GROWTH OF THE NORTH AMERICAN CONTINENT BY ACCRETION OF EXTENSIONAL INTRA-OCEANIC ARCS: Alisitos Arc Field Analog to the Ultra-Deep IBM Site

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In a 2006 paper in the Journal of Volcanology and Geothermal Research[1,] I proposed that the Mexican continental margin grew substantially in Cretaceous time, through accretion of the upper to middle crust of an extensional intra-oceanic arc: the Alisitos arc of Baja California. Accretion was accomplished by detachment along a thick middle crustal tonalitic layer; meanwhile, the lower crust and mantle were coupled, strengthened and densified by mafic rift intrusions, so they subducted. In the 2006 paper, I proposed that this process requires: (1) *the building of a thick tonalite layer and a relatively silicic upper crust through rapid intra-arc extension*, and (2) *immediate accretion of an hot intra-oceanic arc that fringed the continental margin*, rather than accretion of an exotic arc, which is more likely to be accreted cold. More recently, we used detrital zircon, geochemical, and map data to show that, in Cretaceous time, the western third of the Mexican continental margin grew by accretion of the middle-to upper-crustal levels of extensional fringing arcs ("Guerrero composite terrane")[2]. I have also argued that "horizontal" growth of continents is enhanced by extremely efficient trapping of eruptive products in extensional arc basins[3]; this process has been widely under-recognized, because the modern Earth is biased toward extensional arcs[4]. Now that it is more widely understood that extensional arcs are common in the geologic record, geologists must work to decipher the primary strain regime of arc terranes of all ages, and to determine the key characteristics of active extensional arcs. Then we may evaluate the global importance of extensional arcs in "horizontal" creation of continental crust. The Mexican margin grew substantially through this process, where fringing arcs formed along its margin for over 100 myr[2, 5].

I argue that the Alisitos arc forms the best outcrop analog to the ultra-deep IBM site on the planet. It is an extremely large terrane (300 X 30 km) [1, 2], superbly exposed in the Sonoran Desert of Baja California. Our published maps and cross sections from a 60 X 30 km segment of the Alisitos arc show an undeformed and unmetamorphosed, intact west-tilted block that exposes upper- to mid-crustal rocks (Figure 1). These maps and cross sections are shown in our **companion poster display.** This poster discusses Helen Kinvig's future postdoctoral work with Cathy Busby, which will dovetail with the IODP project by: (1) examining the plutonic-volcanic connection in much greater detail, and gathering much-needed geochemical data on this section, and (2) leading interested IODP participants on a field workshop there.

Summary of Published work on the Alisitos Arc (see poster display)

We recognized two evolutionary phases in the mapped segment of the Alisitos arc terrane (Figure 1): (I) extensional oceanic arc, characterized by intermediate to silicic explosive and effusive volcanism, culminating in caldera-forming silicic ignimbrite eruptions at the onset of arc rifting, and (II) rifted oceanic arc, characterized by mafic effusive and hydroclastic rocks and abundant dike swarms[1]. U-Pb zircon data from the volcanic and plutonic rocks of both phases indicate that the entire 4,000 m thick stratigraphic section accumulated in about 1.5 Ma, at 111-110 Ma.

The mapped segment of the Alisitos arc has a central subaerial edifice, flanked by a down-faulted deepwater marine basin to the north, and a volcano-bounded shallow-water marine basin to the south (Figure 1). The rugged down-faulted flank of the edifice produced mass wasting, plumbed large-volume eruptions to the surface, and caused pyroclastic flows to disintegrate into turbulent suspensions that mixed completely with water. In contrast, gentler slopes on the opposite flank allowed pyroclastic flows to enter the sea with integrity, and supported extensive buildups of bioherms. Caldera collapse on the subaerial edifice ponded the tuff of Aguajito to a thickness of up to 3 km. The outflow ignimbrite forms a marker in nonmarine to shallow marine sections of the southern volcano-bounded basin, and in the northern deepwater fault-bounded basin it occurs as blocks up to 150m long in a debris-avalanche deposit (Figure 1). These welded ignimbrite blocks were deposited hot enough to deform plastically and form peperite with the debris-avalanche matrix. The debris avalanche was likely triggered by injection of feeder dikes along the basin-bounding fault zone during the caldera-forming eruption[1].

Field Workshop Proposal

I have led several class field trips and conference field trips to the area, which requires off-road vehicles and primitive dry camping (no facilities). The furthest end of the field area is a 9-hour drive from San Diego (Day 1), so I suggest we hold an IODP planning meeting there before the field trip. Three of the field days will involve day-long cross-country traverses trip on foot, to examine the two basin types and the central edifice; one day will consist of a series of short traverses through the plutonic-volcanic transition; and we will do an additional short traverse thorugh plutonic rocks on the day we return to San Diego (total trip length 6 days and 5 nights). We will camp in the same spot on nights 1 and 2, possibly get hotel rooms and eat out on night 3, camp on night 4, and possibly get hotel rooms and eat out on night 5.

References

[1]Busby, C. J., Fackler Adams, B., Mattinson, J., and *De Oreo, S.,* 2006, View of an intact oceanic arc, from surficial to mesozonal levels: Cretaceous Alisitos Arc, Baja California, Mexico: Journal of Volcanology and Geothermal Research, v. 149, p.1 - 46.

[2]Centeno-Garcia, E., Busby, C., Busby, M., Talavera, O. and Gerhels, G., 2011, Evolution of the Cretaceous Guerrero terrane along the Mexican margin, from extensional arc through retroarc to continental arc settings: Geological Society of America Bulletin, v. 123, no. 9/10, p. 1776-1797, doi:10.1130/B30057.1

[3]Busby, C.J., 2011, Growth of Continents at Extensional Arcs: A View from the Upper Crust: Pardee Keynote honoring Arthur Holmes, Geological Society of America Abstracts with Programs, v. 43, no. 5, p. 145.

[4]Busby, Cathy, 2012, Extensional and transtensional continental arc basins: Case studies from the southwestern U.S. and Mexico: *in,* C. Busby and A. Azor (eds), Recent Advances in Tectonics of Sedimentary Basins, Wiley-Blackwell, p. 382-404.

[5]Busby, C.J., 2004, Continental growth at convergent margins facing large ocean basins: a case study from Mesozoic Baja California, Mexico: Tectonophysics, v. 392, p. 241-277.

These papers are available as pdf files at:
http://www.geol.ucsb.edu/faculty/busby/Publications.php

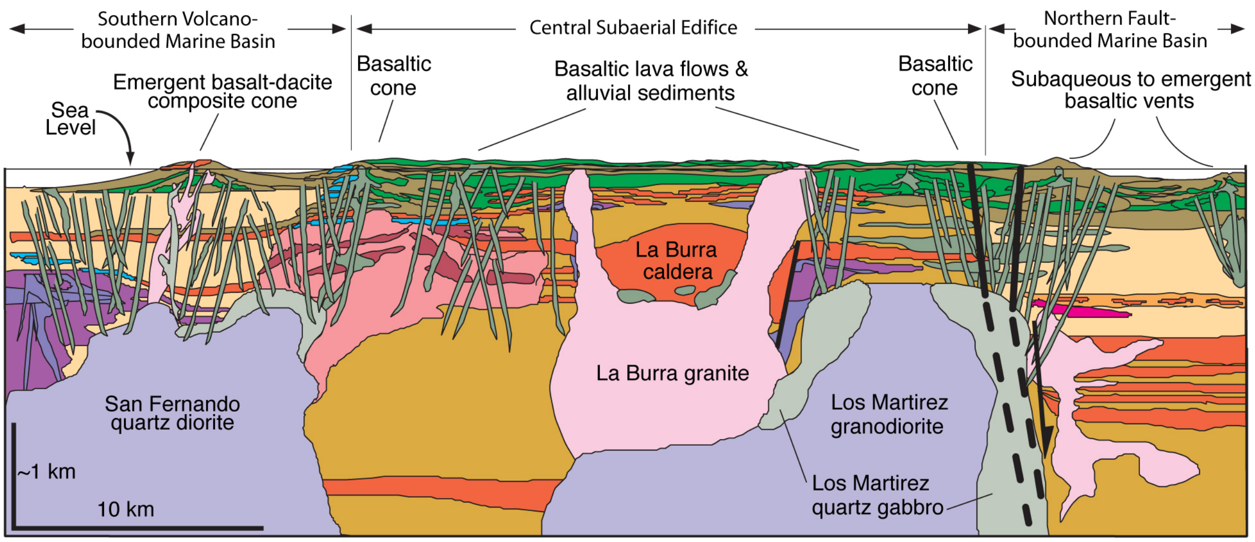

Figure 1 – Cross-sectional view of an intact segment of the Alisitos arc (note vertical exaggeration)[1].