The Quantitative Modelling of the Northern Williston Basin: the McKenzie Lithospheric Stretching Model Approach

Oluseyi Olajide[1] and Stephen L. Bend[1]

[1]University of Regina, Regina, SK, Canada

Abstract

The application of McKenzie lithospheric stretching theory as applied to the modelling of the evolution of the Williston Basin has been a subject of debate over the years. The key arguments for and against the McKenzie lithospheric stretching assessment and its application to the evolution of intracratonic basins are reviewed in this comparative and assessment study vis-à-vis some observed crustal and derived data within the Williston Basin. McKenzie's methodology was used to model the distribution of stretch factors thereby facilitating the calculation of the amount of crustal thinning. Given that the determination of erosional thickness and paleobathymetry constitute one of the most challenging aspects facing geomodellers engaged in building burial history curves, McKenzie's derived paleobathymetry and exhumation solutions was applied to a data matrix comprised of 38 wells within the northern part of the Williston Basin. Paleobathymetry and exhumation results derived from the McKenzie solutions were compared to available data from other methods and sources.

This study produced a number of significant results. Firstly, our modelled crustal stretch factors (βcrust) agree with the CONCRUST refraction seismic data that indicates between 3km to 4km crustal thinning within the northern Williston Basin. Secondly, McKenzie's derived paleobathymetry data concur with available and published biostratigraphic data, permitting the creation of a series of paleobathymetry maps for selected stratigraphic units (Early Turonian Upper Colorado Second White Specks formation and the Upper Devonian/Lower Mississippian Lower and Upper Bakken Shale members). Results also show that paleobathymetry values vary systematically across the basin helping to refine the onset of deposition and basin initiation. Results also concur with widely held belief that the maximum water depth for the Bakken was approximately 250m while the Second White Specks had a maximum depositional water depth of 160m in the Saskatchewan portion of the Williston Basin. Thirdly, exhumation maps reveal trends in erosional magnitude within the northern part of the Williston Basin: Mid Ordovician and Sub Devonian erosion show a NW-SE trend, NE-SW trend characterizes Sub-Jurassic and Sub-Cretaceous erosion. The Sub Triassic erosion shows a transition between NW-SE and NE-SW erosional trends.

The Successful application of McKenzie's lithospheric stretching solutions within the Williston Basin indicates that subsidence was not linear and uplift prior to the initiation of the basin subsidence was not necessary. This assessment also demonstrates the successful application of the McKenzie methodology in an intracratonic basin without block rifting. Results also satisfactorily compare with observed crustal, lithostratigraphic and biostratigraphic data, thereby justifying the applicability of McKenzie's lithospheric stretching model to modelling the evolution of the Williston Basin.