Lithology, mineralogy, and chemical weathering of volcanic rocks from Panama

Matthew R. H. Dugan, School of Earth Sciences, The Ohio State University

Anne E. Carey, School of Earth Sciences, The Ohio State University

Steven T. Goldsmith, School of Earth Sciences, The Ohio State University

1. Introduction

Chemical weathering of silicate rocks is the only known mechanism on a long-term geologic time scale (100s of millions of years and longer) for sequestration of carbon sourced from carbon dioxide. Lithologic and mineralogical analysis of rocks provides understanding of which minerals may be weathering preferentially, and thus what ratio of ions are released into the environment and subsequently, the amount of carbon sequestered. Collision of the Caribbean plate and the Cocos plate and the associated subduction causes melting of crustal layers and andesitic/dacitic volcanism, which contains calcium, the primary element that sequesters carbon.

Rock samples were collected in summer 2006 and spring 2007 from several andesitic-dacitic volcanic centers located in the western part of the country. Previous research has shown that basalts are generally absent from the volcanic centers with basaltic andesites and andesites predominating. Collection was performed as part of a larger project which included water and sediment collection and stream gauging. Previous studies on volcanic centers in the region revealed ages from 17.5 Ma to 300 yr B.P. with the majority of dates focused between 12–7Ma and around 1.3±1 Ma. Volcanism appears to have been significantly reduced between 6 and 2 Ma, with increased activity from 2 Ma to the present.

Mineralogical assemblages of these rock samples and their bulk chemistry show relationships between the volcanic centers along with individual magma chamber evolution. Mineralogical assemblages and chemical content will reveal which minerals are likely to weather fastest and will be used in association with geochemical analyses of stream water sample and associated weathering studies to determine the extent and rates of chemical weathering taking place. Results are expected to show that the silicate minerals of these andesitic volcanic rocks of Panama are rapidly weathering and sequestering significant amounts of atmospheric carbon dioxide, through the reaction of aqueous calcium ions and carbon dioxide.

2. Background

- The basaltic-andesitic to andesitic volcanics of western Panama are the result of the subduction of the Nazca Plate beneath the Caribbean Plate.
- Previous studies on volcanic centers in the region revealed ages from 17.5 Ma to 300 yr B.P. with the majority of dates focused between 12–7Ma and around 1.3±1 Ma (de Boer, 1991).
- Basalts are generally absent from the volcanic centers near the Costa Rica border (El Baru and Tisinigal) with basaltic andesites and andesites predominating.
- El Baru is believed to have undergone three main periods of eruptive history, with a large scale Mt. Everest lateral type eruption occurring approximately 21 ka.
- Geochemistry, mineralogy, and evolution of western Panama rocks is largely understudied.

Table #1: Sample Location Summary

Sample Location #	Watershed Name	Volcanics Drained
1	PAF-1 (Lava Flow)	Mt. Baru
2	PAF-2 (Lava Flow)	Mt. Baru
3	PAF-3 (Lava Flow)	Mt. Baru
4	Rio Chirqui Viejo (near Baja Chiriqui)	Mt. Baru
5	Rio Chiriqui Viejo (lower tributary)	Mt. Baru
6	Rio Chiriqui Viejo	Mt. Baru
7	Rio Conception Chico	Mt. Baru
8	Rio Platanal	Mt. Baru
9	Rio San Pablo	Mt. Baru
10	Rio Cochea	Cerro Chorcha
11	Rio Chiriqui	Cerro Chorcha
12	Rio San Felix	Cerro Fonseca
13	Vigui	Cerro Colorado, Cerro Santiago, Cerro Buenos Aires
14	Rio Tabasara	Cerro Santiago, Cerro Buenos Aires

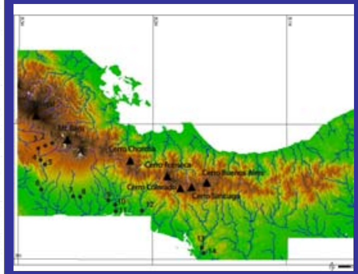
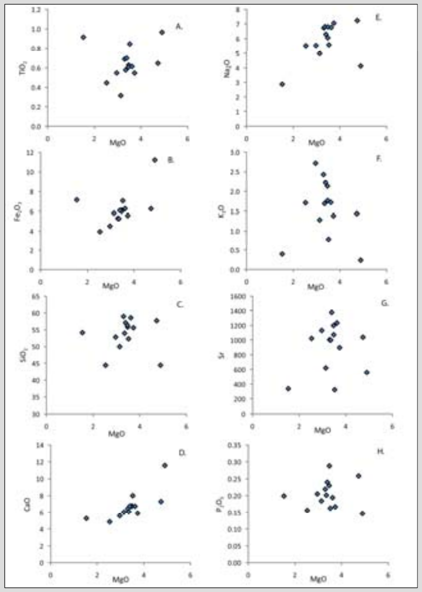


Figure 1: Map of Western Panama. Major strato-volcanoes are denoted by triangles and sampling sites by circles.

4. Results

- Rock composition for samples collected from the Baru region ranged from basaltic to andesitic (~44 to 59 wt% Si).
- A series of variation diagrams vs. MgO yielded a strong positive correlation with Na_2O, Fe_2O_3, and CaO, and a weak negative correlation with K_2O.
- Variation diagrams of TiO_2, SiO_2, Sr, and P_2O_5 vs. MgO do not show significant correlation, which is not consistent with standard chamber evolution, without multiple magma injections.
- The tight grouping of samples throughout all of the elemental charts indicate a likely oversampling of one rock type.

Figure 2:
Bulk Chemistry Analysis



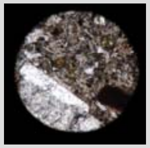
All measurements are in weight percents except for SR; it is in PPM.

Table 2:
Microscope Analysis results

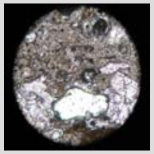
Location #	Sample	Plagioclase	Pyroxenes	Opaques
1	PAF-1	40%	10%(1% Clino and 9% Ortho)	10%
2	PAF-2	80%	5%(4% Clino and 1% Ortho)	5%
3	PAF-3	70%	15%(5% Clino and 10% Ortho)	5%
4	Rio Chiriqui Viejo NBC (Black)	55%	20%	25%
4	Rio Chiriqui Viejo NBC (Red)	45%	15%	20%
4	Rio Chiriqui Viejo NBC (Blue)	40%	20%(1% Clino and 19 % Ortho)	10%
5	Rio Chiriqui Viejo (Blue)	70%	10%	20%
5	Rio Chiriqui Viejo (Black #1)	30%	15%	15%
5	Rio Chiriqui Viejo (Black #2)	40%	15%(3% Clino and 12% Ortho)	15%
5	Rio Chiriqui Viejo (Grey)	20%	15%	5%
5	Rio Chiriqui Viejo (White)	Sample Composed almost entirely of mineral glass		

Abundances of readily weathered mineralogical assemblages rich in Ca, such as plagioclase and pyroxenes, emphasizes the importance and usefulness of determining volcanic mineral assemblages for studies of chemical weathering and CO_2 consumption.

These samples are typical of all of the samples, containing large amounts of plagioclase, and significant amounts of pyroxenes.



Andesite sample from Rio Chiriqui Viejo. Opaques are high and generally cover the pyroxenes



Additional sample from Rio Chiriqui Viejo. Abundance of glass bubbles may signify a phreatomagmatic origin.

3. Methodology

- Rock samples associated with several strato-volcanoes in Western Panama were collected from streambeds during February 2007. In addition, three samples were collected from andesitic flows in the vicinity of Mt. Baru.
- Petrologic thin sections were prepared by cutting samples with a diamond tipped saw to remove the weathering rind. Microscopic analysis of the thin sections was conducted to determine the specific minerals and their relative proportions.
- The samples were also crushed into dust and dissolved into lithium tetraborate, and then XRF analysis was performed on them to determine the bulk chemistry

5. Conclusions

- The strong positive correlation between some elements and MgO suggests that there is one central magma chamber, which is consistent with all the samples coming from the foot of Mt. Baru. However, significant variation of the other elements with MgO suggest that there were possible multiple injection events.
- The bulk chemical data is representative of the Mt. Baru volcanics, indicating that this sampling method is viable for collecting background chemical data for weathering studies.
- Abundances of readily weathered mineralogical assemblages rich in Ca, such as plagioclase and pyroxenes, emphasizes the importance and usefulness of determining volcanic mineral assemblages for studies of chemical weathering and CO_2 consumption.

References

deBoer, J. Z., Defant, M. J., Stewart, R. H., and Bellon, H., 1991, Evidence for active subduction below western Panama: Geology, v. 19, p. 649–652.

deBoer, J.Z., Defant, M.J., Stewart, R.H., Restrepo, J.F., Clark, L.F., and Ramirez, A.H., 1988, Quaternary calc-alkaline volcanism in western Panama: Regional variation and implication for the plate tectonic framework: Journal of South American Earth Sciences, v. 1, p. 275–293.

Acknowledgements

I'd like to thank Dr. Anne Carey for her continued enthusiasm and insight throughout the whole process.

I'd also like to thank Steve Goldsmith for his help with data analysis and Dr. Doug Pride and Brent Johnson for the help with thin section photography.

Finally, I'd like to thank Dan Kelley for his discussion on fractional crystallization.