Wyoming State Geological Survey
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Self-guided Walking Tour of Paleoproterozoic Stromatolites in the Medicine Bow Mountains, Wyoming

by

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Cover: "Big Daddy" is a huge hemispheroidal stromatolite in the Paleoproterozoic Nash Fork Formation of the Medicine Bow Mountains. It is exposed in cross-section on a glaciated surface along the northwest shore of Prospector Lake (Stop #2A, WP 012 in the field guide). The tape has been extended to 5 meters (about 15 feet), but still underestimates the size of this enormous microbialite structure. Big Daddy is an unusually large example of the spectacular stromatolites and related features to be visited by users of the accompanying self-guided walking tour.

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Abstract

Wyoming's Paleoproterozoic Nash Fork Formation hosts some of the most spectacular Precambrian stromatolites in the world. This formation, composed of tan, silicified, stromatolitic metadolomite with interbedded phyllite and quartzite, is near the top of a sedimentary assemblage deposited (*circa* 2000 Ma) along the passive, southern margin of the Wyoming Province. Although sporadic research has been conducted on Nash Fork stromatolites from 1926 (E. Blackwelder) to recent years, the seminal work is that of S.H. Knight (1968). While examining outcrops studied by Knight, we became convinced that significant aspects of the present morphology of Nash Fork stromatolites are products of post-depositional processes. Although the Nash Fork contains many examples of classic stromatolite domes and hemispheroids, there is wide variability in size and shape from wavy, thinly laminated beds to giant oblate spheroids (>5m diameter). Many small domes include as nucleus a tabular fragment of underlying dolomite. Laminae commonly completely envelop the nucleus, transitioning upward to laminae laterally linked to adjacent domes. Such features suggest soft-sediment displacement during which a fragment of a partially lithified bed was incorporated into less rigid laminated material as the latter wrapped around it. This interpretation contrasts with the oncolite analogy in which frequent overturning of the nuclear object permitted microbial growth on all surfaces. We also question the traditional assumption by previous workers that height, slope and axis orientation of individual domes can be taken as representing biogenically constructed sea-floor relief. Many outcrops exhibit over-close packing of hemispheroids, continuity of laminae across interdome troughs, and lateral passage of hemispheroidal forms into distorted, asymmetric lamination. These features suggest that the original laminated deposit could have been a sea-floor microbial carpet with minor relief before it wrinkled and deformed during lateral movement by down-slope sliding or pre-lithification compaction. We conclude that interpretations of Nash Fork Formation depositional environments should not include an unquestioned assumption that present stromatolite morphology represents original sea-floor relief and unaltered evidence of microbial mat development. This self-guided walking tour will take the user to many of the outcrops illustrated in Knight's (1968) paper. At each location, questions encourage the observer to see the details of the outcrop pertinent to the stromatolite's origin and subsequent history.

Figure 1. Please save the outcrop for future generations of geologists!

Introduction

Over the years, many visitors to the Department of Geology and Geophysics at the University of Wyoming (UW), as well as those visiting the UW Geological Museum, have inquired about the location and accessibility of Precambrian (Paleoproterozoic) stromatolites in the Medicine Bow Mountains west of Laramie. The purpose of this "self-guided walking tour" is to provide an illustrated field guide to some of the world's best stromatolite outcrops, with photographs, illustrations, maps and GPS waypoints to guide your walking tour. In doing so, we hope everyone will honor the integrity of these beautiful outcrops and not degrade them through unnecessary rock sampling, core drilling, or random hits of the rock hammer. The delicate lamination and internal structure of the stromatolites are best seen on weathered surfaces (**fig. 1**) where differential relief of silicified and dolomitic layers has developed over thousands of years since the last glacial event, so little is to be gained (and much lost) by "hammering" on the outcrop.

We have written this self-guided walking tour not only to guide people to these wonderful outcrops of ancient stromatolites, but also to raise questions about the origin and history of some of the structures. Some of the stromatolites in the Medicine Bow Mountains are classic microbial growth structures of various shapes and sizes, typical of those found around the world in Precambrian and younger rocks, whereas others tell a more complicated story that may (or may not) have a post-deposition and/or tectonic overprint. We raise questions about the interpretation of various outcrops to encourage a closer examination of the finer details of microbial laminae, orientation and composition of nuclei, relationship of growth structures to surrounding beds, and the degree of later deformation. Thus, we hope this guide will serve to point out to students that "the devil is in the details," or to put it another way, the subtle details of rocks often contain the greatest information and it is often worth the investment of time to examine an outcrop thoroughly before moving on. Therefore, we encourage the reader to ponder these outcrops and mentally reconstruct the stages in their development.

These stromatolites were first described by Blackwelder (1926) in a classic paper on the Precambrian geology of the Medicine Bow Mountains. Subsequent workers provided limited descriptions and attempts to classify the stromatolites (e.g., Fenton and Fenton, 1939; Hensley, 1955; Knight and Keefer, 1966), but it was Knight's in-depth work (1968) that brought international attention to the spectacular stromatolite outcrops in the Medicine Bow Mountains. His 1968 paper titled "Precambrian stromatolites,

Figure 2. Modern stromatolites of Shark Bay (Hamelin Pool) exposed at low tide, western Australia. (http://en.wikipedia.org/wiki/File:Stromatolites_in_Sharkbay.jpg)

bioherms and reefs in the lower half of the Nash Formation, Medicine Bow Mountains, Wyoming" includes many photographs and masterful drawings, as well as discussion, of specific outcrops visited on this walking tour. We have incorporated some of his classic illustrations into this field guide (with permission from the publisher); notations such as "SHK fig. 24" pertain to that publication (Knight, 1968). Following Knight's work, no publication included a detailed discussion of the Medicine Bow stromatolites until Bekker and Eriksson's (2003) report on the depositional history of the Nash Fork Formation, the major geological unit in which the stromatolitic beds occur.

What is a Stromatolite?

The answer to this question has varied during the many decades since Kalkowsky (1908) introduced the term for a variety of limestone characterized by distinctive, finely layered structure. He provided a detailed description of examples in the lower Triassic Bundsandstein of northern Germany, and introduced the term stromatolith for these and similar features he had observed elsewhere. His description of the Bundsandstein occurrences includes the finely layered structure, the convex-upward growth form, and detritus-filled interstices. He concluded that the features are of organic origin, and suggested that a lower form of organized plant life was involved in precipitating the carbonate laminae (Riding, 2000). He argued for a similar origin for ooids comprising the associated oolite banks, but emphasized that the stromatoliths are not giant ooids.

Typical definitions in recent literature (Demicco and Hardie, 1994) reflect increased understanding of the processes capable of producing the distinctive lamination. This advance followed discovery of modern stromatolites (**fig. 2**) at several coastal sites where carbonate sediments are being deposited today. Where undisturbed by bottom-feeding invertebrates (hypersaline coastal bays, for example), microbial communities of bacteria and algae form mats of interwoven filament-shaped cells at the sediment surface. Early descriptions of modern mats (e.g., Logan, Rezak and Ginsburg, 1964) emphasized the role of the microbial meshwork in trapping and binding carbonate silt and sand. The loose particles are immobilized as they adhere to the mucilaginous surfaces of cyanobacteria cells, the dominant component of many mats. When buried by inorganic material, the mobile cells move upward through the sediment and re-colonize the new surface, thus setting the stage for accretion of another sediment layer on the new mat. Repetition of this process results in a succession of thin, irregular layers alternating between those formed by predominantly organic activity and those formed by inorganic sedimentary processes. In recognition of this dual activity in producing the distinctive lamination, the term "organo-sedimentary structure" is now a component of many stromatolite definitions. Where microbial activity is concentrated on high points of an irregular sea floor, the buildups of laminae result in dome-shaped forms typical of ancient stromatolites. Some ancient stromatolites have direct evidence of microbial presence in the form of fossilized microscopic filaments and cells; this constitutes hard evidence for biogenicity. More commonly, as with the Medicine Bow stromatolites, evidence for microbial influence is from similarity of layering in the rock to that of modern stromatolites. Several relatively recent changes in published definitions reflect a better understanding of modern mats (Nofke and Awramik, 2013). Thus, replacement of the term "algal mat" with "microbial mat" was prompted by discovery that modern mats are complex communities of micro-organisms and that certain components once classified as blue-green algae are now known to be cyanobacteria. An early assumption that mats act simply as trappers and binders of sediment has been questioned by evidence that precipitation of calcium carbonate occurs within modern mats (Dupraz et al., 2013). As a result, typical definitions now recognize the contribution of precipitated carbonate to the buildup of laminae. In fact a few workers consider the term "stromatolite" to be applicable to convex-upward laminated calcium carbonate deposits of inorganic origin (Demicco and Hardie, 1994).

Stromatolites first appear in the geologic record at ~3450 Ma (Warrawoona Group, Western Australia; Lowe, 1980) and were diverse and abundant from 2800 to 1000 Ma (Riding, 2000). The photosynthetic metabolism of some of the prokaryotic microbes contributed to gradual oxygenation of Earth's early atmosphere and hydrosphere, spanning about 2 billion years. This was a prerequisite for the evolution of more complex organisms, namely eukaryotes that "grazed" on stromatolite mats and eventually overshadowed their importance in Earth's biogeochemical system. We can speculate that biofilms and various forms of microbial mat-like structures, belonging to the Bacteria and Archaea domains of life, are pervasive throughout the cosmos on other habitable planets and moons.

Geologic Background

Stromatolites of the Medicine Bow Mountains are found in the Nash Fork Formation in the Libby Creek Group, comprising the upper part of the Snowy Pass Supergroup (**fig. 3)**. This thick succession of early Paleoproterozoic metasedimentary rocks (greenschist facies) was deposited along the south margin of the Archean Wyoming craton between 2.45 and 1.78 Ga (Bekker and Eriksson, 2003). Stratigraphic details of the Snowy Pass Supergroup will not be reviewed here, but the interested reader is referred to Knight (1968), Houston and Karlstrom (1992), Houston et al. (1992), Houston (1993) and Bekker and Eriksson (2003). Similarly, the complex Paleoproterozoic tectonic evolution of the south margin of the Wyoming Province will not be reviewed here, except to emphasize the depositional setting of the Nash Fork Formation. Houston (1993) provides an elegant overview of the Late Archean and Paleoproterozoic tectonic evolution of southeastern Wyoming.

The Nash Fork Formation, approximately 2 km thick, consists of tan, stromatolite-bearing dolomite with thick interbeds of pyritic black argillite and phyllite, and lesser amounts of quartzite. The base of the Nash Fork is a structural contact (thrust fault) with the underlying Sugarloaf Quartzite, and is stratigraphically overlain by the Towner Greenstone (Houston and Karlstrom, 1992).

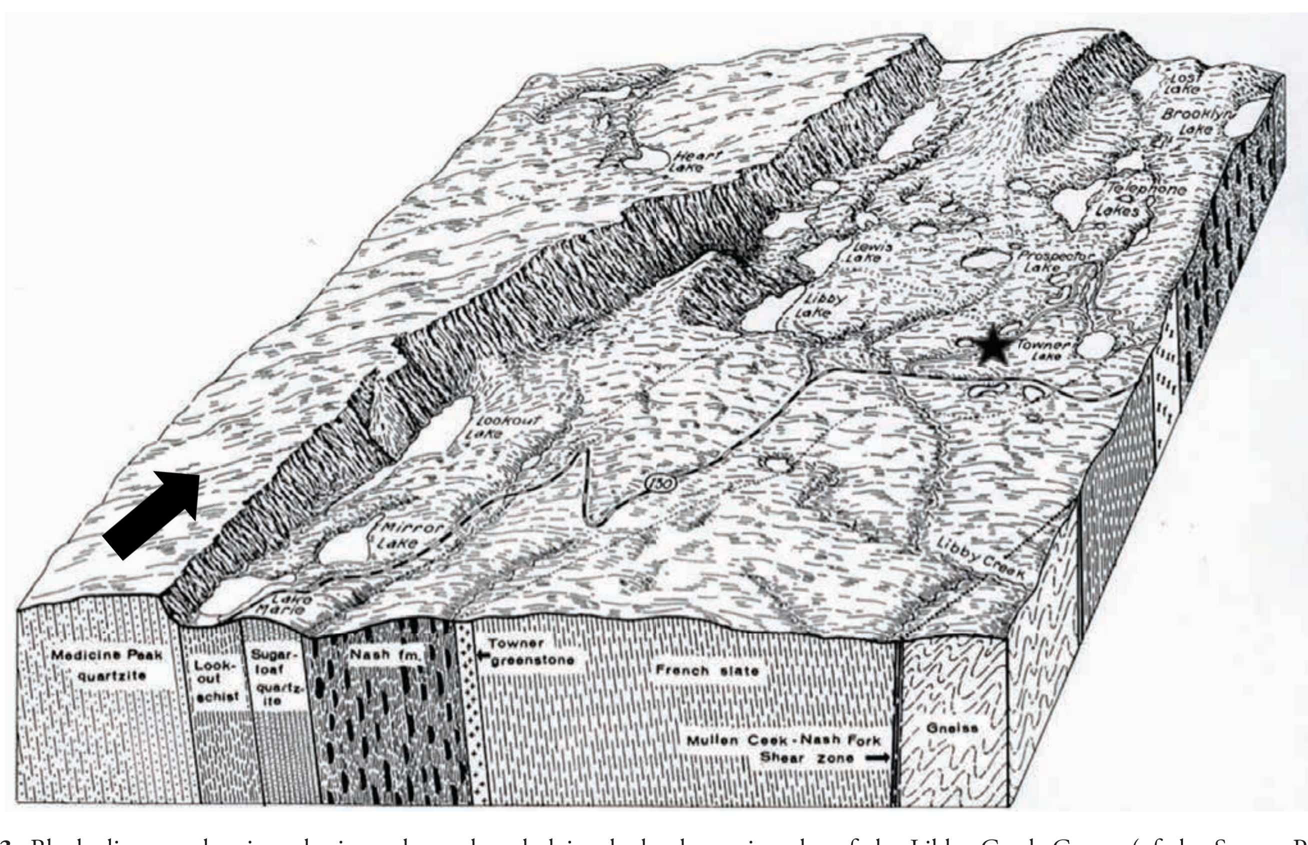

Figure 3. Block diagram showing physiography and underlying bedrock stratigraphy of the Libby Creek Group (of the Snowy Pass Supergroup) as exposed on Libby Flat, a high-level erosion surface immediately east of the crest of the Medicine Bow Mountains (Snowy Range). Note the black stromatolite bioherms or "reefs" in the Nash Formation. Subsequent to Knight's publication, "Nash Fork" replaced "Nash" as the name of the formation. The beginning of the "walking tour loop" is shown by the black star just west of Towner Lake. Bold arrow indicates north (from SHK, 1968, Plate 1).

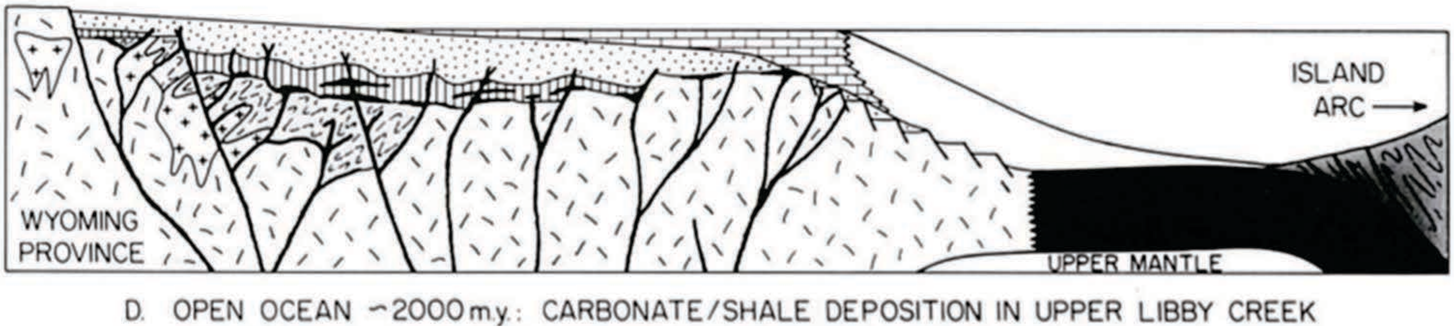

Figure 4. Seaward interpretation of the Nash Fork carbonate shelf (from Houston and Karlstrom, 1992).

Bekker and Eriksson (2003) subdivided the Nash Fork Formation into 12 mappable units on the high-level erosion surface of the Medicine Bow Mountains just southeast of Libby, Lewis and Telephone Lakes. Stromatolitic zones are most common in the lower 700 meters of the Nash Fork Formation; they are typically found in massive dolomite and silicified dolomite intervals. The largest stromatolites (true giants) are found in the "silicified domal digitate stromatolite facies association" in the lower Nash Fork between 100-200 m and 300-400 m from the basal thrust fault contact (Bekker and Eriksson, 2003). Some of these stromatolitic domes are >10 m in width and >5 m in total relief (Bekker and Eriksson, 2003), whereas others are oblate spheroids several meters in diameter – true giants in the world of stromatolites! A characteristic feature of these large stromatolites is "digitate structure," a term adopted by Knight (1968) to describe a growth pattern in which vertical pillars separate sub- and superjacent laminae (Fenton and Fenton, 1939).

Bekker and Eriksson (2003) interpret the overall depositional setting of the Snowy Pass Supergroup as a mature passive margin, not unlike the modern Gulf Coast of North America, with mixed siliciclastic and carbonate sediments and fluctuating sea level over time. During deposition of the Nash Fork Formation, a stable carbonate platform or gently sloping seafloor ramp was developed with extensive stromatolite "gardens" within the shallow water, inner shelf zone. Alternatively, Houston and Karlstrom (1992) interpreted the depositional environment of the Nash Fork Formation to have been more seaward (mid- to outer-shelf) than that of underlying beds (**fig. 4**). Subsequent thrust faulting brought the Nash Fork Formation into contact with subjacent units (Sugarloaf Quartzite) during collision with an encroaching island arc at ca. 1800-1750 Ma (Houston, 1993). Some dolomite beds display intraformational breccia, slumped zones that laterally wedge into undisturbed dolomite and apparently toppled and/or rotated stromatolite mounds, all suggestive of periodic high energy conditions induced by storms and/or seismic events. The carbonate shelf experienced two major "drowning" events marked by the superposition of black argillite (shale) over dolomite, as sea level periodically rose and fell (Bekker and Eriksson, 2003). Transgressive-regressive cycles in which carbonate beds alternate (in a vertical section) with shale are common in the Paleozoic section of the central and northern Rockies, particularly in the Cambrian section; therefore, this aspect of early Paleoproterozoic sedimentation on passive margins appears to be similar to that of the Phanerozoic.

Stromatolites of the Nash Fork Formation are broadly correlative (in age) to those in the Great Slave Supergroup of Canada (Hoffman, 1976; Houston, 1993) and to the Hurwitz Group in the Hearne Province, Northwest Territories (Hofmann and Davidson, 1998).

STROMATOLITE SELF-GUIDED WALKING TOUR: GUIDES I AND II

GPS waypoint numbers are shown in **bold** at locations discussed in the following walking tour; a table at the end of the manuscript provides coordinates and elevations for each waypoint. GPS data were collected using a Garmin Montana GPS handheld instrument and are listed by UTM/UPS coordinates (WGS 84 map datum). For hikers using a GPS, this may facilitate locating outcrops more quickly and accurately, although it is highly recommended that the route taken to various outcrops follow the written directions in this guide. Elevations are given in feet for easy correlation with USGS 7 ½ minute topographic maps of the area. Numbered waypoints (001⟶029) are shown below on a high-resolution Google Earth Pro image of Libby Flat (**fig. 5**), with a corresponding scanned image of a portion of the Medicine Bow Peak 7 ½ minute quadrangle (USGS) for additional reference (**fig. 6**).

Snow cover lingers into late summer in the high country. Depending on the extent of mountain snowpack accumulated during the winter, some outcrops described below at Stops 3, 4 and 5 may still be covered by melting snow banks in late summer. Afternoon thunderstorms are a common occurrence in the high country during mid- to late summer due to a seasonal influx of monsoonal moisture from the southwest; hikers should scurry back to vehicles as quickly as possible in the event of an impending thunderstorm (lightning is the main hazard).

GUIDE I – WALKING TOUR LOOP

Getting to the stromatolites from Laramie (approximately a one-hour drive from the UW Geology Building to the parking spot noted below):

Take Highway 130 west to Centennial, continuing on up the mountain, past Snowy Mountain Lodge, to intersection (8 mi. from Centennial) with well-marked road to "Mountain Meadow Cabins." Stay on 130 for 2.6 miles past this road junction, then turn right on unimproved dirt road (**fig. 7**). This is the road meeting 130 in SW1/4, sec. 16, T. 16N, R. 79W. on the Medicine Bow Peak 7 ½ minute quadrangle (**WP 001**). The turnoff is unmarked along 130, but a "Brooklyn Lake Road 3 mi." sign appears soon after entering the side road. One-half mile on this rutted road (about 4 minutes at the necessary 10 to 12 mph speed) brings you to a wide spot on the left side with parking space for two or three vehicles if parked diagonally (**fig. 8**) (**WP 002**). Park here and proceed on foot along the abandoned but still visible two-track road leading straight ahead from the parking site (where it is blocked by boulders).

Following the abandoned road heading northwest from the parking area:
Distances from the parking site are recorded here in terms of minutes of walking time, initially along an abandoned road and then between various landmarks:

- ~2 minutes from the vehicle the road curves to the right, continuing upslope through diabase…
- ~2 more minutes brings you to a prominent post; road bears left from post and continues upslope…
- ~3 minutes from post to crest of low rise overlooking meadow; enter the meadow and continue (straight ahead but left of midline, as the meadow can sometimes be a wet bog) through the grassy flat; in this area the old road is overgrown by grass…
- ~2 minutes after entering meadow (bearing to the left side of the meadow) note two large quartzite boulders about 6 feet apart at left edge of road; there is also an old, rusty culvert here (**WP 022**); at this point, the road leaves the meadow and can be seen ascending the rocky slope ahead on the right; continue on this road…
- ~4 minutes uphill from the quartzite boulders brings you to a roadcut through a 15-foot-thick phyllite outcrop encrusted by bright-orange lichen (Stop #1; **WP 003**); you will have passed by a rock cairn made of tan dolomite blocks on the left on the way to Stop #1.

Stop #1 (WP 003):
The resistant unit is mainly iron-rich phyllite of interest for details in the fine (mm-scale) lamination (**fig. 9**). The tan dolomite

Figure 5. Google Earth Pro image of Libby Flat showing numbered GPS waypoints (001 ⟶ 029). Yellow star by WP 002 marks the parking area at the beginning of the "self-guided walking tour loop."

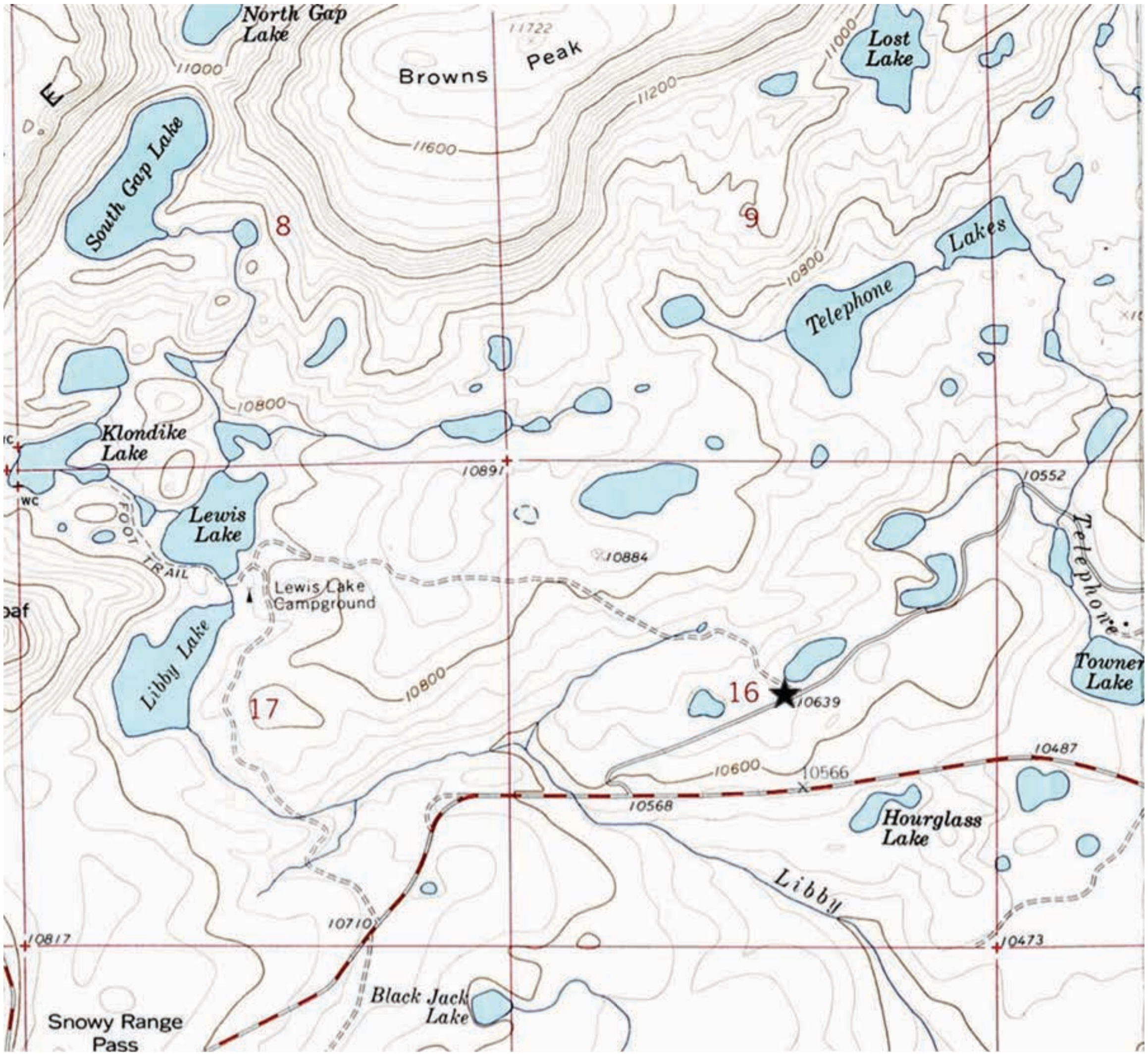

Figure 6. Scanned image of a portion of the Medicine Bow Peak 7 ½ minute quadrangle (USGS), corresponding to the Google Earth Pro image (**fig. 5**). Black star marks the parking area at the beginning of the "self-guided walking tour loop."

outcrops on both sides of the resistant unit appear homogeneous from a distance, but close inspection reveals vestiges of original lamination and penecontemporaneous disturbance. There are no stromatolites to be seen at this stop, but they are not far away!

STOP #2 (WP 004):

Approximately 4 minutes from Stop #1: The road has continued from Stop #1 up a gentle slope, past a hill of gray and tan dolomite on the right, to Stop #2: a thoroughly silicified outcrop of stromatolites at the left (south) edge of the road and a prominent upright float block on the right.

Left side of road: the upslope (oldest-NW) part of the outcrop is a vertical face exposing interbedding of finely laminated brown phyllite with thin layers of tan carbonate. Note pseudo cross-lamination (wrong way up). The adjacent (younger-SE) thoroughly silicified outcrops exhibit diverse perspectives of stromatolitic lamination, depending on angular relation of the outcrop face relative to original bedding. In fitting SHK's sketch map to this outcrop (SHK fig. 26), note that the patterns on several of these faces have been rotated and appear in his figure to be part of a single horizontal surface. Two large concentric patterns, one with a nucleus of laminated phyllite (SHK fig. 24), are exposed on the eastern end of the outcrop, facing away from the road (**fig. 10**). Close examination of the nucleus shows at its right end an angular relationship between its laminae and the enclosing silicified laminae; such a relationship is not as clear at its left end. This is the first of several outcrops where you can ponder how a "nucleus" became incorporated in the enclosing laminae, and the problem of interpreting three-dimensional form from a two-dimensional cross-section cutting vertical strata (i.e., is the nucleus-bearing bull's eye a cross-sectional view of a spherical stromatolite?).

Four feet to the left of the "double bull's eye" outcrop note the contorted silicified layer (2–4 inches thick) and its relation to "normal" stromatolitic layers. Follow it across the exposed face. It appears to be broken in places, but folded elsewhere. Did silicification occur before or after deformation? Also note that the degree of silicification changes laterally from solid silica to "warty" stromatolite. What conditions controlled such a change and why were the thin dolomite layers not silicified? At the base of this block, (which may be slumped) is a non-silicified lens of dolomite with intricate chevron-style microlamination.

Nearby exposures of tan dolomite in the grassy area adjacent to the large "bull's eye" are less thoroughly silicified; they exhibit

Figure 7. Junction (**WP 001**) of Highway 130 with unmarked dirt road (USFS Road 332) to Brooklyn Lake Road in SW ¼ sec. 16, T. 16 N., R.79 W.

Leave the float block and retrace the route about 100 feet downslope (eastward) to the west end of the hill of light tan to gray dolomite outcrops. The first exposures encountered above road level are gray beds, about 6 feet thick, with convex-up laminae and very small-scale digitate structure (both well defined by selective silicification). Overlying tan beds show vestiges of flat lamination and some evidence of soft-sediment deformation. These aspects continue up-section through the interval of light gray beds that form the main part of the hill. At some places the flat lamination in the gray rock is distinctively "varve-like" (i.e., couplet lamination, but not to imply glacial varves). Finally, a thickness of about 20 feet of the gray beds at the eastern end of the roadside exposure exhibits prominent nodules

convex-up patterns and puzzling contorted lamination. Did the contortion occur before or after lithification of the host sediment? Note: Some dolomite layers lack lamination whereas others exhibit detailed lamination. Is the former a primary or secondary condition? Is the laminated dolomite stromatolitic?

Now move to right (north) side of road. These outcrops exhibit a broad expanse of thoroughly silicified and generally flat (originally horizontal) stromatolitic bedding with poor to excellent preservation of cross-cutting, pencil-size columns (SHK's "digitate growth pattern") (**figs. 11-12**). At stratigraphic top of the silicified interval, and approximately 40 feet upslope from the road, a faulted contact between silicified rock and overlying phyllite can be seen in a small exposure at grass level.
Returning to road's edge, examine the prominent upright float block with digitate structure (**fig. 13**). Close examination of the surface facing the road shows internal structure within many columns in the form of microlamination parallel to their long axes. One part of the same surface shows an apparent gradation between well-defined columns and finely foliated rock. Here the columns appear more lath-like than cylindrical. Both columns and foliae are perpendicular to arcuate bands that set apart SHK's "developmental units" (SHK fig. 6). This is one of many places where you can look for column details that provide evidence for or against organic origin of the cross-cutting features.

of dark brown silicified dolomite, with individual nodules varying from 2 to 12 inches in length. What controls can be postulated to explain the shape and spacing of the nodules?
Return up the road to the upright float block described above and choose one of two following options:

OPTION #1: Continue northwest to Stop #2A at Prospector Lake

OPTION #2: Return to vehicle via stops 3, 4, and 5. Those choosing Option 2 should skip the next paragraph and go directly to the Option 2 heading.

Figure 8. Parking area on the left side of the dirt road leading to Brooklyn Lake Road; park here (**WP 002**) and start walking northwest past the white quartzite boulders. If this site is occupied, backtrack for a short distance and park parallel to the road.

Figure 9. STOP #1 (WP 003) – Iron-rich phyllite encrusted by bright-orange lichens along abandoned road.

OPTION #1 – Prospector Lake:
Two minutes onward (to the west) from the float block (shown in **fig. 13**) the road branches (WP 009). One branch continues west (left), whereas the other (now very faint in the meadow) heads off to the right/NW – take the right branch. A three-minute walk on this curvy branch brings you to a gabbro outcrop (**WP 010**) at the left side of the road. From this point, note several hundred yards straight ahead (toward mountain) a large (seven feet tall) quartzite erratic on a steep grassy slope below evergreens. Go directly to the erratic (a three-minute walk). Turning right (northeast) at the erratic, proceed up grassy slope for about 300 feet to overlook of Prospector Lake (**WP 011**). Note along the left edge of the lake the tan, flat-topped outcrop projecting 30 feet into the lake. Proceed to that outcrop, which is STOP #2A.

STOP #2A (WP 012) – "Big Daddy"
The glaciated surface reveals a cross-section of a very large stromatolite dome (apparent radius of about 15 feet), which we have affectionately named "Big Daddy." In all but a few parts of this exposure thorough silicification has obscured details of the digitate structure (**fig. 14**).

Figure 10. STOP #2 – Double bull's eye outcrop with a nucleus (right center) of laminated phyllite; stratigraphic top is toward the bottom of the photo. Metric tape for scale.

This surface is shown in SHK figures 7 and 8. In both cases, Knight shows stratigraphic top toward the northwest rather than southeast and attributes the reversal to faulting. His map (SHK fig. 7) shows a fault about 60 feet northwest of the large dome, and a few exposures of convex-northwest patterns between the large dome and the fault. The arcuate pattern on the lake-level outcrop appears compatible with a convex-southeast interpretation, thereby contradicting the reversal hypothesis, but exposures on the hill overlooking the lake-level outcrop provide support for the reversal claim. To find these, leave the flat lake-level exposure and climb, bearing left, upward about fifty feet. For additional examples, move to the other side of this hill and examine exposures at the edge of the evergreens. Note that outcrop faces perpendicular to one another exhibit patterns that may allow opposite interpretations of stratigraphic top. Continue about 100 feet farther upslope to the next outcrops (**WP 013**); they also exhibit a puzzling diversity of convexity patterns, including reversals within one interval. Could this complexity be the result of lateral movement during which one bed over-rode another? If so, what caused the movement? Overall, however, the majority of connected 3-d outcrops tend to support a topping direction to the south.

Figure 11. Digitate grow pattern with long axes oriented perpendicular to knife; north side of abandoned road at STOP #2.

From this site, either return directly to the 7-foot-tall quartzite erratic encountered on the way to Stop #2A, or before backtracking, go to the tan outcrops of dolomite above dark gabbro knolls visible about 200 feet to the west. The dolomite exhibits vestiges of primary sedimentary structures, including remarkably uniform and close-spaced paired laminae ("varve-like" in appearance, although we are not interpreting these layers as glacial varves) (**fig. 15**). These outcrops can be skipped by hikers interested only in stromatolitic outcrops. If you are interested in seeing an especially photogenic exposure of exquisite sedimentary layering in dolomite, then continue about 80 feet along strike of the dolomite beds.

When back at the large quartzite erratic, either proceed directly south to the road branch 2 minutes west of Stop #2 (WP 009), or tarry a bit to examine the large hemispheroid (shown in **fig. 16**; **WP 014**) (SHK fig. 10) about 120 feet west of the erratic.

Figure 12. Bedding surface expression of digitate grow pattern; north side of abandoned road at STOP #2.

Upon reaching the road branch noted above (WP 009), walk south and down-slope to the smooth, tan outcrops at the head of the "Valley of Stromatolites." This is the site of Stop #3 (**fig. 17**).

OPTION #2 (for those not continuing from Stop #2 to Prospector Lake):
From the upright float block at Stop #2, continue along the road for 16 paces. Note smoothly rounded outcrops of tan dolomite (glacial roche moutonnée) about 100 yards away on the left at upper end of valley. Leave the road and walk down-slope to them (Stop #3).

STOP #3 (WP 015):
This outcrop area, comprising a large glaciated ledge (**fig. 18**), is unusual for lateral continuity of strike-parallel exposures of linked hemispheroids. Look west along the ledge to see great examples of large stromatolites that "top" to the south; look down and to the right (west) at the large, isolated brownish-tan stromatolite (**fig. 21**). This much photographed outcrop serves as the classic example of stromatolites in the Medicine Bow Mountains. This area is a good place to raise questions concerning primary vs. secondary controls on stromatolite morphology. To what extent has lateral compression accentuated (or created) convexity relief, crowded adjacent domes, and/or overturned their flanks? If post-depositional processes influenced the morphology, were they pre-lithification or post-lithification? If the former, what caused compression?
If the latter, what were the processes and when in the history of these rocks were they operative? This array of smooth domes is also a good place to ponder lateral and vertical variation in degree and form of silicification and possible causes thereof. For example, note that the undulating laterally continuous components of the large hemispheroids vary from solid silica, to concentrations of pencil-like columns, to bands of irregular microlaminae.
Start by examining the smooth hemispheroidal knob at the north end of the arcuate belt of valley-head outcrops (**WP 015**). Note the crudely silicified digitate pattern. The pencil-like units connecting laminae are oblique (rather than perpendicular) to the laminae on the hemispheroid flanks. In some areas the digitate pattern gives way to thin layers (about 1 inch thick) of selectively silicified contorted microlaminae. At the top (east) end of this knob the silicified material is interbedded with dark brown dolomite. Note the dike-like penetration of a four-inch-thick silicified band into an eighteen-inch-thick layer of disturbed dolomite.

Figure 13. Float block by abandoned road at STOP #2 with detailed digitate pattern.

Figure 14. STOP #2A – "Big Daddy" exposed along the northwest shore of Prospector Lake (**WP 012**). The tape has been extended to 5 meters (about 15 feet), but still underestimates the size of this structure.

Proceed laterally to mid-length of the arcuate belt of knobs (**WP 016**). Note the distinctive contact zone, several inches wide, between two large domes. Several contorted bands of chert form a ladder-like pattern bridging the gap between the hemispheroids (**fig. 19**). Do the individual "rungs" in the ladder represent brief intervals when microbial mats were continuous between domes, or do they represent fracture-controlled silicification? In either case, what produced the contortion evident in each "rung's" external outline and internal pattern?

A few feet to the south and separated from larger domes on either side, is a remarkable exposure of digitate structure (**fig. 20**) (SHK fig. 12). Examine this face and try to decide to what extent silicification has preserved the original morphology by replacement

Figure 15. Outcrops of evenly bedded tan dolomite above dark gabbro knolls visible about 200 feet to the west of Stop #2A.

or modified it by thickening. In some places individual columns show vestiges of a nested-chevron structure, similar to that in SHK figures 13 and 34.

Continuing southwest about 30 feet along strike in this unit, two more interruptions in lateral continuity can be seen. The first, a silicified body of contorted laminae, separates two very low-relief digitate domes. The second, about seven feet farther south, is a narrow gap oriented oblique to the digitate lamination and partially filled with distinctively shaped bodies of white quartz.

In this general area, note that the lamination defining small adjacent domes exhibits a smooth transition upward into laterally continuous, slightly undulatory laminae. Here (and elsewhere) consider the relative merits of microbial mats versus inorganic processes as the agent responsible for such patterns. Inorganic processes could include rhythmic precipitation either on the sea floor (producing carbonate crusts) or within a sedimentary unit (Liesegang banding). Subsequent silicification would be controlled in the first case by physical discontinuities between crusts and in the second case by chemical discontinuities at band margins.

Figure 16. Large hemispheroid stromatolite (**WP 014**) about 120 feet west of the quartzite erratic encountered on the way to Stop #2A; metric tape for scale. Also, see SHK fig. 10.

Move down-slope to the stratigraphically higher (but topographically lower) belt of orange-brown outcrops more selectively silicified than those described above. Some exposures exhibit small (one-foot diameter) contorted hemispheroids with overturned flanks. They give-way upward to symmetrical laterally-linked domes. One large dome is especially eye catching and has been figured in numerous publications (e.g., Fenton and Fenton, 1939; SHK fig. 27) (**fig. 21; WP 017**). Be sure to examine all sides of this relatively isolated block, as well as other isolated outcrops along strike and north of it. Features of special interest include apparent over-riding of successive levels of linked hemispheroids, and "over-close" crowding of hemispheroids. Are these features the result of soft-sediment deformation (analogous to the folds produced by differential sliding within a stack of carpets), or are they tectonic in origin? The base (uphill end) of this outcrop exhibits complex contortions and disrupted bedding (**fig. 22**), on which the two large domes grew.

Figure 17. Head of the broad "Valley of Stromatolites" looking down-slope from near Stop #3.

Continue down-slope, following the main valley (southeast) several hundred yards to where the slope of the valley floor increases abruptly; just ahead, the valley crosses another belt of stromatolites and tan dolomite. The narrow valley walls (**fig. 23**) exhibit excellent cross-sections of a variety of stromatolitic morphologies: hemispheroidal, planar, and oncoidal, as well as puzzling "churned" intervals. The outcrops end at the valley mouth. Proceed north about 100 feet to the grassy flat at the mouth of a small tributary valley; this is Stop #4. Excellent outcrops of brownish-black dolomitic phyllite are also exposed nearby, uphill from Stop #4 (**WP 018**).

STOP #4 (WP 019):
Gray outcrops in the grassy flat display small selectively-silicified stromatolites with chevron folds and "wrap-around" structures (**figs. 24-25**). Why did silicification affect some laminae but not

Figure 18. Glaciated ledge (roche moutonnée) at the head of "Valley of Stromatolites." This is an excellent locality to observe the lateral continuity of strike-parallel, linked hemispheroids (**WP 015**). Stratigraphic top is to the left (yellow arrow).

intervening ones? To what extent do the intricate patterns reflect original morphology versus post-depositional modification? If the latter is involved, what caused it (and when)? About 50 feet east of the gray blocks, but still in the grassy flat, locate a low flat-topped outcrop some 50 feet long and 3 to 10 feet wide (length perpendicular to bedding) (**WP 020**). In the succession of beds, note the diverse forms of hemispheroids, different degrees of silicification, and evidence of disruption of original layering (**figs. 26-27**). Note (within the succession) a 7-foot-thick dolomite that appears to have been "reorganized." Is this the product of soft-sediment deformation?

From this outcrop, walk a short distance down-slope to the east along the edge of evergreen growth to an opening in the woods, exposing a steep hill of outcrops to the left (Stop #5; **WP 021**).

STOP #5 (WP 021 – base of steep hill):

Climbing up this steep slope, one first encounters an alternation of gray dolomite and thoroughly silicified beds. The latter include both hemispheroidal forms and irregular patterns possibly representing fracture control. Midway up the slope, more selectively silicified laminae illustrate broken and displaced forms as well as laterally linked hemispheroids. Moving further upward, the next band of gray-brown outcrops includes good examples of minutely crenulated laminae and over-close packing of hemispheroids (**figs. 28-29-30**). To what extent have the original morphologies been altered? If altered, what processes were involved and when in the history of these rocks were they active?

Return to base of slope (edge of grassy meadow). From here, a short walk east (about 3 minutes) along the edge of the meadow brings you to the same two quartzite boulders (**WP 022**) used as a reference point on the route from vehicle parking area to Stop #1. Continue on (about 10 minutes) to parked vehicle.

Figure 20. Remarkable display of digitate structure near WP 016 (see SHK fig. 12). Metric tape for scale.

Figure 19. Contorted bands of chert form a ladder-like pattern bridging the gap between two large hemispheroids (**WP 016**).

Wyoming's Paleoproterozoic Nash Fork Formation hosts some of the most spectacular Precambrian stromatolites in the world.

Figure 21. Beautifully exposed (and much photographed) compound stromatolite dome near the head of "Valley of Stromatolites" (**WP 017**). This outcrop exhibits apparent over-riding of successive levels of linked hemispheroids, as well as "over-close" crowding of hemispheroids. See SHK fig. 27.

Some of the stromatolites in the Medicine Bow Mountains are classic microbial growth structures of various shapes and sizes, typical of those found around the world in Precambrian and younger rocks, whereas others tell a more complicated story.

Figure 22. Base of the compound stromatolite dome near the head of "Valley of Stromatolites" (**WP 017**) showing over-close crowding of small stromatolites and disrupted bedding.

Figure 24. Intricate lamination of silicified outcrops in the grassy flat area (**WP 019**).

Figure 23. Narrow gap through dolomite and phyllite at the downhill end of the head of "Valley of Stromatolites."

Figure 25. "Wrap-around" structure of a silicified stromatolite encased in dolomite, near **WP 019**.

Figure 26. Low outcrop with diverse forms of hemispheroids and silicification at **WP 020**, exhibiting disrupted beds that may be interpreted as soft-sediment deformation.

Figure 28. STOP #5 – Large stromatolite hemispheroids overlain by a cauliflower-shaped stromatolite (yellow circle) and thin beds that could represent a succession of semi-flat microbial mats. What change in depositional environment does this represent?

Figure 27. Structure exposed slightly up-section from **WP 020** (same outcrop block). Is this a stromatolite or the product of soft-sediment deformation, or is it a tectonic box fold detached on bedding near the coin?

Figure 29. STOP #5 – Close-up of cauliflower-shaped stromatolite and thin beds that overlie larger stromatolite hemispheroids, shown in previous figure (fig. 28).

Stromatolites first appear in the geologic record at ~3450 Ma (million years ago).

Figure 30. STOP #5 – large stromatolite head or a penecontemporaneous slump/fold of mats?

GUIDE II – ADDITIONAL STROMATOLITE OUTCROPS (STOPS 6-10)

Given below are directions to several stromatolite outcrops documented by S.H. Knight (1968), but not included in Guide I (i.e., not included in stops 1-5 of the Self-Guided Walking Tour Loop). The stops described below correspond to SHK localities shown in his figures 17–18 and figures 14–16, respectively.

Leave highway 130 on the unmarked dirt road (**WP 001**) described at the beginning of the directions to the "Self-Guided Walking Tour," but proceed on this rocky road for only ¼ mi (about 2 minutes at 10 mph) to parking space on right side of road (**WP 005**). [Note: if returning to Highway 130 from the parking area for the "Self-Guided Walking Tour Loop," this site will be found on the left side of the road a very short distance from **WP002**] On the topographic map this point on the road (**WP 005**) is adjacent to the small lake near the center of sec. 16 on the Medicine Bow Peak 7 ½ minute quadrangle, but the water-filled depression is not visible from the road (however, it will come into view soon after leaving the road). Late in the summer, or during dry years, there may not be much water in this depression.

From the vehicle, walk about 3 minutes west around the south end of the lake to the nearest outcrops (Stop #6), comprising the topographically lower end of a thoroughly silicified, ~12-foot-thick stromatolitic unit (**fig. 31**) (**WP 006**).

STOP #6 (WP 006):
Note the "isoclinal folds" in laminated and silicified dolomite exposed on horizontal (glaciated) and vertical (joint) faces (**figs. 32-33**) (SHK figs. 17–18). Are these patterns the result of deformation (flattening) of original stromatolitic morphology, or are they intra-formational isoclinal folds? Knight thought the former to be the case (many of the "folds" are actually oblate elliptical spheres, suggesting an oncoidal stromatolite protolith), and proposed that deformation (local compression) resulted from intrusion of a

Figure 31. Stop #6 – Outcrop of silicified stromatolites (circled area in lower left corner of photo), near the center of section 16 (Medicine Bow Peak 7 ½ minute quadrangle) (**WP 006**).

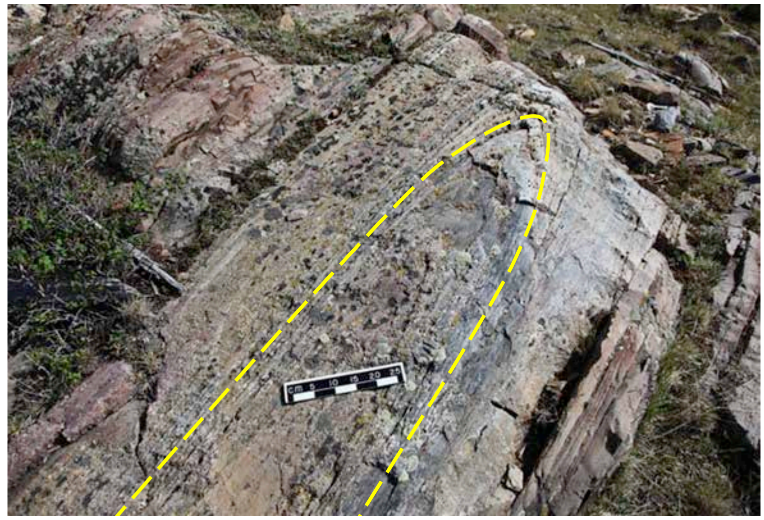

Figure 32. Flattened stromatolite resembling an isoclinal fold; Stop#6.

gabbroic sill nearby to the northwest. Knight presumably sought a nearby source for the stress field, inasmuch as other stromatolite outcrops in the Nash Fork Formation are not "squashed" to this degree.

Follow this silicified dolomite unit along strike (upslope), noting the detailed pattern of close-spaced lines intersecting the folds and parallel to their axial planes. At first glance the linear features suggest compressed relics of the cross-cutting columns of Knight's "digitate growth pattern." Joint faces, however, reveal the pattern to be the surface expression of axial-planar cleavage (**fig. 34**).

Near the upper (topographic) end of this outcrop belt (**WP 007**) note the scattered pods and lenses of tan laminated dolomite. Why did these escape the thorough silicification of the enclosing rock? The outcrop of a "greatly compressed [stromatolite] head" shown in SHK fig. 18 is near the top of the slope where this outcrop belt ends (**fig. 35**).

From the outcrop termination noted above, walk west (less than 2 minutes, oblique to strike) across a grassy area to a glaciated exposure of gabbro. Proceed on, perpendicular to strike, to the nearest easily visible ledges of tan dolomite (**WP 023**). These outcrops are of interest for the enclosed boudin-like siliceous pods at one end and intricate, crinkled and wavy laminae at the other end (**figs. 36-37**). Would the laminated dolomite qualify as stromatolite? Note that adjacent exposures of gray dolomite lack the closely-spaced lamination; therefore, is the laminated rock a relic of microbial mats and the non-laminated rock the product of a different depositional environment, or is the homogeneous rock a result of recrystallization?

Proceed about 2 minutes along-strike across a grassy area with scattered clumps of evergreens to two prominent rounded outcrops overlooking a long slope (Stop #7).

STOP #7 (WP 24-25):
The eastern knob is gabbro in contact with silicified stromatolitic rock; note lack of flattening of stromatolites in latter (**fig. 38**)

(**WP 024**). The western knob includes, at its western end, the outcrop figured in SHK figures 14–16 (**fig. 39-40; WP 025**). Remembering that the picturesque bull's eye patterns are exhibited on a horizontal surface cutting vertical beds, try to visualize the original three-dimensional forms they represent. The several possibilities include: (1) over-size oncoids which were overgrown by, and incorporated in, laterally extensive microbial mats; (2) cross-sections of the flanks of toadstool-like forms; (3) a cross-section through slumped strata analogous to a stack of irregularly wrinkled carpets (i.e. post-deposition but pre-lithification deformation of a succession of laminae); (4) the patterns are post-lithification diagenetic features formed by selective silicification of secondary chemical bands (e.g Liesegang rings).
After pondering the major patterns, consider the details of silicification (e.g., why the alternation of thoroughly silicified layers with "warty" layers?). Return to vehicle.

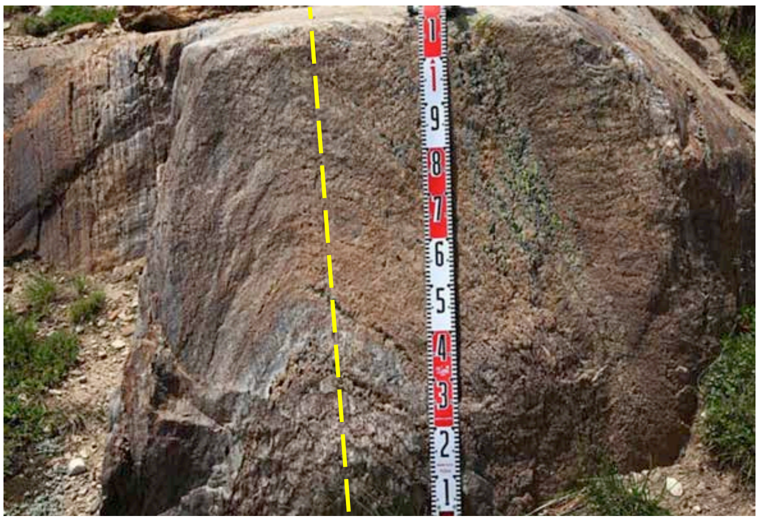

Figure 34. Trace of cleavage parallel to yellow line (and metric tape) on a joint surface of what Knight (1968) interpreted to be a flattened stromatolite; Stop #6.

Hike from Libby Creek Parking Loop: Localities of SHK figures 20, 59, and 60:
Proceed west on highway 130 to a parking loop a short distance (0.1 mi.; less than 1 minute drive) past the turnoff to the unmarked dirt road noted at the beginning of directions to the "Self-guided Walking Tour." The parking loop is just beyond where the highway crosses Libby Creek and, indeed, is identified with a sign as the Libby Creek Parking Loop (**fig. 41**) (**WP 026**). Park and walk back to the northeast side of the creek and then follow it upstream (6 to 8 minutes) to the nearest end of the low escarpment visible ahead (Stop #8). Avoid the dense thickets growing adjacent to the creek by taking a slightly higher, more circuitous route along the upper edge of evergreen growth, passing by a small prospect pit.

STOP #8 (WP 027):
The downstream end of the escarpment exposes interbedded blue-gray phyllite (note the crenulated foliation) and tan dolomite.

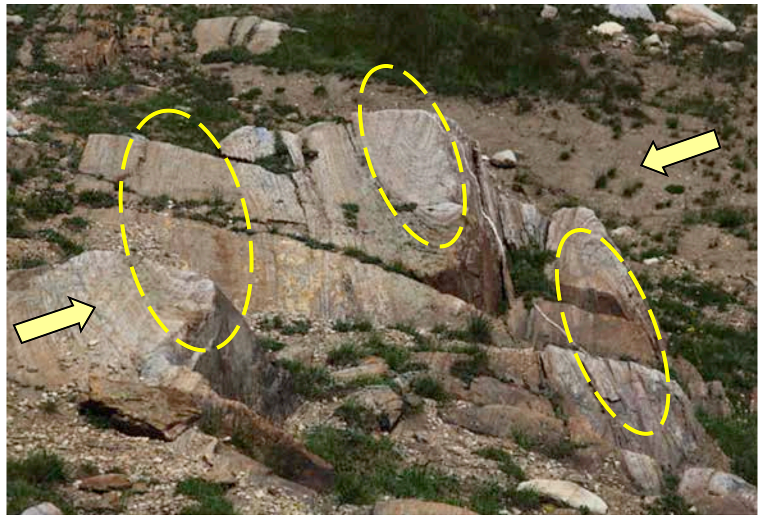

Figure 33. Additional examples of flattened (oblate) stromatolite ellipsoids at Stop#6 (further up-slope and along-strike of the thick silicified bed). Inward-pointing yellow arrows infer the direction of shortening suggested by S.H. Knight's hypothesis of local compression from the intrusion of a nearby sill.

Proceed along the base of the escarpment noting the cross-sections of very large silicified hemispheroids exposed on joint faces. Some of these are ten feet above the alluvium and require a short climb for close observation whereas others (e.g. SHK fig. 20) are at the base of the escarpment. The largest and most picturesque stromatolite (**fig. 42; WP 027**) overlooks a spring hidden in the thicket at its base (beware of treacherous footing). When interpreting the patterns, remember that the sections vary greatly in orientation relative to the axes of the domes they cut. If the ground is not too wet, walk along the base of the escarpment to the accumulation of quartzite boulders and climb up to the first big joint face in tan dolomite (Stop #9, **WP 028**).

Note: Depending on the season, the alluvium at the base of the escarpment may be water-saturated in places. If so, retreat a few steps to where stepped-back ledges allow a climb to the pines along the escarpment rim. Proceed a short distance through the pines (and parallel to the escarpment rim) until a break in the

Figure 35. Knight's (1968, fig. 18, p. 91) photograph of a "greatly compressed [stromatolite] head" at the uphill end of the outcrop belt at Stop #6 (**near WP 007**). Stratigraphic top is indicated by the black

Figure 36. Laminated dolomite at WP 023 between Stops #6-7.

evergreens offers a view of the scattered quartzite boulders noted at the end of the preceding paragraph. Climb down to the tan dolomite ledge about 50 feet above the alluvium and examine the large joint face.

STOP #9 (WP 028-029):

The joint face (**WP 028**) exhibits various degrees of disturbance in the dolomite from completely disrupted (a three-foot thick "churned" interval) to isolated displaced blocks within finely laminated rock. Climb up through dolomite with flat lamination to the next tan ledge where large oncoids with tabular nuclei (SHK fig. 59) are well exposed (**figs. 43-44; WP 029**). Compare the patterns on the vertical joint face with those on the flat surface (**fig. 42**) above it. The latter is a cross-section perpendicular to bedding and includes one two-foot-thick interval consisting of tabular blocks of laminated dolomite (e.g. 6 in. long; 3 in. thick) encircled by selectively silicified laminae. The combination suggests that early cementation affected some thin layers but not others in the accumulating sequence. Perhaps cementation was impeded in layers with high organic content? Given the differential cementation, disturbance of unknown cause broke the rigid layers while the ductile ones wrapped around the blocks. Alternatively, the blocks may be the nuclei of oncoids. In this scenario the latter grew by microbial encrustation during periodic overturn on the sea floor and were eventually overgrown by laterally extensive mats. Yet another possibility to consider is that the accumulation represents inorganic precipitation in a travertine-like setting where collapsed fragments are encrusted as the build-up continues.

Figure 37. Laminated dolomite at **WP 023** between Stops #6-7, showing what could be interpreted as either small disharmonic folds or stromatolite structures (directly below the scale) in which growth was controlled by wavy microbial mats.

Climbing a bit higher, the next ledges encountered are selectively silicified; they exhibit diverse patterns of lamination including flat, undulating, contorted and over-close hemispheroidal forms. These ledges (and the ones topographically lower) provide excellent opportunities to ponder the relative importance of organic vs. inorganic processes in the history of these stromatolites (**figs. 45-46**).

Figure 38. Don Boyd sitting near the contact of dark gabbro to his left (right side of photograph) and well-bedded dolomite to his right. Stop #7, **WP 024**.

Retrace route to vehicle at Libby Creek Parking Loop. Once you arrive back at the highway, take a look at the small outcrop next to the northeast end of the bridge over Libby Creek. Is this evenly-bedded tan dolomite outcrop a fossilized microbial mat succession?

Classic locality of SHK figure 49:

From the parking loop noted above, continue west on 130 for half a mile (about 2 minutes) and turn north on the signed road to the Sugar Loaf Recreation Area. Proceed for 0.6 mi. (about 2 minutes) to the first roadside outcrop, a stromatolite exposure on right side of road (Stop #10). If parking at this site isn't feasible (too many vehicles for the space), then continue 0.2 mi. to Libby Lake Picnic Ground and walk back to the outcrop.

Figure 39. Maze of oblate, bull's eye stromatolite ellipsoids exposed on a horizontal surface at right angles to bedding (Stratigraphic top to the right). This outcrop is figured in SHK figs. 14-16. Stop #7, **WP 025**.

STOP # 10 (WP 008):
Silicified laminae outline small laterally-linked stromatolite domes in the lower (oldest) 2-foot thickness of this classic and highly photographed exposure (SHK fig. 49, and illustrated in many other publications) (**WP 008**). The outcrop, a cross-section perpendicular to bedding, is a textbook example of the utility of stromatolites as "way-up" or topping indicators (**fig. 47**). However, several aspects of the small domes deserve close scrutiny. Try to identify nuclei for individual domes (i.e. a point on the original depositional surface above which convex-upward laminae developed before adjacent domes became laterally linked). Why are there no sediment-filled spaces between basal parts of adjacent domes? Many of the domes have a tabular nucleus formed from the underlying dolomite with laminae that completely "wrap-around" the nucleus, transitioning upward to laminae that are laterally-linked with adjacent domes. Did a storm event disrupt the sediment-water interface, forming rip-up clasts that subsequently became nuclei for stromatolite domes? Alternatively, might the nuclei be "captured" material emplaced during soft-sediment deformation? Also, note that inter-dome laminae appear to have been down-folded into the underlying tan dolomite and that the domes are somewhat flattened (**figs. 48-49**). If these aspects resulted from compaction, the deformation must have involved unlithified layers prior to silicification.

Figure 40. Close-up of ellipsoid to right of metric scale in figure 39. Stop #7, **WP 025**.

The overlying six feet of selectively silicified dolomite exhibits generally flat laminae. Were these layers generated by successive microbial mats? Why the alternation of silicified and non-silicified laminae? Close inspection of the upper part of this interval shows patches of disrupted lamination that suggest soft-sediment deformation.

Walk up-section (and parallel to road) across a short 12-foot wide covered interval to examine the lower part of the next 6- to 8-foot-thick exposure. Note the irregular upper surface of the basal dolomite. In the lower part of the overlying silicified interval, note a central lens of disturbed material followed (upward) by laterally continuous laminae defining very broad domes. In places, these include evidence that laminae were disrupted prior to silicification. To what extent might the undulations and contortions be due to pre-lithification sliding of flat microbial mats (**figs. 50-51-52**)?

Figure 41. **WP 026** – Libby Creek Parking Loop for Stops #8-9.

Continue approximately 10 feet perpendicular to strike across another covered interval to the next 10-foot-thick exposure. In its lower part, differential silicification outlines some unusual patterns which suggest that "typical" stromatolite morphology may be created, or enhanced, by slumping, sliding, and/or compacting of incompletely lithified layers (**fig. 53**). In the lower part of the overlying tan dolomite, note the four-inch-thick disturbed bed (**figs. 54-55**) which resembles bioturbation patterns in Phanerozoic rocks; if you didn't know the age of these rocks, would you have considered this layer to have been burrowed? More likely, this thin zone could be a storm deposit, as it also resembles rip-up flat-pebble conglomerates that are so common in the Cambrian rocks of western Wyoming and Montana.

Figure 42. Stop #8, **WP 027** – large stromatolite hemispheroid located above a hidden spring in the groundcover at its base. Same locality as SHK fig. 20.

Figure 44. Stop #9, near **WP 029**. Outcrop of a jumbled pile of mostly tabular stromatolites with wrap-around laminae that encase, to varying degrees, laminated dolomitic nuclei; see text for various hypotheses about their origin.

Figure 43. Stop #9 near **WP 029**. This outcrop displays large oncoid-like structures, some with tabular nuclei (metric tape for scale). Stratigraphic top is to the right.

Figure 45. Stop #9 near **WP 029**. Is this structure a stromatolite "cone" or is it the result of slumping of partially consolidated sediment including microbial mats?

Figure 46. Stop #9 near **WP 029**. The wedge of imbricated blocks of laminated dolomite on the left (directly above the scale and tapering to the right) suggests localized disruption of partially lithified beds, with lateral displacement of the more rigid fragments. Numerous "wrap-around" structures with nuclei of laminated dolomite are seen on the right side of the photograph.

Figure 48. Laterally-linked and flattened(?) stromatolite domes showing apparent down-folding of inter-dome laminae into underlying tan dolomite. Stratigraphic "top" is toward the top of the photograph.

Figure 47. Don Boyd kneeling by the classic stromatolite outcrop described in Stop #10. Stratigraphic "top" is to the right of the convex-up domes (arrow).

Figure 49. Stop #10. Flattening and apparent down-folding of inter-dome laminae into underlying grayish tan dolomite.

Figure 50. Moving up-section at Stop #10 from the basal zone of laterally-linked stromatolites through a zone of disrupted material that wedges into undeformed strata on the right. One may speculate that this localized disruption was caused by syn-depositional lateral slumping, or perhaps by disruption of sediment due to high fluid pressure after burial (i.e., expulsion of water due to compaction).

Figure 51. Stop #10 showing a layer of highly disrupted dolomite bound above and below by non-disrupted bedding (not shown in photo). Is this a slumped zone, storm deposit, or disrupted interval due to post-burial high fluid pressure?

Figure 52. Stop #10 showing, directly above the scale bar, another example of disrupted (slumped?) material that laterally wedges into undeformed strata on the right.

Figure 53. Example of stromatolite morphology enhanced or modified by slumping, sliding and/or compaction.

Figure 54. Disturbed bed showing evidence of soft-sediment deformation that may be a storm deposit.

Figure 55. Unusual pattern on outcrop surface suggests origin of the bed as either a storm deposit or the result of soft-sediment flowage.

Examine the ledges beyond the next covered interval if you desire more evidence of pre-silicification disruption, then return to vehicle.

End of the Self-Guided Walking Tour of the Paleoproterozoic stromatolites in the Medicine Bow Mountains, Wyoming – we hope you enjoyed this journey across almost two billion years of geologic time to some of the best exposed and intriguing outcrops of ancient stromatolites in the world!

Acknowledgements

The authors gratefully acknowledge the pioneering work of the late Professor S.H. ("Doc") Knight in describing and interpreting the stromatolites of the Nash Fork Formation. We thank *Contributions to Geology* (now *Rocky Mountain Geology*) published by the Department of Geology and Geophysics at the University of Wyoming, for allowing us to use some of Knight's original figures in this guide. Lori Babcock (graduate student in the Department of Earth Sciences at Montana State University) assisted with compiling GPS waypoints. Chamois Andersen (WSGS) assisted with editing and conducted design and layout efforts.

Beautiful roadside exposure of the "French Slate" (phyllite), overlain by quartzite glacial erratics along Highway 130, Medicine Bow Mountains. The French Slate is at the top of the Libby Creek Group of the Snowy Pass Supergroup.

S.H. "Doc" Knight at a contact between phyllite and stromatolite-bearing dolomite in the Nash Fork Formation. Photo by D.W. Boyd while enjoying a field trip with Knight in October, 1965.

Watercolor painting of Precambrian stromatolites by S.H. ("Doc") Knight. Although not dated, this was probably painted during the mid-1960s when he was conducting research on the stromatolites of the Nash Fork Formation in the Medicine Bow Mountains, Wyoming.

Waypoint Data Table

Waypoint	Datum/zone & Easting	Northing	Elevation (ft.)	Description
WP 001	13T 0392913	4578534	10,599	Junction of Hwy. 130 and unmarked dirt road to Brooklyn Lake
WP 002	13T 0393466	4578864	10,656	Parking area for walking tour loop (Guide I)
WP 003	13T 0392911	4579132	10,784	**STOP #1**: orange lichen-covered outcrop of phyllite
WP 004	13T 0392742	4579244	10,845	**STOP #2**: first stromatolite outcrop on walking tour loop
WP 005	13T 0393125	4578691	10,652	Parking area on dirt road at the beginning of Guide II
WP 006	13T 0393121	4578865	10,645	**STOP #6**: first stop on Guide II; base of outcrop band just above small lake
WP 007	13T 0393099	4578860	10,666	General area of SHK fig. 18 (Guide II)
WP 008	13T 0391692	4578634	10,733	**STOP #10**: stop along Sugarloaf Mountain Recreation Area Road
WP 009	13T 0392646	4579257	10,820	Road junction at beginning of Option #1 narrative
WP 010	13T 0392629	4579383	10,851	Gabbro outcrop
WP 011	13T 0392745	4579544	10,887	Overlook of Prospector Lake
WP 012	13T 0392838	4579590	10,862	**STOP #2A**: Big Daddy stromatolite, shoreline of Prospector Lake
WP 013	13T 0392836	4579646	10,908	NW-topping stromatolites uphill from “Big Daddy”
WP 014	13T 0392631	4579544	10,890	SHK fig. 10, near quartzite erratic in meadow
WP 015	13T 0392661	4579210	10,800	**STOP #3**: head of “Valley of Stromatolites” (glaciated resistant ledge)
WP 016	13T 0392645	4579212	10,803	Complex inter-stromatolite ladder structure
WP 017	13T 0392645	4579061	10,796	Disrupted bedding at the base of the “classic” stromatolite shown in SHK fig. 27
WP 018	13T 0392818	4579061	10,733	Brownish-black outcrop of dolomitic phyllite
WP 019	13T 0392846	4579039	10,708	**STOP #4**: small stromatolites with delicate laminae
WP 020	13T 0392861	4579042	10,712	Over-close packing
WP 021	13T 0392927	4579016	10,682	**STOP #5**: base of up-hill traverse through gray/tan stromatolitic dolomite
WP 022	13T 0393066	4579044	10,665	Two quartzite boulders encountered enroute to Stop #1
WP 023	13T 0393027	4578937	10,733	Ledges of tan dolomite between stops 6 & 7
WP 024	13T 0392880	4578849	10,708	**STOP #7**: stromatolite contact with gabbro
WP 025	13T 0392838	4578863	10,700	**STOP #7**: cluster of bull’s eye stroms shown in SHK figs. 14-16
WP 026	13T 0392621	4578556	10,585	Libby Creek Parking Loop
WP 027	13T 0392492	4578740	10,611	**STOP #8**: SHK fig. 20
WP 028	13T 0392438	4578730	10,634	Tan dolomite ledge with stroms
WP 029	13T 0392440	4578732	10,588	**STOP #9**: near SHK fig. 59

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