# Rocks in the making

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Travertine and tufa are important for understanding past geological processes because they are observed forming today.[1] Both rocks are essentially precipitated carbonates. *Tufa* is a sort of framestone, made of 'granular deposits accreting to algal filaments, plant stems and roots at springs, along river banks, lake edges, etc.'[2] *Travertine* is a crystalline, layered and dense calcite (rhombic $CaCO_3$), with no visible organic material incorporated. Usually, travertine is an inorganic precipitate, but occasionally, precipitation is due to bacterial activity.[3] In such situations, however, travertine is mixed with tufa so that a clear delimitation is difficult to make. Tufa deposits are limited in extent, but travertine can grow to tens of metres of thickness and cover a few square kilometres in area.

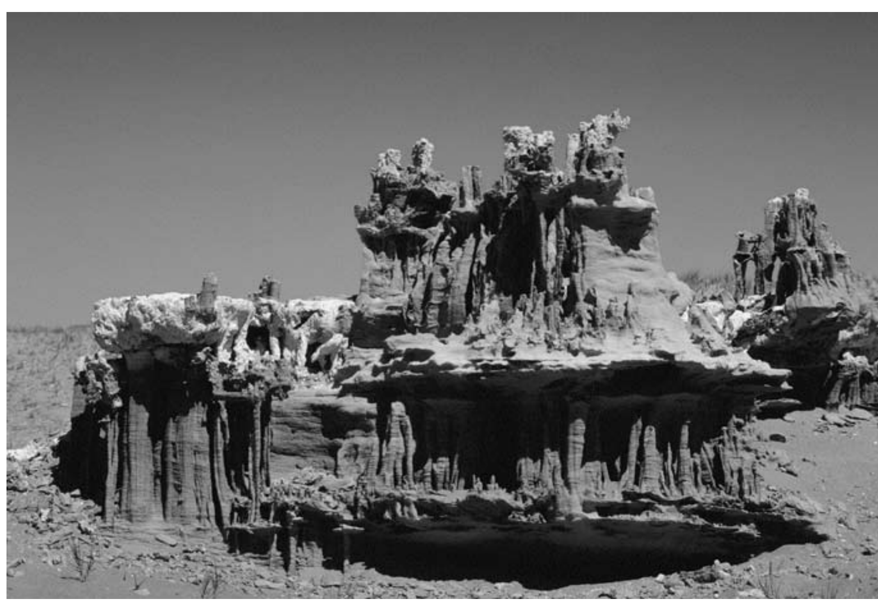
Today, carbonate precipitates commonly occur in fresh water, but some are present in hypersaline water bodies like the Dead Sea and the Great Salt Lake. In the Dead Sea, both gypsum ($CaSO_4 \cdot 2H_2O$) and aragonite (Orthorhombic $CaCO_3$) are precipitated at the surface of the water.[2]

Many documented travertine and tufa are of Pleistocene age:

- North America (Mono Lake, Big Soda Lake, Pyramid Lake, Lake Lahontan, Pavilion Lake)
- Australia (Yalgorup National Park Lakes, Coorong Lakes)
- South East Spain (Ruidera)
- Turkey (Lake Van, Lake Salda)
- Africa (Lake Chad, Lake Bogoria, Lake Turkana).

There are also several reports of pre-Quaternary travertine and tufa (Eocene, Jurassic, Triassic and Devonian), with studies focusing on mineralogy and very few references to organic materials. For example, Richardson *et al*.[4] compared tufas and travertines in Jurassic (Shuttle Meadow Formation, Hartford Basin), Eocene (Chadron Formation, Badlands of South Dakota) and Quaternary (San Ysidoro Quadrangle, New Mexico) sediments in order to assess their preservation potential. They found that preservation of travertine and tufa is generally poor and the chances of misclassification are high.

*Mono Lake with the Sierra Nevada in the background. The lake's highest level is marked by the top of the highest tufa columns and can also be seen extending to the foothills. The tufa-free little tree in the centre-left marks the long-term low-stand of the lake (probably around 1981, when the level dropped to 14 m below the lake's 1940 level, as a result of the dams built on the lake's tributaries to divert water for the city of Los Angeles).*



*Sand tufas: sand grains were bound together by the calcite precipitating from the ground water that was filtering up through the sands. Technically, this constitutes a carbonate sandstone. Note the three ledges marking moments of poor sediment input and maximum tufa growth, when precipitation proceeded laterally rather then along vertical paths. Once a thick layer of sediment covered a tufa layer, the calcite-rich water moved upwards, mainly along higher permeability paths. Once the top of the sediment was reached, the lateral growth resumed, creating another tufa layer. This, in turn, forced the upwelling water to precipitate inside the vertical columns and subsequently spread laterally, binding the sand grains. This cycle appears to have been repeated at this location at least twice.*

Primary precipitation is effectively an early diagenesis,[5] and if the rocks are later submitted to a general

*Tufa built subaerially (unlike in the case of Mono Lake and Big Soda Lake) by a tributary of the Imperial Creek in northern British Columbia, Canada. The tributary emerges from a karst spring less than 50 m from the tufa deposit. The spring's temperature is 18.8°C (epithermal) and the pH is 7.01. Such tufa is typical for karst terrains, but in this particular case the epithermal character of the spring makes precipitation even more intense. The practically neutral pH reveals a very high efficiency of precipitation over a very short distance. There is no tufa along the short flow to the creek; precipitation taking place only at the very confluence with Imperial Creek (10.4°C, pH 7.85), as the temperature drops more than 8°C during summer time and obviously more in the winter time. It is noteworthy how vegetation could grow even on such a poor substrate, most probably due to a combination of biochemical alteration of the calcite and of the organic matter incorporated in the tufa. At its highest point, this tufa deposit measures 1.2 m.*

diagenesis, it is difficult to identify the primary diagenesis of tufa and travertine within a larger sedimentary petrographic province. Normally, any pre-Quaternary travertine/tufa would be transformed into a proper limestone as a result of regional diagenesis, and the chances of preserving their original structure and texture would be slim. Cold seeps (both terrestrial and submarine) produce very similar primary products[6] making identification of the primary diagenesis even more difficult.

## The Big Soda Lake tufa

One recently studied tufa deposit which has challenged conventional thinking about rates of rock formation is located at Big Soda Lake, Nevada, USA. Large tufa mounds, some over 3 m tall, have been forming in the lake since 1907 after its level rose 18 m as a result of the Newlands Irrigation Project. The lake is nested in a volcanic crater, and the water level is controlled by groundwater inflow and evaporation.[7] These mounds grew at an estimated 30 mm/yr which is considered 'exceptionally fast'.[7]

The lake's salinity is mixed: the surface (*mixolimnion*) is eusaline (Total Dissolved Solids (TDS) = 25,000 mg/L), while the bottom layer (*monimolimnion*) is hypersaline (TDS = 87,000 mg/L). The chemocline that separates the two layers is 30 m deep, but throughout the depth of the lake, the pH is 9.7. The primary source of the minerals is calcite-laden groundwater emerging at the bottom of the lake. Precipitation is mainly due to salinity contrast, although, in some cases, biologic influences (organic filaments, reeds, etc.) are the cause.[7]

The authors of the study on Big Soda Lake were surprised by the fast growth rate of the tufa mounds—much faster than long-age geologists usually envisage. But they were also surprised by some unexpected results from their isotopic analyses and sounded a note of caution about using isotopes to determine paleoclimate. They discovered that the isotopic changes, normally assumed to be the result of fractionation processes and an indicator of past climate, were in fact due to mixing with groundwater of different isotopic composition. There is already history of massive errors in paleoclimate interpretations when similar approaches were applied to oxygen isotopes ($\delta\ ^{18}O$ values) in other geological environments.[8,9] It is not surprising, therefore, that this new evidence has revealed similar errors from applying uniformitarian assumptions to tufas.

## Lost City Hydrothermal Field

Deep marine deposits have also presented challenges to the conventional ideas about rock formation rates. While terrestrial travertines have generated a certain amount of research and literature, little has been published about similar formations occurring deep on the ocean bottom, because of hydrothermal activity. The Lost City Hydrothermal Field is located at 30 degrees north, 15 km off the Mid-Atlantic Ridge, near the eastern intersection of the ridge with the Atlantis fracture zone.[10] Carbonate chimneys, some over 60 m high, and various other carbonate edifices have been found on this dome-like massif in which peridotites are present alongside basalt. The vents that supply and build the carbonate structures are relatively cool (40–75ºC) and alkaline (pH 9.0–9.8).

It is believed that the thermal energy that fuels this geosystem comes not from the mid-ocean ridge but from the chemical energy released during serpentinization[11] of peridotites by the ocean water infiltrating the fractures in the area. Thermal convection then pushes mineral-laden water upwards, towards the bottom of the ocean where precipitation takes place.[10] Most of the published materials concentrate on the serpentinization and hydrothermal convection, but little attention has been paid to the source of carbonate. Theoretically, the only source of additional calcium is the peridotite. Clinopyroxenes are an alternative, but no mention is made in the literature about their presence.[12]

Initial thermodynamic calculations of the serpentinization process have yielded ages of 100 to 10,000 years.[10] $^{14}C$ dating of the carbonate structures, on the other hand, have revealed ages of up to 30 ka,[13] while the age of the oceanic lithosphere is 'confidently' established (by way of magnetic anomalies) to be in the order of 1.5 Ma.[10] Once again, there is a major discrepancy between the various dating methods.

## Rapid processes

Long-age geologists generally accept that diagenesis is a very slow process, taking hundreds of thousands to millions of years. These new discoveries have reduced the duration of certain types of diagenesis by two or three orders of magnitude. While, to the secular geologist, travertine and tufa formation is a rapid process, serpentinization and other similar processes are considered to take a very long time. The fact that large amounts of water and heat can dramatically reduce this duration has come as a surprise.

In contrast, young-earth creationists have always emphasized that the exceptional, unrepeatable event of the Genesis Flood was accompanied by tremendous amounts of water and volcanic and igneous heat altering the massive sedimentary deposits that it had created. Regional-scale hydrolyze-type, exothermal, chemical reactions (like serpentinization) are potentially important geological mechanisms, in areas lacking in volcanic activity.[14] Thus, most of the sedimentary deposits could have been subjected to intense heat and water circulation that could have generated almost the complete array of sedimentary and metamorphic rocks known today. And where igneous and chemical heats met, the resulting rocks could have been very complex and of high metamorphic grade.

## References


1. Apart from igneous rocks, the only major bound or diagenized rocks forming today are travertine and tufa, along with some minor beach rocks. Evaporites are not forming as bound rocks, and likewise reefal constructions are not true rocks but rather aggregates, as they need diagenesis to become limestones. So, volumewise, I believe travertine and tufa are the most important true rocks forming today.
2. Ford, D.C. and Williams, P.W., *Karst Geomorphology and Hydrology*, Chapman & Hall, London, p. 20, 1992.
3. Chafetz, H.S. and Folk, R.L., Travertines: depositional morphology and the bacterially constructed constituents, *J. Sed.Pet.* **54**(1):289–316, 1984.
4. <gsa.confex.com/gsa/2004AM/finalprogram/abstract_77540.htm>, October 2004.
5. Diagenesis refers to all the physical, chemical and biological changes that occur within a sediment after deposition as it compacts and lithifies. Diagenesis excludes weathering and metamorphism.
6. Silvestru, E., The standing stones of creation, *TJ* **18**(1):3–5, 2004.
7. Rosen, M.R., Arehart, G.B. and Lico, M.S., Exceptionally fast growth rate of <100-yr-old tufa, Big Soda Lake, Nevada: Implications for using tufa as paleoclimate proxy, *Geology* **5**:409–412, 2004.
8. Pearson, P.N., Ditchfield, P.W., Singano, J., Harcourt-Brown, K.G., Nicolaus Copernicus, C.J., Olsson, R.K., Shackleton, N.J. and Hall, M.A., Warm tropical sea surface temperatures in the Late Cretaceous and Eocene epochs, *Nature* **413**:482, 2001.
9. Schwarzschild, B., Isotopic analysis of pristine microshells resolves a troubling paradox of paleoclimatology, *Physics Today* **54**(12):16, 2001.
10. Kelley, D.S. *et al*., An off-axis hydrothermal vent field near the Mid-Atlantic Ridge at 30º N, *Nature* **412**:145–149, 2001.
12. Normal ocean water does not precipitate carbonate.
11. Oxidizing of olivine and pyroxenes into serpentine (magnesium iron silicate hydroxide).
13. Früh-Green, G.L. *et al.*, 30,000 years of hydrothermal activity at the Lost City Vent Field, <www.sciencemag.org/cgi/data/301/5632/495/DC1/1>, October 2004.
14. In contrast, modern sedimentology has restricted epigenetic formations to areas of known centres of igneous activity, completely excluding such regional-scale processes from the equation. See: Selley, R.C., *Applied Sedimentology*, Academic Press, London, p. 14, 2000. Yet another example of an unholistic approach in earth sciences.