

Effects of Basement Structure, Sedimentation and Erosion on Thrust Wedge Geometry: An Example from the Quebec Appalachians and Analogue Models

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Summary

The Taconian fold and thrust belt of the Quebec Appalachians displays typical structures such as inverted normal faults, ramp and flat structures, sub-horizontal detachments, triangle zones and backthrusts. The development of these structures is not, however, consistent along the belt and seems to be spatially related to variations in palaeotopography and stratigraphic architecture of the Middle-Late Ordovician foreland basin, which developed in front of the Taconian tectonic wedge. A triangle zone is bounded by backthrusts at the southeastern limb of the Chambly-Fortieville syncline and by imbricate faults of the thrust wedge parautochthonous units. The triangle zone pinches out to the northeast as the basement shallows. Re-interpretation of reflection seismic lines shows that there is a link between structural geometry of the thrust belt and depth to basement and the presence of pre-existing basement structures. A 40°-50° deflection of frontal thrusts relative to the general SW-NE strike of the orogen occurs against an oblique, deep-seated basement escarpment.

Thrust systems developed above irregular basement structures and affected by syn-tectonic sedimentation and erosion were studied by analogue sandbox modelling. Sand layers were constructed with a décollement level; step-like escarpments were introduced in model basement oriented either parallel or oblique to the general transport direction. Basement depth variations in models influenced the geometry of thrust wedges. Deflection of frontal thrusts and lateral thrust

expansion across the transverse zone were observed above the deeper-seated basement in the models with no erosion and no sedimentation. Syntectonic sedimentation induced forward propagation of flat detachments, resulting in the formation of a piggy-back basin. The 3D-geometry of frontal detachments was strongly influenced by pre-existing basement structures. Syntectonic erosion and sedimentation affected the thrust wedge kinematics, with development of a series of backthrusts and/or triangle zones. These structures developed above the deeper-seated basement and pinched out towards basement highs. Our modelling results and geological data support the pre-existing basement structure, syntectonic sedimentation and erosion could be responsible for the development of triangle zones and frontal thrust deflection in the Quebec Appalachians.

Introduction

Foreland basins and foreland fold and thrust belts are a significant source of hydrocarbons. Recent drill results from the St. Lawrence Lowlands offer encouragement for future gas exploration in the Ordovician Trenton-Black River hydrothermal dolomites (Seifert, 2007; Smith, 2007).

The Taconian fold and thrust belt of the Quebec Appalachians displays typical structures such as inverted normal faults, ramp and flat structures, sub-horizontal detachments, triangle zones and backthrusts. The development of these structures is not, however, consistent along the belt and seems to be spatially related to variations in palaeotopography and stratigraphic architecture of the Middle-Late Ordovician foreland basin, which developed in front of the Taconian tectonic wedge.

The effects of basement structure, sedimentation and erosion on thrust wedge geometry are studied by geological analysis of the Quebec Appalachians and by analogue sand-box modelling.

Theory and/or Method

Fieldwork and structural analysis were carried out within the St. Lawrence platform in the area of Quebec City. Stratigraphic correlations based on surface data and well-log analysis were made to determine the geometry of stratigraphic bodies of the platform. Re-interpretation of seismic lines was undertaken to define the structural style of the platform. The correlation of seismic lines and drill well data was accomplished using synthetic seismograms to identify key stratigraphic horizons.

Analogue sandbox modelling was used to study thrust systems developed above irregular basement structures and affected by syn-tectonic sedimentation and erosion in order to better understand factors controlling the formation of structures in the study area. Sand layers were constructed with a décollement level and step-like escarpments were introduced in model basement oriented either parallel or oblique to the general transport direction. Basement depth variations in models influenced the geometry of thrust wedges.

Examples

Geological data. A triangle zone is bounded by backthrusts at the southeastern limb of the Chambly-Fortieville syncline and by imbricate faults of the thrust wedge parautochthonous units (Fig. 1). The triangle zone pinches out to the northeast as the basement shallows. Re-interpretation of reflection seismic lines shows that there is a link between structural geometry of the thrust belt and depth to basement and the presence of pre-existing basement structures.

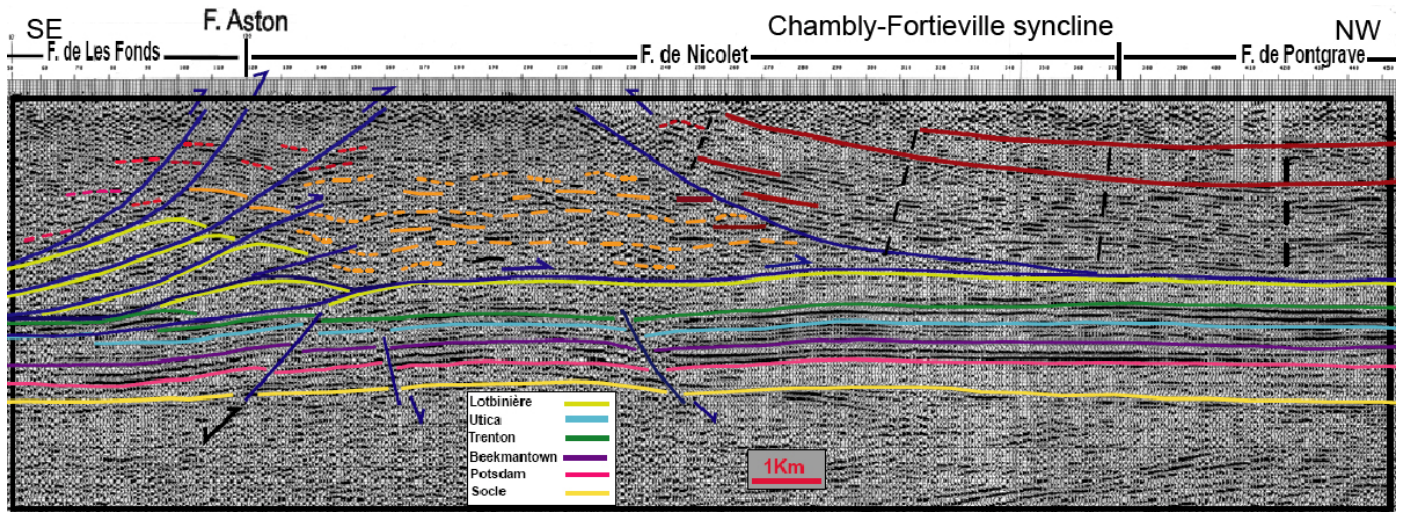


Figure1: Structural interpretation of the seismic line 78-825 across the Chambly-Fortieville syncline, after (Rodriguez, 2007)

A 40°-50° deflection of frontal thrusts relative to the general SW-NE strike of the orogen occurs against an oblique, deep-seated basement escarpment.

Modelling results. (i) Through shortening, frontal thrusts were obliquely deflected, propagating far forward in the thicker part of models due to larger fault spacing and greater wedge thickening above the deeper-seated basement. Thrusts affecting the thicker part of models were progressively expanded over the thinner part with emplacement of late nappes across a transverse zone.

(ii) Syntectonic sedimentation induced forward propagation of flat detachments, resulting in the formation of a piggy-back basin (Fig. 2). The 3D-geometry of frontal detachments was strongly influenced by pre-existing basement structures. The presence of an oblique basement escarpment in front of the growing wedge induced a 50°-60° deflection of frontal detachments with respect to the general strike of the thrust wedge.

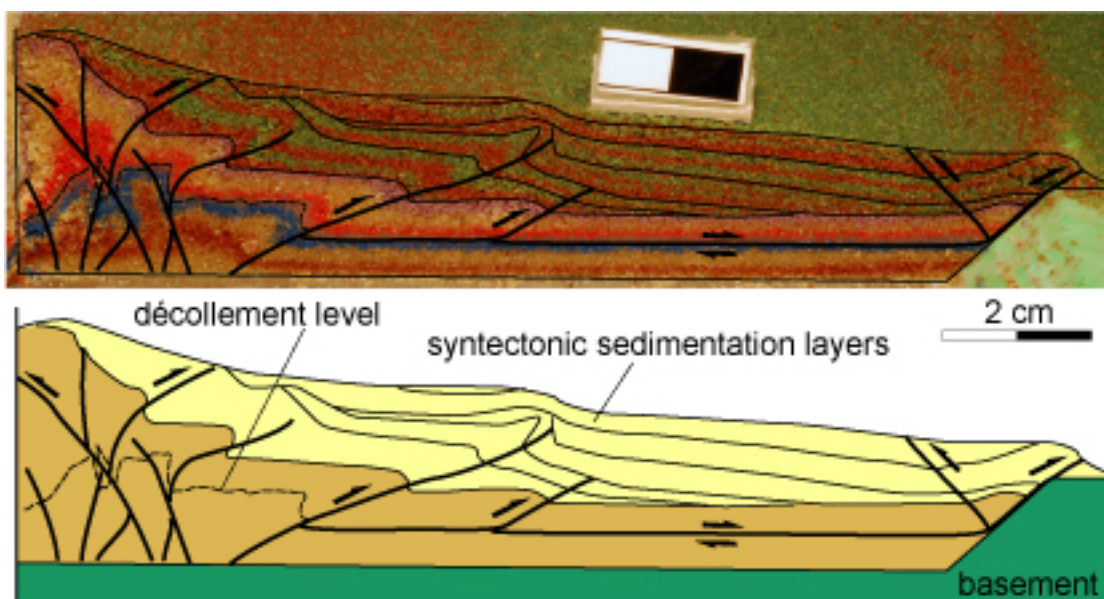


Figure2: Cross-section across the sand-box model (upper section) and its interpretation (lower section).

(iii) Syntectonic erosion and sedimentation affected the thrust wedge kinematics, with development of a series of backthrusts and/or triangle zones. These structures developed above the deeper-seated basement and pinched out towards basement highs.

Conclusions

Our modelling results and geological data support the pre-existing basement structure, syntectonic sedimentation and erosion could be responsible for the development of triangle zones and frontal thrust deflection in the Quebec Appalachians.

Acknowledgements

Research was funded by NSERC, CFI, MELS, and INRS-ETE.

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