Apparent and Actual Strain Variation in the Monterey and Sisquoc Formations, Southern Santa Maria Basin, California: Implication for Cross-Section Construction and Reservoir Characterization

Abstract: Balanced cross-sections test geometric and kinematic models of fold and thrust belts, unravel their deformational histories, and define structural traps for petroleum prospects in basin exploration at map scales, generally less than 1:24,000. Yet, these sections have limitations because (1) they assume constant bed thickness in the reconstruction and (2) they do not account for important mechanical behaviors and strain variation at more detailed scales that may affect geometric and kinematic interpretations, reservoir characterization, and hydrocarbon production. This study quantifies and analyzes the variation of strain at map-scale and outcrop-scale of the diagenetically distinct siliceous sedimentary and deformed rocks of the Monterey and Sisquoc formations in the Lompoc - Santa Rosa (LSR) fold belt, southern Santa Maria basin, California. Advantages in comparing the Monterey and Sisquoc formations are: (1) both units were deposited during the Miocene to early Pliocene just prior to regional contraction, (2) diagenetic modification allows strain quantification of rocks with high competence contrasts including opal-A diatomites, opal-CT chests and porcelanites, and quartz phase rocks at map-scale and outcrop-scale, and (3) numerous surface exposures over 150 km2 in the LSR fold belt. Detailed line-length section balancing at map-scale shows significant strain variation along strike with shortening values ranging from 5.5 % to 21.1 %, variation in the axial lengths of folds ranging from 0.5 km to 12 km, and in fold amplitudes and interlimb angles ranging from 135°to 55°. Apparent shortening in the thin-bedded and mechanically contrasting Monterey Formation is twice as high as in the overlying, thick-bedded, and mechanically homogeneous and highly porous Sisquoc Formation, suggesting that the same amount of actual strain was accommodated by tight folding and faulting in the brittle diagenetic rocks of the Monterey, but by compaction and broad, open folding in the diatomaceous Sisquoc Formation. Strain analysis at outcrop-scale along well exposed transects shows that sub map-scale structures contribute up to an additional 8 %shortening to the map-scale folds. Outcrop folds are commonly parasitic Z- and S-type folds along the limbs of map-scale structures and their shear direction suggests that the observed outcrop-scale deformation is coeval with the map-scale folding. Evidence for significant decoupling of the thin-bedded Monterey Formation

occurs along several intraformational detachment horizons that separate fold structures at outcrop-scale. At map-scale, a balanced cross-section presents a tectonic wedge-model that ties shortening in the Monterey Formation to deeper convergent structures via slip along larger thrusts. Significant differences in strain and structural style of the LSR fold belt along strike were observed and measured at various scales and in rocks of contrasting composition and competence. These observations have implications for geometric, kinematic, and mechanical interpretations of fold and thrust belts, improved cross-section construction, and may greatly improve reservoir characterization.

Biography: Yannick Wirtz is currently working as a graduate research assistant while completing his MS program in Geology at California State University (CSU), Long Beach with the goal to finish this summer. He completed his BS degree in Applied Geology at RWTH Aachen University of Technology in Germany. Yannick originally came to California in the spring of 2011 to go surfing and to conduct climate research at UC Irvine as part of his BS degree thesis. He then went on to work for Earth Consultants International, a geologic consulting firm based in Santa Ana, CA. At Earth Consultants he gained experience in southern California geology and engineering geology practice. He assisted in data collection, processing, plotting, and interpretation of sonic drilling borehole data for the design of a transit tunnel across an active fault during which he learned the critical issues for engineering geological analysis. In Fall 2013, Yannick began work on an MS program in geology at CSU Long Beach where he works with the Monterey and Related Sediments (MARS) research group, an industry affiliates program on the Monterey Formation incorporating field methods, structural geology, sedimentology, and tectonics in his research. His research project was sponsored by generous grants from AAPG, GSA, and the MARS industry affiliates. Yannick was on the CSU Long Beach team at the 2014 AAPG Imperial Barrel Award competition where he and his colleagues utilized petroleum industry software, and an understanding of petroleum systems to analyze the prospectivity of a frontier region and present their findings and recommendations to a panel of industry experts. He has been active in professional societies throughout his academic career and presented at several science symposiums at CSU Long Beach, the National GSA Conference in Baltimore (2015), Pacific Section AAPG conferences (2014, 2015), and the Tectonic Studies Group conference in London (2016).