Classification of caprock associated with salt diapirs

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Abstract

Caprock assemblages associated with salt bodies typically consist of a vertically zoned sequence in ascending order: anhydrite directly above the salt body, a transitional gypsum zone, and occasionally a complex zone of limestone and/or dolomite. Caprock forms when the upper part of a rising diapir is exposed to a crossflow of NaCl-undersaturated water, causing halite to dissolve and the less soluble components, largely anhydrite (CaSO4) and to a lesser extent gypsum (CaSO4*2H2O), to accrete via underplating to the base of the previously formed caprock. If hydrocarbons are present, the CaSO4 minerals are replaced by carbonate minerals in a process mediated by sulfate-reducing bacteria. Previous descriptions of carbonate caprock recognize only two general fabric types: an upper variegated limestone and a lower banded zone that comprises carbonate and sulfate lithologies. Utilizing new facies mapping and petrographic analysis of outcropping caprock from three different salt basins, Paradox Basin and Gulf Coast Region, USA and Flinders Ranges, South Australia, we recognize a wider variety of fabrics and mineralogies. This variety is owed to the location of caprock at the salt-sediment interface, where it is highly prone to substantial chemical and mechanical alteration, resulting in diagenetic textural overprints of precursor caprock fabrics. We propose a new classification based on fabric types in order to facilitate a discussion and interpretation of caprock lithologies in an organized and effective manner. The development of a comprehensive classification is the first step toward deciphering the complex diagenetic processes involved in caprock formation. Understanding the genetic history of caprock fabrics will allow for better identification and prediction of the distribution of caprock mineralogies and fabrics. Our proposed new classification scheme is based on the recognition of four distinct megascopic fabrics: 1) Massive: homogeneous, with micro-to-coarsely crystalline subdivisions; 2) Layered: subdivisions based on thickness of laminae include micro-laminated, laminated, and banded; 3) Brecciated: subdivided into mosaic and disorganized, dictated by clast orientation and volume variations in inter-clast matrix or cement; and 4) Porphyritic: comprising two distinct crystal sizes. These fabrics are not restricted to any one mineralogy (i.e. are found within anhydrite, gypsum and carbonate caprock) and commonly comprise more than one fabric type (e.g. the brecciated clasts of a carbonate caprock can display a layered or massive fabric). To address this issue, the dominant mineralogy and subordinate fabric types is attached to the overall fabric name as prefix-type modifiers (e.g. massive brecciated dolomite caprock). Silicification, carbonate and silica pseudomorphs after gypsum and anhydrite, localized isoclinal folds, secondary dissolution and recrystallization porosity, as well as dead oil are common features found within all fabric types.

NEW CLASSIFICATION OF CAPROCK ASSOCIATED WITH SALT DIAPIRS

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PREVIOUSLY PROPOSED CARBONATE CAPROCK NOMENCLATURE

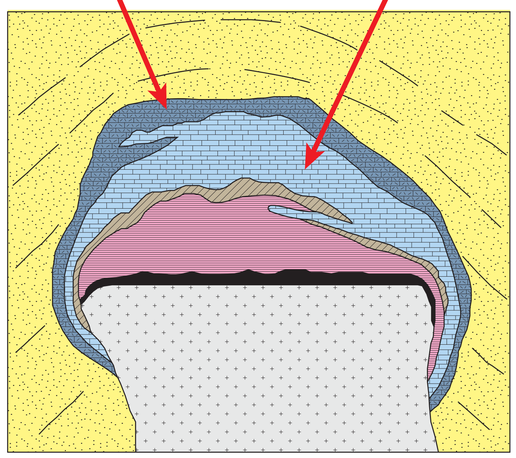
TEXAS GULF COAST CALCITE CAPROCKS:

UPPER VARIEGATED

Upper variegated commonly contains clastic detritus and variegated clasts of carbonate in a carbonate matrix. These carbonate clasts and matrix contain irregular segregations of a later, more coarsely crystalline calcite.
All gulf coast diapirs containing carbonate caprocks contain this fabric.

LOWER BANDED

Lower banded or "zebra textured" zone. Numerous calcite stages form horizontal bands that are commonly cross-cut by late-stage calcite veins. Roughly half of gulf coast diapirs containing carbonate caprocks contain this fabric.

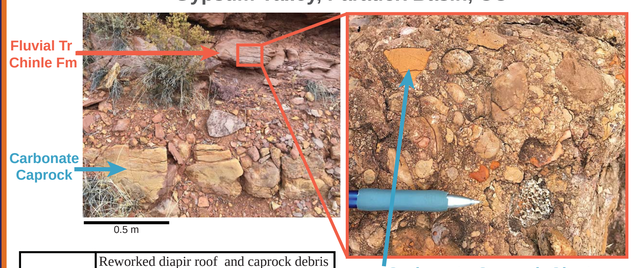


Cross sectional view of a typical caprock bearing salt diapir showing generalized caprock lithologic zonation. Not to scale. Modified from Kyle and Posey, 1991.

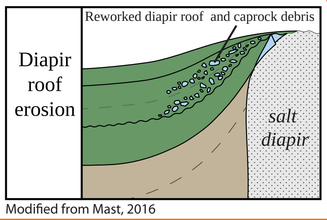
EXPLANATION
- Cenozoic sediments
- Variegated calcite caprock
- Banded calcite caprock
- Gypsum caprock
- Anhydrite caprock
- Salt dissolution zone
- Salt stock

CAPROCK CLASTS IN OVERLYING STRATA

Gypsum Valley, Paradox Basin, CO



Carbonate Caprock Clasts



Modified from Mast, 2016

- Fabric type of caprock clasts within the overly Chinle Formation are all **microcrystalline massive dolomite**
- This suggests that massive microcrystalline dolomitic capstone was the **original fabric type** at the Gypsum Valley salt wall.

CONCLUSIONS

The development of a caprock classification scheme has allowed for the communication between researchers in regard to caprocks found at the salt-sediment interface around the world. Therefore, it has provided a means for comparison of the similarities and differences of caprock at multiple localities.

SIMILARITIES

- Evidence at all localities suggests that the massive fabric is the first to develop, and that the remaining fabrics have been diagenetically superimposed.
- All of the proposed fabrics are found at both localities – with variations.
- The porphyritic, layered and brecciated fabric types exhibit a patchy distribution and are rarely correlative.

DIFFERENCES

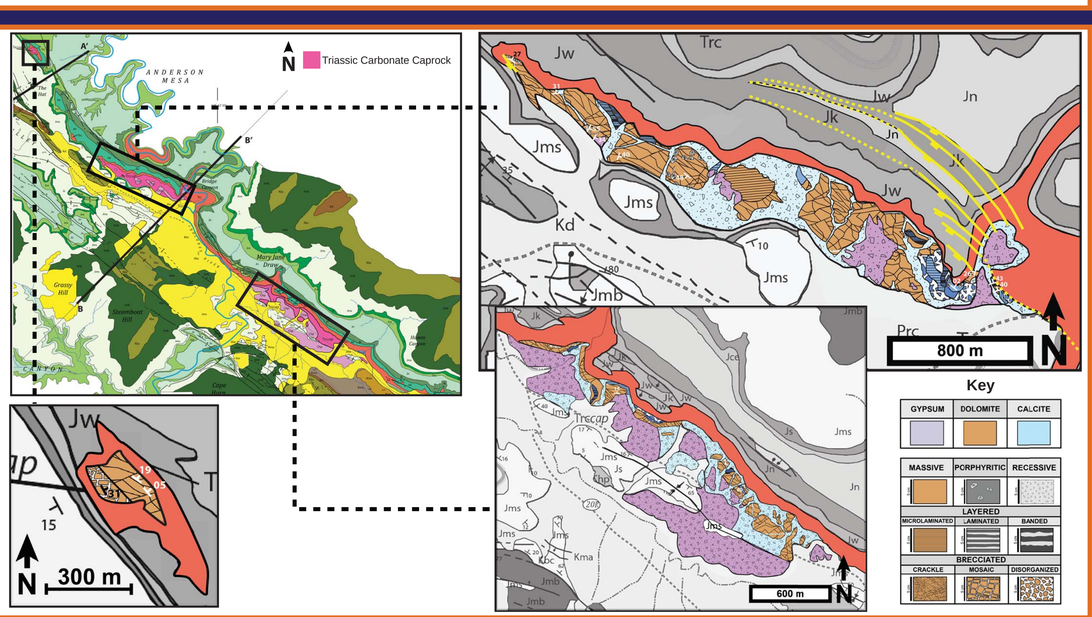
- At Patawarta, clasts from the Callanna (i.e. quartzites, metaigneous) stratigraphy are incorporated into the caprock. We have not observed precursor lithologies incorporated in the Paradox Basin caprock.
- Both gypsum and carbonate caprock are present at the Gypsum Valley (GV) salt wall. The caprock at Patawarta is entirely carbonate.
- The GV caprocks contain dolomite and calcite caprock, whereas at Patawarta, the primary mineralogy is dolomite with only minor calcite present as late-stage vein fills.

CAPROCK CLASSIFICATION BASED ON FABRIC

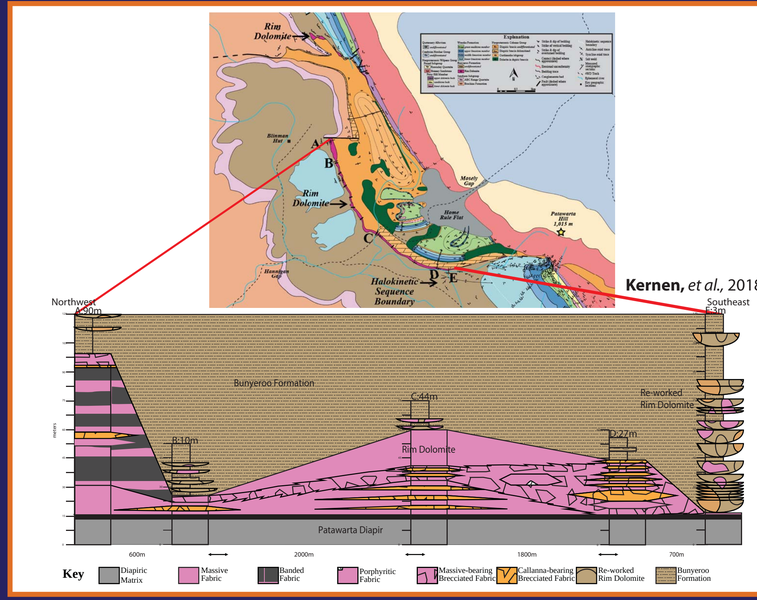
	MASSIVE	PORPHYRITIC	LAYERED			BRECCIATED		
			MICROLAMINATED	LAMINATED	BANDED	CRACKLE	MOSAIC	DISORGANIZED
DESCRIPTION	Massive fabrics consist of a homogeneous mineralogy and crystal size, and lack any internal structure.	Porphyritic fabrics consist of two distinct crystal size populations, one significantly larger than the other.	Microlaminated fabrics consist of **1-3 mm thick laminae**.	Laminated fabrics consist of **3-10 mm thick laminae**.	Banded fabrics consist of **laminae greater than 10 mm thick**.	Crackle breccias contain clasts that display little relative displacement.	Mosaic breccias consist of clasts that are loosly fitted together. Most clast bounaries are typically oriented parallel to each other.	Disorganized breccias consist of spatially independent clasts. Clast boundaries are rarely parallel to one another.
SCHEMATIC DIAGRAM	5 cm	5 cm	5 cm	5 cm	5 cm	5 cm	5 cm	5 cm
FABRIC EXAMPLES	VARIEGATED	SILICIFIED ROSETTES	ENTEROLITHIC	SEGMENTED	SIGMOIDAL	BOXWORK FRACTURES	COASE VEINS	POLYMICT
		GYPSUM ROSETTES	MICROBIAL	UNDULATED	FOLDED	FOLDED	ORTHOGONAL FRACTURES	MONOMICT

PROOF OF CONCEPT

GYPSUM VALLEY SALT WALL, PARADOX BASIN, CO



PATAWARTA DIAPIR, FLINDERS RANGES, SA



EVAPORITE NOMENCLATURE

NODULAR ANHYDRITE				GYPSUM	
CHICKEN WIRE	ENTROLITHIC	AGGREGATE	ELONGATE	LENTICULAR	ROSETTES

IMPORTANCE OF CAPROCK

- **Petroleum system timing** - when and how do these caprocks from? Timing of hydrocarbon migration
- **Misidentified stratigraphy** - implications on well top pics and overall cross-section structure
- **Drilling hazard** - misidentified lithology with unknown fluids and pressures
- **Additional reservoir** - high porosity and permeability depending on fabric type

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