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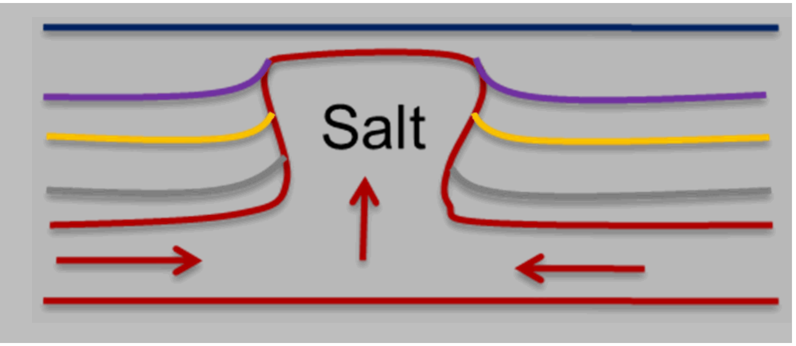

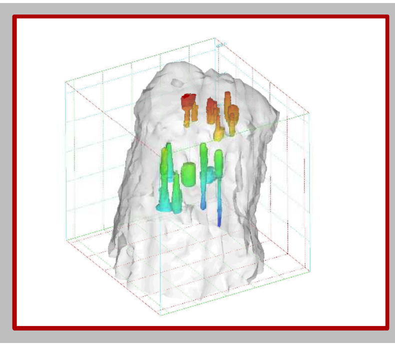

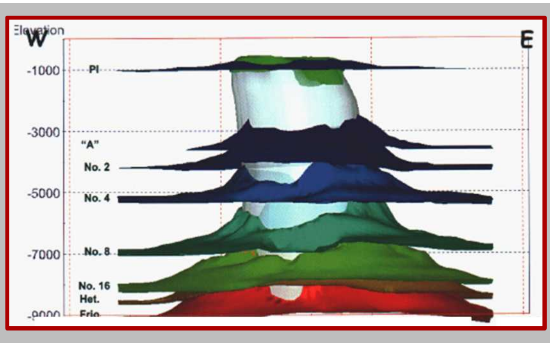

Diapirs and Salt Domes

The Mechanism of Formation

Anna S. Lord

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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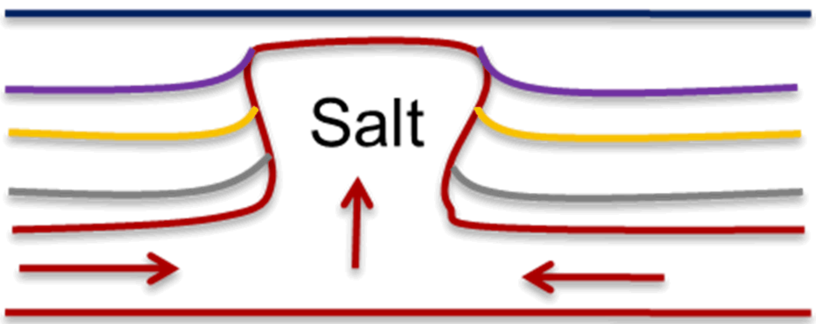
Outline

Purpose: To describe the mechanism of diapir (aka salt dome) formation.

- Salt Domes World Wide
- Historical Perspective
- Evolutionary Stages of Diapirism
- Reactivation
- Internal Structure
- External Margin



Diaperin (Greek) – to thrust-through

Salt Domes World Wide

SMRI Report : Compilation of Geological and Geotechnical Data of Worldwide Domal Salt Deposits and Domal Salt Cavern Fields – Axel Gillhaus, April 2008

General geologic description of domal salt worldwide.

Study describes 145 cavern fields operated in domal salt.

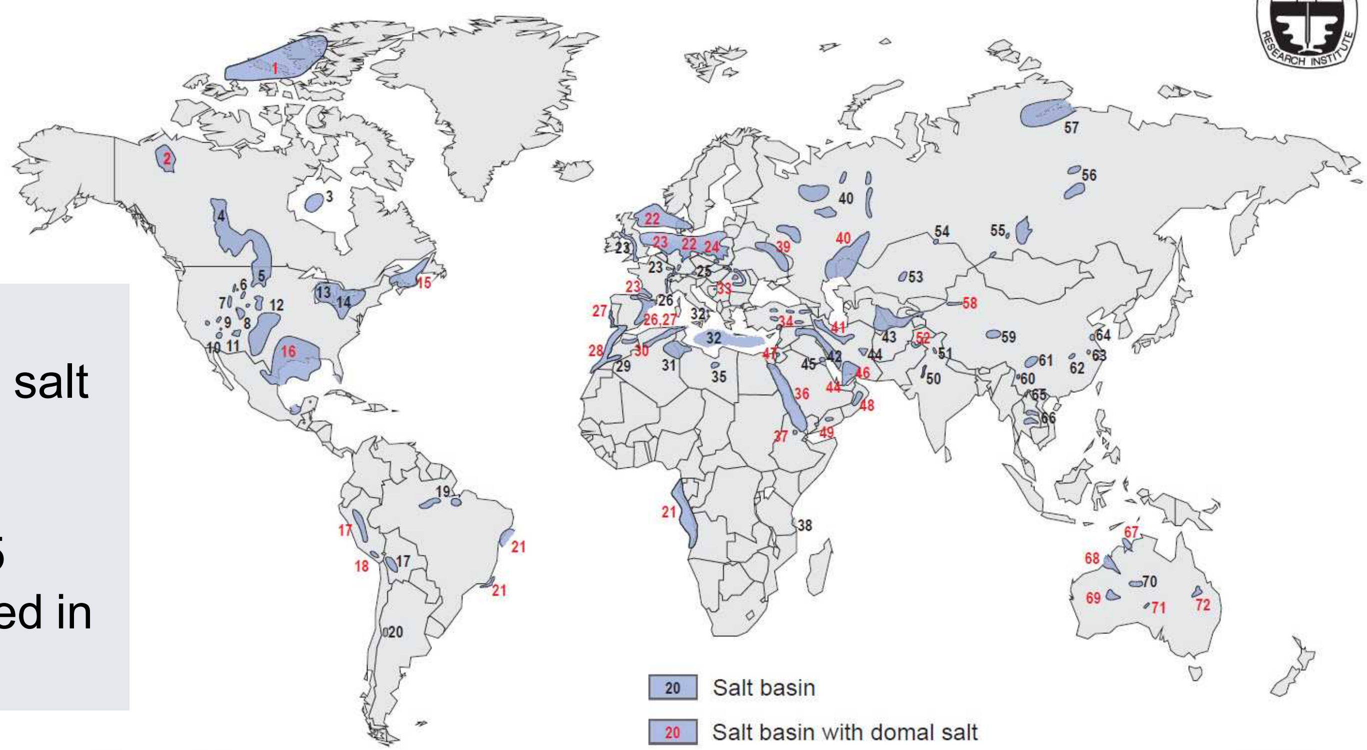
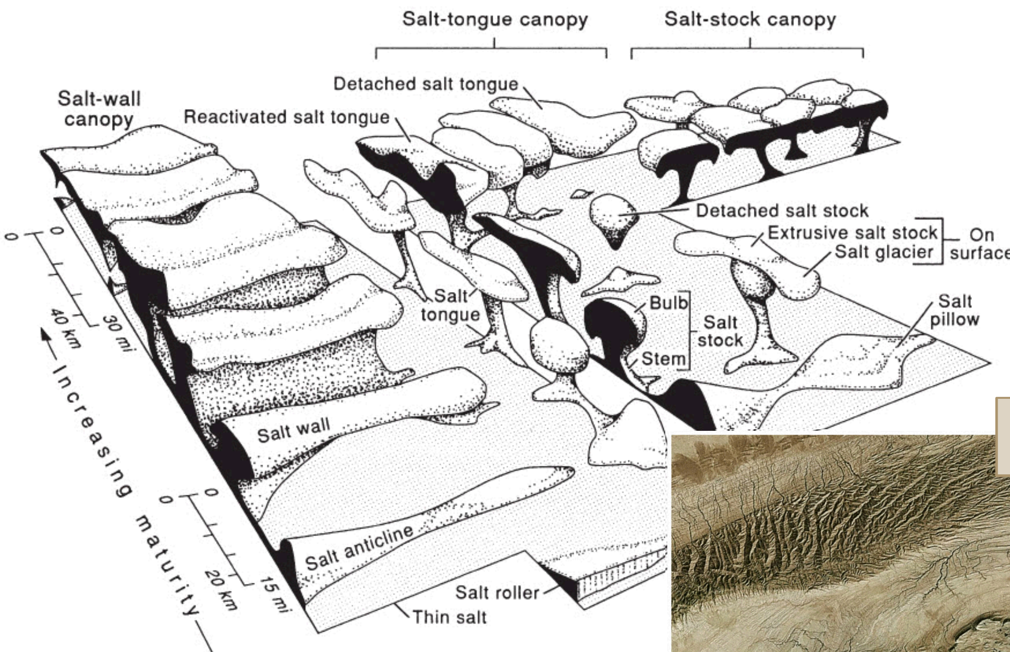


Figure 4-1
World map of underground salt deposits.
Name and stratigraphy of numbered salt basins as listed in tables 1 and 2.
7007-02 Domal Salt\Ausgang\080314 Figures\080609_World-Salt-Map-with-diapirs_SMRI_rev02.cdr

Salt Domes



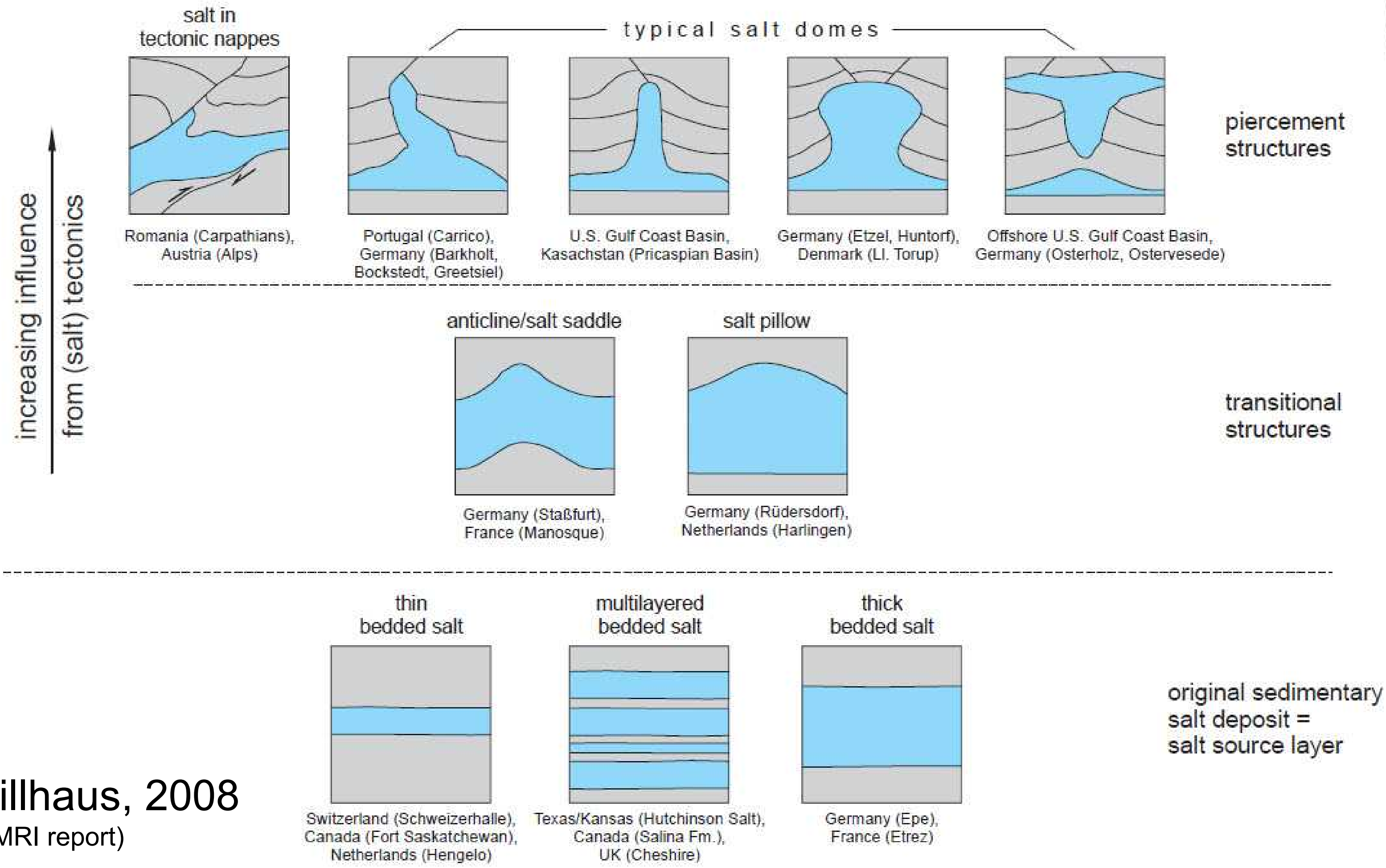
Gillhaus, 2008

(SMRI report)

Great Kavir Salt Canopy, Iran

Great Kavir Salt Canopy from Satellite

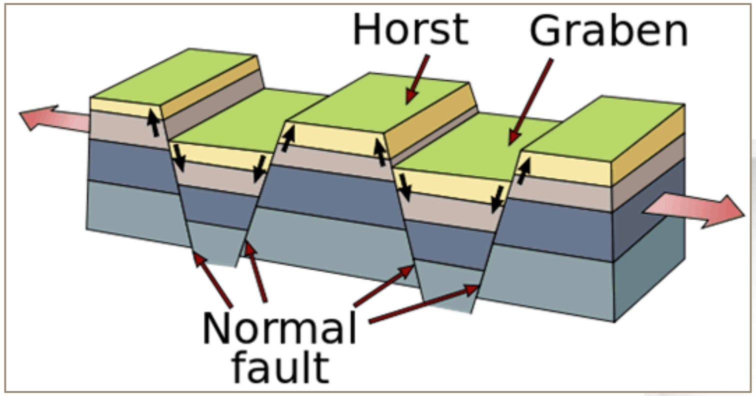
Salt Domes



Gillhaus, 2008
(SMRI report)

Salt Tectonics: Historical Perspective

- Pioneering Era (1856-1933)
- Fluid Era (1934 -1989)
- Brittle Era (1990-current)



Salt Tectonics: Pioneering Era

- Pioneering era (1856-1933) – a time of discovery
  - 1856 first salt dome described: Algeria
  - 1860 first subsurface salt dome: Louisiana, USA
  - 1871 salt domes described as "intrusions emplaced discordantly against their country rocks".
  - 1907 coined the term '**diapir**' as folds cored by piercing salt.
  - Sparse data led to many bizarre formation theories
    - igneous activity, islands, in situ crystallization, osmotic pressures, etc
  - 1901 oil discovered at Spindletop, incentive to obtain subsurface data and knowledge increased fast which led to more realistic theories
    - active intrusion, downbuilding, and differential loading theories

Salt Tectonics: Fluid Era

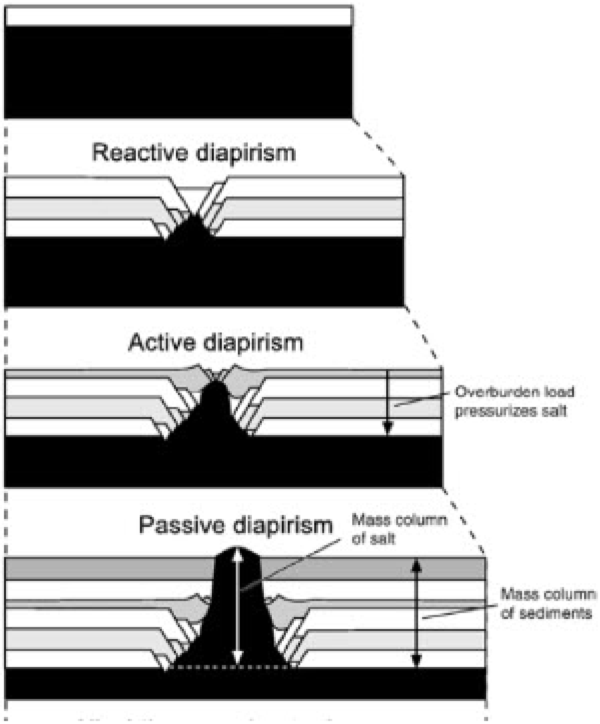
- Fluid era (1934-1989)
  - Both salt and surrounding sediments behave as viscous liquids
  - Dense fluid overburden (sediments 1.7 – 2.0 gm/cc surface; 2.4-2.8 gm/cc at depth) sinks into the less dense salt (2.2 gm/cc) displacing it upward
  - Once salt was buried deep enough to create a density inversion the salt would bulge and punch through the surface
  - Internal structures mapped
  - Diapirs comprised of a series of spines moving at different speeds
  - Rock strength and faulting ignored
  - By the end of the era - downbuilding (passive diapirism) considered the most important driving force for salt flow.

Salt Tectonics: Brittle Era

- Brittle era (current)
  - Sediments are strong, brittle, fractured overburden, NOT weak fluid one.
  - Fluid diapirs accelerated by thicker overburden, but diapirs inhibited by brittle overburden that exceeded a certain critical thickness.
    - i.e. diapirs stop rising when roof becomes too thick
  - Density is a secondary factor and diapirs are triggered by a variety of mechanisms.
  - Three modes of diapirism recognized with reactive diapirism being the most important way to initiate salt flow
    - Reactive, Active, & Passive

Three Modes of Diapirism

- Reactive
- Active
- Passive



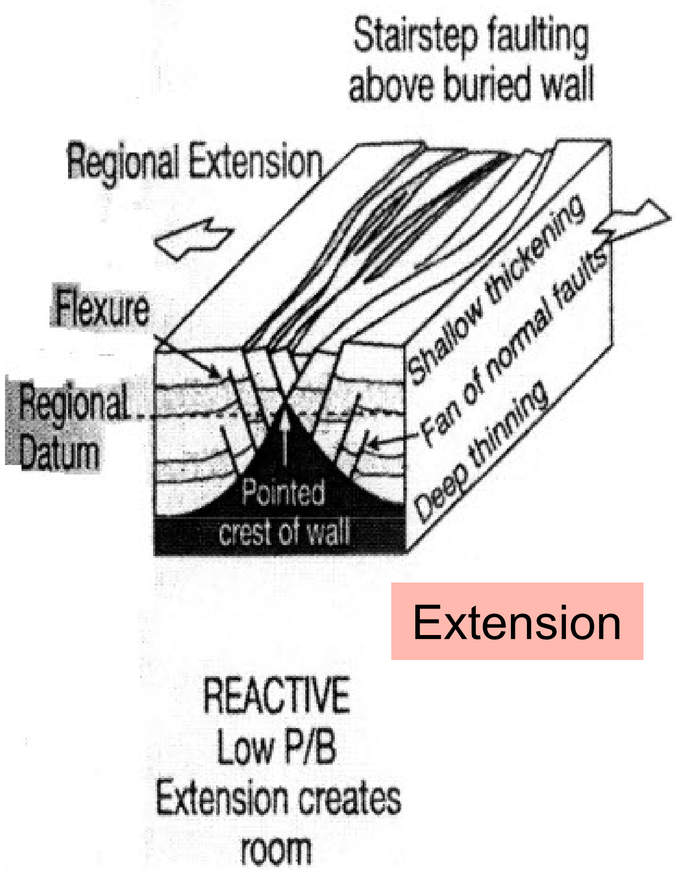
Vendeville & Jackson, 1992
(reproduced with permission from Elsevier)

Mode: Reactive Diapirism

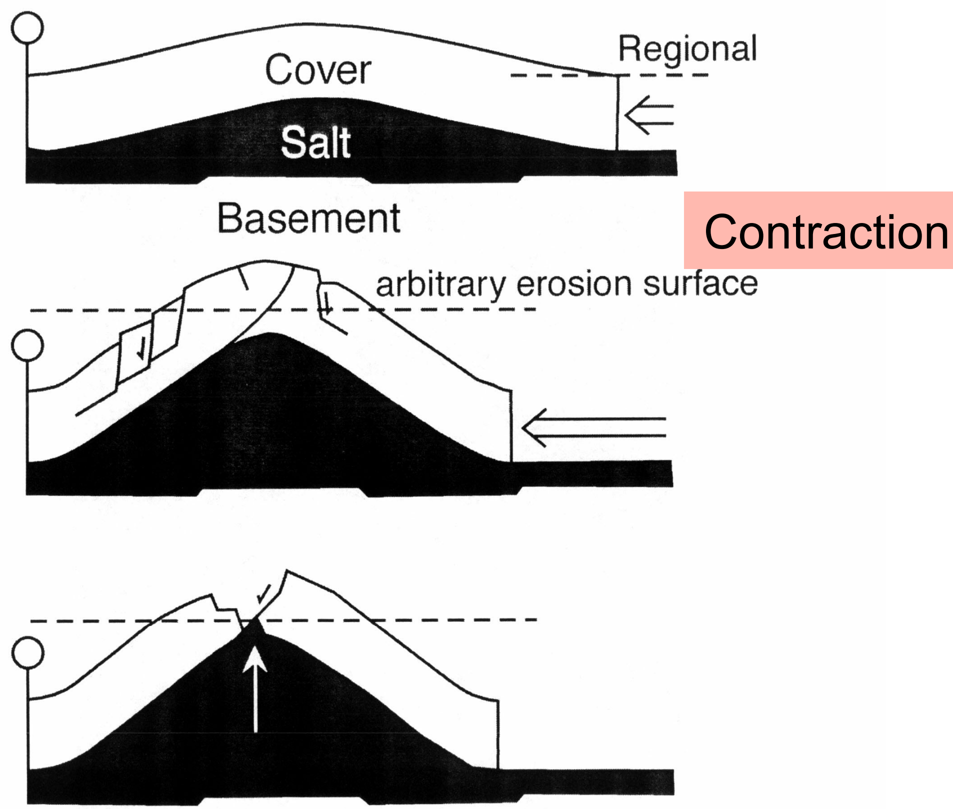
A salt layer buried by overlying strata of a constant-thickness and greater density will not form a diapir until external forces are applied.

- Diapir initiates during extension of contraction
  - Most initiated during regional extension
- Extension: The overburden is lengthened and <u>thinned</u> and allows the salt to fill the space and grow
- Contraction: Is the shortening of a <u>thin</u> overburden by folding, uplifting, faulting and eroding (differential loading), which will allow the salt break through and grow

Mode: Reactive Diapirism



Jackson et al, 1994
(reproduced with permissions from Annu. Rev. Earth Planet.Sci.)



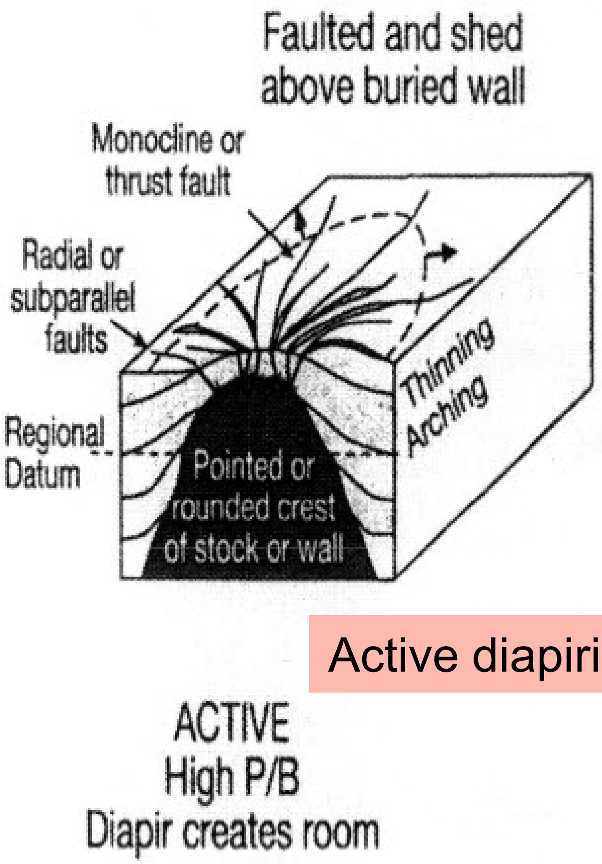
Coward and Stewart, 1995
(reproduced with permissions from AAPG)

Mode: Active Diapirism

When the overburden is thin and weak and the pressure differential is great enough, salt will break through the surface.

- Very brief stage
- Classic model from the "Fluid Era".
  - Nonevaporite sediments increase in density with compaction and water loss at depth.
  - Salt buried below a kilometer of more has positive buoyancy
  - Salt moves as a series of independent spines
  - Salt piercing of brittle overburden occurs when the salt pressure exceeds the overburden strength. This region is termed the "piercement threshold".

Mode: Active Diapirism



Active diapirism

Jackson et al, 1994
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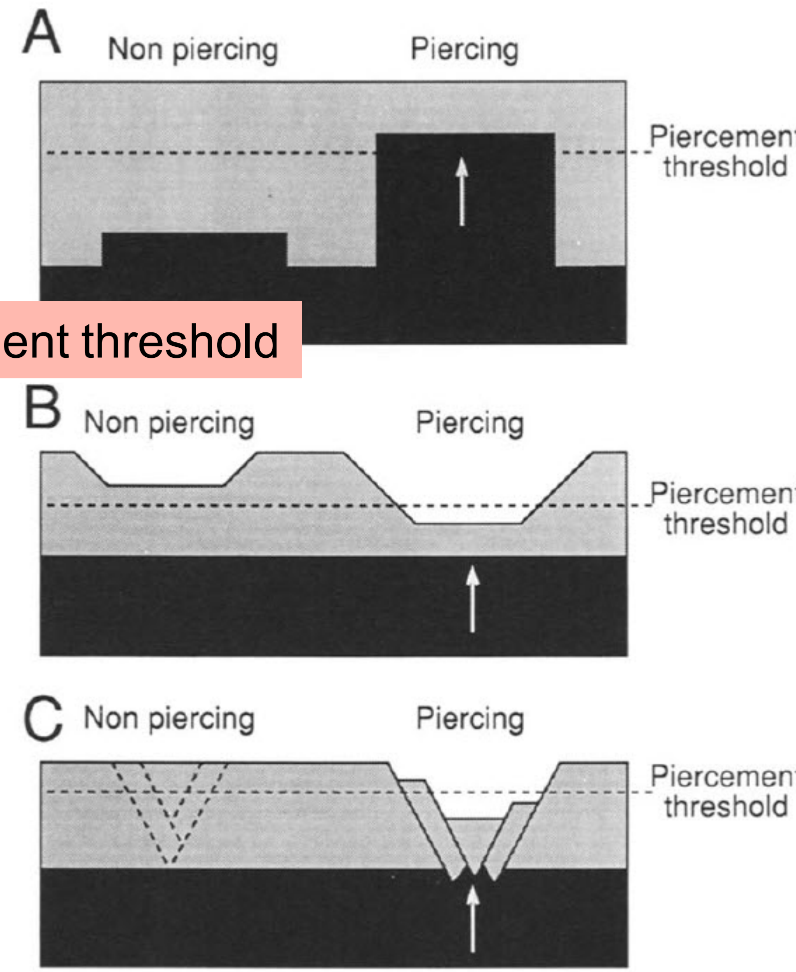


Piercement threshold

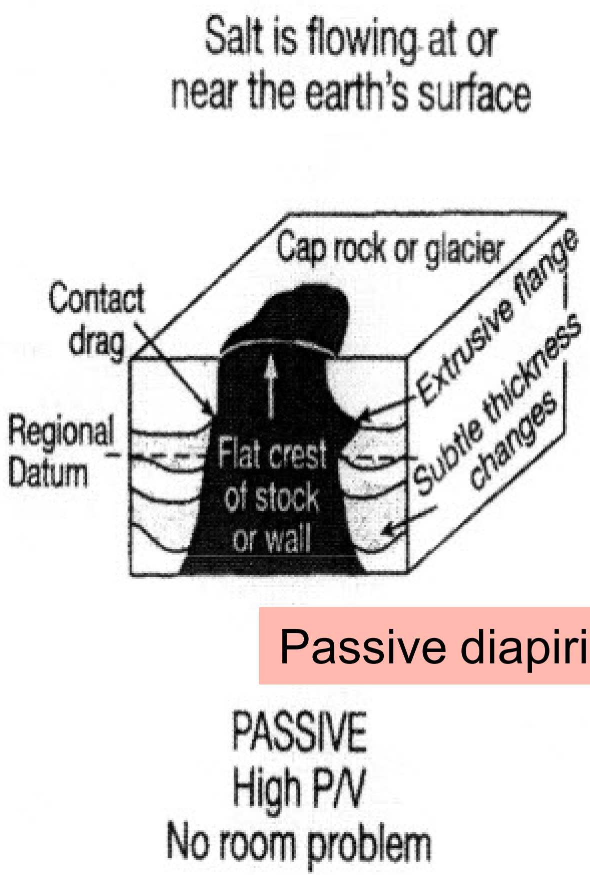
Vendeville and Jackson, 1992
(reproduced with permissions from Elsevier)

Mode: Passive Diapirism

Once the salt breaks through the surface it will continue to grow as the surrounding sediments continue to subside until salt source is depleted.

- Most dominant style of diapir growth.
- Sedimentation rate, salt flow rate, & salt supply control diapir geometry
  - Salt rate < sed rate = narrow diapir → buried
  - Salt rate> sed rate = diapir overflows and widens
- Once the salt source is depleted the diaper stops growing and is buried by sedimentation

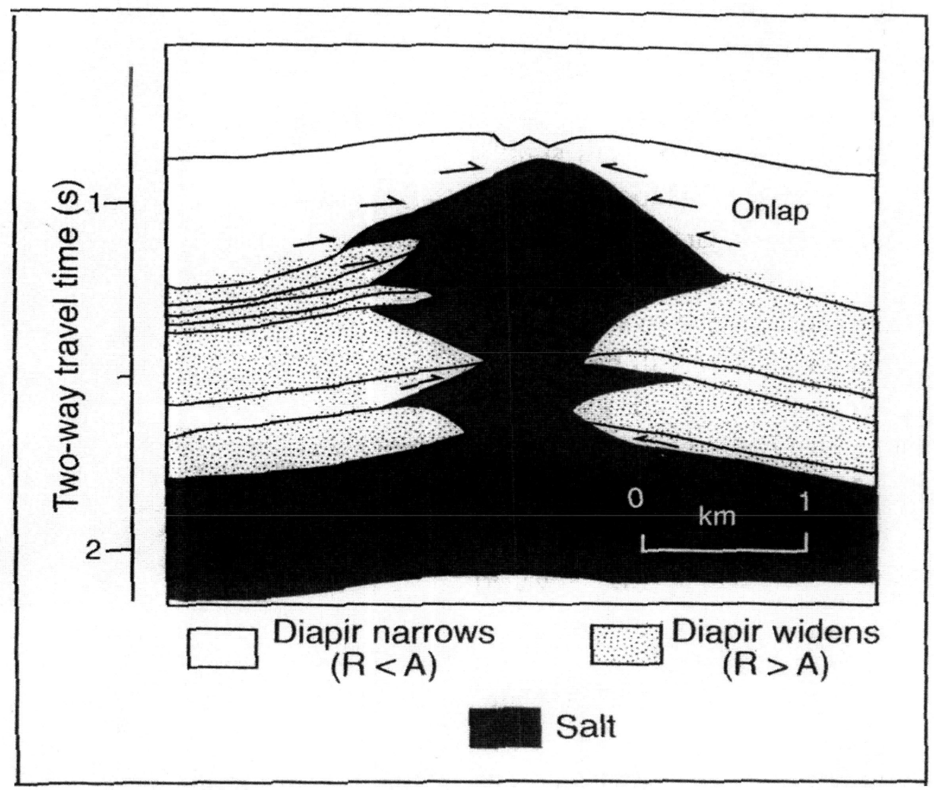
Mode: Passive Diapirism



Passive diapirism

Jackson et al, 1994
(reproduced with permissions from Annu. Rev. Earth Planet.Sci.)

Shape determined by diapiric rise (R) to sedimentation rate (A).



Warren, 2006
(reproduced with permission from Springer)

Modes of Diapirism Can be Altered

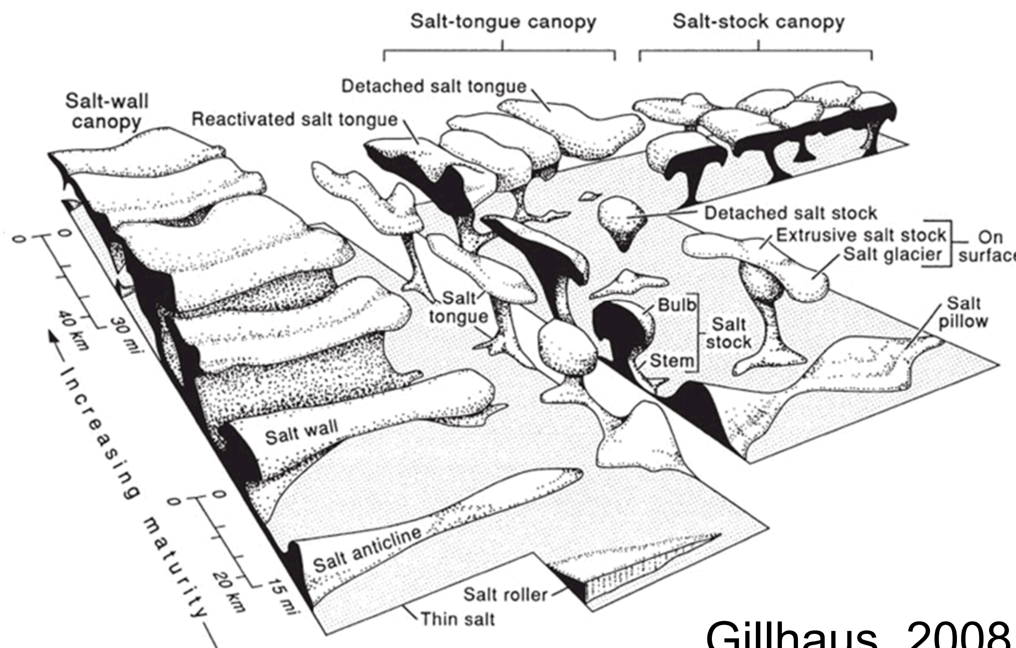
The formation sequence can be altered by,

- Changes in rate of extension
  - Result: Decrease rate = growth stops; Increase rate = growth
- Depletion of the source layer
  - Result: growth stops
- Changes in sedimentation rates
  - Result: Increase rate = dome burial; Decrease rate = passive growth
- May go through several cycles

Salt Structures

Host of other salt structures can be formed through the same processes.

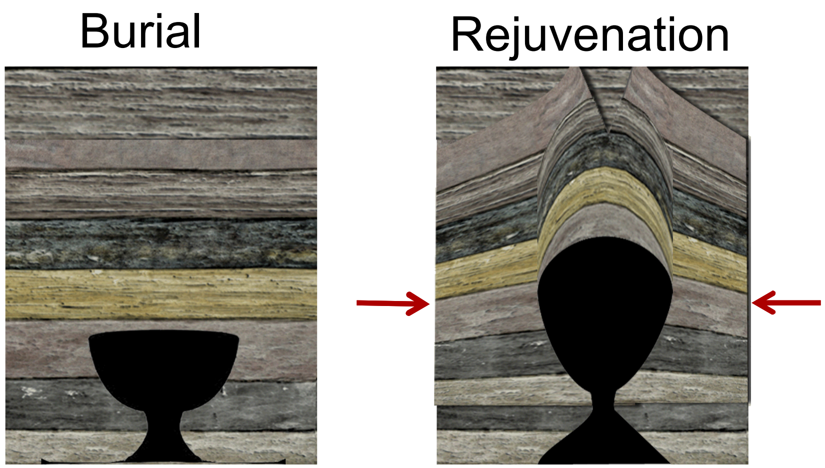
- Salt ridges
- Pinched off diapers
- Overhangs
- Sheets
- Pillows
- Glaciers
- Walls
- Anticlines



Gillhaus, 2008
(SMRI report)

Diapir Reactivation

- Extension
  - Salt source still active: diapir will widen and grow
  - Salt source depleted: diapir will widen and collapse
- Contraction:
  - Salt source active: shortening and differential loading contribute thus increasing salt flow rates
  - Salt source depleted: "Diapir Rejuvenation", buried salt body responds passively to tectonic forces by being displaced and "appearing" to actively push up the overburden.

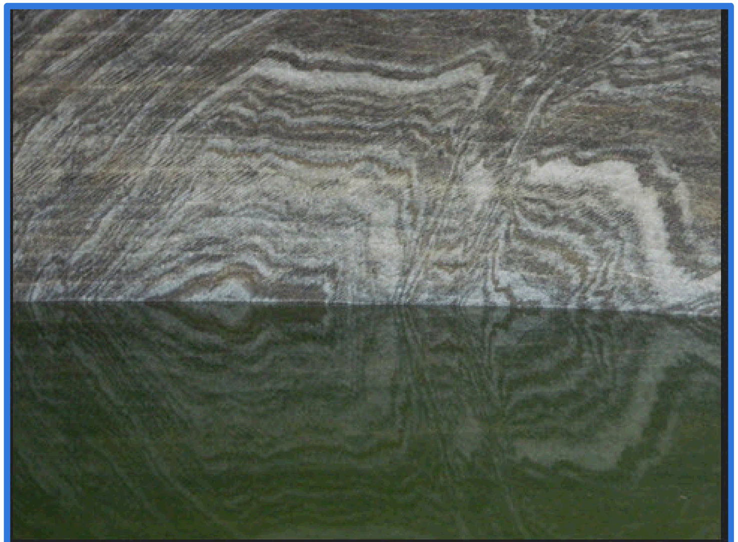


Internal Structure

Diapirs have complex internal structures:

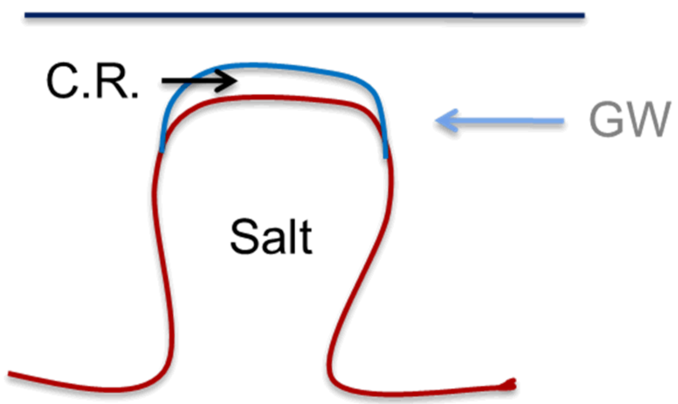
- Vertical lineations
- Isoclinal folds
- Pinch & swell structures
- Etc.

Resulting from salt flow and interbedded lithologies.


Turda salt mine -water line

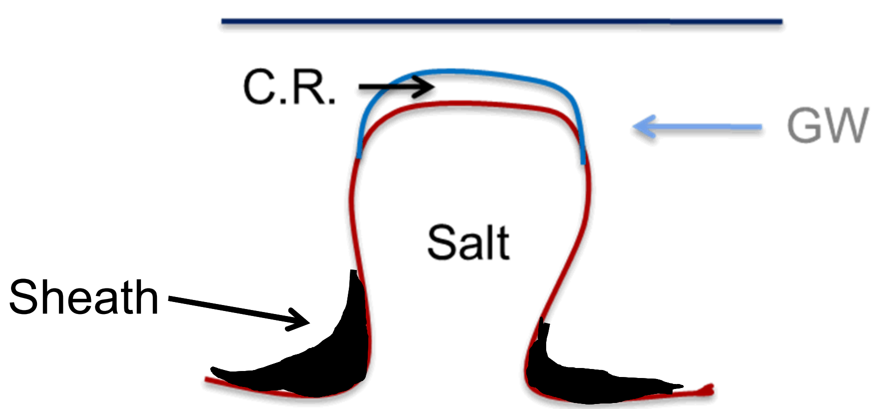
External Margin: Caprock

- Caprock
  - Overlies many salt domes
  - Consists primarily of anhydrite, gypsum, and limestone
  - Insolubles accumulated from the dissolution of halite from meteoric waters between a depth of 3000-5000 ft.



External Margin: Shale Sheath

- Shale Sheath
  - Found flanking the deeper margins of some diapirs
  - Is an overpressured shale
  - Thought to be the remnant of the condensed marine mud section that forms on top of many salt bodies.



Questions?