Salt deposits

The origin of salt deposits is a tough question that Flood geologists need to consider. Stef J. Heerema and Gert-Jan H.A. van Heugten, in "Salt magma and sediments interfingered"[1] posited an original and interesting thesis. Unfortunately, though, I think they fell far short of dealing with many issues realistically.

They did a good job refuting slow evaporation forming kilometres-deep evaporite beds. They also provided a good refutation of centimetres of horizontal expansion for halite being extrapolated into rising columns, and tens of cubic kilometres of migration into diapirs and canopies.

They recognized solid halite does not have buoyancy working for it, and liquid does, so they proposed salt magma being emplaced and moving into the diapirs—raising walls, pillars, and domes—as a liquid. But, their use of Ol Doinyo Lengai volcano in Tanzania as a possible modern analogy is poorly chosen. Moreover, modelling their salt magma interfingering with water-deposited sediment has problems regarding the salts dissolving.

Ol Doinyo Lengai produces a natrocarbonate (ultra-alkaline) lava. Although this confirms that carbonate rock can be directly derived from this alkaline lava, it is not unique. Niu[2] found alkaline lava inland on all the world cratons and even oceanic islands. So, magma like this is more common than Heerema and van Heugten seem to think; it is available where needed to form carbonate sediments, but it does not contribute to the formation of halite.

Closer inspection of Ol Doinyo Lengai eruption shows it to be a black water-like fluid which turns white as it crystallizes and combines with water (figure 1). This is the exact opposite of salt. Thus, it is composed not of water or salt, but predominately ~580°C (1,076°F) carbonate minerals (molten limestone). Yes, this black watery magma does contain all of the elements found in association with the salts, as do all the alkaline magmas of the world. Africano *et al.*[3–5] used fume samples from multiple volcanos and showed by differential crystallization that Na and K were the most prominent cations, followed distantly by Fe.[6] But, the key is 'cooled'; they refer to a differential crystallization cooling process to separate different types of mineral sediments.

The lava of Ol Doinyo Lengai gets to the surface at a relatively low temperature, but it is the great proportion of molten carbonate which lowers the eutectic point to ~580°C from the ~800°C (1,472°F) which liquid halite would require to be molten.[7] The trouble with even a eutectic temperature as low as ~780°C (1,436°F) as Dr Oonk suggests[8] is that it would require crystallization with an intimate mixing of the halite (NaCl), sylvite (KCl), and carbonate

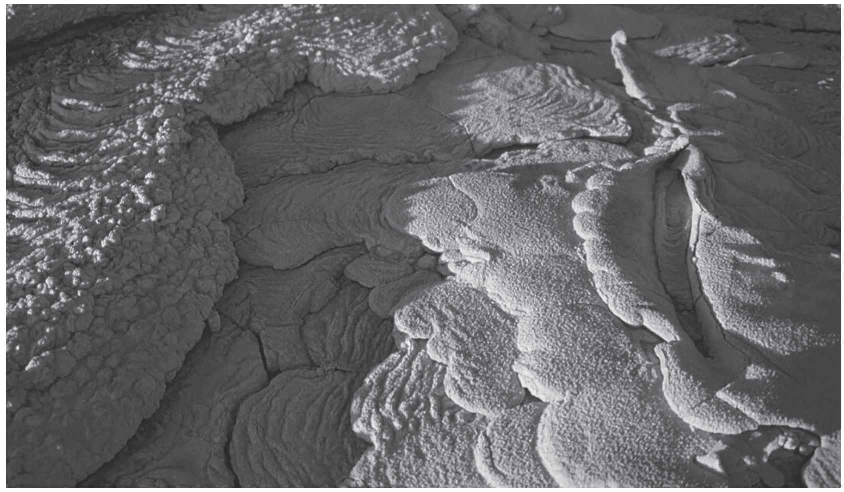

Figure 1. Lava flows from Ol Doinyo Lengai, Tanzania. It cools to a silvery-grey colour, but is still a carbonate mixture, not a salt pan.

Figure 2. Stratigraphic column for the lowest portion of the Gulf of Mexico (after Douglas[11])

Period	Epoch	Rock Unit
Lower Creaceous		Cotton Valley Group
JURASSIC	Upper	Cotton Valley Group
		Haynesville Formation
		Buckner Anhydrite Member
		Smackover Formation
		Norphlet Formation
		Pine Hill Anhydrite Member
	Middle	Louann Salt
		Werner Anhydrite Formation
Upper Triassic		Eagle Mills Formation
Crystalline Basement		

($CaCO^3$) crystals. Intimate mixing of cryptocrystalline forms does occur in some locations of the massive evaporite beds, but most of the deposits are mono-mineral and would require large separated pools of molten halite, sylvite, or carbonate requiring temperatures of ~780–800°C to crystallize separately. The key to salt production is not liquid vs solid, but higher temperatures vs lower temperatures.

They suggest molten halite could 'skin-over' which would protect it from dissolving in the sediment's transporting water. This would just form hot salty steam. Maybe molten halite would solidify faster than it could dissolve, but it would only be a delayed response; NaCl has no protective temperature from solubility.

The only way to get salt interfingering into depositing sediments is to produce the salt and keep it from the floodwaters until it is buried by hydrophobic sediments. The easiest way to get the hydrophobic sediments within the Flood is to produce *hot*, 450–800°C (840–1,470°F) sediments.[9]

Heerema and van Haugten want to attribute anhydrite origin as magma on the authority of Luhr's paper, "Primary Igneous Anhydrite".[10] Luhr shows anhydrite deposition always associates with high temperature, and is found in magma. Today anhydrite is being deposited in hydrothermal vents as long as they stay hot. But, the occurrence as phenocryst in lava is a long way from bedded anhydrite, like the Werner, Pine Hill, and Buckner anhydrite beds around the Louann Salts in the Gulf of Mexico (figure 2). What Luhr does say is that these beds had to have a hot origin, around 800°C (1,470°F). But, a high temperature origin does not necessarily translate into lava. Additionally, the anhydrite had to be protected from *cold* seawater during its deposition, because anhydrites are more soluble in cold water than hot, which eliminates the possibility of sediments depositing in cold waters around this salt magma. (Crystals of anhydrite do not last a year in specimens exposed to surface weathering.)

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» Stef Heerema and Gert-Jan van Heugten reply

We appreciate the letter to the editor concerning our paper "Salt magma and sediments interfingered".[1] Thanks for qualifying our thesis as original, interesting and 'a good refutation' of the evaporation model and the formation of salt diapirs from solid rock salt deposits. That covers about 95% of our paper. We want to take this opportunity to further support the other 5%.

Ol Doinyo Lengai

We stated that "[there] is no modern analogue where a large salt formation is being formed" (p. 119). That includes the active salt volcano Ol Doinyo Lengai (ODL). First, the amount of lava it produces is negligible compared to the millions of cubic kilometres of rock salt. Second, ionic liquids like salt magma can dissolve rock, if there is enough time. During the Flood, a vast quantity of salt magma was produced (and solidified) in a short time according to our model, whereas the comparatively small volume of ionic liquid ODL produces rises slowly through the crust, continuously. Therefore, the salt magma of this volcano becomes contaminated, which is unlike the salt deposits that were formed during the Flood. So it is not a modern analogue. Though we addressed the observation that this salt volcano, together with several salt formations, is situated in the Great Rift area. All chemical elements within salt formations are present in the magma of ODL. ODL is an example of a volcano with a relatively low temperature and high fluidity of its magma (the magma is so thin that it fountains out of small openings like a lawn sprinkler). This corresponds to what we expect from the salt magma that solidified during the Flood. Despite the melting point of pure halite at 1,077 K,[2] a mixture containing also other chemicals is likely to have a lower melting point. The more different chemicals that dissolve in the mixture, the lower the melting point becomes. The ODL shows how $CaCO_3$ with a melting point of 1,073 K,[2] can still be in liquid phase at 783 K.

The uniqueness of ODL lies in the fact that it is the only active salt volcano, producing carbonatites. We are well aware that this rare kind of lava is present at more locations. For future research, we would advise to focus on carbonatites instead of the much wider group of alkali-metal-rich lavas. Alkali-metal-rich lavas, brought forward by the author of the letter, are mostly formed within oceanic lithosphere, whereas carbonatites are almost exclusively associated with continental rift-related tectonic settings. That is the relevant association that has to be addressed, as this is where many salt formations are situated. As an example, we listed the sub Zechstein rifts (p. 122). However, to research them is beyond the scope of our paper, which focused on salt tectonics.

Unlike the author of the letter claims, the limestone in carbonatite is a salt as well. Concerning the carbonatite of the ODL it is widely accepted that it is from a primary igneous origin.[3] As limestone is commonly present in salt formations, it again shows an analogue between the salt formations and this rare salt volcano.

Solidification of salt magma

The writer of the letter claims that a eutectic melt of halite, sylvite, and carbonatite will solidify in mix crystals mostly. However, any reference to underpin this claim is missing. First it overlooks that the melt contains more salts (anhydrite, magnesium chloride, etc.). Second, at this stage of research it is simply unknown if all salts are even miscible in molten state. They might as well flow in separate layers of different composition and density. In which case each layer will solidify at other temperatures and pressures, following different eutectic logic. Third, the author of the letter overlooks that it is quite common to form mono-mineral layers from an eutectic system. Fourth, salt formations solidified 'on the move'. The resulting crystallization will differ largely from regular test set-ups. The solidification process of salt will therefore require extensive study and is beyond the scope of our paper as we stated (p. 122).

Molten salt will not dissolve in water

To see the reaction between molten NaCl and water it might be interesting to check out the experiment of the 'BackyardScientist'.[4] A small amount of molten salt poured into his aquarium caused it to explode. The test shows that water will immediately transform from liquid into steam the moment it comes in touch with molten NaCl. NaCl is barely soluble in steam.[5] When a solidified halite skin formed between the molten core of the salt magma and the unconsolidated watery sediments of the Flood, the water was expelled and the mud dried, which prevented the outer halite skin from dissolving. Although this newly formed sedimentary rock had some permeability, it prevented any fast water flow in which the salt could have been dissolved.

Anhydrite

As the title of Luhr's paper clearly states, the primary igneous origin of anhydrite is a serious option that needs to be considered.[6] The example given by the letter writer of anhydrite deposited out of a hydrothermal vent into *cold* seawater just underlines that anhydrite can crystallize out of a salt magma amidst Flood sediments.

Recommendations

We trust to have answered the concerns of the author of the letter. More clarification can be found in the lecture as presented at the European Creation Conference in London in 2018.[7]

We hope to continue our research in the future. Any and all able and willing to contribute are most welcome to contact us.

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