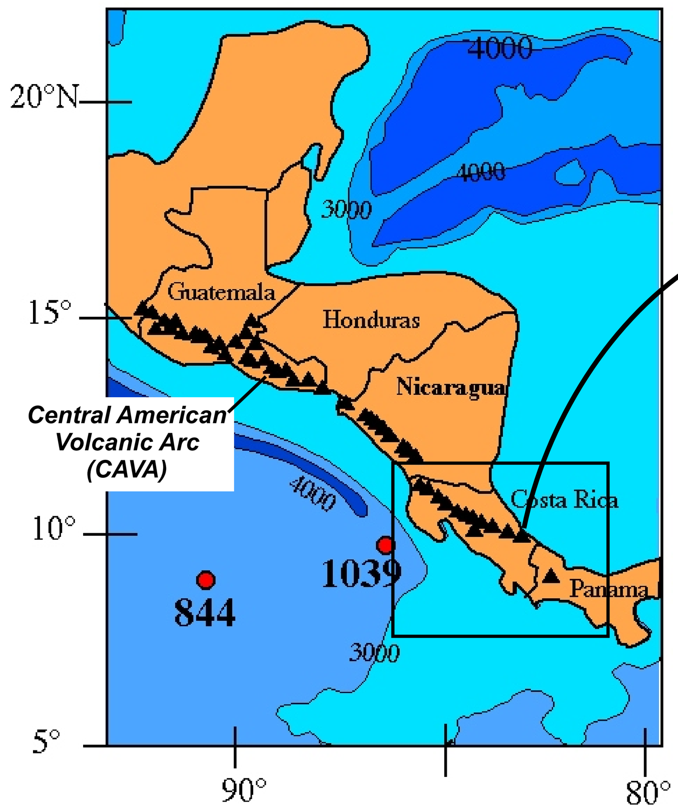
Reconnaissance Field and Geochemical Analyses of Turrialba Volcano, Costa Rica

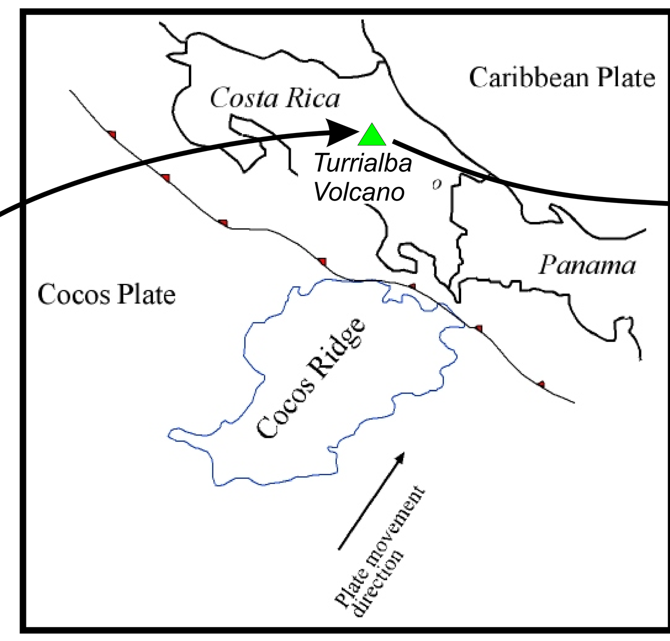
David Kratzmann[1], Ronald Cole[2], Jeffrey Thomas[2], and Melissa Kammerer[2]

[1] School of Earth Sciences, University of Tasmania, Hobart, Tasmania 7001; [2] Department of Geology, Allegheny College, Meadville, PA 16335, U.S.A. (Ron.cole@allegheny.edu)

Published in: Dynamic Earth: past, present and future - Abstracts, Geological Society of Australia, v. 73, p. 276, 2004

Study Area and Tectonic Setting



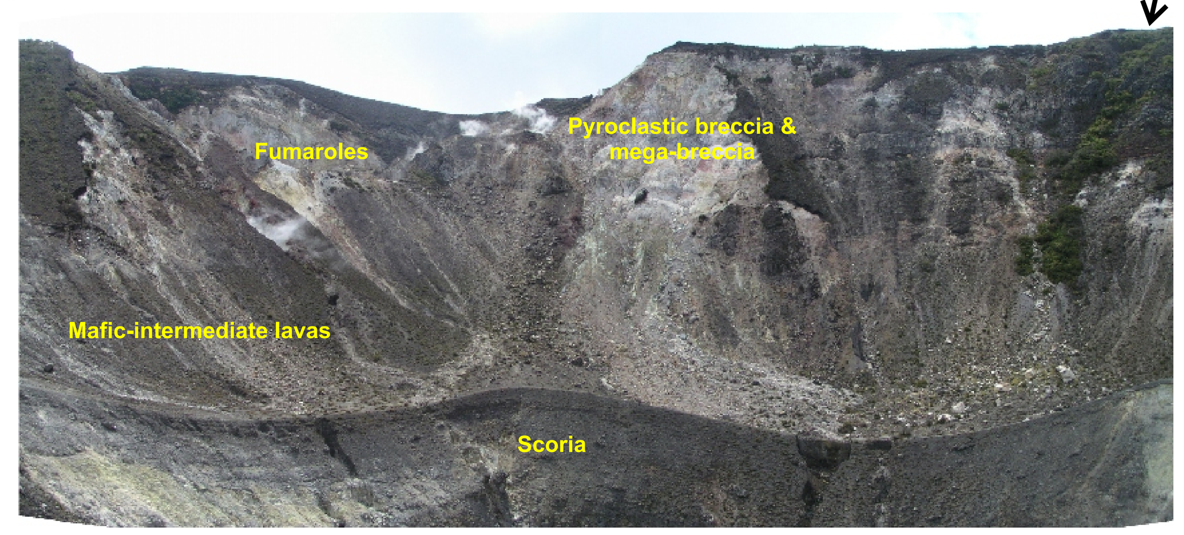


Turrialba crater area - westernmost vent is active (left side)

Turrialba volcano is an active multi-vent stratovolcano located at the southern end of the Central American volcanic arc in southeastern Costa Rica. This portion of the arc is in a unique tectonic setting where the aseismic Cocos Ridge is currently being subducted. The dip of the subducting Cocos Plate shallows from ~60° beneath Nicaragua to ~35° beneath central Costa Rica, corresponding with the Cocos Ridge (Carr et al. 1990; deBoer et al. 1995).

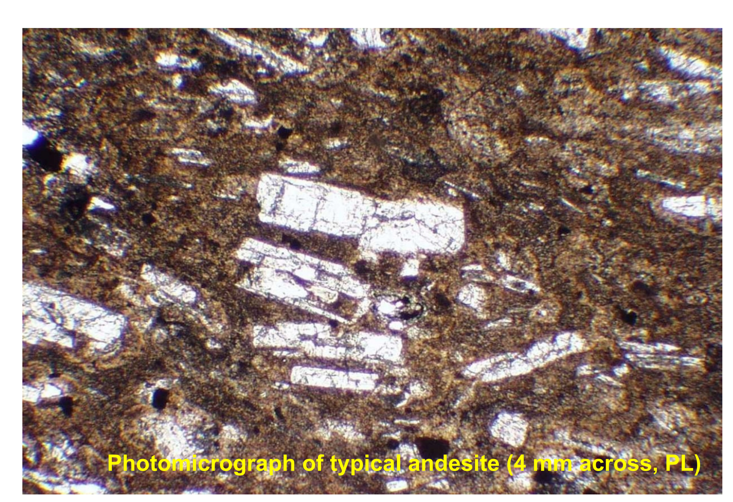
Overview of Volcanic Deposits

Lithofacies	Deposit Characteristics	Possible Emplacement Mechanisms
Massive crystal-rich coarse-tuff	Moderate to poorly sorted, fine-grained, massive deposits Highly altered devitrified matrix & plagioclase grains	Pyroclastic ash-cloud surges & fall out
Laminated lithic>crystal-rich coarse-tuff	Moderately well to poorly sorted, even bedded, fine-grained, laminated Abundant altered plagioclase & volcanic lithic grains in a devitrified cryptocrystalline matrix	Pyroclastic flows (basal layer), surges & fall out
Matrix-supported tuff-breccia	Massive, poorly sorted, matrix supported, devitrified ash Abundant angular/subangular volcanic lithic clasts (to 20 mm) and feldspar microlites present	Pyroclastic flows, debris flows



The central crater facies of Turrialba volcano include a lower interval of scoria deposits overlain by intervals of mafic to intermediate lavas and felsic pyroclastic deposits. This stratigraphy indicates that eruptions at Turrialba began with a mafic scoria cone building phase which was followed by the outpouring of intermediate and less abundant mafic lavas.

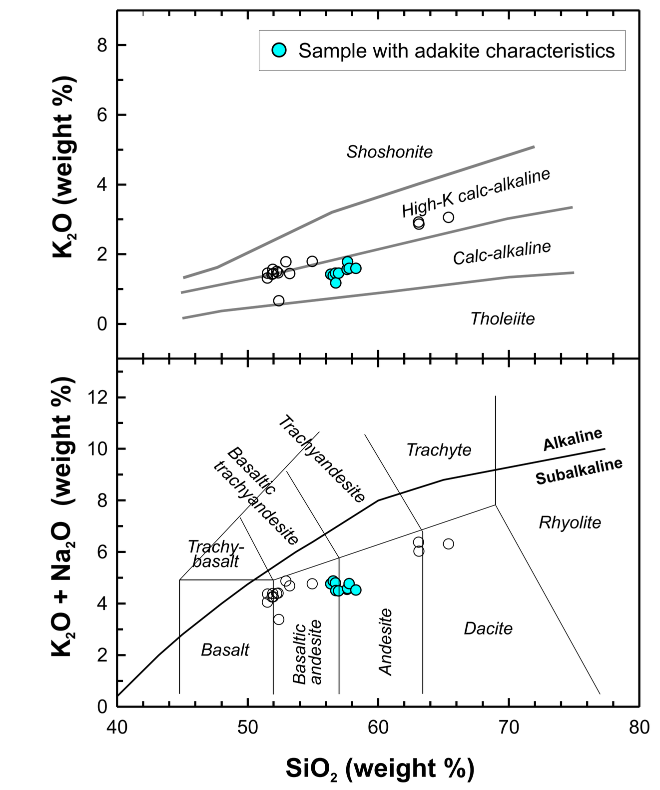
The pyroclastic deposits include lithic-pumice rich pyroclastic flow and surge facies and an interval of mega-breccia that probably represents sector collapse of a past vent wall.



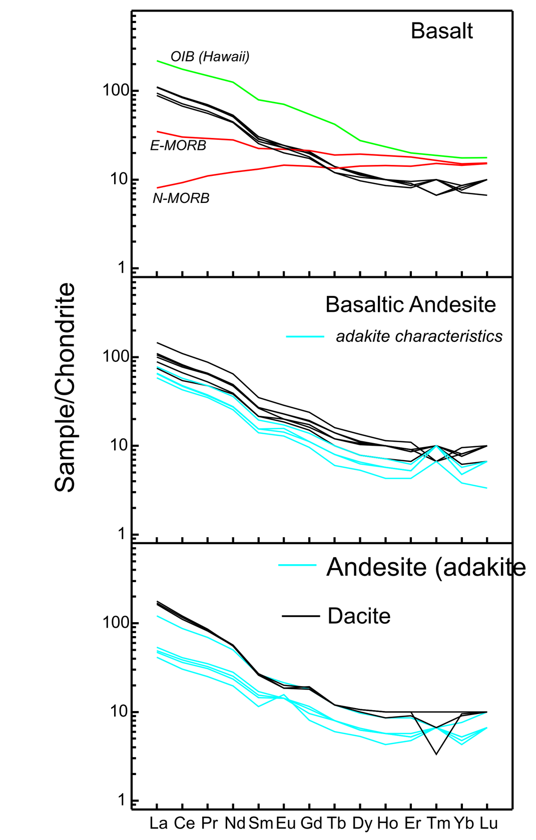
Andesite and basaltic andesite lavas are most abundant at Turrialba with a lower abundance of basalt. The basalts include <10% olivine, 2-15% pyroxene, and 40-90% plagioclase. Basaltic andesites and andesites include trace amounts of olivine, <10% pyroxene, and 50-90% plagioclase.

This study initiated as a research-based independent course at Allegheny College designed to provide an advanced learning experience for students with strong interest in volcanology. The overall goals of the course were to allow the students to: gain real experience in studying a modern volcano, learn field and geochemical techniques for investigating volcanic processes, and document the eruption processes and magma sources at Turrialba volcano. This presentation reports the intial results of the study. The student participants are David Kratzmann, Jeffrey Thomas, and Melissa Kammerer, advised by Professor Ron Cole. *The field research was funded by Allegheny College and geochemical analyses were funded by the National Science Foundation.*

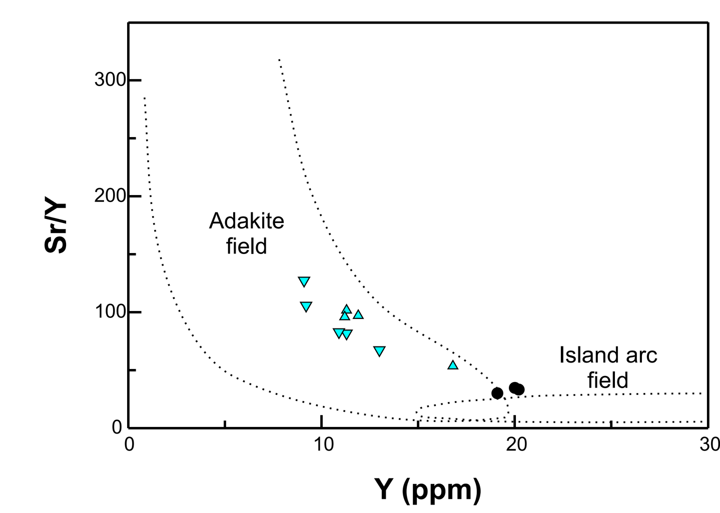
Geochemistry and Regional Implications



Geochemically, Turrialba volcanic rocks are a calc-alkaline suite with a predominance of intermediate compositions.

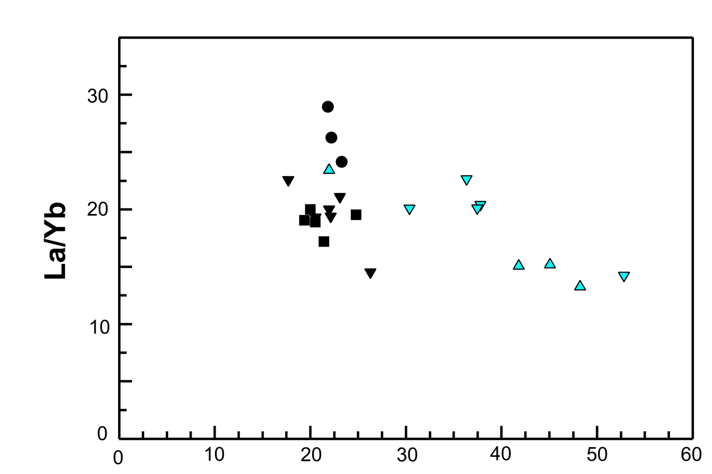


The basalts have chondrite-normalized rare earth element patterns and La/Yb ratios similar to ocean island basalts. The non-adakite andesitic rocks and dacites show increased La/Yb with increasing silica.



	SiO_2	Al_2O_3	Yb	Y	Sr	Sr/Y	La/Yb
Adakite Characteristics (Defant and Drummond, 1990)	≥56%	≥15%	<1.9	≤18	>400	>40	>20
TUR03-68	56.36	17.73	1	11.3	925	81.86	20.40
TUR03-71	56.54	17.88	1.2	13	877	67.46	20.08
TUR03-67	56.72	17.99	1	10.9	905	83.03	20.10
TUR03-78	56.75	18.23	0.8	9.2	974	105.87	22.63
TUR03-34	56.95	18.35	0.9	9.1	1160	127.47	14.22
TUR03-32	57.61	18.43	1	11.3	1150	101.77	15.20
TUR03-44	57.64	17.89	1.6	16.8	900	53.57	23.44
TUR03-53	57.77	18.68	1.1	11.9	1155	97.06	15.09
TUR03-26	58.28	17.32	1.1	11.2	1075	95.98	13.27
TUR03-31	63.08	16.78	2	20	693	34.65	26.25
TUR03-21	63.11	16.64	2.1	20.2	672	33.27	24.14
TUR03-27	65.38	15.21	1.9	19.1	572	29.95	28.95

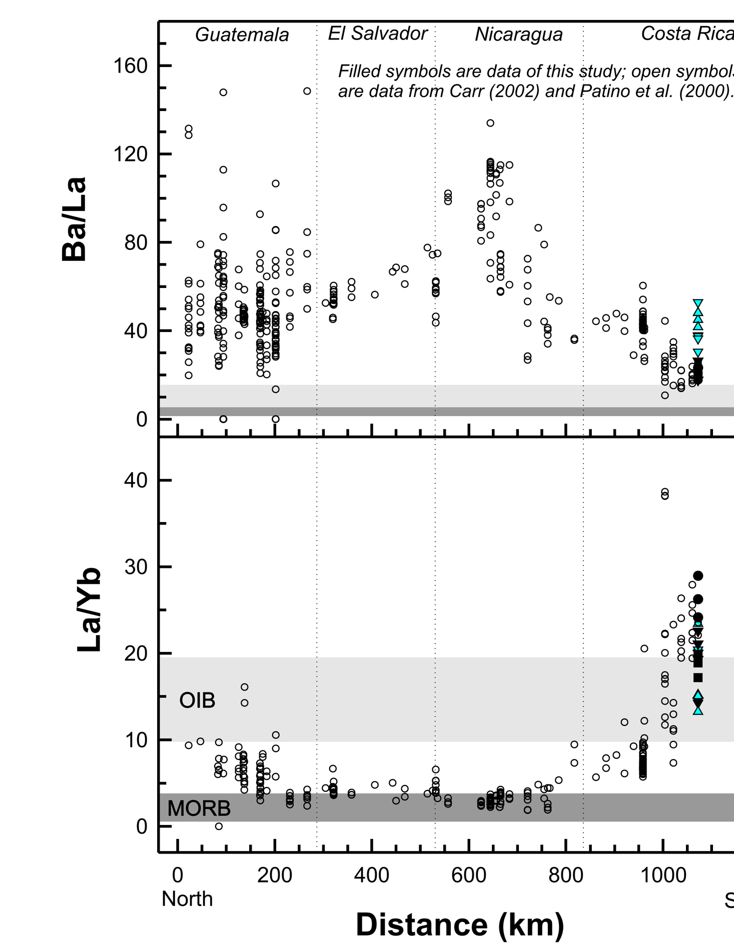
Adakites are present among the intermediate samples at all stratigraphic levels of the volcano (i.e., we did not identify a specific interval of adakite magmatism). The adakites are characterized by high Sr and low Y concentrations and also meet other criteria outlined for adakites. The presence of adakites is significant and indicates partial melting of metamorphosed oceanic crust (Defant and Drummond, 1990).



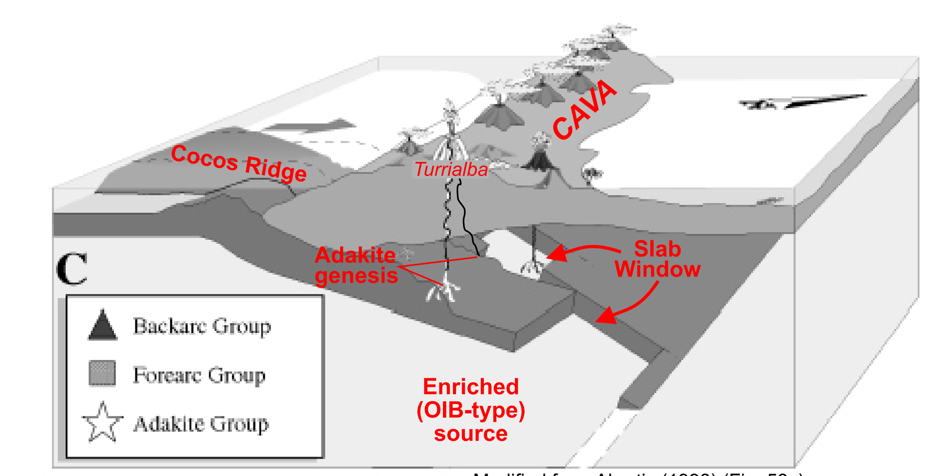
The basalts and non-adakite andesitic rocks and dacites maintain relatively low Ba/La ratios. This indicates only a small influence of the subducted slab on magma genesis.

The adakite samples have high Ba/La ratios, indicating a strong influence from the subducted slab; this is consistent with the adakites being formed by partial melting of metamorphosed oceanic crust.

There is a progressive southward change along the Central American volcanic arc (CAVA) from a depleted mantle source and stronger slab influence beneath El Salvador and Nicaragua (low La/Yb and high Ba/La) (Carr et al. 1990; Reagan et al. 1994; Herrstrom et al. 1995) to an enriched mantle source and a weak slab influence beneath central Costa Rica (higher La/Yb, lower Ba/La) (Reagan and Gill, 1989; Leeman et al. 1994; Herrstrom et al. 1995). In addition, Pb isotope data show that the enriched mantle component beneath central Costa Rica is similar to the Galapagos plume signature (Abratis and Worner, 2001).



The non-adakite Turrialba samples of this study are consistent with the regional CAVA trends (i.e., they have high La/Yb and low Ba/La ratios). However, our adakite samples show lower La/Yb and much higher Ba/La ratios than would be predicted for this segment of the arc.



Modified from Abratis (1998) (Fig. 53c)

The Turrialba adakites were not co-magmatic with the Turrialba basaltic magmas. Turrialba mafic magmas were derived from an enriched mantle source and evolved by fractional crystallization-assimilation to form the low Ba/La ratio felsic end-members. The adakites are consistent with partial melting of oceanic crust, possibly along the edges of a slab window that formed beneath the arc when the Cocos Ridge was subducted (e.g., Abratis, 1998; Abratis and Worner, 2001). In this model the slab window would have provided a pathway for Galapagos-type enriched mantle into the sub-arc realm and the flux of this mantle would have induced melting of the edge of the Cocos Ridge. Our results for Turrialba volcano are significant because they provide new details on magma source variations within a single Quaternary volcano in which adakites were erupted during the same time interval as non-adakite rocks (as opposed to adakites forming during a late-phase of magmatic activity).

References Cited

Abratis, M., 1998, Geochemical variations in magmatic rocks from southern Costa Rica as a consequence of Cocos Ridge subduction and uplift of the Cordillera de Talamanca, Ph.D. Thesis, University of Gottingen, Germany, 148 p.

Abratis, M., and Worner, G., 2001, Ridge collision, slab-window formation, and the flux of Pacific asthenosphere into the Carribean realm: Geology, v. 29, 127-130.

Carr, M.J., 2002, CAGeochem.zip (geochemical data base for Central American volcanoes), http://www-rci.rutgers.edu/~carr/index.html (accessed January 12, 2004).

Carr, M.J., Feigenson, M.D., and Bennett, E.A., 1990, Incompatible element and isotopic evidence for tectonic control of source mixing and melt extraction along the Central American arc: Contribs. Mineral. Petrol., 105, 369-380.

de Boer, J.Z., M. S. Drummond, M. J. Bordelon, M. J. Defant, H. Bellon and R. C. Maury, 1995, Cenozoic Magmatic Phases of the Costa Rican Island Arc (Cordillera de Talamanca): in, Mann, P., ed., Geologic and Tectonic Development of the Caribbean Plate Boundary in Southern Central America, Geological Society of America Special Paper 295, p. 35-41.

Defant, M., and Drummond, M., 1990, Derivation of some modern arc magmas by melting of young subducted lithosphere: Nature, 347, p. 662-665.

Herrstrom, E.A., Reagan, M. K., and Morris, J. D., 1995. Variations in lava composition associated with flow of asthenosphere beneath southern Central America, Geology. 23(7): 617-620.

Leeman, W.P., Carr, M.J. and Morris, J.D., 1994. Boron geo-chemistry of the Central American volcanic arc: Constraints on the genesis of subduction-related magmas. Geochimica et Cosmochimica Acta, 58,: 149-168.

Patino, L.C., Carr, M.J. and Feigenson, M.D., 2000. Local and regional variations in Central American arc lavas controlled by variations in subducted sediment input. Contributions to Mineralogy and Petrology, 138(3): 265-283.

Reagan, M.K. and Gill, J.B., 1989. Coexisting calcalkaline and high-niobium basalts from Turrialba volcano, Costa Rica: implications for residual titanates in arc magma sources. Journal of Geophysical Research, 94: 4619-4633.

Reagan, M.K., Morris, J.D., Herrstrom, E.A. and MurrellL, M.T., 1994. Uranium series an beryllim isotope evidence for an extended history of subduction modification of the mantle below Nicaragua. Geochimica et Cosmochimica Acta, 58(9): 4199-4212.