Thermal Impact of Salt: Simulation of Thermal Anomalies in the Gulf of Mexico
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Abstract—Salt and related structures have played important roles in controlling hydrocarbon accumulations in the Gulf of Mexico. Using a two-dimensional fluid flow/compaction model, which allows for both conduction and convection of heat, an examination is given of the effects on thermal patterns of the combined influence of multiple salt features, including diapirs, pillows, sheets and wedges. The focusing and defocusing of heat due to the higher thermal conductivity of salt are accounted for in the modeling. The results show that there could be as much as a $30^\circ$C anomaly above multi-salt bodies due to the focusing of heat by salt, and as much as $50^\circ$C temperature contrast between internal salt positions and sediments external to the salt in the deep part of a section. The magnitude of the thermal anomaly depends on the size (or width) of the salt and on the depth of the rooted salt. The modeled results provide estimates of the influence of salt in expanding the oil generation window by approximately half of the salt thickness.

Key words: Salt, thermal anomaly, Gulf of Mexico.

Introduction

Salt and related structures have played important roles in sedimentary basins for hydrocarbon accumulations (O'BRIEN and LERCHE, 1988). Several properties of salt have made it unique in various aspects. The thermal effect of salt is one of the aspects which we address here.

Salt has a thermal conductivity 2–3 times greater than that of typical sedimentary rocks (LERCHE and O'BRIEN, 1987). So salt bodies in the subsurface act as conduits for heat transport vertically or horizontally. When salt bodies occur in massive diapirs (sheets) with large vertical (horizontal) relief, they provide a path of low thermal resistance for the conduction of heat in the basin. Local thermal anomalies in the vicinity of salt are expected, owing to the focusing and defocusing of heat by salt. Since the temperature distribution in the basin has a marked impact on the occurrence of oil and gas, especially through the influence of temperature on hydrocarbon maturation, which maturation can be modeled as a first-order chemi-

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cal reaction in which the reaction rate doubles for every 10°C rise in formation temperature (LOPATIN, 1971), any effect which causes a significant variation in temperature distribution from the regional trend may have a substantial influence on hydrocarbon generation and accumulation in the subsurface.

The characteristics of conductive heat flow patterns and the associated temperature distributions around a single salt diapir (or sheet) embedded in the sedimentary rock have been presented by O'BRIEN and LERCHE (1988), assuming a steady-state heat flow and that heat is transported by conduction only.

In this study, we use a two-dimensional fluid flow/compaction model, which allows for both thermal conduction and convection, to examine the thermal anomalies in the Gulf of Mexico with multiple salt features including diapirs, pillows, sheets and wedges.

Two Synthetic Tests

Here we consider two experiments to examine thermal effects of salt under idealized conditions, using the two-dimensional fluid flow/compaction model developed by the Basin Modeling Group at the University of South Carolina.

In these experiments, we assume that the surface temperature and the basement heat flow are constant. The salt thermal conductivity ($K_{\text{salt}}$) and sedimentary rock thermal conductivity ($K_{\text{rock}}$) have a ratio of about 2:1 (CLARK, 1966). The value of 0.015 cal/cm/C/sec for salt thermal conductivity is used in the modeling.

The only heat source we consider is uniform heat flux through the basement. Thus, in the absence of salt, we would expect a constant vertical heat flux through the basin. The model excludes the effects of hot intrusives and of radioactive decay within the sediments. Temperature must be continuous across the sediment-salt interface since the thermal conductivity is finite. The component of heat flux normal to the sediment-salt interface must be continuous across this interface since we have no heat generation or loss at this interface.

It is also important to keep in mind that in order to allow for the heat to be focused or defocused by the higher thermal conductivity salt, enough space must be arranged in the configuration of the strata and the salt so that the steady-state heat flux from the deep basement has sufficient spatial range to adjust the heat flux pathways according to the thermal conductivity of the sediments. Therefore, a very deep section (approximately 2–3 times the basinal thickness beneath the salt) is necessary. The lateral distance of the section should also extend far enough that edge effects are unimportant. A ratio of 2:1 between horizontal and vertical distance has been implemented in the following two synthetic tests, and the simulation results for thermal anomalies are presented.