

Tectonic influences on Speleogenesis in the Guadalupe Mountains, New Mexico and Texas

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The development of caves that were modified by sulfuric acid in the Guadalupe Mountains of New Mexico and Texas is a consequence of the rise of the Alvarado Ridge and subsequent opening of the Rio Grande Rift during the last 38 million years. 35-38 million years ago, a continental-scale arch known as the Alvarado Ridge extended from northern Colorado southward into Mexico. Uplands of this ridge were an immense recharge area that supplied water to aquifers draining eastward toward the Permian basin. In southern New Mexico, this ridge included the Capitan aquifer, which comprises the cave-bearing limestone and dolomite of the Guadalupe Mountains. Beginning 29 million years ago, stretching of the earth's crust along the Alvarado Ridge caused numerous north-trending faults to develop, creating a series of mountain ranges and valleys now known as the Rio Grande Rift. Prior to the opening of the Rio Grande Rift, hydrostatic head caused water to flow upward along fractures to artesian springs in the Capitan aquifer. This resulted in solution enlargement of fractures and development of early stage caves. Extensional faulting after 29 million years ago fragmented the Alvarado Ridge, progressively reducing the size of the upland recharge area and reducing hydrostatic head. Fresh water influx during this time introduced microbes into Artesia Group (Permian, Guadalupian) oil reservoirs, causing biodegradation of petroleum and generating copious H₂S. The water table within the Guadalupe Mountain block began to drop 14-12 million years ago in response to erosion and faulting. During this time, oxygen-rich meteoric water mixed with H₂S connate water to form sulfuric acid, which enlarged passages and galleries at the water table and formed large voids including Carlsbad Cavern and other caves. Episodes of faulting related to the opening of the Rio Grande Rift caused abrupt drops in the water table, shifting areas of sulfuric acid dissolution eastward and downward. Cave levels formed by sulfuric acid record the position of the water table at a given time, and the elevation difference between levels may correlate with episodes of faulting within the Rio Grande Rift during the last 14 million years.