Development and Distribution of Hypogenic Caves and Paleokarst Features in the Arbuckle Mountains of South Central Oklahoma, USA*

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Abstract

The Arbuckle Mountains are a complex geologic province, characterized by thick sequences of intensely folded and faulted carbonates, sandstones, and shales of the Late Cambrian through Pennsylvanian. Cave, karst and paleokarst features occur in relatively high densities within several limestone and dolostone formations and play a significant role in the storage and transport of fluids in the subsurface. Knowing the origins, morphology and distribution of these karst features is necessary for understanding the karst porosity in production horizons in oil and gas fields. Traditionally, the origins and morphology of these karst features has been viewed as being epigenic, developing from the surface downward; however, recent studies have provided compelling evidence for a more complex evolutionary history for the carbonates. Analyses of more than 1,530 caves, karst and paleokarst features indicate that multiple physical and chemical processes may have taken place, with at least 70 of the features displaying classic signatures for having occurred because of hypogenic origins, developing from upwelling corrosive fluids. Hypogenic karst signatures can be found in caves throughout the Arbuckle Mountains, but occur most commonly in the regimes where deformation is most severe, such as the north flank of the Arbuckle anticline. However, there is evidence that hypogenic speleogenesis may have occurred on the south flank of the Arbuckle anticline where the semi-confining Simpson Group overlaid the upper Arbuckle Group, producing maze-like caves, which are indicative of such processes. Hypogenic karst development appears to be continuing today where the soluble carbonates are overlain by confining units along the edges of the anticline where fresh and saline waters mix and microbial interactions with hydrocarbons provide the fluid geochemistry allowing carbonate dissolution. Hypogenic karst processes may also be responsible for the origin and development of cavities and

conduits in these same formations, encountered during drilling in the deeper subsurface, that have otherwise been attributed to eogenetic processes during Paleozoic sea level fluctuations.

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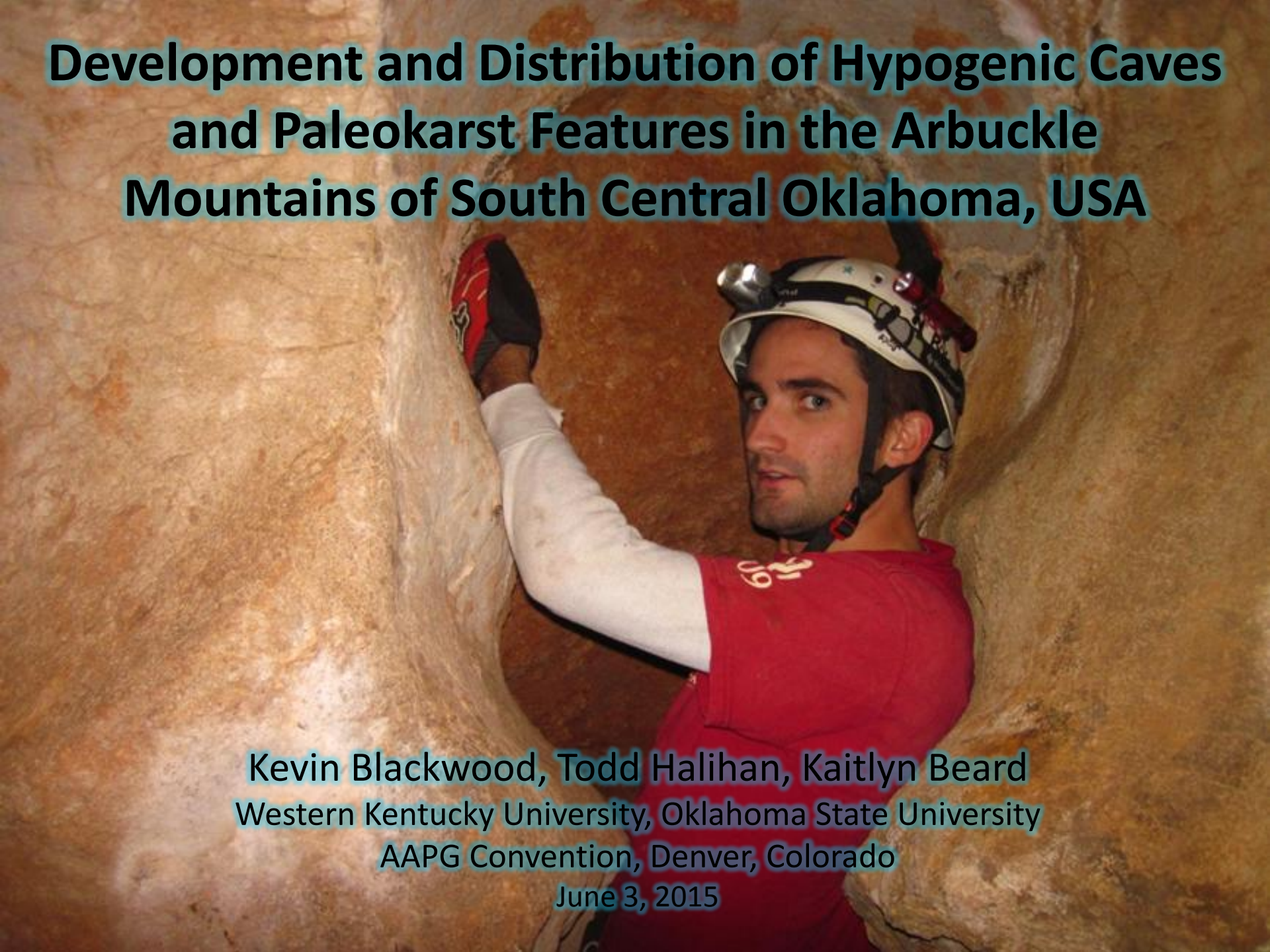

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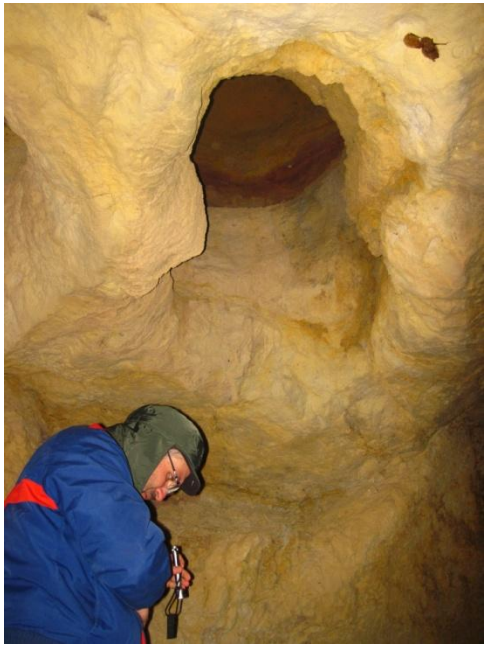
AAPG Convention, Denver, Colorado
June 3, 2015

HYPOGENIC KARST SYSTEMS

KARST: A terrane, generally underlain by limestone or dolomite, in which the topography is chiefly formed by the dissolving of rock, and which may be characterized by sinkholes, sinking streams, closed depressions, subterranean drainage, and caves (Monroe 1970).

HYPOGENE SPELEOGENESIS: The formation of caves by water that recharges the soluble formation from below, driven by hydrostatic pressure or other sources of energy, independent of recharge from the overlying or immediately adjacent surface (Ford 2006).



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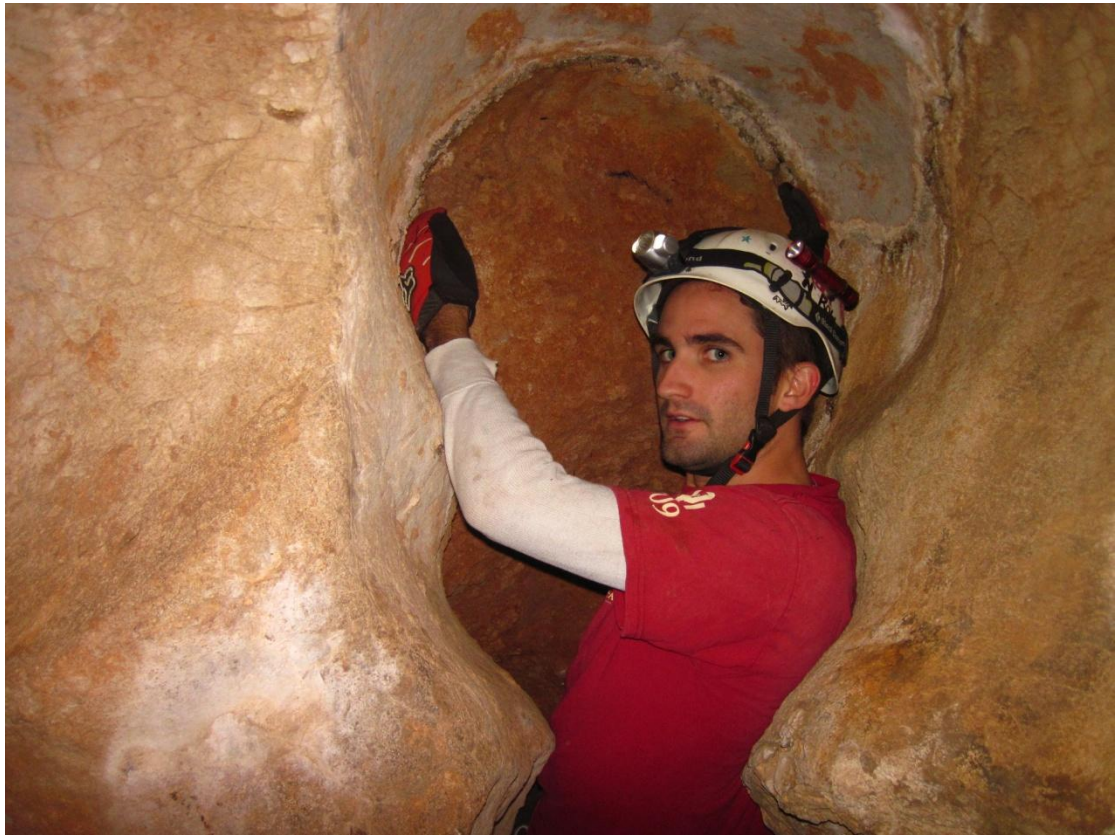
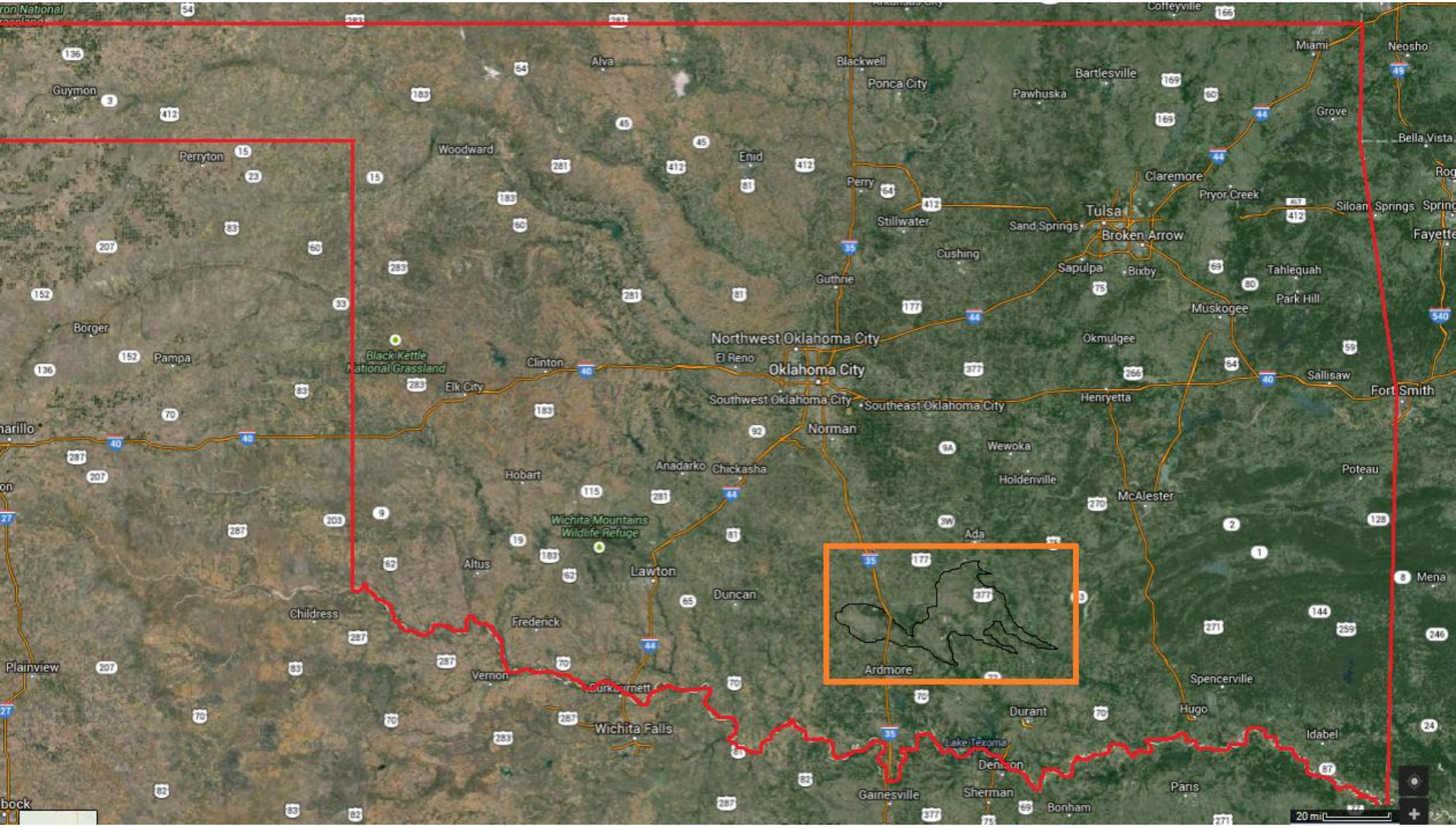


STUDY AREA



Imagery: Google Maps

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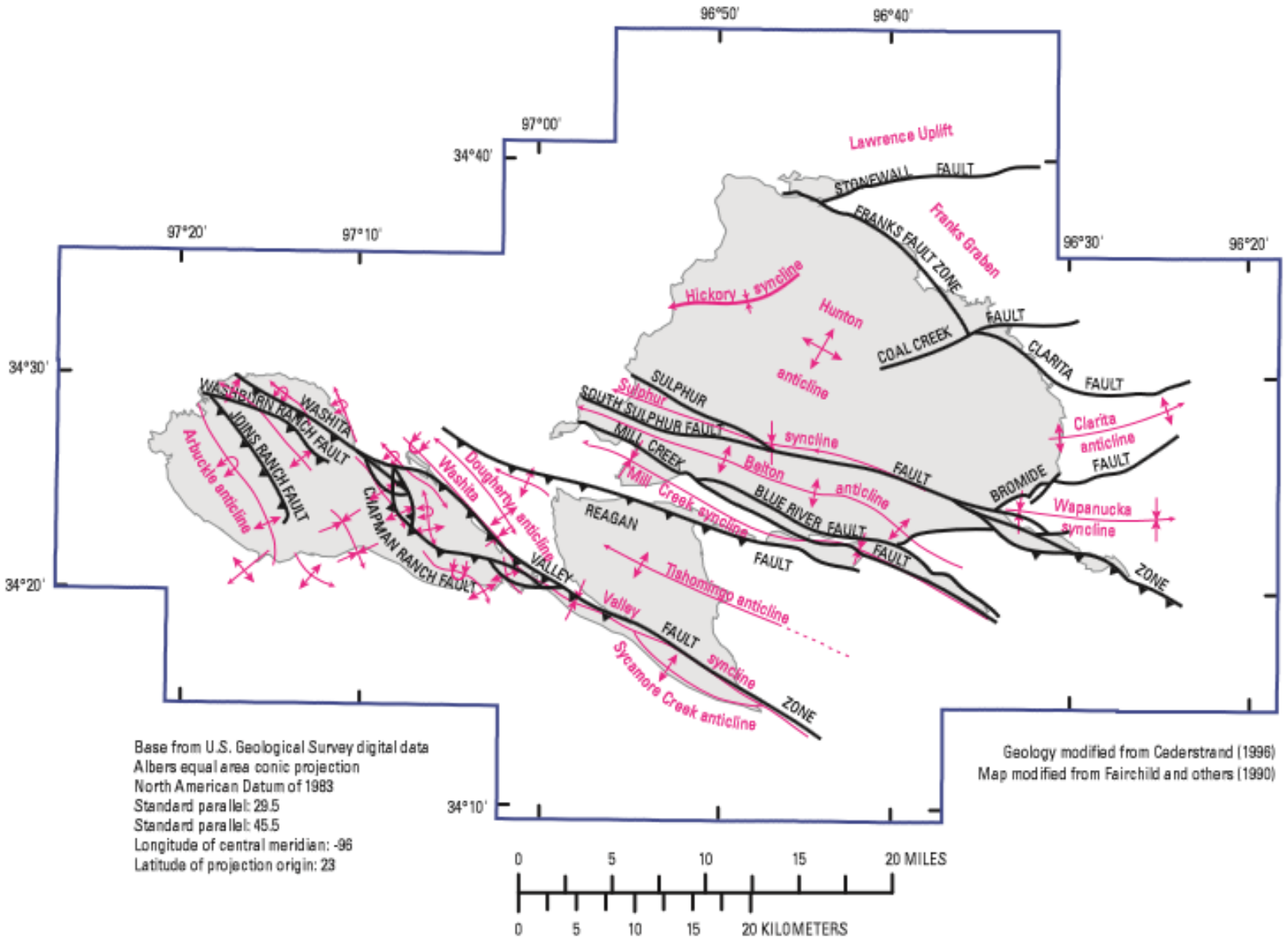

Image: Hydrogeology and Simulation of Groundwater Flow in the Arbuckle-Simpson Aquifer, South-Central Oklahoma (Christenson et al. 2011).

STRATIGRAPHY

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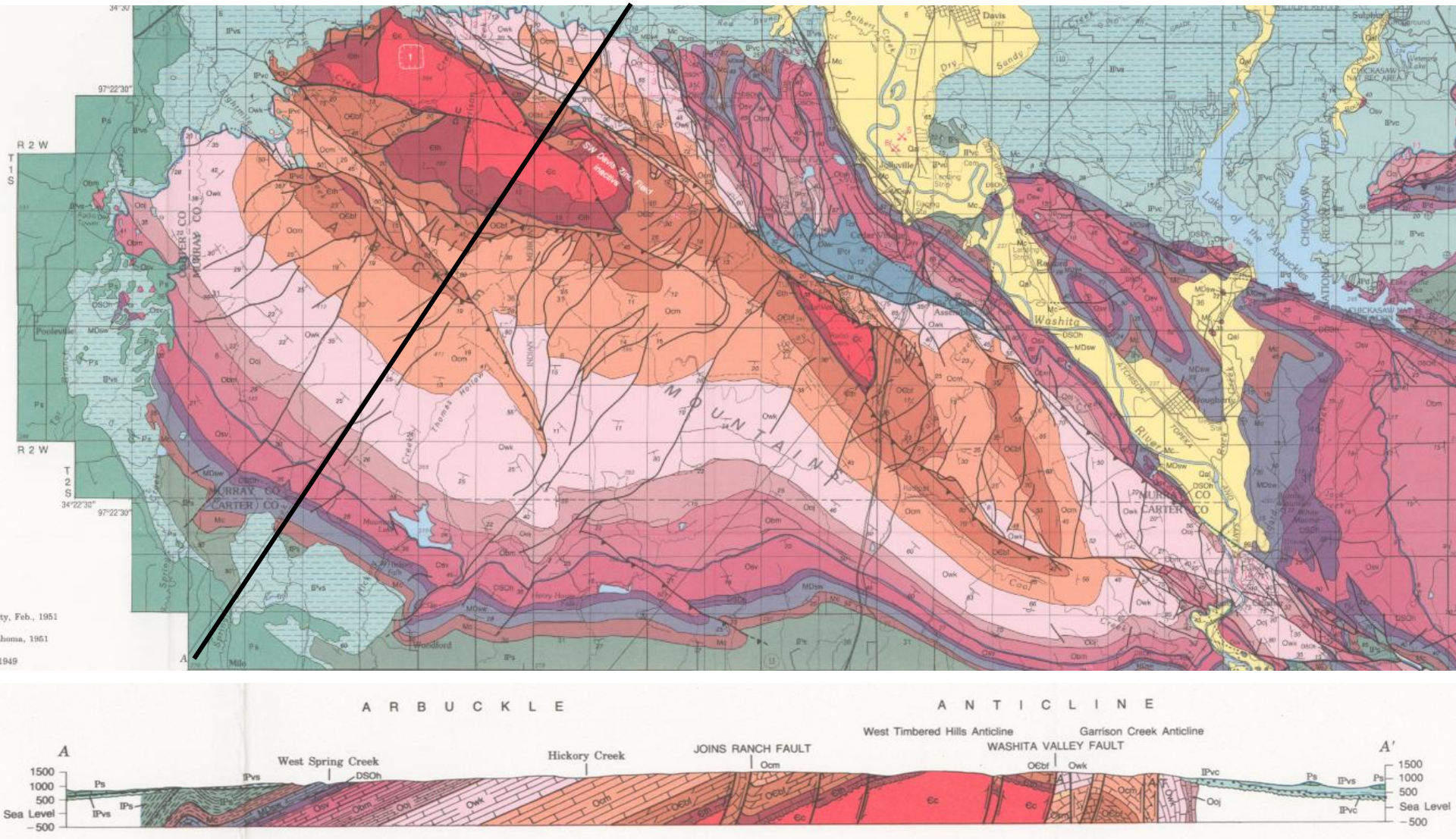
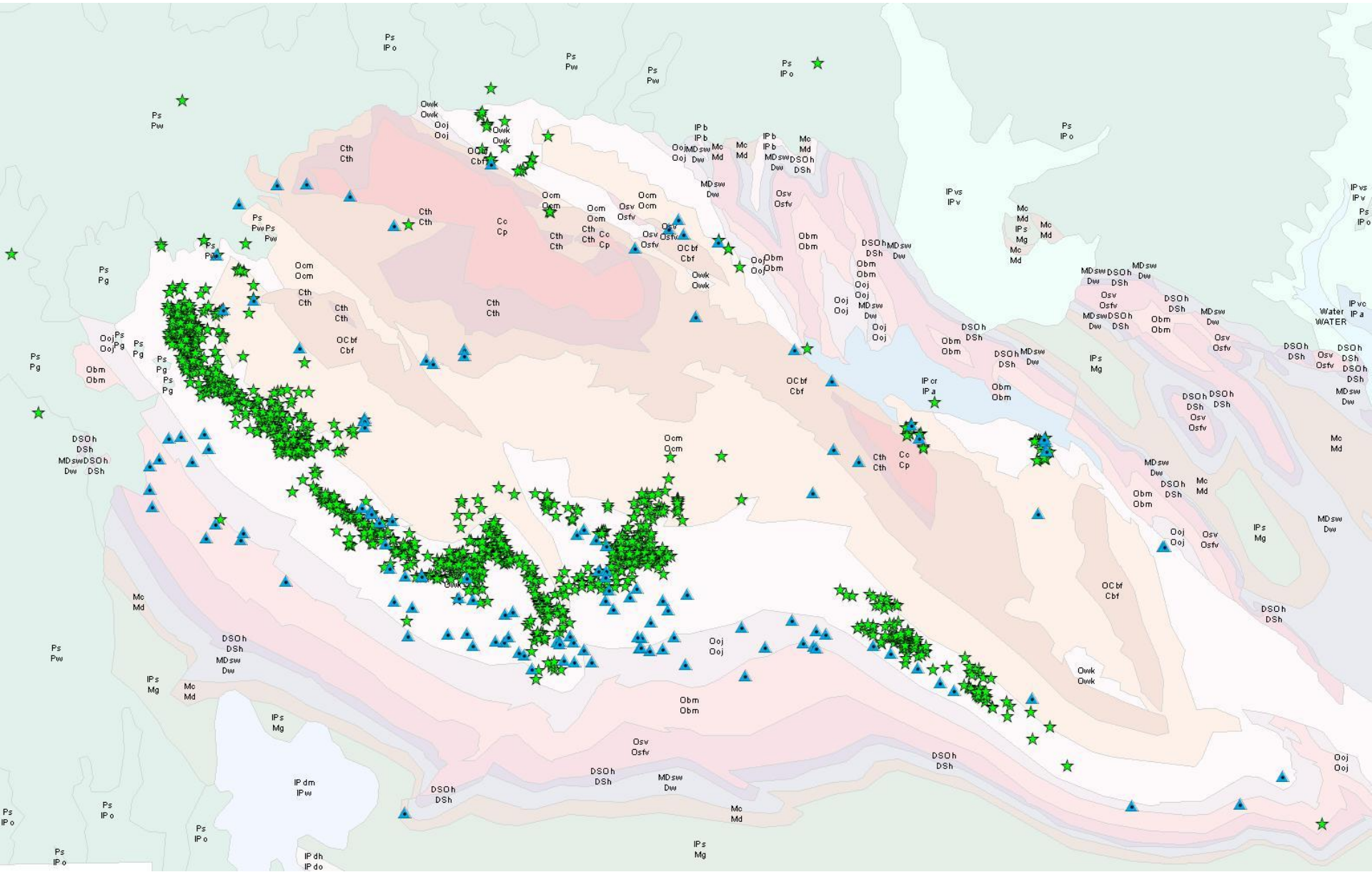


Geologic Map of the Arbuckle Anticline (Ham 1954, Johnson 1991).

KARST AND PALEOKARST



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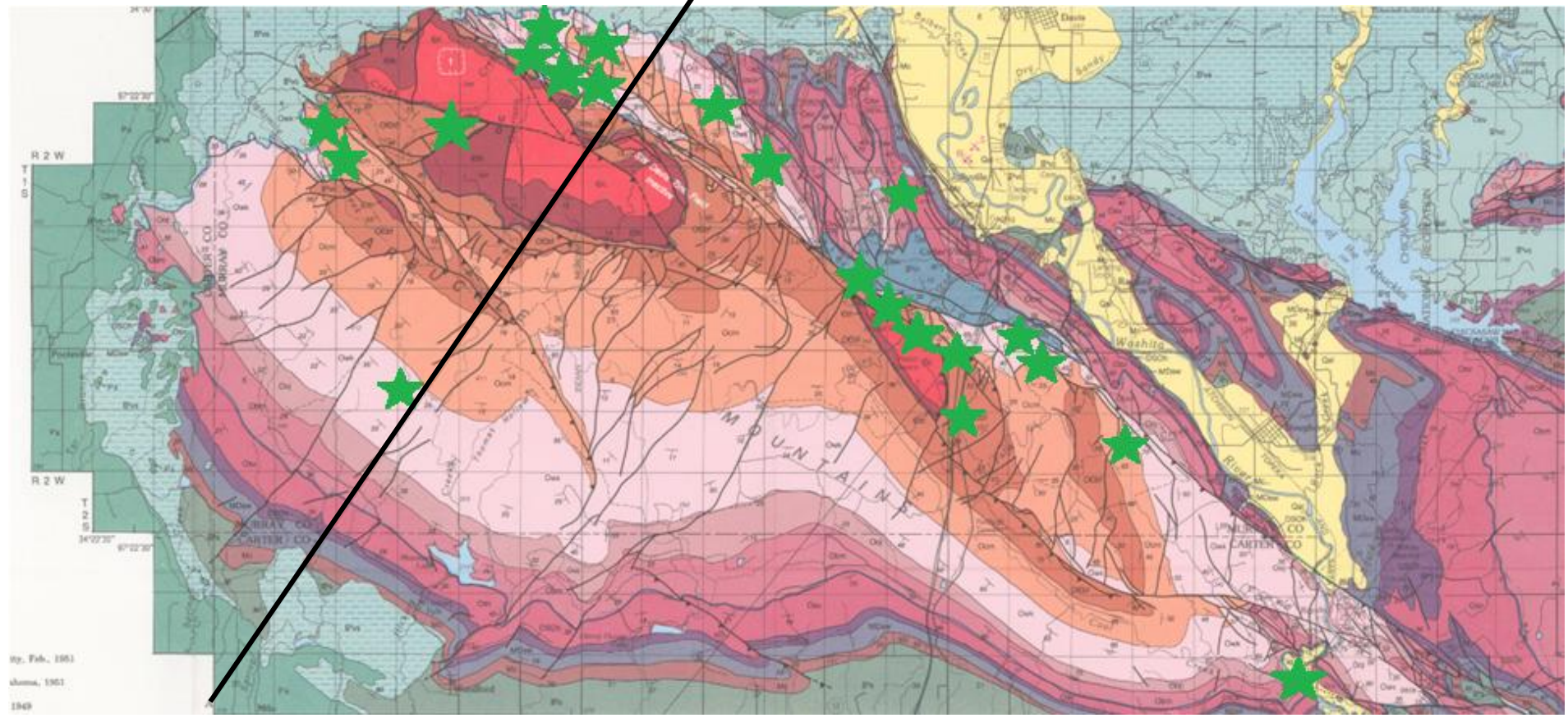

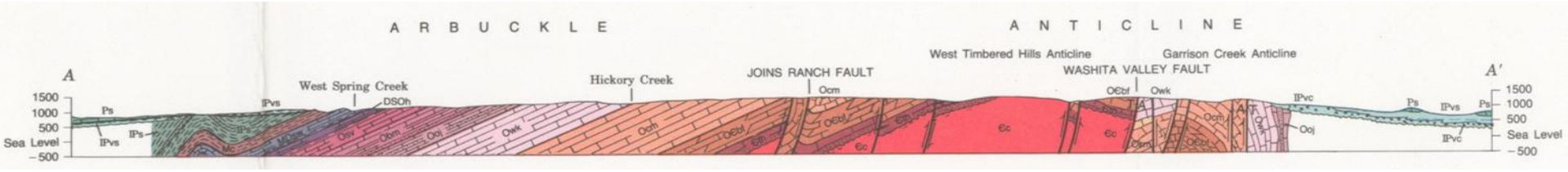

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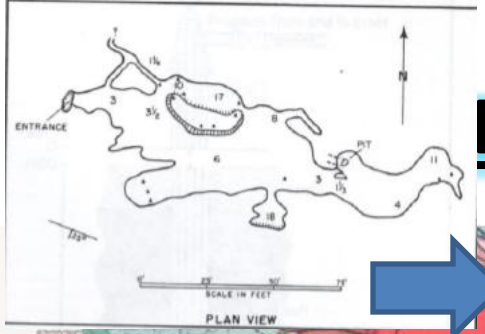

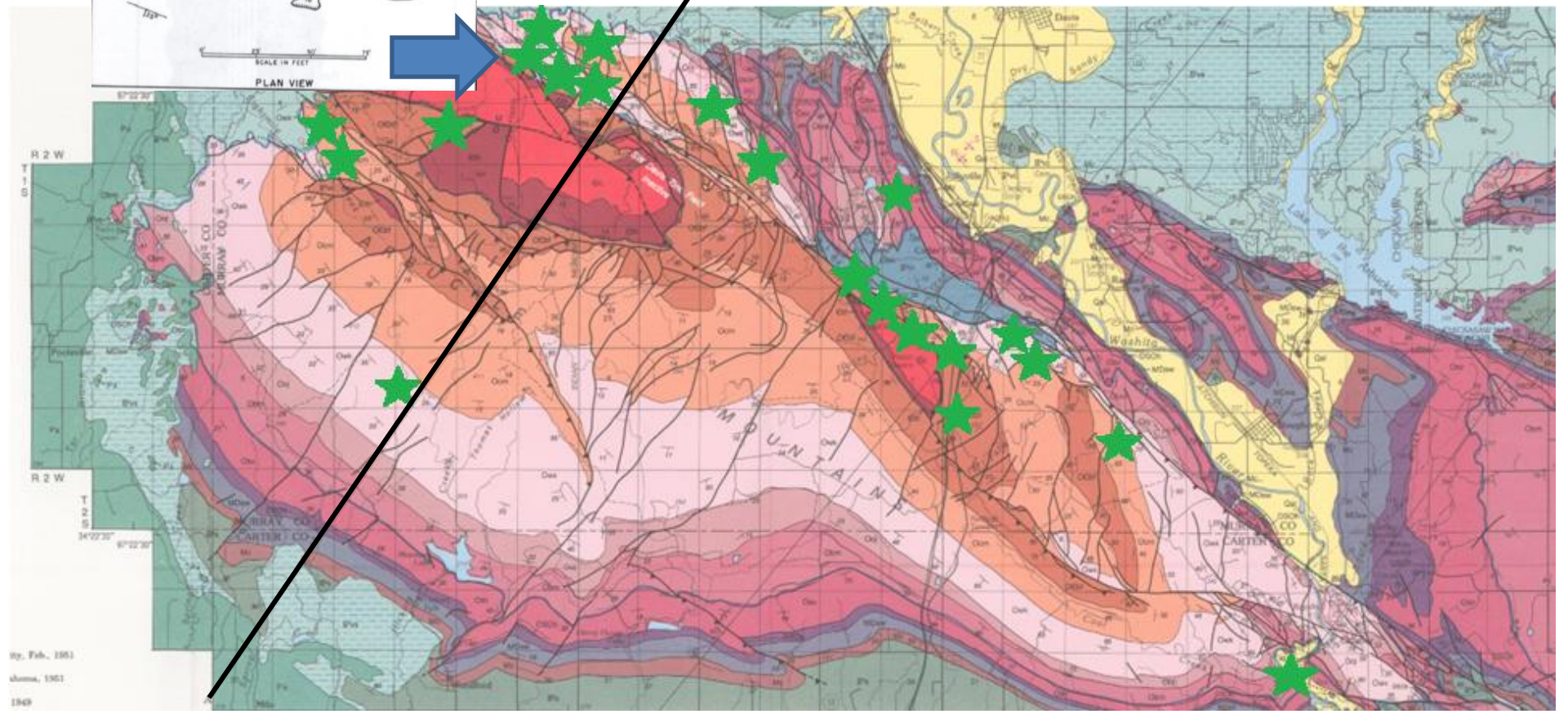

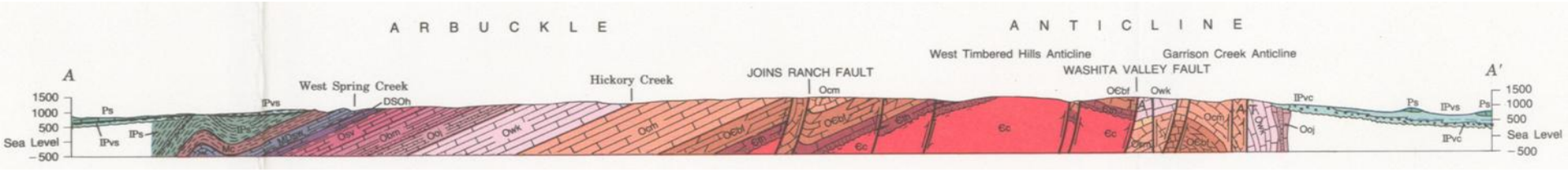

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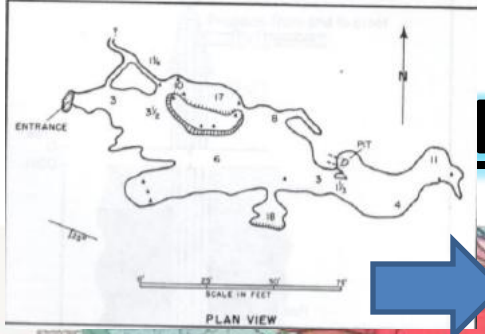

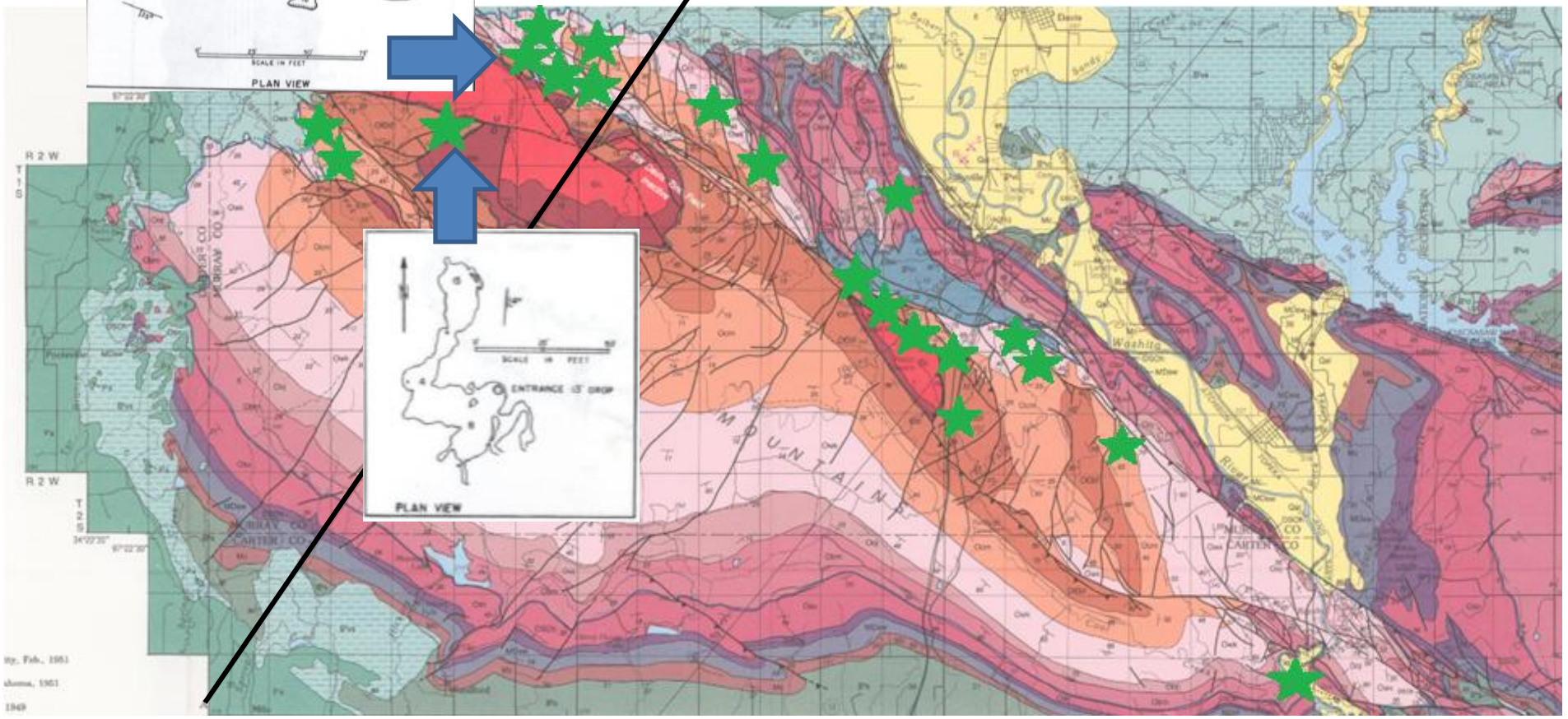

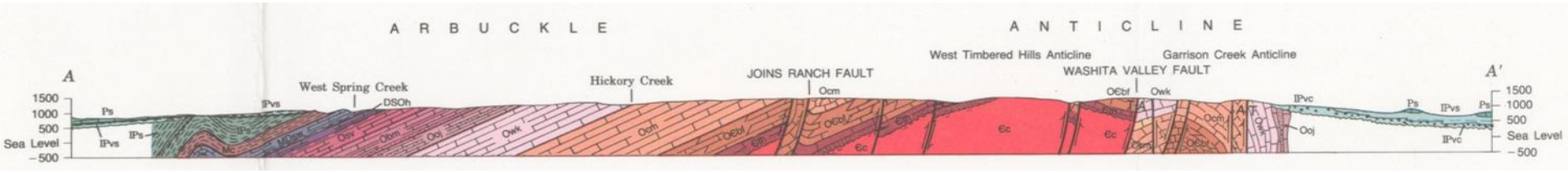

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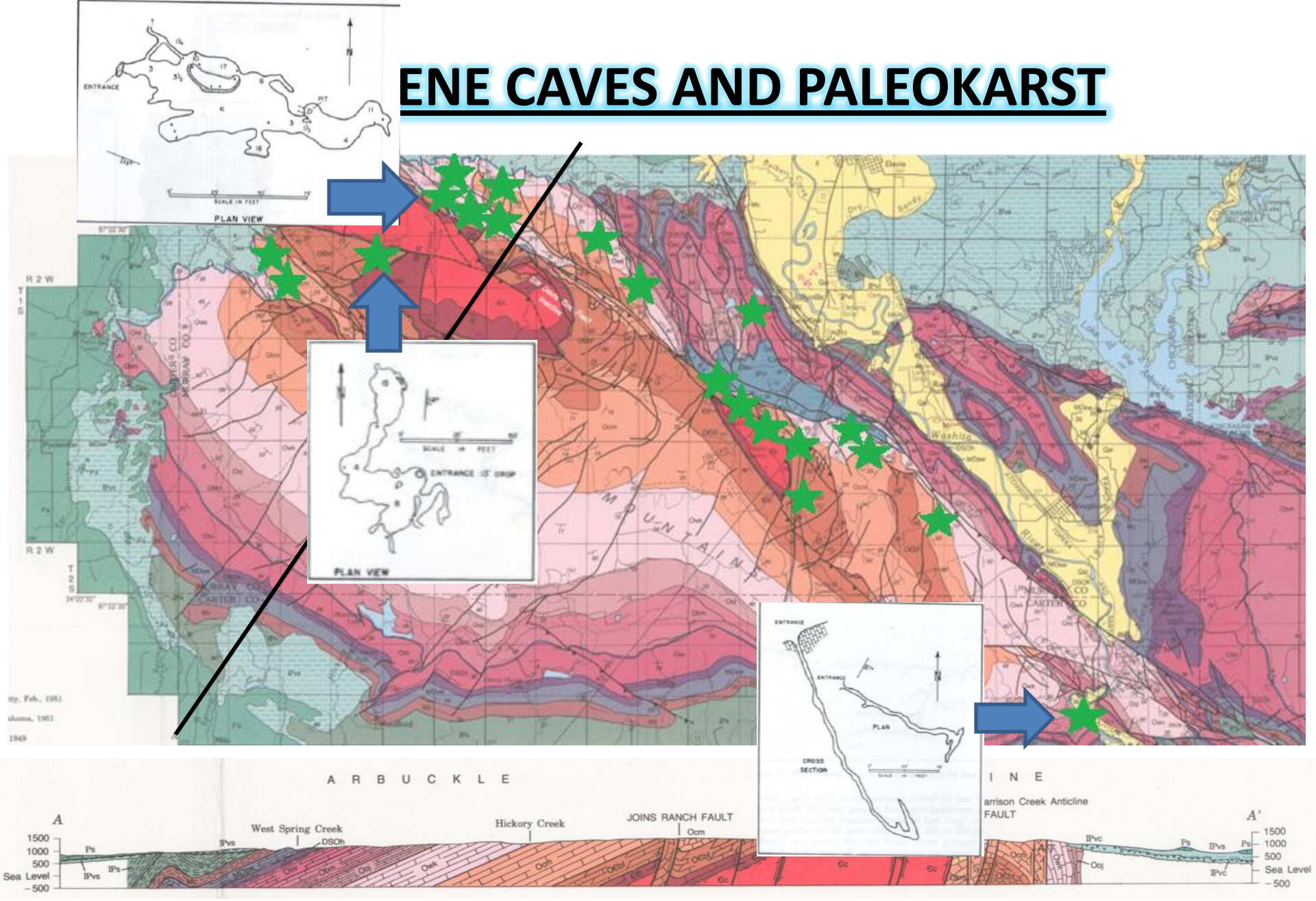

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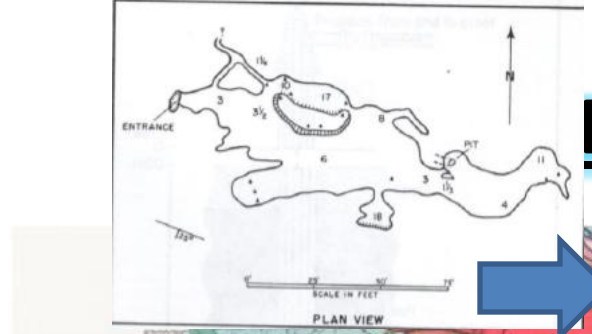
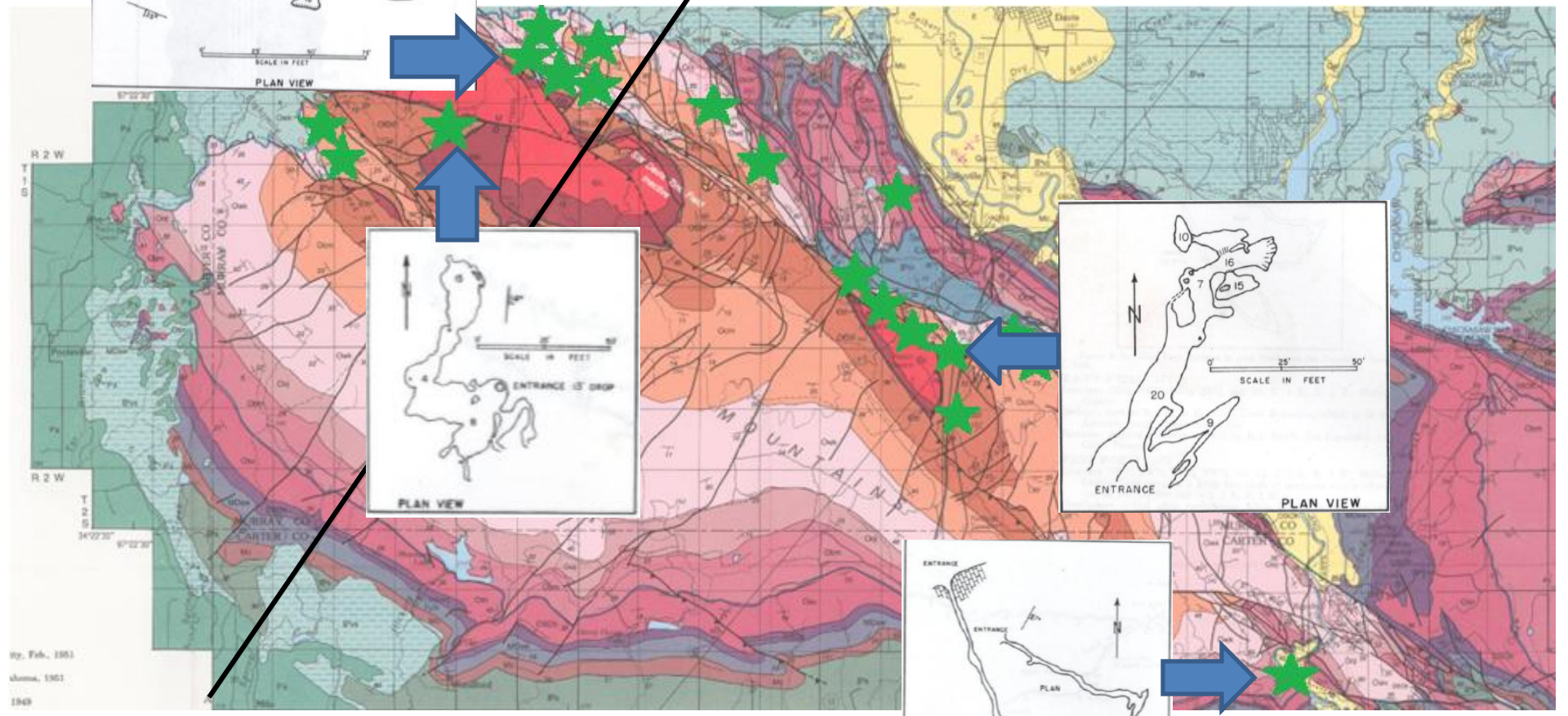
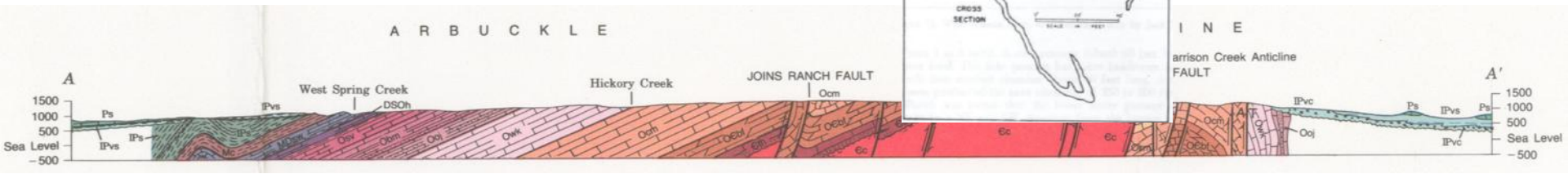


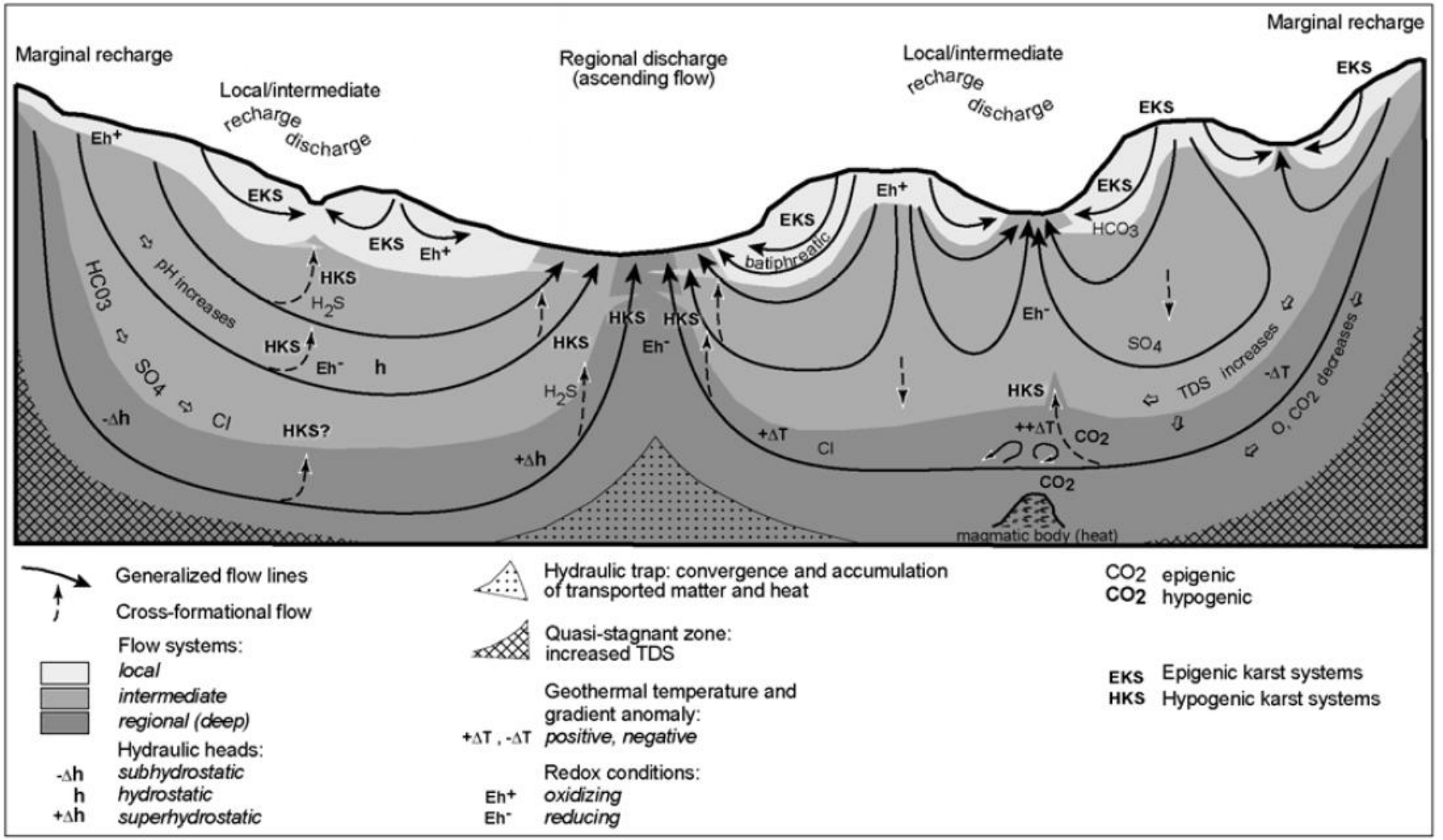




EVOLUTION OF THE ARBUCKLE MOUNTAINS

HYPOGENE SPELEOGENESIS IN A NUT SHELL

EVOLUTION OF THE ARBUCKLE MOUNTAINS



Klimchouck 2007

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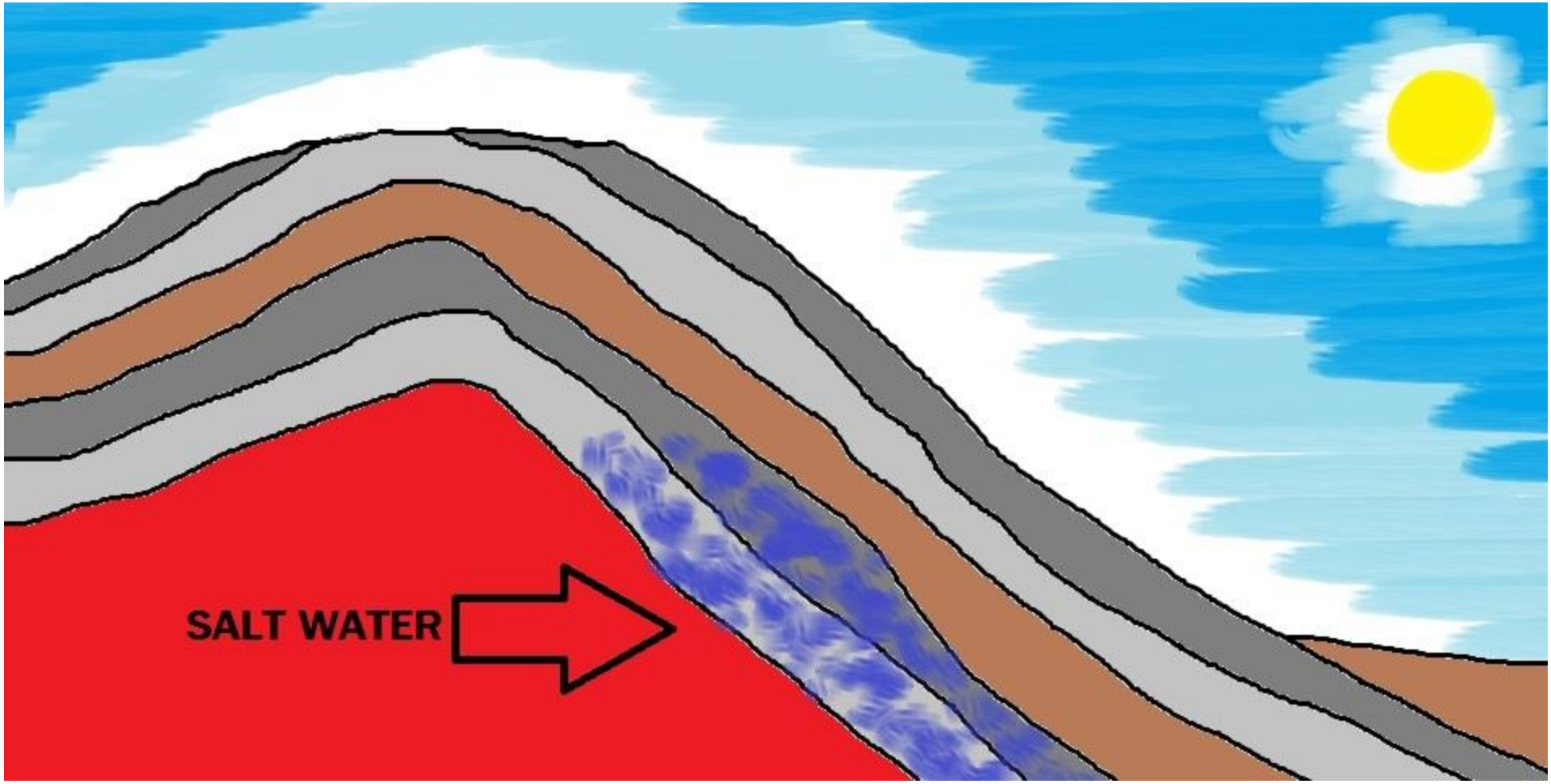

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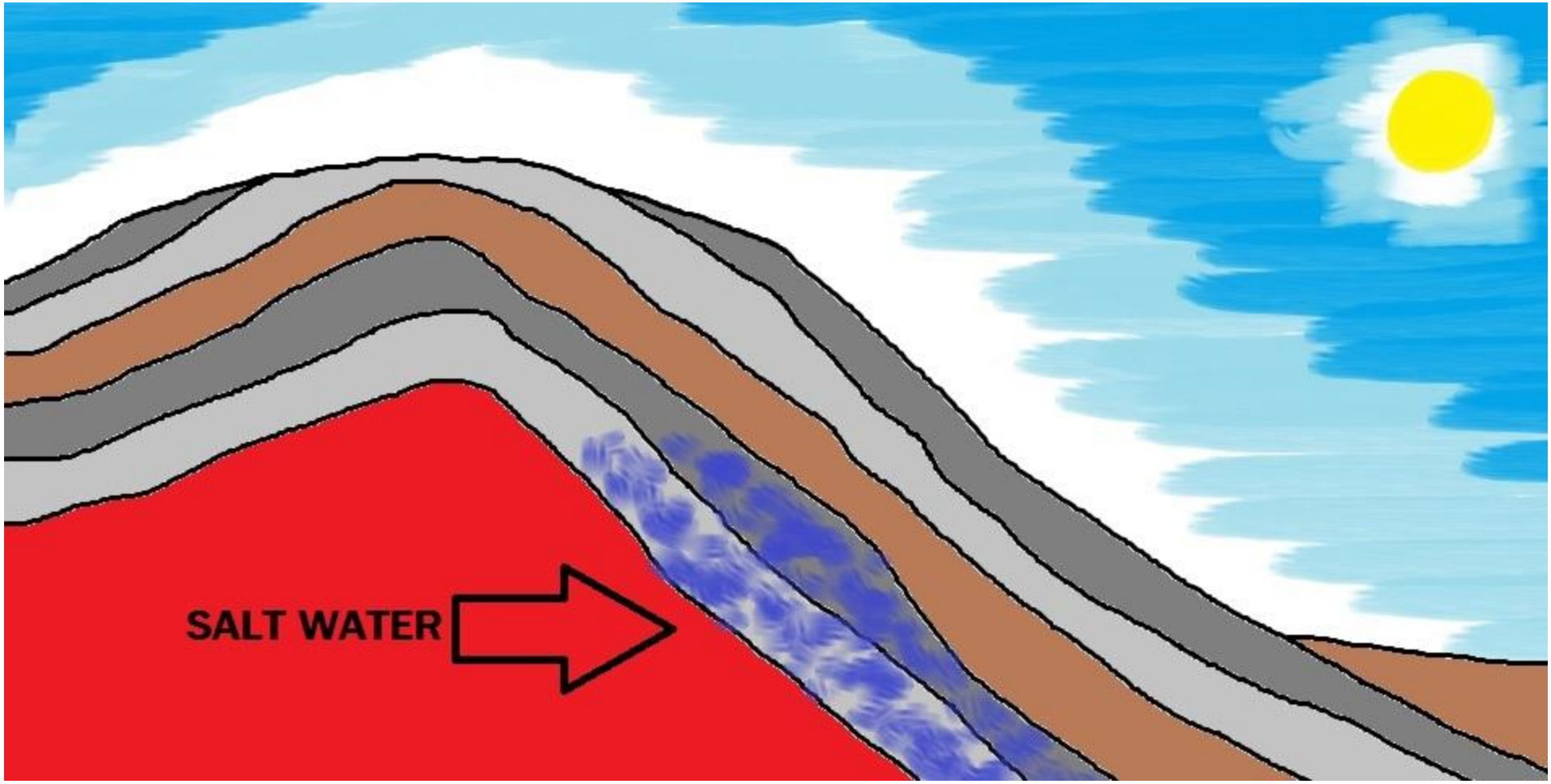

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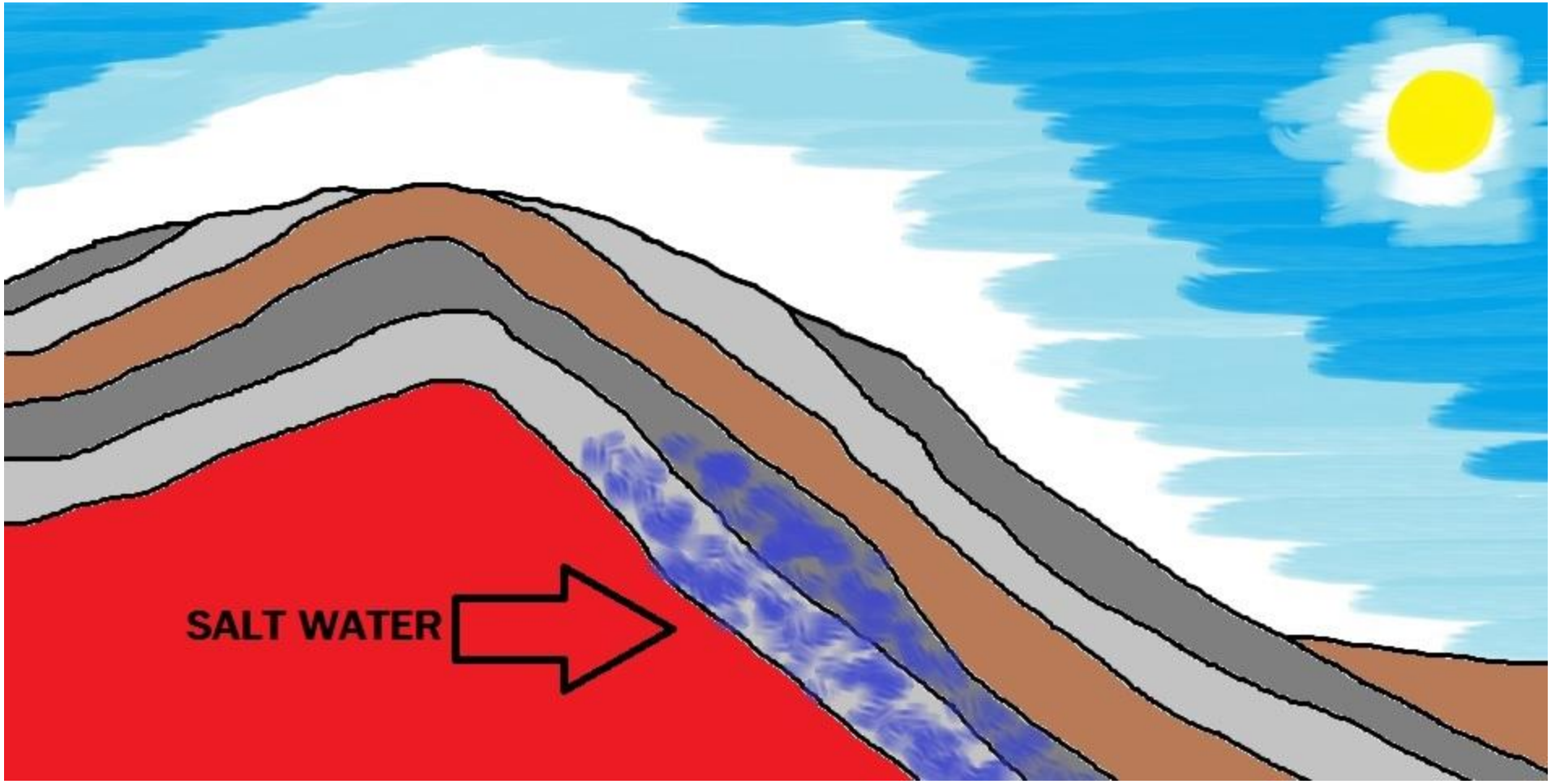

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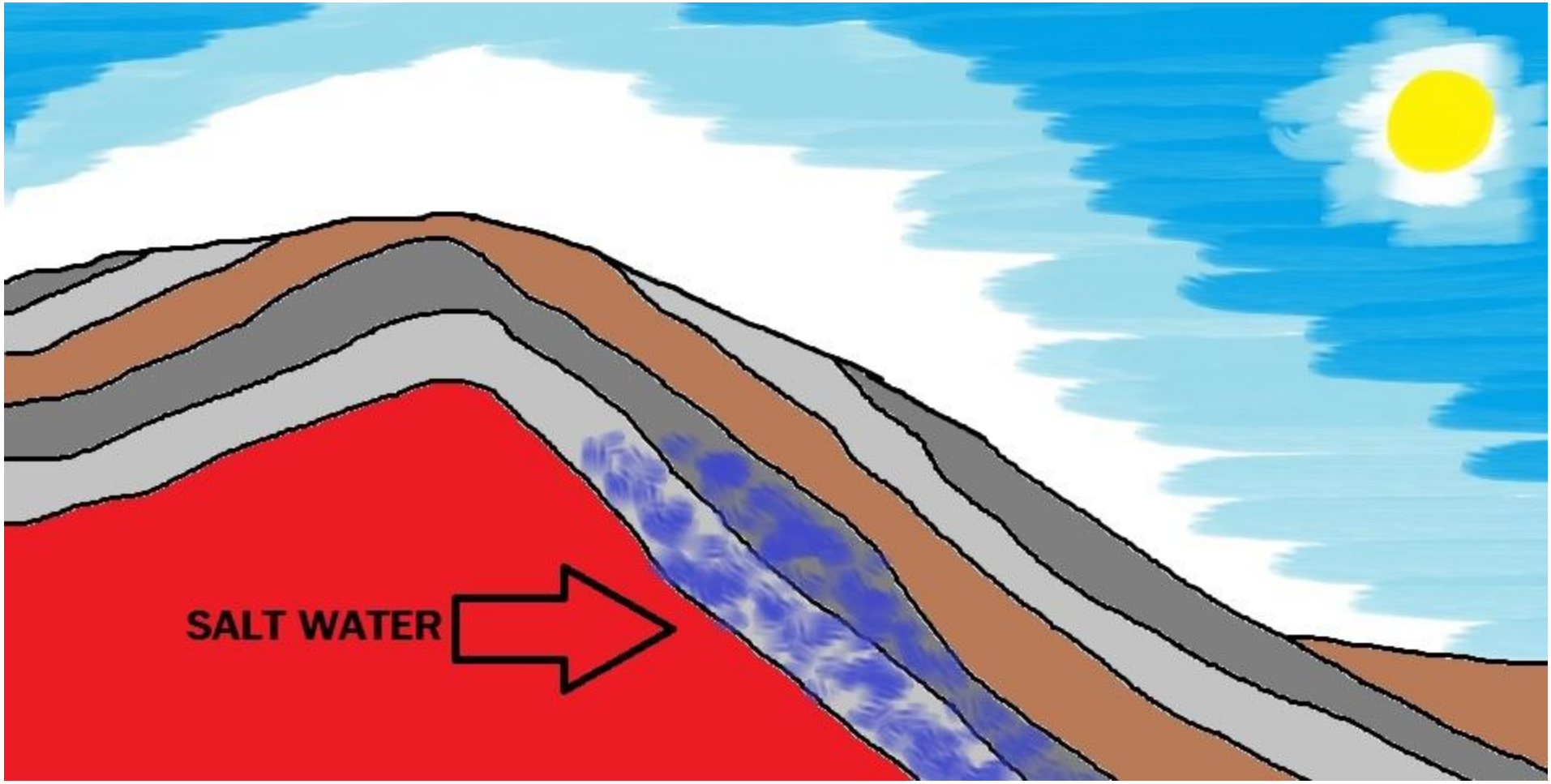

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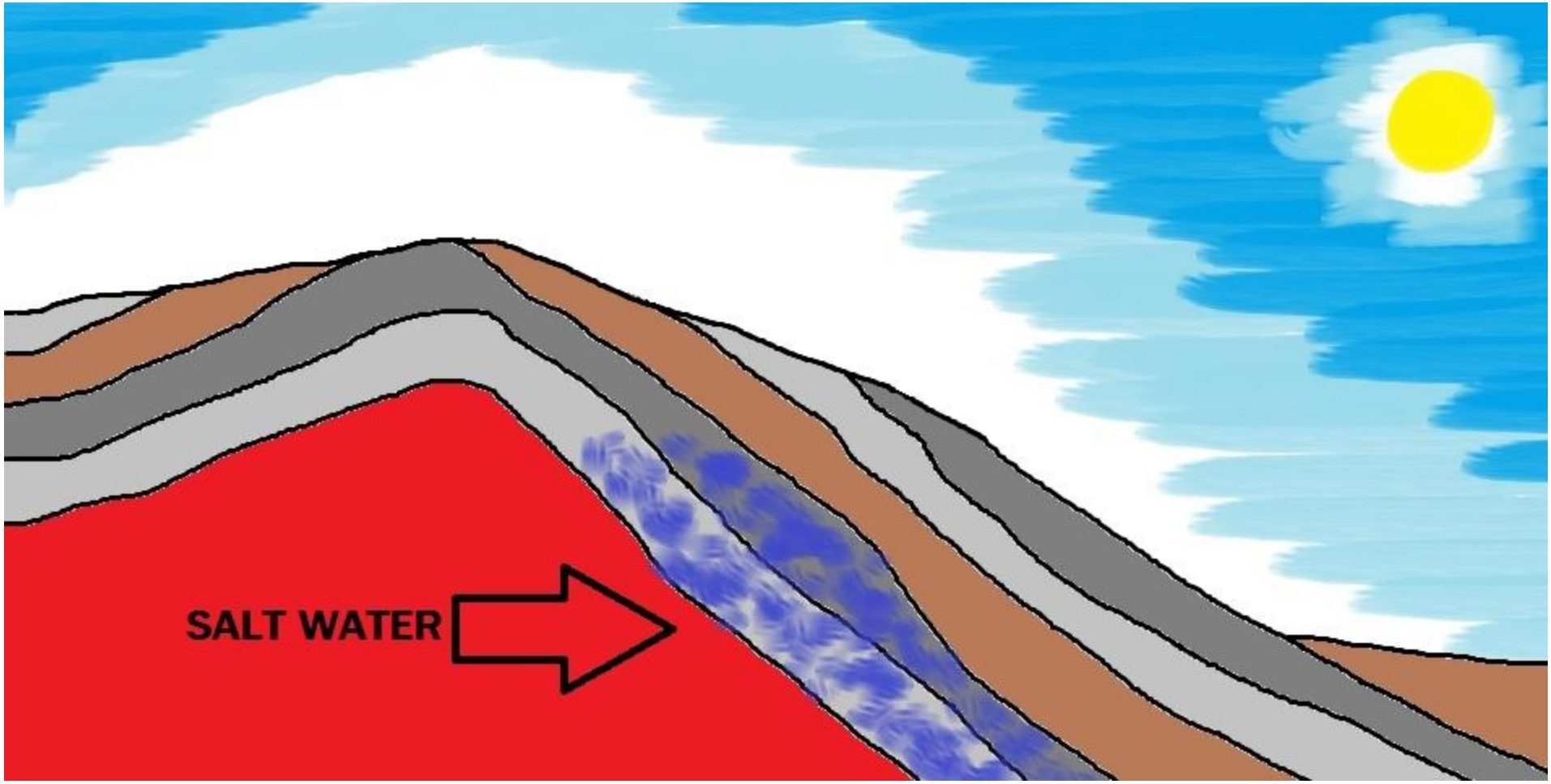

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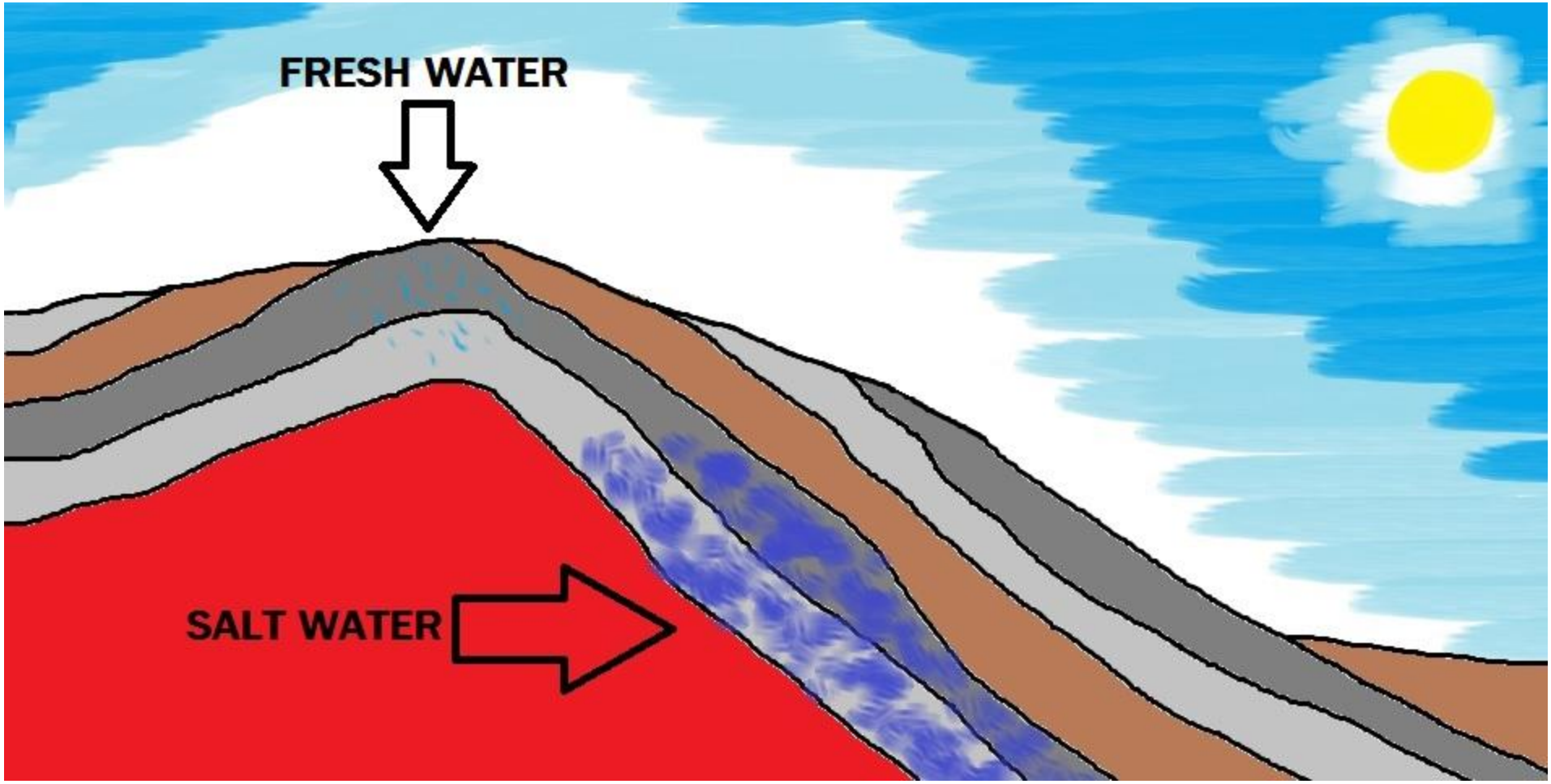

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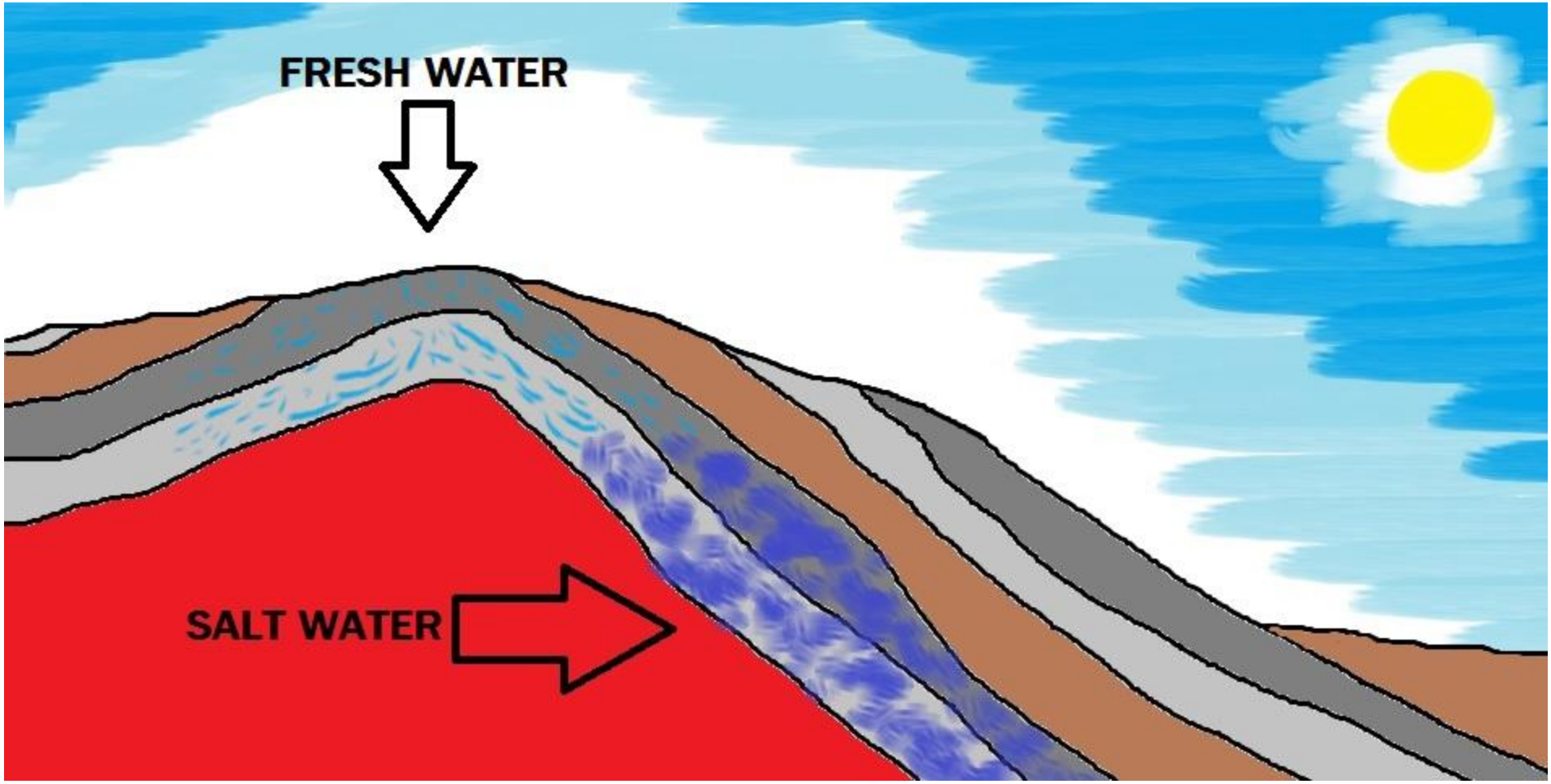

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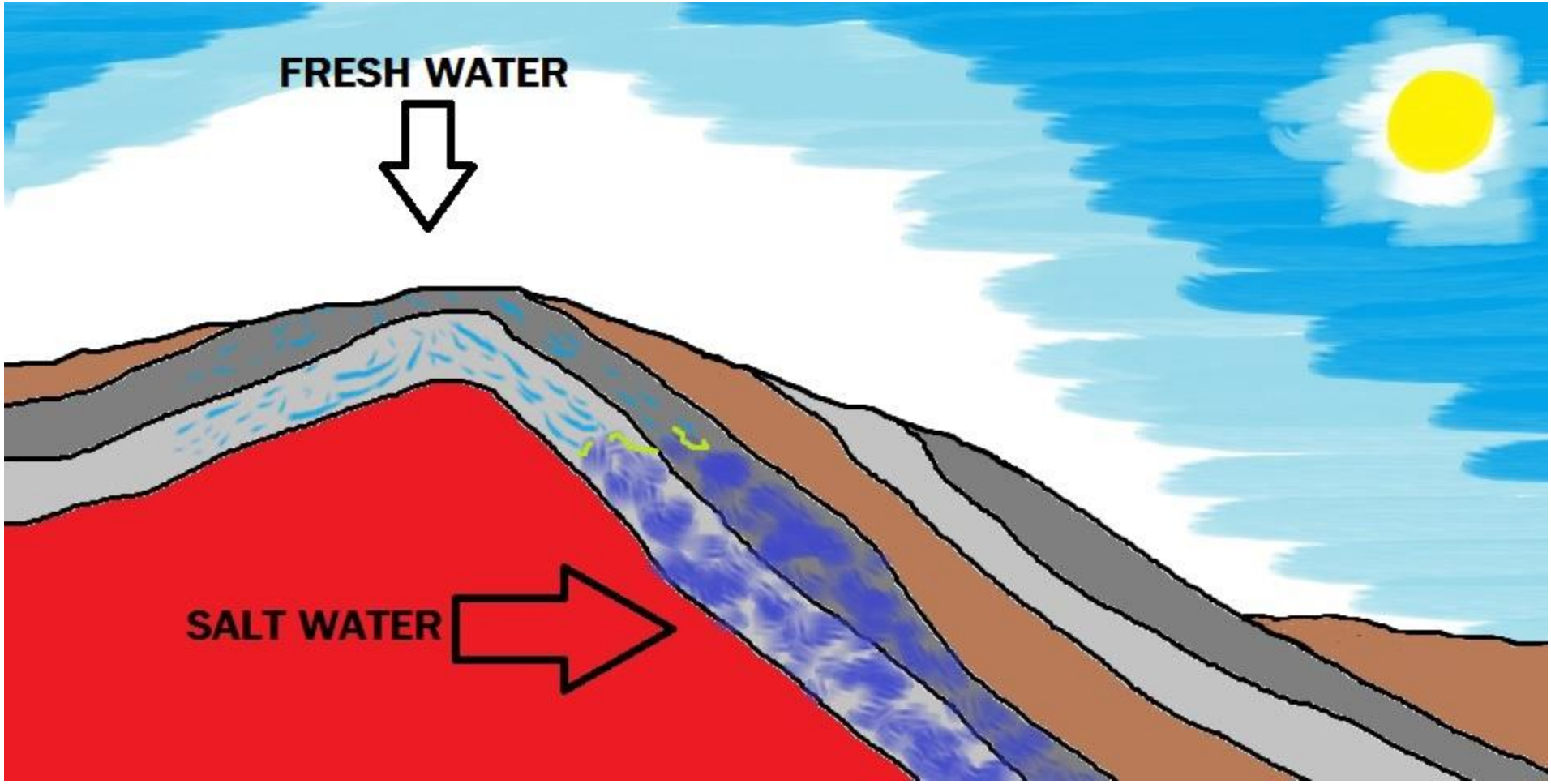

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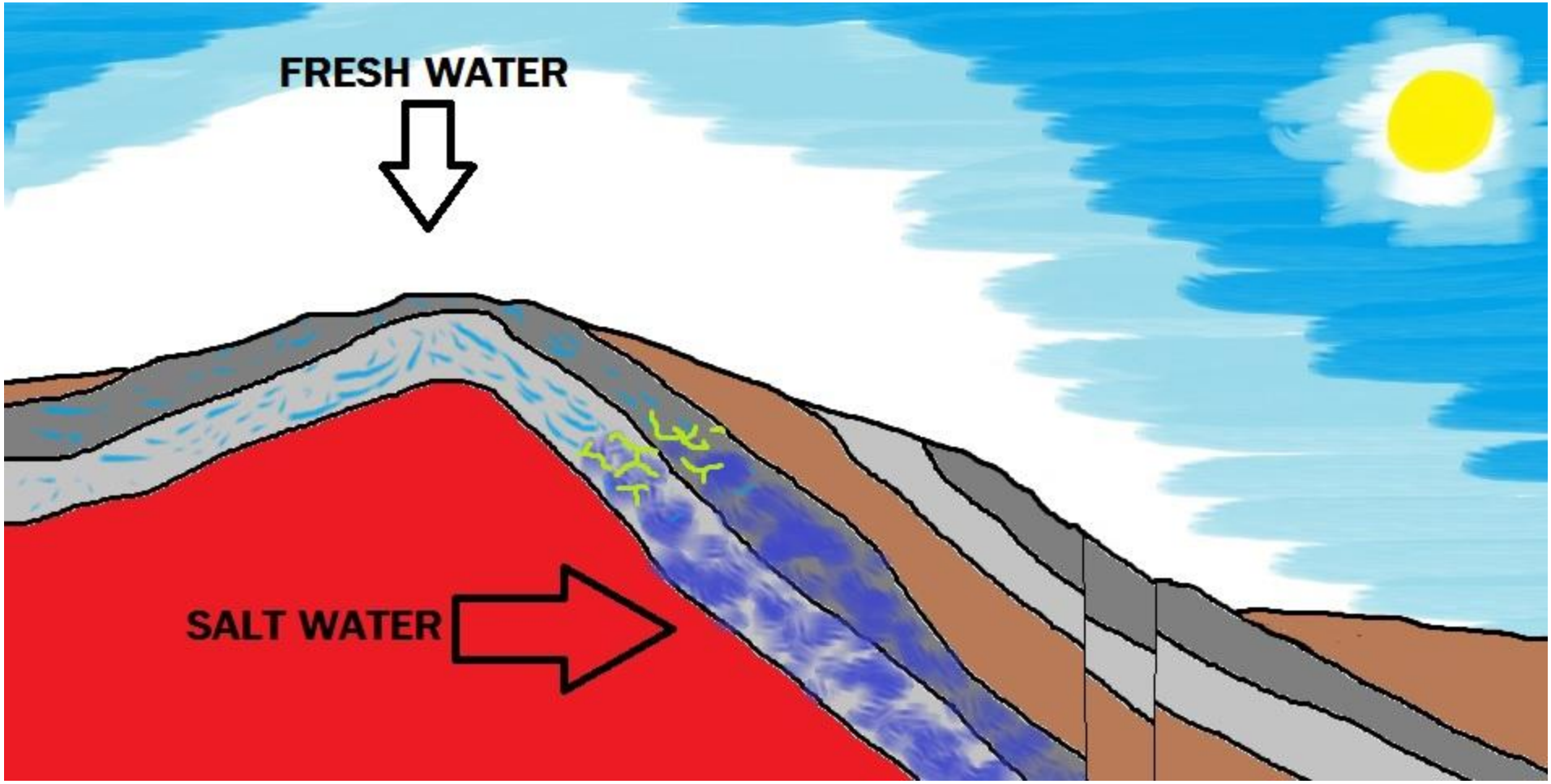

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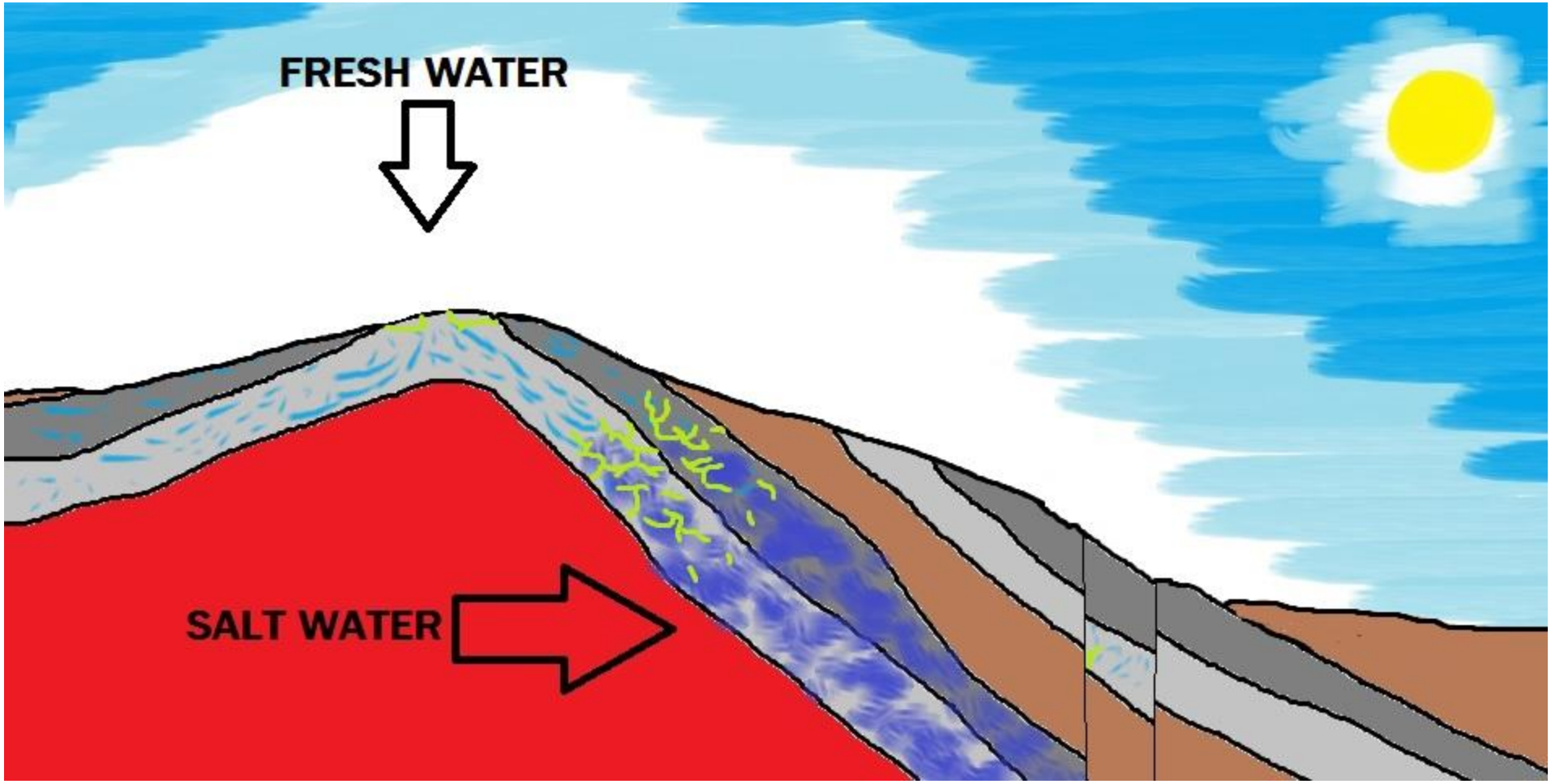

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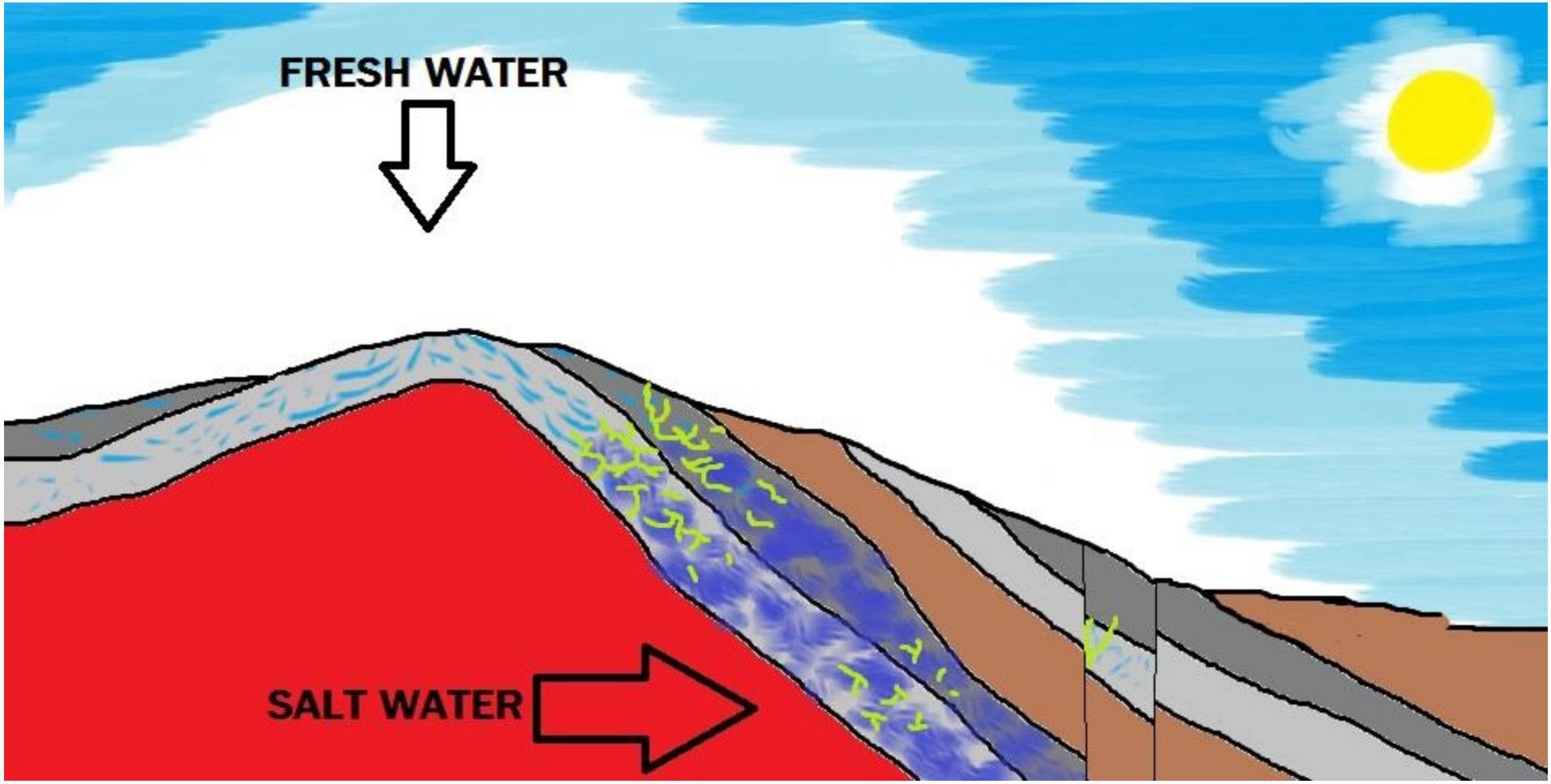

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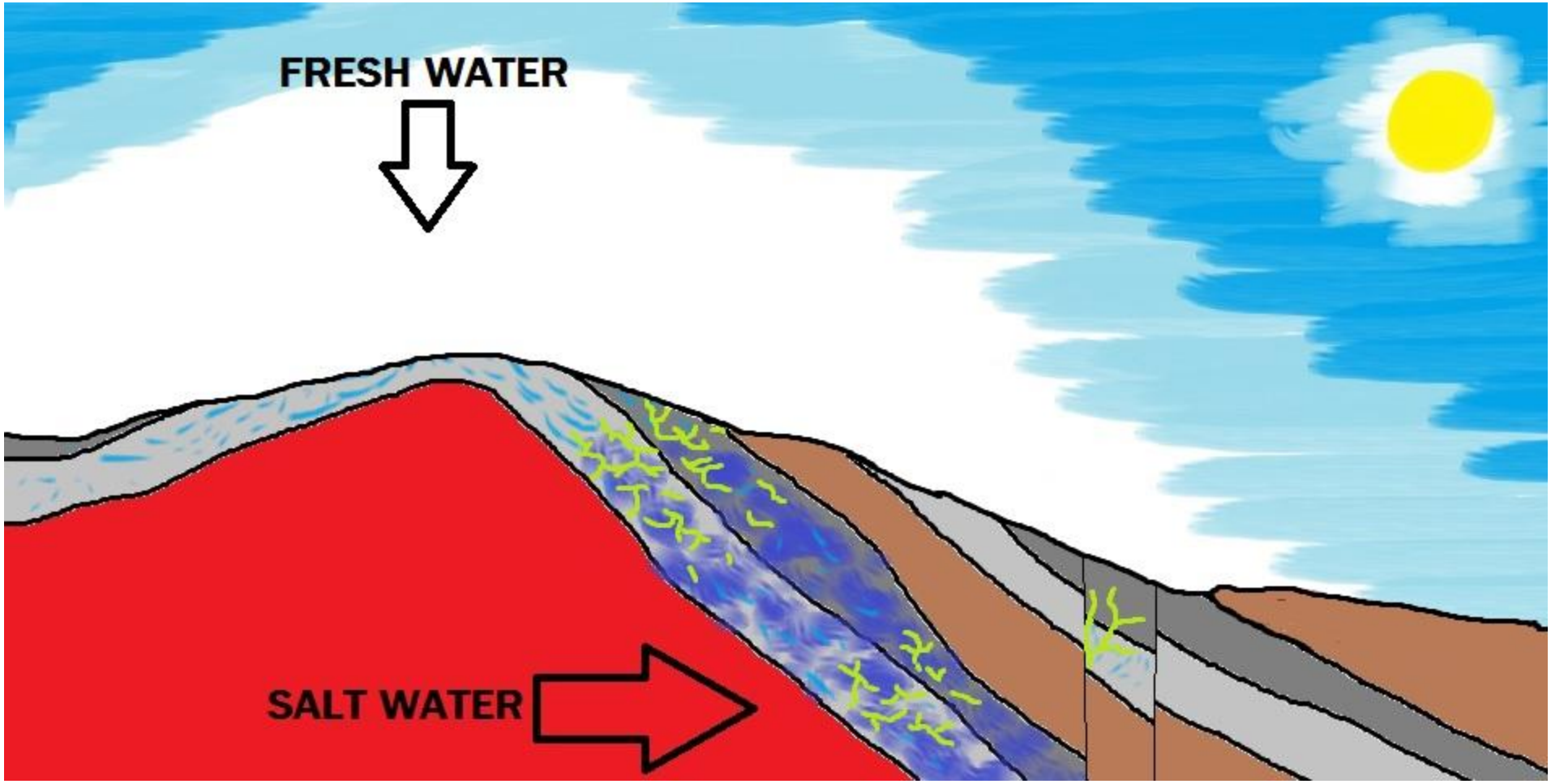

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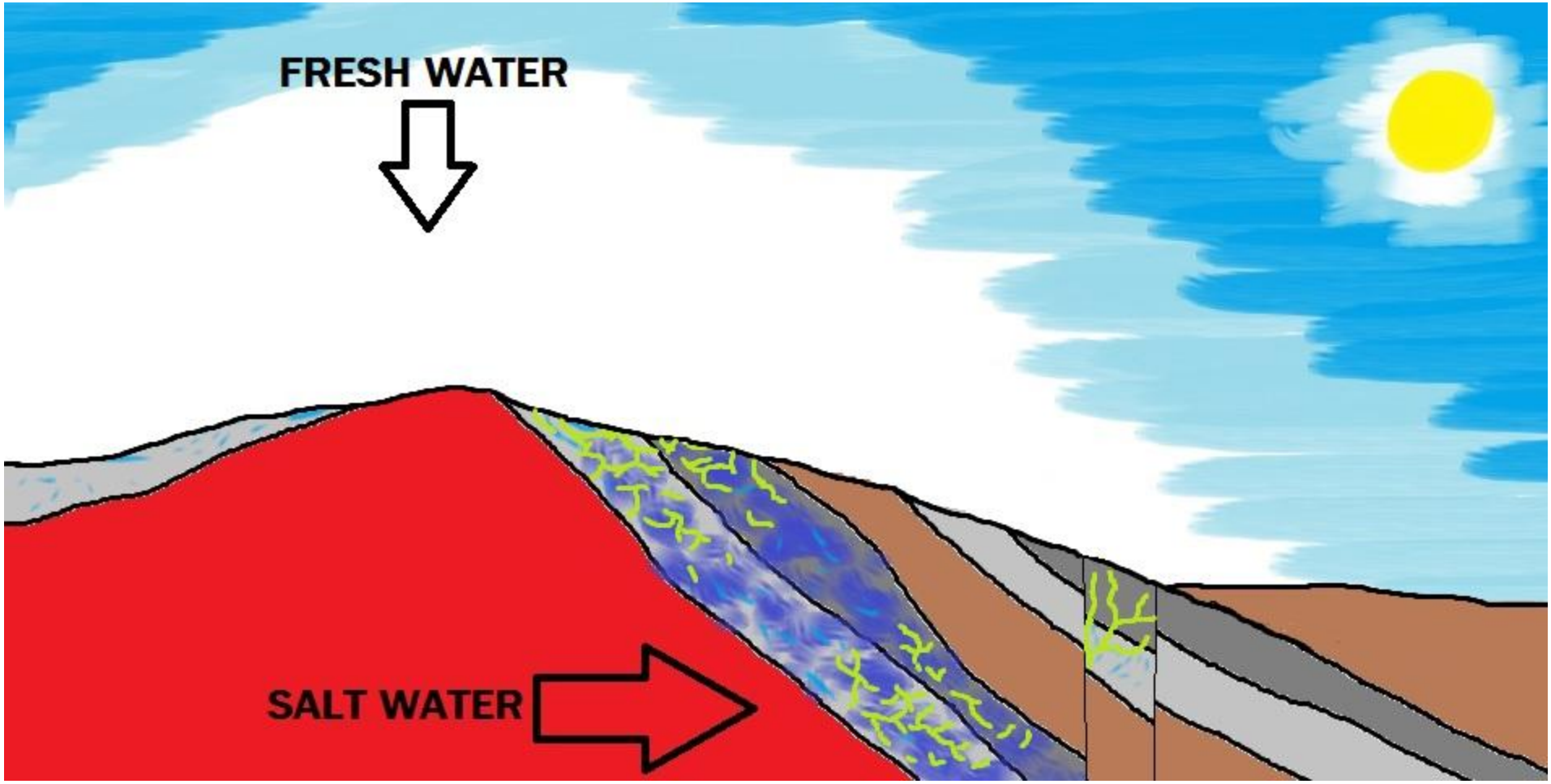

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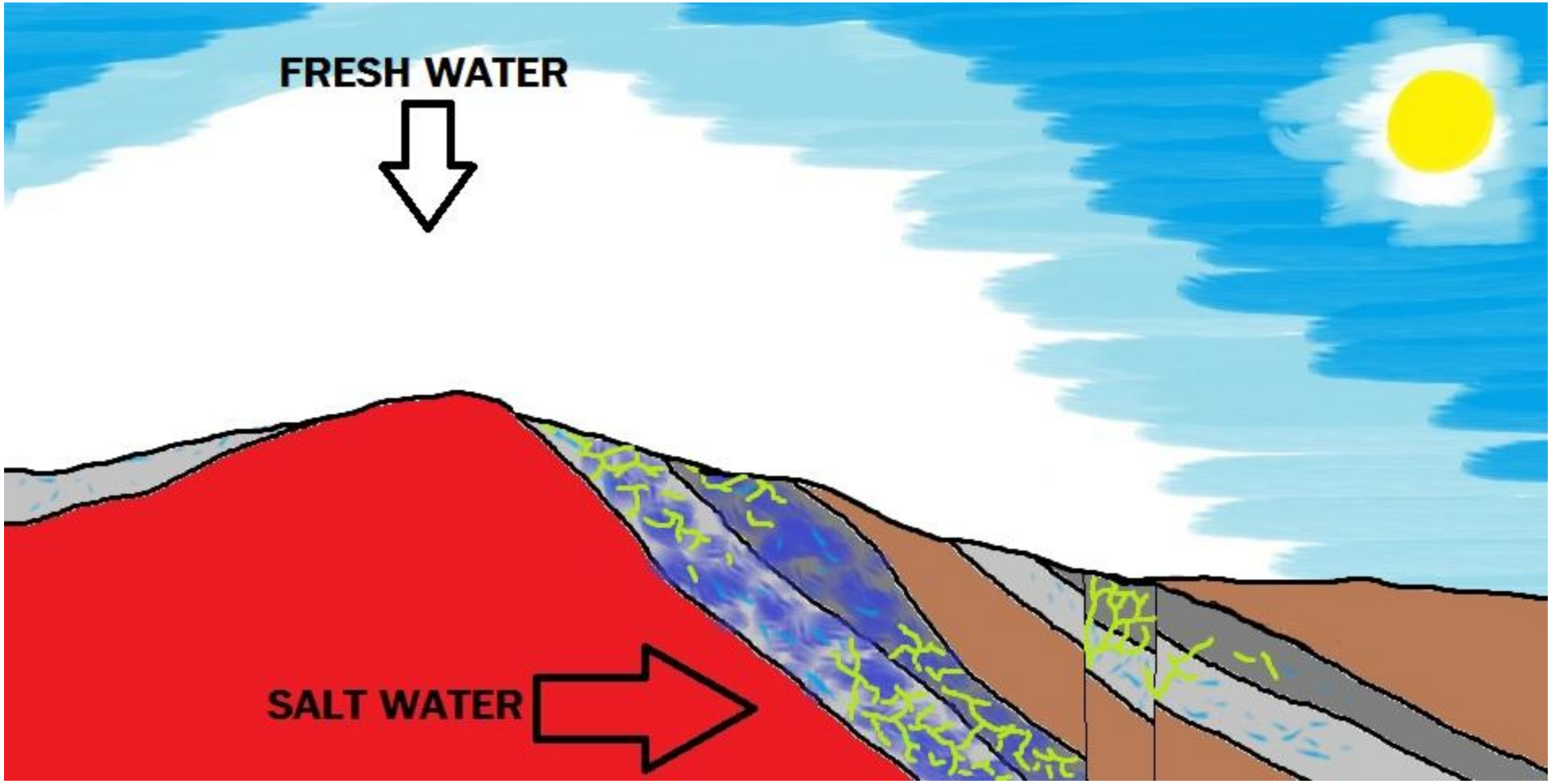


REVIEW

•Hypogenic karst development in the underlying aquifers was multi-episodic and likely occurred due to a variety of geochemical mechanisms. Earliest episodes could have involved Hydrothermal Invasion following volcanic episodes during the Cambrian that proceeded during burial (Eschberger 2013), Orogenic fluids during Pennsylvanian and Permian (Nick & Elmore 1990), Basinal fluids during Permian (Elmore 1993)(Elmore 2000), during the Laramide and post Arbuckle Orogenies (Sykes 1997), and from the flushing of brine and petroleum beneath semi-confining Simpson and Vanoss units since the time of uplift and continuing at present (Puckett 2009) (Christenson et al., 2011), and from freshwater mixing with brine at basement (Christenson 2009).

•Confirmed hypogene caves and paleokarst known mainly from areas of most severe deformation, mainly near thrust faults and in steeply bedded units. In areas of less deformity, epigenic overprinting may erase morphogenic signatures of hypogene features.

DISCUSSION

•Evolution and development of the aquifers has been a long running process with hypogenic and epigenic processes operating simultaneously since at least the Permian.

•Most of the early epigenic caves have likely been eroded with the host rock it was formed within and many of the hypogenic caves intercepted by surface erosion have been exhumed or overprinted by epigenic processes. Many surface streams appear to have removed the ceilings of hypogenic caves to produce deep pools and swallow holes.

•Hypogenic karsting produces deep vertical conduits capable of cross formational hydraulic communication.

SIGNIFICANCE

•Hypogene karst development began near the center of the anticline and appears to continue developing toward the flanks and basement by freshwater invasion into brine zones (Puckett et al., 2009)(Christenson 2009)(Christenson et al., 2011). This development at basement may allow for deep vertical hydraulic communication between units (Halihan et al., 2009)(Klimchouk 2007).

•Secondary porosity from deep karst resulting from hypogene speleogenesis allows for deep and enhanced aquifer storage. Aquifer estimated to be as much as 9,000 feet deep with freshwater extending to depths greater than 3,000 feet (Kumar 2005).

•The Arbuckle and Simpson aquifers are at the center of legal battles and legislation is presented annually to manage the water and mineral resources. Understanding the aquifer development and hydrology on local and regional scales is important for proper characterizations.

•Cross formational hydraulic communication may allow for groundwater exchange between aquifers, allowing effects of over pumping and pollution to affect multitple aquifers (Klimchouk 2007).

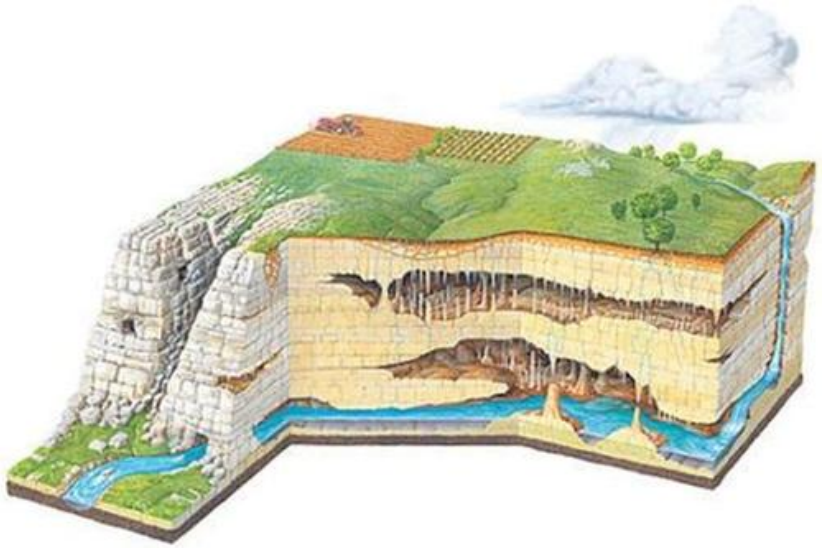
ACKNOWLEDGEMENTS

•The members of the Arbuckle Karst Conservancy and Research Institute

•The members of the Arbuckle Mountains Grotto

•Bob Allen, Neil Suneson, Scott Christenson, Jona Tucker, Wayne Kellogg, Noel Osborn, John Brooks, Corky Corcoran, Mark Micozzi, Guy Sewell, Stacy Blackwood, John Wilson, Jim Weaver, Todd Halihan, William White, Arthur Palmer, Randal Ross, and many others who have assisted with and allowed me to participate in research, exchange ideas, and collaborate in countless otherways.

•Landowners for access to study the majority of the Arbuckle Mountains.



THOUGHTS?

FEEDBACK?

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