ULTRAMAFIC ROCKS IN NORTH CAROLINA: Using Spinel-group Mineral Chemistry to Understand their Tectonic Significance

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Abstract

The Appalachian and Caledonian mountains, which extend from Norway in the north to Alabama in the south, record the closure of the Iapetus Ocean during the early Paleozoic. Ultramafic. Understanding the origin of ultramafic rocks in mountain belts may provide insight into the formation and evolution of convergent margins. Our research compares ultramafic rocks from opposite ends of the Appalachian-Caledonian system: the Leka Ophiolite Complex (LOC) in Norway; and the Buck Creek and Webster-Addie bodies in North Carolina. We present the results of petrographic observations and spinel-group mineral chemistry, with the aim of understanding the tectonic significance of the North Carolina ultramafic rocks. The low Fe^{2+} and Fe^{3+} values represent primary compositions and correspond to spinel grain cores, while the increasing values reflect progressive alteration. North Carolina samples have Fe^{2+} values ranging from 0.48-0.94 and Fe^{3+} values ranging from 0.05-0.43. All North Carolina data Fe and ternary data overlap with secondary compositions analyzed from Leka, suggesting that the samples have undergone heavy metamorphism. Comparison of resulting chemical data and use of Cr # (molar Cr / ([Cr + Al]) and TiO_2 (wt. %) yield two possible conclusions: (1) The North Carolina samples formed as cumulates in a continental magma chamber; or (2) the North Carolina samples indicate a trend of alteration undergone by ophiolites.

Background

Ophiolites are fragments of oceanic lithosphere comprised of massive peridotites, which have often undergone serpentinization; layered ultramafics, gabbroic complex; sheeted dikes complex; pillow basalts; and in some cases, sediment (Dilek and Furnes, 2014). Recent geochemical studies have revealed ophiolites exhibit geochemical signatures like those observed in the forearc (Whattam and Stern, 2011).

Appalachian-Caledonian mountains extend from Norway to northern Alabama. Orogens responsible for the Appalachian-Caledonian mountains include the Silurian (443.8 - 419.2 Ma) Taconic orogeny, and late Devonian (419.2 - 358.9 Ma) Acadian orogeny (Hatcher et al, 1989; Hatcher, 2010; Wilner et al, 2014). Lastly the Alleghenian orogeny, which occurred from the Pennsylvanian to the Permian, and was the continent-continent collision of Laurentia and Gondwana forming the super continent Pangea (Hatcher, 2010). It was throughout these orogenic processes that our sample rocks were obducted and accreted into the system.

Sample regions:

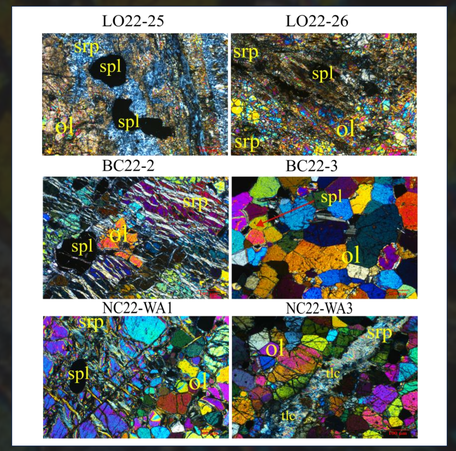
- Leka Ophiolite, Norway: The LOC outcrops on the island of Leka, Nord-Trøndelag, Norway at the northern end of the Appalachian-Caledonian system. The LOC exhibits the standard stratigraphy of an ophiolite (Iyer et al., 2008).
- North Carolina: Buck Creek mafic-ultramafic suite and the Webster-Addie body in North Carolina are a possible ophiolite or fossilized magma chamber located in the southern extent of the Appalachian-Caledonian system.

Methods

Eleven samples were collected. Four LOC samples (Two are analyzed here), Four Buck Creek, and Three Webster Addie, North Carolina (Two were used). The LOC samples were collected by Naomi Becker and North Carolina samples were collected by George Guice. Samples were processed into thin sections for microscopy and electron microprobe analysis. Estimated mineral compositions were taken along with spinel mineral location for electron probe analysis. For utilization of the electron microprobe, calibration of known standards was used for the elements of interest. Six samples were used in our electron microprobe analysis including Two LOC samples, Two Buck Creek samples and Two Webster-Addie samples. Each sample was coated with 7-10µm of carbon for processing in the electron microprobe. Spinel-group minerals were subject to quantitative chemical analysis, with every grain analyzed subject to back-scattered electron (BSE) imaging to contextualize the chemical analyses.

Petrography

Olivine, spinel, and serpentine occur in every sample with chlorite, talc, clinopyroxene, orthopyroxene, and bastite occurring in some samples. Plagioclase also occurs in the North Carolina samples, but only as an accessory phase.



Discussion

Using spinel-ground mineral chemistry, we evaluate the following hypotheses for the origin of the Buck Creek and Webster Addie ultramafic bodies: (1) that they represent a fossil magma chamber; or (2) are fragments of an ophiolite, as previously proposed by Peterson and Ryan (2009). Baltimore ultramafic data from Guice et al. 2021 was plotted to further corroborate the trend where ophiolites plot on the diagram.

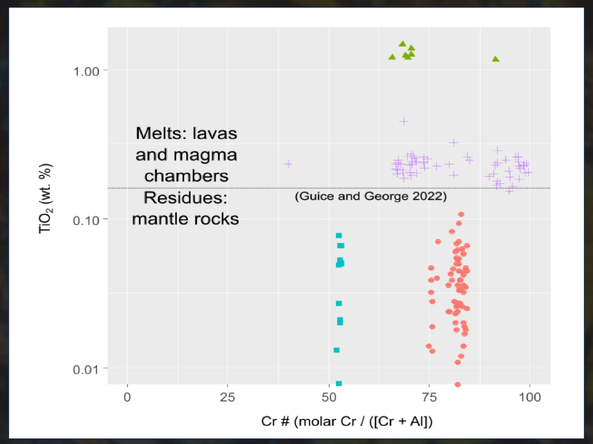
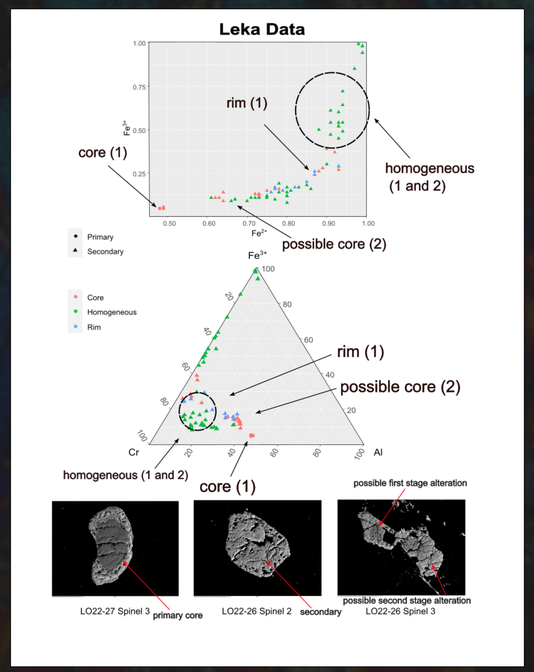


Figure 2. Cr # (molar Cr/([Cr+Al]) and TiO_2 (wt. %) diagram. All data is plotted here including data from Guice et al. 2021 to further illustrate where ophiolites plot. The Guice and George 2022 line distinguishes between mantle rocks and melts. The red circles represent Baltimore data from Guice et al. 2021. The blue square represent Leka data. The green triangles represent Buck Creek data and the purple cross represent Webster Addy data.

Spinel-group Mineral Chemistry Results



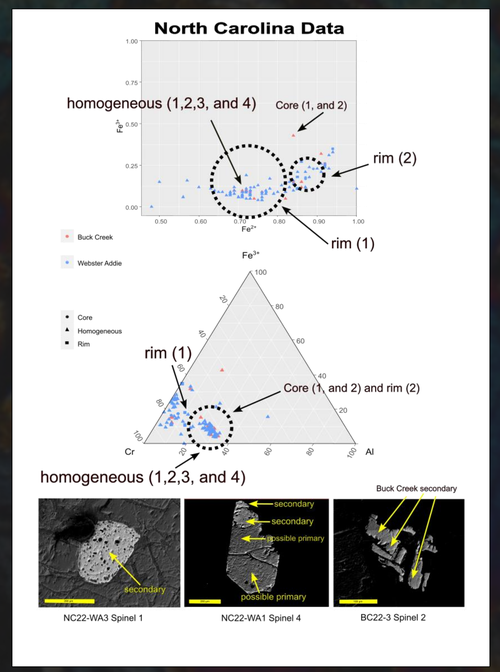


Figure 1. Leka data. R analysis for Fe^{2+} and Fe^{3+} diagram along with ternary diagrams. Core, rim, homogeneous and possible cores are labeled within diagrams. Interpretations are made based on data displayed. Figure 2. North Carolina data presents the same analysis; however, primary and secondary interpretations are not made.

Conclusions

My research revealed two possible origins for the North Carolina ultramafic rocks. However, because of the uncertainty of primary and secondary spinels found in the North Carolina samples it is most probable that the samples do not constitute an ophiolite. Leading to the conclusion that the North Carolina ultramafic rocks represent an ancient fossilized magma chamber.

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