Tectonic Deformation of a Lacustrine Mudstone at Soda Lake Geothermal Field Using OpendTect™ Visualization*

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Abstract

The transition between the two structural regimes of the Walker Lane and the Basin and Range allows for complex transtensional fault interactions (Faulds et al., 2005). NW-trending dextral shear in the Walker Lane and WNW extension in the northern Great Basin imparts enhanced extension and pull-apart basins that bring about structural controls for geothermal systems (Faulds and Henry, 2008). The Carson Sink is the surface expression of this complex interaction of shear and extensional forces that cause crustal block rotation (Faulds et al., 2007). This study investigates this tectonic shift in the Carson Sink using the fault offset of a paleo-planar lacustrine mudstone in 3D seismic at the Soda Lake Geothermal Field. With few mapped intrabasin faults, this gives a unique view into fault offsets inside this basin.

The 3D-3C reflection seismic survey is over an area of 34 sq km (13 sq mi) with 8374 source points and 3001 receivers. The design provides 17 m (55 ft) bins and high fold (~40) in the 600 by 1200 m (2000 ft by 4000 ft) area of geothermal interest. The source is alternating sets of three 28,000 kg (62,000 lb) vibrator trucks doing two sixteen second, 8-72 Hz sweeps per source point.

A sandstone/mudstone package is a strong and the most expansive reflector in this survey, appearing from 0.2 to 0.3 seconds, at an approximate depth of ±240 m (800 ft). The interpreted mudstone reflectors illuminate a fault map of recent active tectonics in this basin (Figure 1). This unit consists of shale, mudstone, and fine sand that formed in a deep lacustrine environment (Sibbett, 1979). Recent Pleistocene Lake Lahontan sediments only account for about 120 m (400 ft) of basin-fill deposition (Morrison, 1964); therefore, this mudstone must be from an older highstand or lake. Assuming the environment of deep-lake sediments, this unit was deposited in a paleo-planar orientation. Therefore, fault offsets of this unit demonstrate post-depositional structural deformation of the Soda Lake Geothermal Gield (Echols et al., 2011). Using well logs and cores to tie this horizon to depth, the deformation in this unit should yield direct evidence of regional strain during the Quaternary, or possibly even the Pliocene, depending on the uncertain age of this unit.

The seismic volume was interpreted in OpendTect®. Multiple steps were taken according to specialized workflows to facilitate the interpretation of faults and horizons in this volume. First a dip-steered volume was produced to allow for the processing of attributes to steer according to the structural dip of the reflectors. A median filter applied to the volume reduced noise spikes and preserved reflector trends.

Similarity attributes show reflector offset in the volume to get a non-interpreted fault map along the Z-plane (Figure 2). To give a sharper contrast at the fault, reflector amplitudes were migrated toward areas of lower similarity using a diffusion filter. Using this fault-enhanced volume assisted in the interpretation of the surface of the mudstone horizon and the faults that offset reflectors above and below the unit.

Faults and horizons provide the interpreted structural data along this paleo-planar mudstone in the seismic volume. The faults are assumed to be planar in orientation. A minimum of 6m of vertical offset in the mudstone is used to delineate faults because it is a quarter of the wavelength of the dominant frequency of the mudstone reflector. The fault patterns show en echelon fault steps, large left bends, and some antithetic striking faults. The vertical offset and dip of the faults are calculated along a cross-section located perpendicular to faulting. If the horizontal offset of all the faults is individually totaled, the offset is calculated at 96m (315 ft) across 5.4km (3.4 mi) yielding 1.8% as a value for extension across the survey.

The horizon map of the mudstone has a relative low point in the accommodation zone that accompanies the left-bending fault and is bound to the north by the east-striking antithetic faults (Figure 1). This accommodation zone coincides with the most productive part of the geothermal field. Along the east side of the survey there is a horst or half-graben structural feature that creates a ridge in the mudstone horizon striking north-south. A structural ramp between the major faults on the east side indicates the possible structural interpretation of a step-over zone if there is a lack of strike-slip motion, or a pull-apart basin if there is dextral motion along these faults (Figure 1). Without a piercing point along these faults, there is no way to determine the degree of oblique slip.

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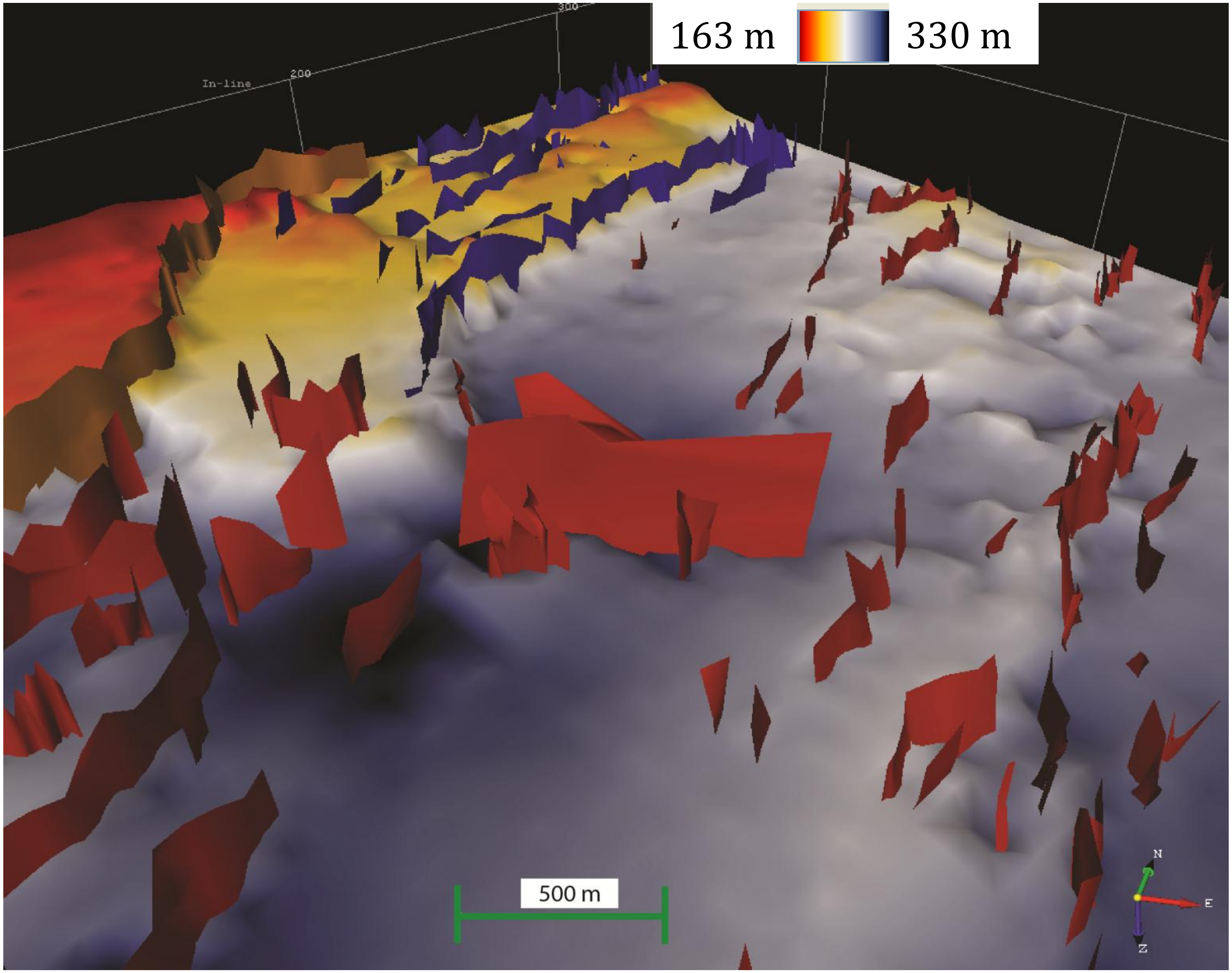

Figure 1. Topographical map of the mudstone horizon with depth ranges indicated. The production and accommodation zone is south of the east-striking faults. The structural ramp is shown on the west side of the image. Color is used just to differentiate zones of faulting across the field.

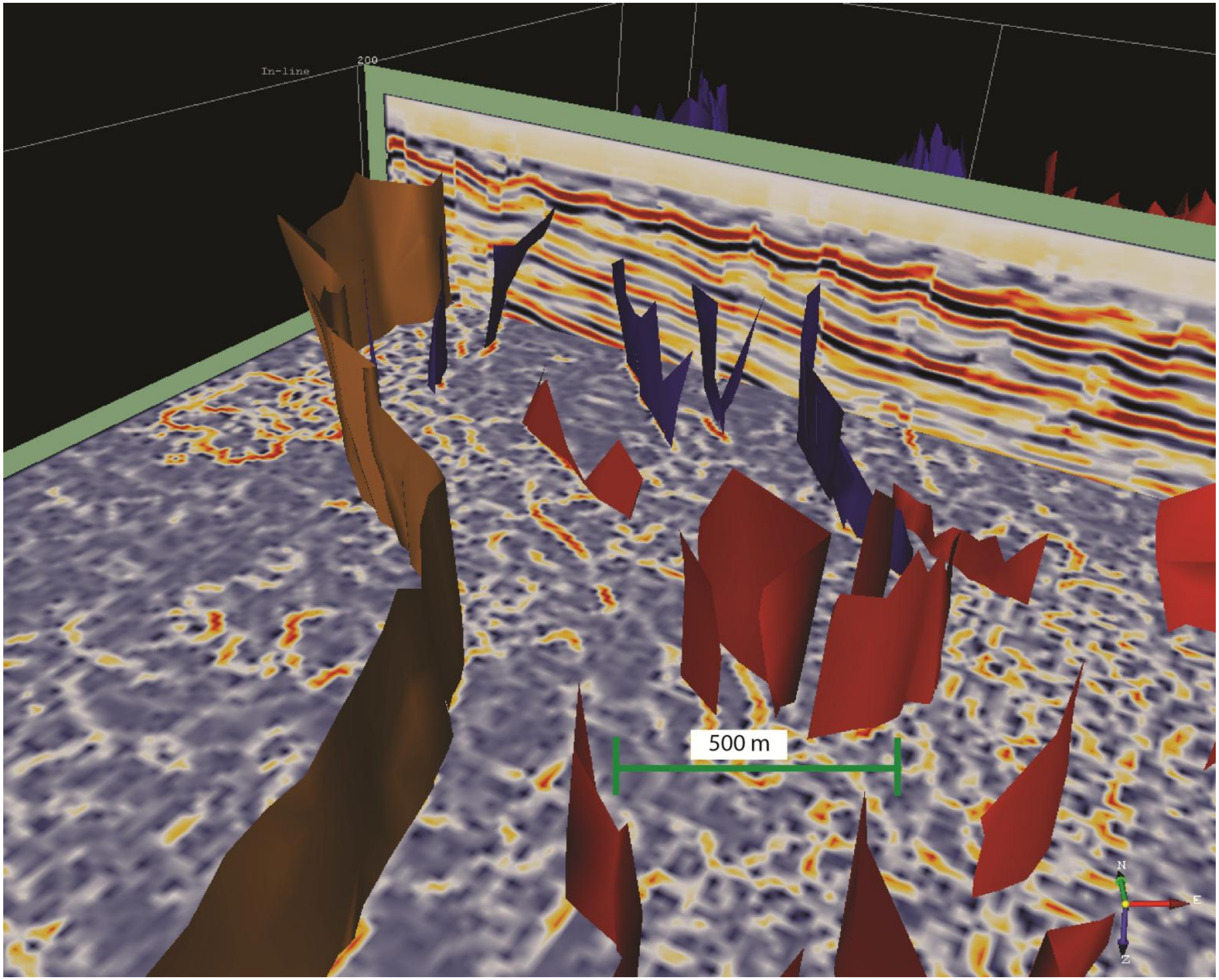

Figure 2. Picked faults are sticking out of a Z-plane image of the similarity attribute at 290 m (950 ft) depth. A crossline illustrates the fault-enhanced seismic volume. Color is used just to differentiate zones of faulting across the field.