

# **PS Microbial Origin of Bioherm-Associated Leopard Rock Holder Formation (Pennsylvanian, Virgilian) and Laborcita Formation (Permian, Wolfcampian), Sacramento Mountains, New Mexico\***

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## **Abstract**

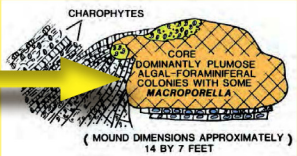
Enigmatic, colloquially named leopard rock of the Holder and Laborcita formations (Late Pennsylvanian-Early Permian) occurs within a cyclic, interfingered, carbonate siliciclastic system in the Sacramento Mountains in southeastern New Mexico. Weathered outcrops exhibit dark, irregular spots (~2 cm in diameter) within a tan matrix yielding a pattern that resembles leopard spots. Layers of leopard rock boundstone occur stratigraphically just above and below phylloid algal bioherm complexes of the Holder and Laborcita formations and have been interpreted as occurring in transgressive and highstand systems tracts. Field observations, polished hand sample and thin section analyses indicate leopard rock is microbial in origin. Locally abundant and lithologically distinct bulbous, domed mounds occur in outcrop stratigraphically below the algal bioherms to the west of U.S. Highway 82, east of Alamogordo, New Mexico. The mounds are composed of irregular, centimeter thick layers that circumscribe them in a composite growth structure that defies gravity. The mounds are approximately 0.3 to 0.9 m (1-3 ft.) thick and 0.6 to 1.2 m (2-4 ft.) wide. Hand samples from both formations reveal significant variability in the size (1-18 cm) and nature of the dark spots. Millimeter scale, asymmetric, concentric layering is occasionally visible in the fine-grained, dark patches. These 'spots' dominate outcrop appearance, are heterogeneous in distribution, and often occur as aggregate clumps or clusters >24 cm in diameter. Optical microscopy on Holder Formation samples reveals thrombolytic patches of micrite, upward-oriented concentric gradational laminae of peloidal micrite, and occasionally micrite-enveloped foraminifera. Geopetal structures indicate gravity-defying fabric structure and support a microbial origin. SEM images reveal distinct logjam clusters of cylindrical, segmented curvilinear strings over 1,000 nm long and 80 nm or less in diameter interpreted as fossilized bacteria. SEM images also show nanometer-scale kidney bean and dome-shaped structures composed of numerous intertwined threads (100-750 nm long) as well as unique, densely packed (100-300 nm long) squat cylinders that resemble foam-packing peanuts. These sporadically distributed fields of rounded nanometer-scale structures, interpreted as relict organic matter, contrast sharply with, and are distinct from, the underlying substrate of smooth and dissolution pitted planar crystal surfaces.



# Microbial Origin of Bioherm-Associated Leopard Rock



## Leopard Knob



Scholle, et al. (2007) after Toomey and Babcock (1983).



## ABSTRACT

Leopard rock of the Holder and Laborcita formations (Late Pennsylvanian-Early Permian) occurs within a cyclic, inter-fingered, carbonate siliciclastic system in the Sacramento Mountains in southeastern New Mexico. Leopard rock boundstone occurs stratigraphically just above and below phylloid algal bioherm complexes and have been interpreted as occurring in transgressive and highstand systems tracts.

Field observations, polished hand sample and thin section analyses indicate leopard rock is microbial in origin. Distinct bulbous, domed leopard rock mounds are composed of irregular, centimeter thick layers that circumscribe them in a composite growth structure that defies gravity. Hand samples from both formations reveal significant variability in the size (1-18 cm) and nature of the dark spots. Millimeter scale, asymmetric, concentric layering is occasionally visible in the fine-grained, dark patches.

Optical microscopy on Holder Formation samples reveals thrombotic patches of micrite, upward-oriented concentric gradational laminae of peloidal micrite, and occasionally, micrite-enveloped foraminifera. SEM images reveal distinct nanometer-scale log-jam clusters of cylindrical, segmented curvilinear strings, kidney bean and dome-shaped structures composed of numerous intertwined threads and densely packed squat cylinders that resemble foam packing peanuts. These sporadically distributed fields of rounded nanometer-scale structures, interpreted as relict organic matter, contrast sharply with, and are distinct from, the underlying substrate of smooth and dissolution pitted planar crystal surfaces.

## Shelf & Basin Stratigraphy

SACRAMENTO MTS. (PEDERNAL SHELF)		SAN ANDRES MTS. (GROGRANDE BASIN)
PERMIAN	LEONARDIAN	SAN ANDRES FM.
		YESO FM.
		ABO FM.
	WOLFCAMPIAN	HUECO FM. (PENDEJO L.S. MBR.)
		HUECO L.S.
MISSOURIAN		L.ABO FM.
		LABORCITA FM.
	VIRGILIAN	HOLDER FM.
		PANTHER CREEK FM.
PENNSYLVANIAN		BEEMAN FM.
	DES MOINESIAN	
	ATOKAN	GOBBLER FM.
	MORROWAN	LEAD CAMP L.S.
MISSISSIPPIAN		CHESTERIAN
		HELMS FM.
	MERAMECIAN	RANCHERIA FM.
	OSAGIAN	LAKE VALLEY FM.
	KINDERHOOKIAN	CABALLERO FM.

Scholle et al., 2008; after Pray, 1959 and Bachman and Myers, 1975.

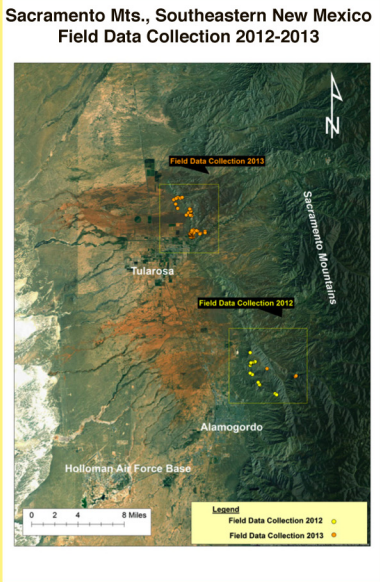
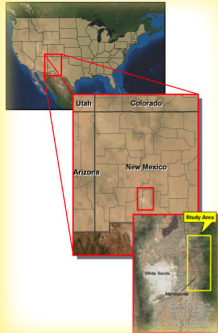


## INTRODUCTION

- Holder and Laborcita formations strata reflect a cyclic, inter-fingered, carbonate siliciclastic system.
- The formations include multiple microbially influenced or microbially deposited lithologies including phylloid algal bioherms and a variety of carbonate boundstones.
- A distinctive boundstone, 'leopard rock', is found in association with the characteristic bioherm complexes.
- The leopard rock occurs in lithologically distinct, large (3 m) bulbous domed mounds, small cabbage-sized mounds, and forms more subtle undulating bulges limited to the upper surface of the outcrop.
- Leopard rock strata exhibit dark, irregular spots on light, often rust-colored matrix, in outcrop surface. The size and shape of the spots vary considerably (1-18 cm, individual asymmetric shapes to concentric laminar rings).



## Project Study Area & Field Data Collection Sites



## HYPOTHESIS & OBJECTIVES

Hypothesis:

- The lithology referred to as leopard rock represents multiple sub-facies of a microbially influenced carbonate continuum that can be defined by outcrop expression and micrometer-scale morphologic characteristics.

Objectives:

- Petrologically and stratigraphically characterize leopard rock within the existing sequence stratigraphic framework for the area.
- Assess biologic influence on leopard rock petrology.



# Microbial Origin of Bioherm-Associated Leopard Rock

## Holder Formation (Pennsylvanian, Virgilian) and Laborcita Formation (Permian, Wolfcampian), Sacramento Mountains, New Mexico

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### OUTCROP

Outcrop variation...

- ~0.3 to 0.9 m thick
- ~0.6 to 1.2 m wide

### Large domed mounds



### Draped bed imbedded mound



- mound dominant
- draping structure

### Strata-cap small mounds



- ~0.5 m thick
- ~0.8 m wide
- upper layer

### Small cabbage-sized mounds



- ~0.2 m thick
- semi-continuous
- upper layer

### Upper surface undulation



- undulating surface
- semi-continuous
- upper layer

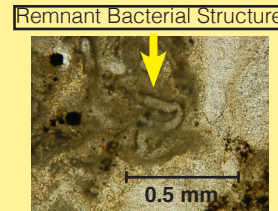
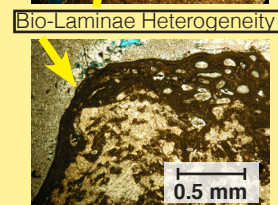
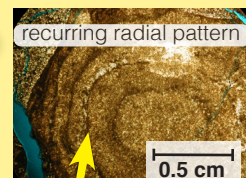
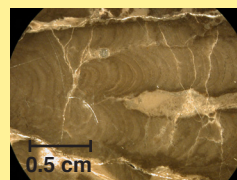
### Hand Sample

- 'Spots' dominate outcrop appearance

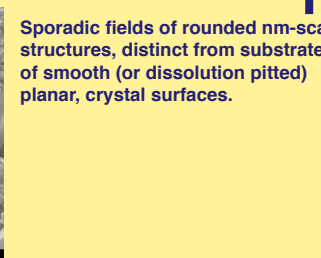
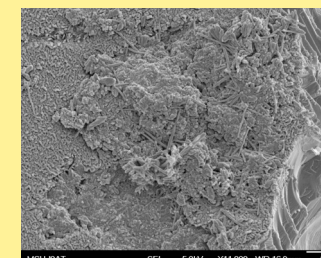
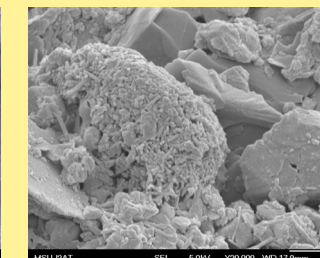
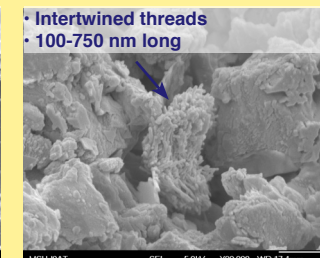
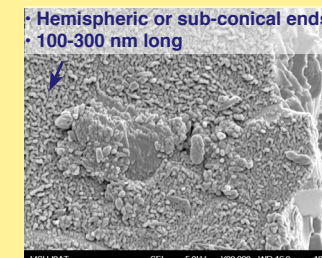
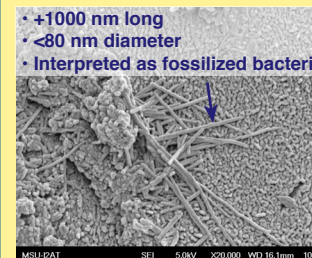


### Optical Microscopy

#### Polished Hand Sample



### Scanning Electron Microscopy



Sporadic fields of rounded nm-scale structures, distinct from substrate of smooth (or dissolution pitted) planar, crystal surfaces.



The Leopard Rock Bio-morphologic Continuum



DISCUSSION

- Evidence for Microbial Origin
- thrombolitic structures in hand sample
  - peloidal structures in thin section
  - arcuate laminae (influenced by sunlight)
  - fossil bacteria
  - nanometer-scale spheroids in SEM
  - gravity defying layers
  - geopetal structures

Outcrop mound and hemisphere structures vary in scale, co-occur, and grade into one another. Different expressions of ‘spots’ (concentric laminae, individual, and aggregate clusters) co-occur within the same outcrops. Unique bio-sedimentary structures observed under the SEM co-occur within samples. This indicates a continuum for a suite of bacterial expressions that dominate, to varying degrees, at different localities.

Laborcita Formation Leopard Rock Future SEM & Optical Microscopy Work Examples



Large Mound and Weathering Variability



Outcrop Surface Topology with Upward Fan Structures



‘Leopard Spot’ Variability Transition



Weathering Variability

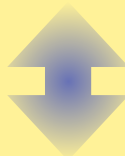


Fan Growth Structures



Lineated ‘Fabric’

‘LEOPARD SPOT’ VARIABILITY OBSERVED INTRA-OUTCROP



CONCLUSIONS

- Leopard rock is bacterial in origin.
- Leopard rock is highly variable in expression and represents a continuum of organo-sedimentary structures.
- Leopard rock existed in a phylloid-algal bioherm favorable environment.

SIGNIFICANCE

This project is the first investigation dedicated specifically to describing and characterizing the leopard rock to aid in paleo-environmental interpretation and stratigraphic interpretation. Petrography from outcrop to nanometer scale supports a microbial origin for leopard rock with a continuum of characteristics. Leopard rock may serve as an indicator for bioherm favorable paleo-environmental conditions and thus aid depositional model-driven petroleum exploration.



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