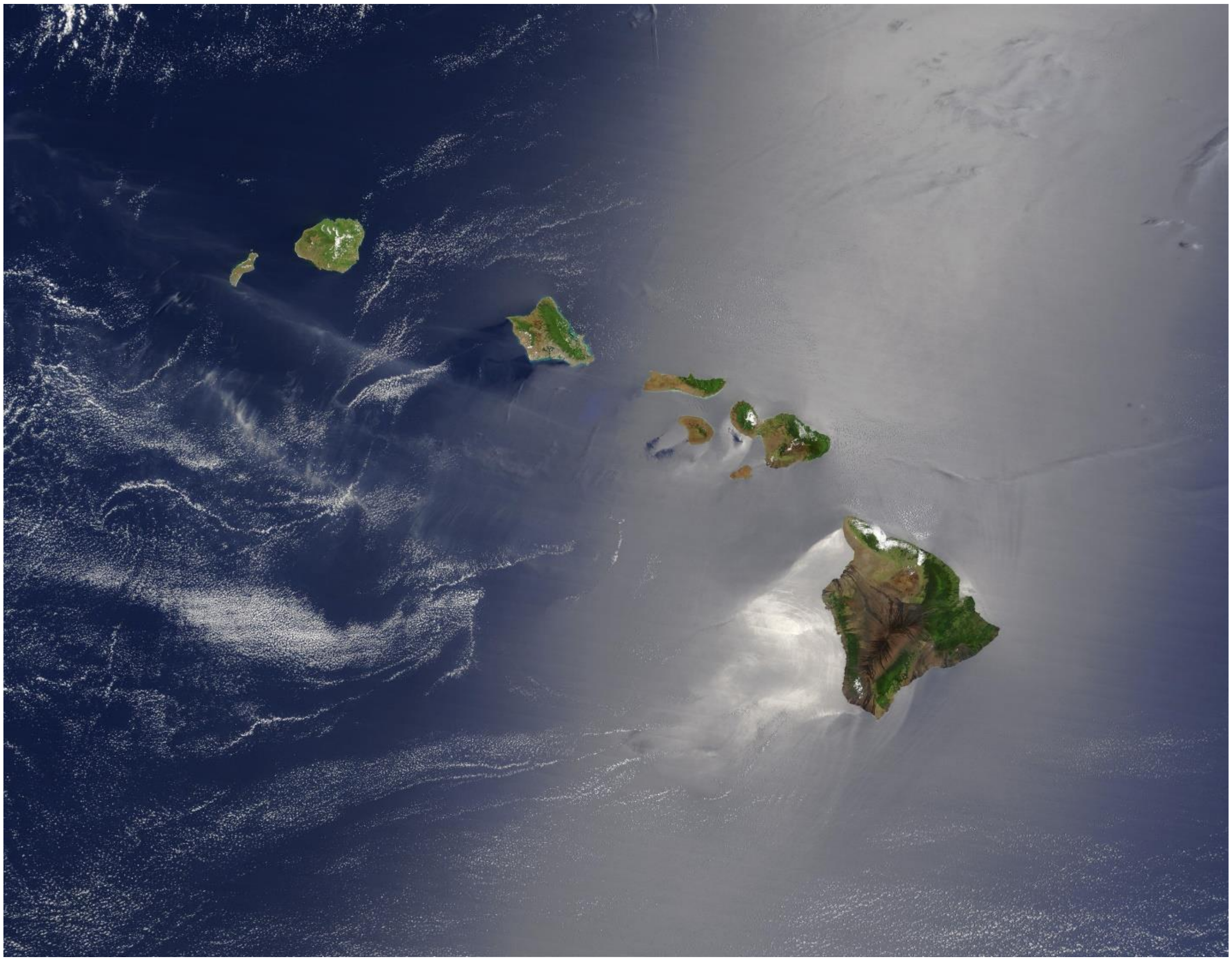
Cullen Scheland
GEOL 307
Dr. Tamara Carley

Geochemical Data – Hawaiian Islands



The first aspect of mantle plumes to address when considering geochemical data is the source. Plumes are believed to be sourced by possibly primordial mantle near the core mantle boundary. This leads to their composition to be considered fertile relative to other mantle source rocks. Fertile entails that the source rock has been altered as little as possible since it first formed. The melts produced at fertile settings tend to have a higher level of incompatible elements than melts from mid ocean ridges which are sourced, generally, by depleted shallow mantle. This can be seen in geochemical trends produced by comparing the presence of various major and trace elements. The following diagrams depict these trends.

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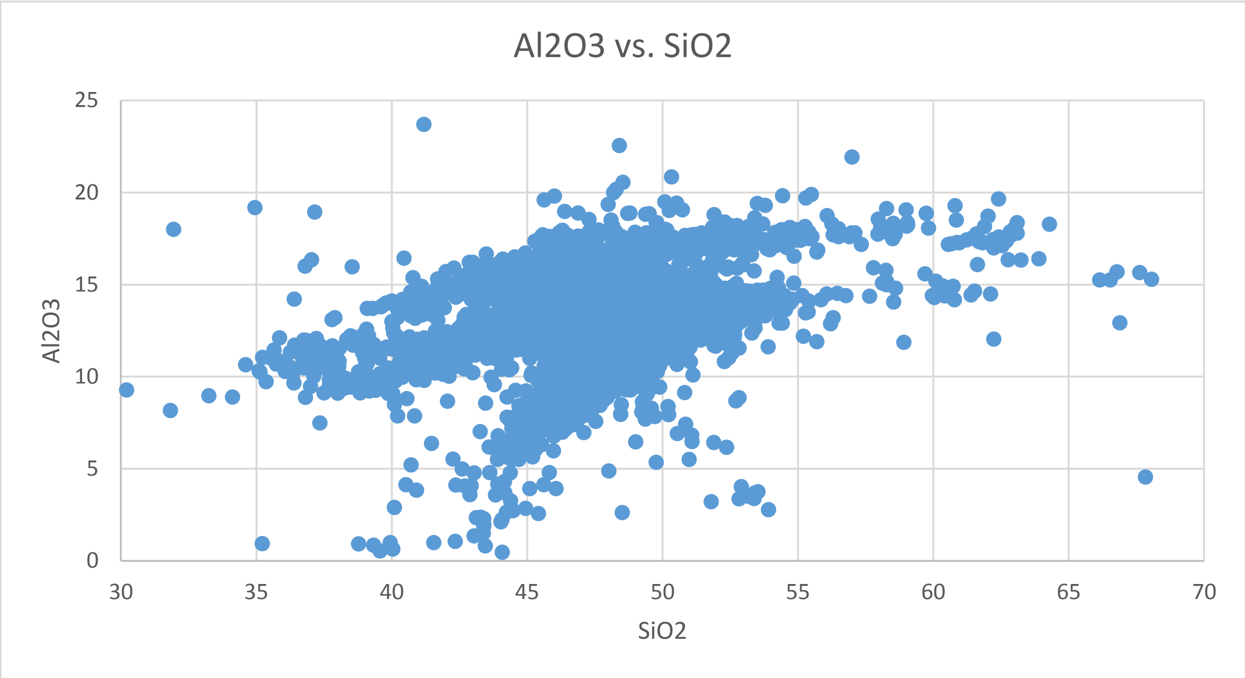

Figure 4: Aluminum appears to become continuously more incorporated into crystal structures as silica content increases. Upwards of 55 wt% SiO2 Aluminum decreases as it seems to leave conditions in which it is favorable as a constituent of a lattice. Al-bearing minerals include pyroxenes, amphiboles, feldspars, clays, and olivines.

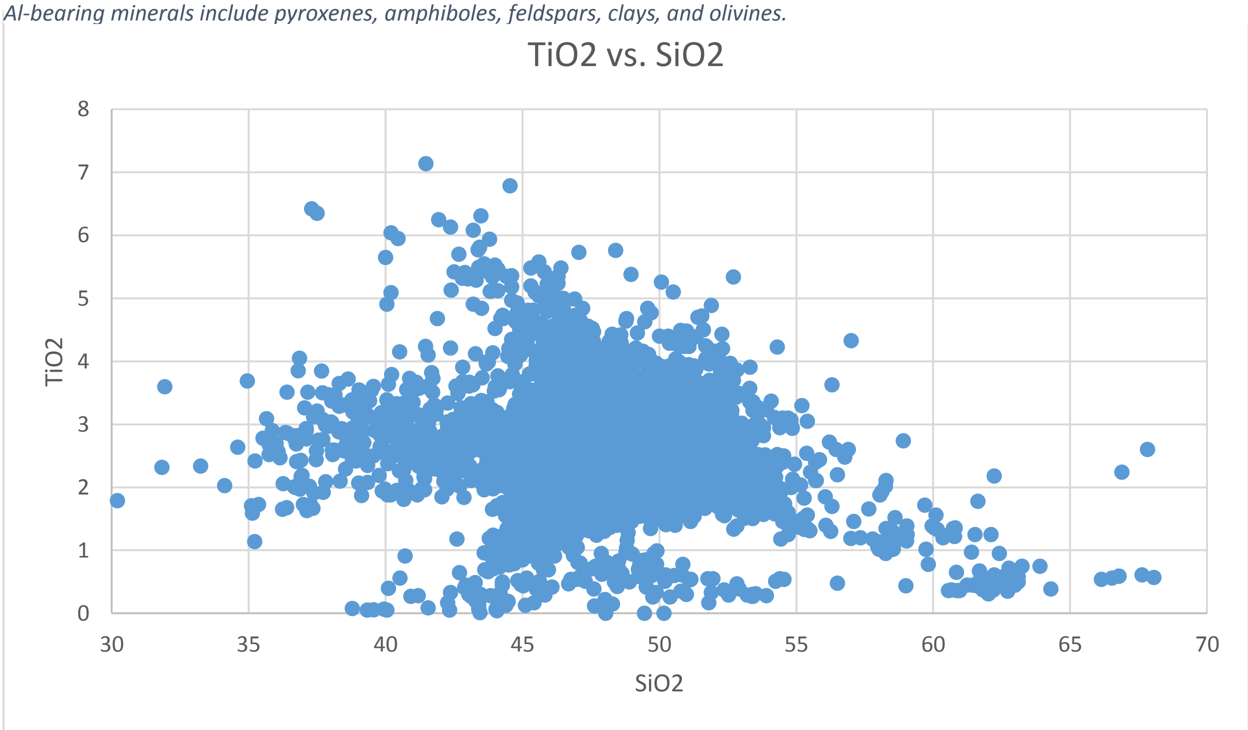

Figure 5: Titanium appears to have a downward sloping trend indicating that is quite compatible. The negative trend means that Ti is incorporated into lattice structures easily at lower silica contents/when the first crystals formed. Illmenite is a titanium bearing igneous mineral.

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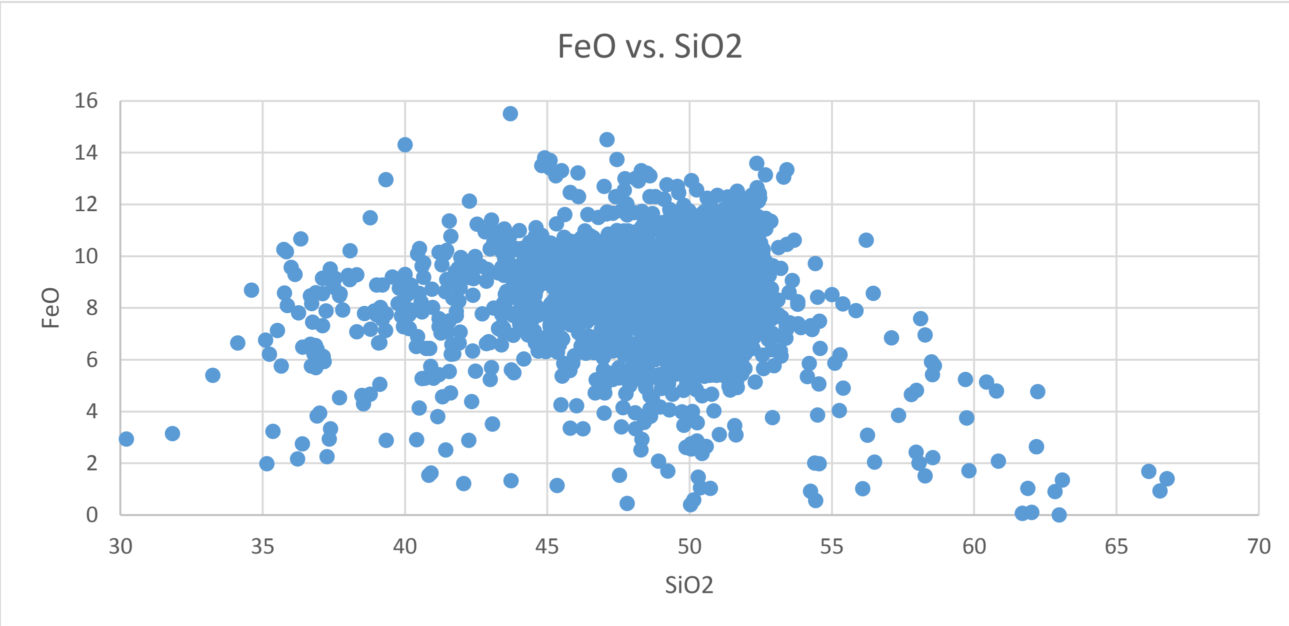

Figure 6: Fe appears not to have a trend, but rather an area of most concentrated. The range of SiO2 at which this occurs is between 40 and 55 wt % which indicates that although Fe is not the most compatible major element, it is easily incorporated into lattice structures. Fe-bearing minerals include olivines, magnetite, and pyroxenes. These all form relatively early in the evolution of a melt.

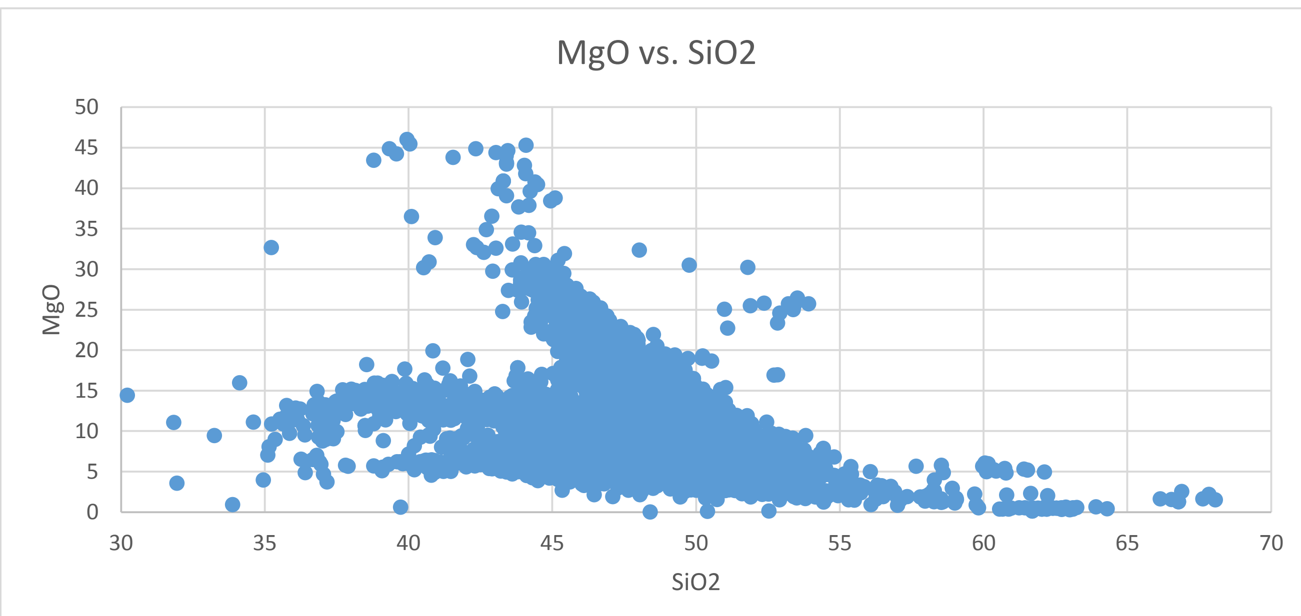

Figure 7: Mg, in comparison to Fe, is more compatible as it is significantly incorporated into crystals starting at 35 wt% silica. At ~43 wt% silica Mg spikes again perhaps signifying the presence of a new crystal phase in Mg is integral. Mg-bearing minerals include olivines, pyroxenes, amphiboles, and micas (biotite).

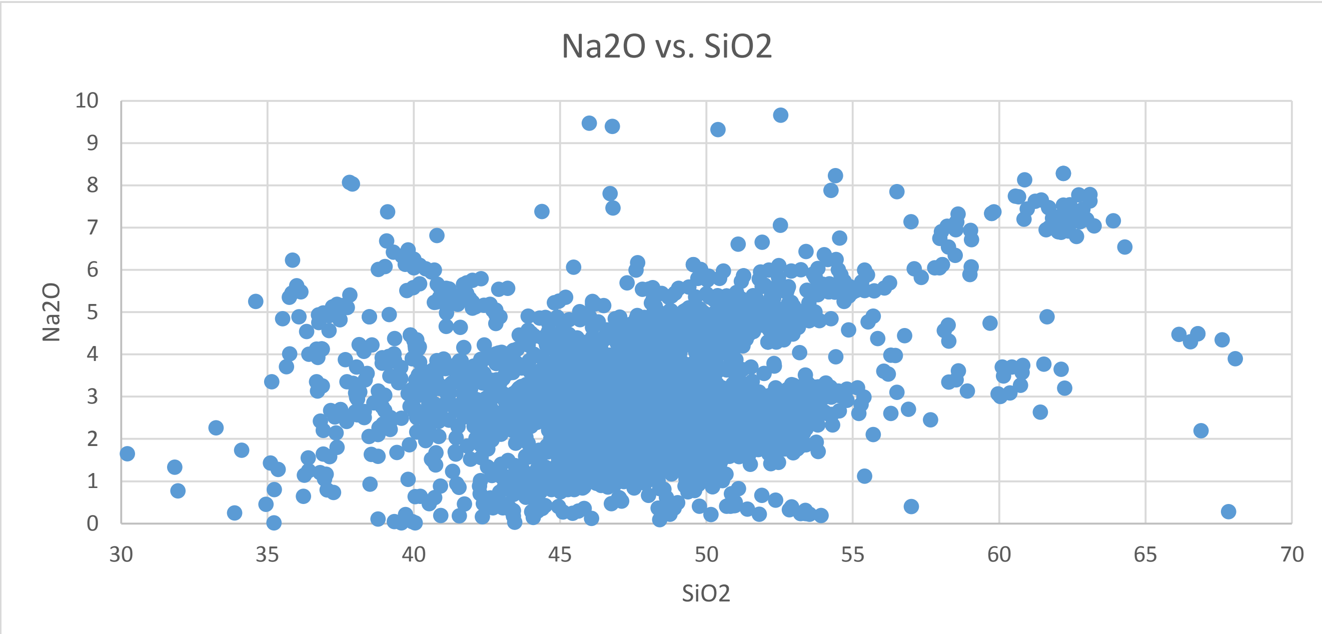

Figure 8: Na appears to have a positive general trend indicating that it becomes more favorable as a cation in a lattice structure at higher silica wt percentages. Thus, Na could be considered to be slightly more incompatible than elements than Fe or Mg. Na-bearing minerals that would be forming include alkali feldspars, albite plagioclase, and clinopyroxenes.

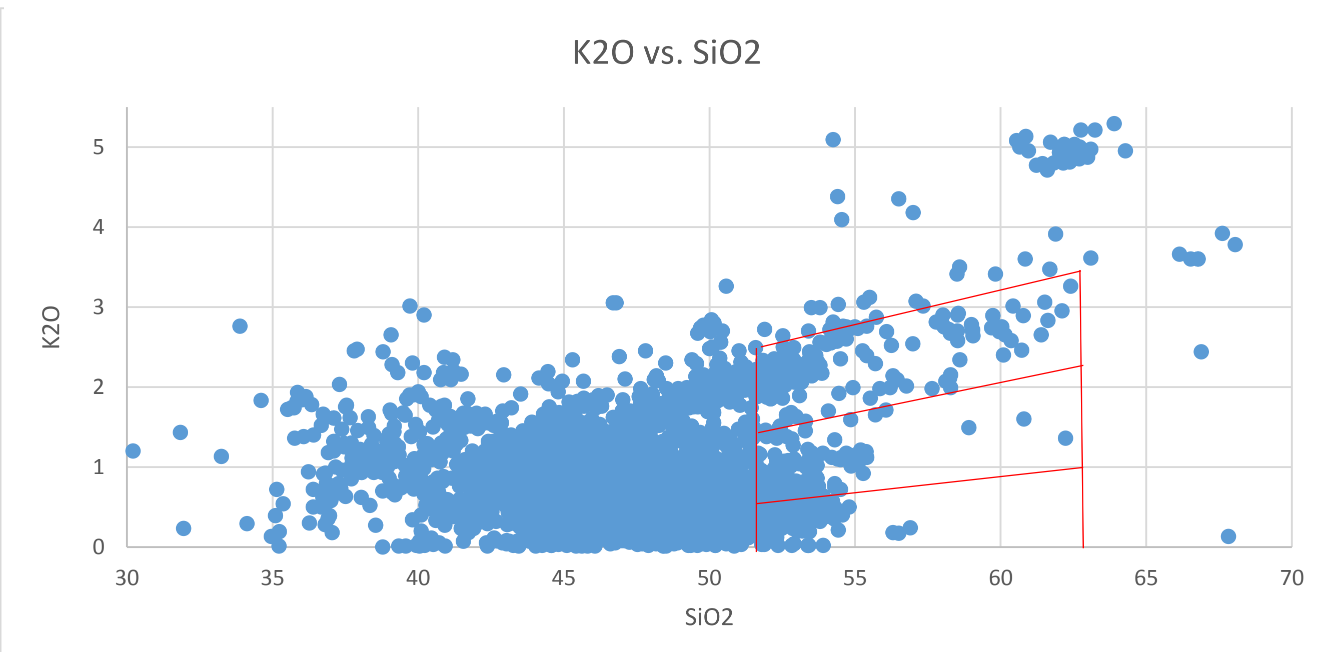

Figure 9: Similar to Na, but without as steep a trend and at lower concentrations K appears to be incompatible relative to other major elements. At high silica content after 55 wt% SiO2 K is incorporated at its highest concentrations. K-bearing minerals include biotites and potassium feldspars. These minerals do not have more than a single K atom in their empirical formula which is why the wt% of K in the rocks are lower than other major elements. Because of this K can be used as a frame of reference for classifying the nature of primary magmas. The trend with increasing SiO2 content can be tied to differentiation within that magma series. The categories are generalized after Gill, 1981, in Winter, 2001

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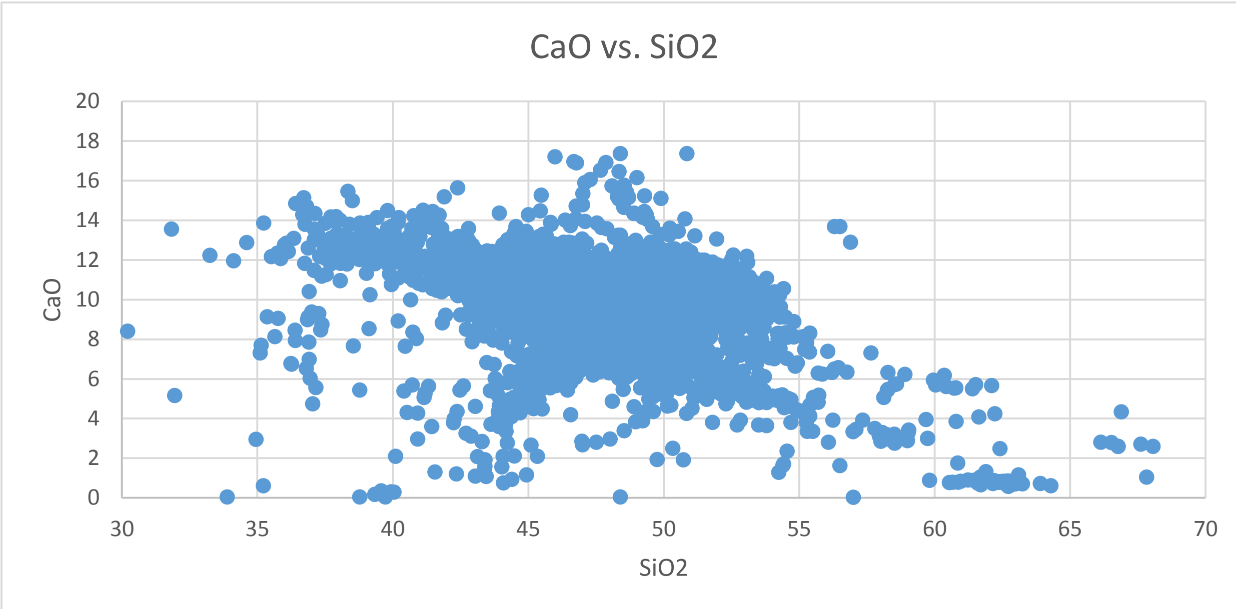

Figure 10: Ca has a negative trend, but appears in high concentrations which is expected of a rock with a mantle source. The negative trend and the range of highest concentrations indicate that Ca can be considered a compatible major element. Ca bearing minerals include plagioclase and

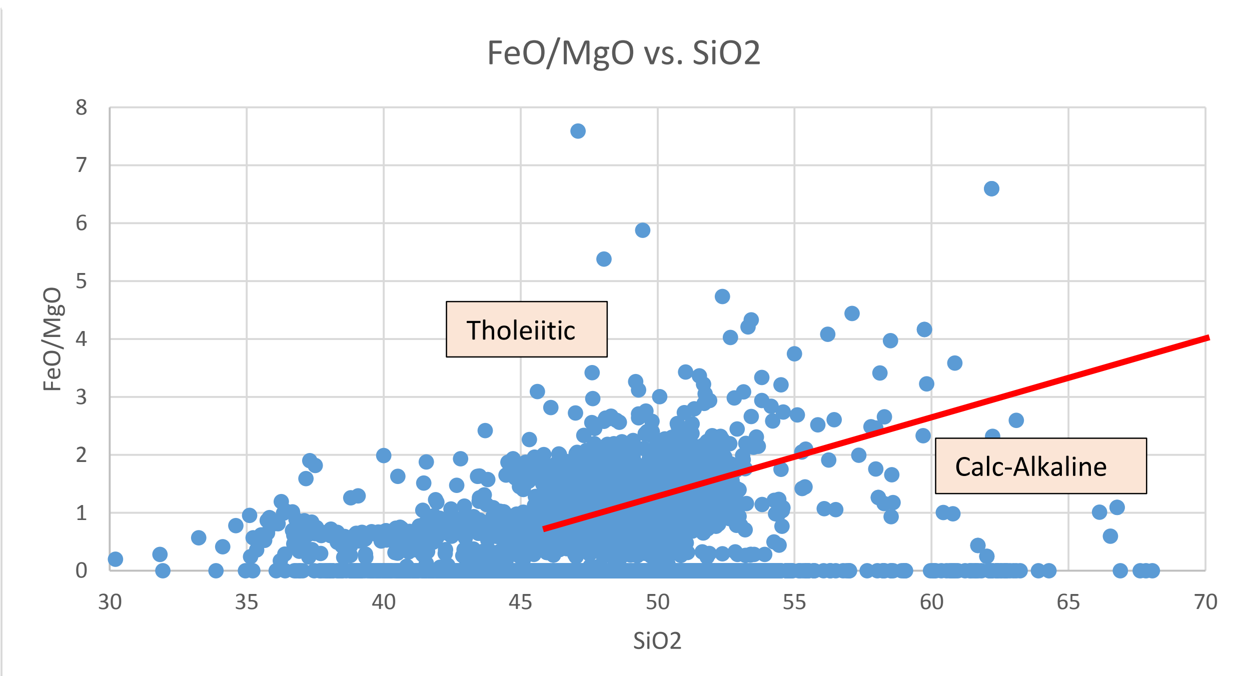

Figure 11: This plot is designed to discern whether the rocks were produced by more tholeiitic or calc-alkaline melts. The concentration of the data points below the red line indicates that the rocks were sourced by a middle ground of the two compositional series. The tholeiitic composition seems to be favored if one ignores the 'zero" values lining the bottom of the plot.

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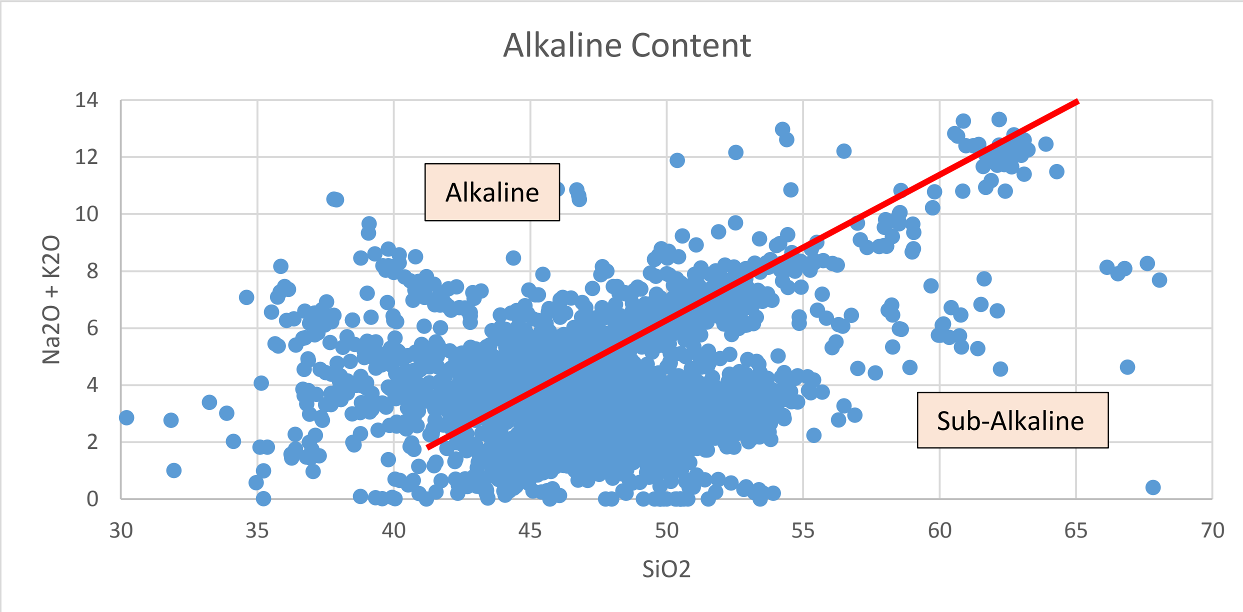

Figure 12: This plot is designed to depict where the compositions fall relative to alkaline and sub-alkaline series. The data for the Hawaiian Islands appears to be well spread between both with a favor for a more sub-alkaline character.

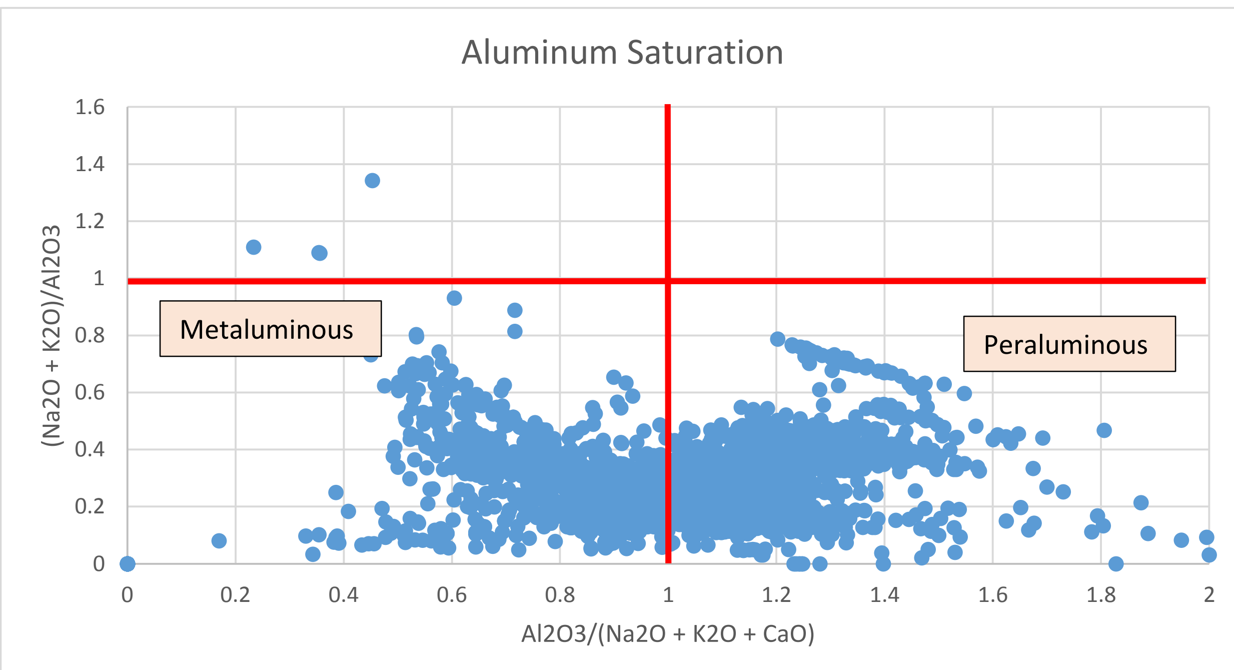

Figure 13: This plot is designed to depict the level of aluminum saturation in the data. The Hawaiian Islands data set appears to have a gradational range as opposed to a single category. However, peraluminous levels appear to be slightly favored.

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Figures 4 through 13 show the behavior of major mineral forming elements, as well as, provide insight into the magma series to which the Hawaiian Island basalts belong. The data suggest that the Hawaiian Island basalts are more sub-alkaline than alkaline (Fig. 12) and within that series more tholeiitic than calc-alkaline (Fig. 11). Tholeiitic magmas are anticipated at normal and enriched mid ocean ridges, but also within the center of a mantle plume. The center of the plume facilitates a higher melt fraction which is how tholeiitic melts are created. Thus, the Hawaiian Island mantle plume must, based on the data above, have a larger than average thermal budget for a plume resulting in high degrees of partial melting. The tholeiitic character of the melts may also be influenced by assimilation of generally tholeiitic oceanic lithosphere.

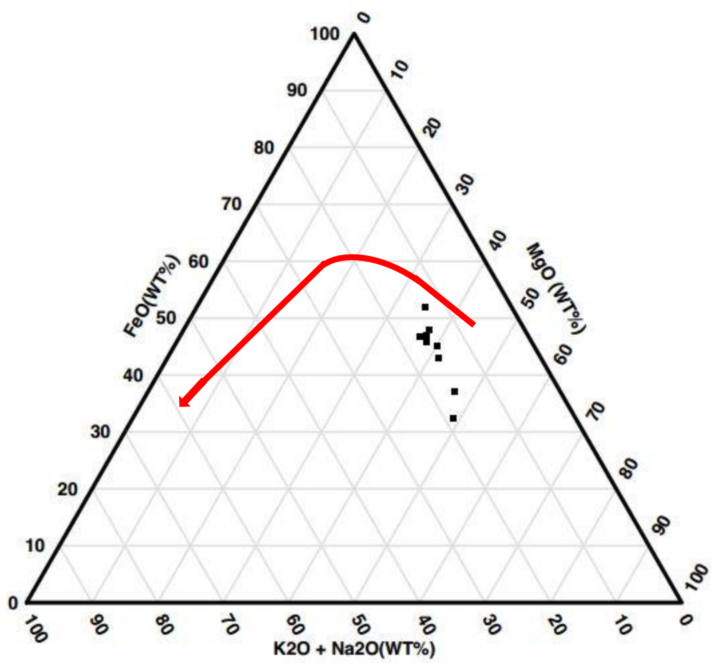

Figure 14: This ternary diagram is designed to display a general path of evolution of magmas based on their alkali, iron, and magnesium content. The red curved arrow shows a very general path that melts take compositionally as they evolve.

In figure 14 the data for the Hawaiian Islands reflects little evolution base on the alkali and ferromagnesian content. This is in line with what is expected of melts with fertile mantle sources.

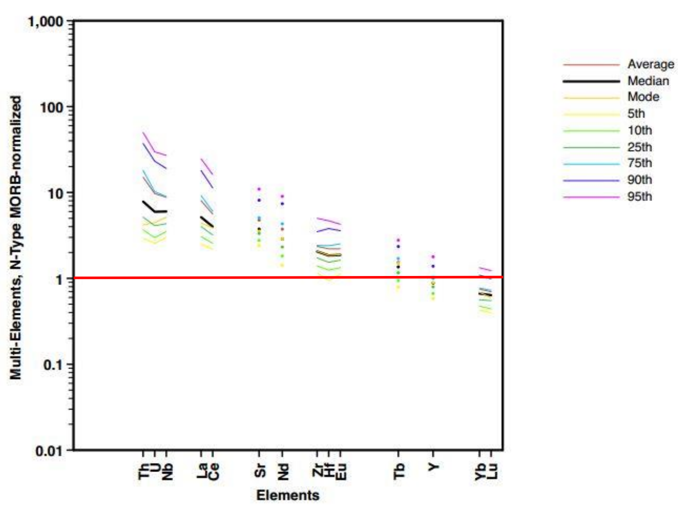

Figure 15: This spider diagram of trace elements functions as an indicator for the incompatible element content in a magma. The horizontal line represents an ideal unaltered mantle source rock.

The diagram to the right shows the concentration of incompatible trace elements relative to the concentrations expected in untapped deep mantle rocks. Fertile melts are as closed to untapped mantle as can be created through magmatism near the earth's surface. Thus, the fact that 90 percent of the data actually dips below the normalized concentration is indicative of the Hawaiian Island basalts being quite fertile.

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Based on the data form GeoRoc of the Hawaiian Island chain, the melts produced are tholeiitic and relatively fertile. The melts do not seem to evolve much before they are extruded.

The size of this data set and the multitude of techniques employed to create it leave room for error in a variety of ways. Some outliers were identified and removed/not displayed in the geochemical plots as they may have skewed the visual representation portrayed by the remainder of the data.

References

A slice through the Earth. (n.d.). Retrieved May 5, 2015, from http://geomaps.wr.usgs.gov/parks/pltec/vigilim.html

Winter, J. D. (2001). *An introduction to igneous and metamorphic petrology*. Upper Saddle River, NJ: Prentice Hall.