Salt magma and sediments interfingered

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Subterranean salt deposits interfinger with kilometres-thick sedimentary overburdens. Currently, the widely-accepted theory concerning salt diapirism is based on a supposed fluid-like behaviour of solid salt. However, creep experiments on NaCl are inadequate to explain horizontal displacements over distances of tens of kilometres. The overburden has also moved in a synchronic, fluid-like manner. However, solid overburden will not flow, but fracture. Therefore, synchronic flow of solid salt and solid rock is impossible.

Field and seismic observations suggest a rise of liquid salt within a fluidized overburden. It is therefore possible that today's salt/sediment deposits found worldwide were formed as salt magma interfingered with watery mud synsedimentarily during Noah's Flood.

Hydrothermal models concerning the genesis of salt layers do not address salt tectonics and, superficially, seem to be strengthened by this rise of liquid salt. However, it is highly likely that a flow of hot water would mix with the muddy overburden, preventing the formation of pure salt pillars. So, hydrothermal models are incapable of explaining salt tectonics.

Subterranean salt deposits can dome up kilometres high (e.g. in the East Texas Basin, figure 1). The structures are usually covered with layers of sedimentary rock. The pressure of this sedimentary overburden forced the salt into pillars and dykes. For instance, the European Permian Zechstein salt formation ('dated' 272–253 Ma) is commonly thought to have started rising after enough Triassic sediments were deposited (~200 Ma).

Sometimes, the salt even penetrates the overburden. One example is the Sigsbee structural high in the Gulf of Mexico (figure 2). This ductile behaviour of solid salt is known as 'diapirism', 'halokinesis', and 'salt tectonics'. Several salts are involved, e.g. NaCl (halite), $CaSO_4$ (anhydrite), $CaCO_3$ (chalk), KCl (sylvite), $MgCl_2$. (To avoid misunderstanding, where we refer to 'salt', we do not refer solely to NaCl, but to all ionic crystalline compounds naturally occurring in these salt formations.[1])

Until the late 1980s, geologists normally described diapirism as a lava-lamp-like, buoyancy-driven process.[2] A lava lamp typically has one immiscible fluid rising while the other gives way. This movement is synchronous; it is driven by density contrasts and without stress or resistance. It was counter-intuitive to expect that solid salt and solid sedimentary rock had moved like this, since solid rock does not show fluid behaviour. Therefore, geologists rejected this model. Today, it is widely accepted that solid salt diapirism is mainly the result of differential loading, with buoyancy downgraded to secondary importance.

Hudec *et al*. wrote in 2007: "Salt is mechanically weak and flows like a fluid".[3] Figure 3 summarizes their explanation. We agree that most salt structures formed when conditions allowed salt to flow like a fluid. However, the question arises whether evidence supports the idea that *solid* salt can flow like a fluid.

Solid salt flow under significant pressure gradients

Solid salt flow is well-known from salt mines, where lithostatic pressure displaces the salt towards the atmospheric pressure inside the galleries and rooms. Lithostatic pressure increases by approximately 20 MPa per kilometre depth. Solid salt, or at least halite, becomes sensitive to creep under such huge pressure differences. This results in a displacement of a few centimetres per year. However, this movement is local, caused by the weight of the overburden leading to a local subsidence in the area directly above the mine only.[4] As the pressure gradient is limited to the mining area, the induced creep cannot influence the rest of the salt formation, which stretches out over thousands of square kilometres.

The creep behaviour of halite has been studied and tested, as it is deemed to be the key to salt tectonics. For example, Urai *et al*.[5] gathered data from strain experiments on halite cylinders with a height of 300 mm and a diameter of 150 mm. Testing several temperatures and humidities, the authors found wet halite was the most sensitive to creep. The data shows creep for wet halite at vertical stresses as low as 0.2 MPa. As salt formations are dry (e.g. anhydrite) this is not representative. Creep within halite with a water content more representative for salt layers was found at differential stress upwards of 10 MPa at an increased temperature of 323 K (the tests showed that, the lower the temperature, the more differential stress is required to cause creep). The prolonged stress caused a shortening of the cylinder and an increase in the diameter.[6] In other words, the vertical stress caused a horizontal orientated stress varying from the isotropic stress in the core (10 MPa) to zero at the edge of the cylinder. This differential stress in *horizontal* direction was applied over a radius of 75 mm, resulting in a mean pressure gradient of 133 MPa/m (10/0.075). However, can this phenomenon account for the huge displacements observed in subterranean salt deposits? Gevantman *et al*. wrote concerning salt buried underneath overburden: "The mobility of rock salt is such that its original site of deposition may be as far as 25 km from the dome where it is presently found."[7]

Let us apply these cylinder strain experiments to a vertical cylinder with a radius of 25 km under a vertical stress of 20 MPa. 20 MPa represents the pressure underneath a 1 km thick layer of sedimentary rock. The resulting differential stress in the horizontal direction is then applied over 25 km. The mean horizontal pressure gradient becomes 8×10^{-4} MPa/m, which is negligible compared to the tests at horizontal pressure gradients exceeding 133 MPa/m. The tests showed that with negligible pressure gradient there will be no creep. Even raising the differential loading factor by assuming additional kilometres of sediments were in place will not help. Therefore, the creep tests do not validate the idea that fluid-like behaviour of *solid* salt formed these salt structures.[8]

An overthrust of salt as far as 200 km on top of an overburden layer, as shown in figure 2, undermines the creep model even more.[9] How can creep cause such an overthrust, without even the differential loading of sediments, as this salt has mainly flowed on top of the overburden? And, of course, any solid rock or ice can become part of a mass waste and slide slowly *down* like a glacier, but that system is unable to move rock upwards and sideways over more than 200 kilometres. Clearly, another approach is required.

Salt structures originated from magma

There is no modern analogue where a large salt formation is being formed, either hydrothermally via precipitation during supercritical phases, or from an igneous origin. The volume and area of salt layers are similar to those of large igneous provinces. They contain hundreds of thousands of cubic kilometres of material. Earlier publications suggested a primary igneous origin of salt,[10,11] and challenge buoyancy-driven salt tectonics in solid rock.[12,13] We embrace that, and suggest that a flow of molten salt brought up from the mantle by volcanic eruptions and deposited underneath muddy water explains the salt structures observed today. Salt with a temperature above its melting point becomes an ionic liquid: a fluid mixture of anions and cations.[14] The relatively low density and melting point of such a salt magma can be estimated (table 1).

Salt formations are often covered with several kilometres of water-deposited sediments. Within the framework of biblical geologic history, these sediments were most likely deposited as the floodwaters were rising during the Flood.[23–27] If this overburden was solid when salt tectonics took place, the layers would have been fractured, which they are not.[28]

To understand the structures, we refer to the original experimental observation that salt domes must have been formed through a lava-lamp-like, buoyancy-driven process

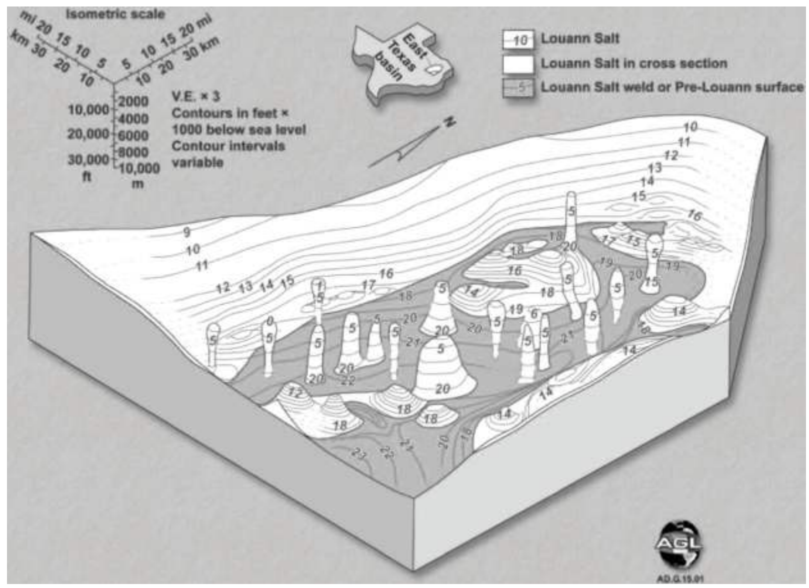

Figure 1. Salt structures present within the East Texas Basin. The Middle Jurassic salt layer interfingered with sedimentary rock. (From Jackson *et al*.[38,39]).

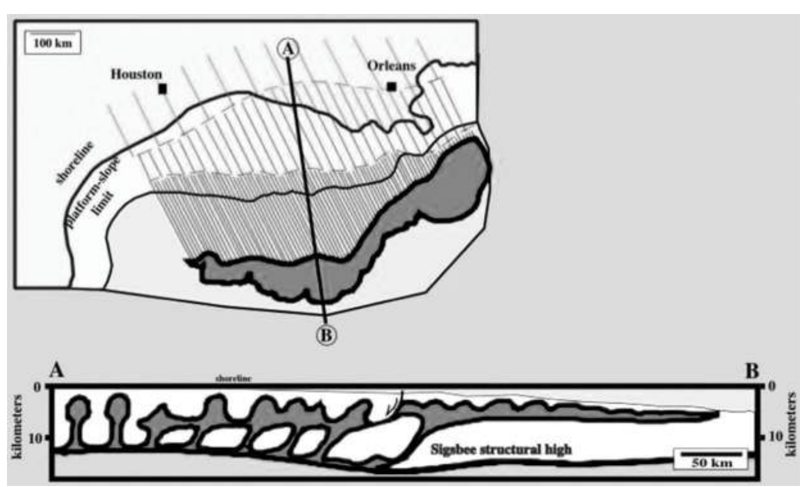

Figure 2. The Sigsbee Escarpment is the southern edge of an allochthonous sheet of Mid-Jurassic Louann Salt in the Gulf of Mexico. It is displaced over 200 km southward from the position where the salt penetrated the overburden. Even if the displacement rate of the solid salt were relatively fast with several metres each year, it would not fit in a biblical timeframe. (After Universidade Fernando Pessoa.[40]).

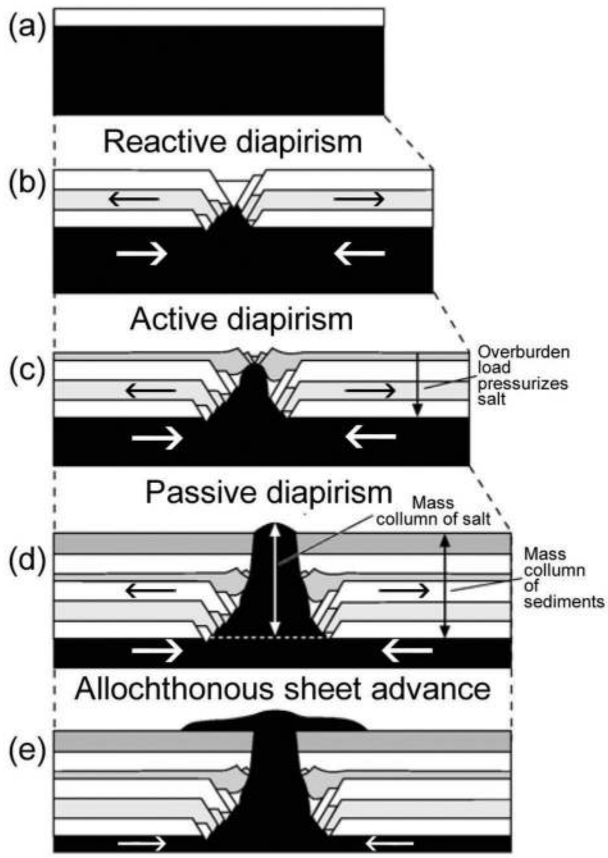

Figure 3. Widely accepted understanding of solid diapir piercement during regional extension. Indeed, if salt deformed synsedimentarily as shown here, then salt must have flowed like a fluid. However, the model implies unnatural behaviour for a solid. (From Hudec and Jackson.[3]).

(figure 4). Therefore, the structures occurred when the salt was in a molten state *and* when the sediments were unconsolidated and water-soaked, allowing for hydrodynamic behaviour. Solid NaCl has a high viscosity, whereas molten NaCl has a viscosity of 1.29×10^{-3} Pa.s (at 1123 K), which is in the same order as the viscosity of water at room temperature.[29] Therefore, we propose that the ionic liquid could run like water. Low density combined with low viscosity would have facilitated rapid formation of pillars in watery sediments.

Steam would have formed on the sides and tops of the pillars, where the molten salt came into direct contact with watery sediments. The higher the steam rose, the more it would have expanded. This must have led to additional gravitational effects per the law of communicating vessels (figure 5).

In this energetic environment, the outside of the pillars would have cooled and solidified rapidly. Additional eruptions would have fed the salt deposits from below and raised the pressure in the liquid core of the pillars. In this way, the pillars would have acted like chimneys, delivering the salt magma into allochthonous salt sheets on top of the overburden.

Hydrothermal models

Some modellers suggest most salt beds formed by precipitation of salt from supercritical water surrounding deep hydrothermal vents.[30,31] However, this would form solid salt, which, as described above, could not flow over tens of kilometres. No hydrothermal model for salt beds addresses the mechanism of salt diapirism. Rather, we have shown that salt was most likely a fluid during the formation of salt pillars.

Hydrothermal models could benefit from that conclusion. However, if hot water were available underneath sediments, the sediments would fall in. The water would end up in the pore spaces and would not form layers of pure salt. Hot water cannot flow tens of kilometres underneath mud without

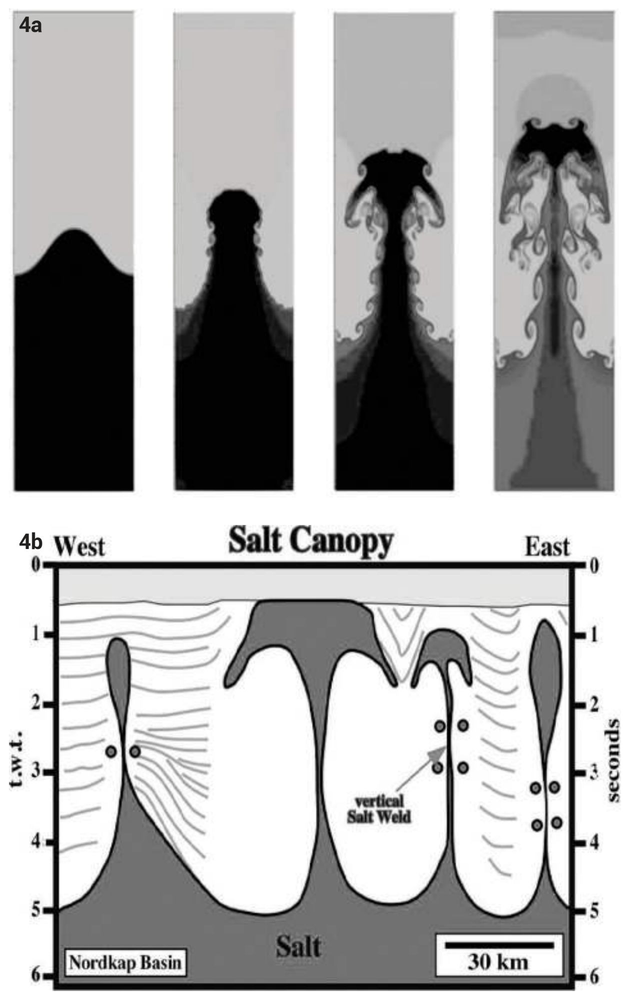

Figure 4. A hydrodynamic model of how liquid salt interfingered with mud. This process has been suggested before[41,42] and is valid only when the sediments and the salt magma acted synchronically in a fluid-like manner.
4a. A Rayleigh-Taylor instability as successively pictured in a test. This shows the hydrodynamics of two immiscible fluids of different densities. (After Los Alamos National Laboratory.[43]).
4b. Salt diapirs in the North Cape Basin (Norway). T.w.t. stands for two-way-travel-time in seconds, which is seismic data. (From Universidade Fernando Pessoa.[40]).

inmixing, whereas a magma flow would be isolated from the mud by a solidified skin. This skin would form out of solidifying magma on the inside, and out of sediments and minerals out of the watery mud on the outside.[32] Such a skin would prevent the magma from becoming contaminated with mud or water. (Note that this immiscibility is essential for correctly referring to a Rayleigh-Taylor instability as shown in figure 4.) This skin in turn would act as a thermal insulator, causing the magma to stay liquid longer and thus be transported over long distances during the eruption.

Figure 4 is an example of how a pillar has been frozen on the move, understandable from a primary igneous origin. What mechanism will freeze a hydrothermal waterflow in the middle of wet sediments?

Where primary igneous salt is probably responsible for most salt beds, this salt magma might have induced hydrothermal deposits. Perhaps that is one of the reasons for the interpretations to date.

Timing

Salt formations worldwide are mostly covered with sediments with a catastrophic, watery origin. As salt magma and mud interfingered synchronously, the eruption of salt and the worldwide watery catastrophe must have taken place at the same time. This must have occurred rapidly, as it is unlikely that the magma would be thermally isolated in a way that would prevent solidification for years. Given that more than one worldwide watery catastrophe is ruled out by the covenant in Genesis 9, Noah's Flood alone fits the evidence, as the floodwaters were rising.

More observations

We believe the above observations suffice to rule out an evaporative or hydrothermal origin for salt formations, supporting a primary igneous origin as the only plausible explanation available. However, there is more positive evidence for a primary igneous origin for salt. Firstly, as mentioned, the volume, area and dryness of salt layers suggest a primary igneous origin, and this has been reported in earlier publications. Secondly, it is worth considering the following:

- Fossil fuels are found abundantly below and above salt structures. The Flood might explain how organic material was buried rapidly, whereas the heat of the salt magma explains the conversion into fuel.
- Each salt pillar has a caprock containing mainly $CaCO_3$ and $CaSO_4$. This might have been deposited by mineral-rich Flood water that turned into steam by the contact with the raising pillar, see figure 5.

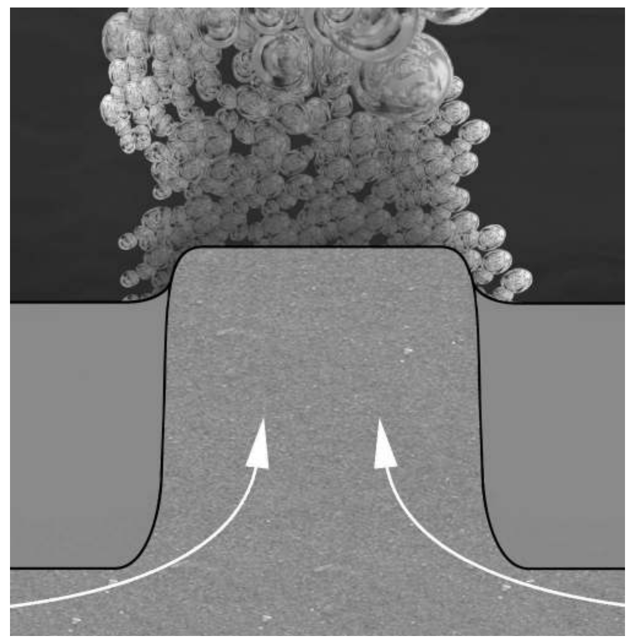

Figure 5. The law of communicating vessels demands equilibrium between the weight of the multiple-kilometres-thick mud layer plus any water above it, and the weight of the salt/steam column within. As the density of steam is relatively low, it favours the rise of the salt pillar. This picture shows the moment the salt protrudes the mud in a sub-oceanic scenario.

Table 1. Density of salt in liquid phase under atmospheric pressure. This configuration at around 1075 K has a weighted average density of 1800 kg/m^3.[15] Note that in magma, high pressures are applicable, which will increase the density. Higher temperatures will lower the density. But lower temperatures are expected as the melting temperature of a mixture of NaCl and $CaSO_4$ is as low as 998 K, and any other chemicals in the mixture will lower the melting point even further.[16] This mechanism explains the temperatures of natrocarbonatite lava, which erupts with the lowest temperature lava in the world (~850 K). The Ol Doinyo Lengai volcano in Tanzania is an example.[17]

Salt (commonly found in the formations)	Temperature (K)	Density (liquid) (kg/m^3)	Source	Estimated volume% of salt in magma (differs per formation)
NaCl	1077	1549	Robertson, 1958 [18]	65%
$CaSO_4$	na	2502	* [19]	20%
$CaCO_3$	1073	2502	Liu, 2003 [20]	5%
KCl	1058	1517	Jaeger, 1917 [21]	5%
$MgCl_2$	1077	1658	Janz, 1988 [22]	5%

- In Europe, beneath a salt deposit, the Copper Shale Formation[33] is found, consisting of a thin (~0.5 m thick) metal-bearing sedimentary layer with fossils. Its origin is debated as fish and heavy metals are not a logical combination to find in sedimentary rock. We suggest that the fossils can be explained if this was a seabed, overrun by salt magma. The heat of the magma then caused hydrothermal alteration which then explains the metals.
- Anhydrite is typically known as an evaporite,[34] but now primary igneous anhydrite has been identified by Luhr.[35] Also, the pegmatite anhydrite member within the Zechstein[36] is evidence for its primary igneous origin, as the name pegmatite is usually allocated to holocrystalline igneous rock crystals.
- All the chemical elements necessary to form NaCl, $CaSO_4$, $CaCO_3$, KCl, $MgCl_2$ (common in salt formations) are available in the magma from the Ol Doinyo Lengai volcano in Tanzania.[17] E.g. sodalite ($Na_8Al_6Si_6O_{24}Cl_2$) containing NaCl precipitated from its melt. This volcano is positioned within the Great Rift fault line that runs from Syria, via the Jordan valley down through the Red Sea and the Horn of Africa. There are multiple salt formations situated within the Great Rift Fault (e.g. the 10-km thick Dead Sea formation).
- Testing the solidification process of ionic liquids might produce typical layers and crystals as found in the salt formations. See figure 6 as an example.
- Underneath salt structures, multiple rifts can be identified. For example, sub Zechstein rifts are: Dutch Central Graben, Central North Sea Graben, Horn Graben, Bramble Trough, Rhein Graben and the Polish Trough. These rifts could hide collapsed salt magma chambers.

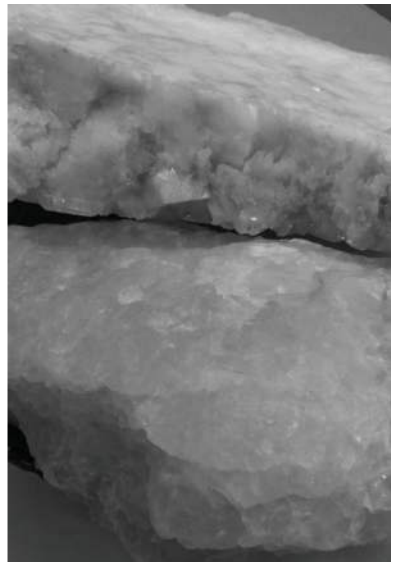

Figure 6. On top, a piece of NaCl molten and solidified in one of the tests we currently run. Underneath, a piece of NaCl (Permian Zechstein) collected from Asse II, a salt mine in Germany.

It is beyond the scope of this paper to deal with all the questions and issues that arise from these considerations. Further research is required and because of its complexity some aspects may require extensive study.

Conclusions

Currently, the widely-accepted theory concerning salt diapirism is based on a proposed fluid-like behaviour of solid salt. However, creep experiments on NaCl are unable to explain displacements over distances of tens of kilometres as observed in salt deposits. Neither do the observations in salt mines. Experimental observations contradict the theory.

Also, hydrothermal models cannot explain salt diapirism as the hydrothermal water would have mixed with the muddy overburden, thus polluting the salt with sediments.

Evidence suggests the overburden and the salt both moved in a synchronic and fluid-like manner. Synchronic flow of solid salt and solid rock is impossible. Therefore, the empirical observations suggest the salt was liquid when it rose through a fluidized overburden at the time. The primary igneous origin of salt formations can be confirmed by the volume, area and dryness of salt layers. The idea of a massive volume of salt magma interfingered with water-saturated sediments conflicts with uniformitarian principles.[37] Hence, the authors conclude that a high energy, short term event, such as Noah's Flood, is responsible for the deposition of salt magmas interfingered with watery mud several kilometres thick.

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References and notes

1. Geologists tend to use 'salt' and 'rock salt' to refer only to NaCl. For example, creep tests are mostly run on NaCl, and the density of NaCl is often taken to represent the density of salt structures. However, from a chemical perspective the word 'salt' covers all crystalline ionic solids.
2. Roberts, D.G. and Bally, A.W., *Regional Geology and Tectonics: Phanerozoic Passive Margins, Cratonic Basins and Global Tectonic Maps*, Elsevier, Amsterdam, p. 24, 2012.
3. Hudec, M.R. and Jackson, M.P.A., Terra infirma: understanding salt tectonics, *Earth-Science Reviews* **82**(1–2):1–28, 2007.
4. Boreholes BAS-1 and BAS-2 are in use for salt production by solution mining. The resulting subsidence is mapped here: Houtenbos, A., Bodemdaling NW-Friesland 1976–2009, waddenzee.nl/fileadmin/content/Dossiers/Energie/pdf/NWFR09.pdf, figure 3, p. 7, 25 February 2010.
5. Urai, J.L., Schléder, Z., Spiers, C.J., and Kukla, P.A., Flow and transport properties of salt rocks; in: Littke, R., Bayer, U., Gajewski, D., and Nelskamp, S. (Eds.), *Dynamics of Complex Intracontinental Basins: The Central European Basin System*, Springer-Verlag, Berlin, figure 5.2.5, p. 281, 2008.
6. Note that the salt displacement in the tests was in the opposite direction of the salt tectonics to be simulated. Unidirectional displacement towards a cylindrical pillar requires more stress. Therefore, this test configuration does not support the actual genesis of salt pillars.
7. Gevantman, L.H. (Ed.), *Physical Properties Data for Rock Salt*, National Bureau of Standards Monograph 167, p. 12, US Department of Commerce, Washington DC, 1981.

8. The line of argumentation that a solid cannot flow like a fluid was initially developed in November 2016 by Dr ir W.M. de Jong, INI-Research, Delft, The Netherlands.
9. Matthews, J.D., The overthrusting paradox: a challenge to uniformitarian geology and evolution, *J. Creation* **30**(2):83–91, 2016.
10. Heerema, S.J., A magmatic model for the origin of large salt formations, *J. Creation* **23**(3):116–118, 2009.
11. Heerema, S.J., Clarifying the magmatic model for the origin of salt deposits, creation.com/clarifying-magmatic-model-origin-salt-deposits, 19 November 2013.
12. Heerema, S.J., Density overburden in relation to salt tectonics, *J. Creation Theology and Science Series C: Earth Sciences* **5**:1–2, 2015; coresci.org.
13. Heerema, S.J., *De dichtheid van gesteenten op het Zechstein in relatie tot zouttektoniek; Zoute magma drong opwaarts vanwege dichtheidsverschil*, Grondboor & Hamer, 134–139, 2015.
14. Rowe, J.J., Morey, G.W., and Zen, C.S., *The Quinary Reciprocal Salt System Na, K, Mg, Ca/Cl, SO_4—A review of the literature with new data*, Geological Survey Professional Paper 741, 1972.
15. This magma configuration leads to an average density of a solid salt formation of 2,370 kg/m3 at room temperature. The solidification process of the ionic liquid is subject to thermodynamic laws for a eutectic melt, which leads to almost pure layers of the individual salts.
16. Personal communication with Emeritus Prof. Dr H.A.J. Oonk, Faculty of Earth Science, University Utrecht. The eutectic point of a mixture of NaCl and $CaSO_4$ is at 998 K (atmospheric pressure). Email per 24 January 2012.
17. Mitchell, R.H. and Belton, F.A., Cuspidine-sodalite natrocarbonatite from Oldoinyo Lengai, Tanzania: a novel hybrid carbonatite formed by assimilation of ijolite, *Mineralogical Magazine* **72**(6):1261–1277, 2008.
18. Robertson, E.C., Robie, R.A., and Books, K.G., *Physical Properties of Salt, Anhydrite, and Gypsum—Preliminary Report*, Trace Elements Memorandum Report 1048, United States Department of the Interior, Geological Survey, p. 23, August 1958.
19. A literature study revealed no densities for the liquid phase of CaSO4. As anhydrite (2,970 kg/m^3) is nearly as dense as chalk (2,930 kg/m^3), we assume the density of liquid $CaSO_4$ will be similar to liquid $CaCO_3$.
20. Liu, Q. and Lange, R.A., New density measurements on carbonate liquids and the partial molar volume of the $CaCO^3$ component, *Contributions to Mineralogy and Petrology* **146**(3):370–381, 2003. Note that $CaCO_3$ liquid cannot be directly measured because it decomposes into calcium oxide and carbon dioxide at temperatures below the melting point at atmospheric pressure. The authors found a method to calculate the density at atmospheric pressure. Decomposition will not happen in a magma, because of the high pressure.
21. Jaeger F.M., Über die Temperaturabhängigkeit der molekularen freien Oberflächenenergie von Flüssigkeiten im Temperaturbereich von -80°C bis +1650°C, *Z. Anorg. Allg. Chem.* **101**:1–214, 1917.
22. Janz, G.J., Thermodynamic and transport properties of molten salt: correlation equations for critically evaluated density, surface tension, electrical conductance, and viscosity data, *J. Phys. Chem. Ref. Data* **17**(Suppl. 2): 70, 1988.
23. Walker, T., A Biblical geologic model; in: Walsh, R.E. (Ed.), *Proceedings of the Third International Conference on Creationism*, Creation Science Fellowship, Pittsburgh, PA, pp. 581–592, 1994.
24. Froede, C.R., Akridge, A.J., A developing schism in Flood geology, *J. Creation* **27**(2):49–54, 2013.
25. Walker, T., The Sedimentary Heavitree Quartzite, Central Australia, was deposited early in Noah's Flood, *J. Creation* **29**(1):103–107, 2015.
26. Oard, M.J., Flood processes into the late Cenozoic—sedimentary rock evidence, *J. Creation* **30**(2):67–75, 2016.
27. Oard, M.J., Geology indicates the terrestrial Flood/post-Flood boundary is mostly in the late Cenozoic, *J. Creation* **27**(1):119–127, 2013.
28. Snelling, A.A., Rock layers folded, not fractured, *Answers Magazine* **4**(2):80–83, 1 April 2009.
29. Natriumchlorid [Sodium chloride]; in: *Ullmans Encyklopädie der Technischen Chemie [Ullman's Encyclopedia of Technical Chemistry]*, 4th revised and extended edition, vol. 17, Verlag Chemie, Weinheim, Germany, p. 180, 1979.
30. Hovland, M., Rueslatten, H.G., Johnsen, H.K., Kvamme, B., and Kuznetsova, T., Salt formation associated with sub-surface boiling and supercritical water, *Marine and Petroleum Geology* **23**:855–869, 2006.
31. Snelling, A.A., *Earth's Catastrophic Past: Geology, Creation & the Flood*, Institute for Creation Research, Dallas, TX, pp. 937–944, 2009.
32. Note that water in supercritical or steam phase cannot contain NaCl. That prevents salt magma from absorbing any water from the muddy overburden.
33. Fringe Coppershale Member ZEZ1E, dinoloket.nl/fringe-coppershale-member-zez1e, accessed 23 November 2016.
34. Warren, J.K., *Evaporites: sediments, resources and hydrocarbons*, Springer, Dordrecht, The Netherlands, table 1.1, p. 3, 2006.
35. Luhr, J.F., Primary igneous anhydrite: Progress since its recognition in the 1982 El Chichón trachyandesite, *J. Volcanology and Geothermal Research* **175**(4):394–407, 2008.
36. Z4 Pegmatite Anhydrite Member ZEZ4A, dinoloket.nl/z4-pegmatite-anhydrite-member-zez4a, accessed 23 November 2016.
37. Reed, J.K., Changing paradigms in stratigraphy—a quite different way of analyzing the record, *J. Creation* **30**(1):83–88, 2016.
38. Jackson, M.P.A. and Seni, S.J., Geometry and evolution of salt structures in a marginal rift basin of the Gulf of Mexico, east Texas, *Geology* **11**(3):131–135, 1983.
39. Figure 1 is still considered an accurate representation, since it is used in: Salt Tectonics—University of Colorado Boulder, yumpu.com/en/document/view/35773055/salt-tectonics-university-of-colorado-boulder, p. 33, accessed 15 June 2017. This course content was put together in 2010–2011.
40. Cramez, C., Salt Tectonics Short Course, Universidade Fernando Pessoa, Porto, Portugal, homepage.ufp.pt/madinis/SaltTectonics/SaltTectonicsFiles/Pages/Page1.htm, March 2006. This particular picture of the Sigsbee Structural High was present in this course in 2010, but is now untraceable. However, the displacement as shown is confirmed in Hudec, M.R. and Jackson, M.P.A., Advance of allochthonous salt sheets in passive margins and orogens, *AAPG Bulletin* **90**(10):1535–1564, 2006; figure 8.
41. Trusheim, F., Mechanism of salt migration in northern Germany, *AAPG Bulletin* **44**:1519–1540, 1960.
42. Nettleton, L.L., Fluid mechanics of salt domes, *AAPG Bulletin* **18**:1175–1204, 1934.
43. Li, S. and Li, H., Parallel AMR Code for Compressible MHD or HD Equations, math.lanl.gov, accessed 18 December 2017.

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