Igneous Rock Compositions from Big Bend Ranch State Park as a Teaching Tool in Petrology

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The Solitario

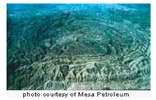


photo courtesy of Mesa Petroleum

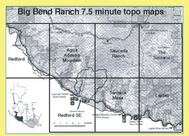
Abstract

A robust data set of ages, chemical and isotopic compositions, geologic maps, and petrography is available for Big Bend Ranch State Park (BBRSP). Geologically, BBRSP is a rugged volcanic terrane, although a spectacular section of Paleozoic sedimentary rocks is exposed around the Solitario. The park is located in Texas just to the NW of the better known Big Bend National Park. It is in the Chihuahuan Desert but is accessible to the public.

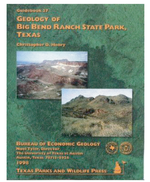
Using a published data set provides a way for students to discover petrogenetic relationships on their own by using a plotting program such as Excel. Volcanic rocks in the BBRSP region are sourced mainly from the Bofecillos vent, but also from distant vents to the north and from vents to the south in Mexico. Therefore, the volcanic pile exposed contains genetically related and nonh-related rocks. One exercise for the students is to have them plot the data in a series of variation diagrams to determine genetic relationships and to distinguish (possibly) between source areas.
Several concepts are reinforced wit this type of exploration of a data set. For example: how trends between mafic and felsic rocks show up in a genetically related suite of rocks; how non-genetically related rocks may or may not show up on the same compositional trends; how trace-element ratio plots may discriminate between source regions when major-element chemistry does not. The idea is to give the students lectures or readings whereby the students are first introduced to the fundamentals of igneous differentiation and the use of X-Y plots to determine igneous processes that can produce compositional trends. The students are then given the data set to plot up and to use to produce hypotheses regarding the origins of the rocks, the relationships between the rocks, and the processes that might have produced one from another. A written report may be required.

A combination of a field trip and a related seminar-style class with limited laboratory and/or computer exercises provides for an extension of the proposed learning experience for undergraduate and graduate students. If the students complete required readings and class presentations before the field trip they are well-prepared. After the field trip, the exercises centering on chemical composition of the rocks are much more meaningful to them.

Park Location



The Incredibly Rugged Rancherias Trail



Oso Peak, highest point

One of the many tuffs

What is the exercise?

I designed an exercise that I found to be quite successful while teaching an undergraduate seminar-style petrology course. Students had had a limited petrology course and they knew the basics. However, they had little opportunity to apply the fundamentals to real data (or any data for that matter). The exercise combines inquiry-based learning with lectures and self-directed investigation of published literature.
I gave the students a data set in Microsoft Excel and let them plot up the data. Another very good program to use is IgPet. The use of the software and the data provides for numerous learning opportunities:

- **the students create a set of variation diagrams (X-Y plots) and on these plots they are able to recognize and delineate various trends**
  - **It seems to mean more and to be more interesting than a plot handed to them.**
- **learning to plot in Excel is not difficult, but many levels of skill can be obtained or demanded**
- **learning to plot in IgPet is really kind of fun, due to the many kinds of plots one can generate (normalized REE and incompatibility plots, ternary plots)**
- **with information from previous lectures regarding how one distinguishes various magmatic processes, the students can determine the magmatic processes reflected in the data trends (hopefully)**
- **initially, however, the students must address issues such as whether or not the data comes from single or multiple sources –this IS an issue in the Bofecillos Mountains at Big Bend Ranch State Park**
- **published work can be provided (or students can do a library search) to find out more about the area and proposed hypotheses**
  - **by reading the provided literature, they can make great strides in connecting the geochemical trends to changes in the tectonic stress regime as proposed by workers such as Price and Henry, 1986, Henry and McDowell, 1986, Henry and Price, 1986, Barker, 1987, Price et al., 1987, Henry et al., 1991, Henry et al., 1998, James and Henry, 1991, Henry and James, 1991.**

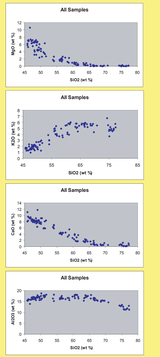
The Rocks

Stratigraphy of Big Bend Ranch State Park (Henry et al., 1998)		
Unit		Source/Ages (Ma)
Closed Canyon Formation		Numerous vents throughout the Big Bend area/ 25 to 18; 16.34 ± 0.09
Rawls Formation		Bofecillos Mountains BBRSP
	Members: Alazan Lavas; Rancho Viejo Tuff; Segundo Lavas; Sauceda Lavas; Leyva Canyon; Las Burras Lavas	27.04 ± 0.09 to < 27.8
Sierra Rica Caldera Complex	Santana Tuff, San Carlos Tuff	27.79 ± 0.10 to 30.50 ± 0.11
Fresno Formation	Members: Campo Javelina Basalt; Peralkaline rhyolite Rancherias Lavas; Rhyolite lava dome	Bofecillos Mountains BRSP 29.2 ± 2.0 to < 32.7
Chinati Mountains Volcanism	Cienega Mountain Rhyolite, Mitchell Mesa Rhyolite, Morita Ranch Formation, Terneros Creek Rhyolite	Cienega Mountains (NW part of BBRSP) 32.72 ± 0.11to 35.51 ±0.12
Chisos Group	Tule Mountain Trachyandesite, Mule Ear Spring Tuff, Bee Mountain Basalt, Alamo Creek Basalt	Chihuahua, Mexico and Big Bend Nat. Park/ Bofecillos Mtns 31.8 ± 1.3 to 47

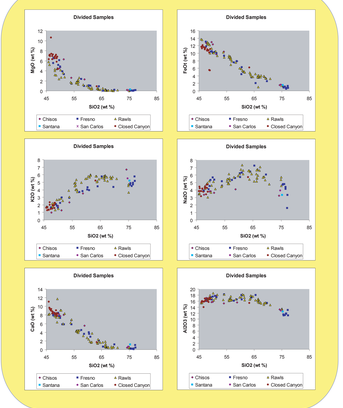
What Can Students DO with this Information?

Starting with Major Element Data

Data from all sources…



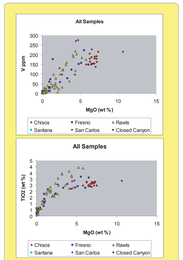
…*vs.* data distinguished by source area or formation



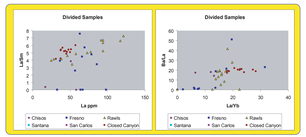
Can they identify crystal fractionation?

Why do samples from different sources plot along the same trends?

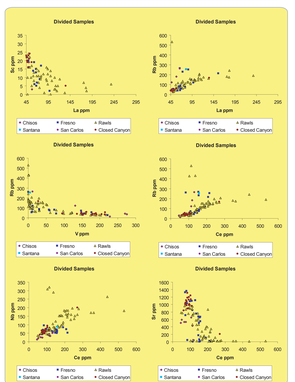
Then Minor Element Data



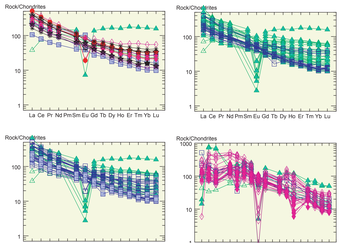
Were the magmas generated by fluid flux melting or decompression melting (diagram from Cameron et al., 2002)? Or, can partial melting be distinguished from crystal fractional crystallization?



Finally, Trace Element Data - are differences between source regions any more obvious?



Incompatible Element Plots - Does plotting the data in this way give the student more information? Can they come up with more processes?



Age and Tectonic Setting

Big Bend Ranch State Park is dominated by the Bofecillos Mountains in Trans-Pecos Texas. The Park contains an impressive volcanic and volcaniclastic section with numerous sources for the lavas, tuffs, and sediments. Many of the volcanic rocks originated from local sources in the Bofecillos Mountains; however, volcanic rocks in the park also erupted from sources to the North (Chinati Mountains area), and to the South (Chihuahua, Mexico). [See Price and Henry, 1986, Henry and McDowell, 1986, Henry and Price, 1986, Barker, 1987, Price et al., 1987, Henry et al., 1991, Henry et al., 1998, James and Henry, 1991, Henry and James, 1991.]

One of the fascinating aspects of this study area is that volcanism spanned a time period during which the stress regime in western North America changed. Pre-31-million Ma magmatism was likely part of continental magmatic arc related to subduction beneath North America. Post-31-Ma magmatism was likely related to regional, basin and range lithospheric extension [Again, see papers mentioned above.]

Much data has been collected from the area, and several papers, Reports and Guidebooks have been published.

BBRSP Panorama

Campsite on the Rio Grande

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