A search for controls on the distribution of oil seeps in the minibasin provinces

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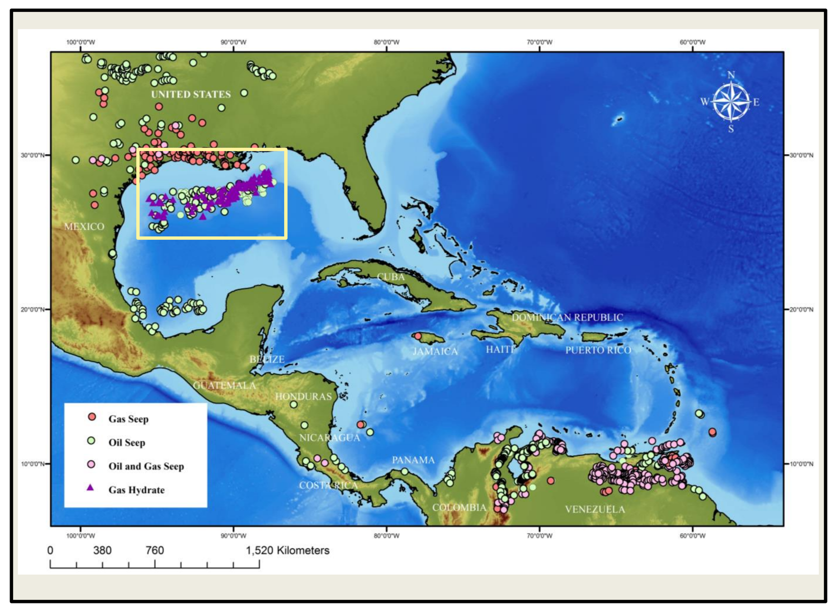
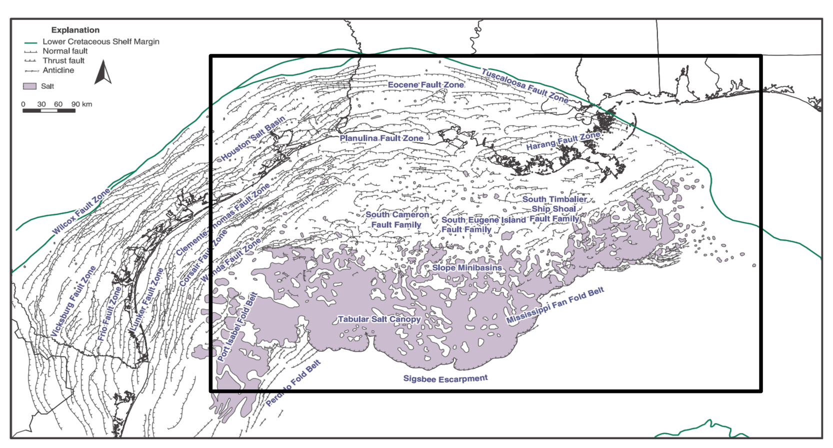
Abstract

In this research, published literature is used to compile information on over one thousand natural hydrocarbon occurrences across the world, focusing primarily on oil seeps in the minibasin provinces and the structural features which control their distribution. Data was collected on 94 submarine oil seeps in the Gulf of Mexico, the principal minibasin province, to better understand the role of minibasins as a primary mechanism in the process of oil seepage. The majority of Gulf of Mexico submarine, oil seeps are located in the US or Mexico salt provinces which were separated in late Jurassic time by the formation of an arcuate band of oceanic crust that underlies the deep Gulf of Mexico basin. Based on surveys of existing data, nearly no seeps have been identified from the shelves of either the Mexican or US Gulf of Mexico. Of the 57 natural oil seeps in the US Gulf of Mexico, 39 are found along the edges of minibasins, or sub-circular, sedimentary basins bounded on all sides by emergent, salt diapirs. Strata at the edges of minibasins are usually steeply dipping and faulted along a rotated, normal fault that forms the upper edge of the rising diapir. The steep dip of the bedding and presence of faults provides conduits for the upward rise of oil and the predominance of natural seeps in this setting. Ten seeps were identified in the flat-bottomed centers of the minibasins that are commonly underlain by strata with low dips and fewer conduits for oil to reach the surface. Eight seeps are observed in the deep Gulf of Mexico basin in areas overlying late Jurassic oceanic crust and not overlying a significant salt body. The Mexican salt body however, lacks the high level resolution bathymetric data we have for the US Gulf of Mexico, and for this reason we are not confident that minibasins play the same prominent role in the control of seeps as observed in the US Gulf of Mexico. Of the 37 seeps from the Mexican Gulf of Mexico, nine are on the shelf, ten are on the slope, and 18 are in the deep basin. Research is currently being done on the potential for hydrocarbon exploration in other minibasin provinces such as offshore Angola, which is a passive margin similar to the Gulf of Mexico, with an abundance of natural oil seeps.

Geologic setting of the northern Gulf of Mexico

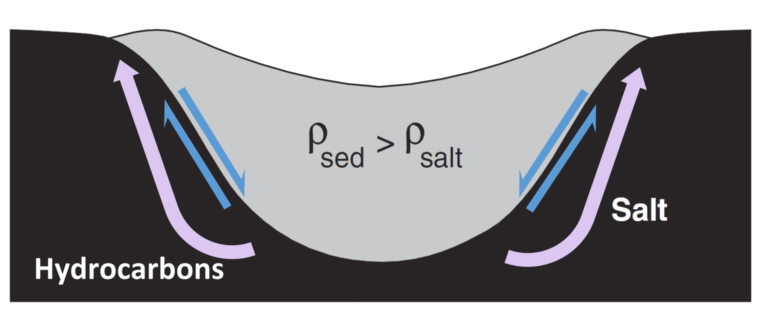


Map shows the locations of various oil and gas seeps along with hydrates within the Gulf of Mexico and Latin America research area. Yellow box indicates the location of the central map on this poster and the study area for this particular research in the north-central Gulf of Mexico.

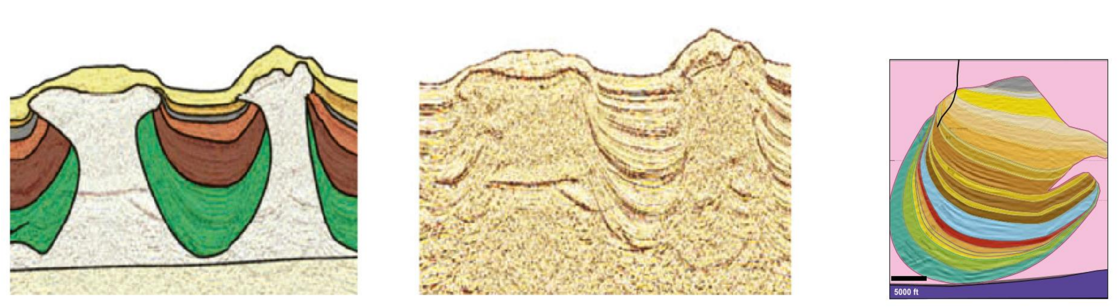


Map shows the area of the seeps relative to the structural features, most notably salt in the northern Gulf of Mexico. Modified from Galloway (2008).

Location and formation of minibasins



Idealized depiction of a minibasin showing density of sediment with respect to density of salt. Salt evacuation promotes the rise of hydrocabons (purple arrows) along faults. Depicted minibasin is characterized by normal faults, typical of the extensional area of the U.S. Gulf of Mexico. Minibasins can also be characterized by thrust faults, typical of the compressional area (see central map figure). Modified from Hudec (2009).

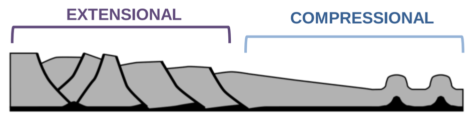


Angolan margin rafted domain **Gulf of Mexico**

Seismic images showing comparing minibasins in the Angolan margin to minibasins in the Gulf of Mexico with high hydrocarbon potential. Images modified from Callot (2016).

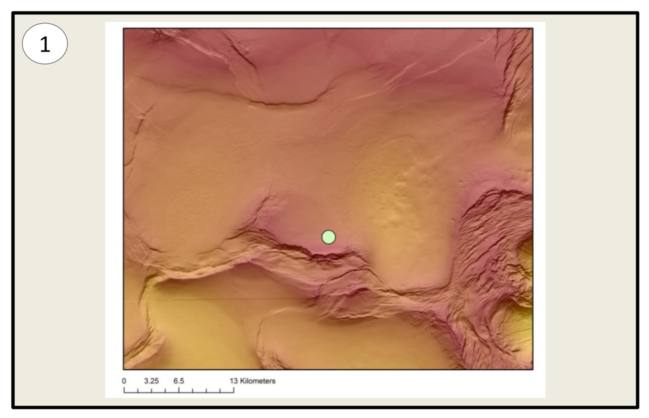
Tectonic history of the passive margin fold belt

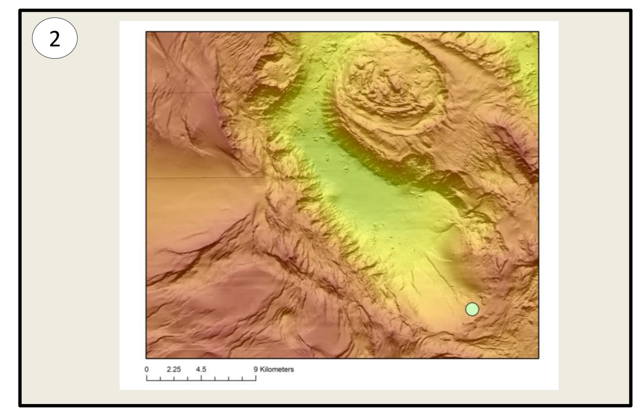
The study area is divided into two main parts based on fault deformation: the extensional (northern area) and the compressional (southern area) depicted in the central figure. Deformation in the passive margin is due to gravitational failure which causes fold-dominated shortening. Passive margin failure is also caused by gravity spreading, most easily seen in the formation of the Mississippi Fan Fold Belt where the gravity potential is decreased by clastic progradation and loading subsidence resulting in the formation of large-wavelength folds. The same salt-detached gravitational failure can be seen in the Lower Congo and Kwanza Basins of offshore Angola.

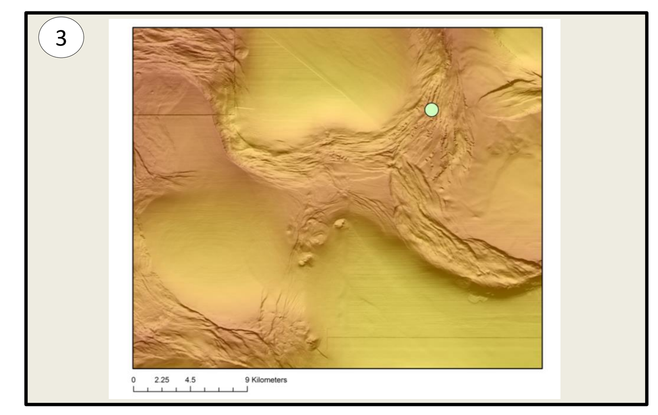


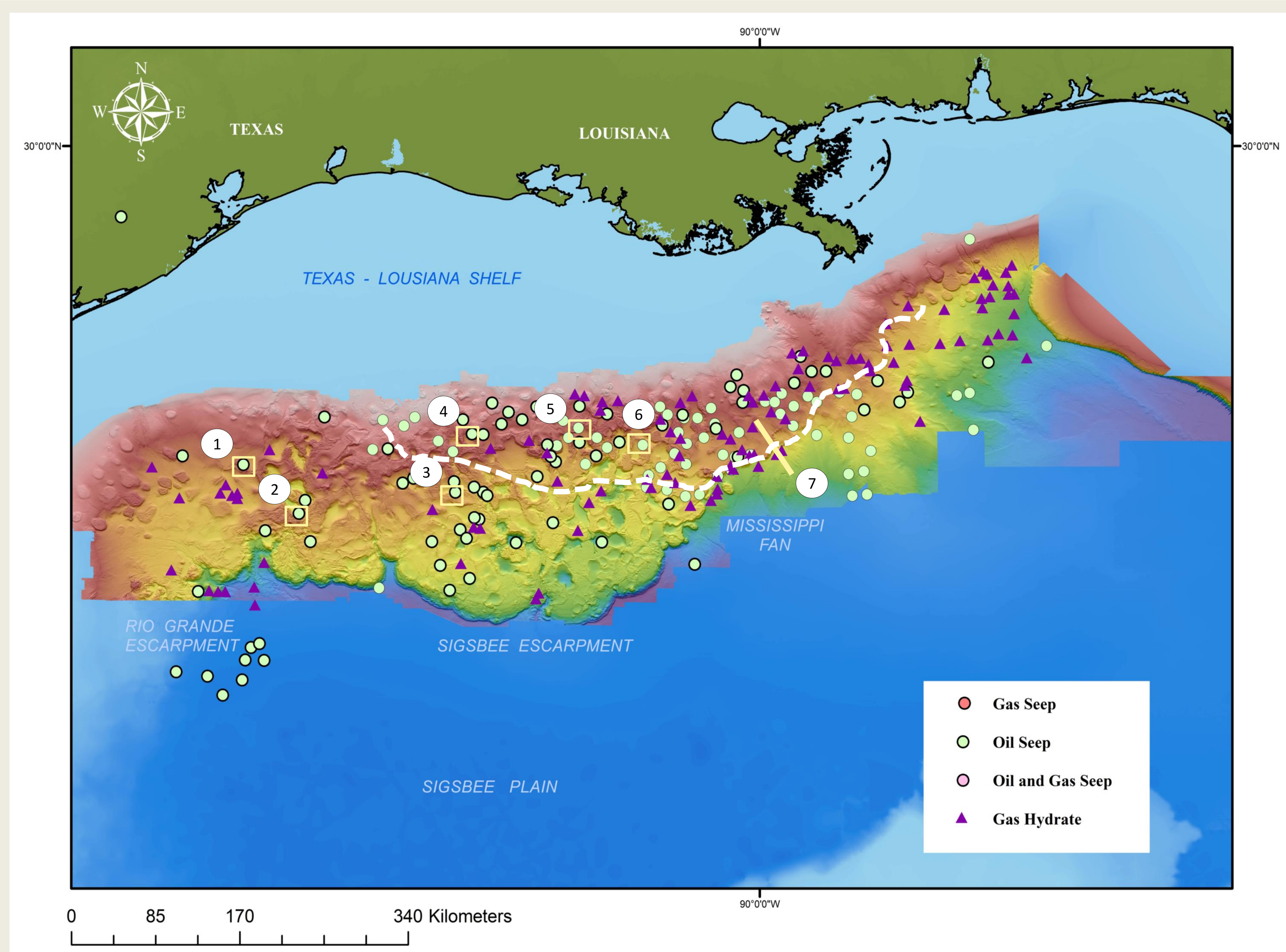
Simplified cross section (to the left) depicting the gravitational failure of a passive margin expressed as fold dominated shortening. The extensional and compressional areas are labeled.

Modified from Rowan et al., 2004.

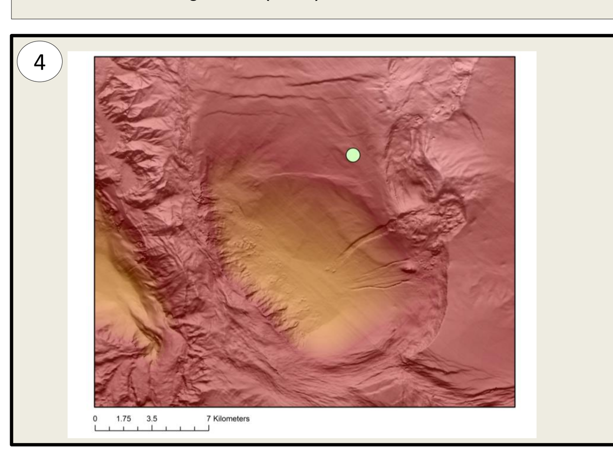


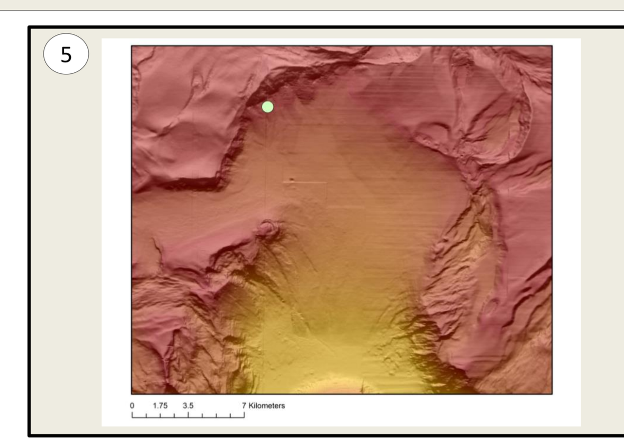


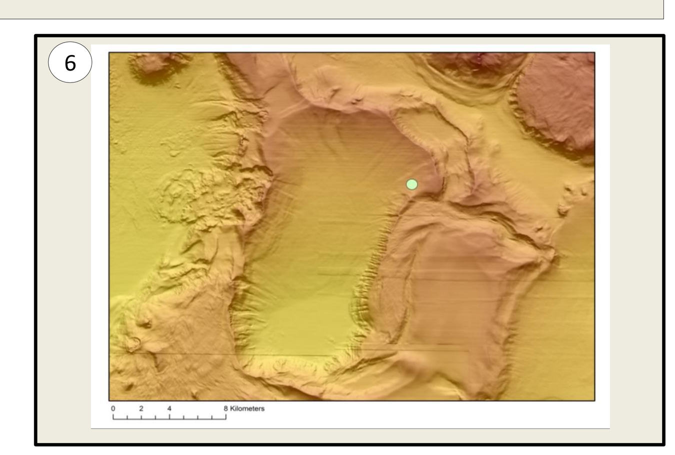




Maps 1-6 depict locations of oil seeps (green dots) occurring along the edges of minibasins. Locations of oil seeps on minibasins are shown by numbered yellow boxes on the high resolution bathymetry map above. Dashed white line marks the boundary between the extensional and compressional fault areas. Bathymmetry map modified from the Bureau of Ocean Energy Management (2017).







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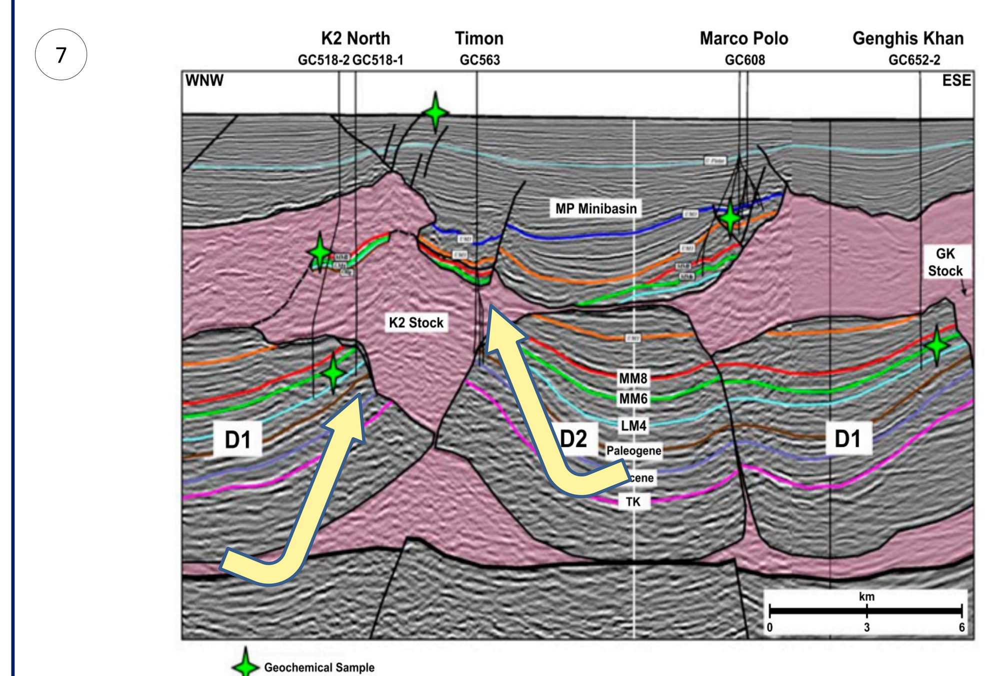
Complete list of references for the compilation map available upon request.

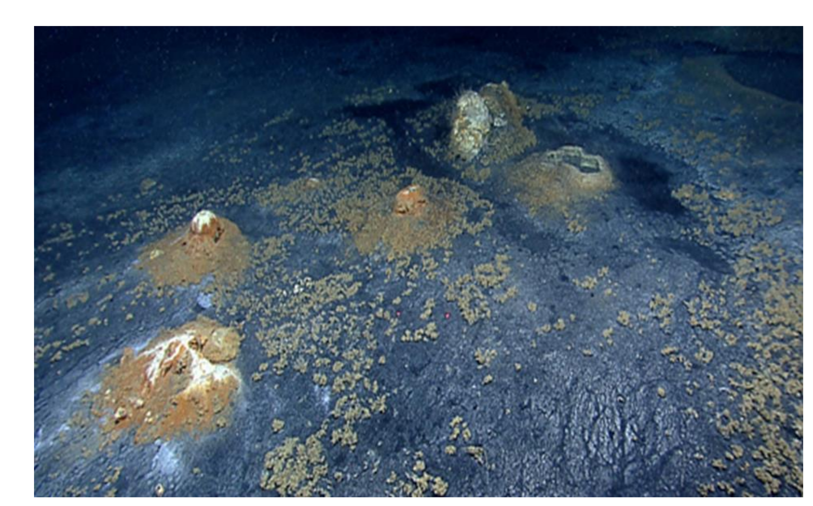
Conclusions



Regional seismic profile across the K2 North, Timon, Marco Polo, and Gengis Khan fields in the Subsalt province of southern Green Canyon. Yellow arrows indicate the upward rise of oil. Location shown by yellow line on map to the left. Modified from Weimer et al. (2017).

Source rocks beneath the salt sheet have produced significant amounts of hydrocarbons. Yellow arrows indicate the migration pathways of hydrocarbons along normal faults that form the boundaries along the edges of the overlying minibasins.

The synclinal structure of the minibasins promotes upward migration of the oil into faulted structures at the basin edges. Natural oil seeps form when active faults penetrate the seafloor and allow the oil to escape.



Salt "volcanoes" with oil, gas, and brine being expelled in the Gulf of Mexico. The small cones are salt expelling droplets of brine-covered oil. The less-dense oil migrated along the edges of the minibasin upwards to the seafloor and passing through areas of brine still trapped below. As the brine-covered oil droplets escaped the seafloor and travelled upward towards the surface of the Gulf, their denser layers of brine were shed, falling back to the seafloor. Droplet by droplet, the salt slowly built up a cone around the oil seep. The brown mineral on the volcanoes and the seafloor is yet to be identified. Image courtesy of the NOAA Okeanos Explorer Program.

Flow structures of heavy oil seeping from the Mictlan Knoll in approximately 3100 meter water depth. These flow structures produced by oil seeps can form habitats for tube worms and bacterial mats. Image courtesy of the Center for Marine Environmental Sciences.