GYPSUM TRAYS IN TORGAC CAVE, NEW MEXICO

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The gypsum trays in Torgac Cave, New Mexico are only the second reported occurrence of this speleothem type in the world. They differ from most other (carbonate or gypsum) trays in that they often have stalactites growing on their flat undersides (thereby forming "claw" shapes), and in that they can exhibit multiple tray growth in the vertical direction on a single stalactite. This deviation from "normal" tray development indicates that for gypsum trays to form, equilibrium must be reached between infiltration and evaporation of water. If infiltration exceeds evaporation, then gypsum stalactites ("claws") will form; if evaporation exceeds infiltration, then trays (with flat-bottomed surfaces) will form. Drier climatic conditions during the Holocene (last 10,000 years) may have influenced the growth of gypsum trays in Torgac Cave.

Torgac Cave is located in central New Mexico, ~100 km northeast of the town of Capitan, on Bureau of Land Management property. The cave is developed in the Permian Fourmile Draw member of the San Andres Formation, a silty-limy dolomitic unit containing gypsum interbeds. Short-grass prairie vegetation and a semiarid climate exist in the vicinity of the cave. The entrance area is a collapse sinkhole approximately 100 m in diameter and 30 m deep (Fig. 1). The entrance sink funnels cold, dry air down into the cave, especially in the winter. The temperature and humidity of Torgac Cave were monitored by Forbes (1998) in January and February of 1995. Temperatures at that time ranged from 5.5° to 10.9°C. Relative humidity ranged from 56% to 96% in different parts of the cave. The cave serves as a hibernaculum for several species of bats (Jagnow, 1998).

Hill (1982) was the first to discuss the mineralogy of the cave, reporting gypsum stalactites ("claw" and anemolite), stalagmites, popcorn and crust, and epsomite flowers, cotton and crust. This report expands on Hill's earlier description; in particular it discusses the gypsum trays in the cave, a type of speleothem not previously recognized there. Other speleothems/minerals in the cave not previously reported are gypsum rims ("eggshell" variety; Fig. 2), gypsum flowers, gypsum blisters, gypsum flowstone, and epsomite stalactites (growing on the tips of gypsum stalactites). The gypsum dripstone and flowstone has a macrocrystalline texture, with individual gypsum crystals up to 3 cm in diameter. This texture gives these speleothems a "bumpy" appearance. Gypsum spar crystals, up to 10 cm long and dating from an earlier phreatic episode (Fig. 3), are found within bedrock cavities (vugs) in the Football Room (Fig. 1).

DESCRIPTION OF TRAYS

Trays are a speleothem type composed of sprays or clusters of popcorn or grape coralloids and frostwork, the composite mass of which ends in a flat, horizontal, traylike surface (Hill & Forti, 1986). Often these flat-bottomed masses occur in tiers or ledges, that is, separated from one another at different levels along a cave wall, in a stairstep-like manner. Maximum development of trays is along their flat, bottom surfaces (trays seemingly "refuse" to grow farther down). The elevation of the flat surface coincides with wall irregularities, the tips of bedrock pendants, or the tips of stalactites.

Both carbonate (calcite-aragonite) and gypsum trays have been reported in the literature. Martini (1986) was the first to formally name and describe this speleothem type from carbonate occurrences in South African caves. These speleothems had been called "flat-bottomed popcorn" by cavers in the Guadalupe Mountains, New Mexico, for many years (Hill, 1986; 1987). Gypsum trays were first documented by Calaforra and Forti (1994) in Rocking Chair Cave, near Carlsbad, New Mexico. Torgac Cave has the second reported occurrence of gypsum trays anywhere in the world.

Gypsum trays can be found at several locations in Torgac, including the Main Formation Area, a smaller room called the Tray Room just off the Main Formation Area, the main north-south passage halfway between the Main Formation Area and the Circle Room, and the Football Room (Fig. 1). In the Main Formation Area, several dozen trays are suspended from the lower ends of gypsum stalactites at a height of about 4 m above the floor. The stalactites, which are ~1.2 to 1.5 m long, widen at their tips to form small trays 0.3 to 0.5 m wide. Often the flat lower surfaces of these trays are not completely horizontal but may be inclined at up to about 10° from the horizontal. Some of the trays in this area are actively dripping, with tiny gypsum stalactites forming on the bottom of the trays, thus giving the composite mass a "clawlike" appearance. Other of the trays are flat and dry, with no stalactitic growth beneath them. Trays in the southwest half of the room appear to have developed as multiple tiers from which small gypsum stalactites have grown, connecting the tiers to one another (Fig. 4).

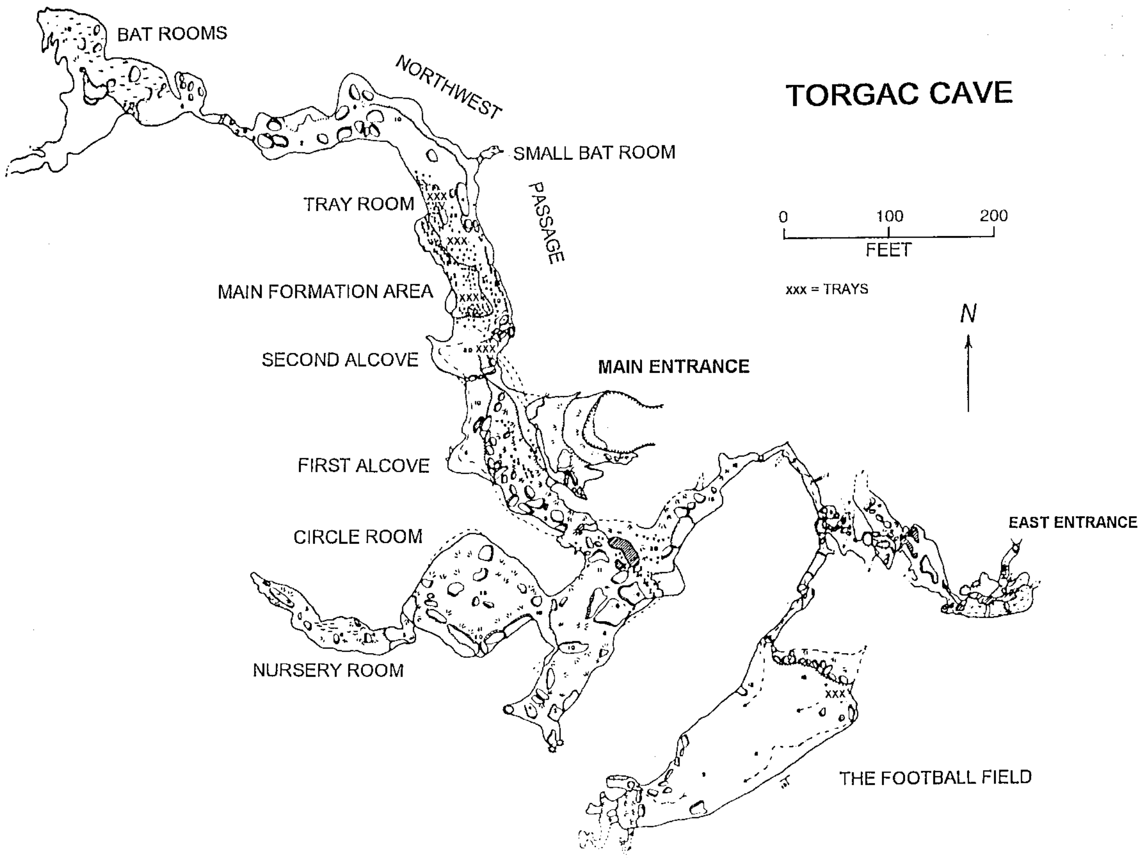

Figure 1. Map of Torgac Cave showing location of trays ("xxx" denotes trays).

On the northeast side of the room the trays are about the same size but are more uniformly flat and have no stalactites extending downward from their bottom surfaces. The flat-bottomed surfaces of the trays are characterized by macrocrystalline gypsum popcorn rosettes in their centers surrounded by gypsum frostwork around their edges. Along the east side of this portion of the cave, the passage slopes sharply upward toward the eastern entrance, a configuration that may result in higher evaporation rates as cold, dry air sinks into the passage from the entrance.

In the Tray Room, at the back of the Main Formation Area, tray tiers extend outward from the walls in the upper half of the gallery. These tiers begin at about 1 m above the floor and can be found at several levels up to about 4 m. These trays are elongated in a north-south direction and measure up to 25 cm in diameter. Many have tiny, actively growing gypsum stalactites extending downward from their flat lower surfaces, and also gypsum stalagmites on the floor beneath these drip points. The highest tray in this room is attached to and nearly flush with the ceiling.

Trays can also be found at the tips of stalactites above the slope on the east side of the passage between the Main Entrance and the Main Formation Area. These trays are suspended from the ceiling between 1.3 m and 2.1 m above the floor. The lower set of trays appears to have developed successive stages of tray growth like some of the trays in the Main Formation Area. The upper trays are much drier and flatter. Like those in the Main Formation Area, these are composed of gypsum rosettes surrounded by gypsum frostwork (Fig. 5). The enlarged mass of the trays is ~0.3 m to 0.5 m in diameter and ~0.3 m long. Several other incipient trays can be seen on the wall behind and around the higher trays.

Well-formed gypsum trays occur in the Football Room near the south end of the cave. One tray (the one closest to the south wall) is suspended from a ~0.8 m-long stalactite and has a stalagmite and a series of drip holes in the sediment floor beneath it. This tray is 1.9 m above the stalagmite and 2.4 m above the floor. It thus appears that some of the dripping water is oversaturated with respect to dissolved calcium sulfate and precipitates gypsum when it reaches the floor; other dripping water is undersaturated and creates drill holes instead. Nearby, a separate cluster of five gypsum trays is suspended 3.4 m above the floor. These trays are 7 to 15 cm in diameter and are attached to three branching stalactites, each about 0.6 m long. Some 25 drill holes occur in the mud floor beneath these wet and dripping trays; however, no incipient stalactites or "claws" extend downward from the bottoms of this cluster of trays.

ORIGIN OF TRAYS

The origin of trays is not well understood and it is hoped that the description of gypsum trays in Torgac Cave will con-

Figure 2. "Eggshell" gypsum rims, in passage leading into the Football Field Room. Photo courtesy of D. Jagnow.

Figure 3. Phreatic tabular gypsum crystals in a bedrock cavity, Football Field Room. Photo courtesy of D. Jagnow.

tribute to the model of origin for this speleothem type. Martini (1986) was the first to speculate on the origin of carbonate (calcite-aragonite) trays, saying that these are subaerial, rather

Figure 4. Tiers of gypsum trays connected by stalactites, Main Formation Room. The tiers may represent alternating wet (stalactites) and dry (trays) climatic episodes. Photo courtesy of D. Jagnow.

than subaqueous, speleothems. According to Martini's model, slightly undersaturated (with respect to calcite and aragonite), thin-film solutions flow down a rock pendant (or stalactite) and reach saturation by evaporation. Where evaporation of these thin films of water occurs, aragonite frostwork is precipitated. Subsequent thin-film solutions rise in this frostwork by capillarity, so that later frostwork growth is upward or lateral, away from the pendant tip (or stalactite), causing a flat-bottomed surface to form. And, since different rock pendants (or stalactites) differ in elevation, trays can form as multiple flat-bottomed tiers or ledges. Aragonite frostwork continues to grow along the edges of a carbonate tray where evaporation is at a maximum, but frostwork in the interior of the tray is gradually replaced by calcite popcorn because these interior solutions (where evaporation is relatively less) are undersaturated with respect to aragonite but oversaturated with respect to calcite. Martini's (1986) model was for carbonate trays, but Calaforra and Forti (1994) proposed essentially the same genetic mech-

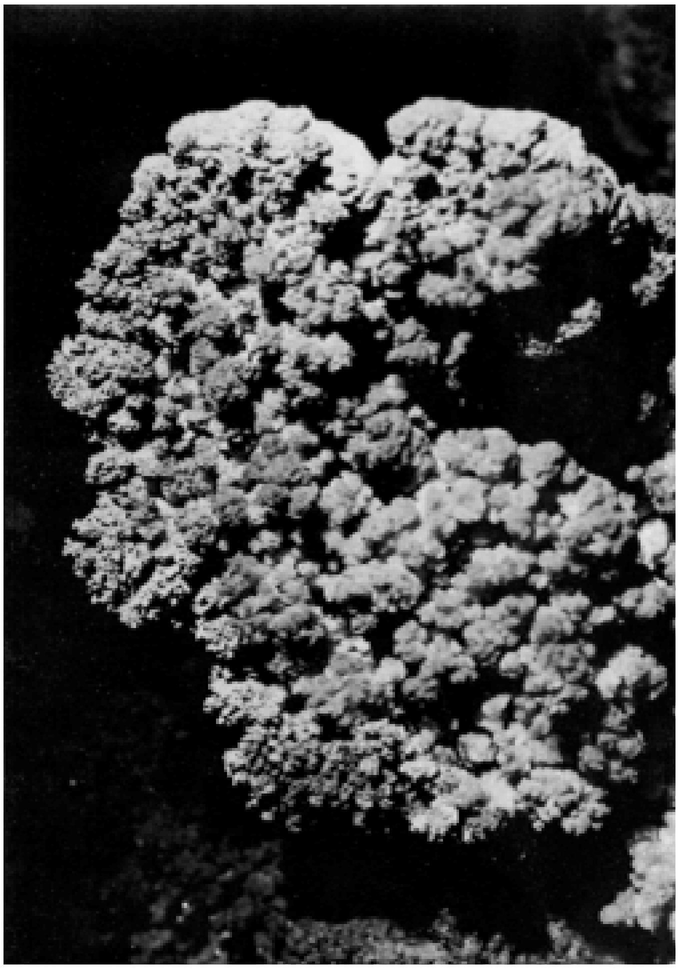

Figure 5. Looking straight up at the flat bottom of a gypsum tray, between Main Entrance and Main Entrance Area. Popcorn rosettes of gypsum make up the center of the tray and gypsum frostwook forms along the edges of the tray. Photo courtesy of D. Jagnow.

anism for the growth of gypsum trays. However, in the case of gypsum trays there is no replacement of one mineral by another (i.e., aragonite by calcite), but a recrystallization of gypsum (from frostwork to popcorn) takes place in the interiors of trays.

DISCUSSION

The gypsum trays in Torgac Cave show that the mechanism for tray growth as described by Martini (1986) is incomplete. Gypsum trays develop frostwork exteriors, popcorn interiors, and flat-bottomed surfaces, even though they are not formed by the replacement of one mineral by another. Instead, tray morphology may be a function of growth from thin films due to microclimate variations. Thin films in a more highly evaporative environment (i.e., the outer surfaces of trays directly subjected to air flow) may promote a dendritic, frostwork morphology, whereas in the center of trays, a less evaporative (less air flow) environment promotes the rounded, botryoidal form of popcorn—either calcite popcorn (replacing aragonite frostwork) or gypsum popcorn (recrystallizing from gypsum frostwork).

In Torgac, gypsum trays commonly form both on wall pendants and stalactites, but some stalactitic trays are different from those in other caves in that they are multiply stacked, with separate tiers of trays forming as part of the same stalactite (Fig. 4). This seems to show that the evolution of these trays is dependent on equilibrium conditions established between the amount of infiltrating water and evaporation. If there is an insurge of water (as during a wetter climatic interval), then dripping water may form stalactites (“claws”) on the bottom of trays (the trays are the “hands” from which the stalactite “claws” hang). But if the infiltration of water slows down or stops (as during a drier climatic interval), a new tray tier may grow at the bottom of these stalactites. The fact that the gypsum trays in Torgac Cave only occur at or near the ends of large (3 to 4 m long) gypsum stalactites (Fig. 4) may reflect drier climatic conditions during the Holocene in the central New Mexico area (Harris, 1985). During wetter periods in the Pleistocene (e.g., the Wisconsin glacial), the large gypsum stalactites may have formed. Then, during the much drier Holocene, the trays could have formed, with small oscillations in climate during this time causing the multiple tray tiers. The fact that some of the trays appear to be “dead” while others are “active” (with water dripping off them) may be the result of seepage patterns, or it may indicate different evaporative conditions within different parts of the cave due to air flow patterns. Where dry desert air descends into the cave along entrance breakdown, evaporation may cause certain trays to be inactive, whereas in more humid passages, the trays may still be growing.

In Torgac, the trays are present in the middle to upper (above ~2m) portions of the passages, but documented trays (both carbonate and gypsum) in other caves are located closer to the floor. This aberrant distribution may reflect microclimate variations in Torgac brought about by its multiple collapse entrance. In a large cave system like Carlsbad Cavern, cold, dry air flows into the cave along the floor, and it is always here, near the floor, that “popcorn lines” and associated trays form (Hill, 1987). But in Torgac, air flow is down many entrance holes, causing local evaporation gradients where trays are not necessarily located near the floor. This distribution also correlates with the findings of Forbes (this issue) where the highest microclimate relative humidities in Torgac were measured within 0.3 m of the floor (92%) and ceiling (90%), and with a relative humidity minimum (83%) at 1.2 m. This height may correspond to the zone of maximum air flow and region of preferred growth for gypsum trays in Torgac.

CONCLUSION

Trays are a speleothem type whose origin and mechanism of formation is still not well understood. Further work needs to be done on the critical microclimate conditions needed for gypsum (and carbonate) tray development.

ACKNOWLEDGEMENTS

Support for this paper was provided by Dave Jagnow, who helped with observations, took photographs, and led trips into Torgac Cave; Jeffrey Forbes, who conducted meteorologic measurements in the cave; and Cyndi Mosch, who provided insight into climatic processes and mineralogy. The Bureau of Land Management, Roswell District, provided research permits and allowed access to the cave; Mike Bilbo, cave specialist for the Roswell District, provided professional and personal support for this project.

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