Investigating Layer Parallel Diagenetic Shortening Using Field Data, Thin Section Analysis, and Analog Models*

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Abstract

Layer parallel shortening (LPS) is deformation that occurs in a compressive stress regime parallel to bedding, including both mechanical and chemical changes. Typically, this deformation is not incorporated into cross-section restoration, although an amount of bulk shortening can be calculated, because the amount and timing of increments of shortening is unknown. Previous research indicates that omitting this deformation can lead to error in palinspastic reconstructions and subsurface predictions up to 20%. A better understanding of when and where LPS deformation is accommodated can improve predictions important to the hydrocarbon industry such as fluid flow trajectories, trap volume, trap location, porosity and permeability. To address this issue, a combination of field measurements and thin section analysis calculated the amount of LPS across the central Colorado Front Range (CFR) system. Though the overarching goal of the research is to locate where and when LPS is accommodated during a deformation sequence, this contribution focuses on how much LPS is taken up by processes such as compaction and pressure solution. A transect of measurements across the central CFR was recorded, including attitude of foliations, bedding, fault planes, and stylolitic surfaces. Trend and plunge measurements of fold hinges and mineral lineations along fault planes were also recorded. Relative stylolite frequencies and fracture patterns were studied to assess variation in mechanical and chemical properties. Layer parallel structural diagenesis was assessed from these data as well as on the micro scale by examining directional grain dissolution and diagenetic histories in thin section. Analog sandbox models, scaled to be representative of the CFR, were deformed incrementally in accordance with Colorado's well-constrained tectonic history. Field data were compared to the model to test the robustness and applicability of the field measurements. Preliminary results indicate that layer parallel deformation occurs at the onset of each tectonic event before discrete structures are formed. LPS can be estimated at outcrop and precise calculations from thin section measurements corroborate the field data. These calculated LPS amounts fall within previously reported ranges. Whilst these results are specific to the CFR, a set of best practice recommendations, applicable to the general case, can be applied to future geomechanical models and cross-sections.
I. Introduction

Layer parallel shortening (LPS) is deformation that occurs in a compressive stress regime parallel to bedding. This includes both thin-skinned, low-angle normal faults, like other events, as they are transmitted great distances to up to 1250 kilometers from the active plate margin (Creedcock & van den Pluijm, 1999). Typically this deformation is not incorporated into cross-section restoration because, though an amount of back shortening can be calculated in this process, the amount and timing of shortening increments are unknown. Though the geometric goal of the research is to locate where and when LPS deformation is accommodated, this deformation is not taken up by processes such as compressional and lateral shortening or using both the field and analog approaches. Initial results indicate that the deformation can be real in palaeostructural reconstructions and back-stress based predictions up to 20%. A better understanding of when and where LPS deformation is accommodated can improve predictions supported to the hydrocarbon industry such as deep navigation, trap volume, location, polarity, and permeability.

II. Field Data

A benefit of thin-section measurements across the central Colorado Front Range was recorded, including altitude of formations, bedding, fault planes, and stratigraphic surfaces. Trend and plunge measurements of fold geometries and mineral lineations along fault planes were measured. Relative strain frequencies and fracture patterns were studied to assess variation in mechanical and chemical properties.

III. Thin Sections

Hand samples taken from the field also assessed layer parallel structural diagenesis at the central Colorado Front Range and cross-section orientations so up-down is compaction and left-right is LPS, as before. A. Location map showing where the thin section’s hand sample was collected. B. Photograph of sandbox analog model cross-section. a. Original sandbox dimensions are shown. b. Outlines of some layer parallel structural diagenesis across the central Colorado Front Range system. c. Restored section showing the sandstone breached and red. These calculated LPS amounts fall within previously reported range (see Table 2). While these results are consistent with the previous models, new models of the Precambrian-Cretaceous boundary, the Precambrian-Cretaceous boundary modified from Orton (1986), and a modified Precambrian-Cretaceous boundary modified from Orton (1986).

IV. Analog Modeling

Analog sandbox models, scaled to be representative of the Colorado Front Range, were deformed incrementally in accordance with Colorado Front Range strain data. Profiles of the cross-sections range from 2 to a total of 17.55% bulk shortening. These calculated LPS amounts fall within previously reported ranges (see Table 2). While these results are consistent with the previous models, new models of the Precambrian-Cretaceous boundary, the Precambrian-Cretaceous boundary modified from Orton (1986), and a modified Precambrian-Cretaceous boundary modified from Orton (1986).

V. Implications and Future Work

Previous research indicates that omitting this deformation can lead to error in palaeostructural reconstructions and back-stress based predictions up to 20%. A better understanding of when and where LPS deformation is accommodated can improve predictions supported to the hydrocarbon industry such as deep navigation, trap volume, location, polarity, and permeability.

VI. References Cited and Acknowledgements

[Further text on references and acknowledgements would be included here]