Experimental Modeling of the Controls of Shapes and Flow Rates of Salt Diapirs*

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Abstract

Analog modeling of salt diapirs was conducted to understand the controls of diapirs shapes and flow rates using garnet and silica sand to simulate sediments and silicone gel to simulate salt. Results show that the key factors are the rate of sedimentation, the sediment load, which is dependent on the column height and the sediment density, and the thickness of the salt layer. Sedimentation rate plays a dual role in the movement of salt. It provides the load, which is the main driving force for the salt movement, but can also restrain the movement of salt. Low rates of sedimentation result in the formation of a cylindrical diapir that eventually develops a flared shape, whereas a high rate of sedimentation results in eclipse and occlusion of the diapir after initial movement. Sediments with low density require a lower rate of sedimentation to compensate for the decreased load for the diapir to grow. Continued salt movement requires an optimum balance between the total load and the rate of sedimentation at all times. Variable rates of sedimentation result in changes in diapir shape over time. An initially slow rate may result in cylindrical and flared shapes of increasing diameter. An increase in the sedimentation rate may result in initial tapering followed by eclipse of the diapir, or continued movement after reduction in the diapir diameter. Tapering enables an increase in the salt velocity by decreasing its surface area, and results in a possible transition from passive to active diapirism. The thickness of the salt source controls both the rate of the salt flow and the dimensions of the diapir. A thick source layer results in a higher rate of flow, and results in a wider diapir and flare, whereas a thin source layer results in a narrower diapir, which flows at a lower rate and is eventually eclipsed. The results provide a guideline to better understand the evolutionary history of diapirs, which can be used for analyzing natural structures. Features observed in natural salt diapirs show similarities to the experimental results, so that their growth histories can be predicted by studying the sediment shapes. Investigation in the East Texas Basin using seismic data

and well tops suggest that the evolution of the Butler, Palestine and Oakwood domes is related to the nature and rate of sediments deposited, as suggested by the experimental models.

Reference Cited

Hudec, M.R., and M.P.A. Jackson, 2007, Terra infirma; understanding salt tectonics: EarthScience Reviews, v. 82/1-2, p. 1-28.

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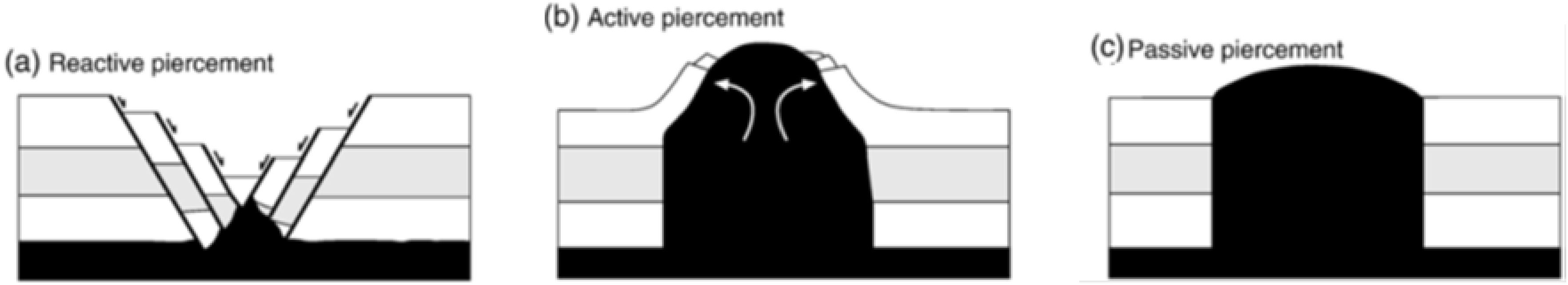
Outline

- Introduction to Salt Structures
- Experimental Setups
- Results & Observations
- Analysis
- Conclusion

Introduction to Salt Structures

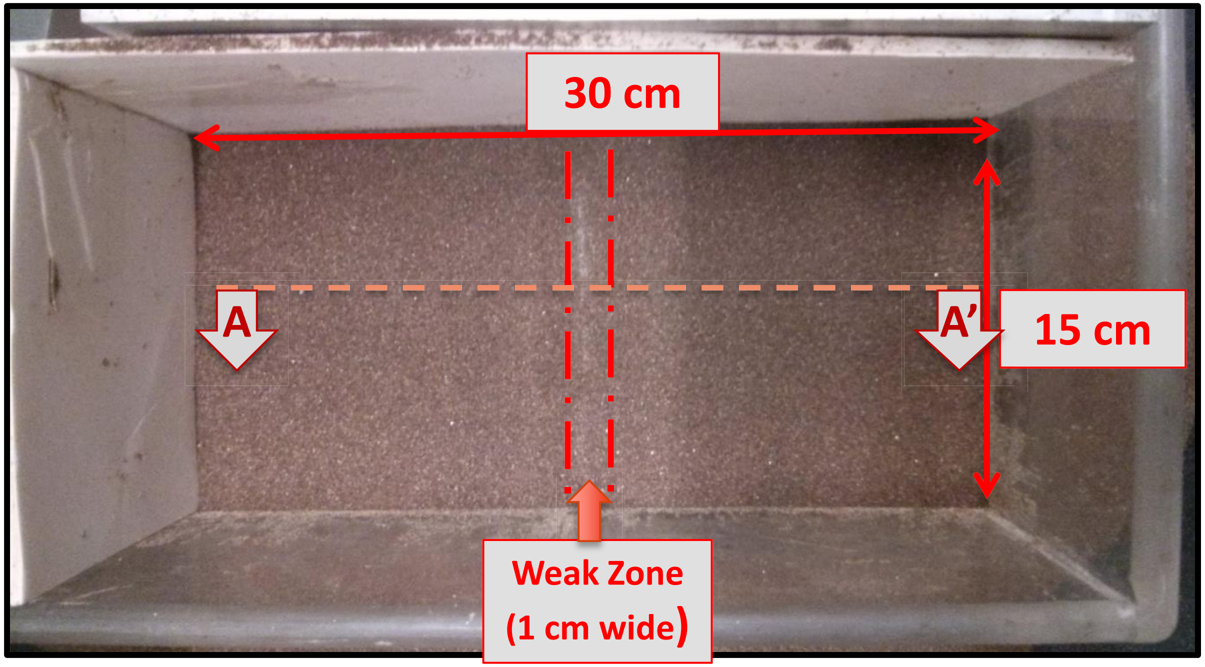
- Mechanisms of Diapir Growth
  - Active (Piercement of overlying sediments)
  - Passive (Downbuilding of overlying sediments)
  - Reactive (Normal faulting in overlying sediments)



Diapir Growth Mechanisms (Modified from Hudec & Jackson, 2007)

- Key controls of salt flow:
  - Sedimentation Rate
  - Sediments Loading
  - Source Bed Thickness

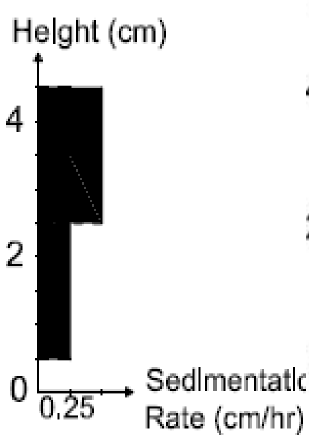
Experimental Setup

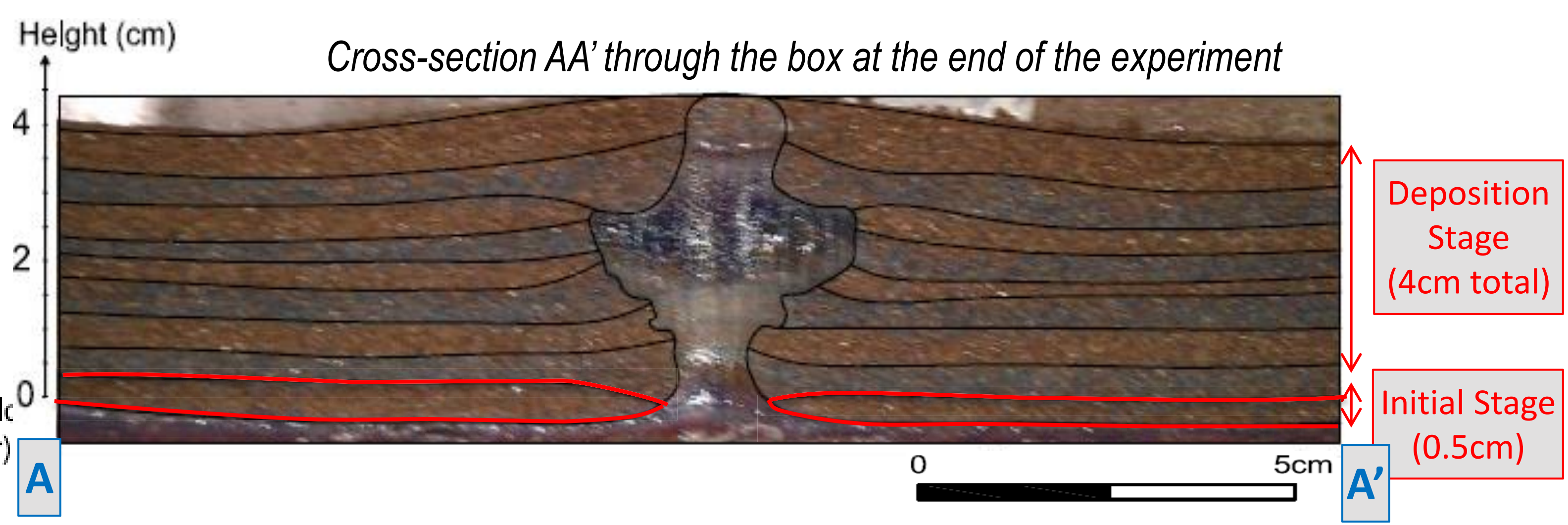


- Silicone Gel (Viscosity of 10.1x10-4 Pa.sec, Density 0.9g/cm^3)
- Garnet Sand (4g/cm^3)
- Silica Sand (2.65g/cm^3)

Sand box top view at the end of the initial stage

Cross-section AA' through the box at the end of the experiment

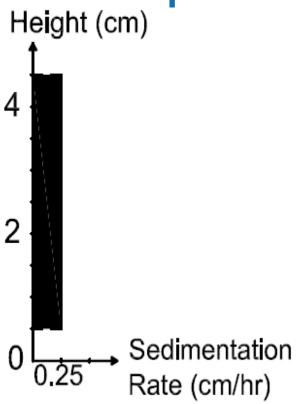


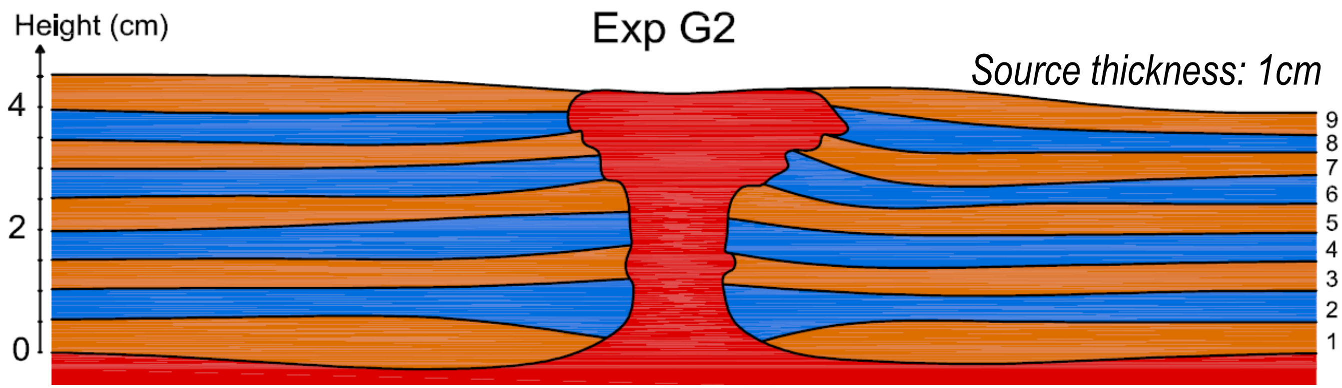


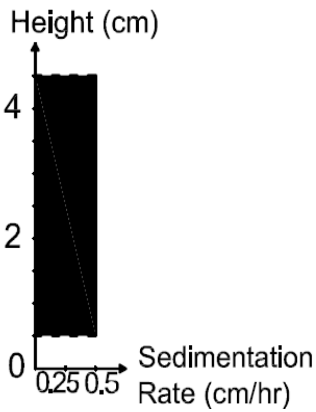
Summary of the Experiments

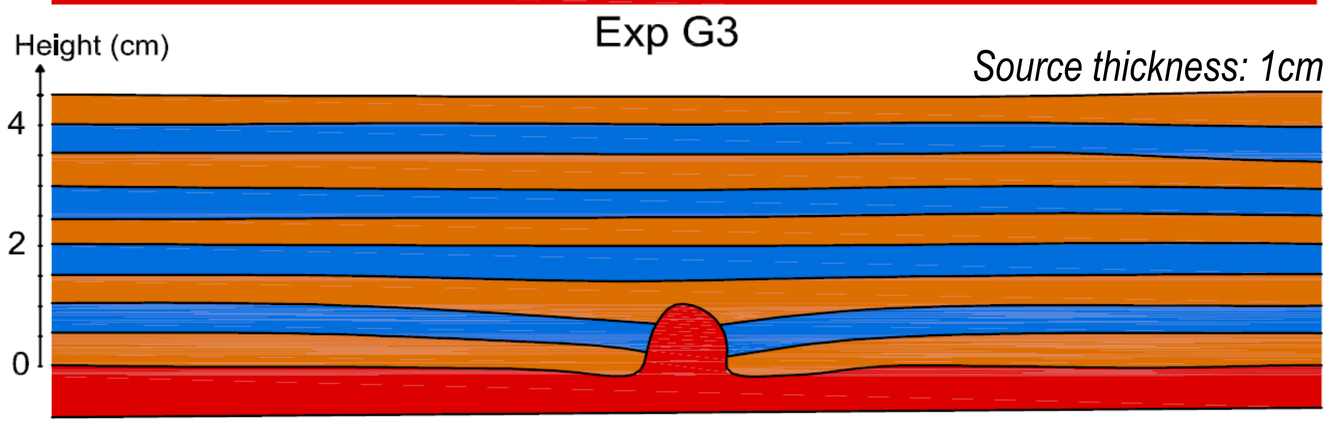
Exp	*Sand Type*	*Silicone Thickness (cm)*	*Sedimentation Rate (cm/hr)*	*Initial Phase*	*Total Duration (hr)*
G1	Garnet	0.75	0.25	0.5 cm for 1 hour	17
G2		1.00	0.25		17
G3			0.50		9
G4			0.75		6
G5			0.25 - 0.35		15
G6			0.25 - 0.50		13
G7			0.25 - 1.00		11
G8		1.25	0.25 - 0.50		13
G9		1.50	0.25 - 0.50		13
S1	Silica	1.00	0.083	0.5 cm for 3 hours	51
S2			0.166		27
S3			0.25		17
S4			0.50		9
S5			0.25 - 0.50		13

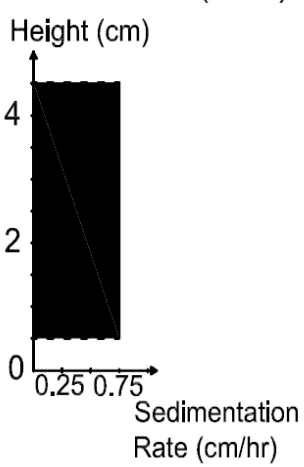
Experimental Results – G2, G3, and G4

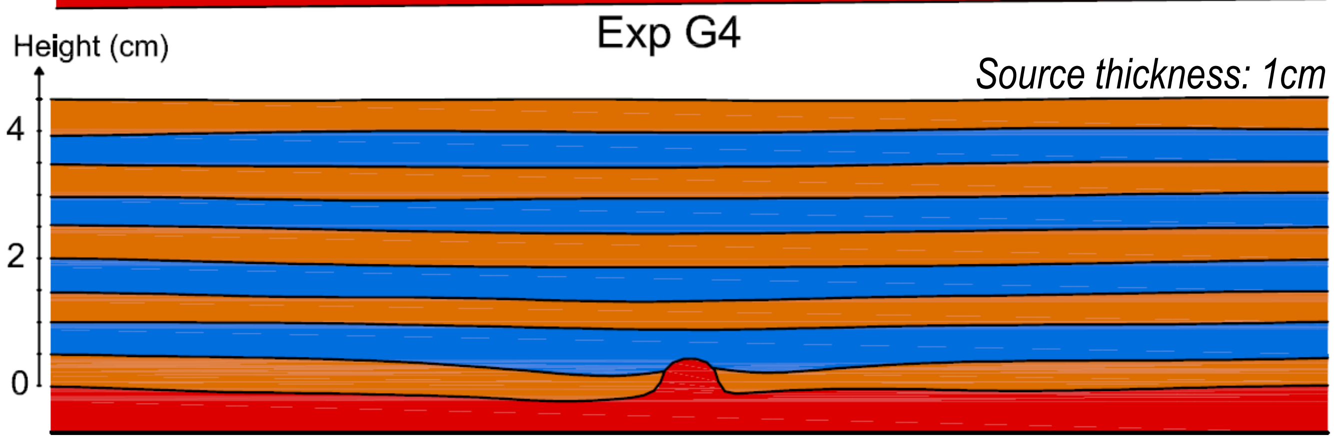






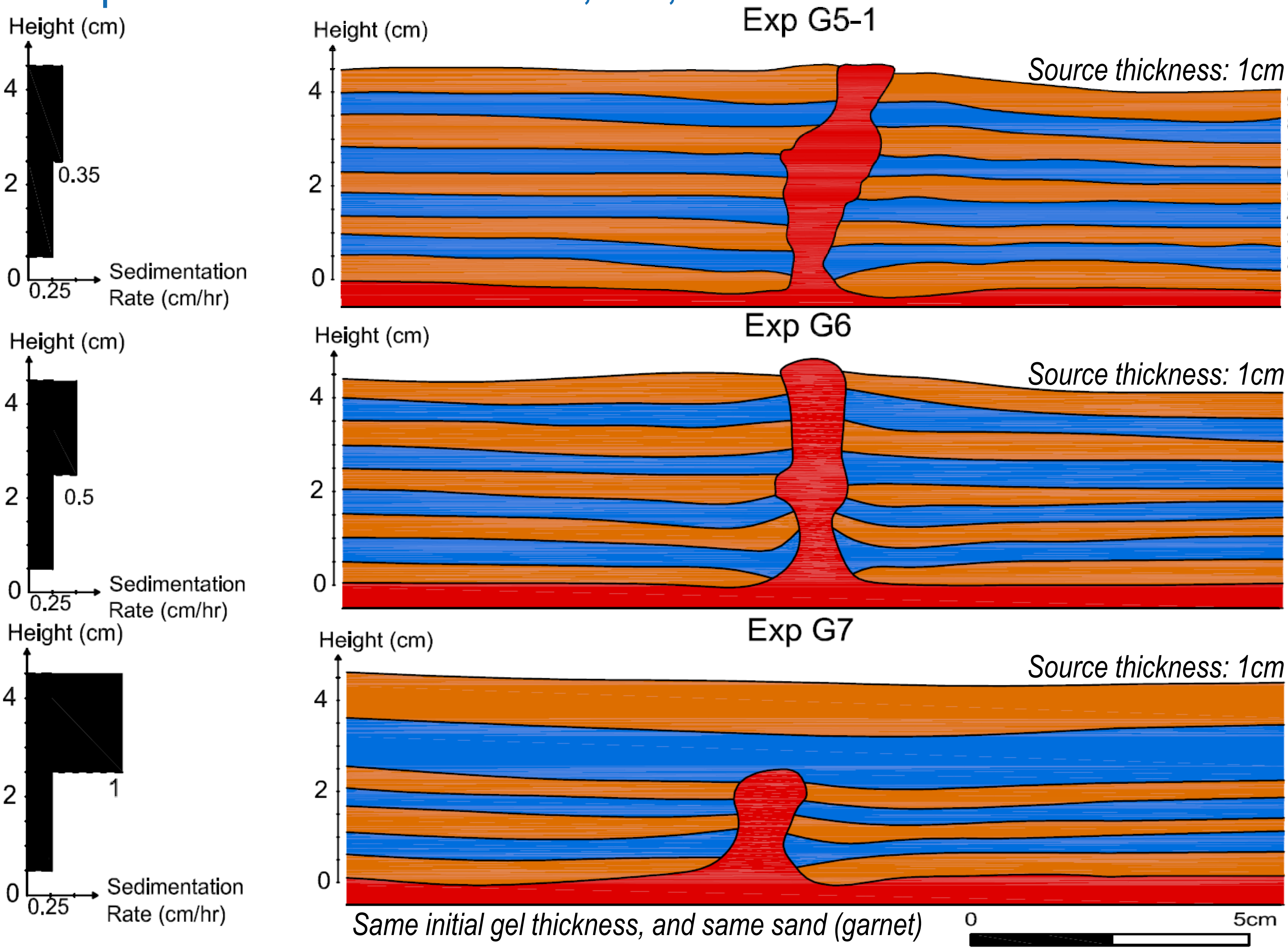






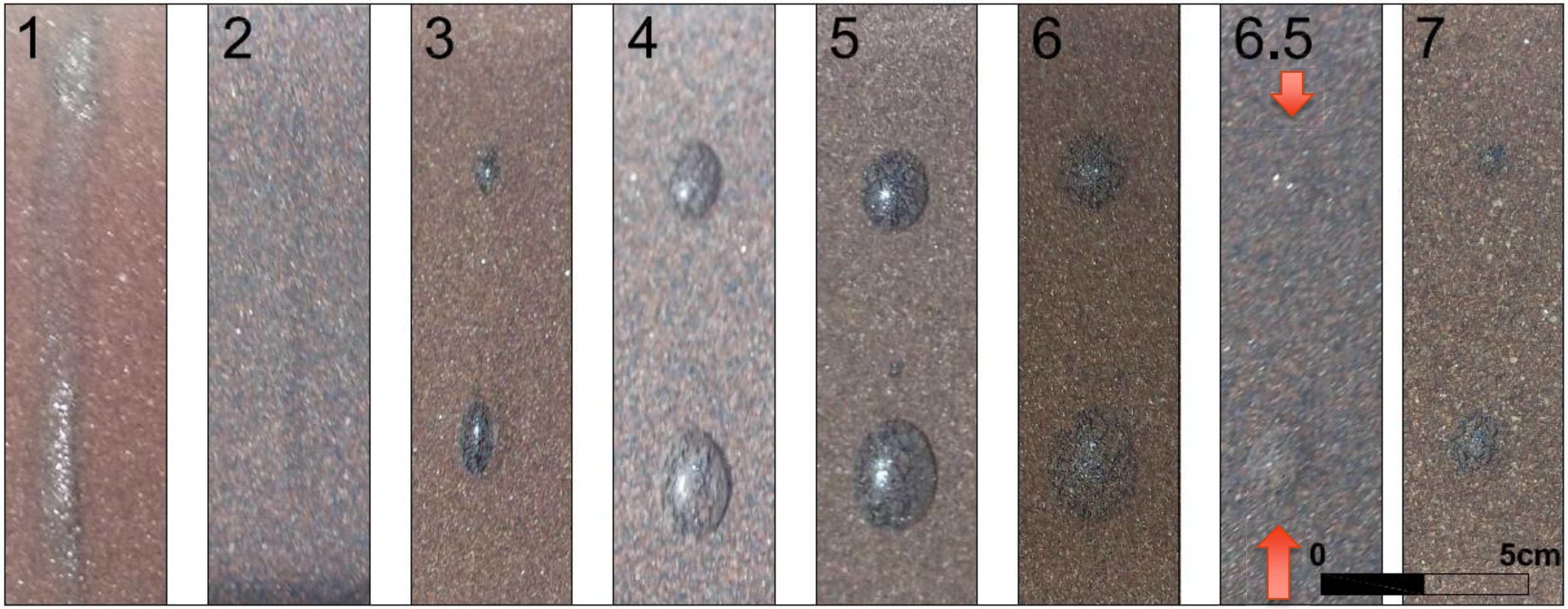
Same initial gel thickness, and same sand (garnet)

Experimental Results – G5, G6, and G7

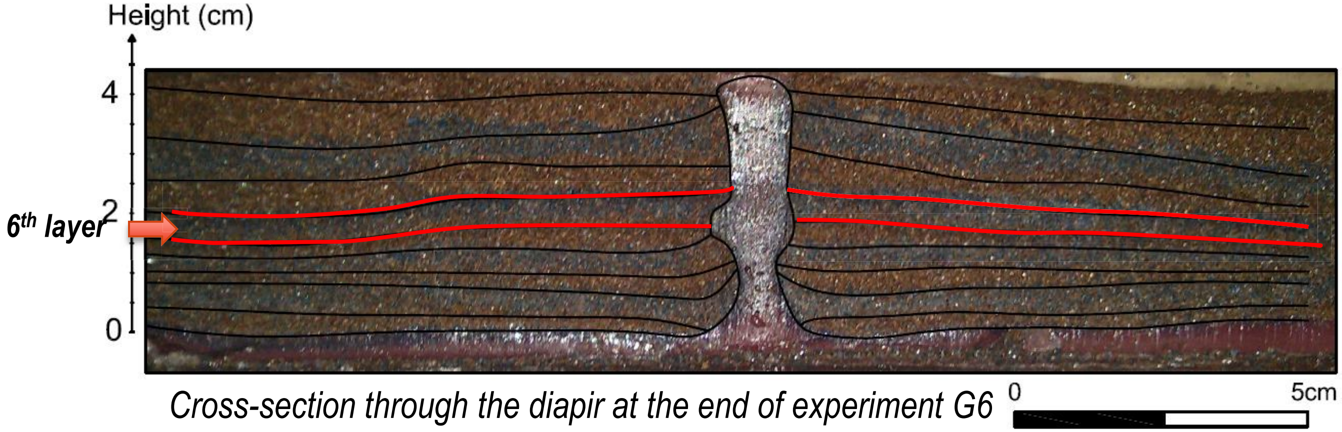


Same initial gel thickness, and same sand (garnet)

Experimental Results – G6



Top pictures for experiment G6 at different stages during the growth revealing active piercement upon the deposition of the 6th layer.

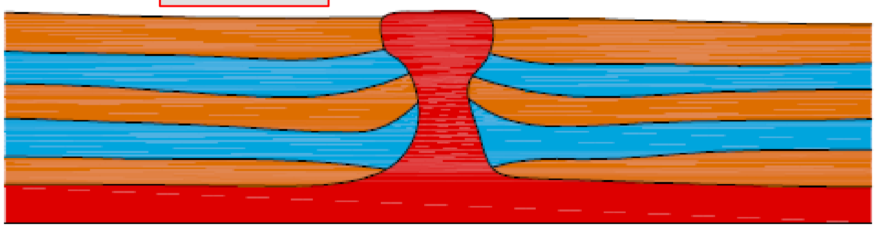


Cross-section through the diapir at the end of experiment G6

Experimental Results - G6 and G7

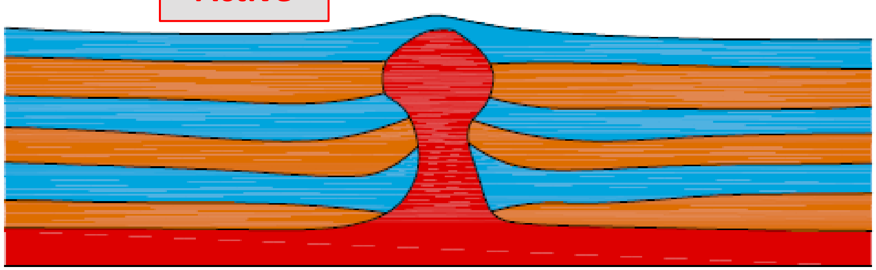
G6 at the Initial Stage

Passive



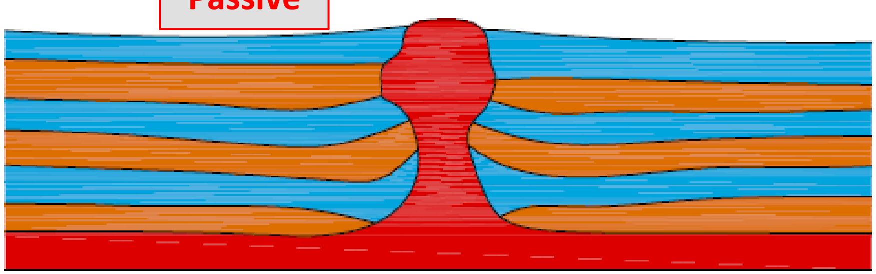
G6 at the deposition of the 5th layer

Active

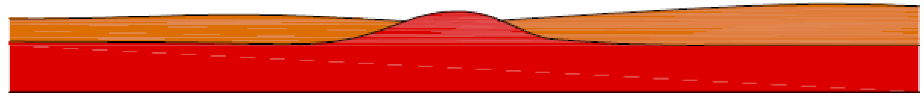


G6 at the deposition of the 6th layer

Passive

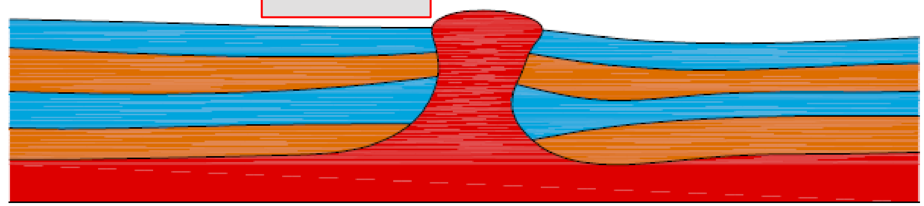


G6 at the deposition of the 7th layer



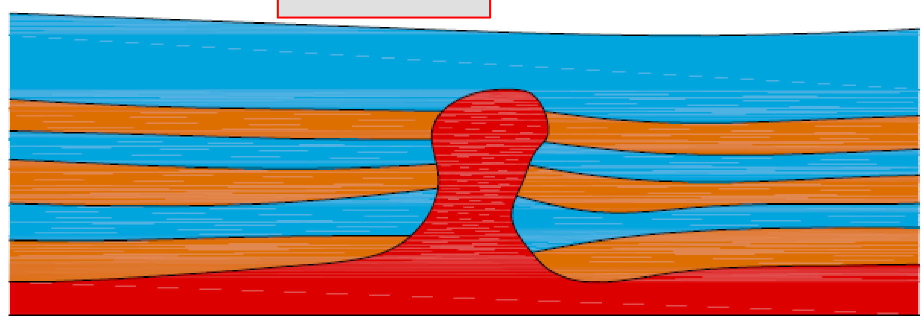
G7 at the Initial Stage

Passive



G7 at the deposition of the 4th layer

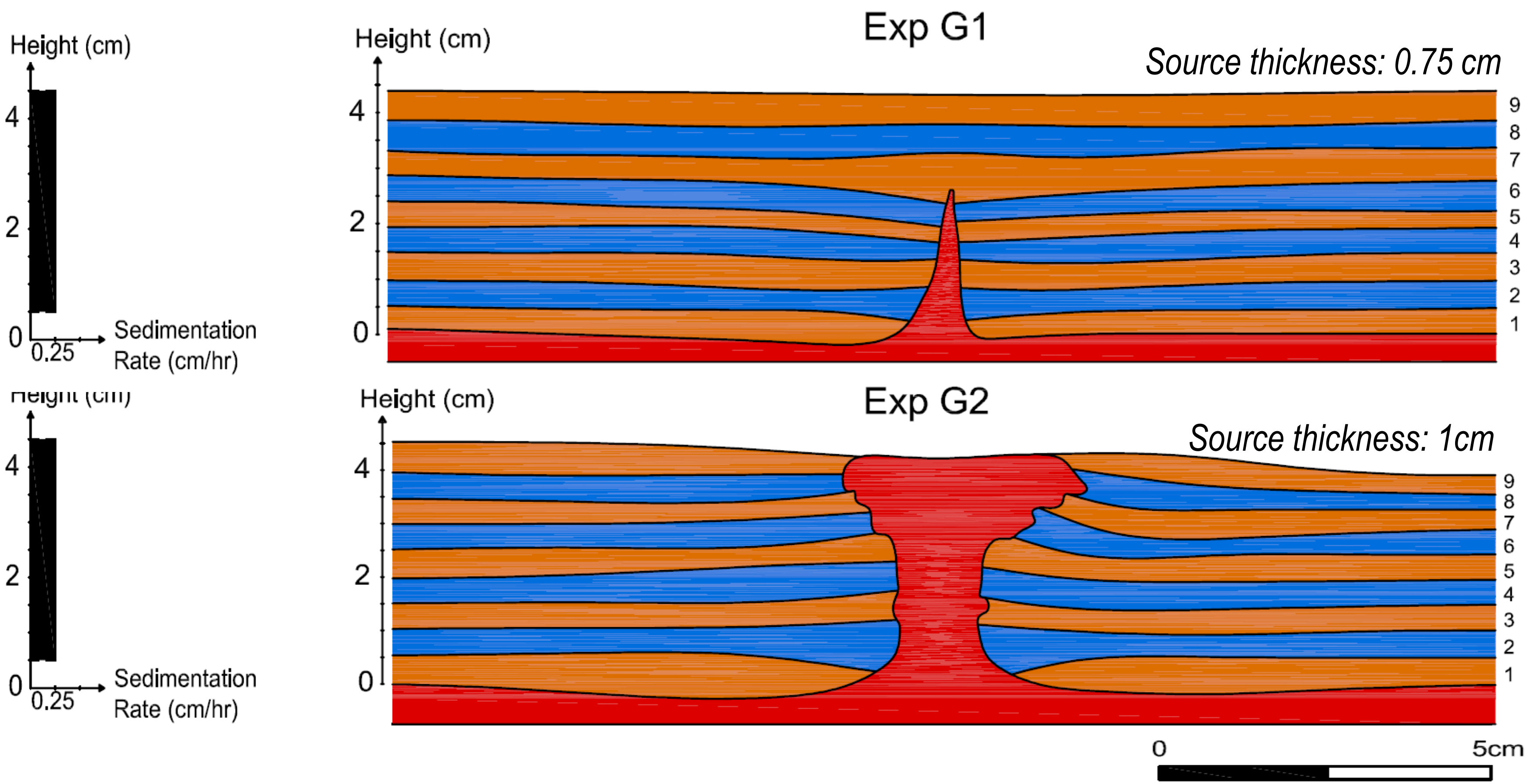
Occlusion



G7 at the deposition of the 6th layer

Schematics showing the growth history for experiment G6 and G7 – The sand column at the crest of the G7 diapir was above the critical thickness that the gel can lift

Experimental Results – G1, G8, and G9

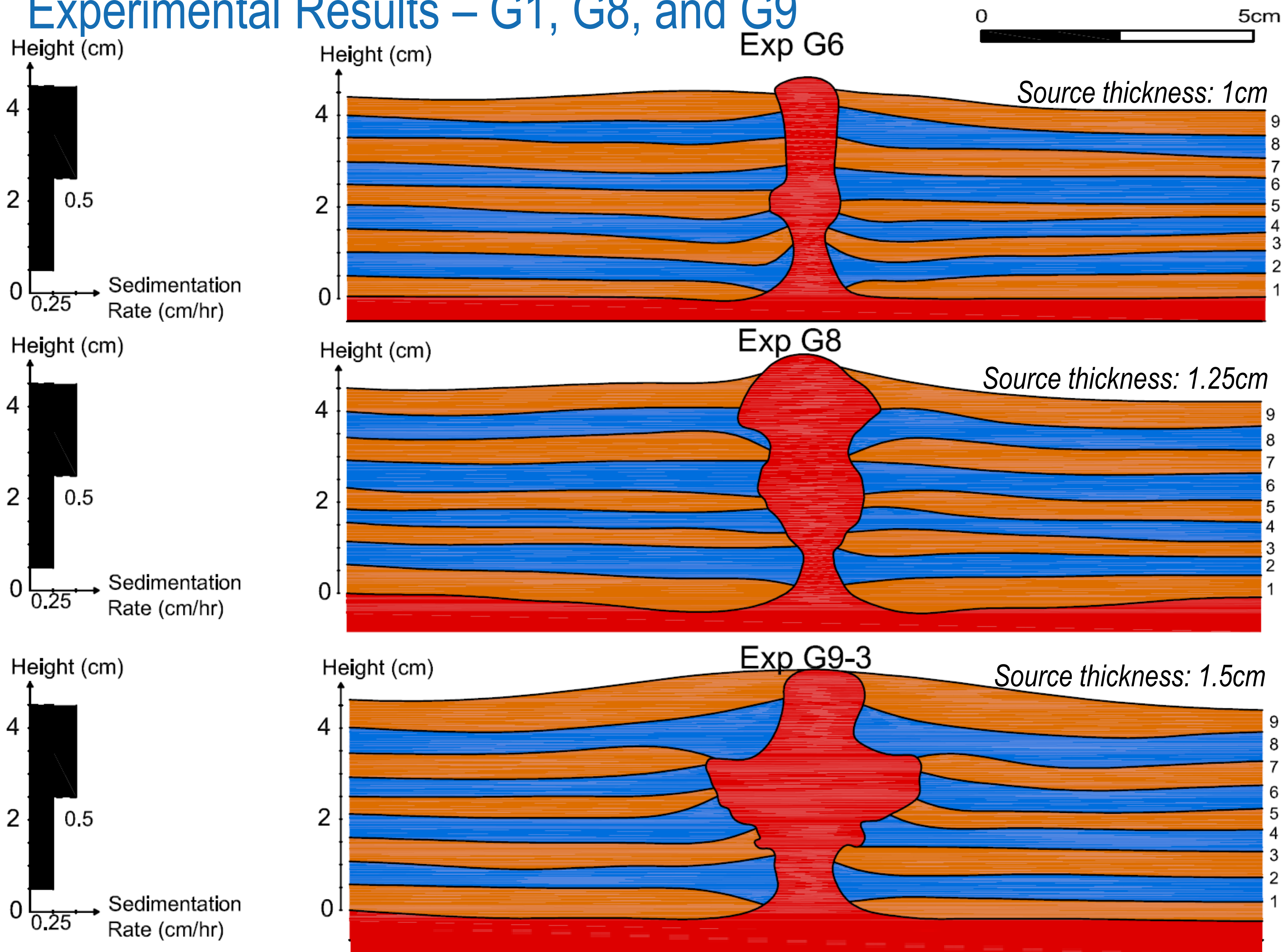


Cross-sections at the end of experiment G1 and G2 revealing a narrower diapir for G1

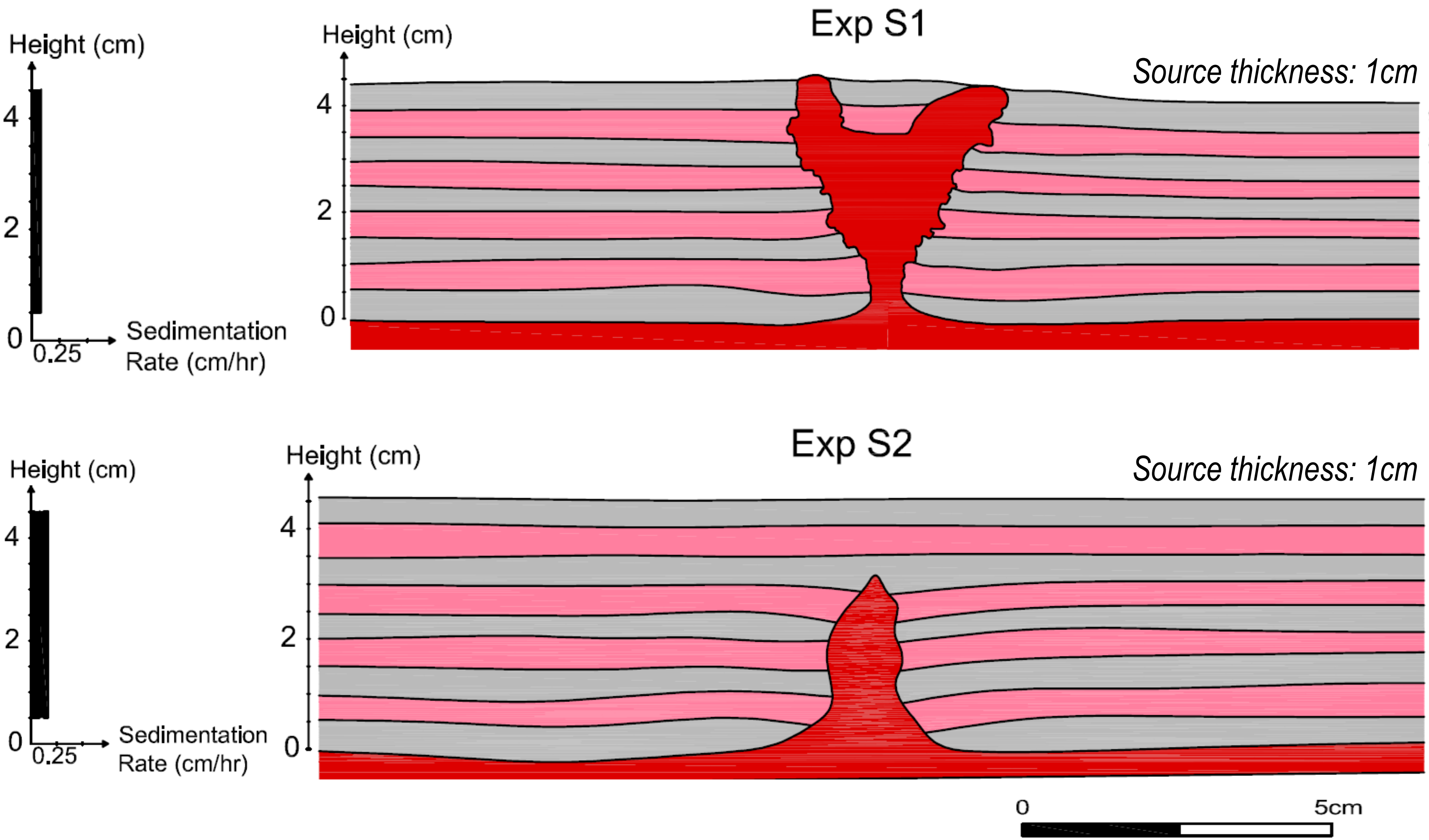
Different initial gel thickness (0.75cm for G1 and 1cm for G2)

Same sedimentation rate, and same sand (garnet)

Experimental Results – G1, G8, and G9



Experimental Results –S1, S2 S3, S4, and S5



Cross-sections at the end of experiment S1 and S2

Conclusions

- Sedimentation rate plays a dual role in the movement of the salt
  - Cause flaring due to the increase in sediments loading
  - Cause tapering due to the increase in sediments deposition
- A thick source layer result in a higher rate of flow, and as a result in a wider diapir and flare
- Density plays a driving role by increasing the sediments loading causing the salt to move at a faster rate
- Tapering is related to changes in the sedimentation rate or to sediments densities or a supply problem
- Flaring is indicative of thick source layers or to an increase in sediments loading