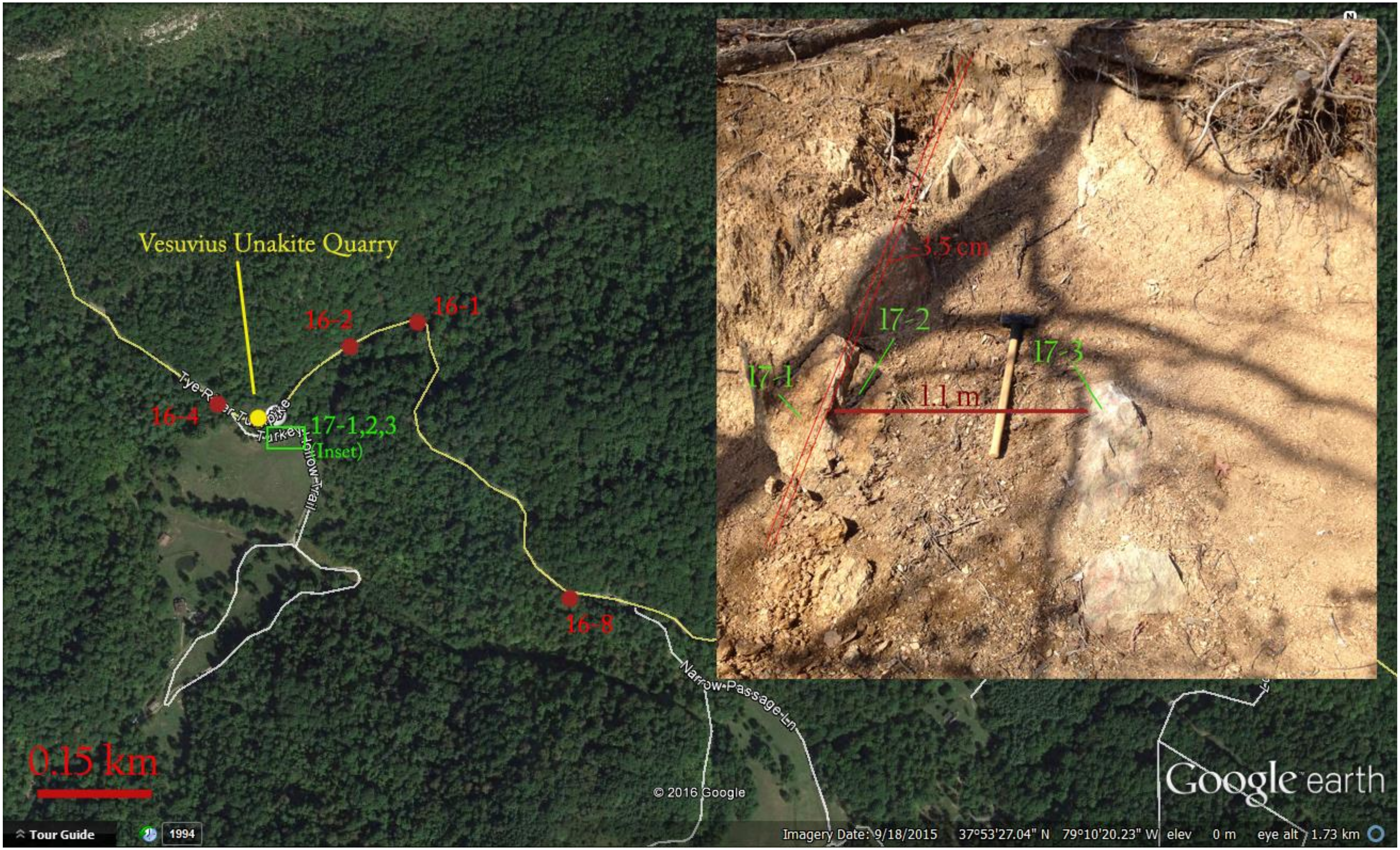


Fig. 4 – Field Area. The town of Vesuvius is ~2km NW on the Tye River TNPK (yellow line). Inset: spatial relation between various grades of unakite/charnockite and alteration contact. The contact strikes roughly north.

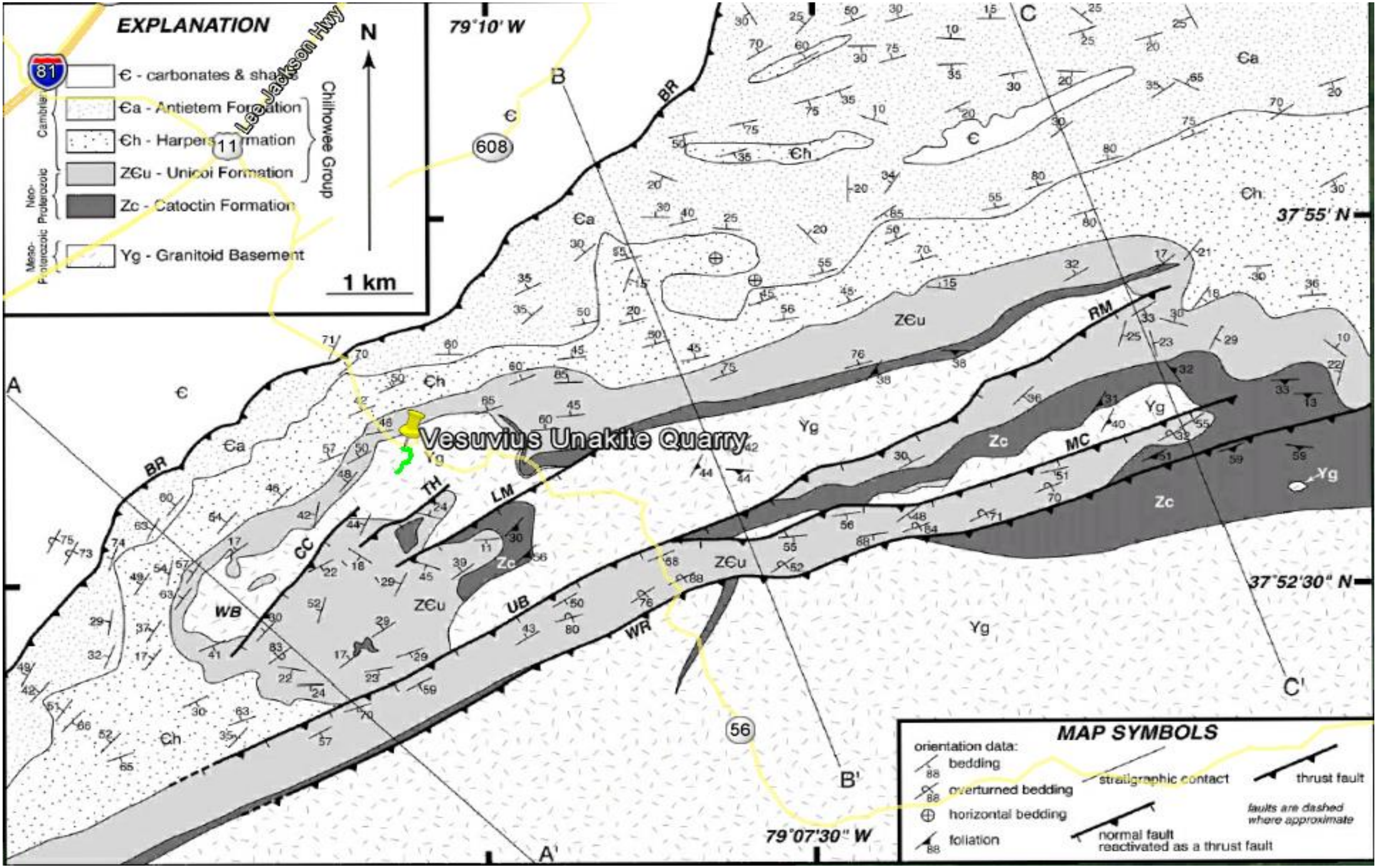


Fig 5. – Geologic Map of the Field Area, Green line is Turkey Hollow Trail. Illustrates spatial relations between charnockite basement and Catoctin. CC, TH, and LM are faults of the Tye River Fault Zone.© Bailey 2001

Fig 6. Highlighted unakite alteration contact exhibiting preferential modality of plagioclase to the left and red K-felds and epidote to the right.

The field location for this study was a defunct unakite quarry nestled in the bend of a state route approximately two kilometers southeast of Vesuvius, Virginia. The quarry now sits on the property of a former geologist named Gary who was able to show us to exactly what we were looking for. There happened to be, right there in the erosional surface of Gary's driveway, an exposed contact that demonstrated visceral spatial relations and something of the scale to which this unakite alteration took place. The contact itself (seen at left) was an alteration zone several centimeters in width which continued lengthwise into the ground, both above and below the outcrop, in a planar fashion.

To the left of this contact, heavily weathered charnockite graded homogenously into more of the same as I scouted west for several meters. This left-of-the-contact rock exhibited both feldspars, was more leucocratic than its right-side partner in addition to the local bleaching (tollo 2004), and its epidote content was microscopic. These suboptical epidote phases were contained within the crystal structures of the remaining plagioclase crystals (exsolving along cleavage planes) and within epidote-quartz veins that run along crystal boundaries.

Contrariwise, on the right side of the contact plagioclase graded out within centimeters and even potassium feldspar (normally regarded as a defining endmember of unakitic production) has begun to grade out, leaving what looks to be epidosite. The outcrop is lost after that, but not before small grains of Kspar show up on the far side of the rock. Whether these are the terminal crystals of the Kspar zone or the gradation reverses back into country rock is something that needs to be explored further.

Figure 7. Unakite/Epidosite visible in Fig XX. Kspar becomes conspicuously and abruptly absent.

From this contact area three samples were collected: one of charnockite to the left, and one each of charnockite and unakite to the right. Four more samples were collected from the nearby area in order to get epidotic Catoctin, unweathered charnockites, and epidosite.

In all, samples were collected from twelve locations, each exhibiting a different rock type. From these, 21 epoxy resin plugs were produced and 8 were selected for analysis. Sample preparation consisted of breaking the rocks into <1 inch pieces to ensure they not only fit in the epoxy mount but also into the EPMA and LA-ICP-MS. Specimens were selected based on mineralogy with special focus given to those phases believed to play a part in the unakite story.

Samples were then placed into an epoxy mount and, covered with epoxy resin, left to dry for at least 24 hours. Hardened samples are labelled and subjected to grinding and polishing to ensure quality readings on the machines. A two stage, 320 & 500 grit grinding process exposes the rock face from the epoxy, and a 4 stage polishing process ensures the samples topographies are smooth enough for a carbon coat and an electron beam. Reducing striations and gouges in the rock to less than one micrometer is recommended.

Samples prepared are as follows. Sample numbers are used in the analyses of graphs and correspond somewhat to field relations but also petrology.

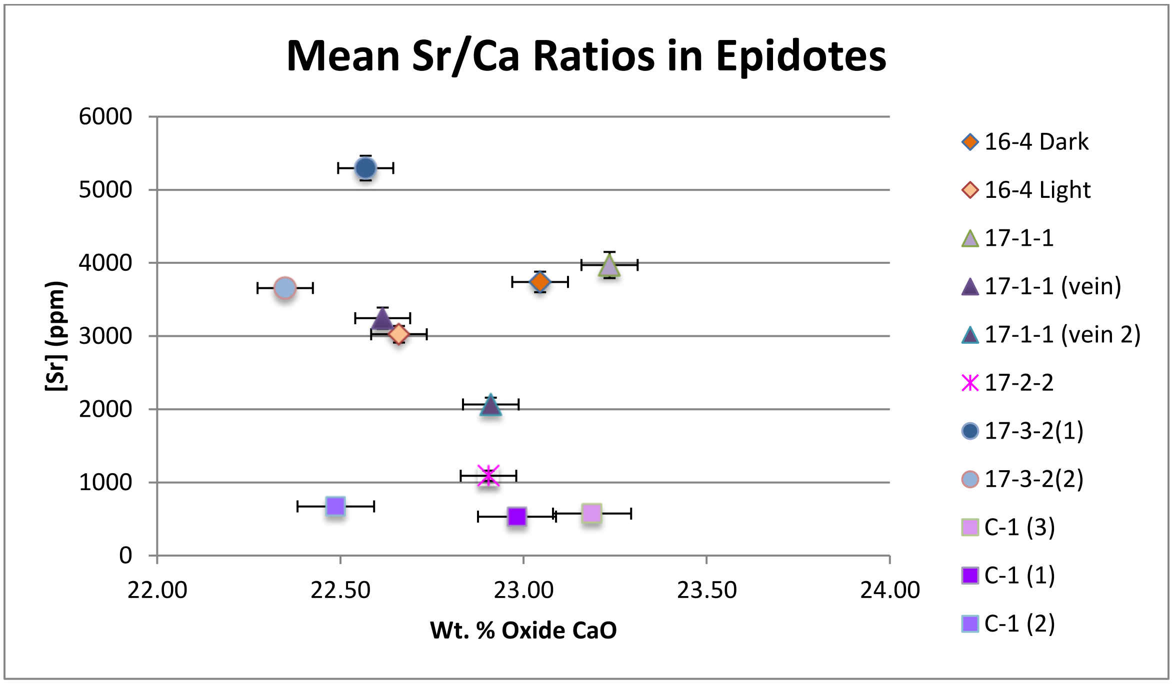
Sample No.	Rock Type	Comments
16-1	Weathered Charnockite	Weathered
16-2-2	Charnockite	Minor Alteration (Uralization)
16-4-1	Epidosite	"High-Grade Unakite"
16-8-2	Charnockite	Megacrystic Kspar (Vesuvius Megaporphyry type locality); Minor Alteration (Uralization)
17-1-1	Charnockite	Heavily Weathered, "Low-Grade Unakite"; **Left of Contact**
17-2-2	Charnockite	Heavily Weathered, "Low-Grade Unakite"; **Right of Contact**
17-3-2	Unakite	Sparry Vugs, **Right of Contact**
C-1	Catoctin	Greenschist Facies w/ Ep. Pods

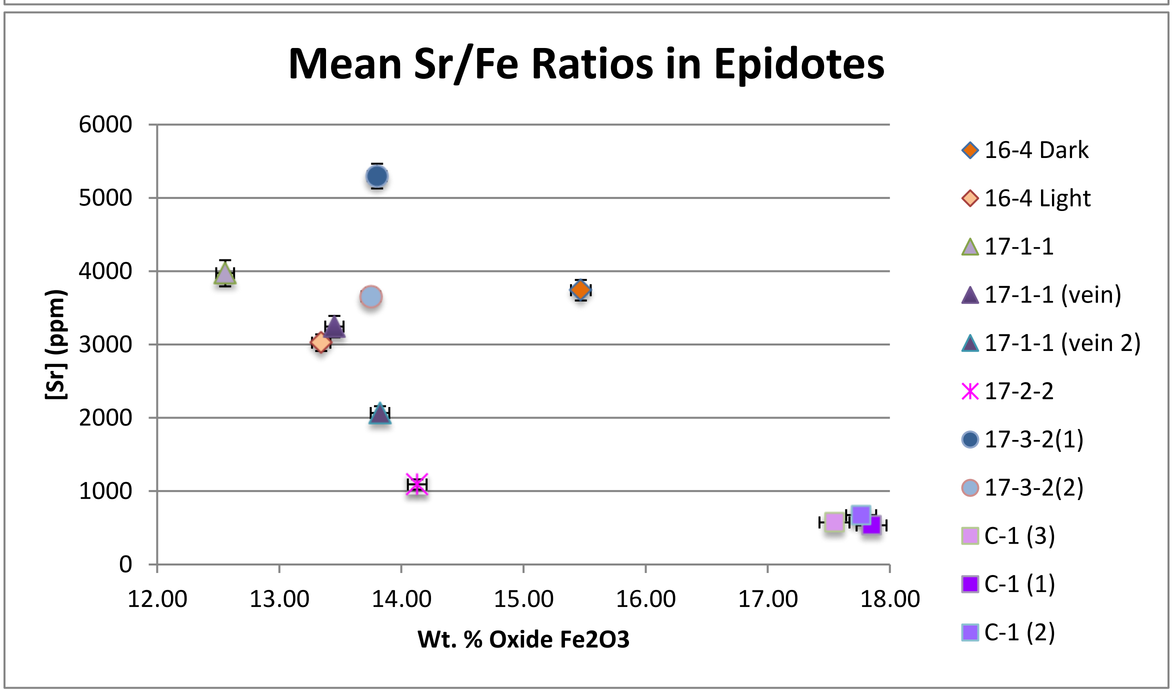
Table 1. Sample Numbers and Descriptions. A second hyphen indicates which plug was selected for analysis from a batch.

The unakite story is an exciting yet complicated tapestry of fluid activity, bulk rock composition, and field relationships. It should therefore not come as a surprise that a complicated rock is made up of complicated minerals, and in our case those would be the epidote group of minerals. Epidote is the eponymous mineral of the epidote group, and forms an Fe3+/Al solid solution with clinozoisite as the ferric iron endmember, as well as boasting a hydrous (OH)- within their crystal structure and a rhombohedral polymorph known as zoisite. Epidote's mineral formula (Ca2(Fe,Al)3Si3O12(OH)) is sophisticated enough to allow for considerable interaction with the large ion lithophile elements (LILEs), strontium, metals, and the rare earth elements (REEs) (Frei 2004), making epidote a mineral of interest for exploration geologists and geochemists alike. Despite this freewheeling attitude towards ions, an epidote's ferric iron content rarely exceeds 33% (pure Ca2Fe33+Si3O12(OH)) is called pistacite, and Xpi is usually how Fe3+/Al ratios are reported).

It is because of this association with strontium that I decided to start my datal interrogation with strontium and the major constituents of epidote, calcium and iron.

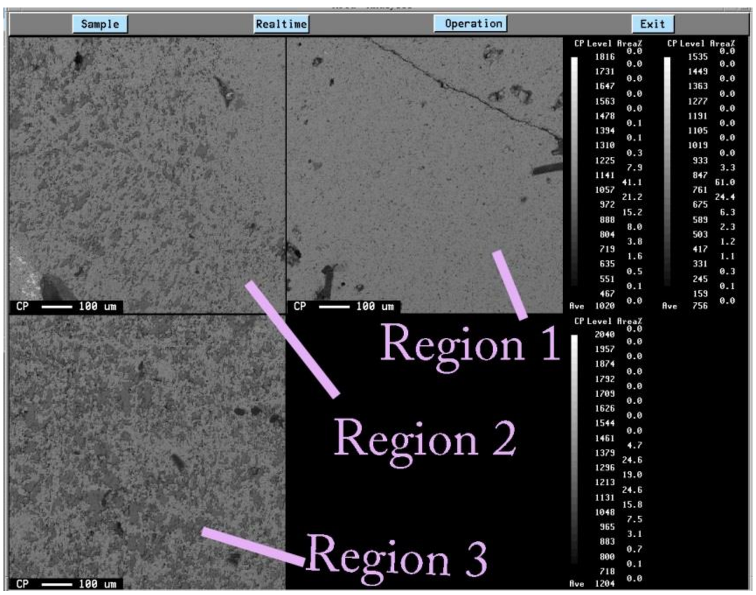
Data and Discussion





Figures 8. and 9. Sr/Ca and Sr/Fe ratios for sampled epidotes

These trends do not launch any eureka moments at first glance, but they do begin to elucidate what could be construed as bulk composition control on epidote formation and element flow. Calcium content in an epidote does not fluctuate much unlike its iron content, and it would be perfectly fine donating its calcium to plagioclase. Therefore it is reasonable to expect that calcium content between petrologies in which epidote is stable would not differ much. What is striking about these diagrams is the fact that although both iron and calcium are fluid mobile, calcium is less inclined to roam within this system. From the diagrams, epidote forms in a more precise calcium range, somewhere in the 23 weight percent calcium oxide plus or minus a half weight percent, whereas its iron contents varies by 4 weight percent (an 800% increase) . A reasonable assumption of an influx of calcium into the epidotic fields of this system follows; this also requires an influx of elements to phases which lose the calcium to compensate for their loss.



This brings me to the apparent albitization of the rocks in question. The sequestration of sodium into plagioclase and finally into albite lamellae with\in epidote suggests that the ever popular CaO-K_2O-Na_2O oxide assemblage plays an important role here. Epidotization of these rocks is seemingly coincident with the influx of sodium into plagioclase and potassium into alkali feldspars, creating a theoretical net flow with which to work from.

Figure 10. BSEs of Epidosite (16-4-1) illustrating albite intergrowths

Let us take for example sample 16-4-1 (Epidosite), depicted in the BSE image. It displays the highest grade of alteration despite being furthest from the Catoctin outcrop, but it also contains a striking pattern of light and dark epidotes. In the BSE mosaic, going counterclockwise from the top right photograph (apparent from the map in Appendix X), we take a journey from the dark epidote into the light epidote travelling right to left on the sample plug. Chemical analyses demonstrate that the differences between these dark and light epidotes are chiefly determined by albitic intergrowths within the epidote, and secondarily by iron concentrations.

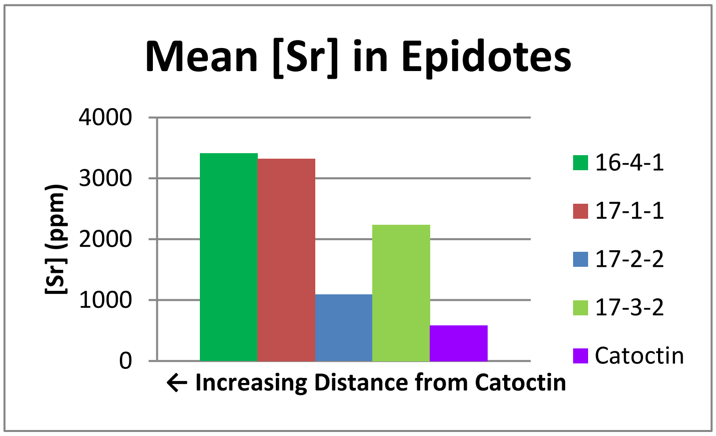


Figure 11. – Strontium concentrations as a function of distance to Catoctin

This presents a bit of a problem for the theory of direct Catoctin influence as the main contributor to epidote formation. If alteration comes from the Catoctin, would it make sense for the most heavily altered rocks to be the furthest away? Common sense would dictate that no, there must be some other mechanism that affects these processes; which brings me back to strontium concentrations. There is a spatial discrepancy in the Sr concentrations found in these rocks: strontium seems to increase its concentration linearly with distance from the Catoctin, but is preferentially depleted before and after the unakite. This could be due to the unakite laying in a geographic low, or it could be something else.

Chemical data can be misleading, but the spatial field relationships of these rocks introduce an unignorable factor. If hydrothermal fluids percolate down from the Catoctin, and Sr is fluid mobile and epidote-philic , why would it concentrate in phases less epidote dense and further from the contact than necessary? 17-2-2 has a greater epidote component than 17-1-1, so it could be that trace elements concentrate themselves higher in environments with fewer site availabilities, i.e. epidote trace elements are found in higher concentrations in rocks with little epidote because that epidote is preferentially saturated in those elements.

But strontium is one element and even though it may form a complete solid solution with calcium (Frei 2004) it has variances of ionic radius and charge that may affect its miscibility. The spatial anomalies witnessed here could not possibly extend to other relevant systems, could they?

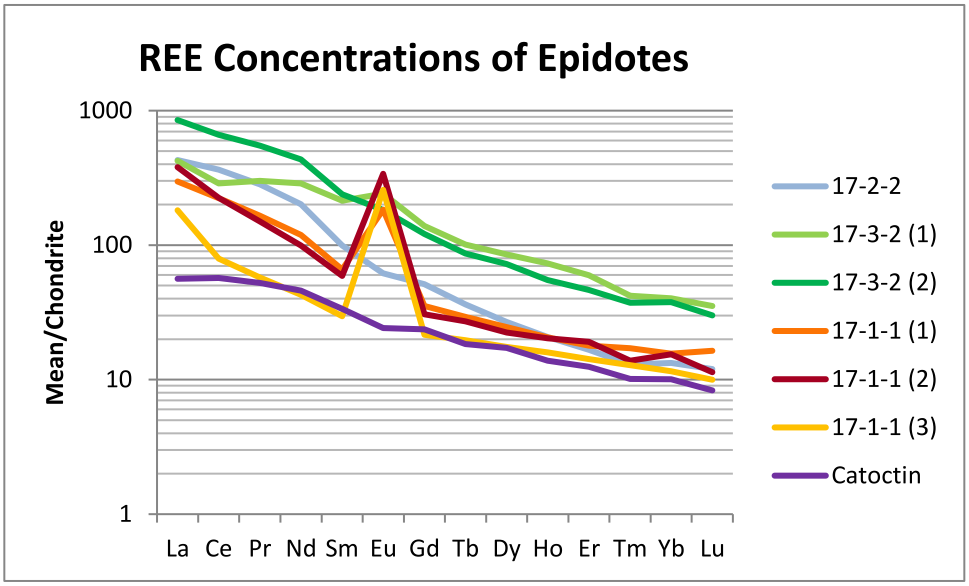


Figure 12. – REE Concentrations in Epidotes across all samples. (+) Eu Anomaly is evident only in 17-1 samples.

Well it just so happens that REE concentrations in unakital epidote exhibit some very unique properties. What we have here is an REE plot of epidotes from the alteration contact and the Catoctin. Epidotes to the left of the contact exhibit a positive europium anomaly, and neither the basalts nor the rocks to the east of the contact exhibit this anomaly, in fact a negative anomaly is seen in some cases. So I went back to each lithology I had REE data for, which were all the 17-X samples, the epidosite, and some epidote-bearing Catoctin. The resulting graphs raised more than a few questions.

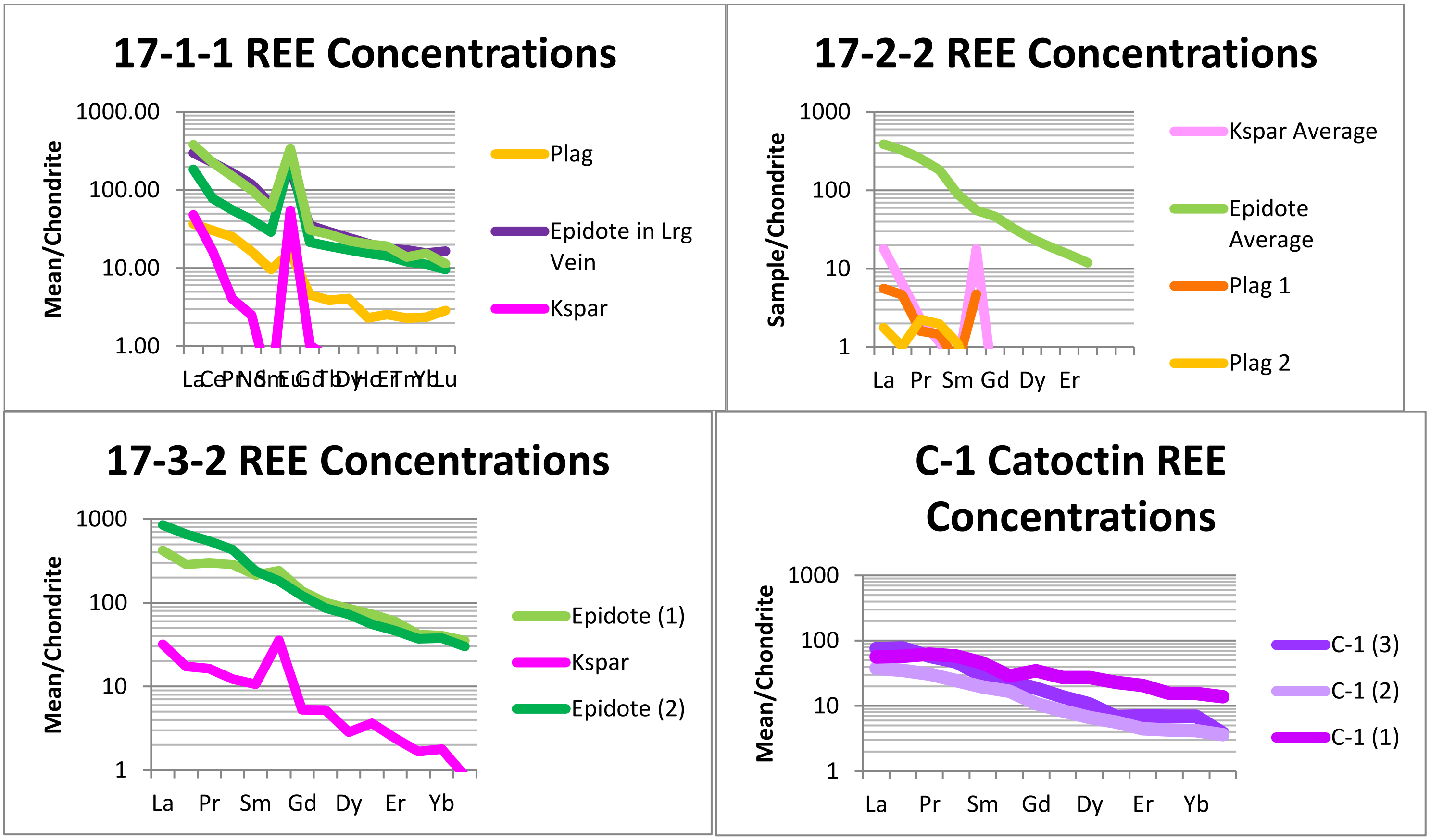


Figure 13. – REE Concentrations for epidote, kspar, and plag for 17-X and C-1 samples.

Positive europium anomalies are evident for potassium feldspars and epidotes, but the peculiar happening is the anomaly shown in sample 17-1-1. 17-1-1 is furthest from the Catoctin basalts besides the epidosite, but shows lithologic degradation rather than alteration. Catoctin basalts are depleted in LREEs, typical of tholeiitic basalt (Reed 1971), which suggests third party fluid interactions in order to LREE enrich the epidotes.

It begs the same question as the strontium that finds its way across the contact, how and/or why do elemental concentrations seemingly disregard spatial field relations to find their way into rocks that neither exhibit noticeable variations in mineralogy/composition nor are especially enticing targets for these elements?

Unakite presents some interesting challenges for determining the factors of petrologic alteration. Why are the protoliths to unakite incredibly disaggregated, but the final product is a well put together rock? Why does unakite occur in linear/planar features in some areas and exhibit massive, structureless features elsewhere? Why do lithologies not associated with the

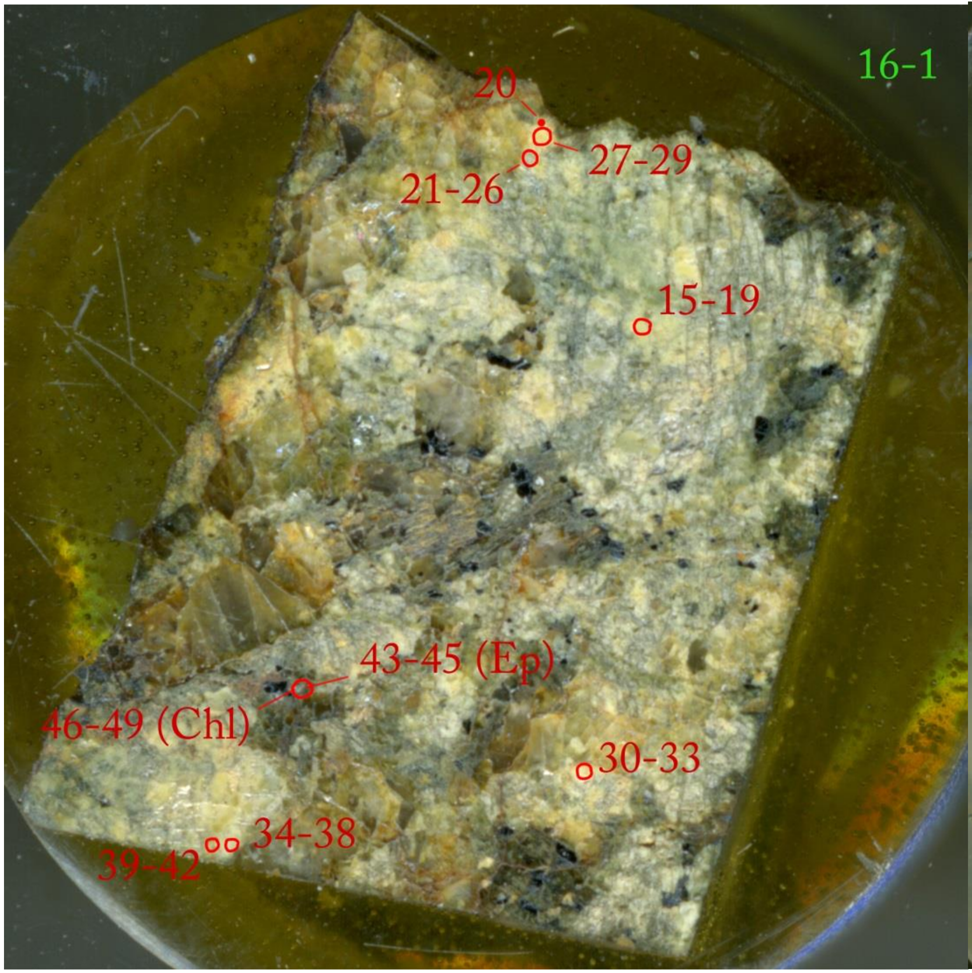
Catoctin (or at least a considerable distance away) exhibit enrichment in REEs, while those classically assumed to form directly from it not show those signatures?

It is clear that the problem of unakite formation is a complicated one, but from the data we can attempt to address my hypotheses. In regards to identical epidote emplacement within different lithologies, it is quite clear that host rock bulk composition exerts considerable control on the formation of epidote. One only need look at the Fe/Al ratios of the basalts versus the granitoids to see that epidotes do form in all these different rocks albeit with varying degrees of Xpi and REE concentrations. These ratios are statistically significant and deserve to be considered in more detail.

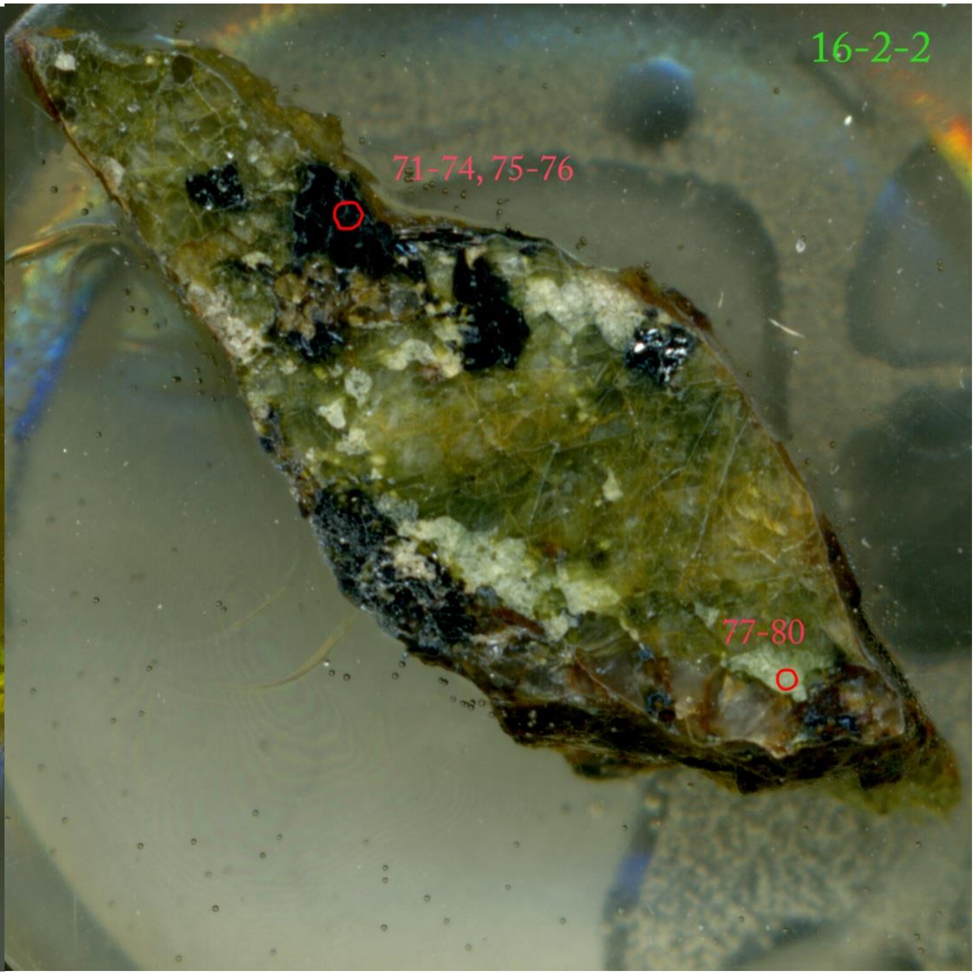
In regards to ion concentrations as a function of distance, I could have never predicted that the signatures would express themselves in the way they did. There seems to be a strong physical control, possibly due to gravity, that concentrates chemically active water in fault zones and along joints in the rock. The inverse relationship between Catoctin basalts (the classical source of unakite alteration) and concentrations of rare earth elements that defy those suggested spatial relations implies that either the Catoctin began as a LREE-enriched lava and then imparted those elements into its constituents, or more likely that a secondary, or possibly even tertiary, fluid had something to do with the changes.

Appendix 1. Epoxy Plug Maps

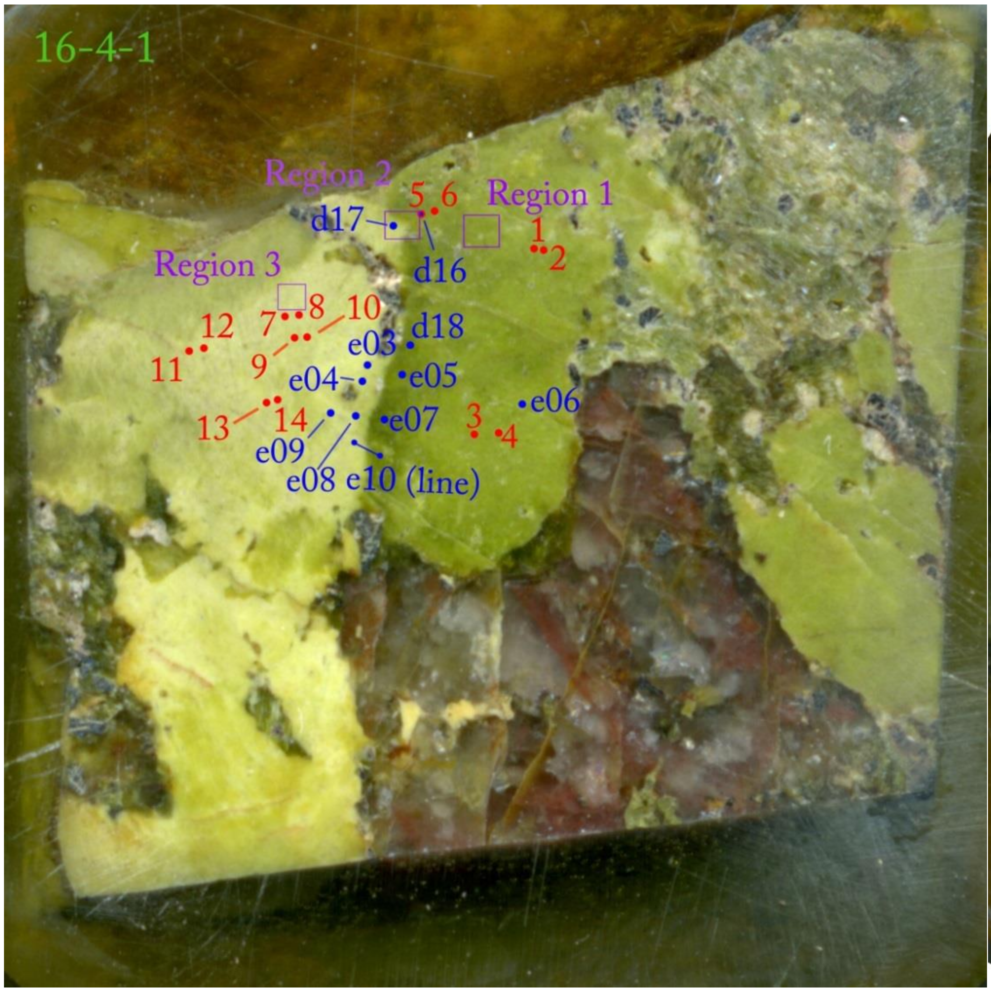
Herein are photo scans of the samples and their associated analysis locations. EPMA analyses are in red, while LA-ICP-MS sample sites are blue. All 8 samples were analyzed on the probe, but only 5 were analyzed using the laser. BSE image fields are in purple.

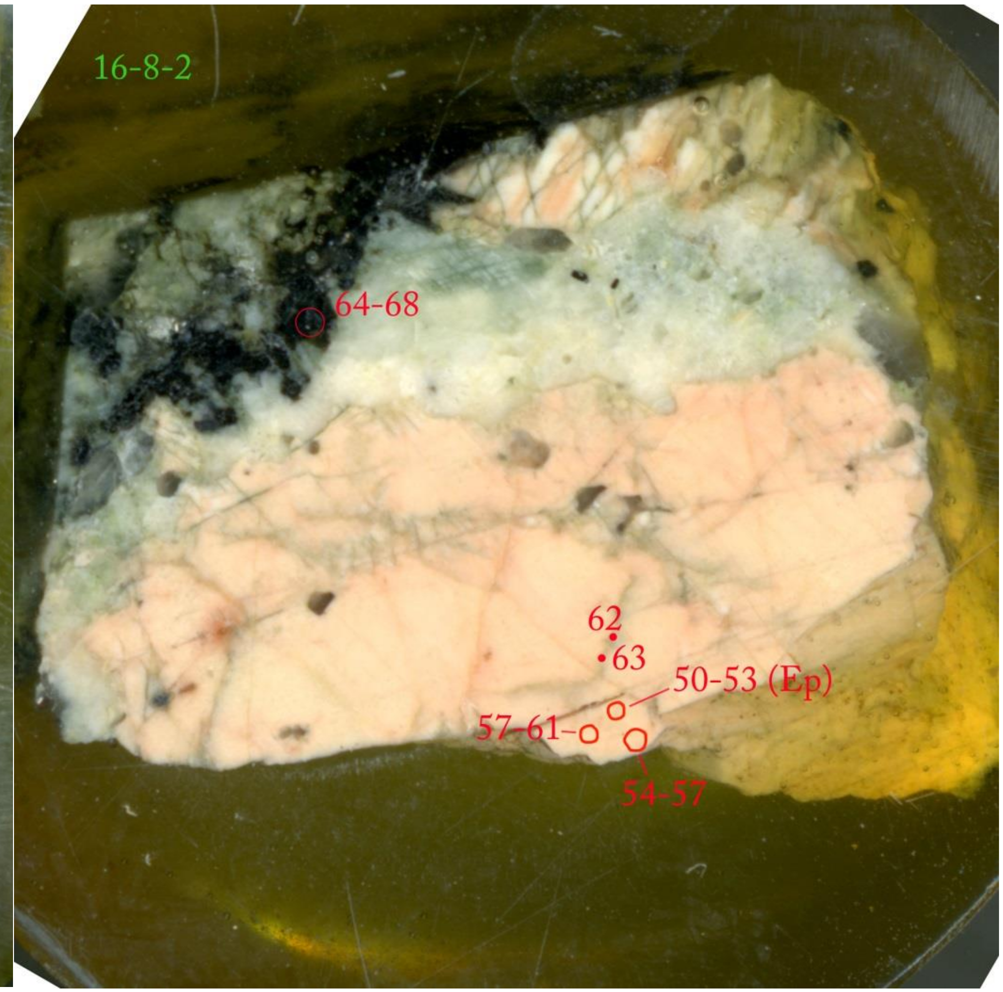


16-1 Weathered **Charnockite**. Color: Dirty Green
Main Phases: Plag, Qtz, Kspar, Chlorite, minor Opaques



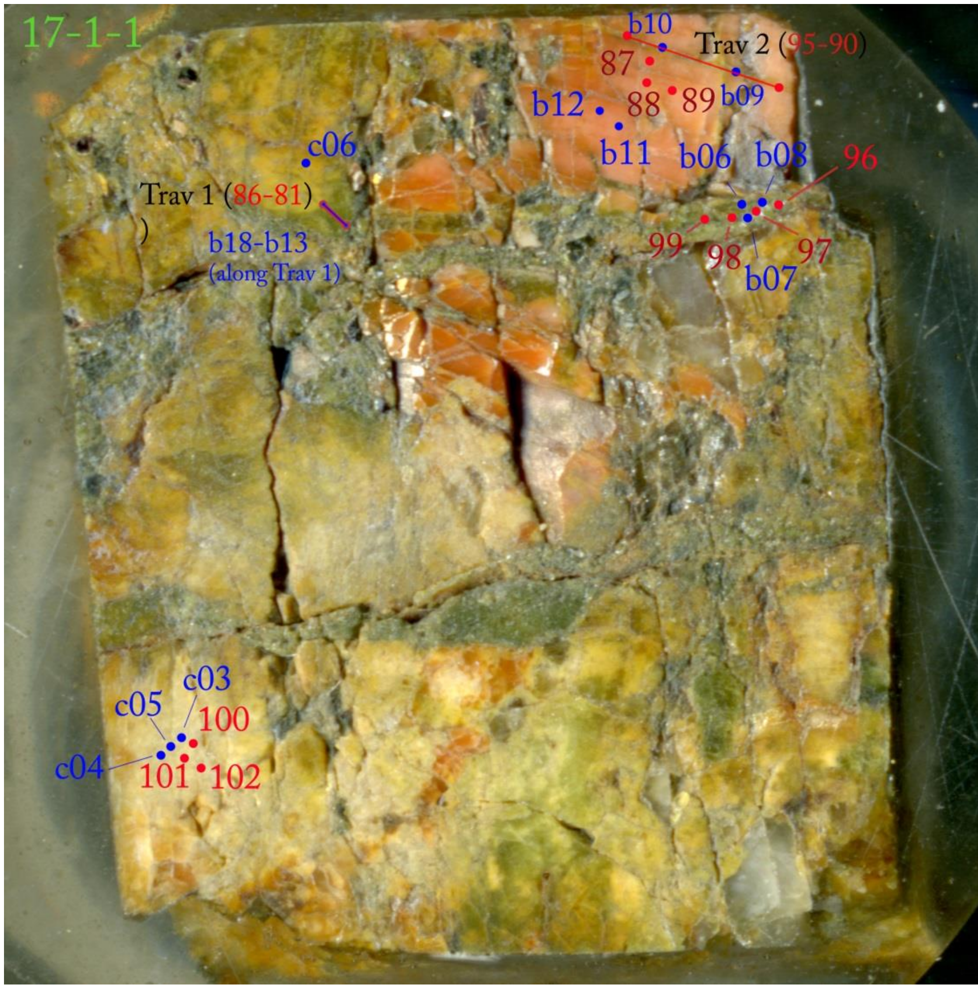
16-2-2 Lightly Altered **Charnockite**. Color: Melanocratic
Main Phases: Qtz, Kspar, heavy Opaques, Pyroxenes present as uralized cores in amphiboles.

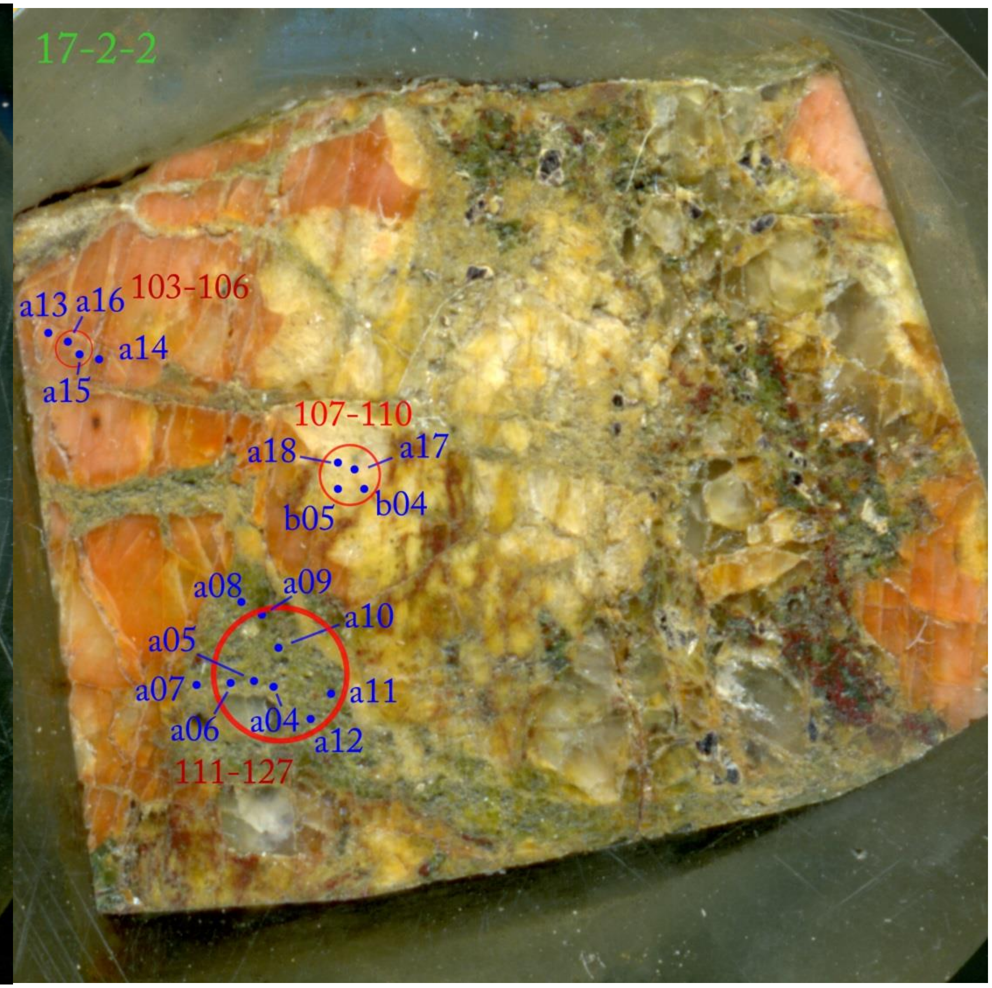




16-4-1 Epidosite Color: Bright Greens
Main Phases: Epidote, Qtz, Chlorite.
Fig. XX. BSE 1 Illustrates Epidote-Albite Intergrowth responsible for paler epidote phase.

16-8-2 Vesuvius Megaporphyry (Charnockite). Color: Melanocratic
Main Phases: Plag, Qtz, (>5cm) Megacrystic Kspar. Kspars have been hematite-stained a deep red, sometimes salmon color.



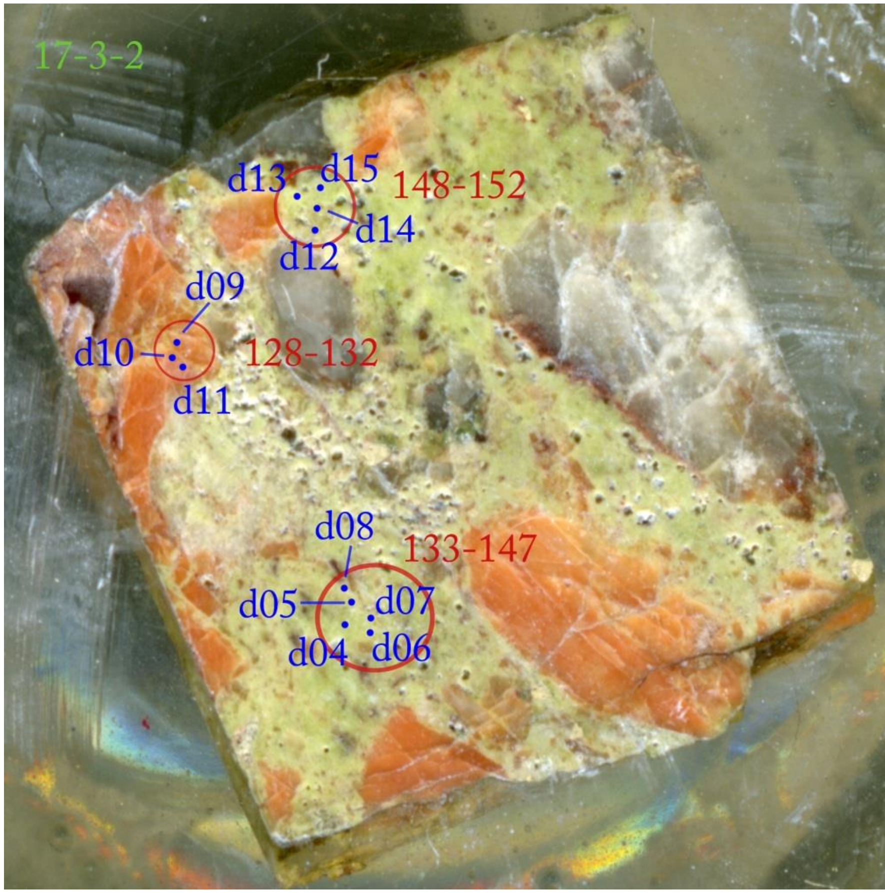


17-1-1 Heavily Weathered **Charnockite.** Color: Leucocratic
Main Phases: Plag, Qtz, Kspar, minor Opaques
Has been bleached, presumably by hydrothermal action

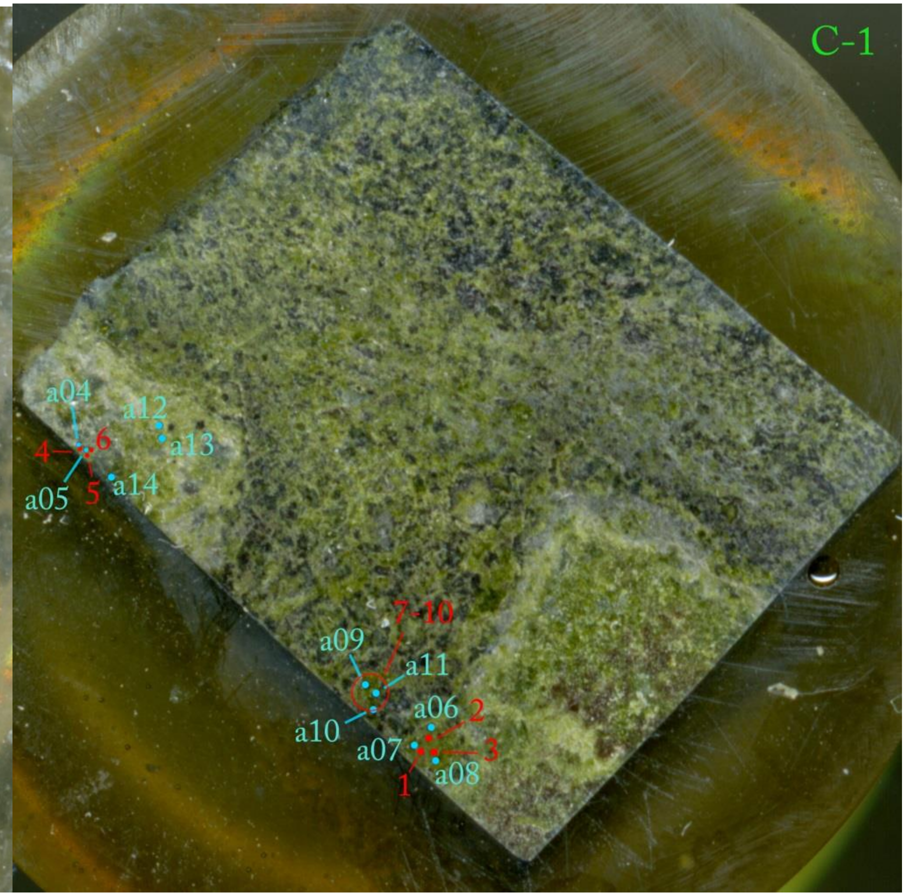
Left of Contact. Notice epidote only occurs in veins.

17-2-2 Heavily Weathered **Charnockite**. Color: Leucocratic
Main Phases: Plag, Qtz, Kspar, Epidote, minor Opaques
Has been bleached, presumably by hydrothermal action

Right of Contact. Beginning to form massive epidote pods.

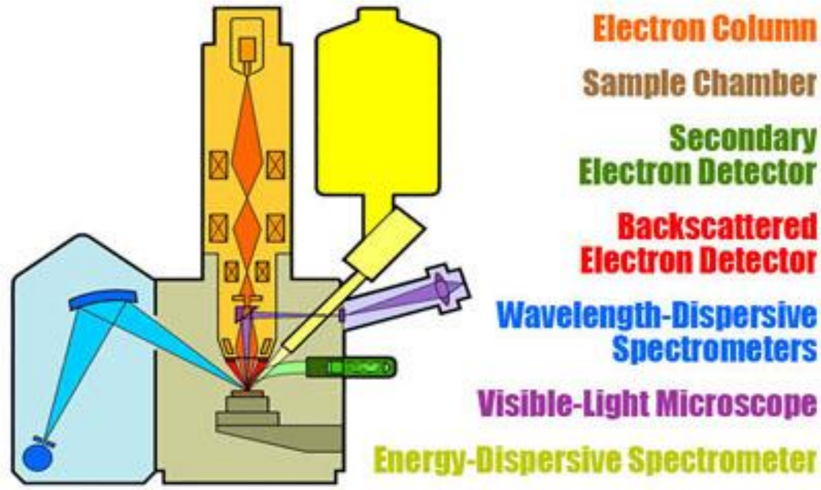


17-3-2 Unakite. Color: Green and Red
Main Phases: Epidote, Kspar, Qtz
Sparry Vugs – Not Typical of Unakite



C-1 Catoctin Greenstone. Color: Melanocratic/Green
Main Phases: Plag, Pyx, Epidote, Qtz
Epidote occurs in pods and veins of Qtz-Epidote solution, as well the as groundmass of the rock.
Light blue used for ease of reading.

Appendix 2. – Instrument Descriptions



The Electron Probe Microanalyzer (EPMA) used was a JEOL JX A-8900R WD/ED Combined Microanalyzer. It is housed within the Advanced Imaging and Microscopy Lab at the University of Maryland's Nanocenter. Work on the probe was accomplished with the help of my advisor Dr. Philip Piccoli. The EPMA functions by focusing an electron beam, generated by heating a tungsten filament to 2200°C, onto a given sample. This electron beam interacts with the sample in a variety of ways, the most significant of which is electron excitation within the orbital cloud of the sample's atoms. Excited electrons "jump" orbitals, emitting x-rays before returning to their ground state. These x-rays have a characteristic *energy* and *wavelength* which are measured by detectors on the side of the machine to give qualitative and quantitative analyses respectively.

Additional interactions with the sample include backscatter electrons, which interact with the nucleus rather than the electron cloud. These "BSEs" are used to produce an image of the minerals affected, with atomic number "Z" dictating the brightness. The higher Z, the brighter the phase (i.e. titanite will appear bright white, while quartz will likely be the darkest gray.)

The detection and analysis methods used on the x-rays were *energy* dispersive (EDS) and *wavelength* dispersive (WDS) spectroscopy. While both methods of analysis require being run against standards, EDS has the benefit of being instantaneous but with drawback that the analyses are only useful for concentrations greater than 1000 ppm (0.1 wt. %). As such EDS analyses were used here only for qualitative analysis and quick phase identification. WDS analyses were, on the other hand, used to measure weight percent oxides and are typically capable of producing accurate quantitative results within 0.02 weight percent. WDS analyses were used here to produce weight percent oxide counts for sodium, iron, potassium, calcium, aluminium, magnesium, manganese, titanium, and silicon. In epidote analyses only, FeO and MgO were converted to Fe_2O_3 and MgO_2 using molecular proportions 1.11 and 1.23 respectively.

The electron beam is produced from a known mass of tungsten which is subjected to a known current, allowing the operator to precisely determine the physical parameters of the beam. Sodium mass drift was corrected for by widening the beam from 5 to 10 µm, lowering the e^- density, and analyzing it first. Raw-ray intensities were corrected for using a ZAF algorithm.

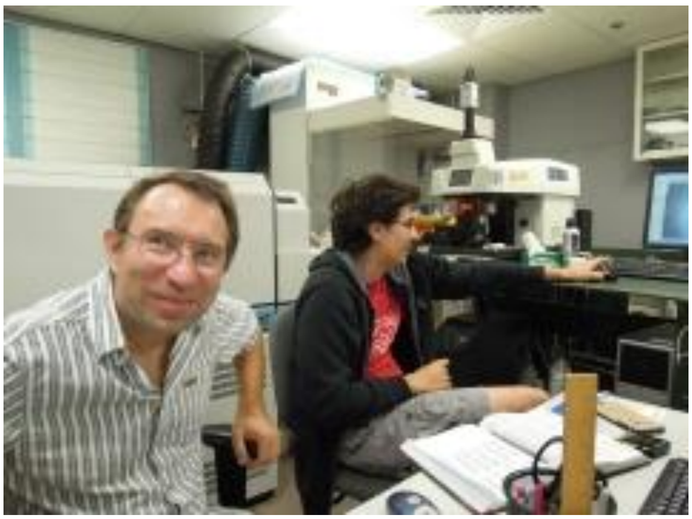
The parameters used here were:

Acceleration Voltage	**Cup Current** ***(Amount of e^-)***	**Beam Width**
15 kV	20 nA	10 µm

As mentioned previously, standards are required for accurate measurements. The standards used here were Albite (Na), Microcline (K), Anorthite (Ca, Al, Si), and Kakanui Hornblende (Fe). Their configuration in the probe was as follows.

	1	2	3	4	5
1	Na (TAP)	Fe (LIFH)	K (PETJ)	Ca (PETJ)	Al (TAP)
2	Mg (TAP)	Mn (LIFH)		Ti (PETJ)	Si (TAP)

Table 2. EPMA Standard Configuration



A Laser Ablation-Inductively Coupled Plasma-Mass Spectrometer (LA-ICP-MS) was used to determine concentrations of elements in the ppm range, specifically trace and rare earth elements. The LA-ICP-MS consists of an UV laser which ablates ~100 nm of sample per firing. The ablated material is swept via a stream of helium into an argon plasma. The plasma then ionizes the sample before the ions are accelerated into the mass spectrometer. Like the EPMA, elemental abundances determined by the LA-ICP-MS are checked against a known standard. For each analytical block of twenty analyses, standards must be run to protect against equipment drift. Because REE are often segregated geochemically between minerals and so theoretically can be used to determine what kind of rock the hydrothermal fluid originated in. By analyzing REE distribution throughout the unakite, charnockite, basalt, and epidosite, these data could potentially be used to determine where the fluid originated, its temperature, its pH, and how ions of interest were introduced or relocated between the different rocks. Operating conditions for the laser are found within the respective data tables. I would like to thank my advisor Dr. Richard Ash for his help on the laser and his speedy processing of data.

Appendix 3. – Data

Table 3. EPMA Data given in weight percent oxide. **Sample : LC-24Mar17**

	Na2O	FeO	K2O	CaO	Al2O3	MgO	MnO	TiO2	SiO2	Total	Comment
1	0.032	14.464	0.003	23.319	21.422	0.020	0.174	0.088	38.100	97.622	16-4-1 (dark green)
2	0.001	13.617	0.020	23.207	21.937	0.003	0.113	0.046	37.861	96.806	16-4-1 (dark green)
3	0.250	13.655	0.028	22.897	21.789	0.011	0.131	0.067	39.065	97.892	16-4-1 (med green)
4	0.000	13.601	0.019	22.774	21.917	0.000	0.223	0.000	37.066	95.599	16-4-1 (med green)
5	0.000	14.327	0.010	23.352	21.571	0.010	0.105	0.012	36.827	96.213	16-4-1 (med green)
6	0.000	13.955	0.030	22.722	21.981	0.000	0.348	0.042	37.283	96.361	16-4-1 (med green)
7	0.046	11.065	0.020	23.293	24.008	0.009	0.279	0.000	37.379	96.099	16-4-1 (light green)
8	0.026	11.654	0.029	23.230	23.304	0.007	0.215	0.023	36.890	95.378	16-4-1 (light green)
9	0.000	12.803	0.045	22.059	23.308	0.036	1.004	0.025	36.740	96.020	16-4-1 (light green)
10	0.010	12.562	0.031	22.058	23.500	0.014	1.063	0.026	37.053	96.316	16-4-1 (light green)
11	12.030	0.171	0.095	0.093	18.060	0.009	0.010	0.011	65.440	95.919	16-4-1 (albite)
12	11.930	0.197	0.088	0.068	19.230	0.000	0.000	0.010	69.720	101.243	16-4-1 (albite)
13	11.960	0.190	0.038	0.048	19.600	0.000	0.000	0.010	70.360	102.206	16-4-1 (albite)
14	11.970	0.216	0.099	0.080	19.120	0.000	0.000	0.033	69.340	100.858	16-4-1 (albite)
15	7.690	0.230	0.216	7.020	25.030	0.000	0.000	0.023	60.800	101.010	16-1(Plag)
16	7.660	0.223	0.170	6.990	24.730	0.010	0.000	0.000	60.400	100.182	16-1(Plag)
17	7.770	0.639	0.322	6.260	24.750	0.098	0.000	0.000	60.500	100.339	16-1(Plag)
18	6.770	2.260	3.170	1.282	24.770	0.486	0.000	0.000	60.050	98.788	16-1(Albite around plag core)
19	7.430	1.370	1.960	2.980	23.930	0.306	0.023	0.000	60.320	98.319	16-1(Albite around plag core)
20	0.923	0.057	14.840	0.201	18.560	0.000	0.000	0.077	65.260	99.918	16-1(Kspar)
21	1.720	0.491	13.820	0.573	19.120	0.134	0.000	0.000	65.310	101.168	16-1(Kspar)
22	0.002	13.286	0.037	22.838	22.536	0.000	0.222	0.023	37.087	96.031	16-1(Epidote)
23	0.000	13.340	0.036	22.901	22.635	0.000	0.169	0.025	37.133	96.238	16-1(Epidote)
24	0.003	13.312	0.022	22.916	22.506	0.005	0.114	0.007	37.101	95.986	16-1(Epidote)
25	0.000	13.697	0.000	22.802	22.361	0.004	0.068	0.049	36.820	95.801	16-1(Epidote)
26	0.007	13.348	0.019	23.292	22.596	0.000	0.070	0.000	37.300	96.631	16-1(Epidote)
27	1.241	0.041	14.220	0.548	18.990	0.000	0.000	0.045	65.360	100.445	16-1(Kspar)
28	0.687	0.077	15.310	0.142	18.740	0.000	0.010	0.065	65.560	100.591	16-1(Kspar)

29	0.887	0.039	15.200	0.042	18.620	0.000	0.000	0.016	65.750	100.554	16-1(Kspar)
30	1.219	0.017	14.680	0.125	18.760	0.000	0.000	0.035	65.600	100.437	16-1(Salmon Kspar)
31	1.238	0.054	14.450	0.556	18.900	0.000	0.022	0.011	64.990	100.222	16-1(Salmon Kspar)
32	1.950	0.046	13.520	0.570	18.920	0.010	0.000	0.010	65.200	100.226	16-1(Salmon Kspar)
33	1.100	0.050	14.810	0.109	18.630	0.000	0.007	0.065	65.340	100.111	16-1(Salmon Kspar)
34	7.600	0.076	0.290	6.850	24.890	0.000	0.000	0.017	60.360	100.083	16-1(White Plag)
35	7.740	0.102	0.269	6.840	24.800	0.000	0.000	0.000	60.390	100.142	16-1(White Plag)
36	7.450	0.119	0.365	6.870	25.080	0.000	0.000	0.000	60.170	100.054	16-1(White Plag)
37	7.550	0.052	0.428	6.880	24.810	0.000	0.000	0.000	60.400	100.120	16-1(White Plag)
38	7.610	0.147	0.356	6.770	25.120	0.012	0.010	0.000	60.700	100.725	16-1(White Plag)
39	8.370	0.788	2.020	1.890	22.700	0.246	0.000	0.000	62.330	98.344	16-1(Altered material around plag)
40	10.850	0.065	0.095	1.790	20.870	0.000	0.000	0.019	67.220	100.909	16-1(Altered material around plag)
41	10.930	0.071	0.108	1.580	20.310	0.000	0.000	0.000	67.190	100.189	16-1(Altered material around plag)
42	7.550	0.258	0.652	6.390	24.930	0.062	0.000	0.032	60.400	100.274	16-1(Altered material around plag)
43	1.620	19.693	2.234	11.397	10.746	8.448	0.176	1.699	41.526	97.540	16-1 Epidote in Comb Structure (Fig 5)
44	1.493	19.572	2.103	10.937	10.017	8.183	0.175	1.657	39.154	93.290	16-1 Epidote in Comb Structure (Fig 5)
45	0.846	31.600	1.390	7.070	10.710	3.970	0.102	1.408	33.320	90.416	16-1 Epidote in Comb Structure (Fig 5)
46	0.075	18.930	0.149	0.466	28.640	0.268	0.010	1.438	37.210	87.186	16-1 Chlorite in Comb Structure
47	0.099	9.630	0.173	0.535	30.760	0.556	0.000	8.270	41.270	91.293	16-1 Chlorite in Comb Structure
48	0.089	16.070	0.168	0.478	30.200	0.323	0.000	0.550	39.940	87.818	16-1 Chlorite in Comb Structure
49	0.110	19.280	0.138	0.486	29.000	0.214	0.000	0.106	37.900	87.235	16-1 Chlorite in Comb Structure
50	0.043	9.232	1.955	20.506	23.205	0.046	0.039	0.104	39.988	95.120	16-8-2 Epidote in Salmon Kspar
51	0.056	9.544	1.268	21.169	23.651	0.061	0.075	0.116	38.502	94.444	16-8-2 Epidote in Salmon Kspar
52	0.000	11.181	0.080	23.288	23.650	0.000	0.060	0.079	37.031	95.368	16-8-2 Epidote in Salmon Kspar
53	0.008	11.172	0.097	23.339	23.605	0.013	0.072	0.060	37.034	95.399	16-8-2 Epidote in Salmon Kspar
54	0.318	0.535	15.630	0.687	17.950	0.018	0.008	0.000	63.360	98.506	16-8-2 Salmon Kspar (Adj)
55	0.267	0.181	15.960	0.069	17.870	0.000	0.000	0.010	63.990	98.347	16-8-2 Salmon Kspar (Adj)
56	0.255	0.142	16.350	0.029	17.930	0.010	0.017	0.010	63.590	98.333	16-8-2 Salmon Kspar (Adj)
57	0.268	1.340	14.440	2.850	18.550	0.000	0.017	0.028	61.630	99.123	16-8-2 Salmon Kspar (Adj)
58	10.550	0.160	1.460	0.308	19.160	0.000	0.000	0.051	68.070	99.760	16-8-2 Albite in Salmon Kspar (Adj)
59	11.530	0.114	0.136	0.307	19.260	0.000	0.017	0.043	68.450	99.858	16-8-2 Albite in Salmon Kspar (Adj)

60	11.350	0.224	0.197	0.307	19.110	0.016	0.000	0.049	67.910	99.162	16-8-2 Albite in Salmon Kspar (Adj)
61	7.100	0.063	6.870	0.145	18.850	0.000	0.000	0.010	66.620	99.658	16-8-2 Albite in Salmon Kspar (Adj)
62	0.006	9.482	0.060	23.230	25.575	0.028	0.226	0.017	37.221	95.845	16-8-2 Epidote (Random-along crack)
63	0.019	10.309	0.040	23.444	25.063	0.048	0.119	0.030	37.411	96.483	16-8-2 Epidote (Random-along crack)
64	1.730	18.830	2.220	11.500	11.170	9.570	0.213	1.080	42.580	98.893	16-8-2 Amphibole
65	1.690	18.900	2.170	11.620	11.000	9.630	0.161	1.053	42.600	98.824	16-8-2 Amphibole
66	1.690	19.060	2.230	11.580	11.250	9.490	0.181	0.864	42.400	98.745	16-8-2 Amphibole
67	1.790	20.040	2.160	11.300	10.860	8.900	0.170	1.447	42.690	99.357	16-8-2 Amphibole
68	1.860	20.080	1.980	11.360	10.830	8.900	0.167	1.422	42.660	99.259	16-8-2 Amphibole
69	0.286	12.559	0.385	20.825	21.722	1.705	0.083	0.764	38.691	97.018	16-8-2 Epidote in Amphibole
70	0.763	15.120	0.876	18.004	19.073	3.437	0.153	0.973	39.085	97.482	16-8-2 Epidote in Amphibole
71	1.940	20.000	2.070	11.220	10.250	8.480	0.246	2.190	42.000	98.396	16-2-2 in Amphibole
72	1.890	20.280	2.110	11.200	10.110	8.540	0.186	2.140	42.140	98.596	16-2-2 in Amphibole
73	1.930	20.100	2.100	11.090	10.350	8.560	0.194	2.120	42.000	98.444	16-2-2 in Amphibole
74	1.840	20.030	2.070	11.230	10.310	8.570	0.203	2.240	42.020	98.513	16-2-2 in Amphibole
75	2.010	20.220	2.150	11.160	9.930	8.460	0.229	2.010	41.280	97.449	16-2-2 in Amphibole (darker BSE)
76	2.000	19.520	2.080	11.710	10.050	8.380	0.198	2.070	41.100	97.108	16-2-2 in Amphibole (darker BSE)
77	7.610	0.308	0.228	7.400	25.180	0.000	0.000	0.000	59.590	100.316	16-2-2 Plag
78	7.620	0.240	0.231	7.290	25.150	0.022	0.000	0.023	60.390	100.966	16-2-2 Plag
79	0.011	0.117	0.011	0.029	0.000	0.000	0.000	0.000	101.620	101.788	16-2-2 Quartz
80	0.000	0.125	0.014	0.014	0.000	0.000	0.009	0.000	102.150	102.312	16-2-2 Quartz
81	0.000	11.922	0.028	22.967	22.864	0.005	0.226	0.012	36.281	94.304	17-1-1 Epidote
82	0.000	11.556	0.014	23.127	23.652	0.026	0.192	0.000	36.854	95.420	17-1-1 Epidote
83	0.000	11.376	0.051	23.245	23.683	0.016	0.060	0.065	36.895	95.391	17-1-1 Epidote
84	0.030	11.305	0.025	23.164	23.745	0.004	0.115	0.023	37.202	95.613	17-1-1 Epidote
85	0.010	10.647	0.049	23.561	24.265	0.020	0.054	0.029	37.180	95.814	17-1-1 Epidote
86	0.006	11.068	0.048	23.344	23.867	0.027	0.134	0.027	36.862	95.384	17-1-1 Epidote
87	0.233	0.067	16.160	0.081	18.140	0.000	0.000	0.070	64.750	99.501	17-1-1 Kspar
88	0.208	0.129	16.250	0.028	17.950	0.000	0.000	0.000	64.470	99.034	17-1-1 Kspar
89	0.298	0.307	16.140	0.031	17.950	0.000	0.000	0.034	64.790	99.550	17-1-1 Kspar
90	0.004	11.590	0.076	22.576	23.474	0.050	0.293	0.000	36.673	94.738	17-1-1 Epidote in Vein
91	0.007	10.762	0.090	22.615	27.129	0.031	0.392	0.013	41.180	102.219	17-1-1 Epidote in Vein

92	0.010	12.373	0.340	21.515	21.515	0.175	0.108	0.083	35.929	92.048	17-1-1 Epidote in Vein
93	0.030	13.692	0.041	22.296	21.753	0.188	0.131	0.019	36.294	94.444	17-1-1 Epidote in Vein
94	0.027	13.260	0.040	23.199	22.251	0.042	0.128	0.010	36.945	95.902	17-1-1 Epidote in Vein
95	0.000	11.031	0.078	23.492	24.329	0.016	0.082	0.022	37.418	96.467	17-1-1 Epidote in Vein
96	0.022	11.577	0.025	23.334	24.118	0.000	0.272	0.003	37.414	96.766	17-1-1 Epidote in Vein 2 (larger)
97	0.000	12.860	0.030	22.665	23.017	0.040	0.165	0.010	37.174	95.960	17-1-1 Epidote in Vein 2 (larger)
98	0.005	12.483	0.006	22.892	22.913	0.115	0.157	0.029	36.943	95.542	17-1-1 Epidote in Vein 2 (larger)
99	0.000	12.899	0.032	22.751	22.708	0.112	0.179	0.002	36.900	95.582	17-1-1 Epidote in Vein 2 (larger)
100	11.020	0.116	0.410	0.161	19.340	0.024	0.000	0.000	67.640	98.710	17-1-1 Plag
101	11.610	0.030	0.091	0.145	19.320	0.010	0.000	0.011	68.850	100.067	17-1-1 Plag
102	11.590	0.056	0.086	0.124	19.220	0.000	0.034	0.015	68.770	99.894	17-1-1 Plag
103	0.468	0.033	16.030	0.010	18.210	0.000	0.014	0.010	65.530	100.305	17-2-2 kspar
104	0.300	0.038	16.270	0.019	18.250	0.000	0.000	0.012	65.230	100.119	17-2-2 kspar
105	0.572	0.067	15.720	0.107	18.050	0.010	0.000	0.000	64.890	99.416	17-2-2 kspar
106	0.502	0.083	15.600	0.016	18.140	0.010	0.000	0.010	65.240	99.602	17-2-2 kspar
107	11.760	0.040	0.064	0.134	19.240	0.013	0.010	0.000	69.360	100.621	17-2-2 Plag
108	11.540	0.279	0.123	0.579	19.200	0.012	0.000	0.000	68.320	100.053	17-2-2 Plag
109	11.790	0.000	0.090	0.076	19.370	0.010	0.000	0.000	68.870	100.207	17-2-2 Plag
110	11.600	0.019	0.075	0.123	18.980	0.009	0.000	0.015	69.390	100.211	17-2-2 Plag
111	0.001	12.810	0.019	22.825	22.851	0.163	0.157	0.019	36.879	95.723	17-2-2 Epidote
112	0.000	11.543	0.040	22.380	23.911	0.003	0.673	0.039	36.849	95.439	17-2-2 Epidote
113	0.029	11.223	0.009	23.173	24.040	0.000	0.090	0.100	37.356	96.019	17-2-2 Epidote
114	0.024	12.502	0.015	23.358	23.129	0.004	0.131	0.000	37.017	96.180	17-2-2 Epidote
115	0.008	11.970	0.021	23.286	23.069	0.000	0.087	0.031	36.884	95.355	17-2-2 Epidote
116	0.004	12.808	0.015	23.209	22.494	0.001	0.068	0.009	36.824	95.433	17-2-2 Epidote
117	0.010	12.180	0.031	22.953	23.190	0.007	0.311	0.079	36.818	95.578	17-2-2 Epidote
118	0.005	13.458	0.007	23.057	22.260	0.071	0.144	0.040	36.628	95.671	17-2-2 Epidote
119	0.015	13.805	0.017	23.177	21.734	0.007	0.090	0.033	36.441	95.319	17-2-2 Epidote
120	0.027	14.276	0.167	21.373	21.664	0.608	0.111	0.008	36.462	94.696	17-2-2 Epidote
121	0.012	13.383	0.013	23.095	22.089	0.000	0.277	0.042	36.713	95.623	17-2-2 Epidote
122	0.010	13.675	0.036	22.837	21.970	0.050	0.231	0.000	36.876	95.684	17-2-2 Epidote
123	0.004	12.973	0.032	22.808	22.779	0.180	0.104	0.070	37.042	95.992	17-2-2 Epidote
124	0.012	12.560	0.024	23.036	22.906	0.045	0.164	0.035	36.944	95.726	17-2-2 Epidote
125	0.000	11.327	0.023	23.221	23.919	0.003	0.074	0.060	37.135	95.762	17-2-2 Epidote

126	0.023	13.233	0.024	22.939	22.466	0.021	0.112	0.032	36.888	95.738	17-2-2 Epidote
127	0.002	12.670	0.031	22.647	23.274	0.350	0.150	0.049	36.614	95.786	17-2-2 Epidote
128	0.300	0.086	15.760	0.027	17.910	0.000	0.013	0.000	64.430	98.525	17-3-2 kspar
129	0.262	0.127	15.960	0.032	17.850	0.010	0.000	0.000	64.230	98.471	17-3-2 kspar
130	0.312	0.099	15.840	0.000	17.880	0.000	0.000	0.014	64.510	98.655	17-3-2 kspar
131	0.250	0.076	16.050	0.034	17.870	0.000	0.000	0.034	64.560	98.874	17-3-2 kspar
132	0.262	0.039	15.910	0.016	17.910	0.000	0.022	0.010	64.380	98.549	17-3-2 kspar
133	0.007	12.028	0.031	21.926	22.661	0.009	0.380	0.015	35.917	92.974	17-3-2 epidote
134	0.007	12.581	0.027	22.521	21.934	0.003	0.127	0.000	35.574	92.774	17-3-2 epidote
135	0.000	13.970	0.013	22.022	21.819	0.007	0.074	0.002	35.651	93.557	17-3-2 epidote
136	0.016	12.666	0.025	22.379	21.735	0.033	0.204	0.000	36.058	93.116	17-3-2 epidote
137	0.000	11.582	0.048	22.340	23.131	0.010	0.248	0.017	36.416	93.791	17-3-2 epidote
138	0.000	11.646	0.075	22.574	22.828	0.007	0.143	0.021	36.606	93.901	17-3-2 epidote
139	0.020	12.881	0.025	22.912	22.194	0.000	0.092	0.000	36.377	94.502	17-3-2 epidote
140	0.017	12.243	0.013	22.115	22.869	0.001	0.421	0.022	36.401	94.101	17-3-2 epidote
141	0.051	12.103	0.008	22.704	22.280	0.017	0.040	0.066	36.340	93.610	17-3-2 epidote
142	0.000	11.790	0.026	23.123	22.911	0.012	0.053	0.022	36.843	94.780	17-3-2 Epidote
143	0.000	13.648	0.015	22.664	21.156	0.000	0.053	0.099	36.213	93.848	17-3-2 Epidote
144	0.000	12.491	0.012	22.687	22.272	0.005	0.112	0.010	36.125	93.713	17-3-2 Epidote
145	0.020	12.908	0.021	22.717	21.832	0.000	0.032	0.013	36.316	93.860	17-3-2 Epidote
146	0.000	12.148	0.040	22.929	22.866	0.012	0.063	0.000	36.785	94.843	17-3-2 Epidote
147	0.010	11.814	0.015	22.925	22.825	0.007	0.099	0.084	36.645	94.424	17-3-2 Epidote
148	0.021	12.844	0.016	22.544	21.991	0.016	0.047	0.026	36.621	94.126	17-3-2 Epidote Region 2
149	0.019	11.700	0.019	22.402	23.496	0.317	0.082	0.026	36.572	94.633	17-3-2 Epidote Region 3
150	0.002	12.530	0.017	22.288	22.543	0.159	0.096	0.034	36.503	94.171	17-3-2 Epidote Region 4
151	0.003	13.578	0.019	22.193	21.786	0.065	0.077	0.058	35.762	93.542	17-3-2 Epidote Region 5
152	0.018	11.286	0.025	22.320	23.268	0.004	0.108	0.013	36.643	93.686	17-3-2 Epidote Region 6
1	0.024	15.026	0.016	23.471	22.186	0.001	0.172	0.130	37.191	98.216	Catoctin 1
2	0.011	16.137	0.019	23.264	20.623	0.009	0.127	0.000	36.990	97.180	Catoctin 2
3	0.034	16.259	0.014	22.827	20.220	0.013	0.107	0.000	36.479	95.953	Catoctin 3
4	0.004	16.481	0.010	22.356	20.757	0.014	0.155	0.083	37.185	97.044	Catoctin 4
5	0.031	16.224	0.020	23.154	20.933	0.000	0.096	0.062	36.785	97.305	Catoctin 5
6	0.002	15.538	0.053	23.437	21.195	0.030	0.067	0.170	36.914	97.404	Catoctin 6
7	0.017	16.084	0.045	23.211	20.628	0.000	0.117	0.037	36.328	96.466	Catoctin 7

8	0.026	15.755	0.026	23.548	21.706	0.000	0.108	0.043	37.167	98.380	Catoctin 8
9	0.003	17.296	0.053	23.211	19.507	0.000	0.216	0.000	36.380	96.665	Catoctin 9
10	0.021	14.882	0.044	21.764	22.136	0.018	1.079	0.019	36.588	96.551	Catoctin 10

Table 4. EPMA Uncertainties Due to Counting Statistics (1σ)

	Na	Fe	K	Ca	Al	Mg	Mn	Ti	Si
1	37.16	0.51	410.79	0.33	0.39	48.46	11.33	41.45	0.29
2	981.49	0.53	61.86	0.33	0.38	312.92	17.80	83.45	0.29
3	6.20	0.53	41.61	0.33	0.38	89.27	14.54	59.53	0.29
4	100.00	0.53	62.35	0.33	0.38	100.00	9.60	100.00	0.29
5	100.00	0.51	124.27	0.33	0.38	97.90	18.78	171.60	0.29
6	100.00	0.52	38.89	0.33	0.38	100.00	6.50	48.73	0.29
7	27.89	0.59	62.31	0.33	0.36	112.24	7.30	100.00	0.29
8	44.36	0.57	42.68	0.33	0.37	140.35	9.44	87.89	0.29
9	100.00	0.54	26.69	0.34	0.37	28.59	2.93	83.51	0.29
10	125.00	0.55	40.45	0.34	0.37	74.98	2.83	85.16	0.29
11	0.53	10.89	15.02	11.72	0.41	105.79	152.75	161.91	0.22
12	0.53	9.78	15.38	16.70	0.39	100.00	100.00	307.09	0.21
13	0.53	9.74	35.41	22.30	0.39	559.56	2920.63	267.45	0.21
14	0.53	8.92	13.43	13.77	0.40	100.00	100.00	56.80	0.21
15	0.68	8.07	7.69	0.62	0.34	176.78	484.77	81.97	0.23
16	0.68	8.89	9.37	0.63	0.35	150.06	100.00	100.00	0.23
17	0.68	3.60	6.11	0.66	0.35	10.20	100.00	100.00	0.23
18	0.73	1.47	1.62	1.61	0.35	2.82	100.00	461.09	0.23
19	0.69	2.04	2.09	1.00	0.35	3.81	71.40	1768.10	0.23
20	2.33	32.20	0.73	6.47	0.39	773.52	100.00	25.22	0.21
21	1.57	4.39	0.76	2.80	0.39	8.20	100.00	100.00	0.21
22	596.47	0.53	31.24	0.33	0.37	100.00	8.81	90.08	0.29
23	3052.12	0.53	34.23	0.33	0.37	100.00	11.85	82.85	0.29
24	381.13	0.53	52.07	0.33	0.37	210.44	17.69	281.02	0.29
25	100.00	0.52	681493696.00	0.33	0.38	249.81	28.70	40.33	0.29
26	179.19	0.53	66.09	0.33	0.37	100.00	26.95	100.00	0.29

27	1.85	43.23	0.75	3.03	0.39	100.00	776.21	45.60	0.21
28	2.81	21.89	0.72	8.82	0.39	100.00	164.99	30.82	0.21
29	2.30	46.01	0.73	30.36	0.39	4310.35	3167.04	130.09	0.21
30	1.93	107.50	0.74	10.25	0.39	100.00	100.00	58.11	0.21
31	1.89	32.08	0.75	2.97	0.39	100.00	80.56	181.18	0.21
32	1.42	39.02	0.77	2.89	0.39	110.56	100.00	283.78	0.21
33	2.05	36.84	0.74	11.20	0.39	100.00	243.62	30.62	0.21
34	0.68	24.10	6.44	0.63	0.34	605.54	100.00	110.45	0.23
35	0.68	17.69	6.89	0.63	0.35	619.46	100.00	100.00	0.23
36	0.69	14.49	5.42	0.63	0.34	845.19	100.00	100.00	0.23
37	0.68	35.84	4.83	0.63	0.34	100.00	100.00	100.00	0.23
38	0.68	12.30	5.53	0.63	0.34	69.76	162.73	100.00	0.23
39	0.65	3.09	2.07	1.28	0.36	4.46	100.00	100.00	0.22
40	0.56	26.67	15.67	1.32	0.38	342.78	100.00	92.07	0.21
41	0.56	24.95	13.27	1.42	0.38	100.00	100.00	100.00	0.21
42	0.68	7.94	3.87	0.65	0.34	15.37	100.00	61.63	0.23
43	1.77	0.43	1.91	0.48	0.57	0.54	11.99	2.12	0.27
44	1.86	0.43	1.97	0.49	0.59	0.55	11.57	2.14	0.28
45	2.83	0.34	2.50	0.61	0.58	0.84	19.14	2.35	0.31
46	19.56	0.44	10.54	3.34	0.33	4.99	317.18	2.33	0.30
47	13.08	0.64	8.80	2.85	0.31	2.61	100.00	0.83	0.28
48	15.91	0.48	9.11	3.22	0.32	4.02	100.00	4.61	0.29
49	13.72	0.44	11.09	3.24	0.33	5.49	3080.54	19.17	0.30
50	29.94	0.65	2.04	0.35	0.36	23.60	50.45	19.59	0.28
51	20.98	0.64	2.58	0.35	0.36	17.16	24.62	18.13	0.28
52	100.00	0.58	16.64	0.33	0.36	100.00	32.75	26.45	0.29
53	148.59	0.58	14.14	0.33	0.36	77.77	26.05	34.83	0.29
54	4.71	4.21	0.71	2.55	0.40	51.99	217.36	100.00	0.22
55	5.27	10.51	0.71	16.39	0.40	100.00	100.00	263.04	0.21
56	5.73	14.27	0.70	42.04	0.40	120.95	101.00	201.45	0.21
57	5.18	2.10	0.74	1.05	0.39	364.00	99.67	71.99	0.22
58	0.57	11.41	2.44	4.32	0.39	100.00	100.00	36.17	0.21
59	0.54	15.79	11.50	4.41	0.39	4118.79	90.50	42.60	0.21
60	0.55	8.52	8.47	4.59	0.40	56.97	317.98	38.33	0.21

61	0.70	28.45	1.09	8.84	0.39	100.00	476.09	196.63	0.21
62	188.03	0.64	21.28	0.33	0.35	33.65	9.18	118.63	0.29
63	58.44	0.61	30.09	0.33	0.35	19.50	16.20	68.14	0.29
64	1.77	0.44	1.92	0.48	0.55	0.50	9.17	2.88	0.27
65	1.78	0.44	1.94	0.47	0.56	0.51	12.95	3.01	0.27
66	1.80	0.44	1.92	0.48	0.55	0.51	11.25	3.44	0.27
67	1.73	0.43	1.95	0.48	0.56	0.53	12.19	2.38	0.27
68	1.69	0.43	2.04	0.48	0.56	0.53	12.56	2.40	0.27
69	5.65	0.55	5.21	0.35	0.38	1.28	23.00	3.70	0.28
70	2.73	0.50	3.15	0.38	0.41	0.86	13.09	3.11	0.28
71	1.65	0.43	1.99	0.48	0.58	0.54	8.30	1.78	0.27
72	1.70	0.43	1.97	0.48	0.58	0.54	11.10	1.82	0.27
73	1.64	0.43	1.97	0.48	0.58	0.54	10.99	1.83	0.27
74	1.72	0.43	1.99	0.48	0.58	0.54	10.00	1.78	0.27
75	1.64	0.43	1.94	0.48	0.59	0.54	9.11	1.90	0.28
76	1.65	0.44	1.98	0.47	0.58	0.55	10.87	1.84	0.28
77	0.68	6.27	7.65	0.60	0.34	100.00	100.00	100.00	0.23
78	0.68	7.79	7.67	0.61	0.34	38.29	100.00	81.18	0.23
79	95.23	15.29	103.02	35.48	3557.54	100.00	100.00	100.00	0.16
80	100.00	14.05	89.02	73.84	214.00	100.00	176.33	100.00	0.16
81	100	0.56	41.27	0.33	0.37	185.39999	9.09	175.14	0.29
82	100	0.58	84.7	0.33	0.36	38.14	10.96	100	0.29
83	100	0.58	24.64	0.33	0.36	63.34	31.4	31.7	0.29
84	34.38	0.58	50.43	0.33	0.36	279.72	16.68	88.76	0.29
85	119.99	0.6	24.52	0.33	0.36	51.25	35.21	71.58	0.29
86	193.56	0.59	25.51	0.33	0.36	35.14	14.12	77.65	0.29
87	5.90	26.10	0.70	15.25	0.40	100.00	100.00	28.92	0.21
88	6.38	14.12	0.70	42.35	0.40	100.00	100.00	100.00	0.21
89	5.04	6.51	0.70	38.59	0.40	4620.31	100.00	57.07	0.21
90	272.32999	0.57	17.72	0.34	0.37	20.12	7.21	100	0.29
91	162.73	0.6	15.87	0.33	0.34	31.44	5.68	163.62	0.27
92	103.81	0.55	5.71	0.34	0.38	5.46	17.16	24.77	0.29
93	39.3	0.52	30.15	0.34	0.38	6.34	14.92	105.38	0.29
94	42.19	0.53	30.2	0.33	0.38	25.18	15.07	217.31	0.29

95	100	0.59	17.48	0.33	0.36	60.28	22.11	96.12	0.29
96	50.12	0.57	48.15	0.33	0.36	100	7.6	620.79999	0.29
97	100	0.54	40.62	0.33	0.37	25.38	12.31	211.58	0.29
98	248.33	0.55	200.78	0.33	0.37	9.72	12.62	72.52	0.29
99	100	0.54	38.42	0.33	0.37	9.36	10.78	1325.41003	0.29
100	0.55	14.75	5.27	7.01	0.39	36.84	425.94	100.00	0.21
101	0.54	54.88	14.78	8.04	0.39	106.35	100.00	161.83	0.21
102	0.54	29.82	15.50	9.59	0.39	203.12	46.69	121.44	0.21
103	3.66	54.17	0.70	166.44	0.40	100.00	113.97	205.94	0.21
104	4.88	46.91	0.70	58.93	0.39	100.00	100.00	163.44	0.21
105	3.05	27.99	0.71	11.89	0.40	119.50	100.00	100.00	0.21
106	3.34	20.99	0.72	71.36	0.40	83.53	100.00	192.92	0.21
107	0.54	40.47	21.07	8.36	0.39	62.99	151.54	100.00	0.21
108	0.54	6.68	12.59	2.76	0.39	71.36	100.00	100.00	0.21
109	0.53	779.96	14.73	13.88	0.39	85.09	100.00	100.00	0.21
110	0.54	85.31	17.35	9.34	0.40	91.00	100.00	119.57	0.21
111	1021.440	0.540	62.610	0.330	0.370	6.880	12.810	107.770	0.290
112	100.000	0.570	28.810	0.340	0.360	320.640	3.940	51.200	0.290
113	39.260	0.580	126.380	0.330	0.360	100.000	20.520	20.060	0.290
114	47.550	0.550	80.930	0.330	0.370	239.980	15.300	100.000	0.290
115	159.640	0.560	59.550	0.330	0.370	100.000	22.140	66.260	0.290
116	277.730	0.540	74.830	0.330	0.370	733.720	26.170	233.600	0.290
117	125.590	0.560	36.110	0.330	0.370	147.130	7.020	26.230	0.290
118	238.640	0.530	158.110	0.330	0.380	16.120	14.090	49.990	0.290
119	81.600	0.520	66.930	0.330	0.380	138.450	21.180	62.370	0.290
120	44.960	0.510	9.430	0.340	0.380	2.460	17.490	244.640	0.290
121	103.010	0.530	87.050	0.330	0.380	4243.050	7.380	50.590	0.290
122	121.700	0.520	33.100	0.330	0.380	20.130	8.820	100.000	0.290
123	341.560	0.540	40.080	0.330	0.370	6.460	18.610	30.210	0.290
124	99.090	0.550	48.390	0.330	0.370	22.180	11.910	57.470	0.290
125	100.000	0.580	50.490	0.330	0.360	369.680	25.400	35.180	0.290
126	49.200	0.530	52.480	0.330	0.370	46.210	17.170	62.090	0.290
127	608.380	0.550	39.120	0.330	0.370	3.660	12.930	42.790	0.290
128	5.07	20.70	0.71	42.08	0.40	100.00	126.39	1202.93	0.21

129	5.38	14.30	0.71	32.99	0.40	142.39	100.00	1829.36	0.21
130	4.89	17.27	0.71	100.00	0.40	100.00	100.00	137.88	0.21
131	5.74	22.18	0.71	33.33	0.40	100.00	100.00	57.83	0.21
132	5.51	47.78	0.71	68.91	0.40	100.00	73.91	185.91	0.21
133	174.800	0.560	37.190	0.340	0.370	108.970	5.900	135.670	0.290
134	174.800	0.550	43.830	0.330	0.380	405.270	14.730	100.000	0.290
135	100.000	0.520	88.190	0.340	0.380	145.850	24.590	1310.240	0.300
136	73.160	0.550	47.970	0.340	0.380	30.380	9.780	100.000	0.290
137	100.000	0.570	27.300	0.340	0.370	96.690	8.260	117.390	0.290
138	100.000	0.570	17.570	0.330	0.370	141.070	13.430	98.470	0.290
139	55.700	0.540	44.990	0.330	0.380	100.000	20.030	100.000	0.290
140	67.560	0.550	97.550	0.340	0.370	738.240	5.320	89.760	0.290
141	23.810	0.560	144.600	0.330	0.370	60.870	44.830	32.070	0.290
142	100.000	0.570	44.540	0.330	0.370	78.170	35.890	94.030	0.290
143	100.000	0.530	79.370	0.330	0.390	100.000	34.750	21.740	0.290
144	100.000	0.550	101.170	0.330	0.380	219.440	16.560	216.030	0.290
145	56.350	0.540	53.090	0.330	0.380	100.000	55.830	155.590	0.290
146	100.000	0.560	29.510	0.330	0.370	77.260	29.200	100.000	0.290
147	110.760	0.570	82.460	0.330	0.370	134.330	19.230	25.060	0.290
148	57.830	0.540	71.870	0.330	0.380	59.120	40.100	80.630	0.290
149	58.770	0.570	61.540	0.340	0.360	4.080	23.030	79.370	0.290
150	635.280	0.550	69.970	0.340	0.370	7.290	20.010	60.100	0.290
151	429.580	0.530	60.320	0.340	0.380	16.360	26.070	35.650	0.290
152	67.300	0.580	47.790	0.340	0.370	225.670	17.930	157.060	0.290
1	67.82	0.72	99.17	0.46	0.54	1121.01001	17.28	22.35	0.42
2	175.13	0.69	84.62	0.46	0.56	168.44	19.90	100.00	0.42
3	50.05	0.69	110.45	0.46	0.56	105.51	25.30	100.00	0.42
4	434.10999	0.68	159.72	0.47	0.56	99.72	17.46	34.01	0.41
5	62.66	0.68	86.90	0.46	0.55	3111.69	28.34	48.17	0.41
6	1158.26001	0.7	28.98	0.46	0.55	50.29	41.16	17.31	0.41
7	104.29	0.69	33.37	0.46	0.56	100.00	22.69	78.10	0.42
8	71	0.7	61.36	0.46	0.55	3375.90	25.07	62.18	0.42
9	571.51001	0.66	28.98	0.46	0.57	100.00	12.61	100.00	0.42
10	90.95	0.72	34.59	0.47	0.54	76.69	3.87	146.52	0.42

Table 5. Mineral Stoichiometry

	No.	Na2O	FeO	Fe2O3	K2O	CaO	Al2O3	MgO	MnO	MnO2	TiO2	SiO2
16-4-1 (dark green)	1	0.00	0.96	0.96	0.00	1.98	2.00	0.00	0.01	0.01	0.01	3.02
16-4-1 (dark green)	2	0.00	0.91	0.91	0.00	1.98	2.06	0.00	0.01	0.01	0.00	3.02
16-4-1 (med green)	3	0.04	0.90	0.90	0.00	1.93	2.02	0.00	0.01	0.01	0.00	3.07
16-4-1 (med green)	4	0.00	0.92	0.92	0.00	1.97	2.09	0.00	0.02	0.02	0.00	2.99
16-4-1 (med green)	5	0.00	0.97	0.97	0.00	2.02	2.05	0.00	0.01	0.01	0.00	2.97
16-4-1 (med green)	6	0.00	0.94	0.93	0.00	1.95	2.08	0.00	0.02	0.02	0.00	2.99
16-4-1 (light green)	7	0.01	0.74	0.74	0.00	1.99	2.26	0.00	0.02	0.02	0.00	2.98
16-4-1 (light green)	8	0.00	0.79	0.79	0.00	2.01	2.22	0.00	0.01	0.01	0.00	2.98
16-4-1 (light green)	9	0.00	0.86	0.86	0.00	1.89	2.20	0.00	0.07	0.07	0.00	2.94
16-4-1 (light green)	10	0.00	0.84	0.84	0.00	1.88	2.21	0.00	0.07	0.07	0.00	2.95
16-4-1 (albite)	11	1.07	0.01	0.00	0.01	0.00	0.97	0.00	0.00	0.00	0.00	2.99
16-4-1 (albite)	12	1.00	0.01	0.00	0.00	0.00	0.98	0.00	0.00	0.00	0.00	3.01
16-4-1 (albite)	13	0.99	0.01	0.00	0.00	0.00	0.99	0.00	0.00	0.00	0.00	3.01
16-4-1 (albite)	14	1.01	0.01	0.00	0.01	0.00	0.98	0.00	0.00	0.00	0.00	3.01
16-1(Plag)	15	0.66	0.01	0.00	0.01	0.33	1.30	0.00	0.00	0.00	0.00	2.68
16-1(Plag)	16	0.66	0.01	0.00	0.01	0.33	1.30	0.00	0.00	0.00	0.00	2.69
16-1(Plag)	17	0.67	0.02	0.00	0.02	0.30	1.30	0.01	0.00	0.00	0.00	2.69
16-1(Kspar around plag core)	18	0.60	0.09	0.00	0.18	0.06	1.32	0.03	0.00	0.00	0.00	2.72
16-1(Kspar around plag core)	19	0.65	0.05	0.00	0.11	0.14	1.28	0.02	0.00	0.00	0.00	2.74
16-1(Kspar)	20	0.08	0.00	0.00	0.87	0.01	1.01	0.00	0.00	0.00	0.00	3.00
16-1(Epidote?)	21	0.15	0.02	0.02	0.80	0.03	1.02	0.01	0.00	0.00	0.00	2.96
16-1(Epidote?)	22	0.00	0.89	0.89	0.00	1.97	2.13	0.00	0.02	0.02	0.00	2.98
16-1(Epidote?)	23	0.00	0.89	0.89	0.00	1.97	2.14	0.00	0.01	0.01	0.00	2.98
16-1(Epidote?)	24	0.00	0.90	0.89	0.00	1.97	2.13	0.00	0.01	0.01	0.00	2.98
16-1(Epidote?)	25	0.00	0.92	0.92	0.00	1.97	2.13	0.00	0.00	0.00	0.00	2.97
16-1(Epidote?)	26	0.00	0.89	0.89	0.00	1.99	2.13	0.00	0.00	0.00	0.00	2.98

16-1(Kspar)	27	0.11	0.00	0.00	0.83	0.03	1.02	0.00	0.00	0.00	0.00	2.98
16-1(Kspar)	28	0.06	0.00	0.00	0.89	0.01	1.01	0.00	0.00	0.00	0.00	3.00
16-1(Kspar)	29	0.08	0.00	0.00	0.89	0.00	1.00	0.00	0.00	0.00	0.00	3.00
16-1(Salmon Kspar)	30	0.11	0.00	0.00	0.86	0.01	1.01	0.00	0.00	0.00	0.00	3.00
16-1(Salmon Kspar)	31	0.11	0.00	0.00	0.85	0.03	1.02	0.00	0.00	0.00	0.00	2.98
16-1(Salmon Kspar)	32	0.17	0.00	0.00	0.79	0.03	1.02	0.00	0.00	0.00	0.00	2.98
16-1(Salmon Kspar)	33	0.10	0.00	0.00	0.87	0.01	1.01	0.00	0.00	0.00	0.00	3.00
16-1(White Plag)	34	0.66	0.00	0.00	0.02	0.33	1.31	0.00	0.00	0.00	0.00	2.69
16-1(White Plag)	35	0.67	0.00	0.00	0.02	0.33	1.30	0.00	0.00	0.00	0.00	2.69
16-1(White Plag)	36	0.64	0.00	0.00	0.02	0.33	1.32	0.00	0.00	0.00	0.00	2.68
16-1(White Plag)	37	0.65	0.00	0.00	0.02	0.33	1.30	0.00	0.00	0.00	0.00	2.69
16-1(White Plag)	38	0.65	0.01	0.00	0.02	0.32	1.31	0.00	0.00	0.00	0.00	2.69
16-1(Altered material around plag)	39	0.73	0.03	0.03	0.12	0.09	1.20	0.02	0.00	0.00	0.00	2.80
16-1(Altered material around plag)	40	0.91	0.00	0.00	0.01	0.08	1.07	0.00	0.00	0.00	0.00	2.92
16-1(Altered material around plag)	41	0.93	0.00	0.00	0.01	0.07	1.05	0.00	0.00	0.00	0.00	2.94
16-1(Altered material around plag)	42	0.65	0.01	0.01	0.04	0.30	1.30	0.00	0.00	0.00	0.00	2.68
16-1 Epidote in Comb Structure (Fig 5)	43	0.25	1.31	1.31	0.23	0.97	1.01	1.00	0.01	0.01	0.10	3.30
16-1 Epidote in Comb Structure (Fig 5)	44	0.24	1.36	1.36	0.22	0.98	0.98	1.02	0.01	0.01	0.10	3.26
16-1 Epidote in Comb Structure (Fig 5)	45	0.14	2.32	2.31	0.16	0.66	1.11	0.52	0.01	0.01	0.09	2.92
16-1 Chlorite in Comb Structure	46	0.01	1.54	0.00	0.02	0.05	3.28	0.04	0.00	0.00	0.11	3.61
16-1 Chlorite in Comb Structure	47	0.02	0.71	0.00	0.02	0.05	3.19	0.07	0.00	0.00	0.55	3.63
16-1 Chlorite in Comb Structure	48	0.02	1.26	0.00	0.02	0.05	3.35	0.05	0.00	0.00	0.04	3.76
16-1 Chlorite in Comb Structure	49	0.02	1.56	0.00	0.02	0.05	3.31	0.03	0.00	0.00	0.01	3.67
16-8-2 Epidote in Salmon Kspar	50	0.01	0.62	0.62	0.20	1.76	2.19	0.01	0.00	0.00	0.01	3.20
16-8-2 Epidote in Salmon Kspar	51	0.01	0.64	0.64	0.13	1.83	2.25	0.01	0.01	0.01	0.01	3.11
16-8-2 Epidote in Salmon Kspar	52	0.00	0.75	0.75	0.01	2.01	2.25	0.00	0.00	0.00	0.00	2.98
16-8-2 Epidote in Salmon Kspar	53	0.00	0.75	0.75	0.01	2.02	2.24	0.00	0.00	0.00	0.00	2.98
16-8-2 Salmon Kspar (Adj)	54	0.03	0.02	0.00	0.94	0.03	1.00	0.00	0.00	0.00	0.00	2.98
16-8-2 Salmon Kspar (Adj)	55	0.02	0.01	0.00	0.96	0.00	0.99	0.00	0.00	0.00	0.00	3.01
16-8-2 Salmon Kspar (Adj)	56	0.02	0.01	0.00	0.98	0.00	1.00	0.00	0.00	0.00	0.00	3.00
16-8-2 Salmon Kspar (Adj)	57	0.02	0.05	0.00	0.87	0.14	1.03	0.00	0.00	0.00	0.00	2.90

16-8-2 Albite in Salmon Kspar (Adj)	58	0.90	0.01	0.00	0.08	0.01	0.99	0.00	0.00	0.00	0.00	3.00
16-8-2 Albite in Salmon Kspar (Adj)	59	0.98	0.00	0.00	0.01	0.01	0.99	0.00	0.00	0.00	0.00	3.00
16-8-2 Albite in Salmon Kspar (Adj)	60	0.97	0.01	0.00	0.01	0.01	0.99	0.00	0.00	0.00	0.00	3.00
16-8-2 Albite in Salmon Kspar (Adj)	61	0.62	0.00	0.00	0.39	0.01	1.00	0.00	0.00	0.00	0.00	2.99
16-8-2 Epidote (Random-along crack)	62	0.00	0.63	0.63	0.01	1.98	2.40	0.00	0.02	0.02	0.00	2.96
16-8-2 Epidote (Random-along crack)	63	0.00	0.68	0.68	0.00	1.99	2.34	0.01	0.01	0.01	0.00	2.97
16-8-2 Amphibole	64	0.51	2.38	0.00	0.43	1.86	1.99	2.16	0.03	0.00	0.12	6.44
16-8-2 Amphibole	65	0.50	2.39	0.00	0.42	1.88	1.96	2.17	0.02	0.00	0.12	6.45
16-8-2 Amphibole	66	0.50	2.42	0.00	0.43	1.88	2.01	2.15	0.02	0.00	0.10	6.43
16-8-2 Amphibole	67	0.52	2.53	0.00	0.42	1.83	1.94	2.01	0.02	0.00	0.16	6.45
16-8-2 Amphibole	68	0.55	2.54	0.00	0.38	1.84	1.93	2.01	0.02	0.00	0.16	6.45
16-8-2 Epidote in Amphibole	69	0.04	0.83	0.83	0.04	1.76	2.02	0.20	0.01	0.01	0.05	3.06
16-8-2 Epidote in Amphibole	70	0.12	1.00	1.00	0.09	1.52	1.78	0.40	0.01	0.01	0.06	3.09
16-2-2 in Amphibole	71	0.58	2.56	0.00	0.40	1.84	1.85	1.94	0.03	0.00	0.25	6.43
16-2-2 in Amphibole	72	0.56	2.59	0.00	0.41	1.83	1.82	1.95	0.02	0.00	0.25	6.44
16-2-2 in Amphibole	73	0.57	2.57	0.00	0.41	1.82	1.87	1.95	0.03	0.00	0.24	6.43
16-2-2 in Amphibole	74	0.55	2.56	0.00	0.40	1.84	1.86	1.95	0.03	0.00	0.26	6.42
16-2-2 in Amphibole (darker BSE)	75	0.61	2.63	0.00	0.43	1.86	1.82	1.96	0.03	0.00	0.23	6.41
16-2-2 in Amphibole (darker BSE)	76	0.60	2.54	0.00	0.41	1.95	1.84	1.94	0.03	0.00	0.24	6.39
16-2-2 Plag	77	0.66	0.01	0.00	0.01	0.35	1.32	0.00	0.00	0.00	0.00	2.66
16-2-2 Plag	78	0.65	0.01	0.00	0.01	0.35	1.31	0.00	0.00	0.00	0.00	2.67
16-2-2 Plag	79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00
16-2-2 Plag	80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00
17-1-1 Epidote	81	0.00	0.81	0.81	0.00	2.01	2.20	0.00	0.02	0.02	0.00	2.97
17-1-1 Epidote	82	0.00	0.78	0.78	0.00	2.00	2.25	0.00	0.01	0.01	0.00	2.97
17-1-1 Epidote	83	0.00	0.77	0.77	0.01	2.01	2.25	0.00	0.00	0.00	0.00	2.97
17-1-1 Epidote	84	0.00	0.76	0.76	0.00	1.99	2.25	0.00	0.01	0.01	0.00	2.99
17-1-1 Epidote	85	0.00	0.71	0.71	0.01	2.02	2.29	0.00	0.00	0.00	0.00	2.98
17-1-1 Epidote	86	0.00	0.75	0.74	0.00	2.02	2.27	0.00	0.01	0.01	0.00	2.97
17-1-1 Kspar	87	0.02	0.00	0.00	0.96	0.00	0.99	0.00	0.00	0.00	0.00	3.01
17-1-1 Kspar	88	0.02	0.01	0.00	0.97	0.00	0.99	0.00	0.00	0.00	0.00	3.01
17-1-1 Kspar	89	0.03	0.01	0.00	0.96	0.00	0.98	0.00	0.00	0.00	0.00	3.01

17-1-1 Epidote in Vein	90	0.00	0.79	0.78	0.01	1.96	2.24	0.01	0.02	0.02	0.00	2.97
17-1-1 Epidote in Vein	91	0.00	0.67	0.67	0.01	1.79	2.37	0.00	0.02	0.02	0.00	3.05
17-1-1 Epidote in Vein	92	0.00	0.87	0.87	0.04	1.93	2.12	0.02	0.01	0.01	0.01	3.01
17-1-1 Epidote in Vein	93	0.00	0.94	0.94	0.00	1.96	2.10	0.02	0.01	0.01	0.00	2.97
17-1-1 Epidote in Vein	94	0.00	0.89	0.89	0.00	2.00	2.11	0.01	0.01	0.01	0.00	2.98
17-1-1 Epidote in Vein	95	0.00	0.73	0.73	0.01	2.00	2.28	0.00	0.01	0.01	0.00	2.98
17-1-1 Epidote in Vein 2 (larger)	96	0.00	0.77	0.77	0.00	1.98	2.26	0.00	0.02	0.02	0.00	2.97
17-1-1 Epidote in Vein 2 (larger)	97	0.00	0.86	0.86	0.00	1.95	2.18	0.00	0.01	0.01	0.00	2.98
17-1-1 Epidote in Vein 2 (larger)	98	0.00	0.84	0.84	0.00	1.98	2.18	0.01	0.01	0.01	0.00	2.98
17-1-1 Epidote in Vein 2 (larger)	99	0.00	0.87	0.87	0.00	1.97	2.16	0.01	0.01	0.01	0.00	2.98
17-1-1 Plag	100	0.95	0.00	0.00	0.02	0.01	1.01	0.00	0.00	0.00	0.00	2.99
17-1-1 Plag	101	0.98	0.00	0.00	0.01	0.01	0.99	0.00	0.00	0.00	0.00	3.00
17-1-1 Plag	102	0.98	0.00	0.00	0.00	0.01	0.99	0.00	0.00	0.00	0.00	3.01
17-2-2 kspar	103	0.04	0.00	0.00	0.94	0.00	0.99	0.00	0.00	0.00	0.00	3.01
17-2-2 kspar	104	0.03	0.00	0.00	0.96	0.00	0.99	0.00	0.00	0.00	0.00	3.01
17-2-2 kspar	105	0.05	0.00	0.00	0.93	0.01	0.99	0.00	0.00	0.00	0.00	3.01
17-2-2 kspar	106	0.04	0.00	0.00	0.92	0.00	0.99	0.00	0.00	0.00	0.00	3.02
17-2-2 Plag	107	0.99	0.00	0.00	0.00	0.01	0.98	0.00	0.00	0.00	0.00	3.01
17-2-2 Plag	108	0.98	0.01	0.00	0.01	0.03	0.99	0.00	0.00	0.00	0.00	2.99
17-2-2 Plag	109	1.00	0.00	0.00	0.01	0.00	0.99	0.00	0.00	0.00	0.00	3.00
17-2-2 Plag	110	0.98	0.00	0.00	0.00	0.01	0.97	0.00	0.00	0.00	0.00	3.02
17-2-2 Epidote	111	0.00	0.86	0.86	0.00	1.97	2.17	0.02	0.01	0.01	0.00	2.97
17-2-2 Epidote	112	0.00	0.78	0.77	0.00	1.93	2.26	0.00	0.05	0.05	0.00	2.96
17-2-2 Epidote	113	0.00	0.75	0.75	0.00	1.98	2.26	0.00	0.01	0.01	0.01	2.98
17-2-2 Epidote	114	0.00	0.84	0.84	0.00	2.01	2.19	0.00	0.01	0.01	0.00	2.97
17-2-2 Epidote	115	0.00	0.81	0.81	0.00	2.02	2.20	0.00	0.01	0.01	0.00	2.98
17-2-2 Epidote	116	0.00	0.87	0.87	0.00	2.01	2.15	0.00	0.00	0.00	0.00	2.98
17-2-2 Epidote	117	0.00	0.82	0.82	0.00	1.98	2.20	0.00	0.02	0.02	0.00	2.97
17-2-2 Epidote	118	0.00	0.91	0.91	0.00	2.00	2.12	0.01	0.01	0.01	0.00	2.96
17-2-2 Epidote	119	0.00	0.94	0.94	0.00	2.02	2.08	0.00	0.01	0.01	0.00	2.96
17-2-2 Epidote	120	0.00	0.97	0.97	0.02	1.87	2.08	0.07	0.01	0.01	0.00	2.97
17-2-2 Epidote	121	0.00	0.91	0.90	0.00	2.00	2.11	0.00	0.02	0.02	0.00	2.97
17-2-2 Epidote	122	0.00	0.92	0.92	0.00	1.98	2.09	0.01	0.02	0.02	0.00	2.98
17-2-2 Epidote	123	0.00	0.87	0.87	0.00	1.96	2.16	0.02	0.01	0.01	0.00	2.98

17-2-2 Epidote	124	0.00	0.85	0.84	0.00	1.99	2.17	0.01	0.01	0.01	0.00	2.98
17-2-2 Epidote	125	0.00	0.76	0.76	0.00	2.00	2.26	0.00	0.01	0.01	0.00	2.98
17-2-2 Epidote	126	0.00	0.89	0.89	0.00	1.98	2.14	0.00	0.01	0.01	0.00	2.98
17-2-2 Epidote	127	0.00	0.85	0.85	0.00	1.95	2.21	0.04	0.01	0.01	0.00	2.95
17-3-2 kspar	128	0.03	0.00	0.00	0.94	0.00	0.99	0.00	0.00	0.00	0.00	3.01
17-3-2 kspar	129	0.02	0.00	0.00	0.95	0.00	0.99	0.00	0.00	0.00	0.00	3.01
17-3-2 kspar	130	0.03	0.00	0.00	0.94	0.00	0.99	0.00	0.00	0.00	0.00	3.02
17-3-2 kspar	131	0.02	0.00	0.00	0.96	0.00	0.98	0.00	0.00	0.00	0.00	3.01
17-3-2 kspar	132	0.02	0.00	0.00	0.95	0.00	0.99	0.00	0.00	0.00	0.00	3.01
17-3-2 epidote	133	0.00	0.83	0.83	0.00	1.94	2.21	0.00	0.03	0.03	0.00	2.97
17-3-2 epidote	134	0.00	0.88	0.88	0.00	2.01	2.15	0.00	0.01	0.01	0.00	2.96
17-3-2 epidote	135	0.00	0.97	0.96	0.00	1.95	2.13	0.00	0.01	0.01	0.00	2.95
17-3-2 epidote	136	0.00	0.88	0.88	0.00	1.99	2.12	0.00	0.01	0.01	0.00	2.99
17-3-2 epidote	137	0.00	0.79	0.79	0.01	1.96	2.23	0.00	0.02	0.02	0.00	2.98
17-3-2 epidote	138	0.00	0.80	0.80	0.01	1.98	2.20	0.00	0.01	0.01	0.00	3.00
17-3-2 epidote	139	0.00	0.88	0.88	0.00	2.01	2.14	0.00	0.01	0.01	0.00	2.97
17-3-2 epidote	140	0.00	0.84	0.84	0.00	1.94	2.20	0.00	0.03	0.03	0.00	2.97
17-3-2 epidote	141	0.01	0.83	0.83	0.00	2.00	2.16	0.00	0.00	0.00	0.00	2.99
17-3-2 Epidote	142	0.00	0.80	0.80	0.00	2.01	2.19	0.00	0.00	0.00	0.00	2.99
17-3-2 Epidote	143	0.00	0.94	0.94	0.00	2.00	2.06	0.00	0.00	0.00	0.01	2.99
17-3-2 Epidote	144	0.00	0.86	0.86	0.00	2.00	2.16	0.00	0.01	0.01	0.00	2.97
17-3-2 Epidote	145	0.00	0.89	0.89	0.00	2.00	2.12	0.00	0.00	0.00	0.00	2.99
17-3-2 Epidote	146	0.00	0.82	0.82	0.00	1.99	2.19	0.00	0.00	0.00	0.00	2.99
17-3-2 Epidote	147	0.00	0.81	0.80	0.00	2.00	2.19	0.00	0.01	0.01	0.01	2.99
17-3-2 Epidote Region 2	148	0.00	0.88	0.88	0.00	1.98	2.12	0.00	0.00	0.00	0.00	3.00
17-3-2 Epidote Region 3	149	0.00	0.79	0.79	0.00	1.95	2.25	0.04	0.01	0.01	0.00	2.97
17-3-2 Epidote Region 4	150	0.00	0.86	0.86	0.00	1.95	2.17	0.02	0.01	0.01	0.00	2.98
17-3-2 Epidote Region 5	151	0.00	0.94	0.94	0.00	1.97	2.12	0.01	0.01	0.01	0.00	2.96
17-3-2 Epidote Region 6	152	0.00	0.77	0.77	0.00	1.96	2.24	0.00	0.01	0.01	0.00	3.00
Catoctin 1	1	0.00	0.99	0.99	0.00	1.99	2.07	0.00	0.01	0.01	0.01	2.94
Catoctin 2	2	0.00	1.08	1.08	0.00	2.00	1.95	0.00	0.01	0.01	0.00	2.97
Catoctin 3	3	0.01	1.11	1.10	0.00	1.99	1.94	0.00	0.01	0.01	0.00	2.97
Catoctin 4	4	0.00	1.10	1.10	0.00	1.92	1.96	0.00	0.01	0.01	0.00	2.98
Catoctin 5	5	0.00	1.09	1.09	0.00	1.99	1.98	0.00	0.01	0.01	0.00	2.95

Catoctin 6	6	0.00	1.04	1.04	0.01	2.01	2.00	0.00	0.00	0.00	0.01	2.95
Catoctin 7	7	0.00	1.09	1.09	0.00	2.01	1.97	0.00	0.01	0.01	0.00	2.94
Catoctin 8	8	0.00	1.04	1.04	0.00	2.00	2.02	0.00	0.01	0.01	0.00	2.94
Catoctin 9	9	0.00	1.17	1.17	0.01	2.02	1.86	0.00	0.01	0.01	0.00	2.95
Catoctin 10	10	0.00	1.00	0.99	0.00	1.87	2.09	0.00	0.07	0.07	0.00	2.93

Table 6. Laser Ablation Data

Filter = <3 X LLD		SiO2	CaO	Cr	Mn	Fe	Cu	Zn	Ga	Ge	As	Se	Rb	Sr	Y
Isotopic mass		29	43	53	55	57	63	66	71	73	75	77	85	88	89
		wt%	wt%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Chondrite		22.84	1.30	2646	1933	184300	131.00		9.71	32.60	1.81	21.40	2.32	7.26	1.56
Run detection limit		0.03	0.01	0.69	0.38	7.87	0.08	0.20	0.02	0.19	0.11	0.97	0.03	0.02	0.01
std-1	01	69.7	12	415	459	460	435	457	426	442	324	141	417	503	451
std-2	02	69.7	11	401	428	456	447	463	441	452	326	135	434	528	473
Ap14a03	03	54.4	4.77	9.22	1008	59839	11	103	14	6.5	*<1.18*	*<8.64*	29	216	19
Ap14a04	04	36	16	*<6.68*	835	64940	4.5	16	51	15	1.4	*<14.97*	0.42	1573	24
Ap14a05	05	36	8.2	15	898	102303	26	522	59	41	6.3	*<18.66*	25	857	42
Ap14a06	06	36	11	8.5	456	56474	11	64	43	29	2.9	*<13.89*	26	964	24
Ap14a07	07	36	7.9	*<9.46*	308	42100	26	37	30	11	2.0	*<13.51*	5.2	760	14
Ap14a08	08	36	14	*<7.28*	537	72524	6.4	80	55	33	3.6	*<16.45*	8.9	1217	28
Ap14a09	09	36	18	6.0	1095	71881	7.2	33	55	27	3.4	*<14.01*	3.6	2028	28
Ap14a10	10	36	10	12	841	95970	29	366	59	54	6.0	*<12.86*	19	1247	35
Ap14a11	11	36	0.58	11	1241	121086	43	968	47	6.7	1.7	*<9.86*	59	47	7.0
Ap14a12	12	36	8.6	15	933	107178	55	557	69	38	6.0	*<11.85*	31	1128	38
Ap14a13	13	64	*<0.14*	*<10.82*	*<43.15*	702	8.9	4.8	4.7	*<2.71*	*<1.25*	*<22.68*	261	18	0.30
Ap14a14	14	64	0.12	*<12.70*	*<36.92*	940	2.0	6.3	4.2	*<7.01*	*<1.25*	*<10.95*	360	21	0.17
Ap14a15	15	64	0.22	*<9.70*	*<30.08*	993	4.1	7.5	7.4	0.61	*<1.51*	*<12.47*	248	44	0.40
Ap14a16	16	64	*<0.16*	*<20.67*	*<54.98*	514	4.0	*<8.56*	4.1	0.41	*<2.47*	*<21.29*	243	20	0.19
Ap14a17	17	60	*<0.18*	*<19.94*	*<51.98*	555	21	*<4.48*	13	*<2.33*	*<1.33*	*<30.56*	6.6	64	0.13
Ap14a18	18	60	*<0.20*	*<22.33*	*<56.28*	808	4.2	*<5.80*	7.2	*<5.49*	*<2.67*	*<26.19*	1.0	30	0.52
std-3	19	69.7	11	384	437	441	426	445	416	418	314	132	394	478	437
std-4	20	69.7	12	432	451	476	456	475	450	477	336	144	459	555	488

Zr	Nb	Cd	In	Sn	Cs	Ba	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er
90	93	111	115	117	133	137	139	140	141	146	147	153	157	159	163	165	167
ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
3.86	0.25	0.68	0.08	1.68	0.19	2.41	0.25	0.64	0.10	0.47	0.15	0.06	0.20	0.04	0.25	0.06	0.17
0.00	0.00	0.09	0.01	0.20	0.01	0.03	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.01
442	455	275	435	424	355	444	425	450	450	437	453	446	452	434	440	456	457
454	475	265	433	436	378	460	455	456	446	423	453	448	446	440	434	443	452
111	8.1	*<1.98*	*<0.08*	1.5	0.76	446	17	35	4.3	18	4.1	1.3	3.7	0.62	3.7	0.80	2.1
2.7	0.5	*<0.61*	0	3.7	*<0.09*	12	54	104	12	43	7.1	2.9	6.2	0.80	4.7	0.97	2.2
1.1	0.19	0.04	0.19	*<4.22*	*<0.27*	95	126	296	37	132	25	4.3	17	2.1	10	1.6	4.0
1.4	1.2	*<1.03*	0.16	2.8	*<0.11*	329	104	228	26	90	14	3.4	9.2	1.2	5.5	1.1	2.4
1.5	0.04	*<0.81*	0.17	*<2.36*	0.09	54	38	84	10	34	5.9	1.9	4.7	0.62	3.1	0.56	1.3
1.1	0.13	*<1.42*	0.20	1.7	*<0.17*	51	117	273	30	105	15	3.8	10	1.4	6.9	1.1	2.8
2.8	0.87	0.16	0.26	5.1	*<0.06*	46	110	223	25	85	13	4.3	8.5	1.2	6.8	1.1	3.0
1.1	0.60	0.05	0.12	2.2	*<0.17*	180	167	364	44	154	23	4.3	15	1.9	9.5	1.5	3.2
0.37	0.02	0.11	*<0.05*	*<3.54*	0.10	351	9.4	12	2.4	11	1.1	0.41	1.8	0.17	0.56	0.19	0.51
0.85	0.13	*<0.64*	*<0.10*	*<2.08*	0.11	103	126	284	34	122	19	3.8	13	1.6	8.0	1.5	3.3
0.12	0.09	0.22	*<0.24*	*<3.27*	0.25	2268	4.1	4.3	0.22	0.77	0.06	1.0	0.06	0.01	0.04	0.02	0.03
0.083	0.14	0.06	0.03	*<1.03*	0.33	2615	4.6	4.5	0.24	0.48	0.15	1.0	0.07	0	0.07	0	0
<0.24	0.32	0.11	*<0.16*	*<3.39*	*<0.22*	2138	7.2	6.2	0.27	0.75	0.06	1.6	0.04	0.01	0.05	0.01	0.08
0.09	0.01	*<5.77*	*<0.15*	2.0	*<0.35*	2157	1.5	1.7	0.14	0.21	0.05	0.51	0	0	0	0.01	0.00
0.10	0	0.2	*<0.13*	*<4.69*	*<0.14*	33	1.4	3.0	0.15	0.69	0.09	0.27	*<1.88*	0.01	0.00	0	0.02
0.10	0.04	0.3	0	*<6.72*	*<0.42*	19	0.43	0.65	0.22	0.93	0.17	0.01	*<0.89*	0.01	0.05	0.01	0
426	438	261	422	410	347	437	426	430	434	419	437	440	442	426	426	446	447
471	493	279	447	451	386	467	455	477	463	441	470	455	456	448	449	453	463

Tm 169 ppm	Yb 173 ppm	Lu 175 ppm	Hf 179 ppm	Ta 181 ppm	Pb 208 ppm	Th 232 ppm	U 238 ppm	Peak secs	Abltn yield	Comments
0.03	0.17	0.03	0.11	0.01	2.53	0.03	0.01			
0.00	0.02	0.00	0.01	0.00	0.01	0.00	0.00			
431	454	434	428	442	422	458	463	50.2	70%	NIST610 55um 7Hz 65% 3.20Jcm-2
440	446	444	442	450	430	456	460	50.2	68%	NIST610 55um 7Hz 65% 3.33Jcm-2
0.27	1.7	0.26	2.8	0.47	6.4	3.6	0.99	39.5	296%	BCR2g 55um 7Hz 65% 3.27Jcm-2
0.32	1.7	0.29	*<0.25*	0.01	27	0.07	0.95	29.5	250%	17-2-2 Epidote 55um 7Hz 65% 3.20Jcm-2
0.43	2.7	0.32	0.06	0.01	13	0.31	0.82	27.5	205%	17-2-2 Epidote 55um 7Hz 65% 3.08Jcm-2
0.27	1.7	0.33	0.08	0.04	10	0.23	0.75	20.8	199%	17-2-2 Epidote 55um 7Hz 65% 3.64Jcm-2
0.19	1.4	0.14	0.07	0	13	0.20	0.60	27.5	171%	17-2-2 Epidote 55um 7Hz 65% 3.39Jcm-2
0.34	2.1	0.33	0.12	0.003	12	0.09	1.3	20.8	213%	17-2-2 Epidote 55um 7Hz 65% 3.45Jcm-2
0.30	2.5	0.34	0.29	0.03	24	0.14	1.2	26.1	255%	17-2-2 Epidote 55um 7Hz 65% 3.57Jcm-2
0.40	2.5	0.33	0.04	0.04	15	0.17	0.96	22.1	186%	17-2-2 Epidote 55um 7Hz 65% 3.08Jcm-2
0.09	0.23	0.05	0.01	0.01	7.7	0.01	0.01	26.1	246%	17-2-2 Epidote 55um 7Hz 65% 3.29Jcm-2
0.40	2.9	0.36	0.07	0.005	23	0.15	0.99	34.9	246%	17-2-2 Epidote 55um 7Hz 65% 3.39Jcm-2
0	0.02	0	0.27	0.22	1.1	0.06	0.003	40.9	109%	17-2-2 K-spar 55um 7Hz 65% 3.76Jcm-2
0	0	0.004	0.14	0.29	1.2	0.06	0.01	34.9	124%	17-2-2 K-spar 55um 7Hz 65% 3.45Jcm-2
0	0.09	0	0.07	0.27	2.5	0.21	0.03	33.5	145%	17-2-2 K-spar 55um 7Hz 65% 2.65Jcm-2
0	0	0.01	0.43	0.26	0.72	0.12	0	35.5	79%	17-2-2 K-spar 55um 7Hz 65% 3.14Jcm-2
0.01	0	0	0	0	1.07	0	0	37.5	85%	17-2-2 Plagioclase 55um 7Hz 65% 3.82Jcm-2
0.01	0.04	0	0	0.01	2.16	0.01	0	34.9	78%	17-2-2 Plagioclase 55um 7Hz 65% 3.82Jcm-2
422	451	436	429	443	417	453	444	38.9	138%	NIST610 55um 7Hz 65% 55um 7Hz 65%3.20Jcm2
448	449	442	441	449	436	461	480	37.5	124%	NIST610 55um 7Hz 65% 55um 7Hz 65%3.77Jcm2

	SiO2	CaO	Cr	Mn	Fe	Cu	Zn	Ga	Ge	As	Se	Rb	Sr	Y
std-1	69.7	11	392	447	451	437	454	426	428	321	135	404	489	447
std-2	69.7	11	424	441	465	445	466	440	466	329	141	447	542	477
Ap14b03	54.4	7.44	14	1596	91273	17	148	22	10	1.8	<8.75	46	351	31
Ap14b04	65.0	<0.20	<12.45	<48.27	593	3.1	5.2	4.0	0.7	<2.36	<17.17	<0.60	10	<0.42
Ap14b05	65.0	0.14	<15.31	<51.90	1154	4.7	9.3	11	<5.81	<2.96	<24.35	3.6	47	0.38
Ap14b06	35.0	8.8	<14.67	531	35735	1.6	10	34	6.4	<0.95	<12.36	111	1645	9.1
Ap14b07	35.0	21	20	1029	101641	17	156	87	46	4.8	<8.27	3.5	2243	66
Ap14b08	35.0	26	<5.88	2547	82642	1.6	8.2	93	12	1.7	<7.27	1.2	2310	14
Ap14b09	35.0	19	<8.07	1309	63236	28	49	67	10	2.0	<10.44	57	3313	17
Ap14b10	35.0	25	8.6	1362	91523	17	30	86	27	3.0	<5.67	1.2	3176	38
Ap14b11	65.0	0.655	<23.28	<85.51	2456	<2.74	<7.65	16	<3.47	<2.80	<19.11	338	146	0.78
Ap14b12	65.0	<0.16	<14.50	<59.18	1748	<2.85	<4.69	20	<2.38	<2.64	<13.79	422	66	0.35
Ap14b13	35.0	26	<9.21	2086	78205	2.2	11	90	11	1.4	<10.53	1.0	2997	13
Ap14b14	35.0	24	<5.58	1282	85642	2.0	10	94	9.5	1.7	<7.98	1.3	3912	21
Ap14b15	35.0	24	<4.98	1397	90320	2.6	5.8	102	11	2.5	<9.53	1.0	3431	34
Ap14b16	35.0	23	<5.50	1292	79433	1.4	10	98	8.2	2.0	<8.99	1.3	3680	32
Ap14b17	35.0	27	<6.09	1502	76906	1.9	14	81	13	1.5	<5.11	1.4	6697	33
Ap14b18	35.0	14	<10.29	952	51027	5.0	7.1	53	8.8	1.1	<13.81	0.86	3117	21
std-3	70	12	418	441	477	463	485	462	459	333	144	420	526	475
std-4	70	11	398	447	439	419	435	404	435	317	132	431	505	449

Zr	Nb	Cd	In	Sn	Cs	Ba	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er
435	448	266	430	418	354	447	434	438	443	428	447	450	452	437	436	457	458
461	482	274	438	442	378	457	446	468	453	432	459	444	446	437	438	442	452
174	13	*<1.43*	0.12	2.3	1.0	701	26	53	6.6	30	7.0	2.0	6.8	0.92	6.2	1.1	3.4
<1.04	*<0.33*	*<4.95*	*<0.17*	*<4.32*	*<0.36*	5.6	0.94	2.0	*<0.24*	0.53	0.10	0.05	*<1.30*	0.02	0	*<0.09*	0
0.07	0	*<2.64*	*<0.10*	*<2.68*	*<0.39*	26	1.5	3.2	0.26	0.97	0.40	0.09	0.18	0.01	0.04	0	0
2.0	0.16	*<1.06*	*<0.27*	1.5	*<0.18*	1181	27	30	3.2	12	3.2	8.5	1.9	0.36	1.9	0.34	0.86
2.3	0.09	0.15	0.40	4.6	*<0.15*	25	138	338	39	136	23	7.0	16	2.4	13	2.7	6.7
2.9	0.09	0.28	0.25	2.2	*<0.09*	11	54	59	5.5	21	4.4	17	3.3	0.58	3.4	0.51	1.4
3.4	0.21	*<0.92*	0.24	2.9	*<0.11*	592	81	82	7.2	25	5.5	24	3.6	0.63	3.5	0.76	2.0
3.0	0.08	0.13	0.37	6.5	0.04	20	106	205	22	69	13	15	8.9	1.4	7.9	1.5	4.3
0.24	0.05	0.57	*<0.20*	*<8.53*	0.42	3302	18	16	0.55	1.6	0.08	4.5	0.42	0.05	0.29	0.03	0
0	0.05	0.26	*<0.14*	*<5.29*	0.62	3335	5.2	4.6	0.23	0.73	0	1.9	*<0.68*	0	0	0	0
2.7	0.08	*<0.65*	0.16	2.3	*<0.11*	10	65	63	6.3	21	4.1	23	3.8	0.51	3.1	0.63	1.3
3.3	0.05	0.46	0.22	*<2.31*	*<0.13*	15	31	39	4.3	16	3.8	8.7	3.3	0.58	3.5	0.73	2.0
2.8	0.07	*<1.28*	0.17	1.2	*<0.08*	6.4	31	45	5.5	20	5.3	9.1	5.4	0.89	5.6	1.1	3.0
3.2	0.06	0.06	0.23	*<2.47*	*<0.09*	9.2	41	42	4.4	18	4.0	15	4.6	0.86	5.1	1.1	3.0
3.9	0.10	0.04	0	1.8	*<0.08*	17	55	62	7.2	26	5.6	19	5.1	0.84	5.0	0.90	2.5
2.4	0.51	*<2.32*	0	*<2.24*	*<0.16*	14	47	45	4.5	17	3.9	15	4.3	0.60	3.9	0.72	2.3
460	474	281	434	429	378	464	460	471	466	442	470	459	469	459	455	474	478
436	456	259	434	431	354	440	420	435	430	418	436	435	429	415	419	425	432

Tm	Yb	Lu	Hf	Ta	Pb	Th	U			
432	462	445	438	452	426	461	452	38.9	114%	NIST610 55um 7Hz 65% 3.20Jcm-2
438	438	433	432	440	426	453	471	38.2	102%	NIST610 55um 7Hz 65% 2.77Jcm-2
0.38	3.0	0.42	4.4	0.81	9.4	6.0	1.7	37.5	200%	BCR2g 55um 7Hz 65% 3.14Jcm-2
0.02	*<0.50*	0.01	0	0.01	3.2	0.01	0.01	30.2	90%	17-2-2 Plagioclase 55um 7Hz 65% 2.96Jcm2
0	0	0.01	0	0	4.1	0	0	21.4	79%	17-2-2 Plagioclase 55um 7Hz 65% 3.45Jcm2
0.19	0.71	0.17	0.10	0.01	14	0.02	0.43	24.8	123%	17-1-1 Epidote (1) 55um 7Hz 65% 3.70Jcm-2
0.94	6.0	0.91	0.31	0.004	34	0.31	2.0	43.6	186%	17-1-1 Epidote (1) 55um 7Hz 65% 3.70Jcm-2
0.19	0.98	0.17	0.13	0	41	0.07	0.94	36.9	208%	17-1-1 Epidote (1) 55um 7Hz 65% 3.14Jcm-2
0.16	1.4	0.19	0.13	0.01	43	0.36	0.86	25.5	152%	17-1-1 Epidote (2) 55um 7Hz 65% 3.14Jcm-2
0.54	3.7	0.39	0.22	0	36	0.60	1.5	16.8	216%	17-1-1 Epidote (2) 55um 7Hz 65% 3.20Jcm-2
0	0.05	0.04	0.30	0.45	7.2	0.41	0.02	26.8	62%	17-1-1 K-spar 55um 7Hz 65% 2.83Jcm-2
0	0.10	0	0.11	0.27	8.2	0.01	0	22.8	77%	17-1-1 K-spar 55um 7Hz 65% 2.53Jcm-2
0.20	1.1	0.13	0.14	0.004	44	0.67	1.1	37.5	195%	17-1-1 Epidote (3) 55um 7Hz 65% 2.90Jcm-2
0.25	1.3	0.17	0.12	0	42	1.1	0.99	36.9	194%	17-1-1 Epidote (3) 55um 7Hz 65% 2.71Jcm-2
0.43	2.4	0.32	0.08	0.004	43	0.59	1.4	33.5	194%	17-1-1 Epidote (3) 55um 7Hz 65% 2.96Jcm-2
0.36	2.0	0.31	0.23	0	38	0.35	1.3	36.9	198%	17-1-1 Epidote (3) 55um 7Hz 65% 3.64Jcm-2
0.42	2.7	0.33	0.09	0.003	54	0.58	1.5	27.5	202%	17-1-1 Epidote (3) 55um 7Hz 65% 3.33Jcm-2
0.22	1.5	0.20	0.07	0.01	22	0.13	0.70	35.5	123%	17-1-1 Plag/Epidote 55um 7Hz 65%3.20Jcm-
459	478	461	447	457	443	469	464	23.5	90%	NIST610 55um 7Hz 65% 2.96Jcm-2
411	422	417	423	435	409	446	459	31.5	93%	NIST610 55um 7Hz 65% 3.02Jcm-2

	SiO2	CaO	Cr	Mn	Fe	Cu	Zn	Ga	Ge	As	Se	Rb	Sr	Y
std-1	69.7	12	416	439	491	462	487	459	461	333	144	429	530	478
std-2	69.7	11	400	449	424	420	433	407	432	317	132	422	501	446
Ap14c03	64.0	*<0.32*	*<30.50*	*<93.24*	888	*<2.58*	*<13.48*	7.5	*<12.28*	*<2.76*	*<42.39*	11	*<63.90*	0.04
Ap14c04	64.0	5.3	*<17.65*	619	17462	*<3.65*	8.9	21	8.5	*<2.38*	*<27.15*	341	1145	10
Ap14c05	64.0	*<0.22*	*<17.11*	*<79.56*	4245	38	19	19	*<3.23*	*<1.70*	*<18.60*	64	*<45.89*	0.41
Ap14c06	64.0	1.5	*<33.41*	120	29688	34	99	23	1.7	*<2.93*	*<38.13*	4.2	218	7.8
std-3	69.7	11	388	436	423	431	448	421	444	316	132	419	511	452
std-4	69.7	12	428	453	494	451	472	445	450	334	144	432	520	472

Zr	Nb	Cd	In	Sn	Cs	Ba	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er
465	476	284	441	435	384	467	462	474	471	444	474	462	474	463	458	478	482
431	454	256	427	425	348	437	418	432	425	416	432	432	424	411	415	421	428
0	*<0.69*	*<6.80*	*<0.34*	0.20	*<0.31*	74	*<0.26*	0.55	0.04	0	0	0.04	0	0	0	0.02	0
0.78	0.07	*<2.68*	0	*<7.39*	*<0.28*	2852	32	68	8.4	27	4.6	3.2	3.6	0.37	2.5	0.28	0.81
0.32	0.05	*<3.04*	*<0.19*	*<6.14*	*<0.36*	206	*<0.40*	0.92	0.02	0.18	0	0.07	0.11	0	0.06	0.02	0.04
0.77	0.24	*<6.66*	0.10	*<12.73*	*<0.51*	59	3.6	8.3	1.3	3.7	1.4	0.42	*<1.41*	0.21	1.6	0.19	0.85
439	454	261	418	417	366	431	427	433	445	427	442	432	427	424	417	429	442
457	476	279	450	443	366	473	453	473	451	433	464	462	471	450	458	470	468

Tm	Yb	Lu	Hf	Ta	Pb	Th	U			
462	481	465	451	459	444	470	466	22.1	109%	NIST610 55um 7Hz 65% 2.96Jcm-2
408	418	413	419	433	407	445	457	32.2	111%	NIST610 55um 7Hz 65% 3.02Jcm-2
0	0.06	0	0	0.01	*<0.27*	0	0	28.1	57%	17-1-1 Plagioclase 55um 7Hz 653.14Jcm-2
0.16	0.85	0.07	0.19	0.10	8.1	1.5	0.23	28.8	84%	17-1-1 Plagioclase 55um 7Hz 653.14Jcm-2
0	0.05	0	0.16	0.06	4.3	0.06	0.03	28.8	74%	17-1-1 Plagioclase 55um 7Hz 652.90Jcm-2
0.08	0.59	0.22	0.34	0.03	6.8	0.07	0.03	36.9	47%	17-1-1 Plagioclase 55um 7Hz 652.77Jcm-2
420	440	426	424	431	402	434	456	37.5	91%	NIST610 55um 7Hz 65% 2.59Jcm-2
450	460	452	446	461	450	480	467	38.9	89%	NIST610 55um 7Hz 65% 2.46Jcm-2

	SiO2	CaO	Cr	Mn	Fe	Cu	Zn	Ga	Ge	As	Se	Rb	Sr	Y
std-1	**69.7**	**11**	**432**	**454**	**448**	**471**	**492**	**452**	**460**	**333**	**142**	**435**	**522**	**472**
std-2	**69.7**	**11**	**384**	**434**	**468**	**411**	**428**	**414**	**434**	**317**	**134**	**416**	**509**	**452**
Ap14d03	**55.1**	**7.6**	**15**	**1526**	**102242**	**17**	**152**	**21**	**8.1**	*<1.74*	*<7.79*	**45**	**355**	**31**
Ap14d04	**36.0**	**28**	*<13.23*	**1228**	**100029**	**4.2**	**5.1**	**97**	**28**	**3.0**	*<7.11*	*<0.39*	**4863**	**128**
Ap14d05	**36.0**	**0.24**	**36**	*<31.92*	**884**	**3.5**	**2.4**	**2.9**	**0.47**	*<1.38*	*<9.14*	**195**	**21**	**0.75**
Ap14d06	**36.0**	**29**	*<6.80*	**1058**	**101022**	**13**	**12**	**97**	**42**	**5.2**	**6.6**	*<0.41*	**4928**	**109**
Ap14d07	**36.0**	**29**	**5.8**	**868**	**103598**	**55**	**41**	**102**	**36**	**4.0**	*<8.86*	**1.8**	**4878**	**88**
Ap14d08	**36.0**	**33**	*<11.31*	**1321**	**115320**	**16**	**11**	**115**	**45**	**5.3**	**9.4**	**1.1**	**6521**	**142**
Ap14d09	**64.0**	**3.2**	*<17.76*	*<71.03*	**16655**	**135**	**36**	**13**	**3.7**	*<3.04*	*<14.10*	**287**	**326**	**10**
Ap14d10	**64.0**	*<0.13*	*<7.06*	*<63.36*	**1088**	**4.9**	**3.7**	**5.1**	**0**	*<2.85*	*<16.39*	**281**	*<41.83*	**0.28**
Ap14d11	**64.0**	*<0.15*	*<7.06*	*<75.65*	**1093**	**2.6**	*<5.12*	**6.0**	**0.69**	*<2.20*	*<19.28*	**312**	*<43.25*	**0.18**
Ap14d12	**36.0**	**26**	**10**	**798**	**105061**	**15**	**13**	**90**	**40**	**3.9**	*<8.54*	**7.1**	**3231**	**51**
Ap14d13	**36.0**	**30**	*<9.32*	**1529**	**109828**	**6.7**	**8.9**	**96**	**33**	**2.8**	*<7.93*	*<0.67*	**3784**	**45**
Ap14d14	**36.0**	**42**	**14**	**981**	**103550**	**215**	**69**	**108**	**84**	**14**	**12**	**7.5**	**3749**	**114**
Ap14d15	**36.0**	**32**	**16**	**1094**	**105149**	**105**	**51**	**96**	**66**	**7.4**	**7.8**	**7.7**	**3866**	**89**
Ap14d16	**36.0**	**28**	*<13.79*	**1580**	**124049**	**2.3**	**4.6**	**59**	**9**	*<2.17*	*<9.46*	*<0.60*	**3702**	**14**
Ap14d17	**36.0**	**26**	*<10.24*	**1505**	**113558**	**11**	**23**	**70**	**28**	**2.9**	*<10.82*	*<0.75*	**3371**	**29**
Ap14d18	**36.0**	**29**	*<7.55*	**1805**	**127051**	**2.2**	**5.7**	**63**	**12**	**1.3**	*<7.20*	*<0.53*	**3934**	**17**
std-3	**69.7**	**11**	**423**	**445**	**479**	**453**	**472**	**440**	**449**	**331**	**144**	**435**	**535**	**480**
std-4	**69.7**	**11**	**393**	**443**	**436**	**429**	**448**	**426**	**445**	**319**	**132**	**417**	**496**	**444**

Zr	Nb	Cd	In	Sn	Cs	Ba	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er
449	469	270	444	438	365	456	449	465	452	439	456	460	457	445	441	465	469
447	461	270	424	422	367	448	431	441	444	421	450	434	441	429	433	434	441
181	12	1.00	0	2.03	1.1	768	28	56	7.2	31	6.7	2.3	7.2	1.0	6.9	1.2	3.8
2.1	*<0.11*	*<2.67*	0	*<1.94*	*<0.11*	8.1	72	122	20	91	25	12	23	3.31	19	3.5	8.9
0.24	0.82	*<0.94*	*<0.08*	*<1.58*	0.15	778	0.39	1.1	0.15	0.87	0.32	0.22	*<0.42*	0.04	0.07	0.02	0.15
1.8	0.15	*<0.71*	*<0.15*	1.4	*<0.22*	11	98	176	30	148	38	14	30	3.8	22	4.1	9.9
17	1.3	0.76	0.28	6.9	0.36	17	139	253	34	142	29	13	24	3.1	19	3.8	7.9
1.7	0.17	*<1.03*	0.16	1.3	*<0.20*	17	106	185	32	163	41	18	35	5.0	26	5.2	13
1.4	0.34	*<1.38*	*<0.12*	*<4.03*	0.37	1461	23	33	4.6	17	4.6	5.9	3.2	0.59	2.0	0.60	1.1
0.03	0.03	0	0	*<3.26*	0.29	1146	0.19	0.36	0.02	0.07	0.09	0.12	0	0	0	0.01	0
0.08	0	0.63	0	*<2.74*	*<0.48*	1271	0.27	0.35	0.07	0.16	0.19	0.15	0	0	0.13	0.01	0.09
7.1	0.30	*<1.36*	0.19	*<3.61*	*<0.31*	74	150	318	38	148	22	6.6	14	1.8	10	1.8	4.4
5.2	*<0.34*	0.55	0.16	3.7	*<0.26*	8.7	118	218	28	110	17	6.9	13	1.6	9.2	1.9	4.0
204	70	0.76	0.66	5.6	0.58	72	333	687	88	335	62	15	40	5.2	29	4.7	12
79	86	1.1	0.49	8.9	0.45	84	233	466	58	231	45	13	31	4.4	25	4.1	10
3.3	0.12	0.22	*<0.23*	*<2.34*	*<0.36*	19	36	58	6.1	22	3.3	2.7	3.1	0.40	2.2	0.40	1.5
4.9	0.11	*<1.05*	0	*<2.80*	*<0.16*	21	121	255	28	98	13	6.1	8.0	1.1	6.3	1.1	3.0
2.7	0.08	*<0.84*	0	0.59	*<0.17*	20	24	42	5.4	20	3.1	2.1	3.0	0.39	2.4	0.45	1.5
463	489	269	443	445	369	458	449	465	456	429	454	444	442	436	439	447	451
433	441	271	425	415	363	446	430	441	440	431	452	450	456	438	435	452	459

Tm	Yb	Lu	Hf	Ta	Pb	Th	U			
447	460	459	457	467	452	476	484	34.2	90%	NIST610 55um 7Hz 65% 3.39Jcm-2
423	440	419	413	425	400	438	439	33.5	111%	NIST610 55um 7Hz 65% 3.70Jcm-2
0.51	3.6	0.48	5.2	0.87	11	6.1	1.8	33.5	220%	BCR2g 55um 7Hz 65% 2.90Jcm-2
0.90	5.8	0.75	0.08	0.004	42	0.04	1.8	26.1	184%	17-3-2 Epidote 1 55um 7Hz 65% 3.39Jcm-2
0.01	0.10	0.01	0.11	0.21	0.86	0.01	0.01	22.8	199%	17-3-2 Epidote 1 55um 7Hz 65% 2.59Jcm-2
1.2	6.8	0.99	0.21	0.002	51	0.03	1.8	38.2	213%	17-3-2 Epidote 1 55um 7Hz 65% 2.96Jcm-2
0.97	5.9	0.78	1.2	0.04	61	0.19	1.8	37.5	178%	17-3-2 Epidote 1 55um 7Hz 65% 3.20Jcm-2
1.3	8.0	1.1	0.10	0.01	55	0.07	2.3	39.5	168%	17-3-2 Epidote 1 55um 7Hz 65% 3.02Jcm-2
0.13	0.88	0.05	0	0.05	4.1	0.36	0.22	11.4	101%	17-3-2 K-spar 55um 7Hz 65% 2.83Jcm-2
0	0	0.01	0.25	0.32	1.6	0	0.01	20.1	104%	17-3-2 K-spar 55um 7Hz 65% 2.03Jcm-2
0	0	0	0.00	0.10	1.2	0	0	20.8	91%	17-3-2 K-spar 55um 7Hz 65% 2.53Jcm-2
0.50	3.2	0.47	0.29	0.01	46	1.7	1.2	37.5	156%	17-3-2 Epidote 2 55um 7Hz 65% 2.60Jcm-2
0.46	3.4	0.40	0.39	0	30	0.47	0.96	31.5	157%	17-3-2 Epidote 2 55um 7Hz 65% 2.34Jcm-2
1.5	10	1.2	5.7	2.4	46	2.6	2.6	36.2	122%	17-3-2 Epidote 2 55um 7Hz 65% 2.22Jcm-2
1.4	8.2	0.94	3.0	2.7	53	1.3	2.7	34.9	160%	17-3-2 Epidote 2 55um 7Hz 65% 2.16Jcm-2
0.21	1.2	0.18	0.12	0	43	0.07	0.21	26.1	160%	16-4-1 Epidote dark 55um 7Hz 5%2.59Jcm2
0.33	2.7	0.37	0.22	0.003	73	2.3	0.31	40.9	163%	16-4-1 Epidote light 55um 7Hz 65% .03Jcm2
0.19	1.5	0.20	0.09	0.003	46	0.13	0.26	34.9	199%	16-4-1 Epidote dark 55um 7Hz 65% .71Jcm2
431	457	437	419	449	423	455	460	38.2	99%	NIST610 55um 7Hz 65% 2.59Jcm-2
439	443	441	451	443	429	459	463	38.2	101%	NIST610 55um 7Hz 65% 2.22Jcm-2

	SiO2	CaO	Cr	Mn	Fe	Cu	Zn	Ga	Ge	As	Se	Rb	Sr	Y
std-1	69.7	11	426	451	485	455	474	441	450	332	145	434	536	482
std-2	69.7	11	390	437	431	427	446	425	444	318	131	417	495	443
Ap14e03	35.0	23	*<7.95*	1358	103980	7.1	17	53	12	*<2.06*	*<7.63*	*<0.35*	2884	13
Ap14e04	35.0	22	*<9.60*	1421	90933	3.7	8.0	45	8.1	*<2.42*	*<7.28*	*<1.07*	2932	11
Ap14e05	35.0	26	*<9.08*	1394	110138	3.2	8.3	54	10	*<1.40*	*<5.19*	*<0.31*	3614	14
Ap14e06	35.0	27	*<8.51*	1386	110122	3.3	7.0	58	10	1.2	*<7.13*	*<0.56*	3811	16
Ap14e07	35.0	28	*<6.87*	1550	115761	1.7	6.2	64	10	1.8	*<5.59*	*<0.60*	3645	16
Ap14e08	35.0	23	*<10.01*	1252	98909	5.2	14	51	13	*<1.43*	*<9.07*	*<0.67*	3255	14
Ap14e09	35.0	19	*<6.42*	1025	78625	4.6	12	43	11	1.7	*<7.44*	*<0.39*	2685	15
Ap14e10	35.0	25	*<6.52*	1530	108735	124	182	58	10	2.4	*<3.99*	*<0.29*	3682	16
Ap14e11	54.0	7.5	13	1639	101983	18	158	22	8.0	1.6	*<7.01*	44	351	32
std-3	69.7	12	403	451	464	442	469	442	452	328	143	424	504	458
std-4	69.7	11	413	437	452	440	451	424	442	322	133	427	527	466

Zr	Nb	Cd	In	Sn	Cs	Ba	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er
462	488	269	440	442	368	455	449	463	454	429	454	445	444	438	442	452	456
434	442	271	428	418	364	449	431	443	442	431	452	449	454	436	432	447	454
3.3	0.10	1.0	0	1.04	*<0.20*	15	50	104	12	44	8.3	3.2	4.3	0.46	2.3	0.51	1.2
2.9	0.12	0.75	0	*<1.51*	*<0.29*	14	26	50	5.9	22	3.6	2.0	1.5	0.37	2.1	0.42	0.70
3.2	0.09	0.60	0.08	*<1.38*	*<0.22*	16	23	39	4.9	19	2.9	2.2	1.9	0.33	2.2	0.42	1.3
3.3	0.13	0.49	0.10	*<1.14*	*<0.21*	17	28	43	5.2	19	2.9	2.5	2.7	0.44	2.6	0.53	1.5
3.0	0.16	0.83	*<0.10*	*<1.02*	*<0.22*	18	37	63	7.4	26	3.7	3.3	3.1	0.37	2.2	0.44	1.2
3.0	0.15	*<1.33*	0.10	*<5.78*	*<0.30*	17	38	75	8.9	32	7.0	2.2	3.3	0.58	3.0	0.46	1.2
2.8	0.19	0.62	0.17	0.84	*<0.20*	19	54	98	11	35	5.2	3.9	3.3	0.47	2.1	0.46	1.6
3.5	0.14	1.5	0.10	2.7	*<0.05*	22	29	60	7.3	25	4.8	2.7	3.3	0.41	2.5	0.45	1.5
177	13	1.6	0.08	*<2.32*	1.0	769	28	58	7.4	32	7.7	2.1	6.2	0.90	6.3	1.3	3.6
447	467	275	430	428	355	426	427	455	445	413	439	431	433	418	418	436	440
449	463	265	438	432	377	479	453	451	451	447	467	463	464	456	455	463	470

Tm	Yb	Lu	Hf	Ta	Pb	Th	U			
434	459	440	423	452	426	457	463	38.9	97%	NIST610 55um 7Hz 65% 2.59Jcm-2
436	441	438	447	440	426	457	460	38.9	99%	NIST610 55um 7Hz 65% 2.22Jcm-2
0.13	1.1	0.13	0.07	0	51	0.30	0.19	23.5	162%	16-4-1 Epidote (light) 55um 7Hz 65% 2.16Jcm-2
0.25	1.1	0.14	0.12	0.004	39	0.57	0.14	30.2	143%	16-4-1 Epidote (light) 55um 7Hz 65% 2.40Jcm-2
0.18	1.3	0.22	0.14	0.004	45	0.11	0.22	22.8	192%	16-4-1 Epidote (dark) 55um 7Hz 65% 2.83Jcm-2
0.25	1.1	0.21	0.06	0.003	47	0.05	0.15	36.9	178%	16-4-1 Epidote (medium) 55um 7Hz 65% 2.46Jcm
0.18	1.7	0.17	0.07	0	50	0.12	0.25	32.8	168%	16-4-1 Epidote (dark) 55um 7Hz 65% 2.46Jcm-2
0.27	1.2	0.15	0.06	0.009	49	0.63	0.33	30.2	133%	16-4-1 Epidote (light) 55um 7Hz 65% 2.65Jcm-2
0.18	1.4	0.13	0.11	0.012	50	0.14	0.25	32.2	145%	16-4-1 Epidote (light) 55um 7Hz 65% 2.34Jcm-2
0.23	1.7	0.20	0.12	0.015	83	0.04	0.35	43.6	256%	16-4-1 Epidote (dark-light) 55um 7Hz 65% (line 15
0.50	3.8	0.47	4.6	0.74	9.9	5.8	1.7	37.5	235%	BCR2g 55um 7Hz 65% 3.39Jcm-2
422	436	424	422	426	404	442	445	39.5	101%	NIST610 55um 7Hz 65% 2.90Jcm-2
447	464	454	448	466	448	472	478	38.2	102%	NIST610 55um 7Hz 65% 3.20Jcm-2

	SiO2	CaO	Cr	Mn	Fe	Cu	Zn	Ga	Ge	As	Se	Rb	Sr	Y
std-1	69.7	11	403	442	481	446	478	442	428	320	138	425	508	451
std-2	69.7	12	413	446	435	436	442	424	466	330	138	427	523	473
Ap25a03	49.3	11	278	1318	86295	117	123	18	11	<1.55	<5.55	8.5	383	22
Ap25a04	36.0	2.9	<10.49	450	21619	8.9	88	6.4	12	3.9	<11.66	<1.12	<25.07	36
Ap25a05	36.0	3.8	13	345	22849	8.8	54	5.8	8.3	2.9	<10.31	<1.28	<20.08	36
Ap25a06	36.0	23	<5.76	3520	102208	24	17	24	6.7	<1.42	<7.83	<0.67	555	15
Ap25a07	36.0	20	<4.40	1828	108023	1.8	3.1	29	4.9	<0.70	<6.45	<0.53	468	3.3
Ap25a08	36.0	22	<7.73	1436	100412	2.1	4.1	32	19	2.1	<5.95	1.2	698	17
Ap25a09	36.0	21	<5.18	3540	107032	<0.90	<2.30	25	2.8	<0.55	<3.93	<0.62	509	3.8
Ap25a10	36.0	22	<4.90	3064	109328	2.2	3.6	29	5.9	<0.74	<9.44	<0.78	720	6.6
Ap25a11	36.0	22	<3.96	1775	104266	1.0	<3.43	36	13	1.7	<4.41	0.68	788	16
Ap25a12	36.0	2.5	<7.30	352	19275	22	48	6.2	12	3.1	<5.99	<1.17	<19.62	33
Ap25a13	36.0	23	6.2	942	105078	7.5	12	27	8.2	0.86	<4.46	<0.51	533	16
Ap25a14	36.0	3.3	<6.56	254	12705	18	34	4.2	12	2.6	<8.88	<0.76	<22.46	43
Ap25a15	49.3	11	266	1347	85176	117	120	20	8.3	1.3	<5.79	8.0	373	21

std-3	69.7	11	405	442	450	433	457	447	449	325	136	421	508	463
std-4	69.7	12	411	446	466	449	463	419	445	325	140	431	523	461

Zr	Nb	Cd	In	Sn	Cs	Ba	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er
434	458	264	427	428	358	457	435	440	433	423	457	427	428	422	423	439	448
462	472	276	441	432	374	447	445	466	463	437	449	467	471	452	451	460	462
152	17	<0.63	0	1.4	<0.37	128	15	36	5.0	23	5.5	1.8	5.7	0.63	4.5	0.79	2.3
65	8.6	<3.48	0	<2.98	<0.55	7.9	14	42	6.2	31	5.9	1.6	7.4	0.94	7.5	1.3	3.1
123	18	0.40	<0.11	1.9	<0.35	7.6	12	41	6.2	29	8.2	1.6	9.7	1.3	7.7	1.5	3.6
133	36	1.4	0.04	3.8	<0.28	28	10	21	2.3	11	2.1	1.2	2.6	0.41	2.6	0.43	1.7
14	0.026	0.98	0.04	<1.63	<0.13	12	3.6	5.6	0.66	3.0	0.51	0.48	0.39	0.08	0.31	0.12	0.43
20	0.089	<2.14	0.17	1.7	<0.26	70	42	122	14	53	10	2.5	8.4	1.1	5.2	0.62	1.4
5.9	0.066	0.53	0.01	<0.80	<0.14	12	1.7	1.7	0.25	0.87	0.20	0.22	0.25	0.03	0.22	0.11	0.37
14	0.061	0.30	0.02	<0.94	<0.29	25	5.9	9.6	1.0	2.8	0.94	0.52	0.93	0.08	0.57	0.16	0.70
28	0.20	0.68	<0.09	<1.94	<0.30	42	20	56	7.6	31	7.8	2.2	5.4	0.83	4.3	0.69	1.2
90	14	<3.60	0.02	0.90	<0.43	8.6	19	53	7.4	35	8.9	2.4	6.8	1.2	6.8	1.1	3.4
168	24	0.58	<0.17	<4.05	<0.16	23	3.6	8.2	1.9	7.7	2.2	0.89	2.2	0.42	3.1	0.71	1.8
80	12	0.81	0	<2.52	<0.47	3.8	20	41	8.4	35	9.6	1.9	9.1	1.2	9.7	1.8	5.1
140	16	0.20	0.08	1.9	<0.18	131	15	37	5.0	22	5.3	1.7	4.9	0.80	4.0	0.85	2.3
446	457	267	428	430	364	442	437	463	454	428	458	447	437	433	437	442	447
450	473	273	440	430	368	462	443	443	442	432	448	447	461	441	437	457	463

Tm	Yb	Lu	Hf	Ta	Pb	Th	U			
438	451	429	418	438	410	437	456	32	141%	NIST610 55um 7Hz 64% 3.94Jcm-2
432	449	449	452	454	442	477	467	34	118%	NIST610 55um 7Hz 64% 3.51Jcm-2
0.30	2.0	*<0.33*	4.1	1.1	1.9	1.2	0.44	29	191%	BHVO2g 55um 7Hz 64% 2.96Jcm-2
0.33	2.3	0.20	1.6	0.47	0.45	0.92	0.20	13	106%	C1-Epidote1 55um 7Hz 64% 3.27Jcm-2
0.31	2.4	0.37	4.0	0.79	1.3	0.96	0.31	15	126%	C1-Epidote1 55um 7Hz 64% 3.02Jcm-2
0.29	1.9	0.14	4.1	1.6	11	0.44	0.38	12	168%	C1-Epidote3 55um 7Hz 60% 2.77Jcm-2
0.03	0.52	0.05	0.14	0	13	0	0.10	36	181%	C1-Epidote3 55um 7Hz 60% 3.27Jcm-2
0.22	1.0	0.10	0.77	0	13	0.25	0.32	16	182%	C1-Epidote3 55um 7Hz 60% 2.71Jcm-2
0.06	0.44	0.08	0.08	0.002	11	0.01	0.08	38	188%	C1-Epidote2 55um 7Hz 60% 2.8Jcm-2
0.11	0.65	0.10	0.22	0	19	0.02	0.14	19	189%	C1-Epidote2 55um 7Hz 60% 2.65Jcm-2
0.16	0.98	0.10	0.84	0	14	0.16	0.24	38	180%	C1-Epidote2 55um 7Hz 60% 2.83Jcm-2
0.45	2.6	0.34	3.3	0.76	1.2	1.1	0.18	11	163%	C1-Epidote1 55um 7Hz 60% 2.58Jcm-2
0.33	2.0	0.19	7.0	1.5	24	0.39	0.25	25	183%	C1-Epidote1 (zircon incl?) 55um 7Hz 0%2.59Jcm
0.56	3.4	0.65	4.2	0.84	1.5	1.6	0.23	15	107%	C1-Epidote1 55um 7Hz 60% 3.02Jcm-2
0.23	1.5	0.23	3.8	0.89	1.6	1.1	0.45	36	189%	BHVO2g 55um 7Hz 60% 2.77Jcm-2
432	450	433	432	445	431	457	467	42	72%	NIST610 55um 7Hz 60% 2.90Jcm-2
438	450	445	438	447	421	457	456	42	69%	NIST610 55um 7Hz 60% 2.29Jcm-2

Appendix 4. Honor Code

I pledge on my honor that I have not given nor received any unauthorized assistance or plagiarized on this assignment.

Luke Councell

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