A CRUSTAL-SCALE 3D GEOLOGICAL MODEL OF THE BUCKSKIN – HARCUVAR LOW-ANGLE NORMAL FAULT AND RELATED METAMORPHIC CORE COMPLEX STRUCTURES BASED ON SEISMIC REFLECTION PROFILES, WESTERN ARIZONA

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Introduction

Abstract

We created a three-dimensional model of the down-dip projection of the low-angle normal fault exposed in the Harcuvar and Buckskin metamorphic core complexes (MCC's) of western Arizona. The model is based on reprocessed and extend-correlated industry seismic reflection profiles obtained by CALCRUST in the 1980's, and was created using EarthVision software by Dynamic Graphics, Inc. Like other profiles in the highly extended terrane, these show distinctive reflection character domains in the crust that define parts of the metamorphic core complex system. The domains include a zone of high-amplitude, discontinuous reflections in the middle crust; dipping reflections at the top of the highly sheared low-angle normal fault (LANF) footwall; high-amplitude subhorizontal reflections in the LANF hanging wall called the Bagdad Reflection Sequence (BRS); a relatively transparent upper crust, and the Moho. A reflective lower crust is notably absent here, consistent with refraction data indicating granitic crust all the way to Moho. The LANF forms a regionally extensive "corrugated" or antiformal-synformal shape like that exposed in the MCC's and present beneath the valleys between them. The corrugation crests plunge northeast at about 15 degrees, and merge into mid-crustal reflectivity at about 18 km. The BRS projects to the surface in the Weaver Mountains, where it is exposed as Proterozoic mafic dikes that are tens to over a hundred meters thick, intruding Proterozoic granites. Reflectivity in the LANF lower plate mimics the mylonitic gneiss fabrics in the MCC's, and are tangential to and merge with the LANF reflections. We interpret the subhorizontal attitude of the BRS to indicate that the plunging LANF corrugations are a primary feature and indicate no rotation of the LANF upper plate during MCC development. Lower plate reflectivity suggests progressive extraction and freezing of mobile middle crust to the rising, tilting lower plate. The top of this reflectivity is the mylonitic front exposed in the Harcuvar MCC.

Location

The study area in western Arizona is in the highly extended terrain between the Basin and Range and Colorado Plateau geologic provinces between the towns of Prescott, Wickenburg, Congress, and Wickieup. The seismic reflection profiles are located down-dip from the surface expression of the Buckskin-Harcuvar low-angle normal fault in the metamorphic core complexes.

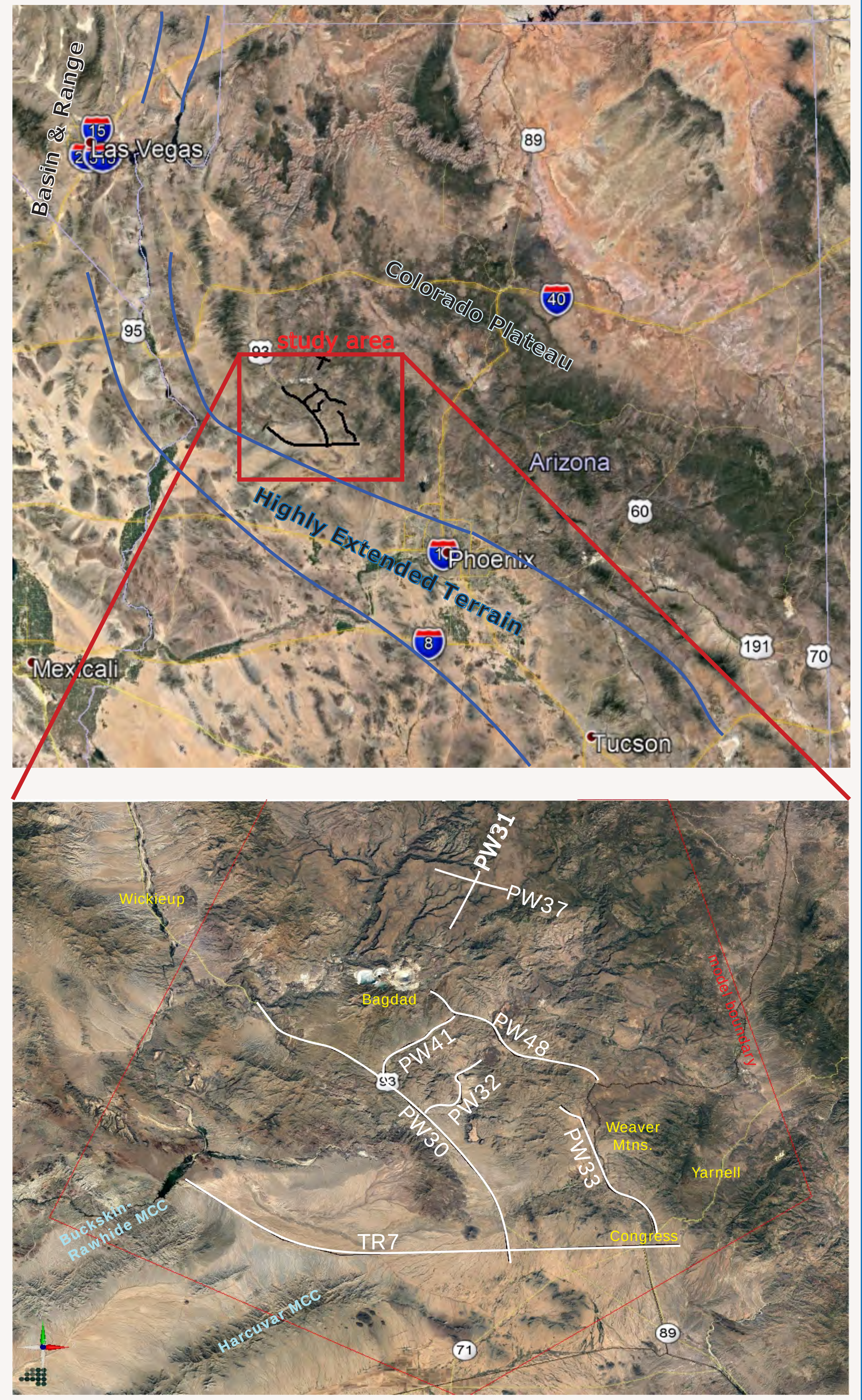

Figure 1. Location of the model area in the Basin & Range -- Colorado Plateau Transition Zone in western Arizona. The seismic profiles are labeled. MCC = metamorphic core complex.

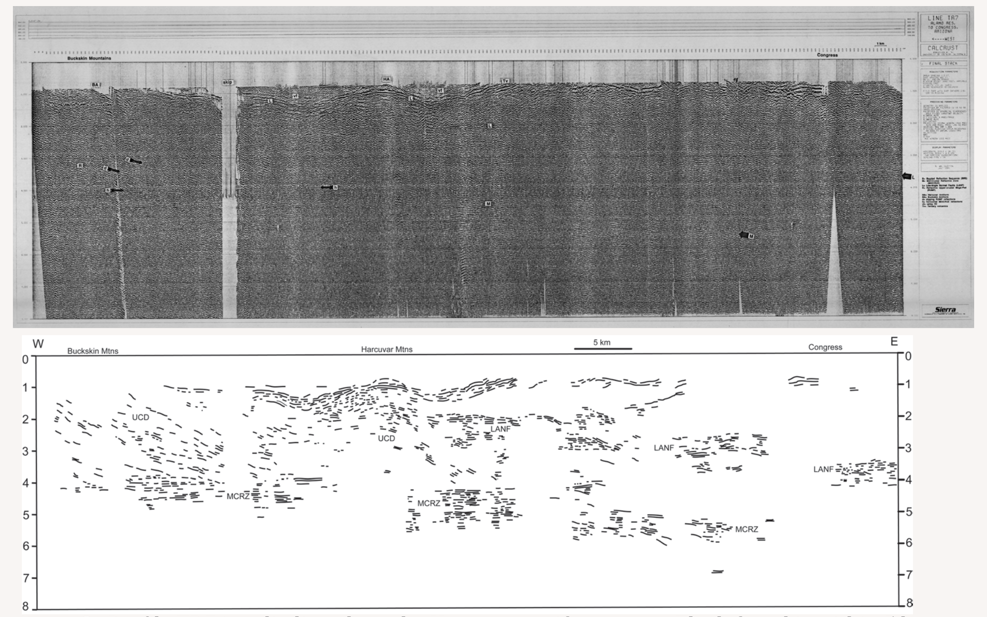

Figure 2. Profile TR7 is a dip line along the Harcuvar antiform crest. The left end is within 5 km of the LANF outcrop. The fault dips less than 15 degrees along this line. The upper crustal reflective zone beneath the fault projects to the mylonitic footwall in the Harcuvar MCC.

Based on regional seismic refraction data, crustal velocity here is 6 km/sec all the way to Moho, indicating a granitic crust (McCarthy & others, 1991). That translates to 3 km per 1 sec. TWTT.

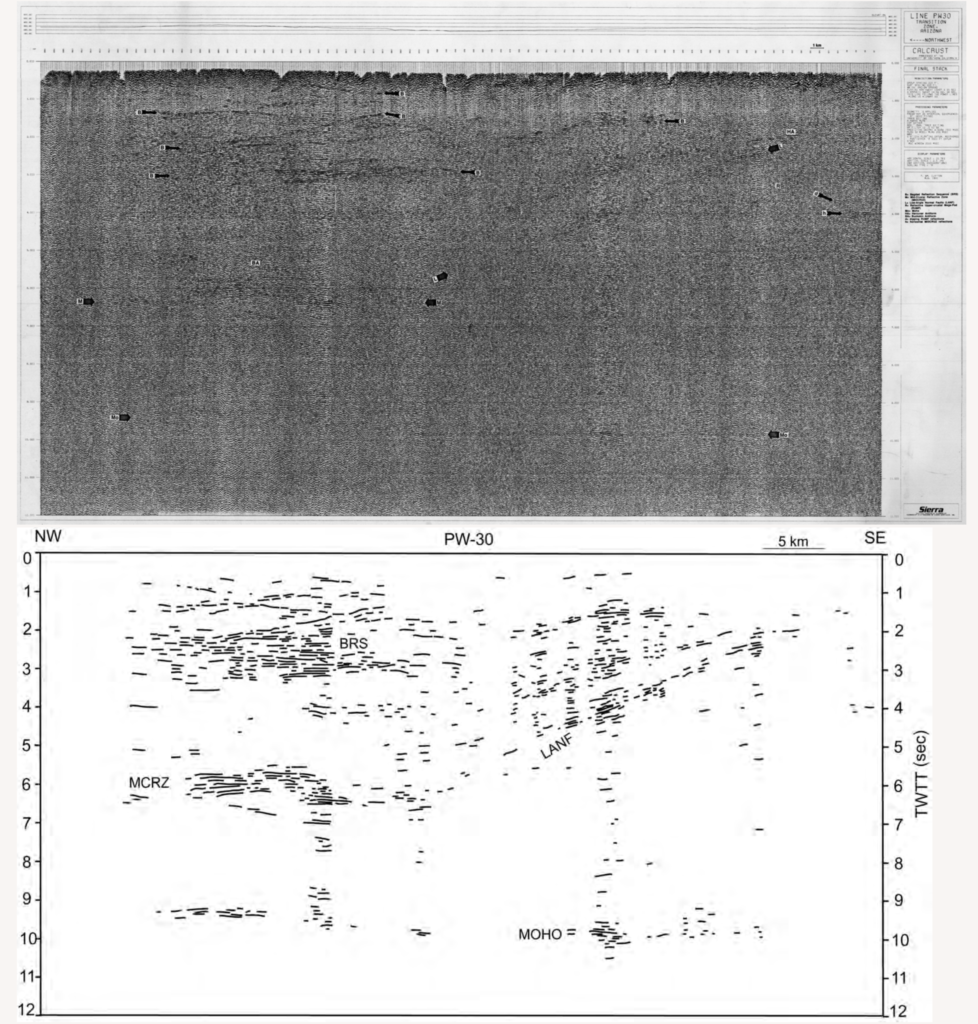

Figure 3. Profile PW30 is a strike line across the Harcuvar and Buckskin-Rawhide LANF corrugations. The high amplitude stacks of reflections in the upper crust are called the Bagdad Reflection Sequence (BRS), and they project to the surface at the Weaver Mountains, where we mapped a stack of subhorizontal mafic dikes up to 30 m thick. The dikes are spaced 100 to 150 m apart, and are dated as approx. 1.7 Ga (unpublished data) in host granites dated as 1.4 to 1.7 Ga. Synthetic seismic modeling of the dikes shows they are a close match to BRS reflections. The subhorizontal attitude of the BRS indicates a lack of tilting in the LANF upper plate, which indicates that the shallow dip of the LANF (~15 degrees) is primary. The LANF is imaged as a dipping band of discontinuous reflections. The Moho is imaged as distinct, discontinuous reflections at 27-33 km depth, shallowing toward the NW.

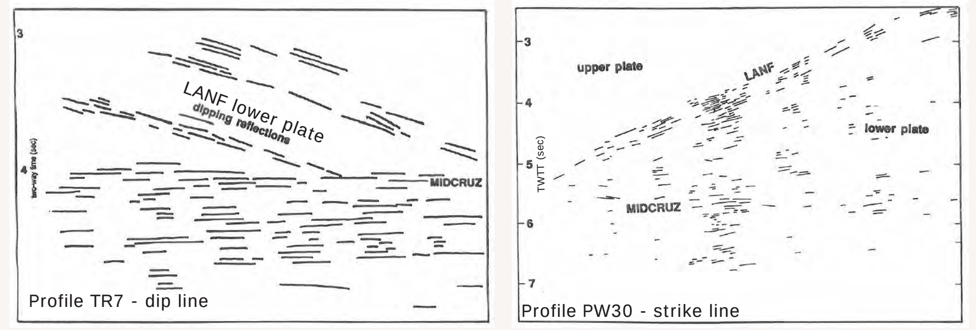

Figure 4. The reflection profiles show a zone of high-amplitude, discontinuous reflections in the middle crust (MIDCRUZ) at 4 sec TWTT (12 km) under the core complexes, and deepening to 6 sec TWTT (18 km) under the Transition Zone. The MIDCRUZ has been interpreted as distributed shear fabrics. It is present throughout the Basin and Range province, but is most distinctive under the highly extended terrane of metamorphic core complexes. The MIDCRUZ truncates dipping reflections under the MCC's (upper crustal reflective zone, UCRZ). We interpret the UCRZ dipping reflections as mylonitic fabrics that were progressively uplifted and "frozen" during displacement along the LANF.

Modeling Methods

We used EarthVision software by Dynamic Graphics, Inc. for geologic modeling. It includes outstanding features like minimum-tension gridding that realistically represent geologic surfaces, useful data manipulation tools, versatile & simple visualization capabilities, powerful workflow management, and intelligent algorithms for creating geologic features like unconformities, pinch-outs, and channel fill.

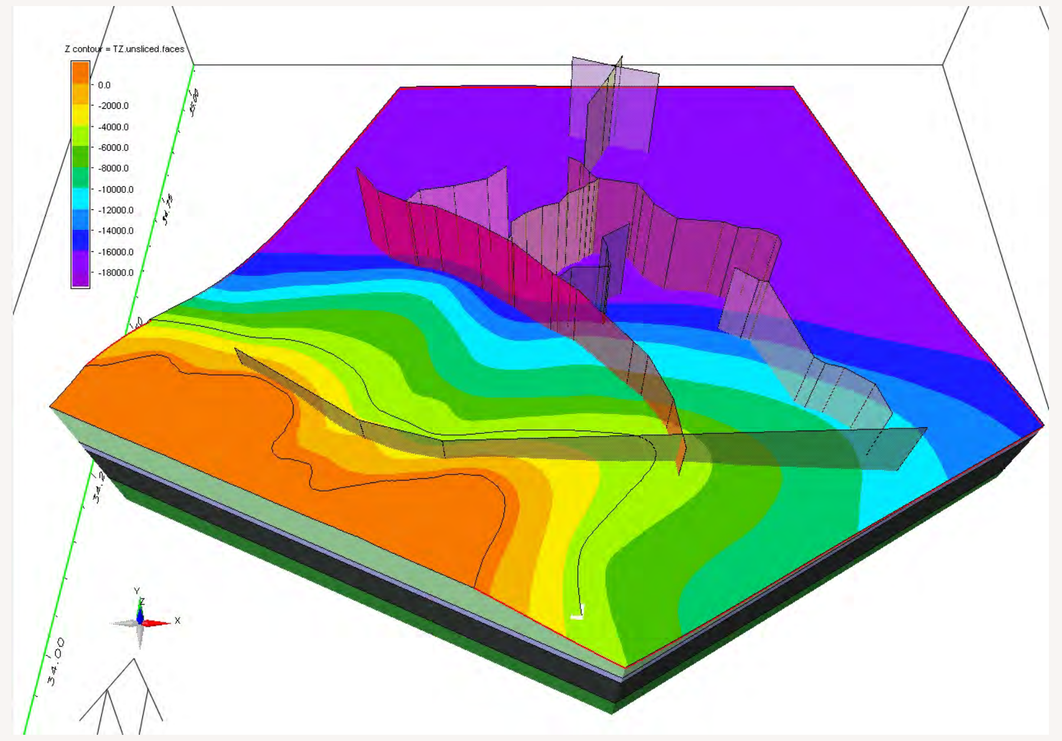

Figure 5. This northward oblique view shows the reflection profiles as fences, and the LANF color contoured by depth in meters. The model input consisted of depth-converted points along each of the seismic profiles. In this area, the crust has constant velocity of 6 km/sec to Moho, so that 1 second TWTT equals 3 km.

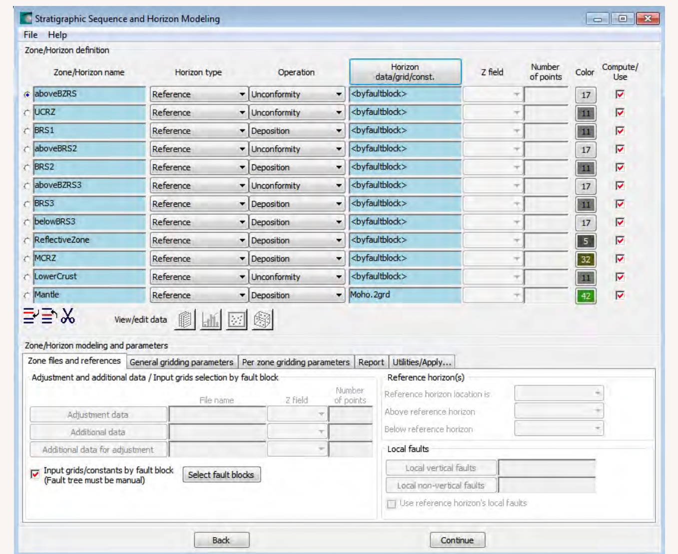

Figure 6. To create the model, we defined the stratigraphic column shown here. The Bagdad Reflection Sequence (BRS) is defined in three levels, similar to its most prominent expression in the seismic profiles. A set of lenses were defined in each level to represent mafic intrusions (subhorizontal dikes) as exposed in the Weaver Mountains. EarthVision allowed definition of an unconformity at the base of each intrusion level to truncate them. UCRZ = upper crustal reflective zone in the LANF footwall under the core complexes. MCRZ = mid-crustal reflective zone.

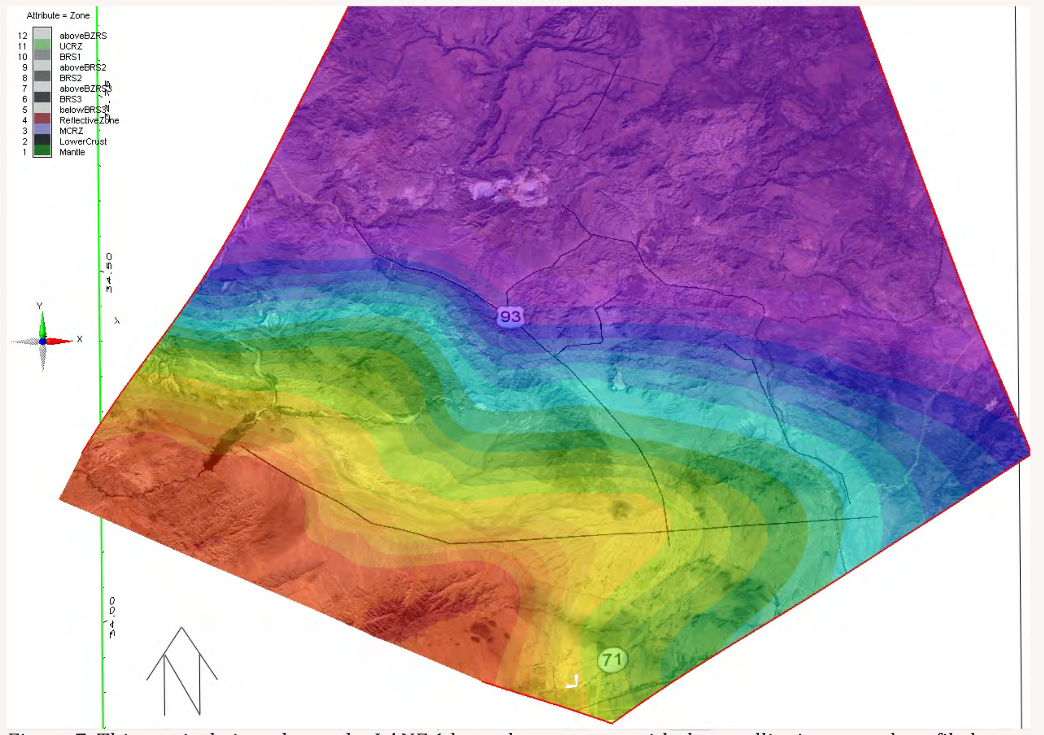

Figure 7. This vertical view shows the LANF 1 km color contours with the satellite image and profile locations shown with transparency. [This kind of visualization is always easier to understand on screen.]

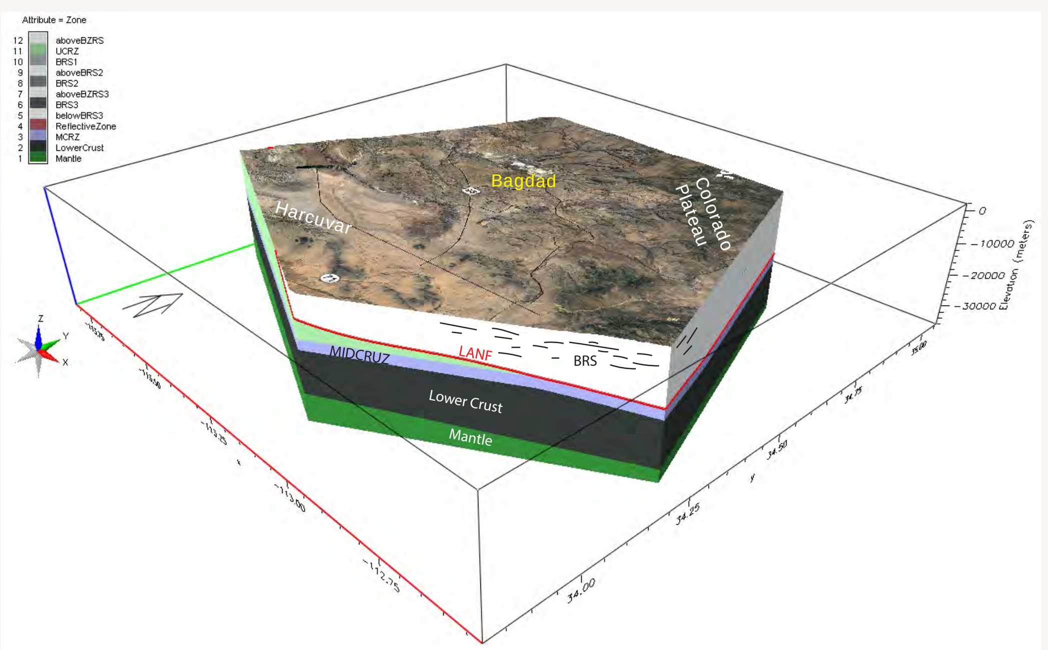

Figure 8. View to the NW of the total model. The front surface is a dip-section along the Harcuvar LANF antiformal crest. Seismic profiles are shown on the satellite image at the surface.

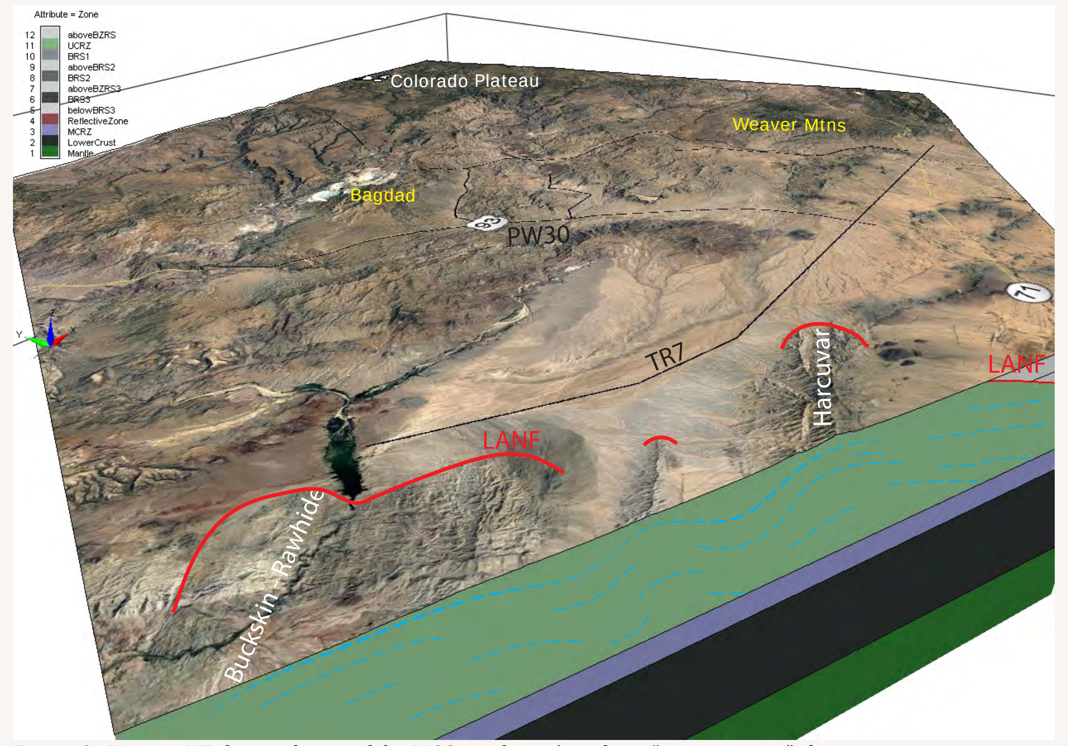

Figure 9. View to NE down-plunge of the MCC antiform / synform "corrugations," showing approximate locations of the LANF in red. The blue lines represent reflections in the LANF footwall, which mimic the LANF corrugations and are truncated below by the subhorizontal MIDCRUZ. At its west end, seismic Profile TR7 is a strike line within 5 km of LANF outcrop. The rest of its length is a dip section along the Harcuvar antiform. The mafic subhorizontal dikes responsible for the Bagdad Reflection Sequence (BRS) are exposed in the Weaver Mountains.

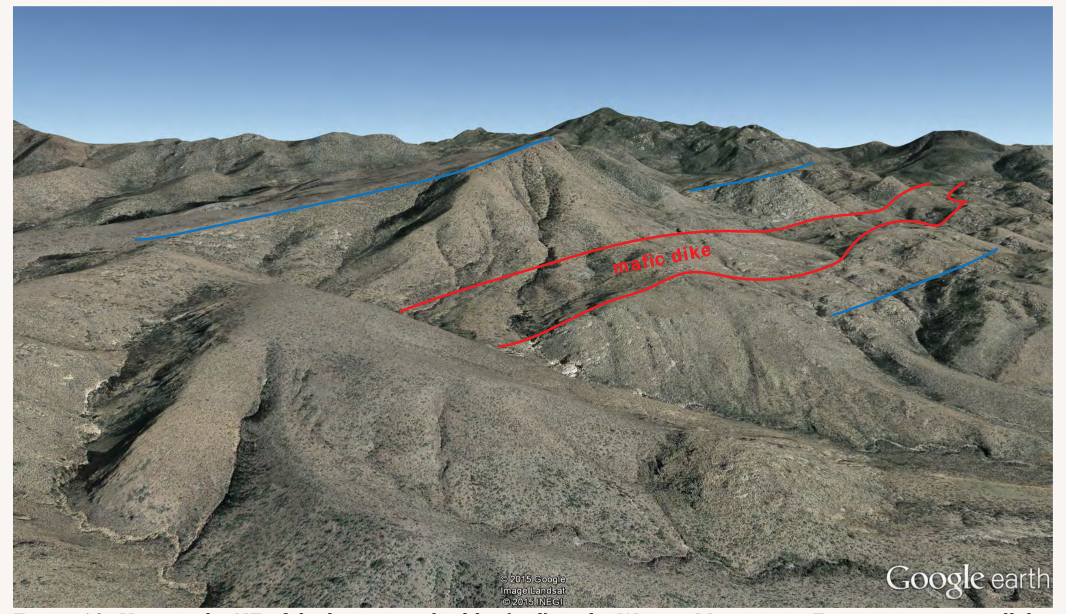

Figure 10. View to the NE of the largest mafic dike (red) in the Weaver Mountains. Fracture zones parallel to the dike are in blue, and often contain mafic dikes. These dikes project northwestward into the subsurface in the seismic profiles where the BRS is strongest. The dike was dated by K-Ar methods as about 1.7 Ga (unpublished data). The host rock is 1.4 to 1.7 Ga granite.

Results

The geometries of the low-angle normal fault (detachment fault; LANF), mid-crustal reflective zone (MICRUZ), Moho, and the Bagdad Reflection Sequence (BRS) provide important constraints on models of metamorphic core complex development.

The LANF consists of antiforms and synforms ("corrugations") that plunge northeast and sole into a zone of horizontal reflectivity at 18 km depth under the Transition Zone. The corrugations are expressed at the surface as the metamorphic core complexes and the bedrock beneath intervening valleys. Overall topographic expression of the LANF footwall is, therefore, neither high nor low relative to topography in the area.

A subhorizontal zone of reflectivity interpreted as being caused by shear fabrics underlies the MCC's in the middle crust (MIDCRUZ), and merges with the LANF to deepen to 18 km under the Transition Zone, where its reflectivity fades.

The Moho deepens from about 27 km under the MCC's to about 33 km under the Transition Zone. It shows no indication of bowing, flexing, or faulting.

The subhorizontal attitude of the BRS, its Proterozoic age, and its location in the hanging wall of the LANF indicate that the hanging wall did not rotate during development of the metamorphic core complexes. This indicates that the shallow dip of the LANF and its corrugated shape are primary features.

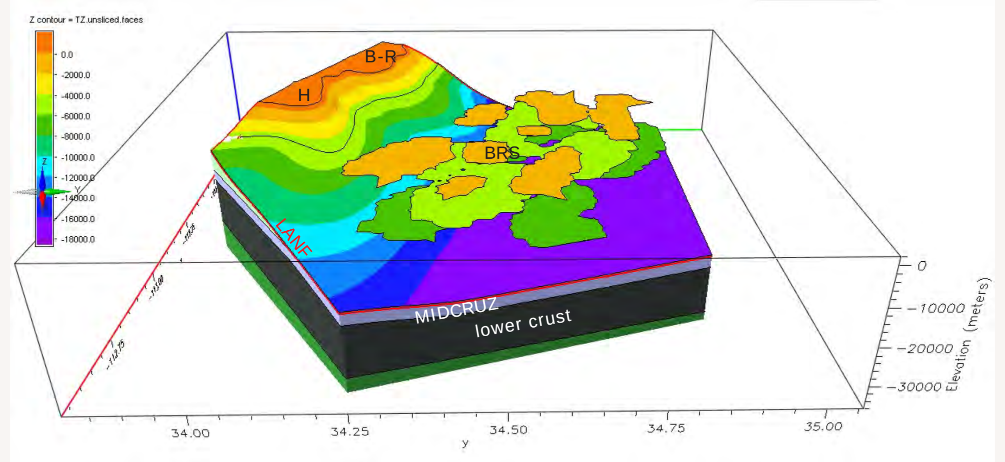

Figure 11. View to the west showing color contours on the LANF and Bagdad Reflection Sequence (BRS).

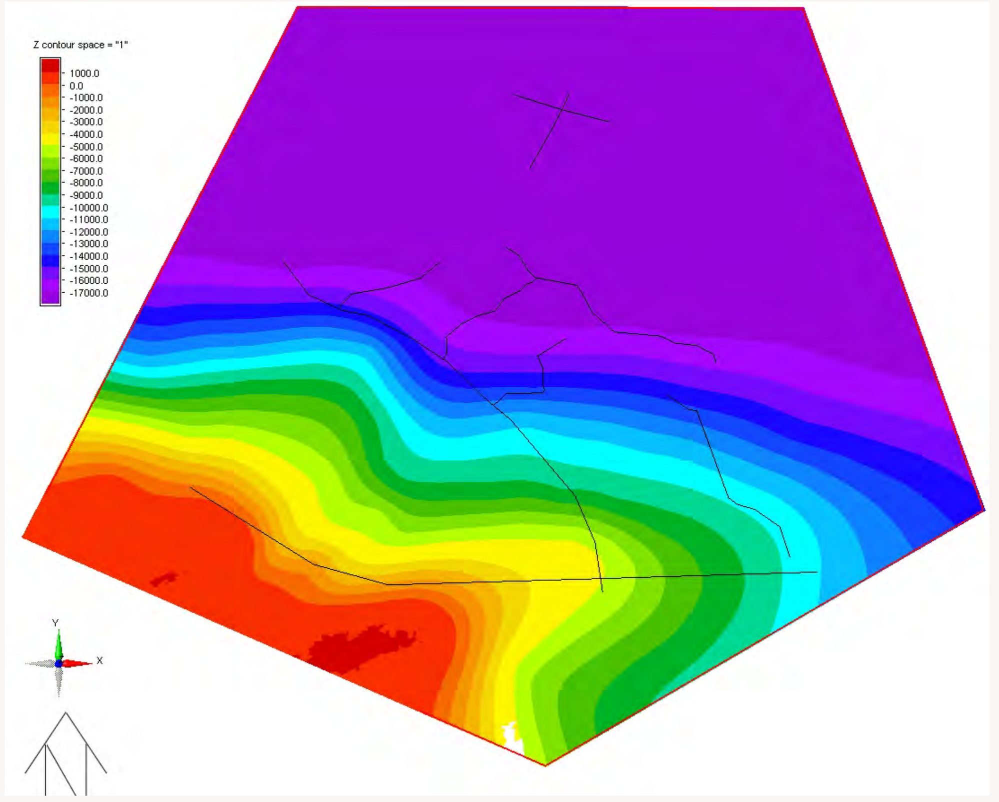

Figure 12. Vertical view of contours on the LANF. Contour interval is 1 km. Seismic profiles are shown as black lines.

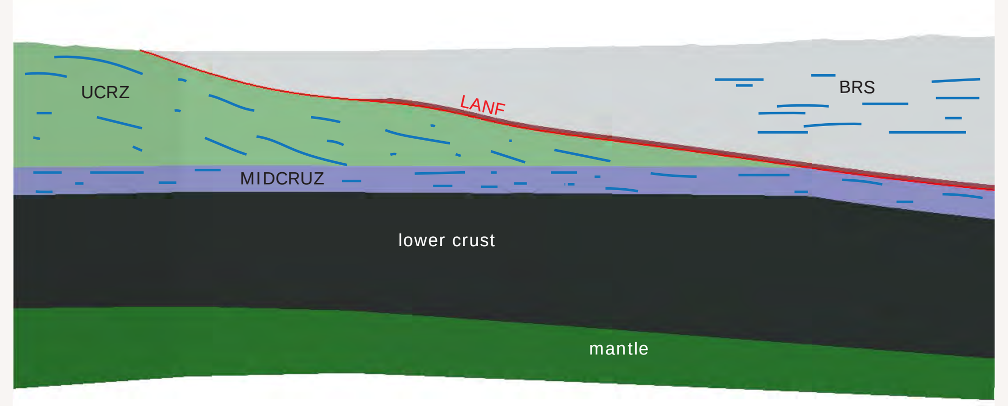

Figure 13. Dip section along the Harcuvar antiform on the LANF.

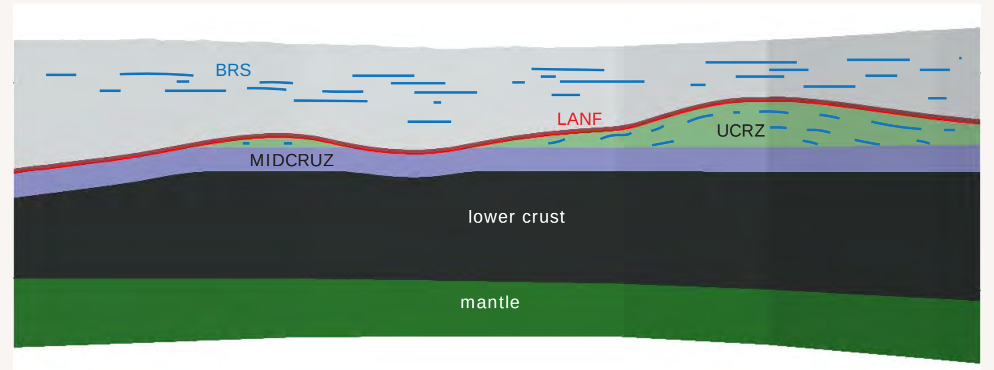

Figure 14. Strike section of the LANF (red), showing the Buckskin-Rawhide (left) and Harcuvar (right) antiforms.

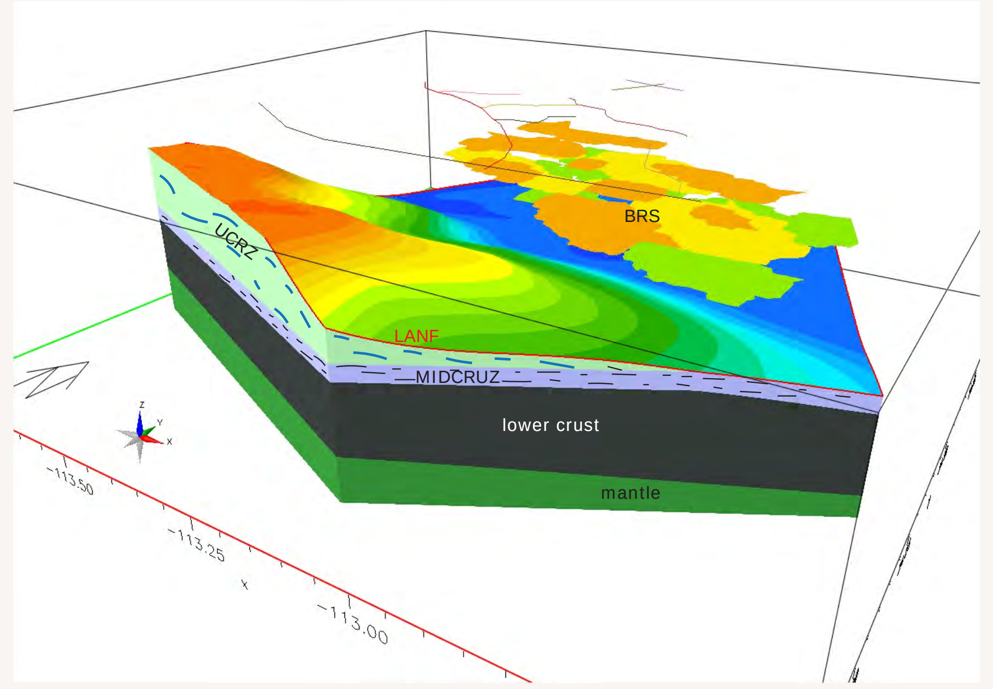

Figure 15. View to NW of the LANF lower plate with the Bagdad Reflection Sequence above it.

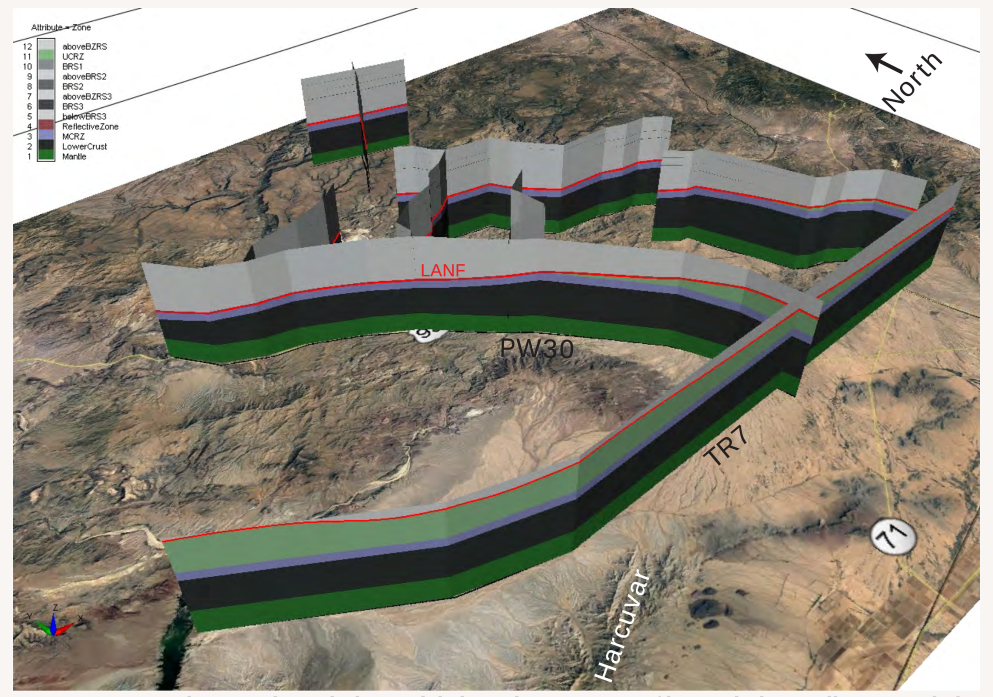

Figure 16. Fence diagram through the model along the seismic profiles, with the satellite image below.

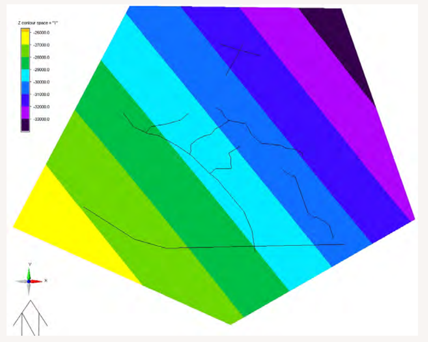

Figure 17. Color contours on the Moho. Contour interval is 1 km. Seismic profiles are shown as black lines.

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References

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McCarthy, J., S.P. Larkin, G.S. Fuis, R.W. Simpson, and K.A. Howard, 1991, Anatomy of a metamorphic core complex: seismic refraction and wide-angle reflection profileing in southeastern California and western Arizona: JGR 96, 12259-12291.