SOUTHEASTERN GEOLOGY
V. 40, No. 3, September 2001, p. 201-212

INSIGHTS FROM RARE EARTH ELEMENTS INTO THE GENESIS OF THE BUCK CREEK COMPLEX, CLAY COUNTY, NC

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ABSTRACT

The Buck Creek complex is among the largest and most lithologically diverse of the mafic/ultramafic bodies found in the eastern Blue Ridge province of the southern Appalachians. Rare-earth element (REE) analyses on a representative suite of Buck Creek amphibolites and meta-troctolites supplements an ongoing undergraduate research program examining the origins and history of mafic/ultramafic units in southwestern North Carolina. While some of the REE (particularly Ce) show effects of the metamorphic alteration of the Buck Creek complex, overall its REE systematics reflect the compositions of igneous protoliths. "High Ti" and "Low Ti" amphibolites show REE patterns consistent with basaltic and cumulate gabbroic protoliths, indicating an ocean crustal origin for the Buck Creek Complex.

Buck Creek amphibolites show similarities in REE systematics to the Group 2 amphibolites of Misra and Conte (1991), as well as to a garnet pyroxenite from the nearby Lake Chatuge complex. Amphibolites from the Carroll Knob mafic complex and pyroxenites from the Moore's Knob and Webster-Addie bodies show overall lower rare earth element abundances, and variable REE patterns.

INTRODUCTION

A range of hypotheses has been proposed to explain the origins of mafic and ultramafic rock bodies exposed within the Eastern Blue Ridge province of the southern Appalachians: deep seated magma bodies (Hartley, 1973; Meen,1988), magnesian metamorphic rocks (Swanson, 1980), ultramafic diapirs (Stevens and others, 1974; Yurkovich, 1977), random blocks in a subduction melange (Laccazette and Rast, 1989; Raymond and others, 1989), or fragments of ophiolite sequences (Misra and Keller, 1978; MacElhaney and McSween, 1983; Tenthorey and others, 1996). Amphibolite-granulite facies metamorphism and complex deformation typical of the eastern Blue Ridge province have pervasively modified these mafic/ultramafic rock bodies and obscured many pre-deformational physical relations (Absher and McSween, 1985; Eckert and others, 1989; Tenthorey and others, 1996). Geochemical analysis in conjunction with outcrop- and map-scale field relations allow us to see through the effects of metamorphism, both to ascertain protoliths and to provide indications of tectonic settings. REE systematics have been used to successfully constrain tectonic settings in metamorphosed terranes (Grauch, 1989). With a few exceptions, the REE are not strongly mobilized in H_2O-rich metasomatic fluids (Brookins, 1989); and REE variation patterns have been used for many years to relate suites of rocks and to constrain their tectonic settings.

The relatively large size and lithological complexity of the Buck Creek mafic/ultramafic complex make it an excellent place to establish a basis for REE geochemical characterization. Participants in the 1997 and 1998 NSF-sponsored Buck Creek Research Experiences for Undergraduates (REU) Site research program generated an extensive database of major and

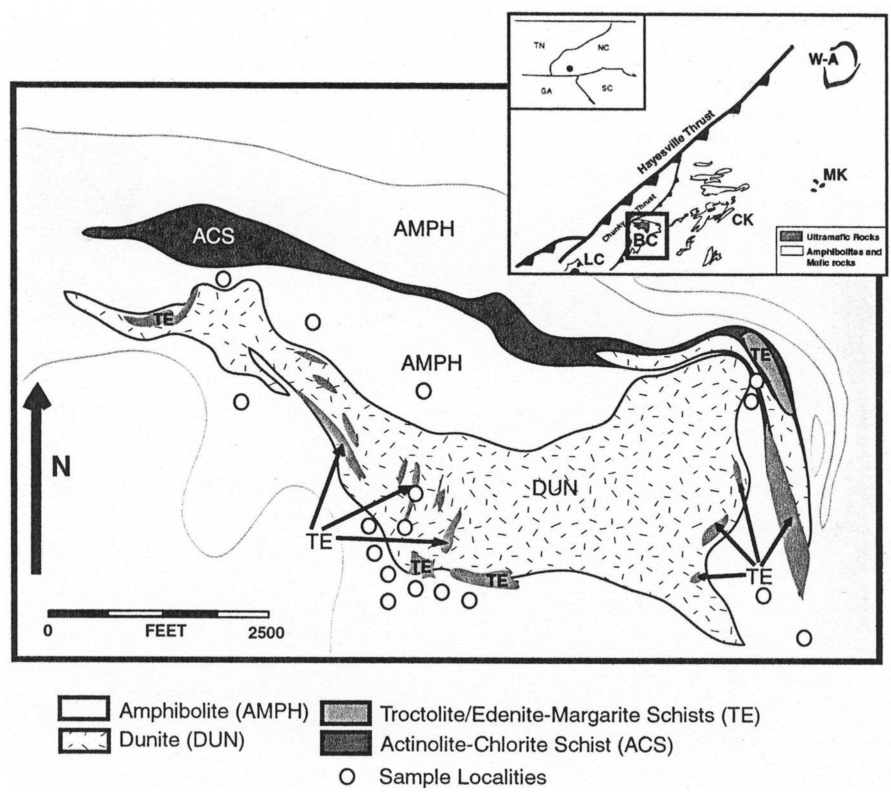

Figure 1: Simplified map of the Buck Creek complex, modified from Hadley (1949), and based on mapping results of 1997 and 1998 REU research working groups (Stonesifer and others, 1998; McCoy and others, 1999), showing the locations of samples for this study. Note that the edenite-margarite schist and anhydrous meta-troctolite units cannot be resolved at the scale of this map. Inset is a schematic regional map noting the positions of the Buck Creek (BC) Lake Chatuge (LC) and Carroll Knob (CK) complexes, as well as the Webster-Addie complex (W-A) and the Moore's Knob dunite (MK) to the east.

trace element compositions for rocks of the Buck Creek complex, constrained by detailed outcrop- and map-scale field observations. These field and geochemical data point to an origin for the Buck Creek complex as a fragment of a layered magmatic sequence, dominated by amphibolite (metabasalt or gabbro) with abundant dunite, and lesser troctolite and other ultramafic assemblages. Post-summer research by some REU participants led to analysis of REE abundances in selected samples from the Buck Creek complex, and from nearby mafic/ultramafic rock bodies. Our results point to genetic affinities among the different lithologic units of the Buck Creek complex, and indicate similarities to other mafic/ultramafic associations of the southeastern Blue Ridge.

SETTING AND PETROLOGIC OVERVIEW OF THE BUCK CREEK COMPLEX

The Buck Creek complex (BC) is made up of metamorphosed mafic and ultramafic rocks, and is located in Clay Co., North Carolina, in the Blue Ridge province of the southern Appalachians (Warner, in this volume; Fig. 1). The BC is the largest of numerous mafic/ultramafic exposures that form a broad chain within the Eastern Blue Ridge province, southeast of the pre-metamorphic Hayesville-Fries fault. The Buck Creek ultramafic rocks have also been described as part of the Chunky Gal Mountain Complex (defined based on extensive exposures of amphibolites, which enclose the ultramafic

Table 1. Bulk Compositions of Typical Buck Creek Lithologies.

	Amphibolites		Troctolites/EMS		Dunite
	High Ti	Low Ti	Troct.	EMS	
Sample	BC97SM1d	BC97SM1b	BC97AB6d	BC97PG4d	BC97JL1b1
SiO2 (%)	45.85	50.15	48.08	42.19	37.78
Al2O3	14.50	16.20	21.78	20.49	2.72
Fe2O3	13.59	6.39	5.88	6.19	13.08
MnO	0.20	0.12	0.09	0.08	0.16
MgO	9.21	9.27	7.20	19.32	46.07
CaO	13.78	14.29	14.23	9.47	0.34
K2O	0.13	0.15	0.11	0.17	0.01
Na2O	1.75	2.39	2.20	2.83	0.01
TiO2	1.41	0.24	0.21	0.02	0.01
Total	100.42	99.19	99.78	100.75	100.17
LOI (%)	1.75	1.24	0.91	4.49	3.77

rocks at Buck Creek; Fig. 1) (McElhaney and McSween, 1983; McSween and Hatcher, 1985). As the amphibolites and ultramafic lithologies at Buck Creek show both stratigraphic and geochemical relationships, we use the term "Buck Creek complex" to denote both the mafic and ultramafic rocks of the area. The BC rocks are enclosed within late Precambrian to early Paleozoic metamorphosed sediments and volcanics of the Tullalah Falls Formation and Coweeta Group (Eckert and others, 1989, Hatcher and others, 1984; MacElhaney and McSween, 1983).

The BC contains a variety of mafic and ultramafic lithologies, first delineated by Hadley (1949), and recently revised by participants in the NSF-sponsored Buck Creek (REU) Site program (Ryan, Peterson, and others, in prep; Stonesifer and others, 1998; McCoy and others, 1999). The complex includes five distinct map units: dunite, anhydrous meta-troctolite, edenite-margarite schist (metasomatically altered meta-troctolite), actinolite-chlorite schist, and amphibolite, with locally gradational contacts and transitions between units. Geochemically, these map units represent gradations from ultramafic to mafic cumulate protoliths, including dunites, troctolites, gabbros, clinopyroxenites, and anorthosites (Collins and others, 1998; Thomas and others, 1999; Table 1). All of the Buck Creek units have undergone variable hydration during a multistage metamorphic history, with peak conditions reaching ~1.2 GPa and 800-850°C (Tenthorey and others, 1996; Emilio, 1998).

The BC lies in close proximity to two other large complexes of associated mafic and ultramafic rocks: the Lake Chatuge complex, 10 miles to the southwest in NE Georgia, and the Carroll Knob Complex 10 miles ENE in Macon Co, North Carolina (Hartley, 1973; Hatcher and others., 1984; Figure 1, inset). All three of these units include amphibolites coexisting with dunites, metamorphosed gabbros, and/or meta-troctolites. The multilithologic nature of these larger complexes distinguishes them from the small, podiform exposures of dunite +/- minor harzburgite and pyroxenite, such as the Moore's Knob dunite, which are enclosed in Eastern Blue Ridge metasediments of the Ashe Metamorphic Suite (Misra and Keller, 1978; Raymond, 1984; Abbott and Raymond, 1984; Yurkovich and Eckert, 1992). The Webster-Addie dunite, 60 miles northeast of Buck Creek, is a relatively large ring-shaped body that is lithologically similar to the small podiform bodies (Figure 1, inset).

ANALYTICAL METHODS

Samples analyzed for rare earth elements were selected from the 150+ rock samples that were chemically and petrographically characterized during the 1997 and 1998 REU Site Research Program at Buck Creek. We limited our work to BC amphibolites and samples which showed bulk chemical similarities to gabbros/diabases/basalts, partly to ensure that the REE would be at measurable abundances, and also to simplify our inferences to parental magma rare earth contents. Representative mafic rocks from the Lake Chatuge and Carroll Knob complexes were analyzed toward making first-order comparisons among these nearby units. As well, a websterite from the Webster Addie complex, and an orthopyroxenite from the Moore's Knob dunite, were analyzed to assess REE variations among these bodies regionally.

Whole-rock samples were digested via an Na_2CO_3 fluxed-fusion procedure to ensure that all phases (including spinels, corundum, and sapphirine, which are common in many Buck Creek lithologies) would be completely digested. Water-soluble carbonates (and associated Na_4SiO_4) in the fusion cakes were removed by extensive rinsing, leaving carbonate residues that quantitatively retain REE. These residues were dissolved in HNO_3, and diluted at 1000:1. All sample solutions were spiked with the internal standard elements Cs, and Re at the 10 ppb level.

ICP-MS Methods

Most of the REE measurements reported in this study were made via quadrupole ICP-MS using the high-sensitivity Agilent Technologies (formerly HP) 4500 Plus Series 200 ICP-MS instrument in the Department of Marine Sciences on the USF-St. Petersburg campus. Some earlier determinations were made using a VG Elemental PQ2+ ICP-MS, which the Agilent instrument replaced. Oxide and doubly-charged ion interferences were minimal on the Aligent instrument, at less than 1% and 2% of the elemental signal on a 10 ppb Ce solution, so corrections for oxide contributions to signal intensities were found to be unnecessary.

We analyzed the full suite of rare earth elements (La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu) as well as yttrium, which was compared to our DC plasma spectrometry results on the same samples to assess the quality of our REE digestions. A two-step calibration procedure was used to determine concentrations. First, REE signal intensities were corrected to those of the internal standards. The light REE (La through Eu) were corrected to Cs, and the heavy REE (Eu to Lu) were corrected to Re. Mismatches in corrected Eu intensities were used as an indicator of machine performance, and samples with mismatches were re-analyzed.

In the second calibration step, sample concentrations were calculated against a working curve of gravimetric, matrix-matched REE solutions, all diluted from a stock rare-earth standard solution made with an abundance pattern resembling that of the samples. Calibration solutions included a blank and 5000, 1000, 500, 200 and 100-fold dilutions of the stock standard, yielding REE concentration ranges of 0.4-20 ppb for the LREE and 0.04–2.0 ppb for the lower abundance HREE. Each standard contained 10 ppb of Cs and Re internal standards, and were intensity corrected with the samples.

Detection limits for the REE vary with element, but reproducible measurements were routine at the 1x chondrites (1 x CI) level for all REE, and at ~0.1x CI levels for many of the LREE. Precision for individual analyses based on replicates is ± 10%, but the relative precision among the REE was better, comparable to the precision of our calibration standard solutions (i.e., ± 1%). Accuracy was assessed through replicate measurements of USGS reference material BIR-1. Our values for the LREE were somewhat lower than reported values, but HREE abundances were within ± 10% (Table 2). Yield tests and tests of our calibration solutions convince us of the accuracy of our LREE determinations, which are at 3-5 x CI abundance levels in this standard.

RESULTS AND DISCUSSION

The REE data collected in this study are presented in Table 3, and diagrammatic presentations of our data on "Masuda/Coryell" type chondrite-normalized plots (after Masuda and others, 1973), may be found on Figures 2-6. REE data for BC amphibolites reflect the two different chemical subtypes found by the REU

Table 2. Comparison of REE Data for USGS Reference Material BIR-1.

Element	Recommended	USF ICP-MS
La	0.62	0.49
Ce	1.95	1.88
Pr	0.38	0.34
Nd	2.5	2.19
Sm	1.1	1.04
Eu	0.54	0.49
Gd	1.85	1.70
Tb	0.36	0.34
Dy	2.5	2.51
Tm	0.57	0.57
Er	1.7	1.71
Ho	0.26	0.26
Yb	1.65	1.67
Lu	0.26	0.25

program:

1. Samples with TiO_2 contents greater than 1.0% wt. ("high Ti" amphibolites) show subparallel REE patterns, with modest LREE depletions in most cases ($[La/Sm]_N$ _ 1.3; Table 3; Figure 2). Abundances of the heavy REE range from 10-20 x CI levels, comparable to many tholeiitic basalts and gabbros.
2. Samples with TiO_2 contents less than 1.0% ("low Ti" amphibolites and troctolites) show more variable REE patterns, and range from 1 - 10 x CI levels in the heavy REEs (Table 3; Figure 3,4). A characteristic of most of these samples is a distinct positive "Eu anomaly." Europium exists as both ^{2+}Eu and ^{3+}Eu, and ^{2+}Eu readily substitutes for ^{2+}Ca in plagioclase feldspar. All of these samples contain abundant modal plagioclase; and some preserve relict primary plagioclase (i.e., "coronal troctolites"; Tenthorey and others, 1996). The chemical compositions of these rocks are consistent with abundant primary plagioclase. Heavy REE in these rocks show largely flat patterns, while the light REE vary from enriched to markedly depleted.
3. $[La/Sm]_N$ ratios in these rocks vary from 0.15 to 2.0, with one extreme value of 4.6 (sample 11C). $[La/Yb]_N$ ratios vary from 0.1 to 3.2.

Sources of REE Variability at Buck Creek

The effects of the regional high-grade metamorphism on the REE systematics is presumed to be minimal, with the REE patterns of metamorphosed rocks reflecting that of their protoliths (Grauch, 1989). The BC amphibolites show REE patterns broadly consistent with basalts/diabases and associated gabbros, but also show some anomalies. The most evident of these are the variable "Ce anomalies" that appear in many of the REE patterns. In the presence of oxidizing metasomatic fluids, Ce will occur partly as Ce^{4+}, and, as has been noted in oceanic settings (Brookins, 1989) Ce^{4+} is readily removed from solution. While marine alteration of ocean crust is known to produce Ce anomalies, in the case of Buck Creek, which has undergone a complex metamorphic history (Emilio, 1998), it seems probable that metasomatic fluids moving through the complex are responsible for Ce redistribution. Ce variability is more evident in the "Low Ti" amphibolites, at lower overall REE contents.

Greater LREE variability in the low Ti BC samples may be partly induced by high-temperature metasomatic interactions. At low REE contents, interactions with CO_2-bearing metasomatic fluids may produce marked enrichments or depletions in the LREE. "U" shaped REE patterns in some ophiolitic dunites are believed to arise via small inputs of fluid borne LREE added to very depleted ultramafic protoliths (McDonough and Frey, 1990). Our strongly LREE enriched ($[La/Sm]_N > 3$) BC samples all have rather low heavy REE contents, and thus may reflect secondary additions of LREE-enhanced fluids, as some of these samples show REE patterns similar in shape to those of the local country rocks (Figure 4). The meta-troctolite sample AB6D has La/Sm _ 0.7, while 11C, a hydrothermally altered meta-troctolite with strongly elevated LREE, and an extreme negative Ce anomaly, has La/SmN of 4.6.

These variations aside, the REE patterns of the different Buck Creek units do not suggest extensive remobilization of the rare earth elements, or pervasive contamination by crustal

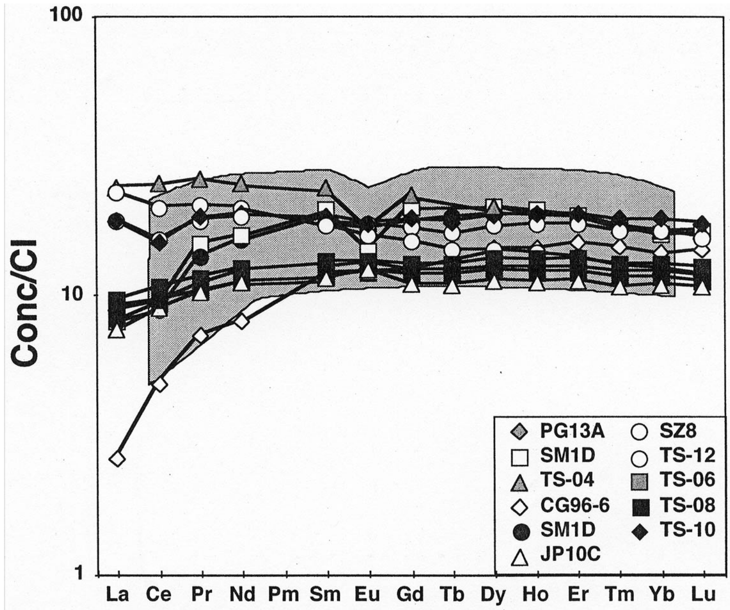

Figure 2: Masuda-Coryell type rare earth diagram (Masuda and others, 1973) of REE data for "high Ti" Buck Creek amphibolites. CI chondrite normalizing values in this and all diagrams are from Taylor and Gorton (1977). Shaded field represents depleted "normal" mid-ocean ridge basalts, based on Bender and others (1984).

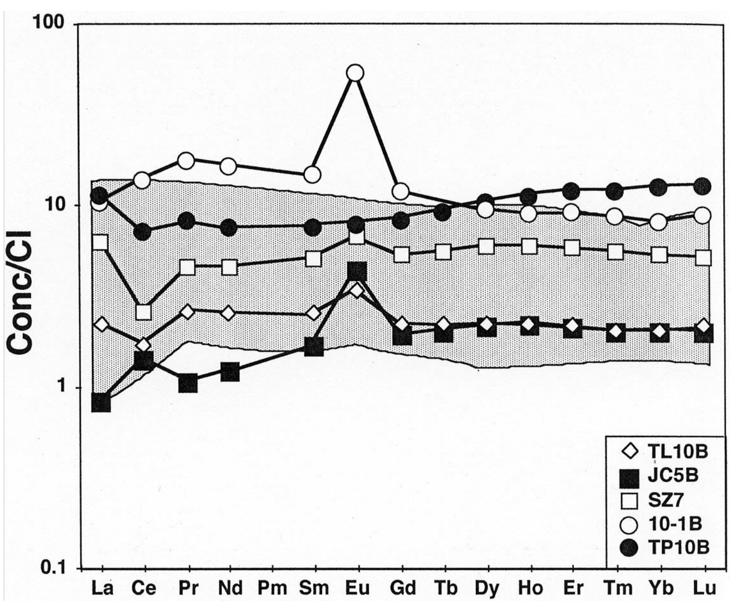

Figure 3: REE data for "low Ti" Buck Creek amphibolites. Shaded field represents cumulate gabbroic rocks from the Balkan-Carpathian ophiolite (Savov and others, in press), a well-preserved, "high Ti" ophiolite complex.

Table 3: Rare Earth Element Data for Buck Creek and other Mafic-Ultramafic Complexes

REEs, ppm	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
	"High Ti" Amphibolites													
BC97 TS04	7.54	20.1	3.16	14.8	4.69	1.28	5.90		6.62	1.39	4.04	0.57	3.54	0.55
CG96.6	0.81	3.89	0.87	4.76	2.28		3.33		4.72	1.06	3.23	0.48	2.94	0.47
BC97SM1d	2.48	7.10	1.68	9.45	3.47	1.27	4.79	0.89	6.31	1.39	3.95	0.57	3.55	0.52
BC98SZ8	5.71	12.7	2.24	11.5	3.57	1.31	4.49	0.79	5.65	1.29	3.75	0.55	3.51	0.52
BC97 TS12	7.14	16.5	2.56	12.3	3.44	1.20	4.05	0.69	4.70	1.01	2.87	0.41	2.60	0.38
BC97 TS06	2.95	8.53	1.39	7.48	2.57	0.96	3.38	0.62	4.36	0.96	2.84	0.42	2.70	0.41
BC97 TS10	5.72	12.4	2.30	11.7	3.74	1.33	4.83	0.87	6.21	1.41	4.12	0.61	3.91	0.58
BC97PG13a	2.73	7.65	1.34	7.30	2.45	0.95	3.19	0.58	4.06	0.90	2.64	0.39	2.53	0.38
BC97 JP10c	2.32	7.23	1.23	6.66	2.23	0.90	2.85	0.51	3.60	0.80	2.34	0.34	2.26	0.34
	"Low Ti" Amphibolites													
10-1B	3.17	10.93	2.12	9.75	2.83	3.85	3.07		3.03	0.63	1.89	0.28	1.67	0.28
BC98SZ7	1.94	2.10	0.55	2.69	0.98	0.49	1.38	0.26	1.90	0.42	1.22	0.18	1.12	0.17
BC98TP10b	3.51	5.80	0.99	4.53	1.46	0.57	2.13	0.43	3.30	0.79	2.48	0.39	2.62	0.41
BC98 TL10b	0.68	1.37	0.32	1.51	0.49	0.25	0.57	0.10	0.71	0.16	0.45	0.066	0.43	0.06 9
BC97 JC5b	0.25	1.14	0.13	0.72	0.33	0.32	0.50	0.10	0.69	0.16	0.45	0.06	0.42	0.06
	Pyroxenite													
BC98 SM11	2.29	4.07	1.38	7.95	3.15	0.87	4.39	0.83	6.16	1.40	3.99	0.57	3.62	0.53
	Troctolites													
BC97 SM1B	2.24	5.47	0.74	3.09	0.71	0.30	0.76	0.12	0.85	0.19	0.52	0.08	0.48	0.07
BC97 AB6D	0.42	1.24	0.14	0.77	0.33	0.32	0.50	0.09	0.66	0.15	0.43	0.06	0.41	0.06
11C	6.53	3.09	1.14	3.31	0.83	0.13	0.68		0.78	0.16	0.47	0.07	0.32	0.07
	Other Complexes													
LCH-gt	1.90	7.60	1.60	8.36	3.23	1.01	4.50	3.20	5.63	1.23	3.52	0.50	3.04	0.48
CK-199	1.07	3.66	0.61	3.54	1.25	0.45	1.55	0.26	1.74	0.38	1.05	0.15	0.94	0.14
CK-299	0.05	0.20	0.03	0.16	0.09	0.06	0.14	0.03	0.22	0.06	0.16	0.03	0.17	0.03
MK OPXite	0.29	1.08	0.14	0.61	0.18	0.05	0.18	0.04	0.28	0.07	0.21	0.04	0.25	0.04
W-A Webst.	0.77	2.25	0.33		0.33		0.25		0.34	0.08	0.25	0.04		0.03

fluids. In particular, the higher concentration amphibolite samples are distinct in their REE patterns from the nearby country rocks, and show abundances and patterns suggestive of mafic igneous protoliths.

Relationships Between BC "High Ti" and "Low Ti" Rocks

The rare-earth element systematics of the "high Ti" and "low Ti" Buck Creek amphibolites are consistent with associated basalt/diabases and cumulate gabbros, respectively, as found in ophiolite associations. The "high Ti" amphibolites possess REE patterns similar to ocean floor basalts both in terms of overall REE abundances and pattern shape. The origins of the "Low Ti" amphibolite patterns are somewhat more complicated. These samples have lower overall REE contents and are clearly more susceptible to metasomatic disturbance. However, these rocks show strong positive Eu anomalies, which complement the modest negative Eu anomalies observed in many of the "high Ti" samples; and relatively flat patterns in the heavy REE. We interpret these samples as representing a range of mafic cumulate protoliths. The markedly lower TiO_2 contents of these samples supports this interpretation, as do their more variable Mg/Al and Ca/Al ratios (Collins and others, 1998). The chemical variations in these rocks probably reflect variations in the proportion of four igneous components: plagioclase, clinopyroxene, olivine crystals,

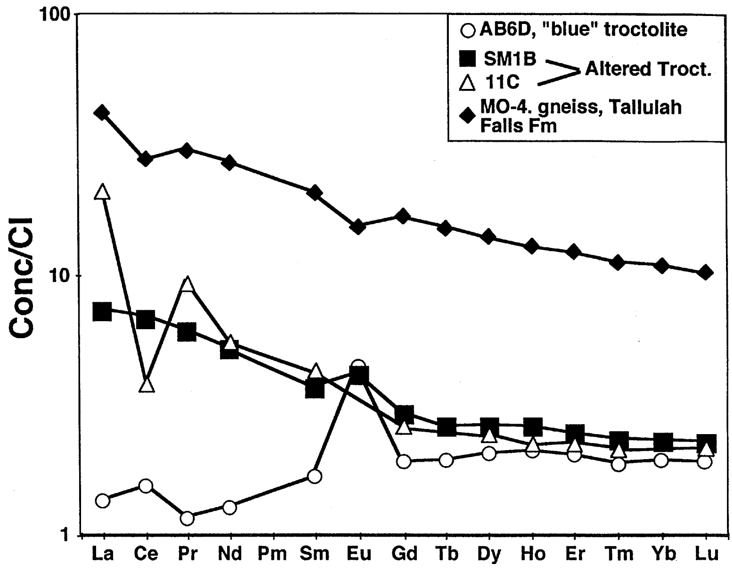

Figure 4: Comparison of REE data for metasomatically altered Buck Creek edenite-margarite schists 11C and SM-1B and for the unaltered "blue" metatroctolite AB6D. Shown for comparison is the REE pattern of MO-4, a pelitic gneiss from the surrounding Tallulah Falls formation.

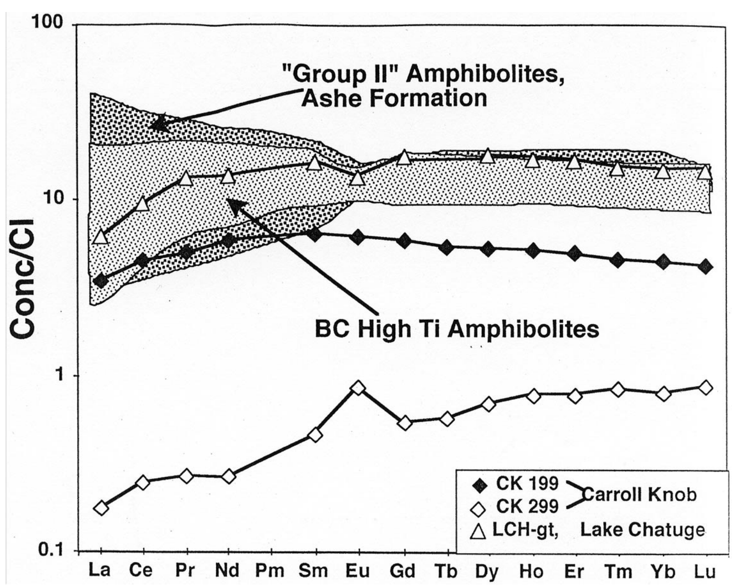

Figure 5: Overlay of the range for Buck Creek "High Ti" amphibolites on the field for depleted "Group II" amphibolites from Misra and Conte (1991), along with REE patterns for a garnet pyroxenite from the Lake Chatuge complex (Meen 1988; Dallmeyer 1974), and two amphibolitic samples from the Carroll Knob mafic complex (see Hatcher and others, 1984).

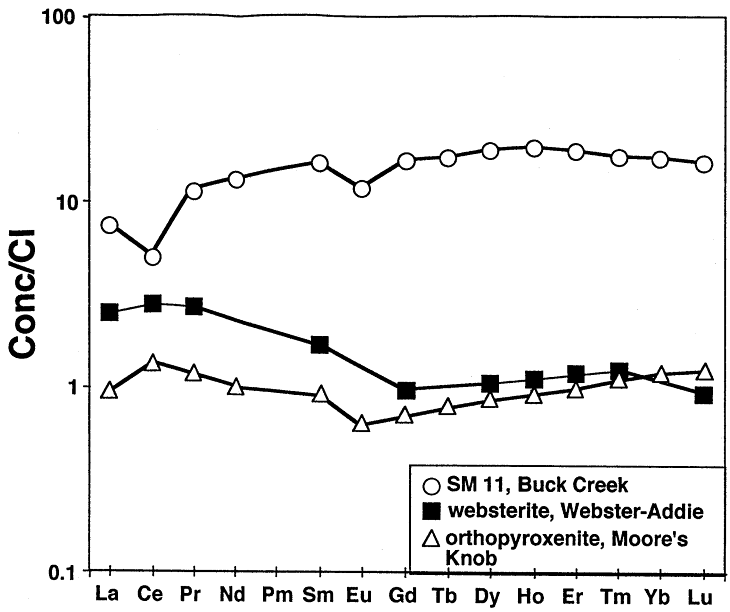

Figure 6: Comparison of REE data for pyroxenites from the Webster-Addie and Moore's Knob ultramafic bodies to sample SM-11, a massive clinopyroxenite from the Buck Creek complex.

and small (but in some cases significant) amounts of intercumulus melt. Prominent, positive Eu anomalies indicate the presence of primary, accumulated plagioclase. The relatively flat HREE patterns shown by most these rocks are consistent with the presence of significant amounts of clinopyroxene, similar in composition to sample SM–11, an augitic clinopyroxenite found in the complex (Figure 6). Sample 10-1B has an overall REE pattern and rare earth abundance levels similar to the "high Ti" amphibolites, but also includes a prominent positive Eu anomaly (Figure 3). This combination of features, along with an intermediate TiO_2 content (0.62% wt) points to a melt containing significant accumulated plagioclase, as might occur if plagioclase flotation were occurring in a mafic magma chamber.

Overall, the BC amphibolites and troctolites show REE systematics consistent with a suite of associated gabbroic and cumulate rocks, as might be found in the "oceanic", high TiO_2 class of ophiolites (Serri, 1981; Savov and others, in press). The LREE depleted character of our "high Ti" BC samples are similar to those of rocks from mid-oceanic or distal back-arc settings. This interpretation is consistent with inferences made from the bulk chemical variations of all the Buck Creek lithologies by Collins and others (1998), and with past studies of BC amphibolites (i.e., MacElhaney and McSween, 1983).

Comparisons to Other Blue Ridge Mafic and Ultramafic Rocks

The "high Ti" Buck Creek amphibolites show similar REE abundances and REE patterns to "Group II" amphibolites from the Ashe Metamorphic Suite (Misra and Conte 1991). No Buck Creek mafic rocks we have analyzed exceed 2.0% wt TiO_2, and so they are chemically distinct from Group III Ashe Metamorphic Suite amphibolites, which have TiO_2 contents >3.0%, and REE patterns that reflect an enriched mantle source (Misra and Conte, 1991). Our "low Ti" amphibolites show the same range in overall REE contents as the Group I amphibolites from the Ashe Metamorphic Suite, although the poorer detection limits for INAA data make a comparison of REE patterns problematic.

Among nearby mafic-ultramafic bodies, the Buck Creek complex bears considerable lithologic similarity to the Lake Chatuge complex, as both include meta-troctolites and amphibolites, and record similar metamorphic histories (i.e., Hartley, 1973; Dallmeyer, 1974; Meen, 1988; Tenthorey and others, 1996; Emilio, 1998). A sample of garnet pyroxenite from the Lake Chatuge complex with a major element composition similar to BC "high Ti" amphibolites displays a similar REE pattern (Figure 5a). This observation concurs with Nd isotopic results for BC and Lake Chatuge that indicate comparably LREE depleted mantle source regions (Shaw and Wasserburg, 1984)

The Carroll Knob Complex, which lies ENE of Buck Creek (Figure 1 inset), includes abundant amphibolites enclosing small lenses of dunite and rare meta-troctolites (Hatcher and others, 1984). Carroll Knob amphibolite and meta-troctolite samples both show LREE depleted patterns, but at lower abundance levels than at Buck Creek. While the LREE-depleted nature of the Carroll Knob rocks point to a chemically similar mantle source, the petrogenesis of this unit as compared to Buck Creek is unclear. Hatcher and others (1984) suggest that the Carroll Knob protoliths may have formed in an oceanic or arc setting.

Pyroxenites from the Webster-Addie and the Moore's Knob dunite, which lie well east of Buck Creek (Figure 1 inset; Condie and Madison, 1969; Yurkovich and Eckert, 1992) show overall low REE abundances and slightly "U" shaped rare earth patterns. These types of patterns are more typical of residual, mantle-derived ultramafic rocks (McDonough and Frey, 1989), and thus reflect a very different history than the rocks at Buck Creek. Whether these different patterns point to a different mantle source is unclear, as metasomatic enhancement of the LREE is possible. However, Nd isotopic data that exists for Webster-Addie are consistent with a modestly LREE enriched source region (i.e., $\varepsilon Nd=-1$; Shaw and Wasserburg, 1984).

CONCLUSIONS

The REE systematics of rocks from the Buck Creek mafic/ultramafic complex largely preserve igneous protolith signatures. The REE patterns of "high-Ti" BC amphibolites are similar to mid-ocean basalts, while those of "low-Ti" amphibolites are consistent with mafic cumulate rocks. The REE systematics of BC amphibolites indicate the complex was once part of an oceanic crustal section. BC amphbolites show similar REE signatures to Group I and Group II amphibolites in the Ashe Metamorphic Suite, and to mafic rocks from the Lake Chatuge complex. Other mafic and ultramafic rocks that have been examined in the Blue Ridge, as compared to BC, may reflect different evolutionary histories, or different mantle sources.

ACKNOWLEDGEMENTS

This work was supported by EAR-9709803 to Peterson and EAR 9709932 to Ryan, and a Sigma Xi student research grant to Suzette Berger and Deborah Cochrane. The work was conducted as part of the post-summer REU research projects of Simons, Cochrane, and Berger. We are grateful to Keith Willse and Tom Slusser, who collected some of the samples examined in this study as part of individual student research projects; and also to Drs. Robert Byrne and Johan Schijf of the USF Marine Sciences Department for continued access to his ICP-MS facilities. Ryan also thanks the Department of Terrestrial Magnetism, which hosted him for a sabbatical semester during which this manuscript was written. Participants in the 1997 and 1998 summer Buck Creek REU research groups provided the basis for this work.

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