EXPLORING IGNEOUS ACCESSORY MINERAL TEXTURES:
TITANITE FROM NOTCH PEAK GRANITE AND LITTLE COTTONWOOD STOCK, UTAH

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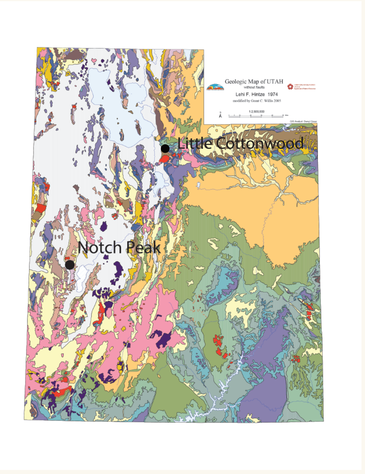
Introduction

Titanite is an accessory mineral in many granites. Due to its incorporation of a wide variety of trace elements, low elemental diffusion rates, and relative abundance, titanite is useful in the study of petrogenetic processes. In addition, titanite also retains clear growth zoning from past events. We sampled titanite from two localities, the Notch Peak Granite located in Western Utah, and the Little Cottonwood stock located near Salt Lake City, Utah in order to evaluate Titanite textures in interpreting magmatic and hydrothermal histories.

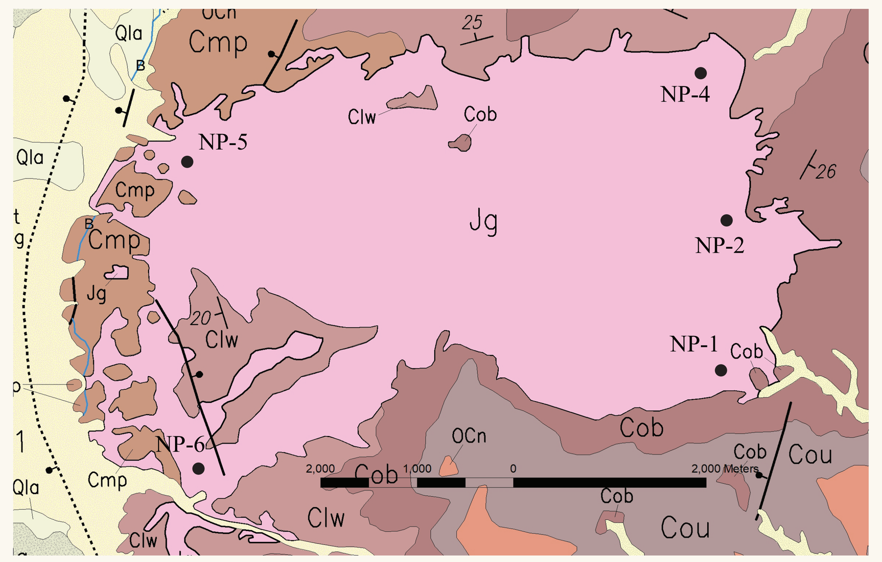
The Notch Peak (NP) granite formed in the mid Jurassic (~167 Ma) from a single pluton. It is more chemically evolved than the Little Cottonwood stock. Titanite grains from Notch Peak tend to form simple, euhedral grains with prominent sector and oscillatory zoning. Some grains exhibit prominent dark zones that contain distinct irregular zonation from a replacement event (Fig. 2).

The Little Cottonwood (LC) granite formed in the early Oligocene (~31 Ma) and is more mafic than Notch Peak. Its titanite grains also display a more complex texture than Notch Peak's. Titanite grains from Little Cottonwood tend to have primary patchy, or mottled, core zoning with abundant inclusions of apatite and rounded ilmenite, mantled by and oscillatory zones and interstitial overgrowth. Titanite grains from mafic enclaves found in the Little Cottonwood stock have unique patterns including poikilitic textures and patchy rims (Fig. 2).

Sample Sites



Notch Peak Granite



Little Cottonwood Stock

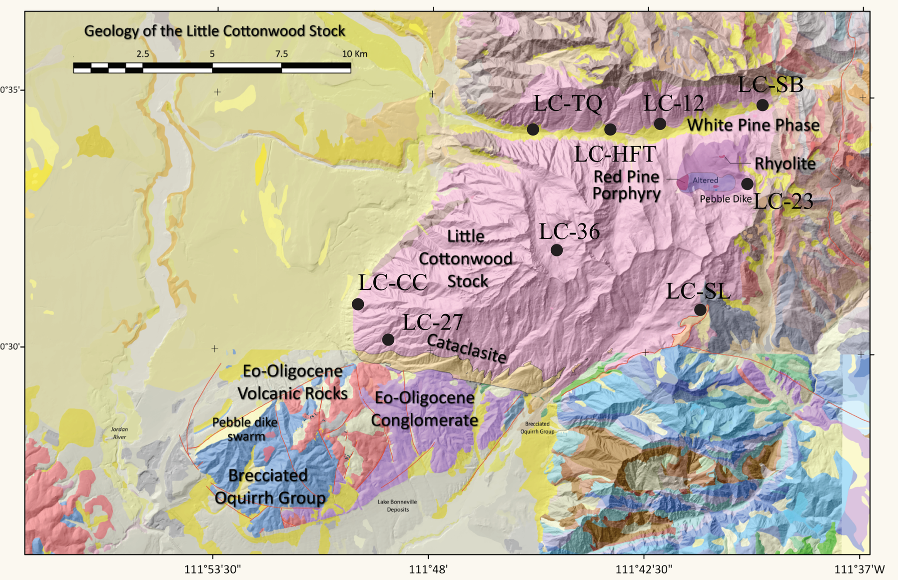


Figure 1. Maps of Notch Peak and Little Cottonwood stock. Sample locations are included on map.

SEM Textures

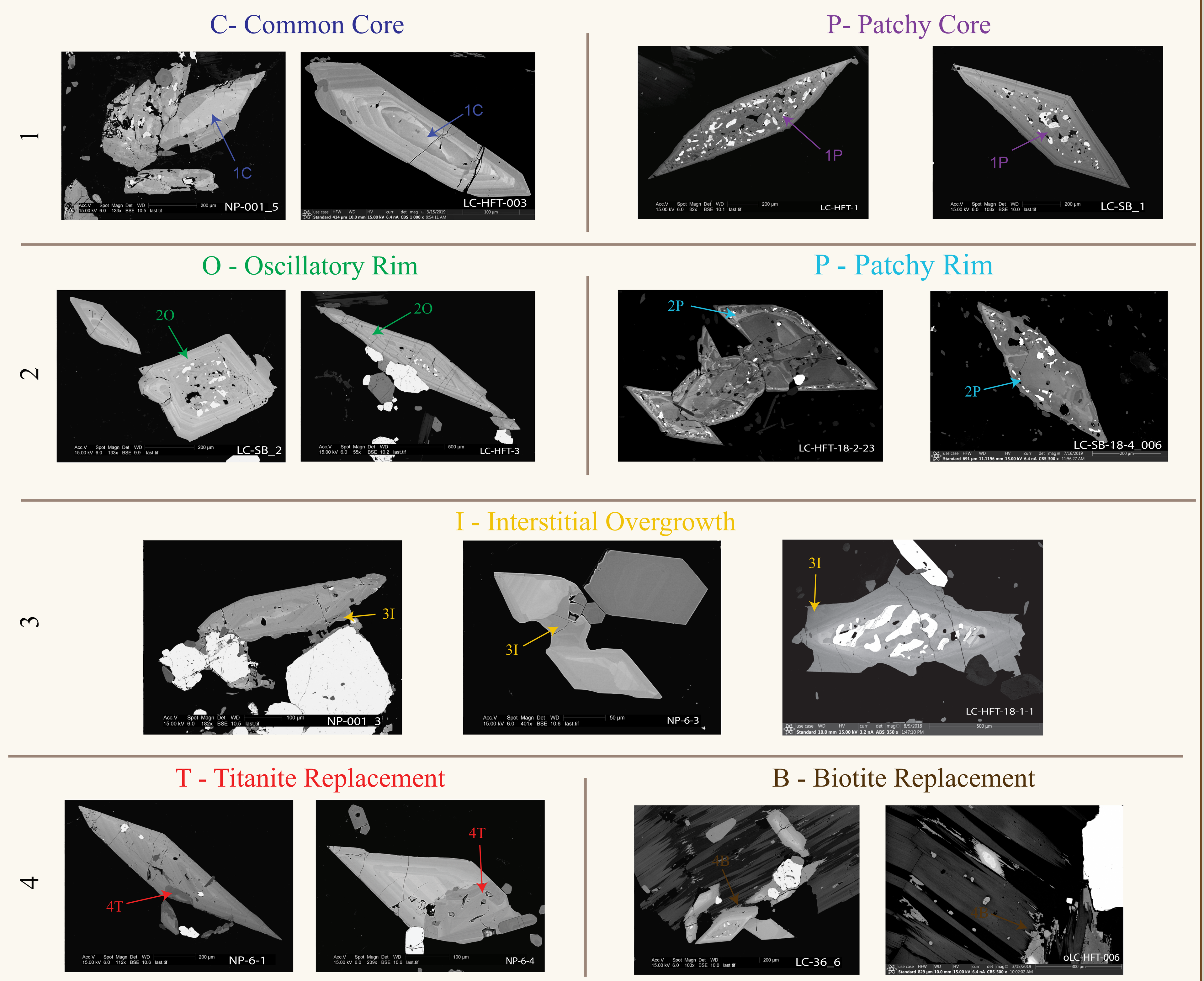


Figure 2. Electron Backscatter Imaging of titanite grains found from Notch Peak and Little Cottonwood granites. Textures have been classified as cores (1), rims (2), interstitial overgrowth (3), and replacement (4). Textures have been further classified by type of texture: common core (C), patchy (P), interstital overgrowth (I), titanite (T) or biotite (B) replacement. Brightness is correlated with average atomic weight. Thus brighter zones tend to have higher concentrations of REE than dark zones.

Whole Rock Analysis

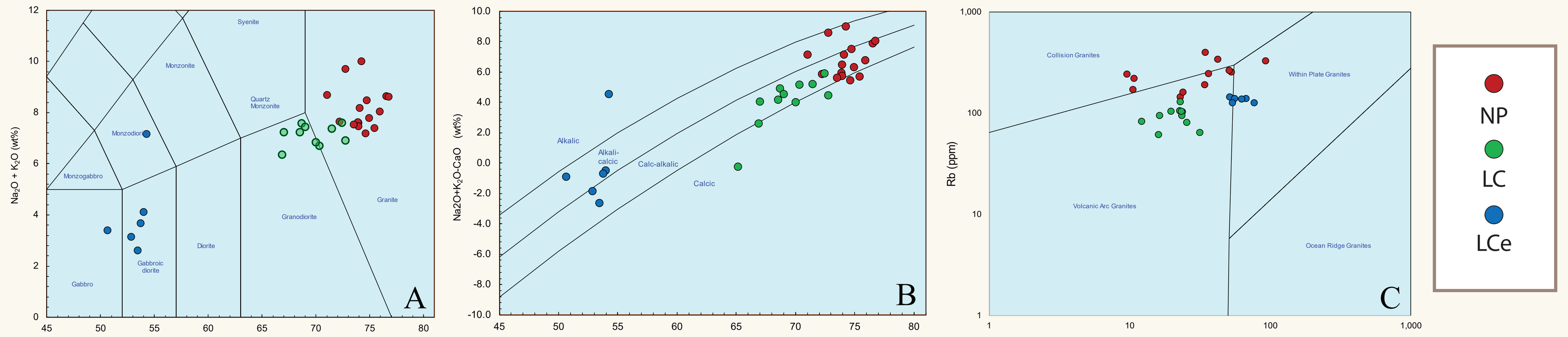


Figure 3. TAS (A), MALI (B), and Pearce (C) diagrams created using XRF techniques. Whole rock samples have been divided into three groups: Notch Peak granite (NP), Little Cottonwood stock (LC) and Little Cottonwood enclave (LCe). Diagram A shows that Notch Peak originates from a more chemically evolved source and sits solidly in the granite section while Little Cottonwood is more mafic. The little Cottonwood is much more mafic than Little Cottonwood enclave, and may indicate a different, more mafic source that was mixed in. Diagram B indicates the alkalinity of each granite. Notch Peak and Little Cottonwood tend to be more calc-alkalic than the Little Cottonwood enclave which is more Alkali-Calcic. Diagram C indicates different intrusion settings for each granite. Notch Peak and Little Cottonwood came from a volcanic arc into paleozoic limestone, although Notch Peak adopts some characteristics of other settings.

REE diagrams

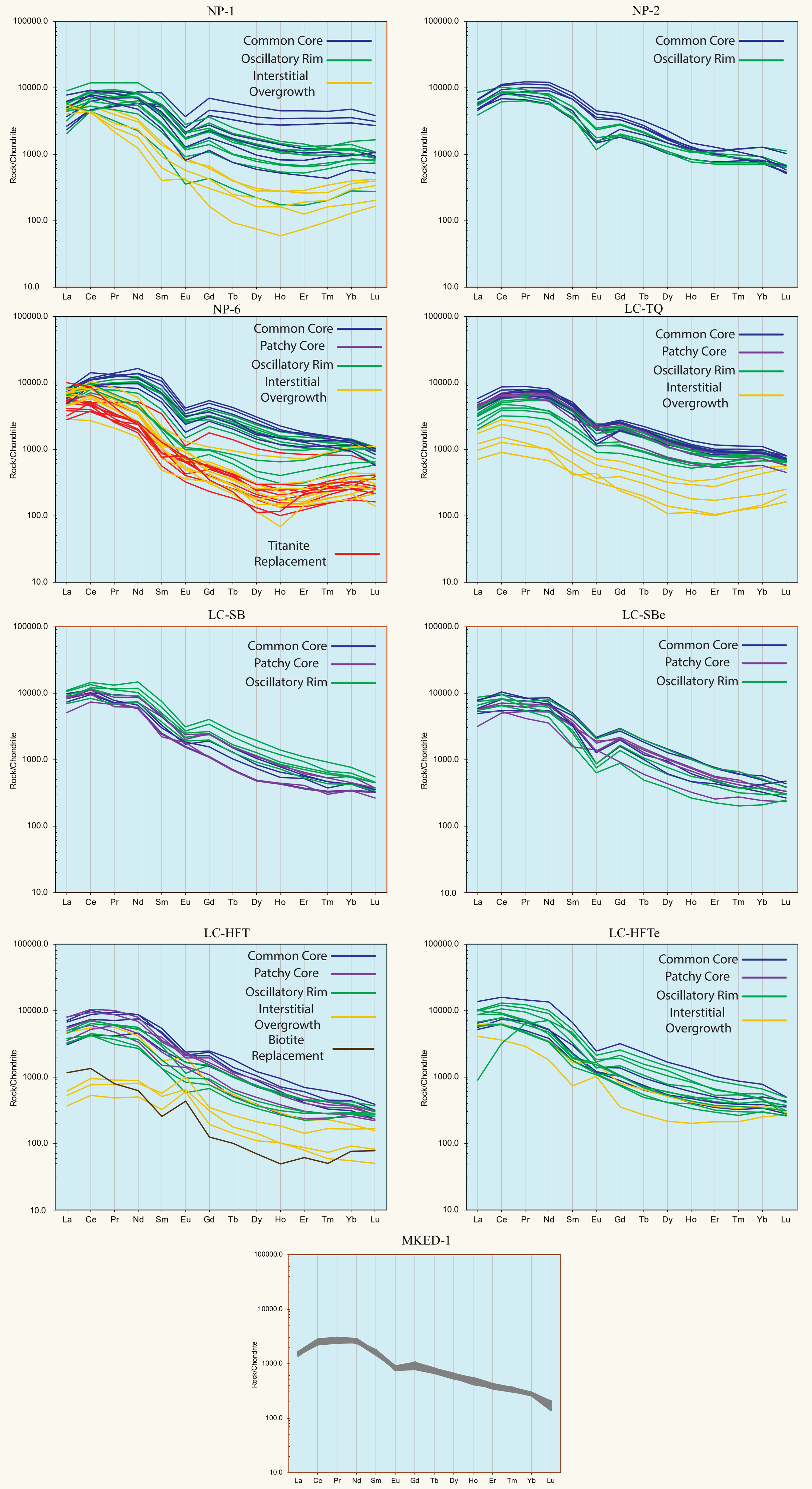


Figure 4. REE diagrams created from data taken from LA-ICPMS and normalized to chondrite meteroites (Mcdonough et al., 1992) Patterns are colored according to their texure. Cores and Patchy cores (1C and 1P) tend to follow similar patterns such as a negative Eu anomaly, higher light rare earths and lower heavy rare earths. Oscillatory rims (2O) tend to follow the same pattern, but overall have lower concentrations of REE. Interstitial overgrowth titanite (3T), titanite, and Biotite replacement (4t and 4B) has much lower REE concentrations, a neutral to positive Eu anomaly, and increased amounts of HREE such as YB or Lu. Analysis were compared to MKED standards for consistency.

Compare grains to comp

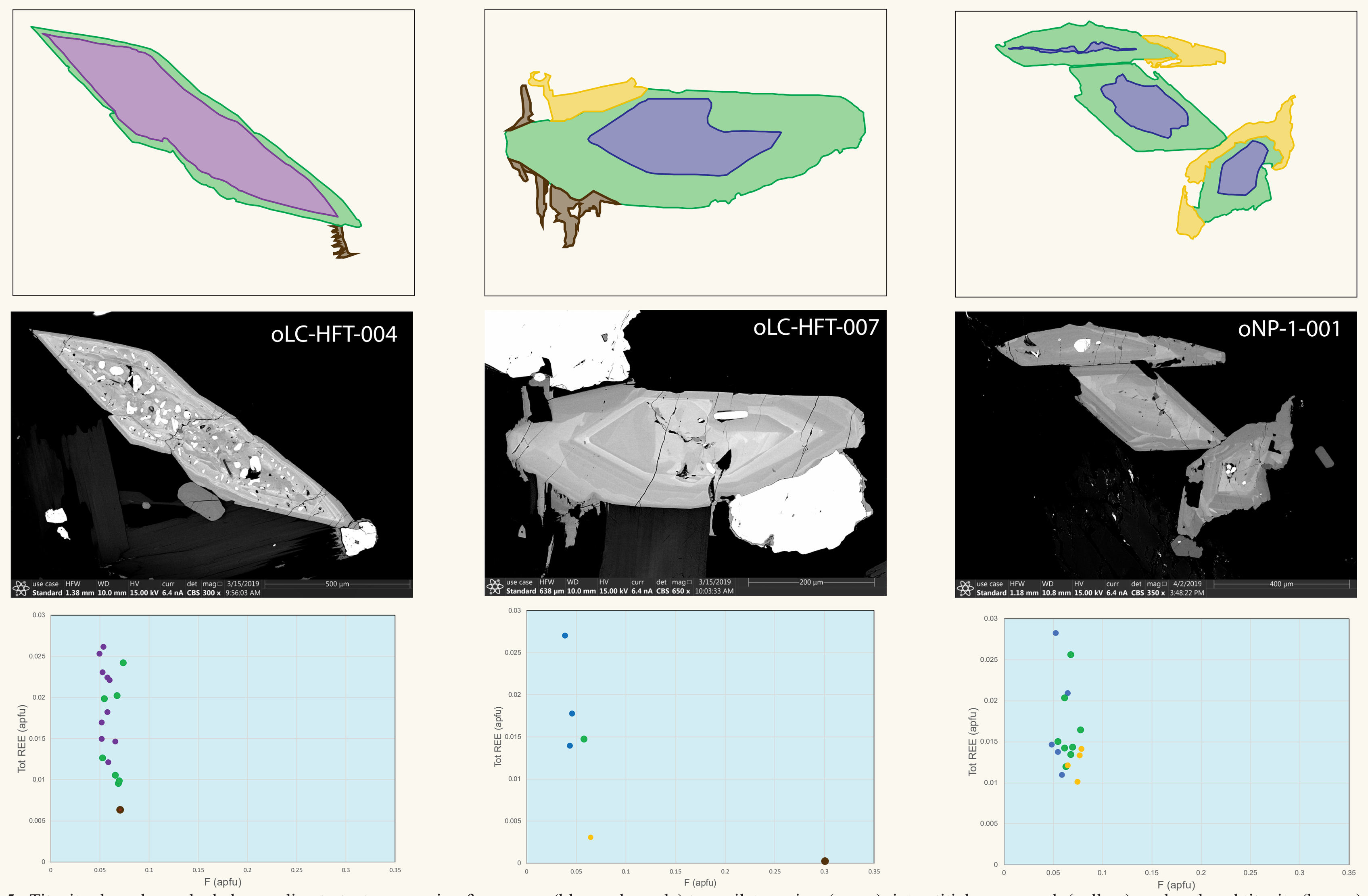


Figure 5. Titanites have been shaded according to texture, ranging from cores (blue and purple) to oscilatory rims (green), interstitial overgrowth (yellow), and replaced titanite (brown). Analysis were done by electron microprobe and F and REE's have been plotted. Titanite cores and rims have the higheset REE (0.02-0.03 apfu) and lower F (0.02-.05 apfu), while overgrowth and replacement textures have lower REE's (0.01-0.02 apfu) and high F (0.04-0.3 apfu). Replacement textures tend to have higher F, especially when replacing biotite, which may indicate hydrothermal alteration.

Crystallization path

Notch Peak

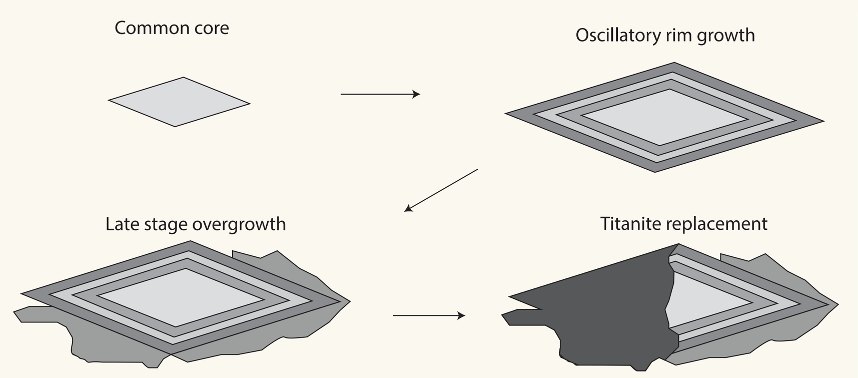


Figure 6. An example crystallization path for the Notch Peak granite. Core texture crystallizes initially in the melt. Oscillatory rims then mantles the core between bright and dark bands seen in BSE images. During late growth, dissolution surfaces may form and zoneless overgrowth may occur. Some grains undergo titanite replacement which exibits hard texturless titanite

Little Cottonwood

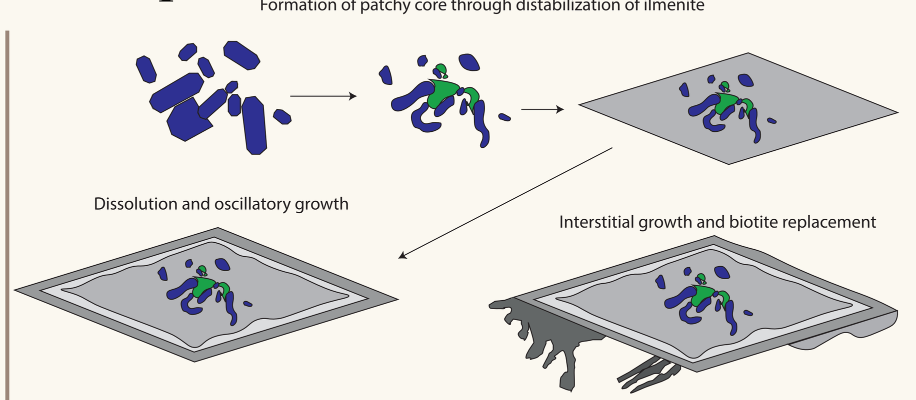


Figure 7. A standard crystallization path for Little Cottonwood. A lower FO_2 favors ilmenite growth. A higher FO_2 magma mixes and stabilizes titanite while Ilmenite exsolves. patchy core titanite begins to grow in the same pattern as Notch Peak. Oscillatory growth occurs. During late crystallization, interstitial and replacement titanite grow on or replace existing titanite and surrounding biotite.

$\delta^{18}O$

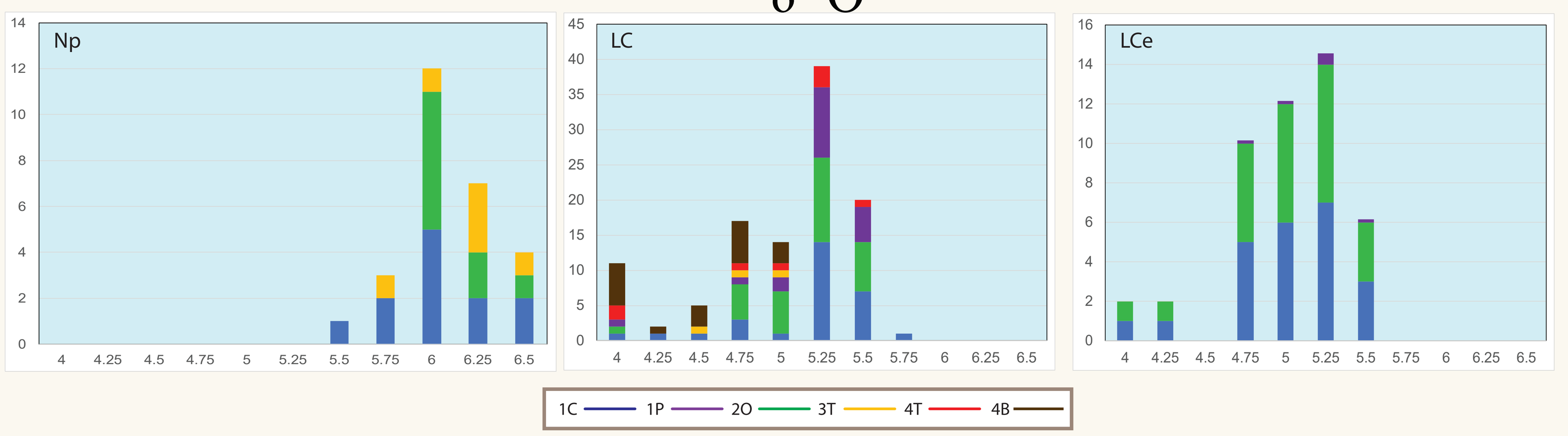


Figure 8. Histograms of $\delta^{18}O$ of each granite analyzed using $\delta^{18}O$ SIMS technique. Notch Peak has higher $\delta^{18}O$ values (5.5-6.5) than both the Little Cottonwood and Little Cottonwood Enclave, which have similar values (4.0 -5.75). Little Cottonwood granites 4B, 4T, and 3T tend to have lower $\delta^{18}O$ values (4.0 -5.25) while Notch peak's 3T tend to be similar to other textures (5.5-6.5), which may indicate stage of growth. 1C, 1P, and 2O all seem to have simlar $\delta^{18}O$ values which indicate crystallization during the same growth stage.

Conclusion

Titanite is becomming more popular as an indicator mineral and geochronometer. Understanding textures of titanite can lead to better understanding the evolution of thegranite. Initial common and patchy cores (1C and 1P) are grown intially and have high REE concentrations. Oscillatory growth (2O) has slighly lower REE concentrations, but similar patterns. $\delta^{18}O$ values of cores and oscillatory growths are simlilar as well as temperatures. In late stages of crystallization, interstitial overgrowth (3I) may occur on some grains, causing dissolution surfaces and large zoneless growths. This texture tends to have lower REE, $\delta^{18}O$ values, and temperatures, but has a neutral to positive Eu anamoly. Replacement textures featuring titanite and biotite (4T and 4B) my occur from late crystallization to post-hydrothermal alteration, which results in more sporadic chemistry patterns, temperatures, and $\delta^{18}O$ values. However these patterns are still lower than other textures

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