Studying one Precariously Balanced Rock in the Coyote Mountains using UAVSAR interferograms and the April, 4th, 2010 El Major-Cucapas Mw 7.2 Earthquake.

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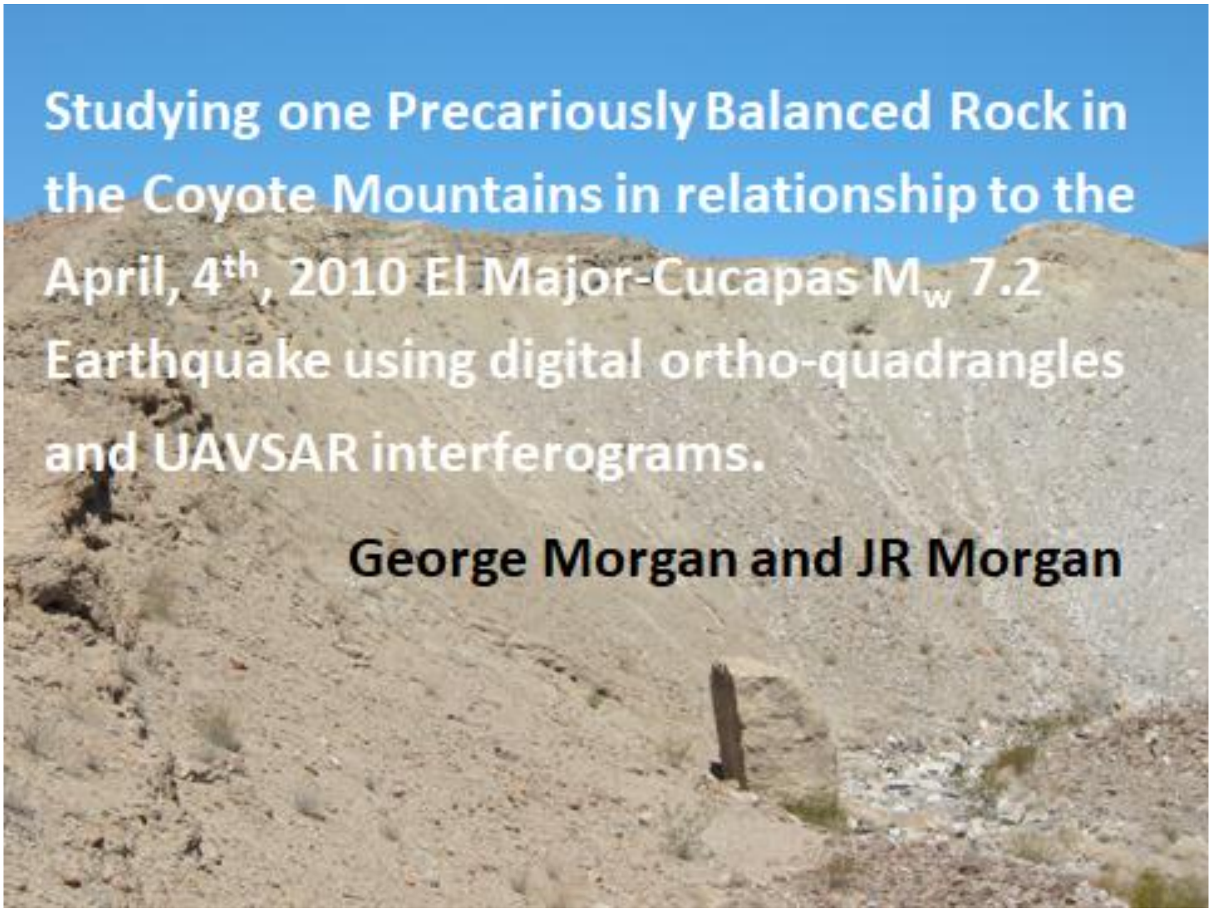
Abstract

In the southwest U.S., Jim Brume, 1996, Anooshehpoor, 2007 and others have been studying Precarious Balanced Rocks (PBR) and their relationship to seismic events. In the Coyote Mountains a PBR failed (a rock fall) during(?) the April, 4th, 2010 El Major-Cucapas M_w 7.2 Earthquake (Hauksson et al., 2010). Two problems became evident while studying this PBR: 1) knowing which rocks are precariously balanced and; 2) the time when this particular PBR failed. Using the July 1, 2010 dated UAVSAR interferograms, provided by Jerry Treiman (2012), help with the study of this particular PBR and other types of seismic failures in the Coyote Mountains. The PBR was first thought to have failed during the main shock of the El Major-Cucapas Earthquake. Further studies of air photos indicated that the block did not fail during the main shock of the El Major-Cucapas M_w 7.2 Earthquake, but the earthquake may have contributed to the instability of the PBR block. The June 15, 2010, M_w5.7 aftershock(?) that was north of the international border and closer to the PBR, probably triggered the failure of the PBR. Using UAVSAR interferograms after a seismic event can help in defining when an unrecognized PBR fails.

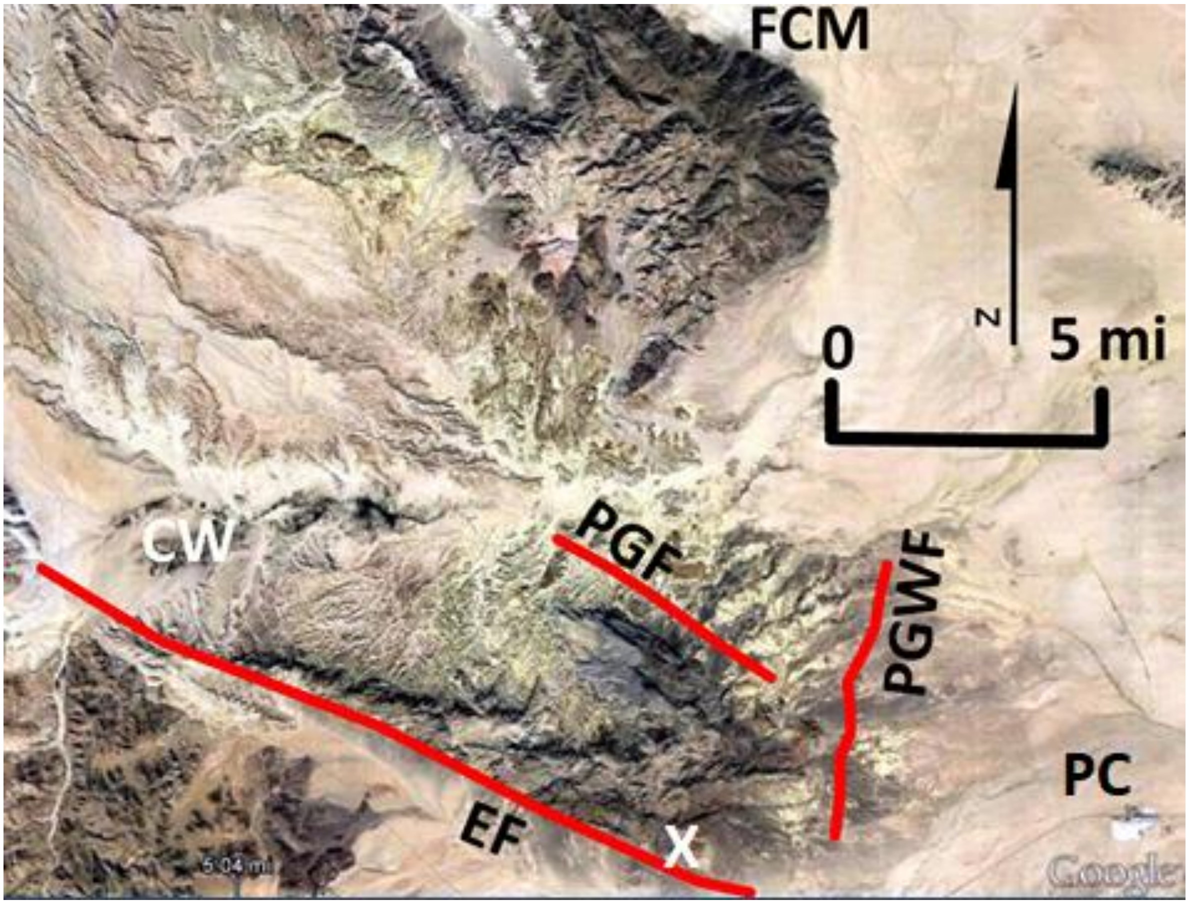
Morgan, G, J., and Morgan, J. R., 2018a, Studying one Precariously Balanced Rock in the Coyote Mountains using UAVSAR interferograms and the April, 4th, 2010 El Major-Cucapas Mw 7.2 Earthquake: Geological Society of America Abstracts with Programs. Vol. 50, No. 5, ISSN 0016-7592doi: 10.1130/abs/2018 RM-314073



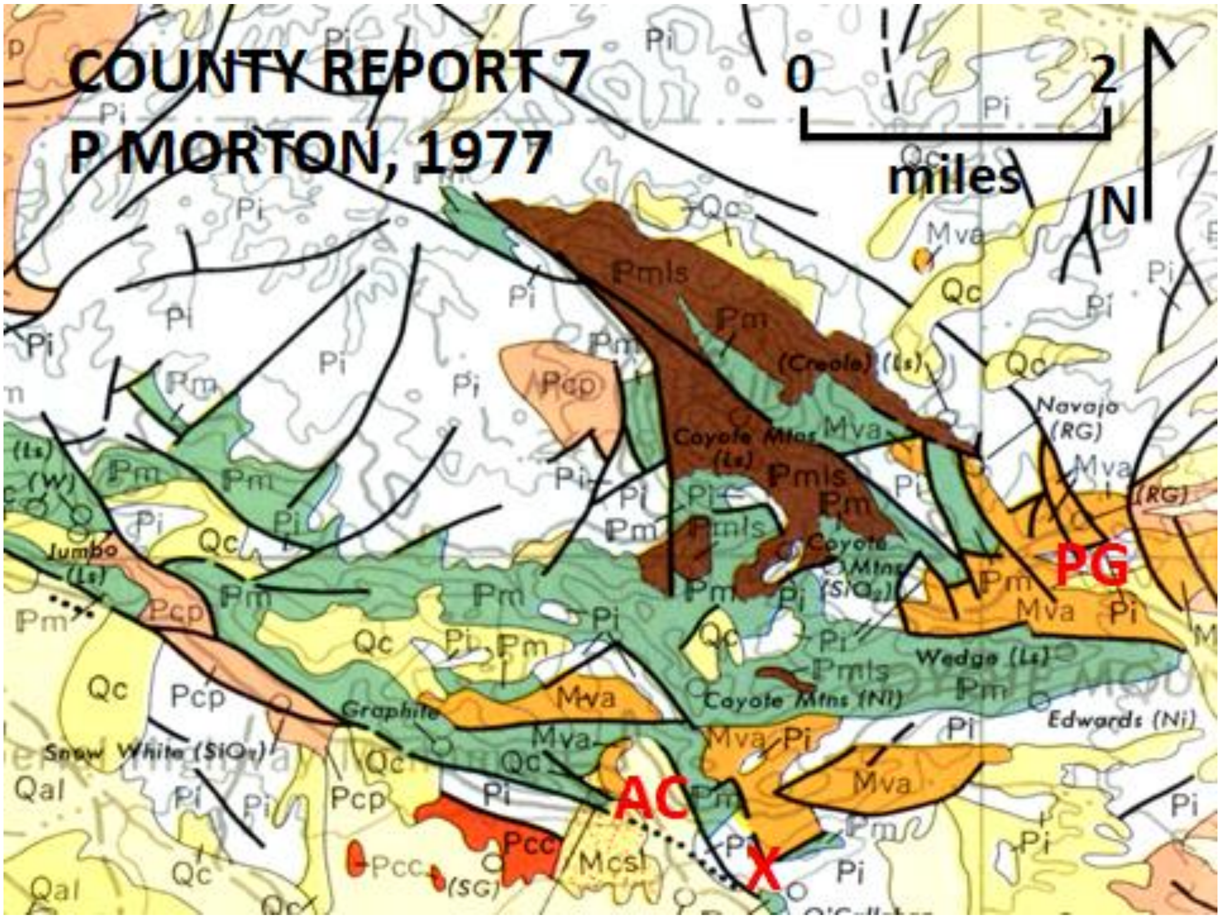
Slide 1. Looking to the northwest at rock under the authors names. This is the rock fall.

Slide 2. Photo of an obvious granitic PBR in the Kingston Range, Mojave Desert, southern California. If the PBR in the Coyote Mountains were this obvious even we would recognized them.

Slide 3. Location (red star) of Coyote Mountains and the April, 4th, 2010 El Major-Cucapas M_w 7.2 Earthquake **(**Hauksson, et al., 2010). **ChM**-Chocolate Mountains. **EF**- Elsinore Fault. **FC**-Fish Creek Mountains. **GM**-Gila Mountains **LS**- Laguna Salada (dry lake?). **LSF**-Laguna Salada Fault. **SJ**- Serra Juarez. **SAF** -San Andreas Fault. **SJF**-San Jacinto Fault. **SS**-Salton Sea. Approximately 53 miles between the rock fall and the Mw 7.2 earthquake. NASA photograph.



Slide 4. Google Earth photo of the area around the fish hook shaped Coyote Mountains. **CW**-Carrizo Wash flowing east into the Salton Sea. **EF**-Elsinore Fault, an active right lateral fault. **FCM**- Fish Creek Mountains. **PGF-**Painted Gorge Fault, some believe (Bykerk-Kauffman et al., 2016) is an active right lateral fault. Morgan and Morgan, (2017b) believe **PGF** is a dip-slip fault, predominantly down to the north fault. **PGWF**- Painted Gorge Wash Fault is an active left-lateral fault (Morgan and Morgan, 2006). The white **X** is the location of the PBR. The town of Ocotillo is just to the southeast of the center-edge of the map.

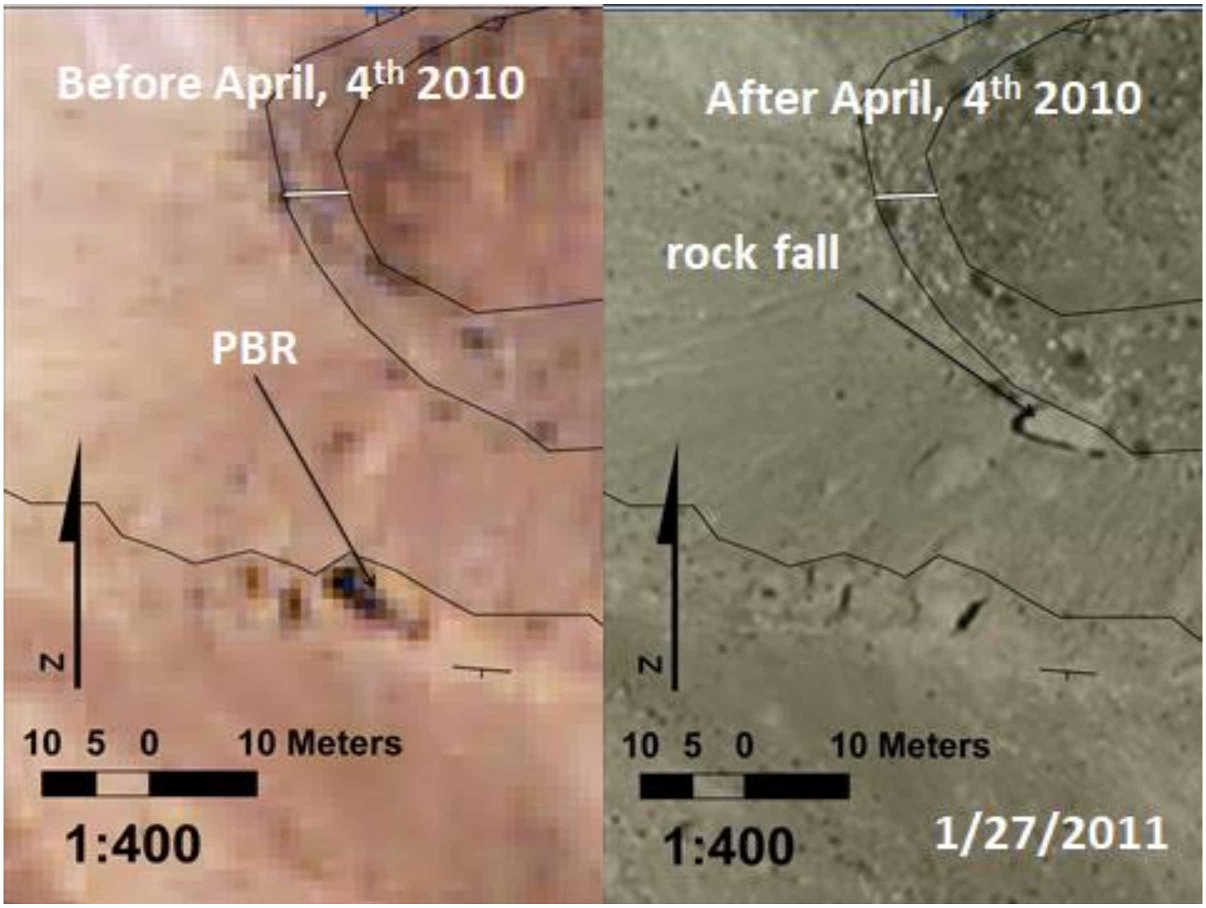


Slide 5. This is a part of Morton's, 1977, geological map of Imperial County. Morton's map is a good summary of the geology found in and around the Coyote Mountains. Morton used portions of Dibblee's (1954) and Christensen's (1957) maps. Brown and green colors indicate the crystalline basement of the Coyote Mountains. The simplified basement rocks consist of billow basalts and Paleozoic (Dibblee, 1954; Miller and Dockum, 1983) limestones, sandstones, mudstones, cherts and conglomerates. Intruding, deforming and metamorphosing the section are igneous Jurassic rocks (Morgan and Morgan, 2015). We have yet to find Cretaceous rocks in the Coyote Mountains. The orange color represents the volcanics (17.1 Ma; Morgan et al., 2012) of the Alverson Canyon Formation (Ruisaard, 1979). White represents the marine and fresh water units of the

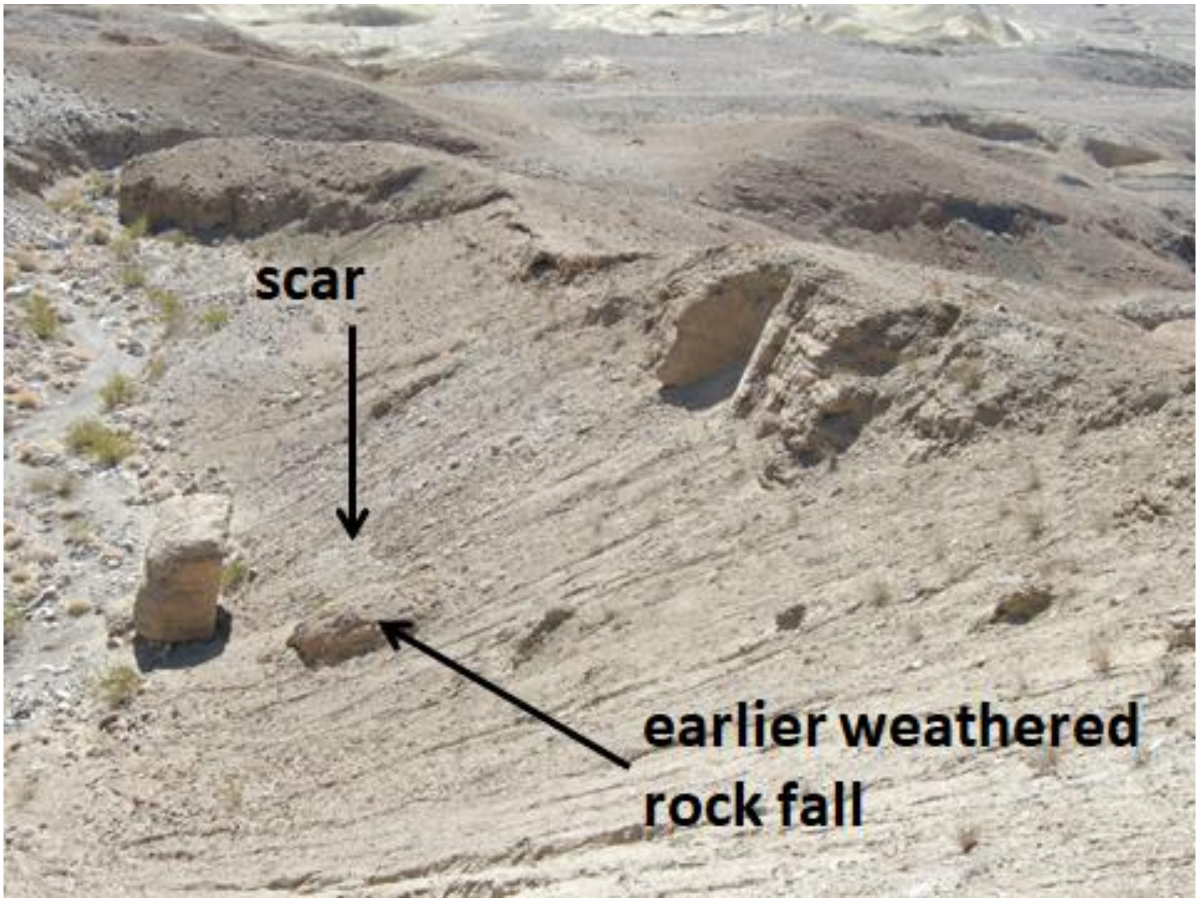
Winker and Kidman's (1996) Imperial Group. **AC-** Alverson Canyon (Fossil Canyon). **PG**-Painted Gorge. **X**- location of PBR.

Slide 6. Over a year after the Major-Cucapas Earthquake we found this rock in an area that we had previously mapped. We did not remember this rock being there. The view is to the southeast. The rock is approximately 7 feet wide, 11 feet high and 20 feet long. Two joints in the cliff line mark the source of the rock. Location: 32° 46′ 49.2"N, 116° 00' 23.1"W.

Slide 7. Another view of the rock looking to the northwest. We initially assumed the rock fall was triggered by the April, 4th, 2010 El Major-Cucapas M_w 7.2 Earthquake. Note the two joints in the rock match the joints in the cliff line in the previous slide. The rock rolled down the slope and landed right side up.



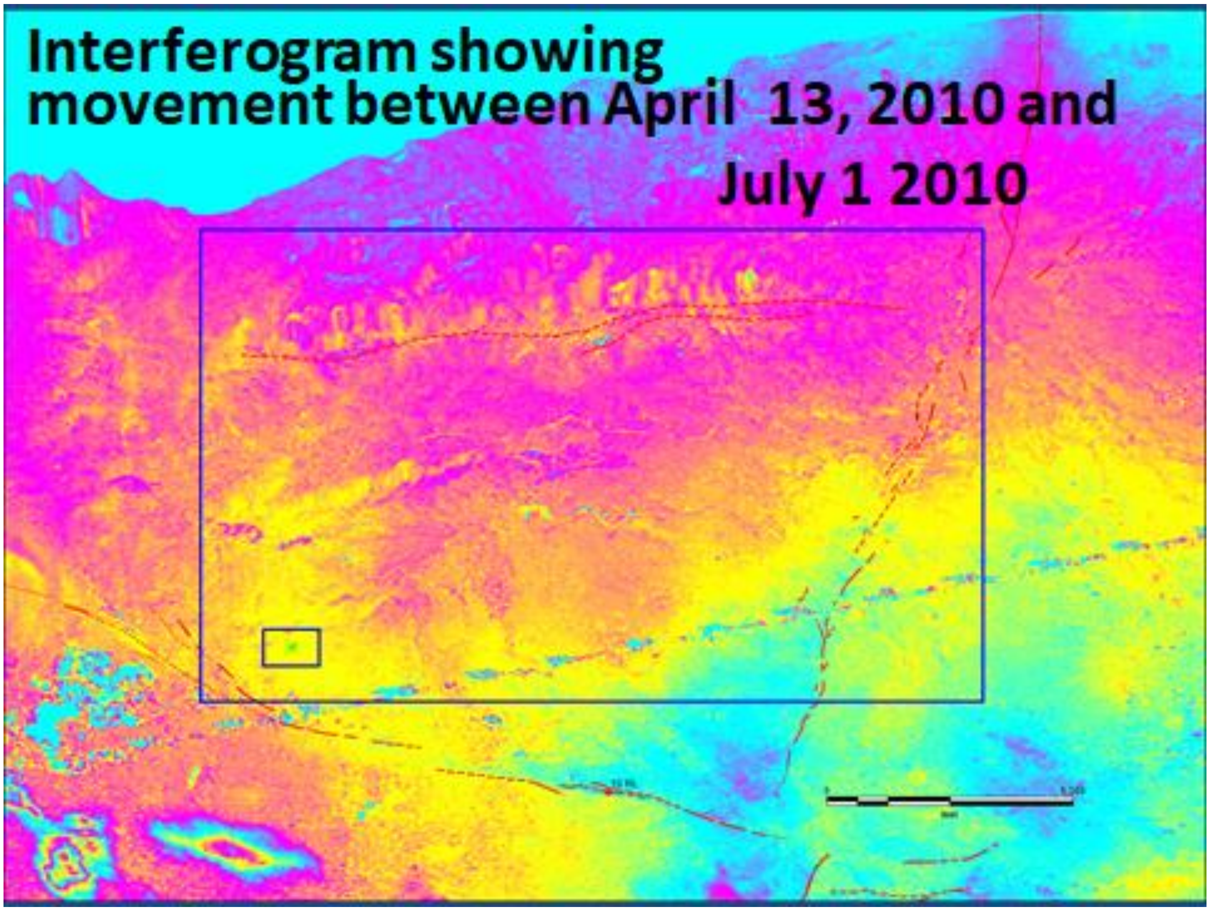
Slide 8. In an initial check of our air photos, it appears the rock failed during the April, 4th, 2010 El Major-Cucapas M_w 7.2 Earthquake. In the photo to the left taken before April 4th, 2010, the PBR has not fallen. The PBR does show a rotation away from a joint forming a part on the cliff line. This rotation may have been in response to an earlier seismic event. In the photo to the right, taken nine months after the earthquake, the PBR has failed.



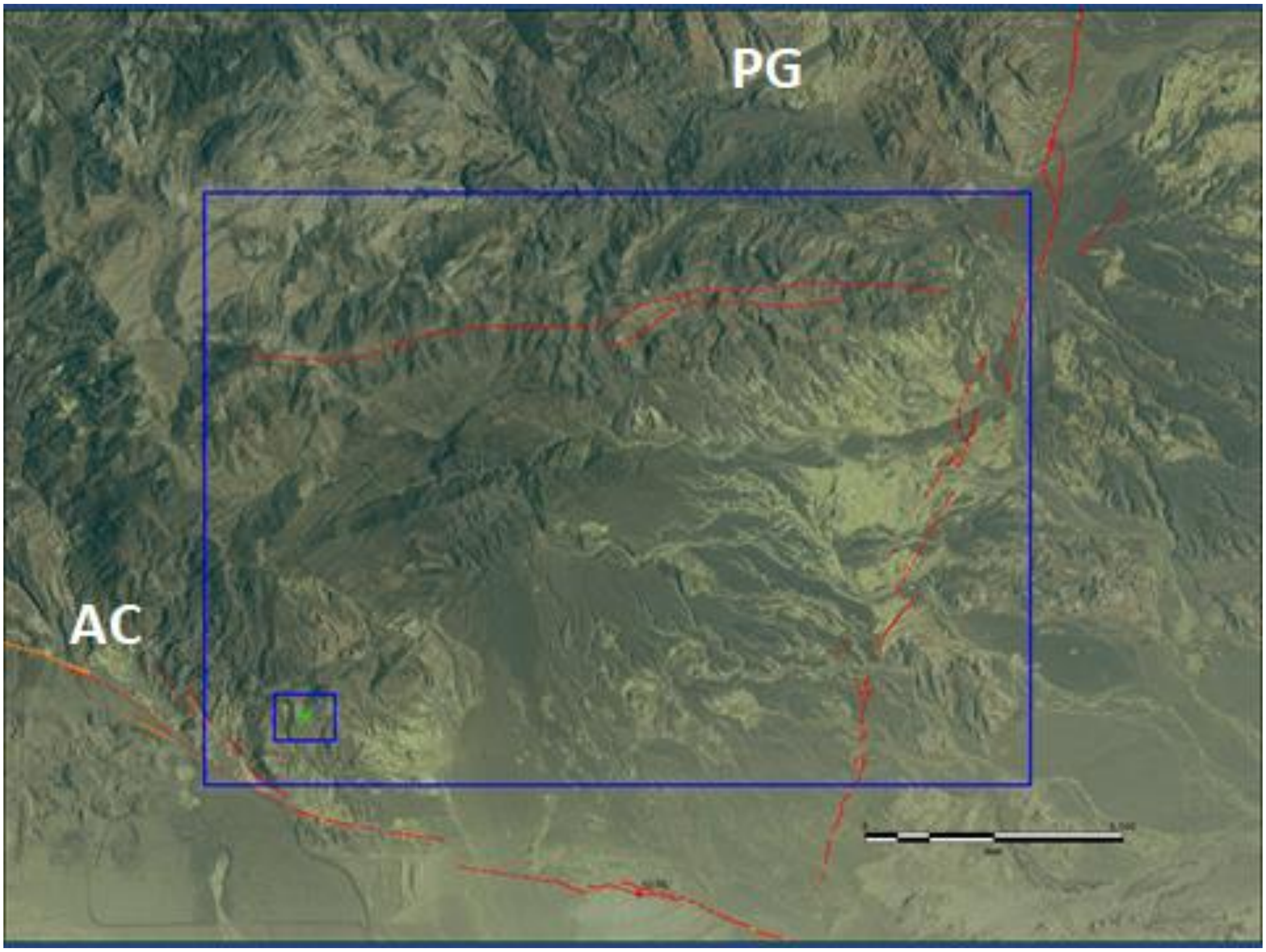
Slide 9. The PBR and the cliff forming rocks are made up of a moderately cemented, locally derived, fanglomerate belonging to the Green Fanglomerate Member, a nonmarine unit of the Viejo Formation (Morgan and Morgan 2017a), a unit of Winker and Kidwell's (1996) Imperial Group. In the photo the scar was made by the rock rolling downhill. The earlier weathered rock may represent an earlier rock fall. This earlier rock fall may represent an earlier seismic event.

Slide 10. Further research into the timing of the rock fall presented a problem. This Google Earth photo, dated April, 24th, 2010, shows that the PBR is still in place 20 days after the April 4th 2010, 7.2 El Major-Cucapah Earthquake. The Mw 7.2 earthquake did not cause the failure of the PBR but the EL Major-Cucapah main shock may have weakened the PBR.

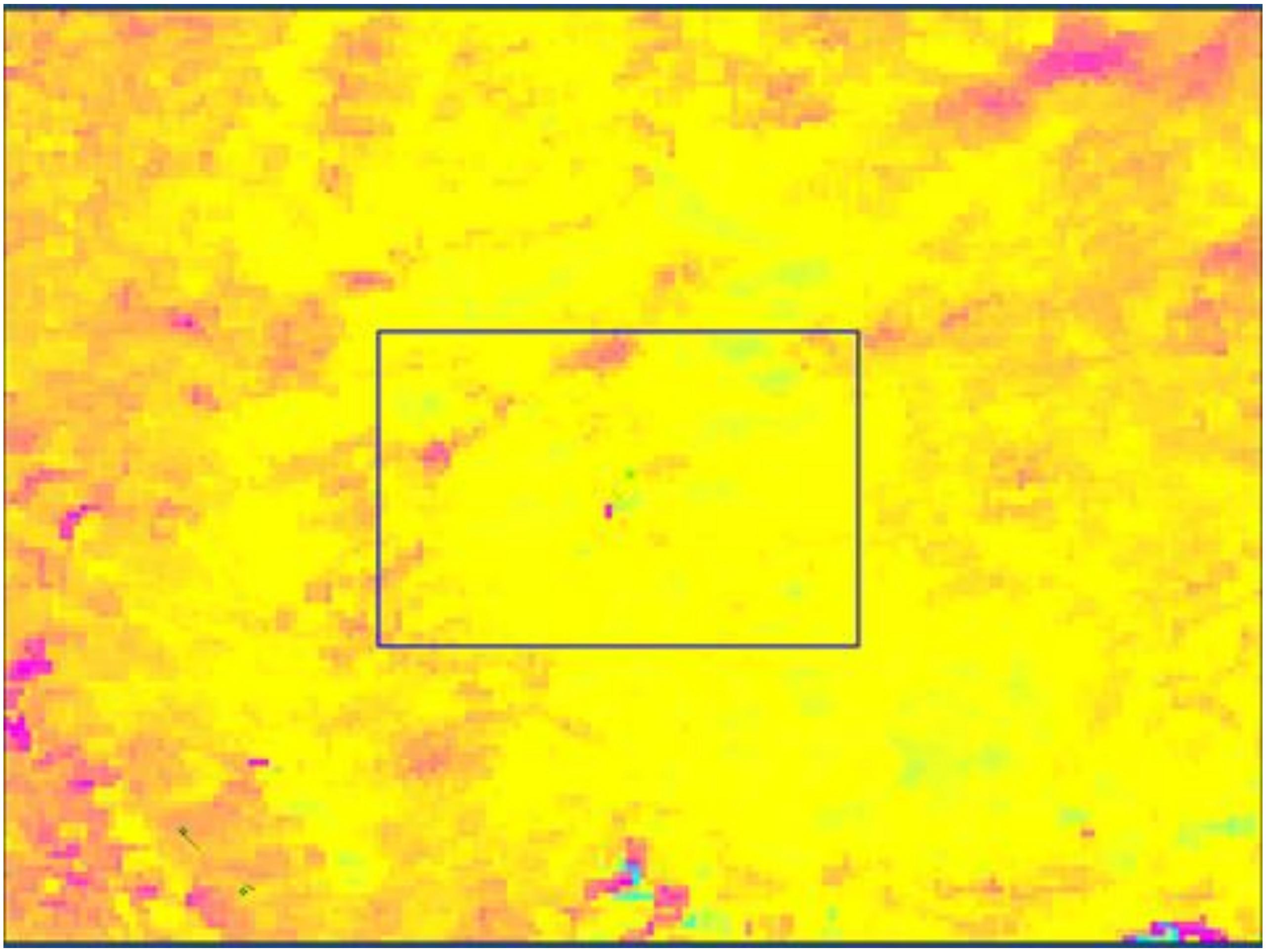
Slide 11. A Mw 5.7 aftershock(?) of the El Major-Cucapah Earthquake **(**Hauksson, et al., 2010) occurred on the 14th of June, 2010. It was only 6.5 miles from the rock fall. We believe this was the trigger for the rock fall. NASA photo.



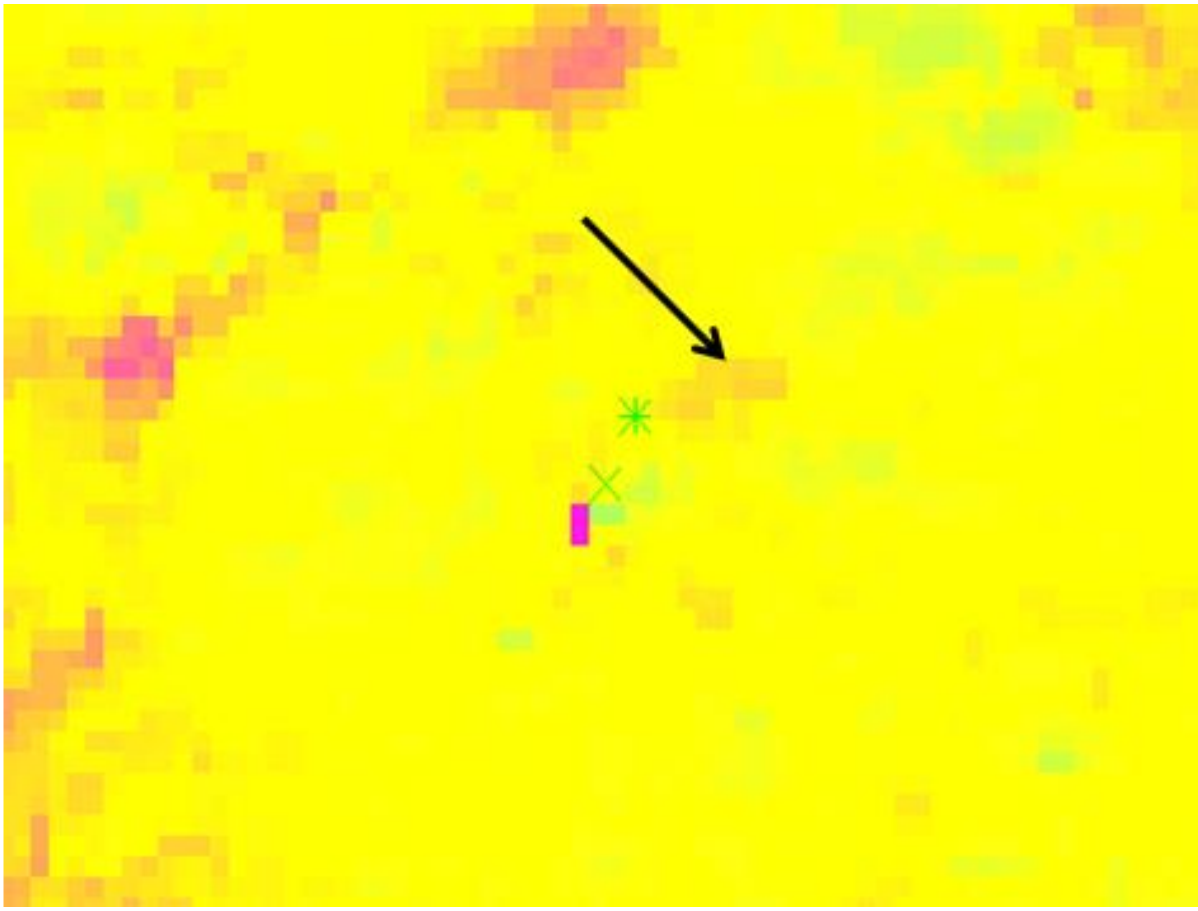
Slide 12. Jerry Treiman (2012) study the fault scarps north of the international border that were related to the El Major-Cucapah earthquake using interferograms. We asked him if he could see evidence of the rock fall. On an earlier interferogram he did not see the any evidence. But on the interferogram for April 13, 2010 to July 1, 2010 he could some evidence for the rock fall. This time interval brackets the June 14th aftershock. Jerry Treiman mapped faults at the top of the large box based on disturbed areas north and south of the faults. The disturbed areas are talus slope failures that delineate the crest of the ridge. The small blue box is the location of the rock fall. The disturbances in the southwest corner of the slide are slope failures in a gravel quarry.



Slide 13. The air photo of the area under the interferogram. **AC**- Alverson Canyon (Fossil Canyon). **PG-** Painted Gorge area.



Slide 13. Close up of the small blue box. Rock slide is in the center of the box.



Slide 14. Close up showing the rock slide. Red-brown rectangle in the center of the slide is the large block.

Some Conclusions.

Not all PBR are easily identifiable.

It may be difficult to correlate a rock fall to a particular seismic evert.

> There may have been an earlier seismic event that is associated with the rock fall.
>
> At least three seismic events are associated with this recent rock fall.

UAVSAR interferograms are helpful in identifying and timing rock falls.

Interferograms with more resolution would help with the identification of recent rock falls.

Thanks to: Jerry Treiman, John Prall, Bill Elliott, Mike Hart, Ann Bykerk-Kauffman, Thomas Zmudka, Gordon Gastil, Gary Axen, Larry Busch, Charles Winker, Jim Senn and the BLM, El Centro Office for a mapping permit.

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