CHARACTERIZING SPRING DEPOSITS IN TEN MILE GRABEN, UTAH, USA; POSSIBLE TERRESTRIAL ANALOGS FOR ANCIENT AQUEOUS ENVIRONMENTS ON MARS. J. Williams1, S.L. Potter-McIntyre1, C. M. Phillips-Lander2, and L. O’Connell1 1Southern Illinois University, Geology Department, Parkinson Lab Mailcode 4324, Carbondale IL, 62901, pottermcintyre@siu.edu, 2University of Oklahoma, Conoco-Phillips School of Geology.

Introduction: Environmental conditions in springs with low temperatures and high ionic concentrations allow for the preservation of organic material on geologic time scales [1]. Geobiological processes affecting spring environments are well-studied and are crucial to determining the history of water and finding any potential biosignatures on Mars. However, recognizing and differentiating hot or cold spring deposits in the rock record can be difficult. This study documents the sedimentary structures common in spring deposits in an effort to understand how structures in springs are altered and preserved over geologic time scales. Herein, we compare a modern cold spring with progressively older tufa terraces (<400ka) with a previously undescribed Jurassic spring deposit to provide a library of recognition criteria to help interpret similar rocks at Gale crater.

The detection of finely layered rocks enriched in silica in Gale Crater, Mars has generated multiple hypotheses explaining the anomalously high levels of silica. The Curiosity Science Team drilled and analyzed samples near Marias Pass, Mars (Big Sky, Greenhorn, and Buckskin drilling sites) [2]. The high levels of silica are of great interest because locations enriched in silica provide ideal conditions for the preservation of biosignatures [3]. Microbially induced sedimentary structures (MISS) are one biosignature of interest. Structures that potentially resemble MISS have been hypothesized in the Gillespie Lake Member (an ancient playa lake system) on Mars [4]. The aim of this study is to document diagnostic criteria for ancient spring deposits as an analog for similar deposits on Mars.

Geological Setting: The Jurassic Brushy Basin Member of the Morrison Formation in Ten Mile Graben, Utah is predominately a mudrock with silcretes interbedded. The unit is topped by a previously undescribed <10m thick limestone deposit interpreted as a small spring-fed lake. A modern spring system also located in Ten Mile Graben (unrelated to the Brushy Basin Member) consists of a series of progressively older tufa terraces that range in age from 0-400ka [5].

Field Observations: Jurassic Brushy Basin Member spring deposit: At Ten Mile Graben, the Brushy Basin Member consists of 30.0m thick exposures of variegated smectitic clays and tuff (Fig. 1A). Silcretes (cryptocrystalline chert) are present throughout the area. The silcretes are typically black; however, some silcretes are white. They exhibit

![Figure 1](image-url)

Figure 1: Layers forming the Brushy Basin member of the Morrison Formation at Ten Mile Graben. A: image represents the base of the outcrop to the top of the 6.0m limestone layer. B: silcrete layers that are horizontally discontinuous. C: 6.0m thick massively bedded micritic limestone. D: 1.5m thick microbialite layer in direct contact with the underlying micritic limestone.

bedding and some exhibit wavy lamination within the thicker bedding. SEM (and associated EDX) analysis shows the silcretes are microscopically interbedded chert, barite and clay (Fig. 2).
Atop the mudstone, a massively bedded limestone has a lateral extent of > 8 k㎡ and ranges from 0-10m thick (Fig 1C). Veins of chert are present at the base of the limestone and delicate micro-terrace structures (Fig. 2) are also preserved. A 1.5m thick wavy laminated microbialite overlies the limestone (Fig. 1D).

Figure 2: close up image of the micro-terrace structures observed in the Brushy Basin limestone layer.

Modern springs: Two modern spring sites were characterized:
1. Big Bubbling Spring is located in Salt Wash and consists of an active cold spring that is approximate 12.0m in diameter. Micro-terraces form around the outer edges as a result of water flowing outward from the active springs. Microbial communities actively precipitate minerals around the vent.
2. Crystal Geyser is a modern cold spring set on the east bank of the Green River. An oil well was drilled into it in the 1930’s, which unintentionally created the geyser and it is now the largest CO2-charged cold water geyser in the world [6]. The area consists of tufa terraces formed from 18°C waters that surround the drill pipe and cascade into the river [6]. The terrace is approximately 30m diameter and 10m high. Collected in the pools surrounding the pipe are pisoids (~2.5.0mm diameter) that are not present in any of the pristine springs and likely formed via the agitation of the water from the eruption of the geysers. Photosynthetic microbial communities turn some pools green.

Quaternary terraces: Six terraces deposits were examined in this study. A 100ka is located just southwest of Crystal Geyser and consists of a 10.0m terrace deposited on the paleo-landscape [7]. This was the youngest of the terraces observed and had the most sedimentary structures preserved. Present in this terrace are delicate structures consisting of spheres of calcite as well as laminated iron-rich mat structures. Small calcite veins and larger fractures filled with calcite were present. There was also wavy bedding and parallel laminations preserved in the deposit.

Five older tufa terraces up to 400ka are also perched on paleo-surfaces along Salt Wash southwest of Big Bubbling Spring. These remnant terraces are less than half a meter tall and approximately 3-4.0m in diameter. They all have varying levels of sedimentary structures preserved as a result of erosional processes. Three terraces of note are the 200, 300, and 400ka. The 200ka had been moderately affected by erosion but delicate micro-terrace structures and parallel laminations were preserved. The 300ka was the only terrace that had no sedimentary structures preserved and the host rock appeared to have undergone an alteration process. The 400ka terrace is heavily eroded and consists of broken pieces of carbonate; however, parallel laminae are still preserved.

Conclusions: Delicate micro-terrace structures, mineral veins, wavy bedding, and parallel laminae are all common in the ancient spring deposits observed in this study. These structures represent some of the physical features that can be used to recognize ancient spring environments in the rock record.

The Brushy Basin outcrop bears some similarities with the sites drilled at Marias Pass. 1. Finely bedded layers enriched in silica. 2. Composition dominated by non-crystalline or cryptocrystalline silica. 3. Phyllosilicates layers interbedded silica-rich beds. These similarities suggest that the silica-rich Greenhorn and Big Sky targets at Marias Pass may be part of the remnants of an ancient spring-fed lake. The silica-rich beds may mark the source of the spring which contributed to the ancient lake recorded in the rocks at Gale crater.