Case Study

Mississippi Canyon

The petroleum geology of the Mississippi Canyon, offshore northern Gulf of Mexico, is controlled by the interaction of salt tectonics and high sedimentation rate. This context results in a complex distribution of reservoirs and hybrid structural/stratigraphic traps. Such a challenging dataset can be tackled by sequencing its tectono-stratigraphic evolution.

Location:
Gulf of Mexico

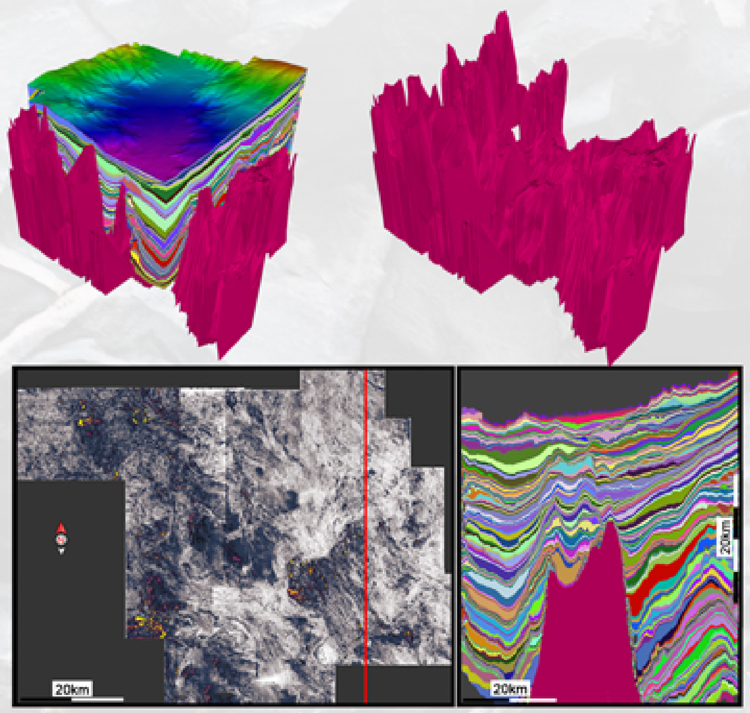
Surface area:
3.800 km²

Age of sediment:
Miocene

Geological context:
Halokinesis & mini-basins

Depositional environment:
Deep marine

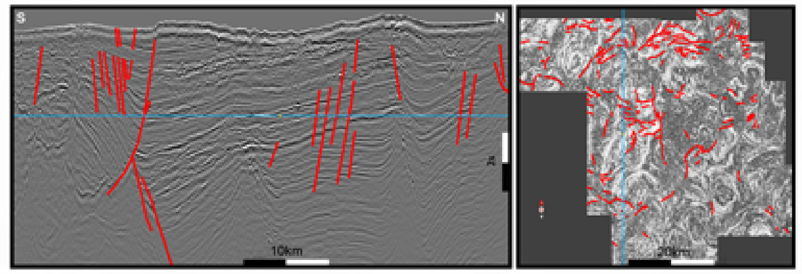
Main challenges:
Halokinetic sequences & sediment reworking

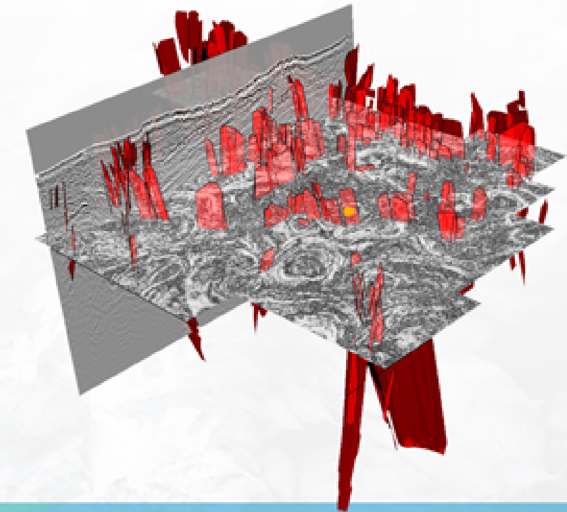


Intrusive and extrusive salt modeling

Halokinesis sequence analysis reveals multi-story sediment flow and deposition with spatially heterogenous subsidence rate for each mini-basin.

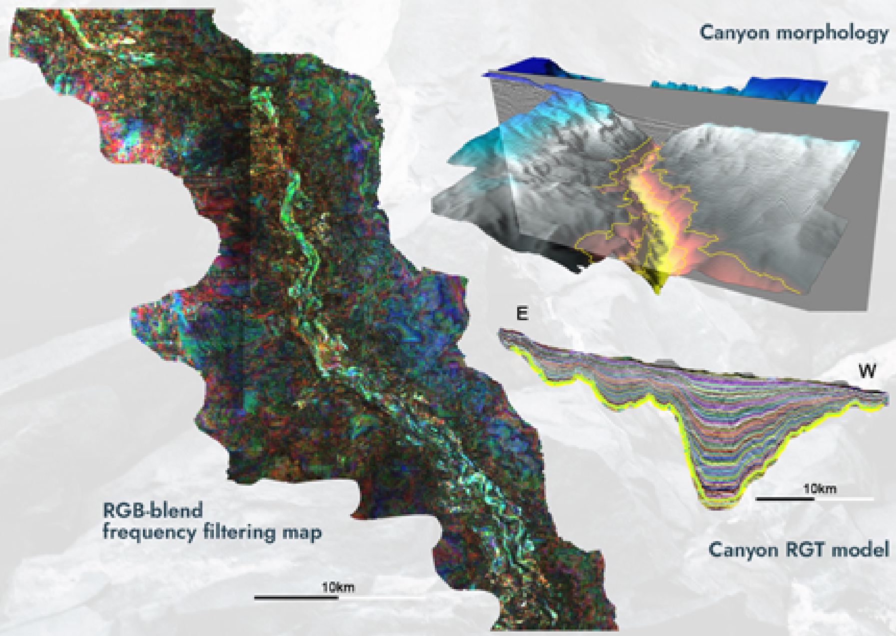
Full 3D architectural elements identification





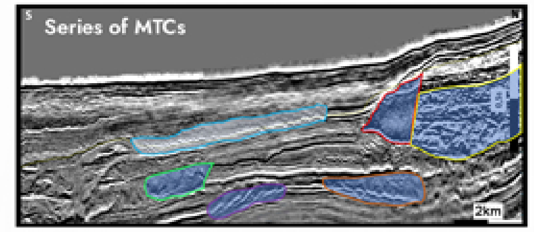
Full 3D fault modeling

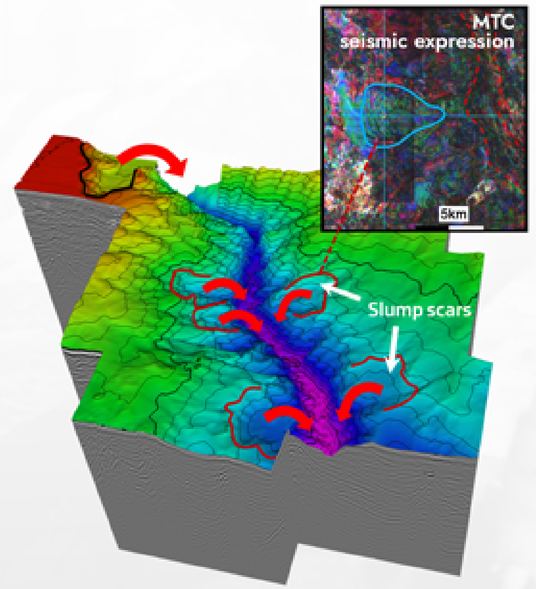
Fracture imaging and fault extraction show a broad range of azimuth with almost 360° fault direction, all driven by a mix between geodynamic tectonics and salt tectonics.

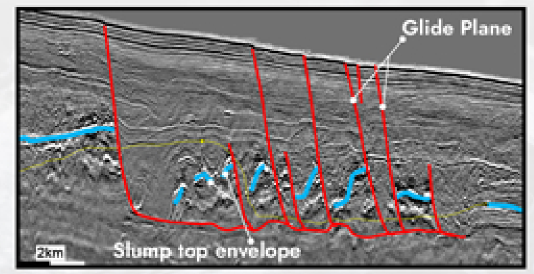


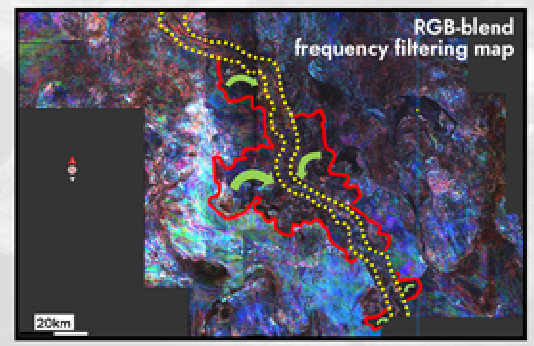
RGT modeling of the Mississippi canyon with complete filling history

The topographic contouring reveals the dip of flanks, where gravity flows may have statistically occurred.
A frequency decomposition process discriminates thicker, thinner, thin sediment packages and beds. An RGB blender emphasizes sandstone-prone deposits from canyon and channels.









Sub-sample stratal slicing of MTC based on a tailor-made selection of signal-driven key stratigraphic surfaces

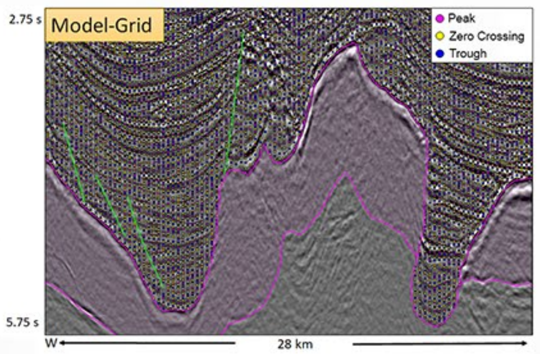
Key morphological criteria enable to interpret seismic expressions as slumps: typical fish scale map pattern, concave-up glide plane, combination of extensional, contractional and translational strains resulting in normal faults, thrust faults and folds. They are all related to the broad variation of multiple directions and phases of flow.

Courtesy of The National Archive of Marine Seismic Survey, United States of America

Salt-controlled minibasins correlations & characterization of syndepositional passive diapirism

Multi-scenarios approach

The discrete sequence stratigraphic framework "Model-Grid" is fully editable and enables to test different scenarios of deposition, burial and halokinesis kinematics, in 3D and real time. *Scenario 1* shows RGT correlations with similar depositional kinetics for both of the reference secondary minibasins. *Scenario 2* shows a chronology of depositional history between allochthonous minibasin 6 (first) and minibasin 3 (second).



Accommodation-based classification of minibasins: at early stage and survey scale

The RGT model allows stratal slicing in a vertically continuous way the three-dimensional network of the secondary minibasins. The topography (Z-value) is used to describe three key stages of this network evolution, revealing heterogeneities in the accommodation distribution. Applying a dynamic isochrone-driven flattening to the seismic data illustrates the subsidence and burial kinematics, and helps to match the three stages with three main phases of salt tectonics:

Phase 1: Intense salt tectonics activity leading to the development of halokinetic sequences over the shown 1st and 2nd stages with various aggradation kinetics (slow *vs* fast).

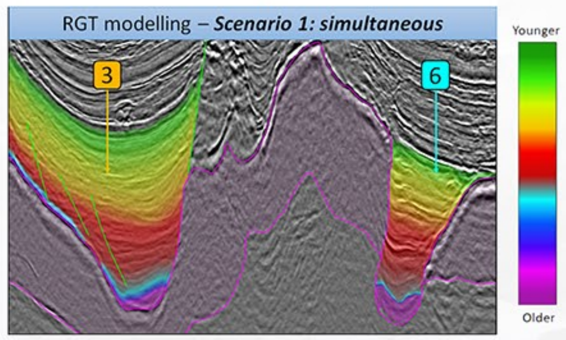
Over stages of development, secondary minibasins are quickly classified according to the observable accommodation space.

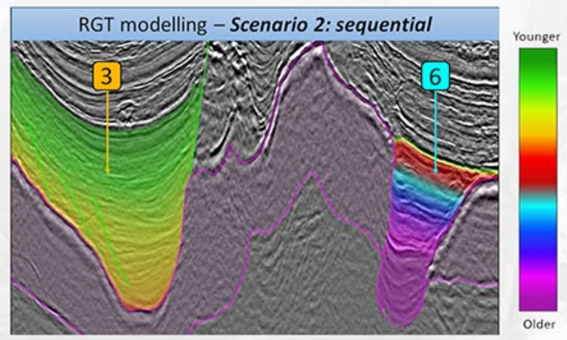
Maximum
Intermediate
Minimum

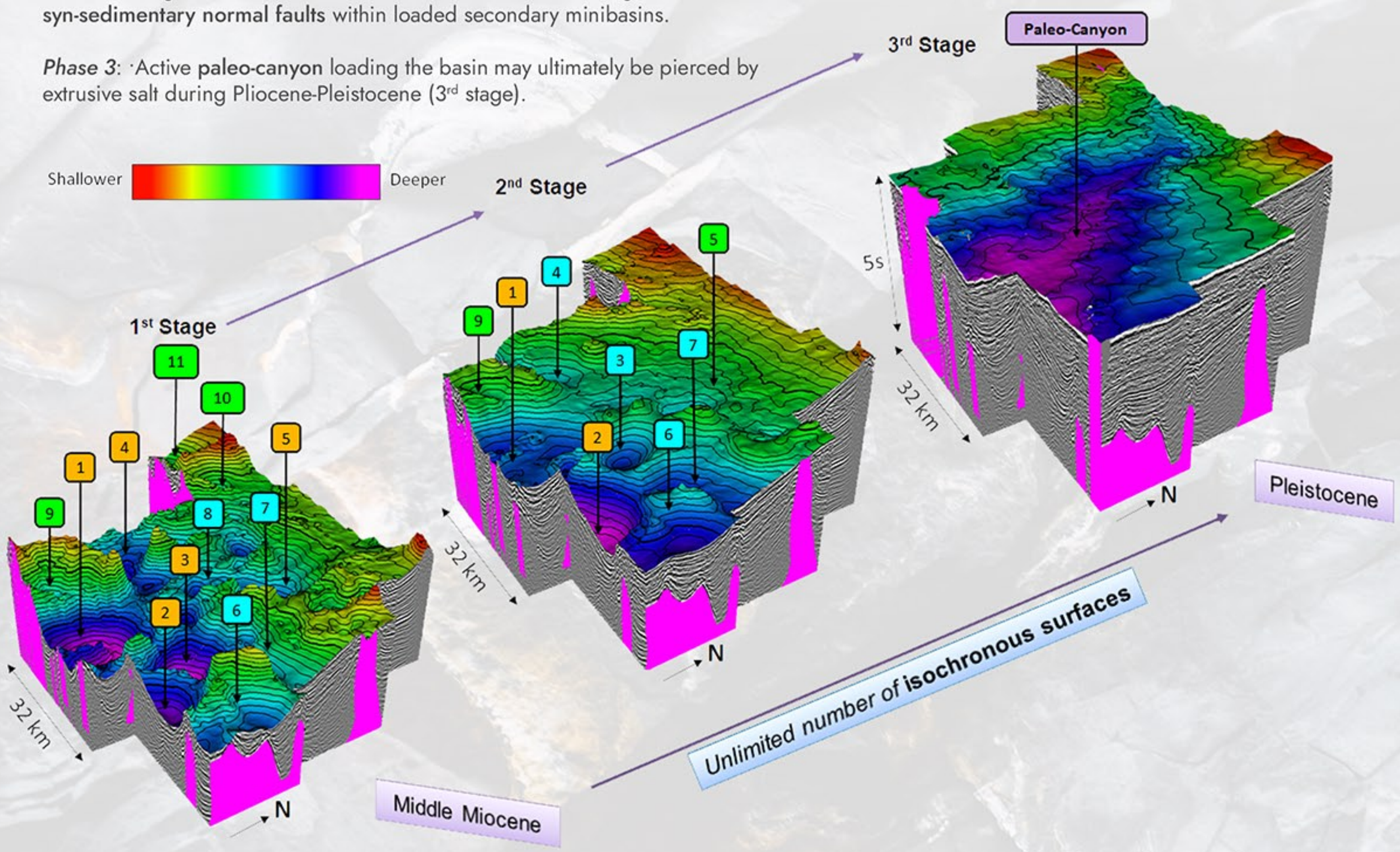
Minibasins (ex: 1) may eventually sink into base-salt allochthonous structural lows, expelling salt from beneath and rejuvenating salt structures to form new generation diapirs (**feeders**). Late minibasins (ex: 9) develop above subsequent **salt sheets** but may stay **perched** due the limited amount of available allochthonous salt material.

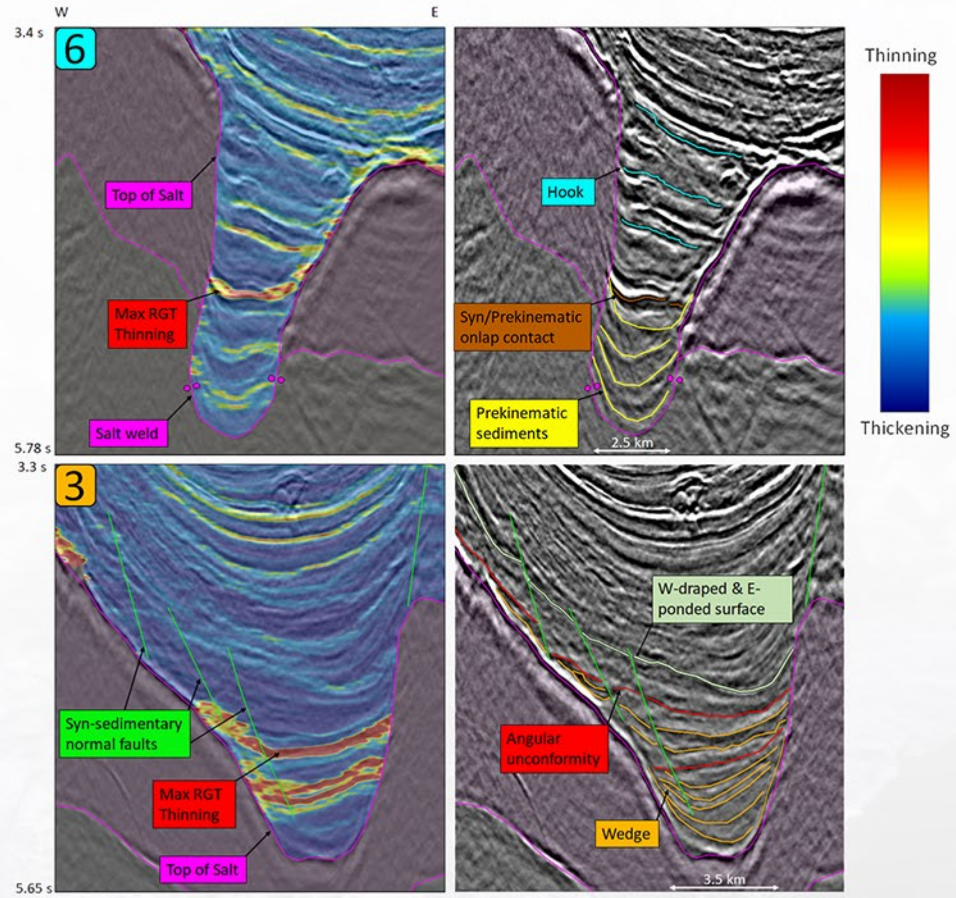
Phase 2: Relative decrease of salt rise from 1st to 2nd stage correlated with a more homogeneous basin scale subsidence and the generation of **syn-sedimentary normal faults** within loaded secondary minibasins.

Phase 3: ·Active **paleo-canyon** loading the basin may ultimately be pierced by extrusive salt during Pliocene-Pleistocene (3rd stage).









Halokinetic sequences and minibasin classification based on stratal geometries

The Thinning attribute (RGT vertical derivative) is used as a stratigraphic gradient to emphasize zones of strata convergence and relative instantaneous variations of accommodation. It allows focusing on small scale structures such as stratal onlap on dipping salt surfaces, and angular unconformities bounding halokinetic sequences.

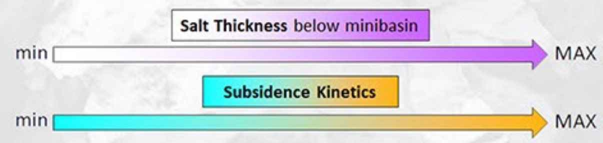
Minibasin 6 is filled with deeper concave up strata of prekinematic sediments (yellow-colored), overlaid by a tabular composite sequence (subparallel blue-colored **hook** sequences): low ratio of sediment-accumulation rate to diapir-rise rate.

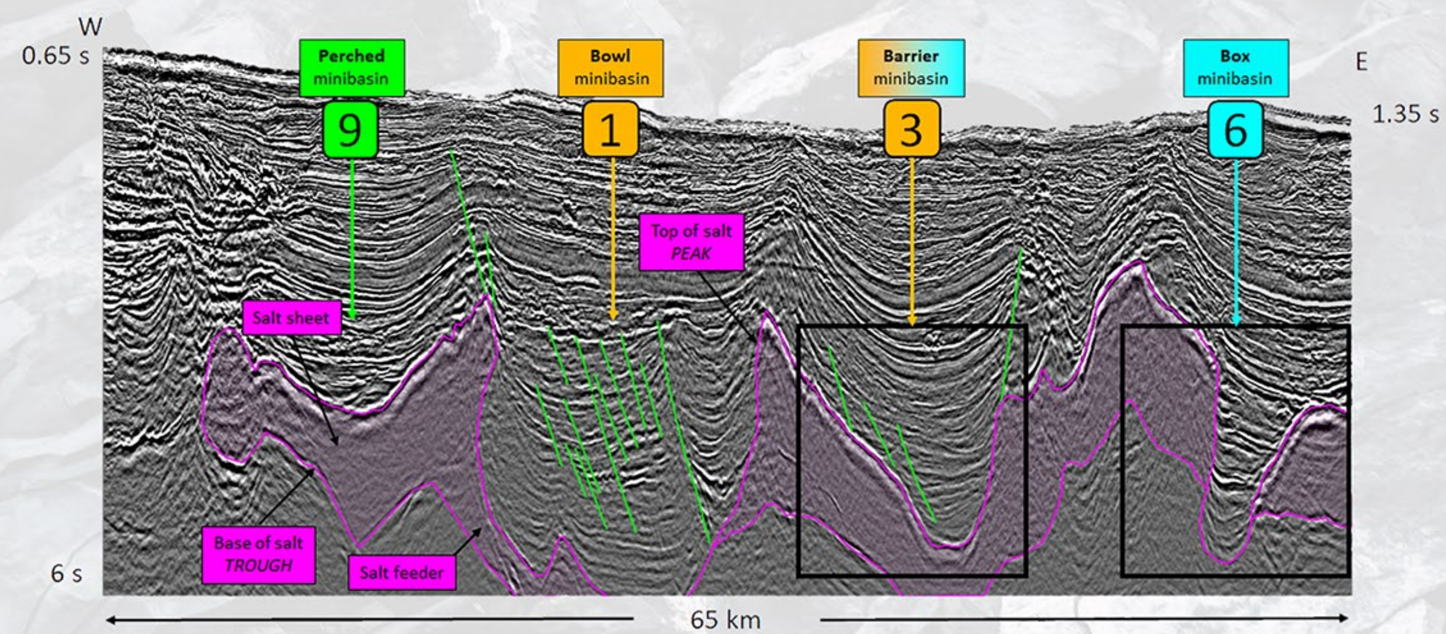
Minibasin 3 is stacked with a tapered composite sequence (convergent orange-colored **wedge** sequences): : high ratio of sediment-accumulation rate to diapir-rise rate. The ligh green surface and overlying strata drape across the western flank while sediments are ponded on the downthrown eastern syn-sedimentary fault.

The minibasin classification from Pratson & Ryan (1994) enables to discriminate the three reference minibasins as following:

- 6 as **box**, early stage of infilling when sediment input is too low to fill the deepening minibasin;
- 3 as **barrier**, hybrid midstage of infilling, when sediment input begins to outspace subsidence and fed the basin from West side (shallow-dipping salt draped by strata) while East side is confined (steep salt);
- 1 as **bowl**, mature stage when sediments are deposited across the basin and drape the surrounding diapirs or bypass the area. The sagging minibasin may ultimately evolve into a **bucket** if it expels most of the salt below it to rest directly on presalt strata.

Correlations between salt thickness, subsidence kinetics and minibasin types





Courtesy of The National Archive of Marine Seismic Survey, United States of America