**SALT TECTONICS IN A TANK: A NEW EXPERIMENTAL APPROACH WITH APPLICATIONS TO ALLOCHTHONOUS SALT-BODIES**

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**Summary**

We designed and built a new experimental set-up allowing to model the transport and deposition of turbidity currents combined with the ability to simulate spontaneous gravity-driven salt tectonic. We tested the effect of turbiditic lobe deposition onto various shapes of salt-bodies, ranging from salt-stock or salt-ridge. Surprisingly, the model deformed rapidly even under the effect of minute differential loading. On one hand, the first turbiditic lobe generated sediment ripples that induced local differential loading on the viscous substratum, triggering local passive diapiric rise. On the other hand, if the salt-body is long enough, the growth of the turbiditic fan and the build-up of a regional bathymetric slope triggered regional collapse and spreading of the entire sedimentary wedge. Spreading was accommodated by distal compression and proximal multidirectional extension, where grabens and associated salt ridges individualized mini-basins evolving in turtle structure. If the salt-body is narrower and thicker, spreading is not allowed and deformations are characterized by a set of normal faults that accommodated the sinking of the overburden into the salt. Owing to this new experimental approach we produce roho or stepped counter-regional systems as encountered in allochthonous salt-bodies in U.S. Gulf of Mexico.

**Introduction**

Clastics sediment wedges along passive margin have been the topic of two radically different experimental approaches.

*Stratigraphic modelling:* On one hand, experimental stratigraphers have focused on the processes of transport and deposition, and their impact on the stratigraphic architecture. Many flume experiments simulating turbidity current deposits (fluid-mechanically similar to natural flows) have been designed to understand the stacking patterns of deep-sea turbidite fan systems. Luthi (1981) used natural silt to produce a single, thick lobe deposit that exhibited distal fining and thinning. More recently, Parsons et al. (2002) constructed a facility capable of producing multi-bedded deposits from turbidity currents. The device was designed to produce stacking of several millimetre-thick lobes constituting a realistic fan system. Results demonstrate how one depositional lobe was abandoned, while another one formed (lobe switching). Baas et al. (2004) performed a flume experiment studying the flow properties and depositional characteristics of high-density turbidity currents. Their study focused on the depositional processes, the geometry of sediment bodies, their vertical and horizontal sequences of sedimentary structures and the grain-size distribution. They successfully produced lobes with distinct fan shapes (varying from circular to elongate) with proximal channel-levee. They demonstrated that structureless sediments filled the channel and the lobe’s centre, whereas levee bodies and lobe fringe were laminated. However, most of this experiment did not combine sediment transport and deposition with synsedimentary deformation.

*Tectonic modelling:* On the other hand, significant number of workers has modelled experimentally or numerically how deposition of successive sediment wedges onto a weak substratum (salt or shale) triggers the overall collapse and spreading of the sediment wedge (Ings et al., 2004; Vendeville, 2005). These approaches were strictly tectonically oriented; deposition of each sediment wedge was somewhat crudely modelled by adding one new layer instantaneously. The physical processes by which sediments are transported and deposited were not truly modelled using these approaches.
Figure 1. Tectono-stratigraphic modelling tank.

Figure 2. Top and side views of an experimental flow above a viscous salt-analogue substratum (left part of the tank). Note the Head (H) at the front of the flow and the following body (B) of the turbidity current (mean velocities of the head are noted on the side view).

Figure 3. Various salt-body shapes tested in the deformation box for this study.
Experimental approach and modelling apparatus

In 2007, we designed a new tectono-stratigraphic modelling tank at the experimental laboratory at the University of Lille 1 (Figure 1) with the aim to combine modelling of the transport and deposition of turbidity currents transport as well as their salt-related deformation. The Set-up comprises one channel connected to one main under-water tank. A deformation box is placed at the bottom of the tank, at the mouth of the channel. The base of the box can be filled with various kinds of substratum either rigid (e.g., sand) or viscous (e.g., silicone polymer, simulating rock salt). Thus, the set-up permits to mould various salt-body shapes. The set-up also includes a container in which a mixture of water and fine-grained artificial or natural powder kept in suspension by a stirrer (i.e. glass microbeads, sand or plastic powder having grain sizes ranging between 50 to 150 μm). Each turbidity episode was triggered by opening a valve at the bottom of the container, releasing the mixture into the tank (Figure 1). In the experiments describe below, the analogous material simulating the mobile salt was made of viscous silicone (SGM36) (Figure 2). For each experiment, we conducted several consecutive turbiditic episodes in order to test whether deposition of the lobes could trigger spontaneous gravitational deformation of the viscous substratum. We tested various allochthonous salt-body shapes, ranging from salt-stocks to salt-tongue (Figure 3).

Results

The dynamics of turbidity currents lead to differential deposition: each lobe was thick in the proximal area, and thinned progressively towards the distal area, all this creating a very gentle surface slope (less than 1°). Each individual wedge thinned out forward, from about 5 mm in the proximal are down to sub-millimetric thickness in the distal part. The differential loading of the salt-bodies induced two responses at different scale.

Salt response to local differential loading: To our surprise, salt’s response to local differential loading was fast and swift. In our models, the flows generated sub-marine sedimentary ridges that have a sub-millimetric height. Thus the ensuing differential load was low. Nevertheless, the deformatonal response of the underlying salt was immediate, with rapid subsidence of the sedimentary ridges and passive rise of the less-loaded inter-ridge areas. The rise of the diapirs produced bathymetric highs and lows who, in turn, affected the depositional patterns during all subsequent turbiditic episodes. For example, thicker series were deposited downstream of the salt ridges, while the upstream flank was more erosive.

Salt response to regional differential loading: Regional salt response to differential loading is function of the salt bodies extent. On one hand, in the case of a salt tongue (i.e. a long and thin salt-body), the growing maturity of the sedimentary fan and the progressive build-up of a bathymetric regional slope triggered regional spreading and collapse of the entire edifice. Spreading induced shortening at the distal salt basin’s edge accommodated by folds reverse faults and a bulge where salt was thickened (Figures ?), and radial extension in the proximal area generating multidirectional grabens and associated underlying salt ridges, that eventually evolved into piercing diapirs (Figures ?) (Gaullier and Vendeville, 2005; Vendeville, 2005). Because of the subcircular planform of the sedimentary fan, spreading was radially oriented, leading to formation of multi-directional grabens in the overburden, with concentric and radial trends (Figures ?) similar to those observed in the Sigsbee region in the deep-water Gulf of Mexico (Diegel et al., 1995; Gaullier and Vendeville, 2005). On the other hand, when the salt body is narrow and thick (i.e. salt stocks or salt ridges), gravitational spreading is not allowed. Thus, salt-related deformations are mainly characterized by a set of normal faults at the landward salt-body edge. These extensional structures accommodate the subsidence of the turbiditic fan into the mobile salt. More distally, where the clastic fan is thinner, the salt was inflated or totally evacuated, leading to the formation of a counter-regional weld between the overburden and the subsalt units.

Conclusion

Owing to the ability of the experimental apparatus to create very gentle bathymetric slope (less than 0,75°), this new experimental approach demonstrates and validates the concept that even low gravitational instabilities, due to differential loading of a sedimentary fan deposited onto a mobile salt layer, can trigger deformation by gravity spreading (Gaullier and Vendeville, 2005; Vendeville 2005).

By varying the salt-body shapes, the experimental apparatus is able to produce common structures encountered on allochthonous salt-sheets at laboratory scale (i.e. roho or stepped counter-regional systems from the U.S. Gulf of Mexico) (Diegel et al., 1995). Futhermore, the deposits and their deformations carried out in the tank could be considered at two-different scale. At local scale (i.e. for salt-bodies ranging between 20 to 60 km), each lobe could be analogous to a turbiditic sand lobe that is internally deformed above an allochthonous salt-body. Or, at margin scale, the experimental lobe could be analogous to a bigger edifice; in this case the apparatus appears as a new experimental method well suited for produce low-angle lobes.
This new experimental approach was carried out in prototype, thus the results constitute an overview of what could be done in greater device.

Figure 4. Deformation box set-ups, map views and cross sections of two salt-bodies shapes tested for this study.

REFERENCES