Observations on Subsurface Stratigraphy at the I&W Brine Site in Carlsbad, New Mexico

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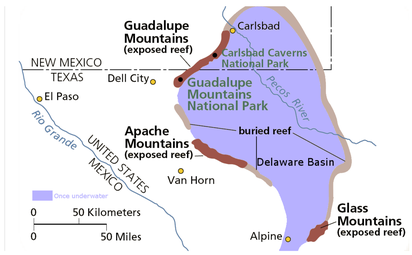
Introduction

The I&W Brine Well Remediation Site was a brine water production facility that operated from 1979 to 2009. In 2008 three other similar facilities in Southeastern New Mexico and West Texas with similar geology experienced collapses leaving large sinkholes. Like I&W, these facilities created large underground cavities from solution mining salt layers in the Salado Formation.

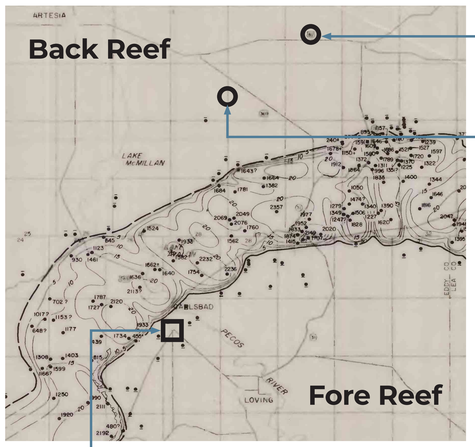
The City of Carlsbad, NM is on the northern edge of the Delaware Basin, a fore reef basin mostly encircled by the Capitan Reef and containing thick sequences of evaporites deposited in the Ochoan Age of the Permian Period.

In 2013 and 2019, WSP installed microseismic arrays in coreholes 400-700 feet deep and surrounding the I&W site for monitoring and triangulation of underground movement events. The drilling and retrieval of rock cores and acquisition of downhole geophysical logs in these borings presented a unique opportunity to directly observe lithologic, structural and diagenetic changes; because oil and gas drilling within city limits is prohibited by City ordinance. This allowed us to better conceptualize the subsurface at I&W for factor of safety modelling and discover important engineering consequences of differing regional geologies between I&W and other brinewell sites, important steps for the remediation of the underground cavity at I&W.



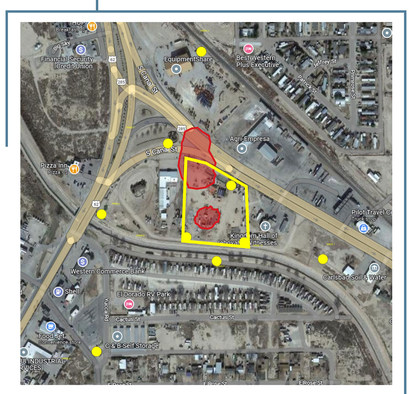
Delaware Basin (Wikipedia)

Loco Hills brine well collapse. Photo by Lewis Land of National Cave & Karst Research Institute (NCKRI)

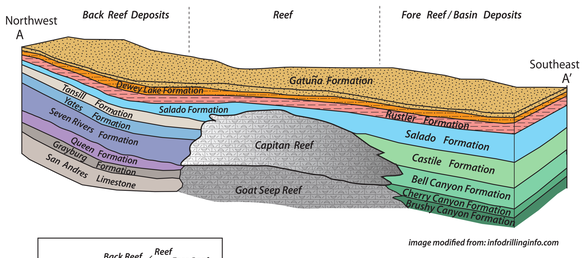


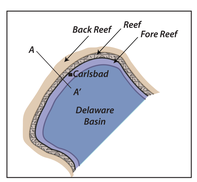
Capitan Reef near Carlsbad (Hiss 1975)

Jim's Water Service brine well collapse. Photo by Lewis Land of NCKRI



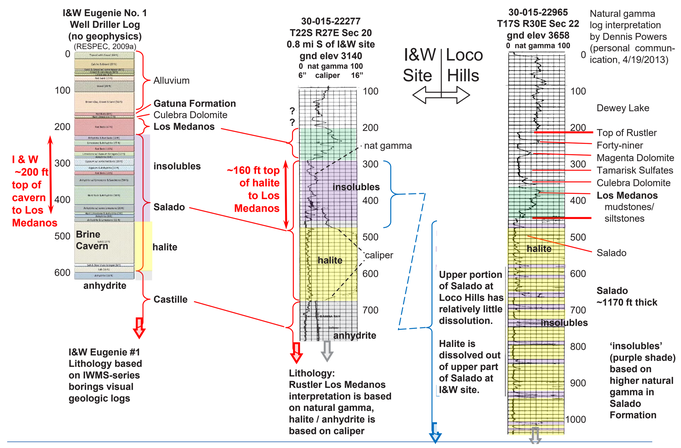
The I&W Brinewell Site (outline in yellow) with locations of microseismic array coreholes (yellow circles) and positions of underground solution mining voids (red)



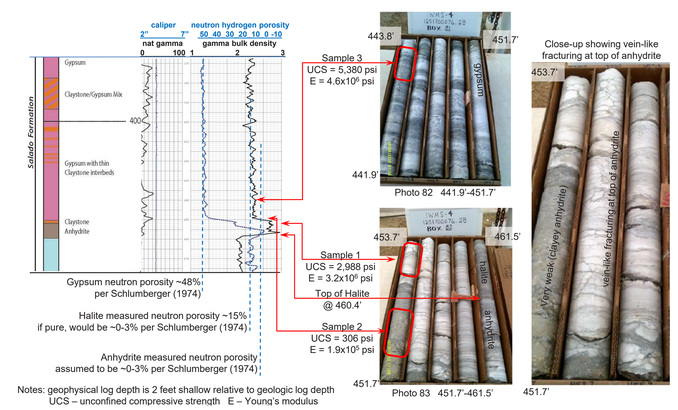


Generalized cartoon of regional stratigraphy in the study area.

Note that local stratigraphy at the I&W site varies from the regional stratigraphy. The nearby Capitan Reef daylights at Carlsbad, the Salado Fm thins as it approaches the Capitan Reef, Dewey Lake Fm and upper portions of the Rustler Fm are missing, and the Gatuña Fm underlies alluvium.



Above figure (middle) shows how layers of "insolubles" (clay, gypsum, polyhalite, minor anhydrite) –highlighted in purple- coalesced during dissolution of the upper halite layers in the Salado in the Pecos River Valley. Solution mining at I&W created a void in a single layer of halite.



Above figure shows the transition of gypsum to anhydrite in microseismic borehole IWMS-4 with downhole geophysics. Introduction of freshwater into the subsurface during dissolution of the upper Salado in the Pecos River Valley hydrated most of the coalescing anhydrite layers into gypsum, leaving only a few thin relict layers of anhydrite above the existing halite interval.

Probably the most salient difference we see between strata underlying the I&W Site and the collapsed brinewell sites to the north is the dissolution of halite in the uppermost Salado Formation, the formation in which solution mining occurred during brine production.

The Ancestral Pecos River Valley, which started forming as early as the Late Cretaceous Period as a result of the Laramide uplifts, brought much groundwater flow into the area , and dissolved out the upper halite layers of the Salado.

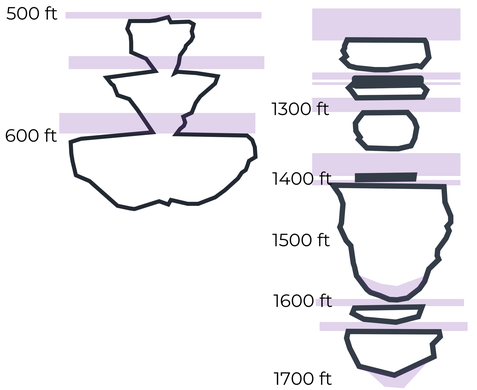
The remnants of the upper Salado halite beds show up as collapse structures and breccias of gypsum, clay and polyhalite in surface exposures and in cores from I&W.

Above: collapse structure in the upper Salado Formation south of Carlsbad, south of Black River off Old Cavern Highway (CR 748), WSP field trip 2013.

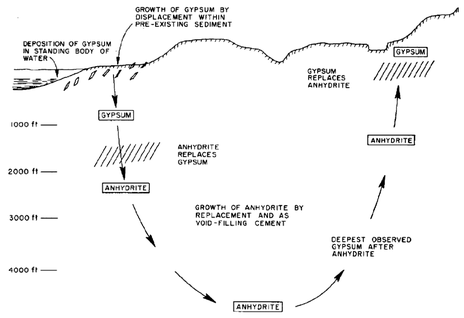
Closeup of a mélange of gypsum (gray) and polyhalite (salmon -colored), which was also seen in rock cores at I&W. (photos by E. Koenig)

Clay/gypsum breccias in rock cores taken 318 feet below ground surface at I&W (Photo by E. Koenig)

Below figure presents sketches of the voids created by solution mining at Loco Hills (left) and Jim's Water Service (1997 sketch at below right). Note how the wells at these sites penetrate multiple halite layers, separated probably by thin interbeds of mostly anhydrite (purple), which may have created multiple points of weakness within these cavities.



This is consistent with R.C. Murray's cyclical gypsum-anhydrite-gypsum diagenetic model (Murray, 1964) (see figure below) where gypsum evaporite deposits are buried, become dehydrated into anhydrite and are later rehydrated back into gypsum upon either exhumation or hydration from groundwater.



Discussion and Conclusions

Accumulation and consolidation of relatively insoluble remnants of dissolved halite layers and formation of massive gypsum layers above the halite at the I&W Site likely imparted additional strength to the roof of the brine well solution mining cavity and delayed a full collapse that would have affected highway and city infrastructure in Carlsbad. This contrasts with the brine well operations at Loco Hills and Jim's Water Service to the north, where the lack of halite dissolution by groundwater caused no such formation to occur; and the roofs of those cavities collapsed, leaving large sinkholes.

WSP would like to acknowledge and thank consulting geologist Dennis Powers, PhD. and, for his knowledge and insight which greatly facilitated WSP's geological conceptual modeling and remediation efforts at I&W.