Introduction

Several authors have identified salt karst as a geohazard for drilling and seafloor installations both onshore (Johnson 2013) and offshore (Augustin and Talbot 2016). To assess what information the expression of salt karst at the seafloor can provide to offshore shallow geohazard detection, I have studied evaporite features near and at the seafloor in deep-water Gulf of Mexico in the Green Canyon sector, an area that was studied by Augustin and Talbot (2016). The texture of the seafloor obtained from high-resolution 3D seismic measurements (Figure 1a) reveals three types of salt bodies: salt diapirs (SD), salt stocks (ST) and salt canopies (C1, C2). The salt tectonics involved with the salt movement towards the seafloor results in exposing the salt to the seawater, causing collapse of the caprock and dissolution of the salt, i.e., salt karst. In the study area, I distinguish three mechanisms for generating salt karst, resulting in the collapse of the caprock:

1. Active salt diapirism (AK),
2. Compressional stress from the collision of salt diapirs with a gravity gliding salt canopy (CK),
3. Shear stress induced by the differential velocities of two gravity gliding salt canopies (SK).

Colour-processing the seismic data (Laake 2015) yields information about the rock type exposed at the seafloor and, thereby, assists the interpretation of seismic data to understand the karst-generating mechanism (Figure 1).

Figure 1 Observations at the seafloor at bathymetry (a), and colour-processed seismic data (b). For abbreviations, see Table 1.

Assessment of mechanisms generating offshore salt karst

To understand karst generating mechanisms, 3D seismic data are analysed at the seafloor for textural features along 2D sections to study the correlation of subsurface structures with their outcrops at the seafloor, and with 3D geobodies to understand the relative movements of the individual salt bodies. In this analysis, I use the abbreviations listed in Table 1 to ease the labelling in the figures. In the figures, white arrows indicate the direction of salt movement and yellow arrows point to salt karst features; continuous white lines indicate axes of ridges and dashed lines are used to show faults.

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<th>Mechanisms generating offshore salt karst:</th>
<th>Abbreviations used in the figures.</th>
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<td>1. AK – active salt diapirism</td>
<td>C1, C2 – Salt canopies</td>
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<td>2. CK – compression</td>
<td>CR – Caprock</td>
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<td>3. SK – shear-related faulting</td>
<td>SD – Salt diapir</td>
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<td>ST – Salt stock</td>
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<td>L – Seafloor lineaments</td>
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Extensional faulting occurs at the top of an active salt stock when the salt reaches the seafloor (Figure 2). The extensional stress breaks the protective caprock (CR), possibly consisting of evaporites and carbonates. Once this protection is removed, the seawater dissolves any exposed salt, leaving rough areal salt karst (AK) behind. Augustin and Talbot (2016) considered that deep currents, indications for which are clearly visible in the deep furrows in Figure 2a, are the reason for the dissolution of salt, but the rough collapse texture of the salt stock surface (Figures 2a and 2b) suggests that a combination of erosion through currents and collapse of the protective caprock through extensional stress is the more likely cause.

![Figure 2](image)

**Figure 2** Extensional stress at the top of an extruded salt diapir. (a) Surface lithology and texture at the seafloor, (b) salt geobody and seismic section, (c) seismic section.

Stress in a salt body can also result from the collision of a salt diapir (SD) with a gravity gliding salt canopy (C1) (Figure 3). The surface of the salt diapir has the shape of a ridge, which is indicated by the white line and the dipping arrows. At one end, which is indicated by the yellow arrow in Figure 3a and 3b, the protective caprock is disrupted by the stress, thus exposing the salt to dissolution.

![Figure 3](image)

**Figure 3** Compressional stress at the top of a salt wall colliding with a gravity gliding salt canopy. (a) Slant 3D view at seafloor, (b) 3D view of subsurface salt bodies.

When two salt canopies gravity glide into the basin at different speeds, I assume that shear stress can be generated in the accommodation zone (Figure 4b). Lineaments (L) in the seafloor can be observed through their topography (Figure 4a) and through changes in the lithology highlighted by dark patches in the colour-processed seismic data (Figure 4b). These lineaments can be interpreted as strike-slip faults disrupting the caprock, thus opening access for the seawater to dissolve the salt (SK1 in Figure 4)
Figure 4 Shear stress from differential gravity gliding of two salt canopies, breaking the caprock of the salt crown. (a) Surface texture highlighted by surface dip angle, (b) slant 3D view from Sigsbee Escarpment (C2) towards the basin floor with lineaments (L) indicating faults (dashed lines) interpreted from seafloor texture in colour-processed seismic data.

Figure 5 Salt karst features in their geological context at the edge of Sigsbee Escarpment (C1, C2). (a) Slant view of structural interpretation proposing two accommodation zones. and SK2 in Figure 3). These salt karst features occur either perpendicular to (SK2) or turned away from (SK1) the seafloor currents and, thus are interpreted as tectonically generated features rather than erosion by currents as described by Augustin and Talbot (2016).
The three different cases of salt karst generation at the seafloor can now be brought into their geological context (Figure 5). Active salt diapirism (ST and SD) generates extensional stress on the caprock, which results in extensive collapse and karsting of the exposed salt (AK). The collision of the salt diapir with the gravity gliding of salt canopy C1 causes compressional stress on the caprock of the salt wall, which results in compressional salt karst (CK). Differential gravity gliding of salt canopies C1 and C2 generates shear stress in the accommodation zone, which may create strike-slip faults breaking the caprock. These features are observed at the salt diapir (SK1) and at one end of the salt wall (SK2).

Conclusions

The expression of offshore salt karst at the seafloor can be mapped from high-resolution 3D seismic data using the colour-processing method. Three different mechanisms for salt karst generation were identified:

1. The disruption of the protective caprock can be caused by active diapirism, which excites extensional stress on the caprock, breaking it and giving access to the seawater to dissolve the underlying salt and causing widespread caprock collapse.
2. Collision of salt diapir with a gravity gliding salt canopy, which results in compressional stress excited on the caprock, thus breaking it.
3. Differential gravity gliding of different sections of the salt canopy at different speeds, thus creating shear stress in the accommodation zones, which may subject the caprock to strike-slip faulting.

In the study area, these three mechanisms are interpreted as the primary causes for salt karsting; whereas, deep ocean currents near the seafloor should be considered secondary causes, i.e., the currents only increase the efficiency of salt dissolution.

Understanding salt karst and its generating mechanisms can assist in mapping geohazards in the seafloor such as unstable caprock. The approach shown here also allows delineating lineaments in the seafloor that are interpreted as strike-slip faults and that cannot be detected otherwise because strike-slip faults do not show any vertical offset of the strata that could be detected in seismic data. An alternative interpretation of the seafloor lineaments may be regional strike-slip faults.

Acknowledgements

The author thanks WesternGeco Multiclient for processing the data and for permission to publish the results.

References

