Integrated Approach for Basin Modelling of the Gaspé Belt (Québec, Canada)*

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Abstract

The development of new prospects for oil and gas exploration will rely on our ability to detect reservoirs in complex settings. In compressive tectonics, many difficulties are encountered for a reliable application of techniques like 3D seismic imaging, structural restoration and basin modelling. In this context, the determination of the accurate geometrical features remains a challenge, even at basin scale. The main obstacles obviously come from the building of a current and past structural model. For basin modelling, the numerical description of this model must be consistent with the simulator grid parameterization. To develop new solutions and software, a methodological project based on real case studies is proposed (Jardin et al., 2007). Our approach integrates geophysical and geological data and techniques for a reliable determination of complex structures before basin modelling application. The Gaspé Belt example will illustrate the benefits of this approach for the limitation of geological ambiguities and for the building of a coherent model. This model will then be used to improve the 2D modelling of the HC generation timing performed to validate new prospective zones.

Integrated Seismic and Geological Method

The Gaspé Peninsula is located in the Québec part of the Northern Appalachians and the objectives of recent studies are to better determine the architecture and the structural style of the Acadian fold belt (Kirkwood et al., 2004). Regional northeast-trending open and upright folds dominate the Gaspé Belt, with major east-northeast to east-trending dextral strike-slip faults. Major faults either border (e.g. the Shickshock Sud fault) or cut across (e.g. the Grand Pabos fault) the three main structural zones (Figure 1 and Figure 2).

The integrated approach is applied across the central part of the peninsula taken into account the 2D seismic lines 2001-MRN-10a and 2001-MRN-10b and surface data from geological field work. A depth seismic imaging study using pre-stack depth migration processing is performed in order to both improve the quality and the time to depth conversion of seismic profiles (Bêche et al., 2007). Then the interpretation of the main structural features e.g. faults, folds, and thrust events can be directly carried out on the depth-migrated seismic images. Geophysical information is then integrated into complex structural modelling to build the geological model at current time (Figure 1) (Jardin et al., 2006).

Building of a 2D Kinematic Coherent Model

The second step of structural modelling is to perform the kinematic restoration. The geometrical consistencies of the subsurface are ensured by the cross-section balancing using Locace® software based on the interpretation of the depth seismic cross-section and on the knowledge on regional geology. This step is complicated by the fact that the Gaspé belt is constituted by two imbricate fold and thrust belts (from Taconian and Acadian orogenies). It is possible to accurately balance the syncline structure of the Connecticut Valley-Gaspé Synclinorium (CVGS – Figure 1 and Figure 2) due to the Acadian and Salinic pulsation tectonic phases. With the restoration technique, it is possible to accurately evaluate the erosion during this tectonic phase to improve the kinematic modeling.

It is more difficult to retrieve the detailed geometry of the structures during the Taconian orogeny in the past geological times and especially to estimate the timing of the erosion phases. Then, for the petroleum system evaluation step, we will use the balanced structural model determined by kinematic restoration for the formations of the Lac des Huit-Miles Syncline, a part of the Connecticut Valley-Gaspé Synclinorium and of the Causapscal anticline. The validation of kinematic model is important in complex structure as Gaspé Belt to understand the geodynamic evolution, which is next used for the petroleum system evaluation step.

Modelling of Source Rock Maturity and HC Generation and Expulsion

The hydrocarbon potential of the Gaspé Peninsula is mostly restricted to the Late Ordovician to Early Devonian rocks of the Gaspé Belt. This region presents favourable signs indicating the presence of an active petroleum system, even if the geological context seems to be not in favour of hydrocarbon reservoirs. Most of the Silurian-Devonian rock succession in the northeastern part of the Peninsula is within the oil and gas window and potential reservoir rock units include clastic rocks as well as fractured limestones (Kirkwood et al., 2004).

Temis2® software technique is applied on the central part of the study zone where a piggyback basin is developed during the Acadian orogeny and presents a relatively simply structure allowing the use of Temis2D.

Using the results from structural interpretation of the 2D seismic line 2001-MRN-10b and from geochemical data from neighbour well and rock samples, it is possible with Temis2D to predict the pressure regime through time, the maturity of the source rock, and the HC generation and expulsion.

Conclusion

In the Gaspé belt case study, the depth seismic imaging has led us to improve depth seismic images by integrating the a priori geological information in the seismic processing. The cross section balancing has led us to build a coherent evolution of the basin through time and to estimate the reliability of the geological interpretation. This kinematic scenario was used to complete the understanding of the geodynamic evolution of the Gaspé Belt and provided a new geometry more favourable to the existence of petroleum system. The reliable structural model was introduced in the basin modelling study. This work represents the 2D phase of the 3D basin modelling study of the Gaspé Belt: the ongoing project concerns the extension from 2D to 3D kinematic restoration using Kine3D® software and the development of QC process for 3D basin modelling in any structural settings (Jardin et al., 2007).

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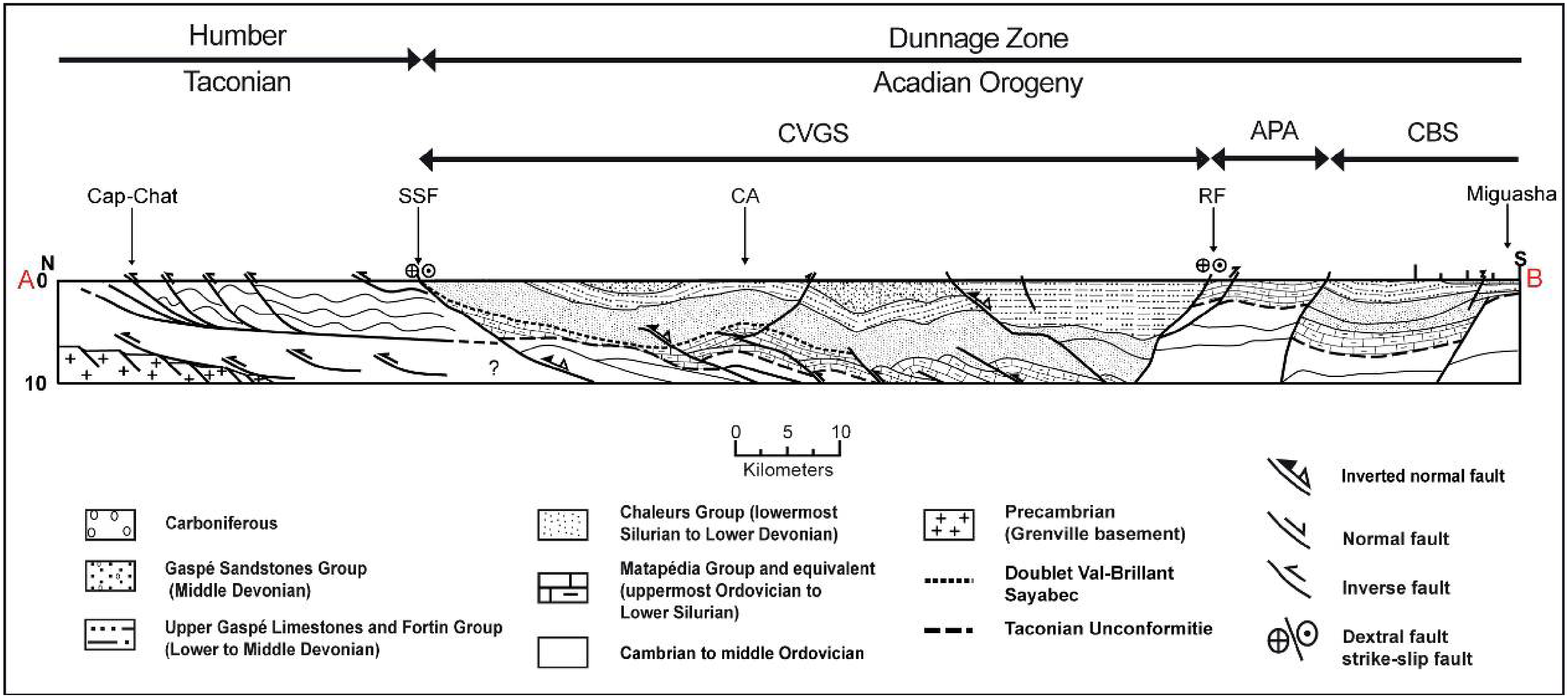

Figure 1. Structural interpretation through the Gaspé Peninsula (cross-section A-B), CVGS: Connecticut Valley-Gaspé Synclinorium; APA: Aroostook-Percé Anticlinorium; CBS: Chaleurs Bay Synclinorium; SSF: Shickshock Sud Fault; CA: Causapscal Anticline; RF: Restigouche Fault.

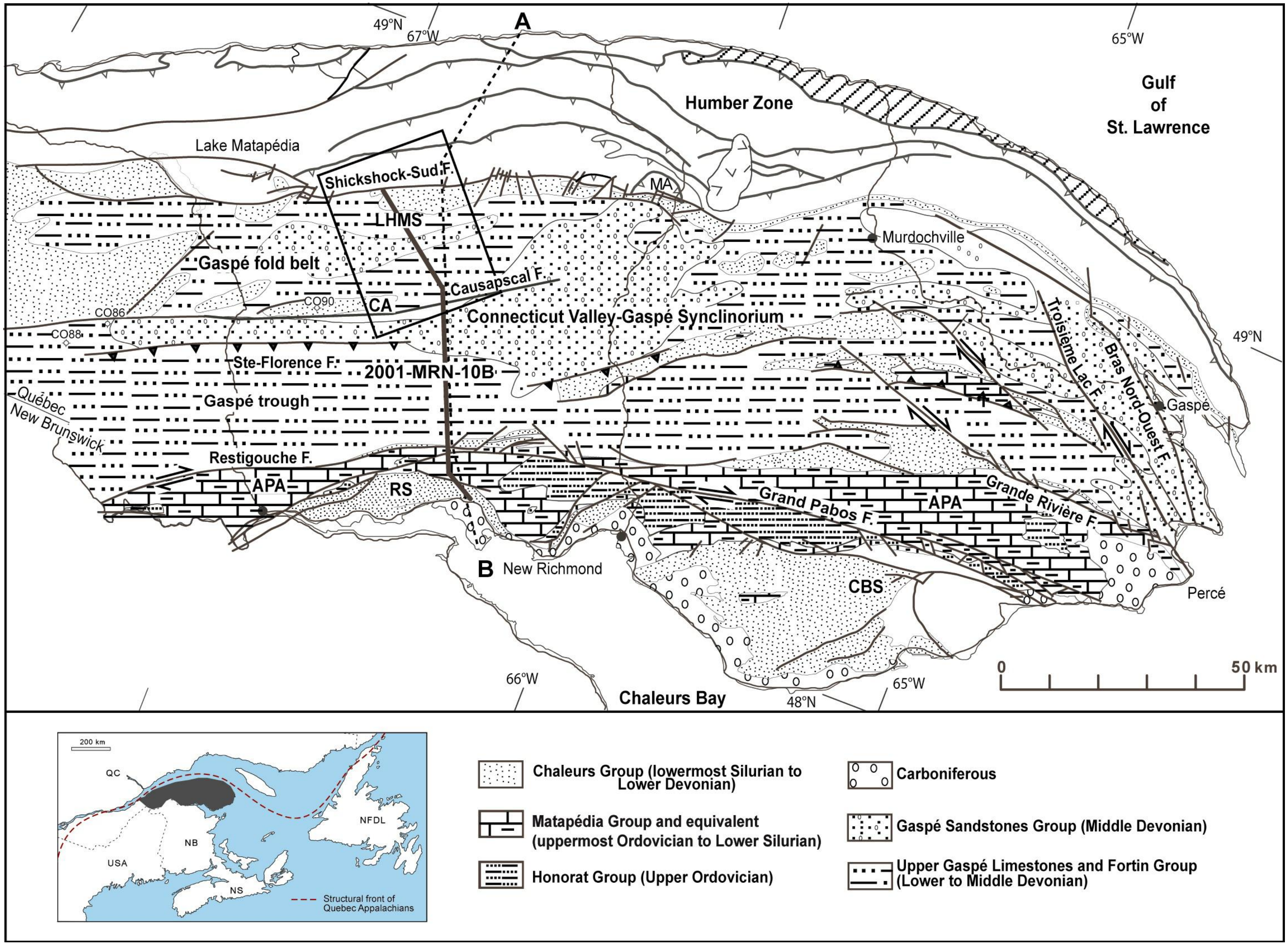

Figure 2. Simplified geological map of Gaspé Peninsula, northern Appalachians (Canada). Modified from Kirkwood et al. (2004). Note location of the seismic lines 2001-MRN-10A & B, and the study area for HC generation in the boxed zone. Transect AB: cross section shown on Figure 1.