GEOGULF2021
AUSTIN
October 27–29, 2021

Regional Basin Modeling and Source Rock Maturation of the Port Isabel Passive Margin Foldbelt, Northwestern Gulf of Mexico

Muhammad Nawaz Bugti and Paul Mann

Department of Earth and Atmospheric Sciences, University of Houston,
Bldg. SR1, 3507 Cullen Blvd., Houston, Texas 77204–5008

ABSTRACT

The northeast-southwest trending Port Isabel passive margin foldbelt spans over an area of 17,000 square kilometers in the deepwater Gulf of Mexico. Of the seven well drilled in the area, there was only one uncommercial hydrocarbon discovery at well PI#525. The abnormally thick Oligocene section prevented drilling activity from penetrating the inferred source rocks. To better understand the maturation history of these source rocks, we constructed 1D petroleum systems models for three representative wells in the area. 2D models were then generated using Zetaware software for inferred source rock intervals in the upper Jurassic, lower Cretaceous, and the lower Tertiary. The selection of source rocks is inferred because wells have not penetrated beneath the Oligocene. A grid of seismic data were used to constrain the stratigraphic depths and thicknesses across the area.

2D basin model assumptions include: (1) a homogeneous heat source from the crystalline, continental basement; (2) no distinction is made between radiogenic basement heat and heat from mantle convection; (3) heat was transferred by conduction and by water expelled vertically during compaction; and (4) higher heatflow values than the surrounding areas based on bottom-hole temperature measurements. We also made unrestrained models with extreme cases of high and low scenarios resulting from the scarcity of drilled stratigraphy. A series of maps were created to illustrate the source rock maturity and transformation ratios for source rocks of Oxfordian, Tithonian, Turonian, and Paleogene ages.

Bugti, M. N., and P. Mann, 2021, Regional basin modeling and source rock maturation of the Port Isabel passive margin foldbelt, northwestern Gulf of Mexico: GeoGulf Transactions, v. 71, p. 23–28.

INTRODUCTION

Port Isabel in the deepwater, northwestern Gulf of Mexico Basin stands out as one of the least productive areas of the U.S. Gulf of Mexico based on its scarcity of oil and gas production platforms (Fig. 1). Mesozoic rifting and seafloor spreading ended by the earliest Cretaceous and was followed by the development of the passive margin (Pindell, 1985; Marton and Buffler, 1999; Hood, 2002; Pindell and Kennan, 2009; Nguyen and Mann, 2016). A passive margin foldbelt formed in the Oligocene and Miocene and created the Port Isabel passive margin foldbelt. The regional distribution of prolific upper Jurassic–lower Cretaceous (including Tithonian age) source rock acmes (Pepper and Roller, 2021) is a crucial element for making the deepwater Gulf of Mexico one of the most productive hydrocarbon basins in the world (Weimer et al., 2017).

The relatively few well penetrations in the Port Isabel area means that the regional distribution of source rocks is inferred from oil composition and biomarker data from petroleum recovered from wells or sampled from natural oil seeps on the slope (Wenger et al., 1994; Cole et al., 2001a, 2001b; Hood et al., 2002; Jacques and Clegg, 2002). Two source intervals are interpret-

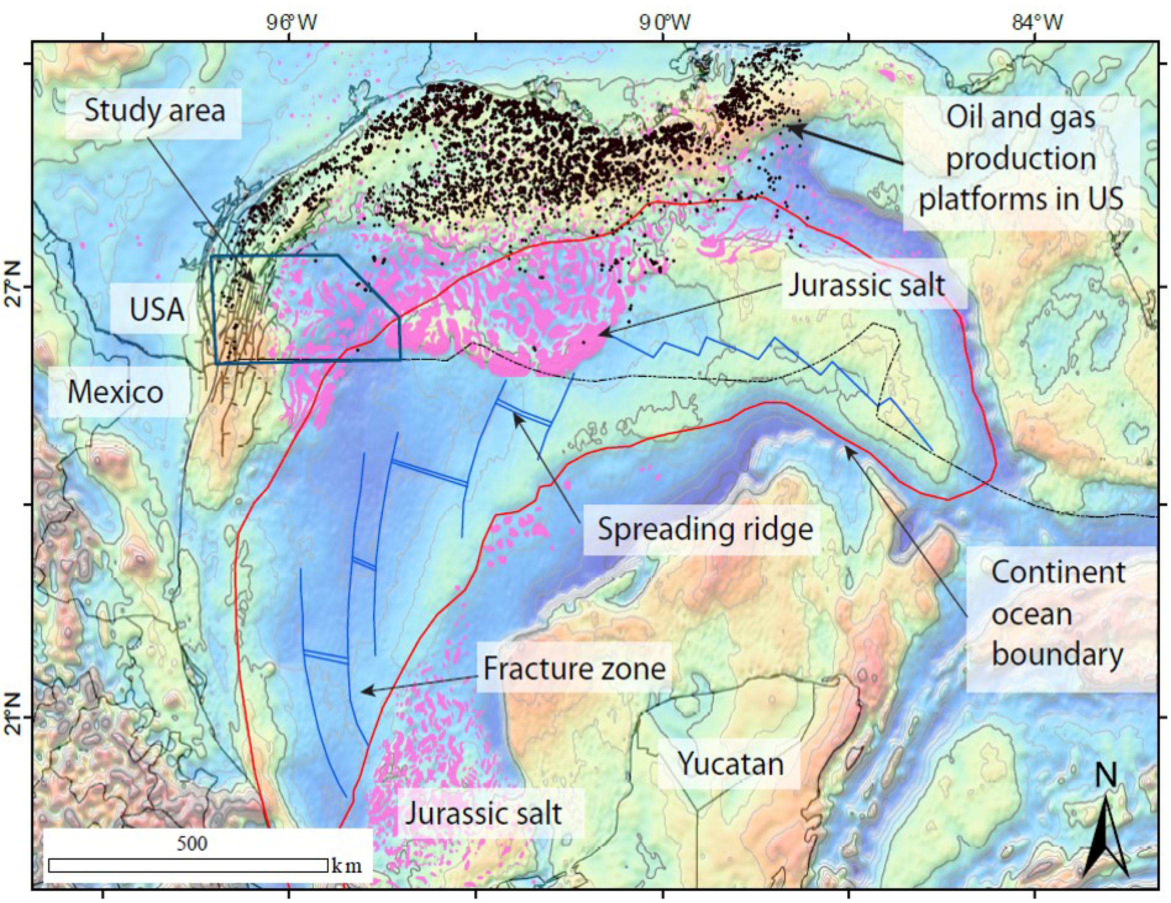

Figure 1. Map showing the main structural and basinal areas of the Gulf of Mexico and its surrounding area. The Port Isabel foldbelt is located in the U.S. maritime zone of northwestern part of the deepwater area. The majority of the hydrocarbon production platforms are concentrated along the shelf and only a few are in the deepwater area. The map was compiled from Gray et al. (2001), Sandwell et al. (2014), Nguyen and Mann (2016), and BOEM (2021).

ed as contemporaneous to the upslope shallow-marine–equivalent strata: (1) Oxfordian shallow marine limestone and marl; and (2) widespread Kimmeridgian to Valnaginian shale (equivalent to the Bossier Formation; Weimer et al., 2017). Teerman et al. (2010) inferred a Turonian source interval, although Pepper et al. (2020) showed that the potential of this source rock is inferior in paleo-deepwater than on the coeval shelf (Eagle Ford Formation).

METHODS USED IN THIS STUDY

This study uses a regional 2D post-stack depth converted (PSDM) seismic grid of 133,711 line-km of seismic reflection data of the TGS DeepFocus survey that was provided to us by TGS for this study. The ZetaWare Inc. 1D Genesis software was used to model wells drilled along the main, dip-oriented, regional seismic line across the entire passive margin of Port Isabel foldbelt in the northwestern Gulf of Mexico (Figs. 2 and 3). The initial 1D modeling reconstructed the thermal history, using a range of parameters for continental crust, lithosphere, and lithologies and thermal properties of the sedimentary column, including the source rocks.

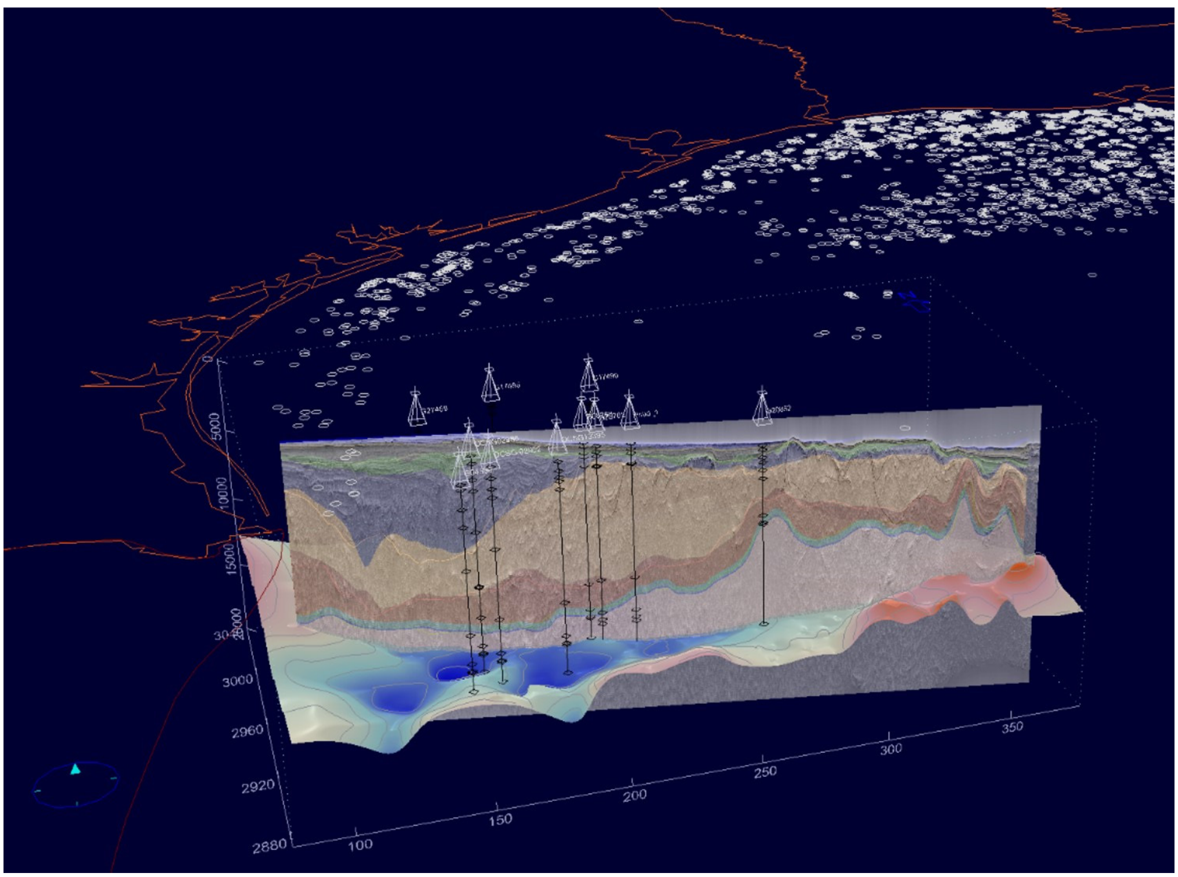

Figure 2. Perspective view of the key seismic lines used in this study relative to hydrocarbon producing platforms. The drilled wells near the seismic lines are shown with the drilling rig symbol. The line along the wells shows the 1D basin models that were created.

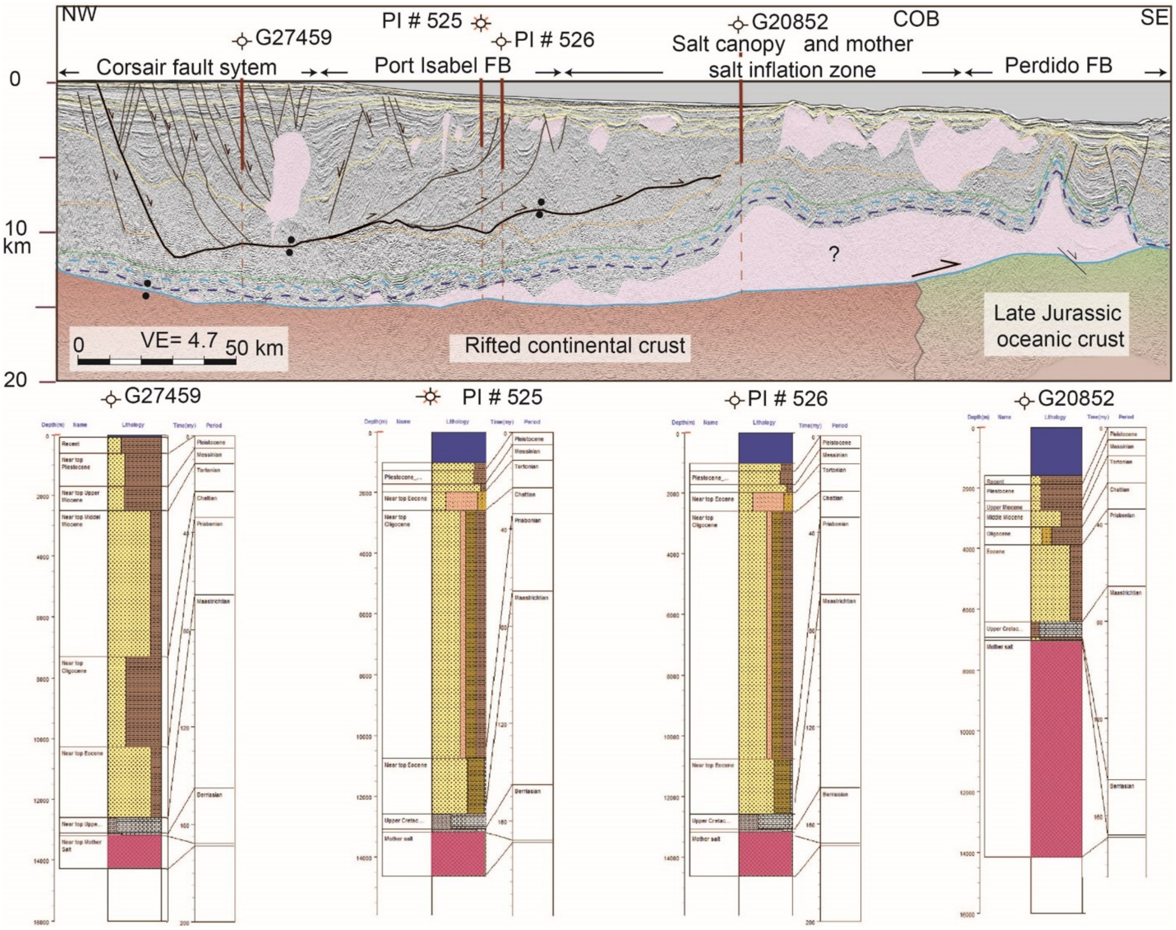

Figure 3. Interpreted dip regional seismic section showing the mapped seismic horizons in the study area. Existing drilled well locations and their simplified lithology are highlighted. The lithologies are compiled from Fiduk et al. (1999).

RESULTS

Thermal modeling suggests a gas-prone petroleum system that can be related to the deeply-buried Tithonian-centered source rocks that began to expel gas in the early Oligocene (30 Ma). Expelled gas accumulated in structural traps that had formed due to the formation of the Port Isabel passive margin foldbelt by the end of the Oligocene (23 Ma) (Fiduk et al., 1999). We predict a 7 m.y. time lag between expulsion in the source bed and trapping due to the transit time of vertical migration through the 11 km thick sedimentary section.

SUMMARY AND CONCLUSIONS

Port Isabel foldbelt is a complexly deformed passive margin foldbelt with only one uncommercial hydrocarbon discovery. The crust underneath the study area is continental crust that was thinned during phase one rifting that occurred from the late Triassic to middle Jurassic.

Heat flow related to the underlying crust is lessened by the transient effects induced by the deposition of ~12 km of sedimentary rocks since the Eocene.

Thermal modeling predicts mainly gas expulsion from the early Oligocene to the middle Miocene, although an exploration risk is the precise timing of hydrocarbon generation and trap availability, adjusted for 'time lag.' We predict at least a 7 m.y. time lag between the end of maturation and the formation of traps.

REFERENCES CITED

BOEM (Bureau of Ocean Energy Management), 2021, Geographic mapping data in digital format, <https://www.data.boem.gov/Main/Mapping.aspx>.

Cole, G., A. Yu, F. Peel, R. Requejo, J. DeVay, J. Brooks, B. Bernard, J. Zumberge, and S. Brown, 2001a, Constraining source and charge risk in deepwater areas: World Oil, v. 222, no. 10, p. 69–77.

Cole, G. A., A. Yu, F. Peel, C. Taylor, R. Requejo, J. DeVay, J. Brooks, B. Bernard, J. Zumberge, and S. Brown, 2001b, The deepwater GOM petroleum system: Insights from piston coring seepage versus anomalies versus background, *in* R. H. Fillon, N. C. Rosen, P. Weimer, A. Lowrie, H. Pettingill, R. L. Phair, H. H. Roberts, and H. H. van Hoom, eds., Petroleum systems of deep-water basin—Global and Gulf of Mexico experience: Proceedings of the 21st Gulf Coast Section of the Society of Economic Paleontologists and Mineralogists Foundation Research Conference, Houston, Texas, p. 315–342.

Fiduk, J. C., P. Weimer, B. D. Trudgill, M. G. Rowan, P. E. Gale, R. L. Phair, B. E. Korn, G. R. Roberts, W. T. Gafford, R. S. Lowe, and T. A. Queffelec, 1999, The Perdido fold belt, northwestern deep Gulf of Mexico, part 2: Seismic stratigraphy and petroleum systems: American Association of Petroleum Geologists Bulletin, v. 83, p. 578–612.

Gray, G. G., R. J. Pottorf, D. A. Yurewicz, K. I. Mahon, D. R. Pevear, and R. J. Chuchla, 2001, Thermal and chronological record of syn- to post-Laramide burial and exhumation, Sierra Madre Oriental, Mexico, *in* C. Bartolini, R. T. Buffler, and A. Cantú-Chapa, eds., The western Gulf of Mexico Basin: Tectonics, sedimentary basins, and petroleum systems: American Association of Petroleum Geologists Memoir 75, Tulsa, Oklahoma, p. 159–181.

Hood, K. C., L. M. Wenger, O. P. Gross, and S. C. Harrison, 2002, Hydrocarbon systems analysis of the northern Gulf of Mexico: Delineation of hydrocarbon migration pathways using seeps and seismic imaging, *in* D. Schumacher and L. A. LeSchack, eds., Surface exploration case histories: Applications of geochemistry, magnetics, and remote sensing: American Association of Petroleum Geologists Studies in Geology 48 and Society of Exploration Geophysics Geophysical References Series 11, Tulsa, Oklahoma, p. 25–40.

Jacques, J. M., and H., Clegg, 2002, Late Jurassic source rock distribution and quality in the Gulf of Mexico: Inferences from plate tectonic modelling: Gulf Coast Association of Geological Societies Transactions, v. 52, p. 429–440.

Marton, G. L., and R. T. Buffler, 1999, Jurassic–Early Cretaceous tectono-paleogeographic evolution of the southeastern Gulf of Mexico Basin, *in* P. Mann, ed., Sedimentary basins of the world, v. 4: Caribbean basins: Elsevier B. V., Amsterdam, The Netherlands, p. 63–91.

Nguyen, L. C., and P. Mann, 2016, Gravity and magnetic constraints on the Jurassic opening of the oceanic Gulf of Mexico and the location and tectonic history of the Western Main transform fault along the eastern continental margin of Mexico: Interpretation, v. 4, no. 1, p. SC23–SC33.

Pepper, A. and E. Roller, 2021, Ultimate expellable potentials of source rocks from selected super basins: What does “world class” look like?: American Association of Petroleum Geologists Bulletin, 105, 1069–1097.

Pindell, J., 1985. Alleghenian reconstruction and subsequent evolution of the Gulf of Mexico, Bahamas, and proto-Caribbean: Tectonics, 4, p. 1–39.

Pindell, J. L., and L. Kennan, 2009, Tectonic evolution of the Gulf of Mexico, Caribbean and northern South America in the mantle reference frame: An update: Geological Society, London, Special Publications, v. 328, p. 1–55.

Sandwell, D. T., R. D. Müller, W. H. Smith, E. Garcia, and R. Francis, 2014, New global marine gravity model from CryoSat–2 and Jason–1 reveals buried tectonic structure: Science, v. 346, no. 6205, p, 65–67.

Teerman, S. C., R. W. Howe, R. Hwang, and R. Lytton, 2010, A deepwater Gulf of Mexico source rock penetration: Applications to Mesozoic source rocks and depositional systems: American Association of Petroleum Geologists Search and Discovery Article 90104, Tulsa, Oklahoma, 1 p., <https://www.searchanddiscovery.com/pdfz/abstracts/pdf/2010/annual/abstracts/ndx_teerman.pdf.html>.

Weimer, P., A. Bouroullec, J. Adson, and S. P. J. Cossey, 2017, An overview of the petroleum systems of the northern deepwater Gulf of Mexico: American Association of Petroleum Geologists Bulletin, v. 101, p. 941–993.

Wenger, L. M., L. R. Goodoff, O. P. Gross, S. C. Harrison, and K. C. Hood, 1994, Northern Gulf of Mexico: An integrated approach to source, maturation, and migration, *in* N. Scheidermann, P. Cruz, and R. Sanchez, eds., Geologic aspects of petroleum systems: First Joint American Association of Petroleum Geologists–Association of Mexican Petroleum Geologists Hedberg Conference, October 2–6, Mexico City, 5 p.