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Arizona Geological Survey

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GEOLOGY AND GEOLOGICAL HAZARDS FIELD TRIP OF SABINO CANYON: RESULTS OF THE JULY 2006 STORMS

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ARIZONA GEOLOGICAL SURVEY

Introduction

This field trip guide was created for a Project WET conference held in Tucson, Arizona, June, 2007. This guide discusses the general geology of the Santa Catalina Mountains in Sabino Canyon, and points out evidence of the July 2006 floods and debris flows. There are stops in the first few miles of canyon, and towards the end of the tram road, where the most spectacular debris flows are located.

The storms of July 2006

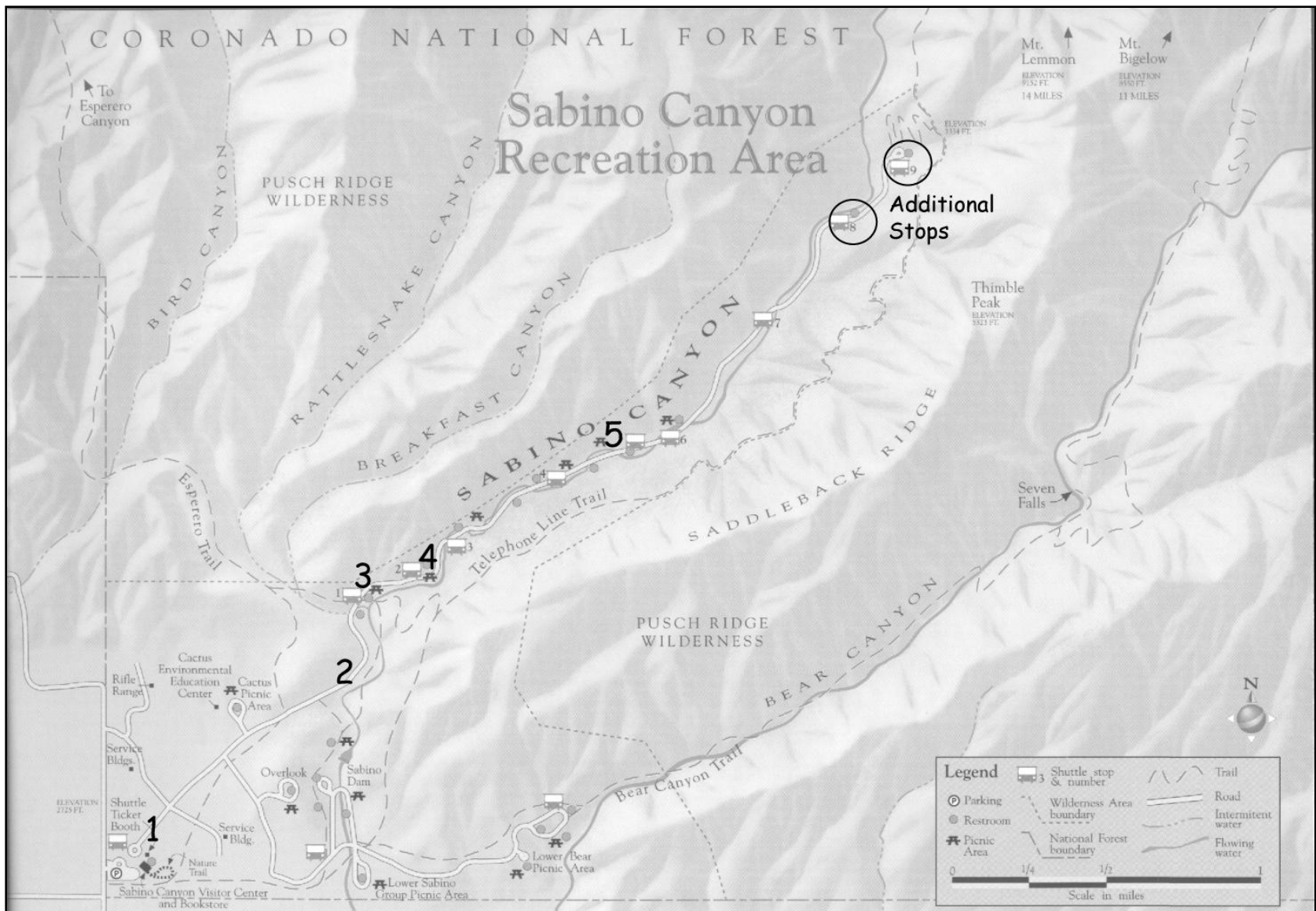
In July, 2006, southern Arizona experienced an extremely rare five day series of early morning storms generated from monsoonal moisture mixing with an upper-level persistent low-pressure system centered over northwestern New Mexico. These increasingly wet storms culminated on July 31, 2006, and resulted in floods of record in several drainages and numerous debris flows generated in four southeastern Arizona mountain ranges. (Pearthree and Youberg, 2007). To date 259 slope failures have been identified in the Santa Catalina Mountains (Webb and others, 2006). These slope failures coalesced into debris flows that exited, or nearly exited, from five canyons along the front range of the Santa Catalina Mountains, which caused significant damage to infrastructure and houses. Sabino Canyon was temporarily closed due to road damage from the floods and debris flows. Although the road is now repaired and the canyon open, there is still plenty of evidence of the 2006 debris flows.

What is a debris flow?

A debris flow is a slurry of sediment (70-90%) and water (10-30% by weight), often with the consistency of wet concrete, that moves rapidly down channels. Sediment in debris flows are very poorly sorted, ranging from clay-size particles to very large boulders. The finer particles, clay, silt and sand, form a dense, viscous matrix that can support and transport very large boulders making these flows very destructive.

Debris flows are initiated when pore pressures in soils on steep slopes reach a threshold and fail, often due to intense or prolonged rainfall. As debris flows move downslope they deposit boulder levees that keep the flow confined and moving forward.

Debris flows often have a relatively matrix-free bouldery snout at the front, followed by the main body of liquefied debris, and a tail, or recessional flow, that is a sediment-charged flood (hyperconcentrated flow). Debris flows may move down channels in surges or pulses due to either longitudinal sorting, non-simultaneous triggering of slope failures, or rolling dams.



Map of Sabino Canyon with field trip stops numbered or circled. (from http://www.sabinocanyon.org/pdf/sabinomap_200dpi.pdf)

Stop 1 – Visitor’s Center

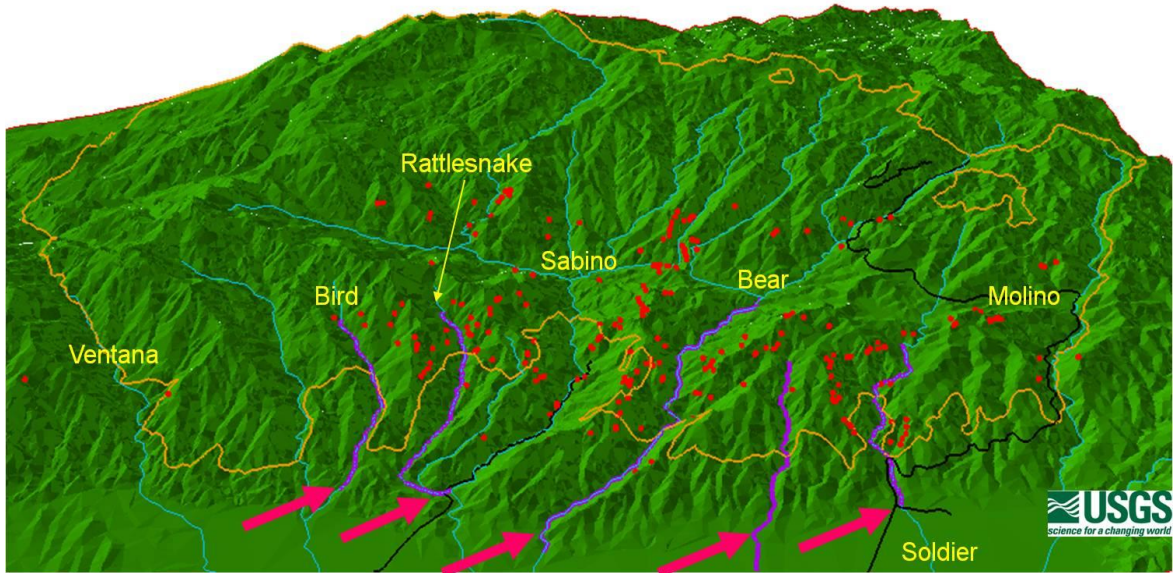


Figure 1. Initiation points (red) and debris flows exiting or nearly exiting the front range (purple with pink arrows). Modified from Webb et al. PowerPoint presentation.

Stop 2 – Bluff Trail Overlook

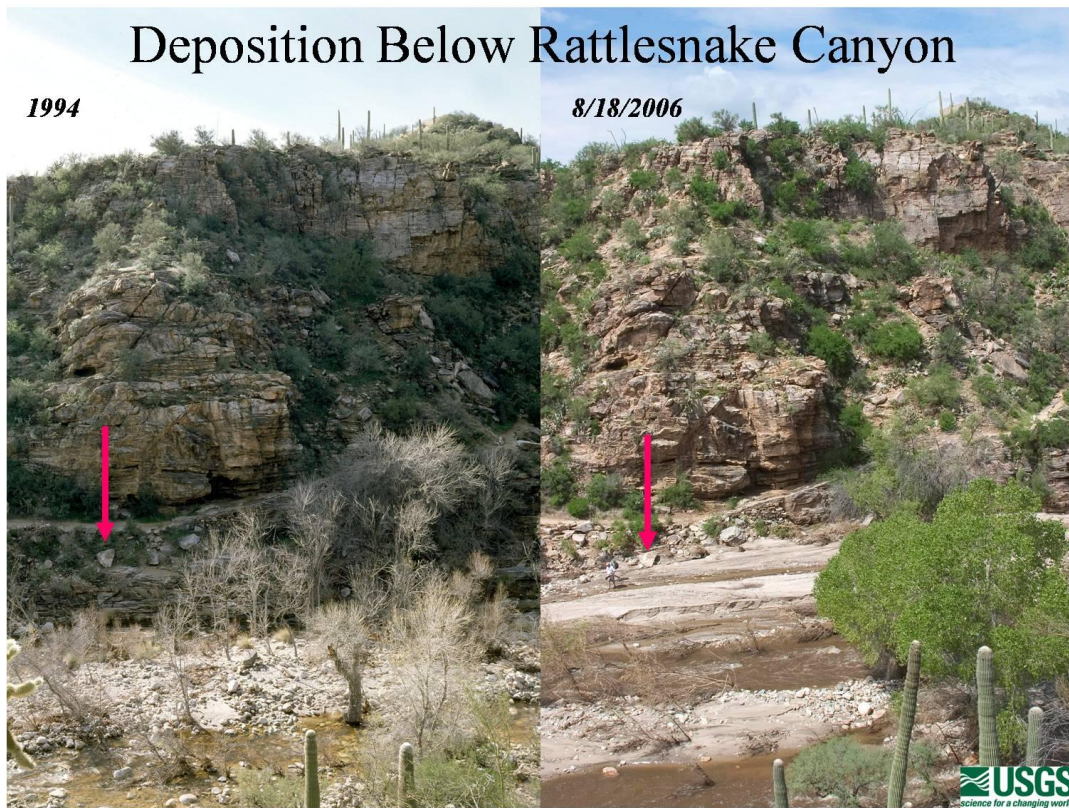


Figure 2. USGS repeat photographs along the Bluff Trail showing approximately 20' of deposition from the Rattlesnake debris flow. Photos: US Geological Survey.

The Bluff Trail leads to Sabino dam. You can hike back this way. Once you get to the picnic area and the road turn right to return to the Visitor's Center. Watch for a large path leading off to your left for the quickest route back. It's ok if you miss the path as you'll end up on the same road we walked into the canyon.

Stop 3 – Rattlesnake Bridge

The Rattlesnake debris flows from several drainages coalesced and flowed about 2 miles destroying the bridge. Take a few minutes here to walk in the wash. Look at the new culverts. What do you think about conveyance of more debris? Examples of debris-flow levees can be seen on river-right (think of rafting down a river to determine river-right and river-left) between the bridge and Sabino Creek. Walk out to the confluence. Look upstream.



Figure 3. View downstream of the remaining part of Rattlesnake bridge. Photos: US Geological Survey.

Stop 4 – Between Tram Stop 1 and 2

General Geology of Sabino Canyon

Sabino Canyon is an erosional feature cut into the bedrock of the Santa Catalina Mountains. The banded gneiss seen in abundance throughout the canyon is a result of detachment faulting during the formation of a metamorphic core complex beginning about 35 million years ago. The Santa Catalinas are one of many (more than two dozen) metamorphic core complexes extending from northern Mexico into southern Canada. These complexes result

from crustal stretching or thinning in which rock nearer the surface is broken in a brittle manner while rock at depth is stretched and deformed plastically (Figures 4 and 5). Minerals composing a rock become ductile at different temperatures. In granite, the original igneous rock, the main rock-forming minerals are quartz, feldspar, and mica (muscovite or biotite). Quartz and mica become ductile at a lower temperature than feldspar. This phenomenon, when combined with shearing of the rock at depth, can result in interesting metamorphic rock fabrics such as banded or augen gneiss.

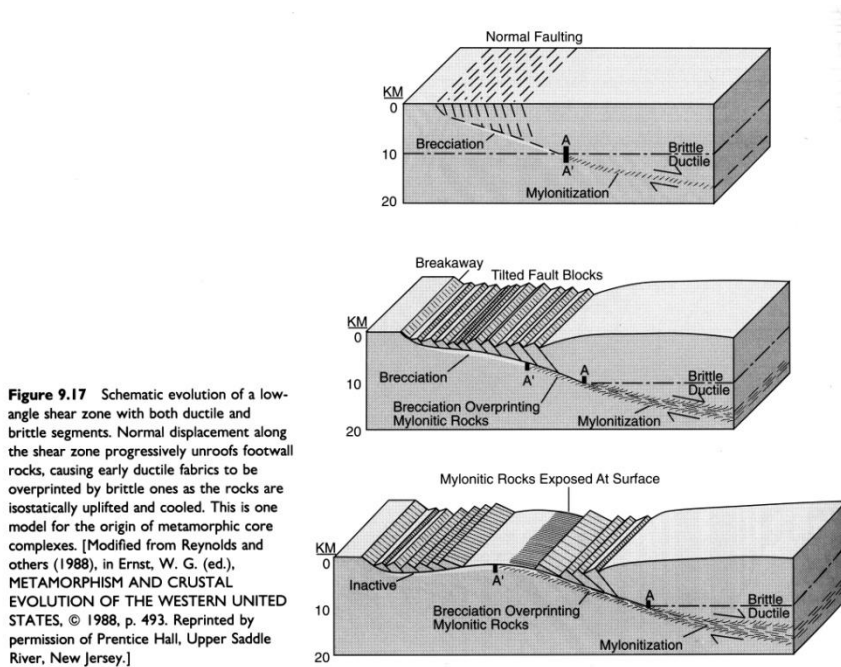


Figure 9.17 Schematic evolution of a low-angle shear zone with both ductile and brittle segments. Normal displacement along the shear zone progressively unroofs footwall rocks, causing early ductile fabrics to be overprinted by brittle ones as the rocks are isostatically uplifted and cooled. This is one model for the origin of metamorphic core complexes. [Modified from Reynolds and others (1988), in Ernst, W. G. (ed.), METAMORPHISM AND CRUSTAL EVOLUTION OF THE WESTERN UNITED STATES, © 1988, p. 493. Reprinted by permission of Prentice Hall, Upper Saddle River, New Jersey.]

Figure 4. Modified fro Davis, G.H. & Reynolds, S.J. 1996. /Structural Geology of Rocks and Regions,/ 2nd. John Wiley, New York..

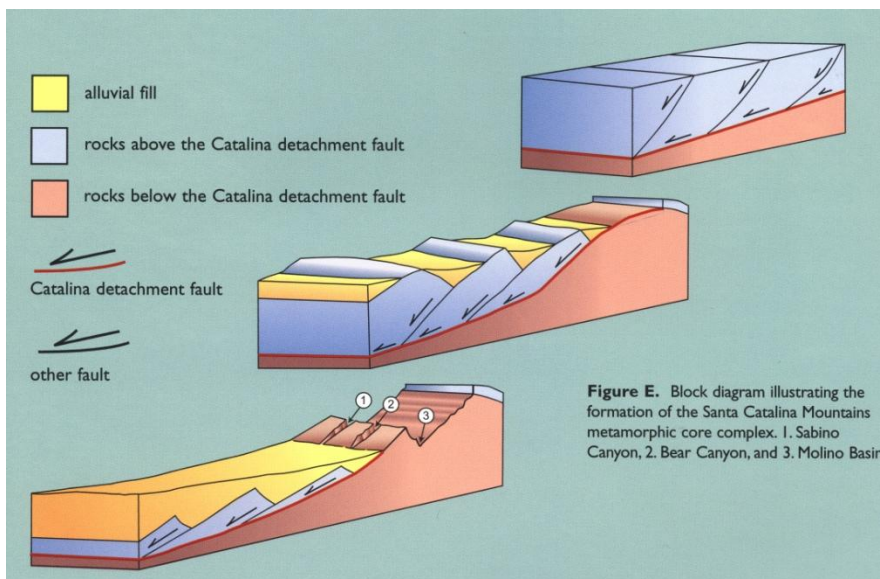


Figure E. Block diagram illustrating the formation of the Santa Catalina Mountains metamorphic core complex. 1. Sabino Canyon, 2. Bear Canyon, and 3. Molino Basin.

Figure 5. Modified from Bezy, AZGS Down-to-Earth 17.

Through subsequent faulting and uplift, these deformed (metamorphic) rocks are now exposed at the surface where they are subjected to erosion by water, wind, and ice. Through time, downcutting streams erode away the loose rock and transport sediment away from the mountains. Heavy rains can initiate large mass movements of sediment such as debris flows, rockfalls, and landslides. Many of the very large boulders occupying the channel today are evidence of these processes. Boulders transported in canyon environments such as Sabino, Bear, and Molino canyons are progressively broken down into smaller particles. Stream transport of these sediments scour the channel floor and more deeply erode the canyon into the bedrock. Smaller sediments such as cobbles, pebbles, sand, and silt eventually make their way beyond the mouth of the canyon, filling the Tucson basin and forming alluvial fans.

Stop 5 – Road damage

What are these features in the road? During the floods, water scoured under the asphalt washing away finer material (sand and silt) leaving larger pebbles and cobble. When the wet asphalt settled the remaining rocks broke through, forming what one person thought looked like little volcanoes (Figure 6).



Figure 6. Interesting road damage.

Additional Stops

The most spectacular debris flows are near, and at, the end of the tram road, specifically between Tram Stops 7 and 9. It is 3.7 miles from the Visitor's Center to Tram Stop 9.

Tram Stop 8

One of the most impressive debris flows in Sabino Canyon was located at Tram Stop 8. It has been informally named Ocho Grande. Very large boulders (not shown in figures) were moved in this debris flow, and the channel was scoured quite deeply. Black PVC culverts filled with sediment which then held the culverts in place as the road washed away (Figure 7).

This drainage, and the drainage at Tram Stop 9, also had debris flows after the 2003 Aspen Fire. Post-fire debris flows can be triggered by much smaller rain events than the late July, 2006, storms. The following figures show comparisons between the 2003 post-fire debris flow and the 2006 precipitation event debris flow. Red bars in Figure 8 show the same location within the two photos. Figures 9 and 10 show Ocho Grande's debris-flow deposits on the tram road. Note the difference in the number and size of boulders.

The road up to Tram Stop 9 affords excellent views of numerous debris flows in this location. Figure 11 shows a debris flow deposit, now removed, on the road up to Stop 9. Figure 12 was taken on the approach to Stop 9. Figures 13 and 14 show the difference in debris-deposit thickness, and size of material transported. The rest station shown in Figure 14 is buried under the debris in Figure 13. Only the roof was removed.



Figure 7. Ocho Grande is the largest debris flow in Sabino Canyon. This is not the first time Ocho Grande has had a debris flow. Photo. US Geological Survey.



Figure 8. Ocho Grande in 2006 on left. Right is a 2003 Post-Aspen Fire debris flow in the channel of Ocho Grande. To orient yourself in these three photos look at the large boulders on the left side of the channel and photos. August 2003 Photo: US Forest Service.



Figure 9. Debris fan of Ocho Grande in 2006. Photo: US Geological Survey.



Figure 10. Post-Aspen Fire debris flow fan at Ocho Grande, 2003. Photo: US Forest Service.



Figure 11. The road to Stop 9. Several debris flows crossed this section of road.



Figure 12. Tram Stop 9. Debris flow chute in upper right of photo.



Figure 13. Tram Stop 9. The rest station was buried by the debris flow.



Figure 14. Photo of the rest station at Tram Stop 9 after the Post-Aspen Fire debris flow. As you can see there is a vast difference in clast size between these debris flows.

Thank you for joining us on this walk through Sabino Canyon. If you have any questions please ask, or feel free to contact us at a later date.

For further information please contact the Arizona Geological Survey (AZGS).

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References

Bezy, J.V., 2004, A guide to the geology and geology of Sabino Canyon and the Catalina Highway, Down-to-Earth 17, Arizona Geological Survey, Tucson, 45 pp. (Available at the Visitor's Center).

Magirl, C.S., Webb, R.H., Griffiths, P.G., Schaffner, Mike, Shoemaker, Craig, Pytlak, Erik, Yatheendradas, Soni, Lyon, S.W., Troch, P.A., Desilets, S.L.E., Goodrich, D.C., Unkrich, C.L., Youberg, Ann, Pearthree, P.A. (2007), Impacts of recent extreme Arizona Storms, *Eos, AGU*, 88(17). Pearthree, P.A. and Youberg, A., 2006, Recent debris flows and floods in Arizona, *Arizona Geology*, Vol 36, No 3, Arizona Geological Survey, Tucson.

Webb, R.H., Griffiths, P., Magirl, C., Boyer D, Pytlak, E., Shoemaker, C., Schaffner, M., Evans, T., Pearthree, P.A., and Youberg, A., 2006, Floods and debris flows in the Catalina Front Range and southern Arizona, July 31, 2006, PowerPoint presentation.