

Camino Real Paleohydrologic Study

New Mexico Bureau of Geology & Mineral Resources, A Division of New Mexico Tech

- Funded by NM Spaceport Authority
- The vision began at a party in Santa Fe
- 2+ years of hammering out details
- Initiated in 2012 as a part of the Mitigation Plan for El Camino Real De Tierra Ardentro 2010

Aims and Objectives

- To assess the relationship between local water sources and features along the El Camino Real
 - To assess current hydrogeologic framework and groundwater flow conditions in the Jornada Del Muerto in the vicinity of the Spaceport
 - To map land forms to identify extinct and historic water sources such as paleo-springs and paleo-wetlands

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Outline

- Geology Dave Love
- Hydrogeology Talon Newton
- Water availability and implications on travel on the Camino Real – Ethan Mamer and Trevor Kludt
- Strategies for navigating the Camino Real – Trevor Kludt







Landscape Features of Jornada del Muerto





physical features develop from geological substrates and events "Civilization exists by geological consent, subject to change without notice." --Will Durant (1885-1981)













Paths of the Rio Grande 1 – 5 million years ago

























Cross section across Palomas, Engle, and Northern Jornada del Muerto Basin

















1 Summary <u>Geologic Landscape of the Jornada del Muerto</u>

- The landscape is one of cuestas formed by erosion of tilted strata due to the structure of a south-plunging syncline from Engle south to the Rio Grande at Tonuco
- The Quaternary Jornada Draw fault zone offsets strata down to the east near the axis of the syncline
- The Jornada Draw fault zone creates a zone for playas and a connected drainage system southward to Flat Lake, the end of the closed basin
- The Jornada Draw fault zone has created enough relief that the margins of the Jornada basin have developed several levels of stepped topography preserving old piedmont slopes
- Deflation of playas and lowland alluvial plains creates eolian lunettes, sheet sands, and dunes downwind

2 Summary Geologic Landscape of the Jornada del Muerto

- Much of the upland landscape outside of the valleys of the Jornada del Muerto has been stable, not eroding nor aggrading much sediment for more than a million years as evidenced by mature petrocalcic soils at or near the surface
- Basaltic volcanoes erupted along the Jornada Draw fault zone and in the Cutter Sag accommodation zone 2-5 million years ago
- Modern drainages crossing Cenozoic strata tend not to be incised—rather they spread out across broad alluvial valleys and distal alluvial fans
- Modern drainages crossing Cretaceous strata tend to be incised as arroyos in narrower valleys partially filled with fine-grained alluvium
- The Jornada del Muerto trail crosses distal alluvial fans between the string of playas and springs along the Jornada Draw fault zone rather than the lowest valley of Jornada Draw and Flat Lake, probably because of seasonally deep mud



Inventory

- Study area
 - 612 square miles

Sites visited

- 59 Wells
- 3 Springs

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2 Surface water















Water Levels

- There appears to be a perched shallow groundwater system throughout most of the study area
- Shallowest groundwater exists along Aleman and Yost Draws
- Responses to precipitation events is variable

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Water Sampling

19 sites

- 14 wells
- 2 springs
- 2 playas
- 1 seep

Analyses

- Stable Isotopes (O and H)
- General Chemistry
- Tritium
- Carbon-14



Stable Isotopes of Oxygen and Hydrogen



Isotopic Composition of Precipitation



Isotopic composition of groundwater and surface water



Isotopic composition of groundwater



I		Min (mg/L)	Max (mg/L)	Average (mg/L)	EPA & NM standards
ſ	TDS	121	1930	1017	500 mg/L - drinking water
10	Hardness	11	783	325	> 300 mg/L - extremely hard
	SO ₄	4.5	1000	450	> 500 mg/L – health advisory
< \$	Na	1.37	608	205	> 20 mg/L – health advisory
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Water Chemistry



Groundwater Age

Tritium

- Hydrogen atom with 1 proton and 2 neutrons
- Radio isotope created in atmosphere by cosmic rays
- Becomes part of water molecules in atmosphere
- 5-15 TU modern water (5-10 years old)
- 0.8-4 TU mixture of modern and older water
- <0.8 TU >50 years old

Carbon-14

- Radio isotope created in atmosphere by cosmic rays
- Water DIC equilibrates with soil CO₂
- Apparent ages, not corrected for hydrogeologic processess

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Geochemical Data



- Shallow groundwater can be identified with stable isotopes, major ions, and age dates
- Mescal spring and Aleman seep appear to part of the shallow, local system
- Ojo Del Muerto is chemically distinct and is the oldest water sampled
- Playas provide the highest quality water

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Water Availability –Implications for traveling the Camino Real

Possible water sources

- Streams
- Springs
- Shallow groundwater
- Playas

Important factors

- Quantity
- Reliability
- Quality

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Accessibility



Local Water Table Fluctuations: Wet Period

- Seeps and local springs rely on local water table fluctuations
- Can be respond rapidly to wet periods and dry periods
- Mescal Spring and Aleman Draw Seep are examples



Local Water Table Fluctuations: Dry Period

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Regional Spring

- Regional springs have a much longer flow path and residence time
- Not as reponsive to local rain events
- Ojo Del Muerto appears to be a regional spring







Likelihood of Water Present in Playas



WATER AVAILABILITY AND IMPLICATIONS FOR TRAVEL ON THE CAMINO REAL



Water along the Camino Real: Availability vs Need

4 Basic Categories of travel across the Jornada

- Large herds of livestock driven to market
 - In 1800, 18,784 sheep and 213 horses in one herd
 - During 1800's, 2,000 to 5,000 head common
- Highly organized, state sponsored triennial caravans
 - Initial endeavor that established the Camino
 - 32 carts, 100 + people, 600 + livestock
- Periodic small scale communication/commercial groups
 - Dispatches being sent up and down the line; commercial travelers
 10-20 people, 20-40 livestock
- Episodic movements up and down the Camino from settlement to settlement
 - Individuals and micro groups moving short distances along camino
 1-10 people, ? livestock

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Water Requirements by Group size and composition

Group Size	# of People (1 gallon/person)	Large Livestock (5 gallons per)	Small livestock (2 gallons per)	Total daily water needs
Large	500 (500)	500 (2500)	10,000 (20,000)	23,000 gallons
Medium	250 (250)	300 (1500)	1,000 (2000)	3,750 gallons
Small	100 (100)	200 (1000)	200 (400)	1,500 gallons
Micro	10 (10 gallons)	25 (125)	0 (0)	135 gallons
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Water Sources Ranked by Quantity

Playas	Large group	3	
Streams	Medium group	2	
Regional spring (Ojo Del Muerto)	Medium group	2	
Local springs and seeps	Small group	1	5





Water Sources Ranked by Reliability

Regional spring (Ojo Del Muerto)	Highest reliability	3	
Local springs and seeps	High reliability	2	
Playas	Intermediate reliability	1	
Streams	Lowest reliability	0	



Water Source Evaluation: Reliability and Quantity

Water Source	R	Q	Total	
Regional spring (Ojo del Muerto)	3	2	5	
Playas	1	3	4	
Local springs and seeps	2	1	3	
Streams	0	2	2	
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Water Source Rank

- 1. Ojo del Muerto regional spring
- 2. Playas
- 3. Local springs and seeps
- 4. Streams

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Parajes within the study area

- Fra. Cristobal
- Cruz de Anaya?
 - 11 miles
- Laguna del Muerto
 - Ojo del Muerto (6 miles)
 - 14 miles
- Aleman
 - 13 miles
- Perillo

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- 17 miles
- San Diego
 - 8.6 miles

Fra. Cristobal 11 Miles Cruz de Anaya? 14 Miles Ojo del Muerto 1 aguna del Muerto 13 Miles Aleman 17 Miles Perrillo Legend Paraje (Camp) 3.6 miles Rated Water Source Camino Real San Diego Study Area Spaceport Ame

Strategies for crossing the Jornada

- Cross in fall/winter
 - Cooler
 - Monsoons over, playas may be filled

Scout ahead

Send scouts out to determine availability of water and forage

Forced marches

- Marshall caravan at river side paraje, rest and water livestock
- Depart for next available water
 - Nighttime crossings
 - Avoid worst of heat
- Don't stop until water reached

`Leapfrogging'

- Split caravan into groups
- Send livestock ahead to reach next water,
- Return for supplies after livestock have reached water

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Future Research

Assess past hydrologic regime

Check existing paleoclimate records for precipitation

- Tree ring data analysis
- El Nino/La Nina oscillations
- Anecdotal data from historic records
- Dating playa deposits

Hydrologic modeling

- Calibrate 3-D flow model to existing pumping conditions
- Model pre-development (no pumping) conditions
- Compare past and present water levels and spring locations

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Future Research

Archival Research

Create list of all past caravans, extract information on:

- Composition
- Dates for crossing Jornada
- Indications of water availability along route

Historic air photos

- Scan 1930s air photos of corridor surrounding El Camino Real
- Georeference images in ArcGis
- Search images for traces of El Camino Real no longer visible

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MAPPING

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