# GEOCHEMISTRY OF METAIGNEOUS ROCKS FROM THE WESTERN MÉLANGE BELT, LAKE CHAPLAIN, SNOQUALMIE, AND SULTAN 7.5 MINUTE QUADRANGLES, WESTERN CASCADES, WASHINGTON: EVIDENCE FOR A PREDOMINANTLY VOLCANIC ARC SETTING

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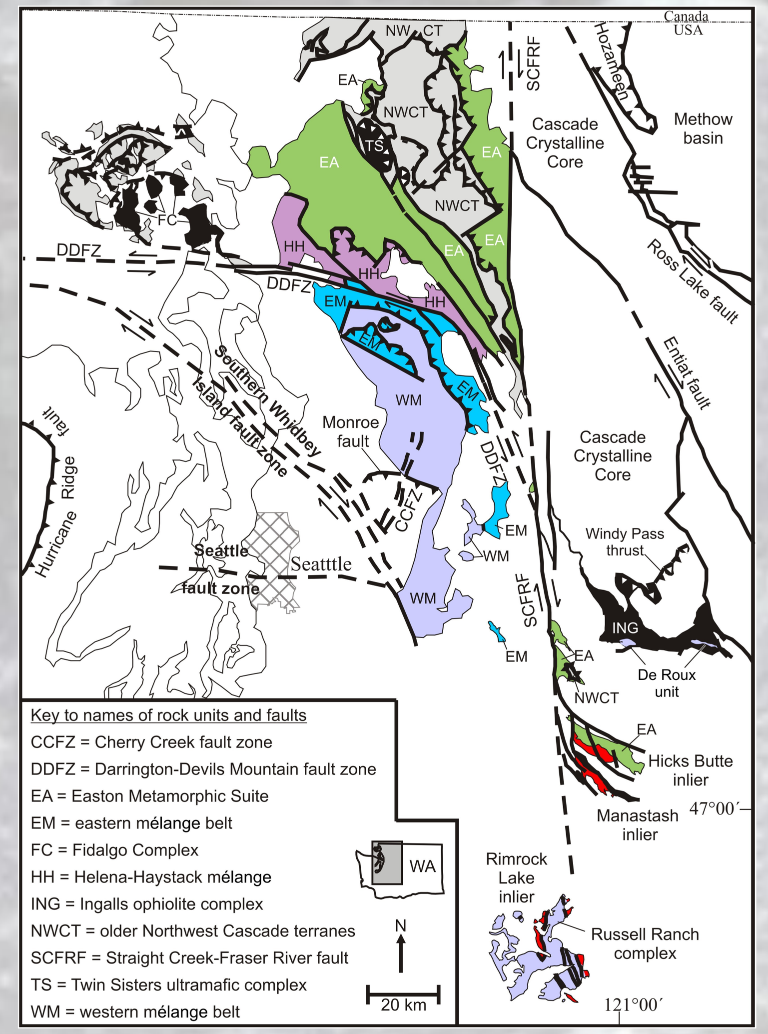
## ABSTRACT

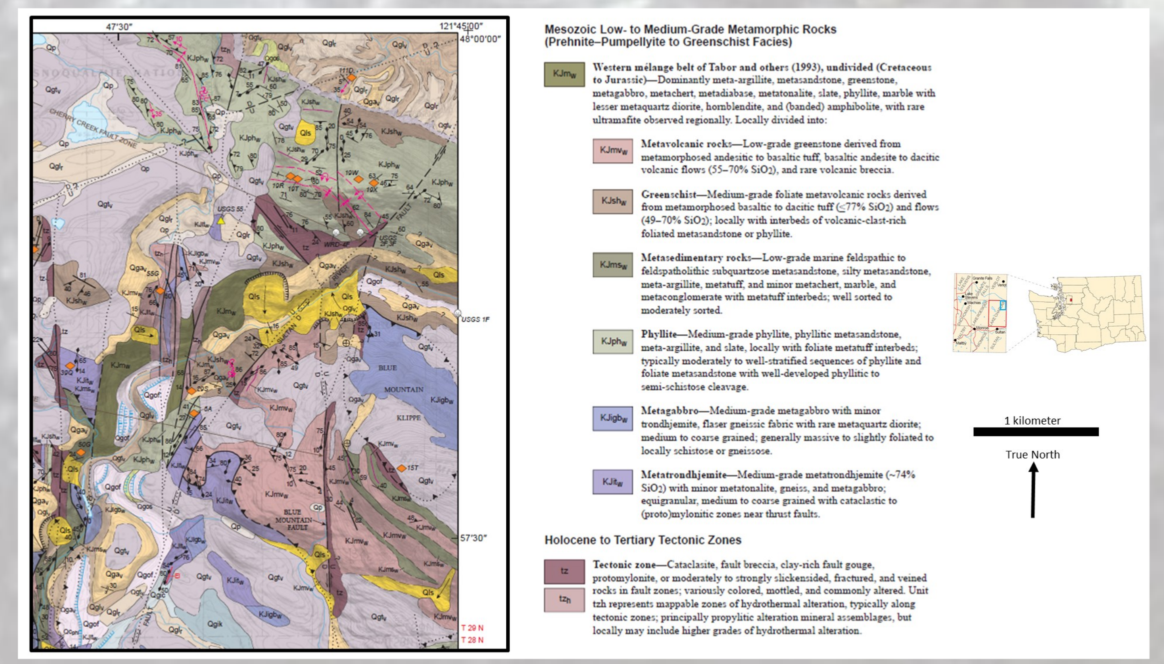
The western mélange belt (WMB) is a mostly low to medium grade and penetratively deformed accretionary complex. It consists of meta-argillite, metasandstone, metaigneous rocks, and metachert, with phyllite, slate and rare marble and serpentinite. U-Th-Pb zircon age from a metatonalite is 150-160 Ma. Detrital zircons from 3 metasandstones have youngest average age populations of 74 Ma, 87 Ma, and 96 Ma, respectively. Fossil ages are predominantly Late Jurassic to Early Cretaceous. Rare metachert is Early Jurassic and preserved fossils in marble are Permian. North of our study area the mélange is extremely disrupted; however, in our study area it consists of large-scale blocks with intact well bedded strata in most areas.

Previously published WMB geochemistry include arc (n = 5) and MORB (n = 2) affinities. New whole rock geochemical data for 16 metaigneous samples furthers this interpretation of the original tectonic setting of the WMB. Metagabbros were excluded from most plots due to the high Al and Eu values indicative of cumulate compositions. Metaigneous samples predominantly have high Th, low Nb/Yb, and volcanic arc chondrite- and N-MORB normalized patterns. They also plot in fields defined by modern volcanic arcs on discrimination diagrams. Metatrondhjemite and two metatuffs are magnesian, calcic, and metaluminous. Another metatuff is peraluminous and may be the product of assimilation. The metatuff have Nb/Yb ratios that are higher than all other arc affinity samples. Five of the metaigneous samples have calc-alkaline affinities, while the rest are tholeiitic. Geochemistry suggests that the metaigneous samples in our study area primarily originated in a Cretaceous to Jurassic volcanic arc setting. The calc-alkaline and tholeiitic affinities and diversity of the Nb/Yb ratios suggest a complex arc system that may have evolved over time. This is supported by sandstone petrography, detrital zircon age populations, and metasedimentary geochemistry. One greenstone has high Nb/Yb, low Hf, and likely originated in an oceanic island setting. The predominantly arc setting, with lesser within-plate and MORB affinities, is consistent with geochemistry from the likely correlative De Roux unit and Russell Ranch complex, Washington.


## Figure 1

Simplified geologic map displaying pre-Cenozoic tectonic elements of the central and northwest Cascades. Note the location of the western mélange belt (WM), De Roux unit, and Russell Ranch complex. Modified from Miller et al. (1993), Tabor (1994), and Brown and Dragovich (2003).




## Figure 2

Geologic map displaying western mélange belt and overlying Quaternary deposits. Note the internal contacts and different metamorphic grades. Modified from Dragovich et al. (2014).

## STATEMENT OF PROBLEM

- The tectonic origin of the western mélange belt is not well constrained.
- The western mélange belt was defined by Frizzell et al. (1987) to combine numerous units that had similar lithologies and ages.
- This resulted in a wide-range of lithologies and metamorphic grade in this mélange.
- In some areas the mélange is extremely disrupted; while in our study area large-scale blocks with intact, well-bedded strata are preserved (Fig 2).
- We use 16 new whole-rock major and trace element geochemistry to suggest possible original tectonic settings for the metaigneous rocks in the western mélange belt. This is combined with published data for 7 additional samples (Vance et al., 1980; Tabor, 1994).
- Geochemistry also allows us to compare magmatic affinities within the western mélange belt; and, to compare mélange units internally and to other correlative units (De Roux unit and Russell Ranch complex [Fig. 1]) in the Washington Cascades.
- The western mélange belt samples have undergone prehnite-pumpellyite to greenschist-facies metamorphism; thus , only elements that are immobile up to and including amphibolite-facies metamorphism were used for this study.

3A.

3B.

3C.

## Figure 3

A. Scaly argillite of the western mélange belt with a dike of unknown origin cutting.

B. Marble block displaying open folds.

C. Lithofeldspathic metasandstone and metasiltstone (19R on Fig. 2; lithic facies of Jett and Heller, 1988). The lithofeldspathic metasandstone consist of subrounded grains dominated by volcanics clasts and significant plagioclase, monocrystalline quartz and possible few granitic lithics. Beds are overturned and contain siltstone rip-up clasts and troughs. Partial Bouma sequences suggests the metasedimentary rocks were deposited as turbidites along an accretionary wedge.

4A.

4B.

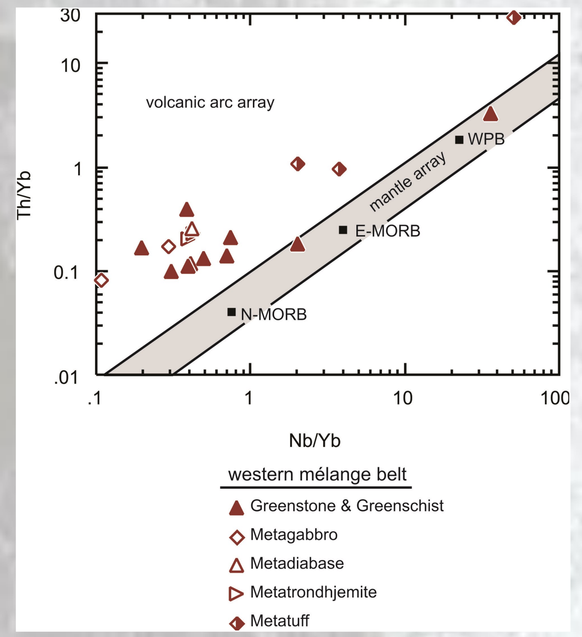
4C.

## Figure 4

A. Metagabbro displaying equigranular texture.

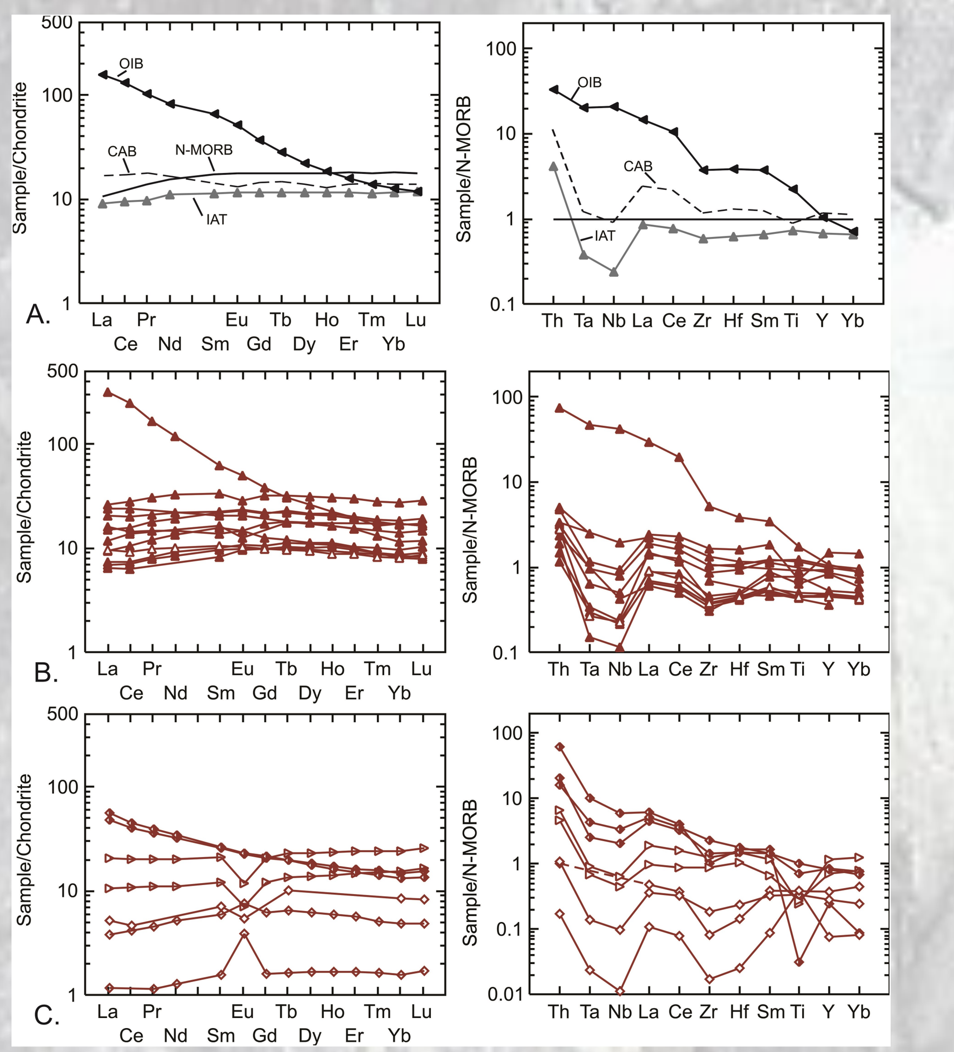
B. Greenstone on Blue Mountain (Fig. 2) displaying relic pillow flows. Greenstone is also vesicular.

C. Strong metamorphic fabric in this volcanic or tuffaceous phyllite or semischist. Note the strong metamorphic fabric as well as the boudinage of some of the thin relict beds.



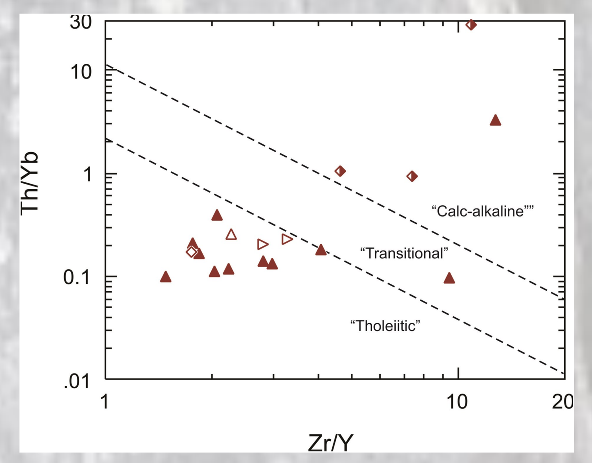

## Figure 5

Th/Yb vs. Nb/Yb diagram of Pearce (1982, 2008) for western mélange belt samples. Data from Vance et al. (1980), Tabor (1994), & Dragovich et al. (2009a,b, 2013, 2014). Note the primarily arc composition.



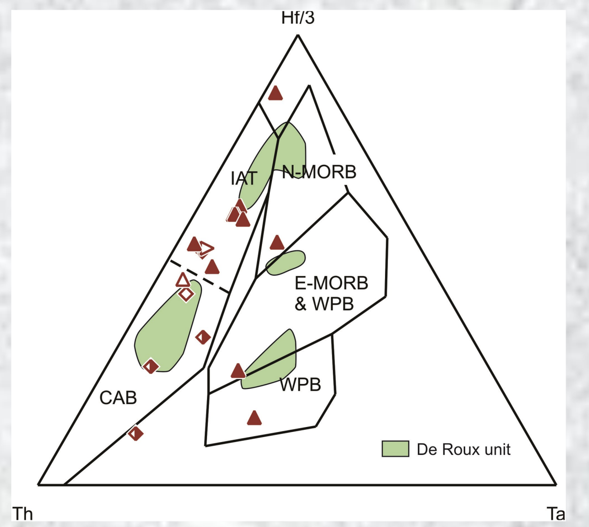

## Figure 6

Chondrite– and N-MORB-normalized diagrams for western mélange belt samples. Symbols are from Fig. 5. Data from Vance et al. (1980), Tabor (1994), & Dragovich et al. (2009a,b, 2013, 2014). Normalized values are from Sun and McDonough (1989) and McDonough & Sun (1995).



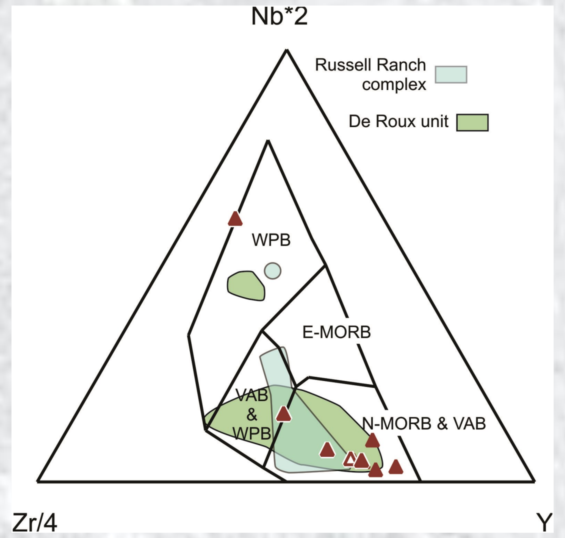

## Figure 7

Th/Yb vs. Zr/Y magmatic affinity discrimination diagram (Ross & Bédard, 2009). Symbols are from Fig. 5. Data from Vance et al. (1980), Tabor (1994), & Dragovich et al. (2009a,b, 2013, 2014).



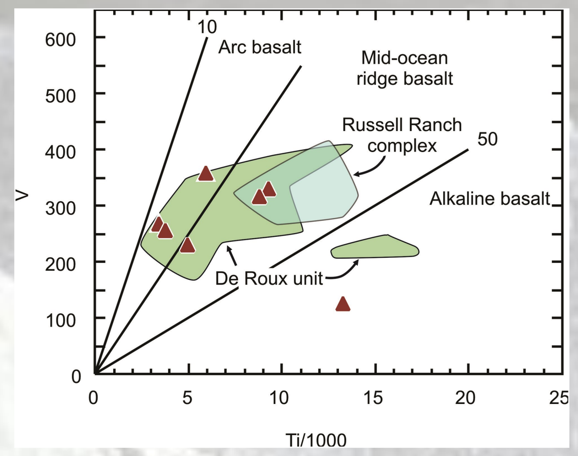

## Figure 8

Th-Ta-Hf discrimination diagram of Wood (1980). De Roux unit data also plotted (MacDonald, 2006). Symbols and data sources are from Fig. 5.



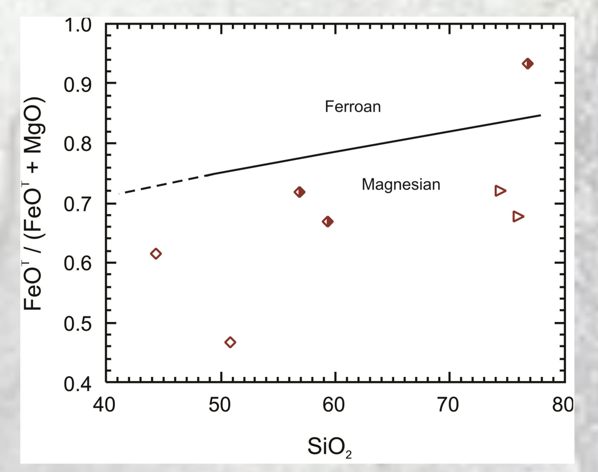

## Figure 9

Zr-Nb-Y discrimination diagram of Meschede (1986). De Roux unit data (MacDonald, 2006) and Russell Ranch complex (Shultz, 1989) data also plotted. Symbols and data sources are from Fig. 5. Only mafic samples are plotted.



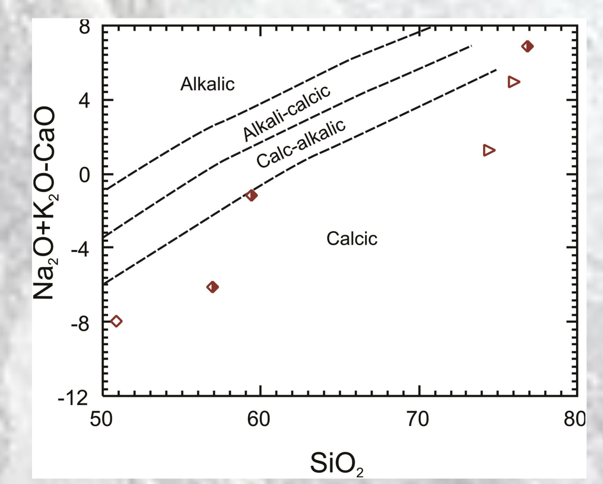

## Figure 10

Ti-V discrimination diagram of Shervais (1982). De Roux unit data (MacDonald, 2006) and Russell Ranch complex (Shultz, 1989) data also plotted. Symbols and data sources are from Fig. 5. Only mafic samples are plotted.



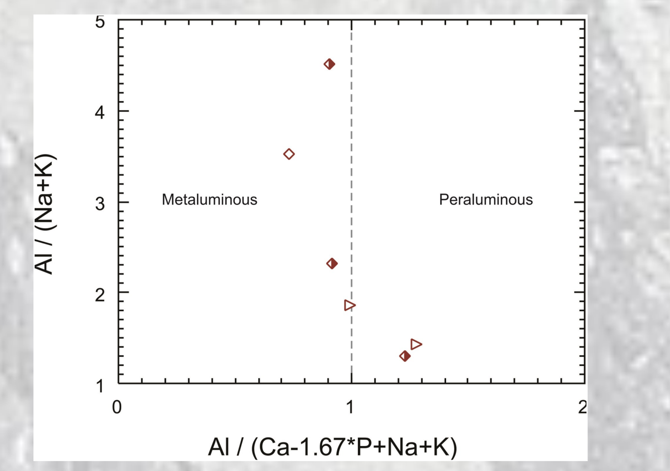

## Figure 11

Fe-number vs. $SiO_2$ for western mélange belt plutonic and tuff samples (Frost et al., 2001). Symbols and data sources are from Fig. 5.



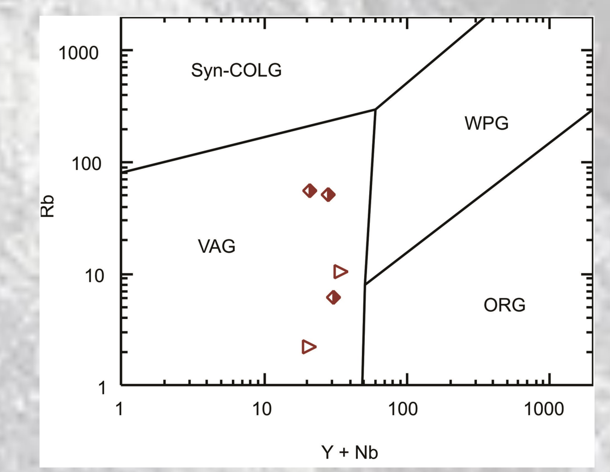

## Figure 12

MALI vs. $SiO_2$ for western mélange belt plutonic and tuff samples (Frost et al., 2001). Symbols and data sources are from Fig. 5.




## Figure 13

ASI vs. $SiO_2$ for western mélange belt plutonic and tuff samples (Frost et al., 2001). Symbols and data sources are from Fig. 5.




## Figure 14

Rb-Y-Nb discrimination diagram for western mélange belt felsic samples (Pearce et al., 1984). Symbols and data sources are from Fig. 5.

## DISCUSSION

- The western mélange belt in our study area consists of large-scale, faulted blocks that contain well-bedded strata in most areas (Fig. 2).
- The Nb/Yb ratios and chondrite– and N-MORB-normalized values for most of the western mélange belt samples suggest that they resulted from the partial melting of a depleted mantle source (Fig. 5 & 6).
- Several samples originated from the partial melting of more enriched mantle sources (Fig. 5 & 6).
- The majority of the samples have Th/Yb and Zr/Y ratios that suggest they are tholeiitic, while the metatuffs have calc-alkaline affinities (Fig. 7).
- The high Th (Fig. 5 & 8), chondrite– and N-MORB-normalized values (Fig. 6), and Ti-V ratios (Fig. 10) suggest that most western mélange belt samples originated in a volcanic arc setting.
- One sample has depleted Yb, Hf, and Y (Fig. 5, 8, & 9), elevated large ion lithophile and light rare earth elements (Fig. 6) and a Ti-V value that suggests it has alkaline within-plate basalts affinities; and, it resulted form decompression melting in a deeper, more enriched mantle source than other mélange metaigneous samples.
- This alkaline within-plate basalt affinity sample is interpreted to have formed in a seamount setting.
- The alkaline within-plate basalt affinity sample plots in the “calc-alkaline” filed on figure 7 due to its depleted Y and Yb.
- Minor samples also have MORB geochemical affinities by plotting on the mantle array in figure 5, and in MORB files on figure 8.
- The metaplutonic and metatuff samples are primarily magnesian and calcic (Fig. 11 & 12).
- One metatuff and one metatrondhjemite are peraluminous, while all other metaplutonic and metatuff samples are metaluminous (Fig. 13). The peraluminous samples may be the result of assimilation (Fig. 13).
- The magnesian, calcic, metaluminous affinities of the metaplutonic and metatuff samples is consistent with a volcanic arc setting (Fig. 11, 12, & 13).
- These samples also plot in the volcanic arc granitoid (VAG; Fig. 14). This is consistent with the chondrite– and N-MORE-normalized patterns of these samples (Fig. 6), and their elevated Th on figures 5 and 8.
- The metatuffs have Nd/Y and normalized values that suggest they originated from a more enriched mantle source than other arc-affinity samples (Fig. 5 & 6).
- The western mélange belt samples have geochemical affinities that are similar to metaigneous samples from the De Roux unit and Russell Ranch complex (Fig. 1, 8, 9, & 10).
- The lithology and geochemistry of the western mélange belt suggest it is a collision-mélange that involved a volcanic arc.

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