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Structural Failures of Single Wall Construction in a Western Mining Town: Bodie, California

Andrea Sue Morrison
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Structural Failures of Single Wall Construction in a Western Mining Town: Bodie, California

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STRUCTURAL FAILURES OF SINGLE WALL CONSTRUCTION
IN A WESTERN MINING TOWN: BODIE, CALIFORNIA

Andrea Sue Morrison

A THESIS

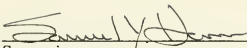
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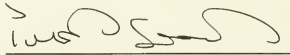
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MASTER OF SCIENCE

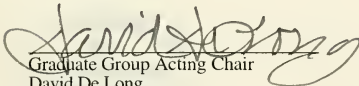
1999



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California Department of Parks & Recreation



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Professor of Architecture

Faint handwritten text at the bottom left, possibly a date or reference number.

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FOR PETE

There was a time when a man with a few drinks under his belt who wished to impress people would proclaim himself a “Badman from Bodie!”

Bodie, California, was a rich camp, and a tough one. On one day in 1880 they had three shootings and two stage holdups, and the town was just getting warmed up. Another man noted six shootings in one week and made no mention of various knifings, cuttings, or other passages of arms.

In approximately three years, from 1879 to 1881, miners took something over \$30 million in gold from the mines of Bodie. Laundrymen were getting rich panning out the dirt they washed from miners’ clothing.

It is reported that Rough-and Tumble Jack, Bodie’s first badman, was explaining how tough he was when someone saw fit to challenge him. He and his antagonist went outside and opened fire on each other at point-blank range. Rough-and Tumble Jack staggered back into the saloon, but his opponent, with one arm broken, reloaded his gun by holding it between his knees and then went back into the saloon and finished the job. Jack became one of the first to bed down in Bodie’s Boot Hill.

Much of the town still remains, although a fire in 1932 swept away many of its buildings.

Louis L’amour
Law of the Desert Born

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PREFACE

I was first introduced to the structural problems with the single wall building technique in Bodie, California, while working for the California Department of Parks and Recreation in 1996. I was employed to systematically measure the buildings and to record their present condition. While working under Senior State Archeologist, Peter D. Schulz, I photographed the structures and constructed HABS type measured drawings of each building using MiniCad 6.0. This effort was organized through a three-year (1996-1998) Bodie Stabilization project proposed to document the single-wall buildings before any stabilization or repairs were made on the buildings. Of 122 buildings in Bodie, we were able to survey 47 structures, 39 of which were single-wall construction. Many of the structures had previous stabilization done, and several have been stabilized since recordation. All eight exterior facades have been photographed for every building (122), and the interiors of the 47 surveyed buildings have been systematically photographed. These photographs served as the base for my study of the structural failures.

After working on a large sampling of single-wall buildings to a high level of detail, I had gained a thorough understanding of how single-wall construction worked as a system, and gained an appreciation for the unique collection that remained in situ. I find Bodie State Historic Park to be an integral example of early mining in California and the westward movement; both of which are a large part of my personal heritage as a Californian. It goes without saying that Bodie is a highly significant cultural site and is in desperate need of care due to the delicacy of the structures that remain. But the inclement environment is an ever present problem, and the fact remains that the structures will eventually reach their demise. By analyzing the way in which the buildings are failing, and figuring a way to combat those failures, I hope to provide a tool to prolong the lifespans of the structures.

ACKNOWLEDGMENTS

The completion of this thesis would not have been possible without the assistance and support of many people. I first want to recognize my thesis advisor, Sam Harris, who provided the right balance of patience and push to keep me on track and was available without call for consultation when needed. I would like to thank particularly, the California Resource Agency's Archeology Lab for providing me with the plethora of materials needed to complete this study. I am especially indebted to Peter D. Schulz who took the time to read and meticulously edit my thesis throughout its evolution. Without his help and enthusiasm, I would not have chosen or completed this topic. I am grateful for his availability, in particular on early Saturday mornings and other off-peak hours for answering inane queries about the park, its history, etc. Thank you to Jeanette Schulz for her overwhelming moral support and guidance in dealing with the stress of writing a thesis. Your words were taken to heart.

Various other people deserve special thanks for their help and support, that however consequential really made a difference. The park personnel at Bodie State Historic Park were terrific in providing information and access to the buildings. All of my colleagues at the Archeology Lab that helped with the surveys and whose reports were invaluable sources of information; Glenn Farris, Larry Felton, Lee Motz, Christina Savitski, Kathleen Davis, Norbert Walery, and Richard Hastings. Of course I can't forget Betsy Leber, whose hugs, smiles, and enthusiasm kept my chin up throughout the tougher times.

All of my classmates at the University of Pennsylvania were great in encouraging me to complete my thesis on time, expressed interest and understanding, and most importantly were available for haphazard sessions of commiseration throughout the year. I especially want to recognize Heather Conahan for perusing my paper for clarity and content, and for lending a sincere ear in times of turmoil. Thank you.

Finally, I must acknowledge my family who have always been an inspiring and loving group. They are always there when I need moral support, financial help, or just love in times of loneliness. It has been a challenge living so far from them for these past few years, but I couldn't have made it without the long telephone conversations. My mother more than anyone deserves recognition as my sole support, who kept my personal life in balance so that I could concentrate on finishing my studies. Only she understands the gravity of this thanks.

ABSTRACT

Bodie State Historic Park is a Western ghost town that was once a thriving mining community in California at the end of the nineteenth century. Common among Western boom towns, the town's rapid erection facilitated the use of single-wall construction techniques due to its ease of fabrication and economic use of materials. Single-wall construction is a vernacular building technique that utilizes no internal skeleton (stud framing); where the 1" siding acts as the structural support that connects the floor to the rafter plates.

Today, 122 of Bodie's single-wall buildings remain nearly unaltered, yet due to the region's inclement environment, many of these structures are in danger of collapse. This paper analyzes the specific forces that contribute to the structural failures of the single-wall buildings within this harsh climate. Three types of structural failures were found in the single-wall buildings in Bodie: those caused by the soil, those due to stresses induced by loads, and those caused by the building materials. Two general types of soil-related failures exist that are categorized as either settlement related problems (vertical sinking, tilt, and slumping), or soil movement problems (erosion build up, and heaving). Stresses that have resulted in structural failure are induced by vertical loads (snow and rain), lateral loads (wind), or a combination of loads (buckling). Finally, both physical and chemical failures of the dominant material (wood) contribute to the failure of the structure as well.

Three systems (horizontal closure, vertical closure, and structural system) act together to resist deformation and provide shelter in the single-wall buildings in Bodie. When any one of these systems are compromised, then the entire structure fails. This thesis looks at the various systems and provides systematic intervention strategies to counteract the structural failures in an attempt to prolong the lifespans of these delicate single-wall structures.

CHAPTER ONE

INTRODUCTION

Statement of Thesis

The sustainability of a structure is dependent upon the quality of its construction and the forces imposed by its environment. In order to prolong the life of a structure, either the environmental forces must be altered, or the structural system must be continually maintained. This paper is geared to analyze the forces that impose detriment to the single-wall buildings in Bodie and to measure the impact that those forces have on the stability of the structures as a system. The findings of this study are specific to the non-skeletal framed single-wall buildings and the environmental conditions of the high desert region. Using the findings of this study in conjunction with the stated philosophy of the Bodie State Historic Park, intervention strategies will be offered to potentially prolong the single wall buildings as a collection rather than as individual structures.

Justification of the Study

Traditionally, the study of architectural history and preservation has focused on singular monumental buildings, and little has been documented on large-scale landscapes of vernacular buildings as a set or collection. This thesis is geared to look closely at a large number of similar vernacular structures instead of one singular unit. Out of 122 buildings still standing in Bodie, at least 80 of the structures are of single wall construction. The buildings were constructed during the 20-year period of Bodie's significant growth, which contributes to their homogeneity in construction technique and materials. Although a handful of buildings have fallen to ruin, a large collection of barely altered single-wall buildings remains, creating a useful laboratory for studying the failures of single wall construction techniques. The

structures have remained intact due to the presence of State park personnel. Yet, despite the efforts of the Park, Bodie's valuable resources remain threatened by deterioration and collapse.

Research Methods and Field Work

This thesis studies a large sample of single-wall buildings in Bodie as a means to ascertain the condition of the buildings at their present state. Through analysis I have categorized several of the sources of the structural failures, and prioritized the failures in an intelligible manner to be used by the maintenance staff at the Park. Based on the findings, I have made suggestions as to how to prioritize the building failures and how to rectify some of the current problems. Further suggestions are included for the mitigation of future problems in an effort to prolong the general lifespan of the buildings as a collection, rather than restoring only a few of the buildings to a pristine level.

Most of the analysis for the structural failures were done through various on-site surveys and photo-documentation. Numerous visits to Bodie State Historic Park allowed for a thorough understanding of the failures present. I had access to thousands of photographs, site records, measured drawings, and previous inventories that were taken by a team of archeologists and myself over the past three years in an attempt to document the present condition of the buildings in Bodie. I systematically surveyed the photographs to identify the different building failures. The building failures were organized into categories and given a title. Examples of the various failures were then drawn diagrammatically to be used as a guide to identification. Once the various building failures were identified, I could then group the failures based on their cause. There were three major causes found, each of which will be described in detail in chapter three. Once the structural failures and their causes were identified, then various intervention strategies could be looked at to counteract the failures.

Only the single-wall buildings in Bodie were included in the study. Eighty of the 122 buildings in Bodie were built using the single-wall construction technique. This group

includes structures in various states of disrepair. Nine of the single-wall buildings are currently lived in by park personnel (only a few are lived in year round), and are in good condition. Five of the buildings are in ruin, three of which were entirely of single-wall construction. An on-site survey of 47 of the 122 buildings was conducted to a relatively high level of detail; 39 of those buildings were of single-wall construction and included in this study. Every building in Bodie was photographed on the exterior eight facades to be used in my analysis. A building-by-building conditions assessment was not feasible for this study. Instead, the photographs, previous surveys and measured drawings were used to analyze the site as a collection of buildings. The information presented in this thesis thus provides a useful guide to general building failures, but is not intended to address specific failures in any individual building.

There are a few discrepancies in the research methodology that must be pointed out, such as the difficulty in doing analysis by the use of photographs, or the fact that some buildings were more thoroughly documented than others. Because the buildings were treated as a general construction type, only in a few specific instances where the names of the building is mentioned directly. Illustrations and photographs of individual structures are included only as examples to demonstrate specific failures. Other than the resources available to me in the Department's Archeology Lab, very little documentation of the buildings and previous alterations was available (before and after pictures, written notes, etc.). The exact number of altered or stabilized structures is unknown.

CHAPTER TWO

GENERAL BACKGROUND AND OVERVIEW

Gold was discovered in Coloma, California, in 1848, leading to a widespread westward migration of rugged men who had dreams of getting rich quick. Waterman S. Bodey was one of those ambitious men, whose premature end marked the beginning of a boom for one of the most prolific gold mining towns in California that would later adopt his name.¹

Bodie,² California, is located near longitude 199° west and latitude 30° north, on the northern side of the 700-square mile Mono Basin that drains into Mono Lake just 10 miles to the South. Yosemite National Park is immediately to the west of the Mono Basin, over the crest of the Sierra Nevada mountain range, and San Francisco is approximately 180 miles westward [Figure 2.1]. At an elevation of 8,300-8,670 feet above sea level, Bodie can be reached by way of U.S. Route 395 (20 miles East on California Highway 270), from the northwest through Bridgeport, or from the south by way of Lee Vining and Mono Lake. Adjacent hilltops are between 9,000-9,200 feet in elevation, creating the natural barren high-desert bowl that has isolated and protected Bodie from the vandalism that had decimated several nearby early mining towns [Figure 2.2].

¹ Prospectors W.S. Body and E.S. ("Black") Taylor arrived in the Mono Basin in 1859 during the Monoville rush. Because the Monoville district was crowded with miners and prospectors, they prospected several miles to the northeast in the Bodie Hills. Body and Taylor located placers in the bottom of a gulch (later called Taylor Gulch) on the east side of Silver Hill and prepared to winter at their claim. Returning to their camp from a provisioning trip to Monoville, Body lost his way in a snowstorm and froze to death. Frank S. Wedertz, *Bodie 1859-1900*, (Bishop, CA: Sierra Media, 1969) 1-2; Ella M. Cain, *The Story of Bodie*, (San Francisco: Fearon Publisher and Mother Lode Press, 1956) 1-8, 10. Taylor and other miners organized the Bodie Mining District in the spring of 1860, naming it in honor of its late discoverer. It extended five miles in all directions from the initial claim. David L. Felton, Francis Lortie, Kathleen Davis, and Leslie Lewis, "The Cultural Resources of Bodie State Historic Park" (State of California, Department of Parks and Recreation, Resource Preservation and Interpretation Division Cultural Heritage Section, 1977), 11.

² The current spelling of "Bodie" originated sometime after the organization of the mining district. The earliest records of the Bodie Mining District spelled the name at least three different ways (Bodey, Bodie, Body), but by late 1862 the current spelling of "Bodie" had been established. Wedertz, 1-2; Cain, 1-10; Joseph Wasson, *Bodie and Esmeralda*, (San Francisco: Spaulding, Barto, and Co., Steam Book and Job Printers, 1878), 5. Ann Huston, Leo R. Barker, and David Quitevis, "Draft Bodie National Landmark Documentation" (National Register Programs Division, Western Regional Office, National Park Service, San Francisco: 10 Oct 1991), 34.



Figure 2.1. Map of California Showing location of Bodie to other California tourism regions.

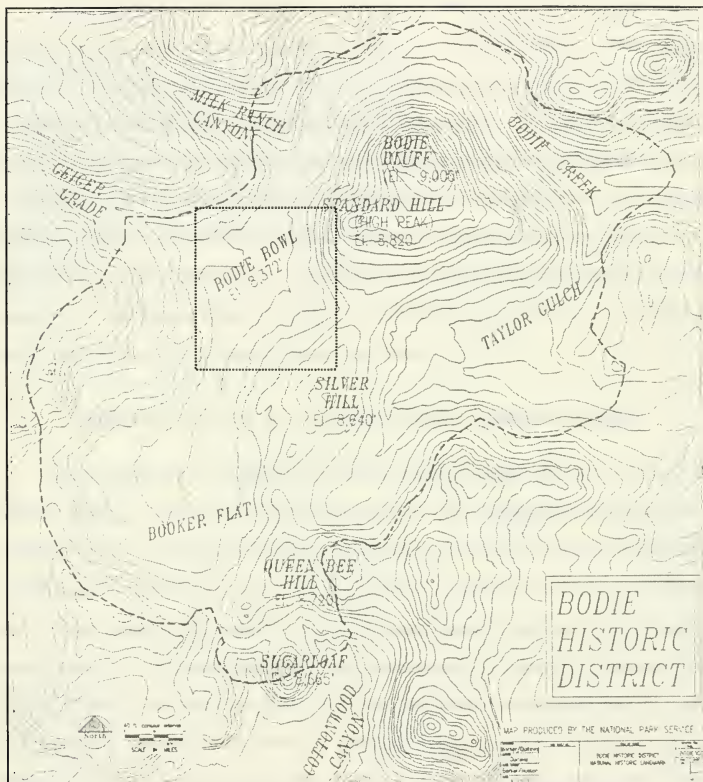


Figure 2.2. Topographic Map of Bodie Historic District and surrounding region.

The townsite of Bodie comprises approximately 320 acres of land, divided into 29 blocks, which are subdivided into approximately 875 lots of various sizes.³ Today Bodie, managed by the California Department of Parks and Recreation as a State Historic Park, is a popular site that attracts hundreds of thousands of visitors per year.⁴ No permanent inhabitants occupy Bodie (other than a few park rangers and maintenance workers who monitor the site as an historic ghost town), yet approximately 120 buildings are still standing, including a Church, the school house, a few hotels, a fire house, and the old Miner's Union Hall [Figure 2.3]. Although the remaining structures only comprise about a fifth of what once existed, the town remains one of the best examples of an early western mining ghost town, and is in desperate need of preservation if it is to survive generations to come.

Significance of Bodie as a National Historic Landmark District

Interest in Bodie as a significant historical site first started around the turn of the twentieth century. The then nearly abandoned town was highlighted in various local newspapers during a time when ghost towns “stood as a symbol of the wild and wooly West; evoking images of gunslingers, dance hall girls, and the rough miner with his secret stash of gold.”⁵ These romantic perceptions of the old West lured visitors westward, as the automobile became popular and increasing numbers of Americans explored the country via the newly built highways. Many of the auto tours in the 1920s and 30s focused on the more popular coastal sites such as the Spanish colonial missions, beaches, Yosemite, and the redwoods-- yet the intrigue of Bodie's pristine landscape full of historic mining relics drew the travelers to the opposite side of the Sierras, despite its distance and isolation.⁶

³ “Report on State Park Potentialities of Old Town of Bodie, Mono County, California, Project No. 3033,” (State of California Department of Natural Resources, Division of Beaches and Parks, November 12, 1958), 3.

⁴ Visitation records for the fiscal year 1995-96 indicate 216,539 cars entered Bodie State Historic Park. Park Basics, Cal-Parks Home Page, Bodie State Historic Park, available from <http://www.cal-parks.ca.gov/DISTRICTS/sierra/bshp324.htm>; Internet; accessed 21 April 1999.

⁵ Huston et al., 48.

⁶ Huston et al., 33, 48.

BODIE

STATE HISTORIC PARK

Visitors with disabilities should contact the park office to inquire about availability and accessible facilities to determine if they meet their specific needs.

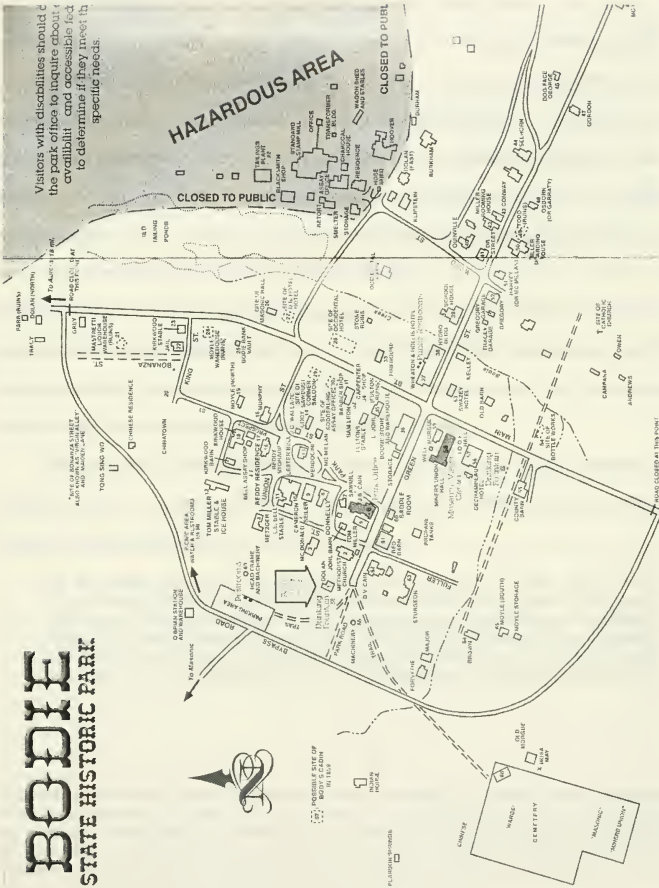


Figure 2.3. Current Map of Bodie Townsite from Park Brochure

Bodie's integrity as a 'true ghost town' is due largely to the care of local banker J.S. Cain, who purchased the abandoned properties as people moved away.⁷ For several years, Cain personally gave tours to passing visitors interested in witnessing the emerging ghost town first hand. Because of Cain's guardianship, the majority of structures were protected from the scavengers and vandals who plundered several nearby mining towns. Consequently, Bodie was left with a large and well-preserved collection of homogeneous buildings in situ, each possessing various clues to the lifestyle and material evidence of the construction techniques of the early mining town. Because of the decline of 20th-century construction activity, and its virtual cessation after 1940, Bodie gains its integrity from the lack of intrusive, non-contributing resources in its historic landscape, rather than the condition and number of individual contributing resources that remain.⁸ Bodie's significance is due to the multitude of remaining buildings in their natural setting, unlike other Western towns that have managed to maintain only select vestiges of their mining past [Figure 2.4a].

Recognition by California officials of Bodie's significance as a highly valuable cultural site began in 1956. A letter from Historian Aubrey Neasham to Newton B. Drury, Chief of the Division of Beaches and Parks, on February 27 notes:

"It is hoped that every consideration will be given by the State Park Commission for the incorporation of Bodie in the State Park System. Not only will it be an illustrious addition to our historical areas, representing an important theme of the early American period, but, also, its scenic setting is such that it represents a typical desert park where sagebrush, the pinon, and rabbit-brush predominate... Provided enough land is acquired, here would be preserved one

⁷ According to *The Sunset* guide to Western ghost towns, a companion to *Sunset's* other popular guides to cultural and natural sites in the West, a 'true ghost town' has a population at near zero; and its contents may range from many vacant buildings to rubble and a few roofless walls. By this definition, Bodie therefore is a 'true ghost town' versus a 'partial ghost town' which is mingled with modern elements or a 'tourist ghost town' which is a living town that has significant elements from mining rush or other historic eras, but the old structures are spruced up or rebuilt to promote tourist atmosphere. *Ibid.*, 50.

⁸ *Ibid.*, 8. The National Register Programs Division defines in their National Landmark Documentation that there are 152 contributing buildings, six non-contributing buildings, one contributing sites, three non-contributing sites, 490+ contributing structures, 86+ non-contributing structures. This totals 652+ contributing elements to 95+ noncontributing elements. *Ibid.*, 1.

of America's great historic scenes in a natural setting little changed during the last century."⁹

The 1958 National Survey of Historic Sites and Buildings summarizes the significance of Bodie best by stating:

"its location, setting and total isolation from civilization make it almost the prototype of the Western ghost town; in terms of the number of buildings which have survived and their unusually good condition, Bodie is one of the best preserved of the old mining camps; its history, while typical of the strike, boom and decline cycle, was unusually long and colorful, and in a period when desperadoes and hard cases were a dime a dozen, a 'Bad man from Bodie,' was universally recognized to be a particularly unpleasant ruffian. Few gold towns of the West today so aptly typify the life and times of the mining frontier."¹⁰

In response, a Report on State Park Potentialities of the town of Bodie was filed shortly thereafter in 1958. Following the request of the State Division of Beaches and Parks were an appraisal of the personal property made by Butterfield and Butterfield Auctioneers of San Francisco, and an investigation of the town by J.T. Arsenio and L. I. Backstrand in 1960 which resulted in a Factual Data Report.¹¹

Bodie was designated a National Historic Landmark by the U.S. Department of the Interior on July 4, 1961 as an Historic District of Mono County, California.¹² It became a California State Historical Park in 1962, and continues to be protected under their supervision.

⁹ Aubrey Neasham, Historian to Newton B. Drury, Parks Chief, Regarding the Proposed Bodie State Historical Monument, (State of California Division of Beaches and Parks Department of Natural Resources, 27 February 1956), 3.

¹⁰ William C. Everhart, ed. The National Survey of Historic Sites and Buildings, Theme XV, Westward Expansion and the Extension of the National Boundaries to the Pacific, 1830-1898, "The Mining Frontier." (U.S. Department of the Interior, National Park Service, 1959) quoted in Huston et al., 30.

¹¹ Reeder Butterfield, Auctioneer to Mr. John A. Hennessey, Senior Land Agent, "Appraisal Personal Property Bodie Project, Bodie California" (San Francisco: November 10, 1960); J.T. Arsenio and L.I. Backstrand, "Factual Data Report covering Old Bodie Townsite" (Submitted to Division of Beaches and Parks Department of Natural Resources State of California, March 20, 1960. (The California Division of Beaches and Parks, within the Department of Natural Resources, was reorganized as the Department of Parks and Recreation, within the Resources Agency, on July 1, 1961.)

¹² In the opinion of NPS staff, the Context for Evaluation: "This nomination form addresses only the NHL qualities of the Bodie Historic District within the original intent of its designation. The district and individual properties within it are assumed to possess State and local values, as well as other national values, which would meet some or all of the National Register criteria. Bodie's position in the local and State mining economy should be examined under National Register Criterion A. Bodie's associations with such notable persons as Thomas Leggett, Theodore Hoover, A.J. McCone, and J.S. Cain may be significant under Criterion B. The large collection of late 19th century vernacular architecture would appear to be significant under Criterion C; the mining-related resources also may possess engineering/industrial significance under this criterion. Surveys

Despite Bodie's recognition as an extraordinarily intact and complex historic landscape, the historic mining town remains threatened by its harsh environment. Other threats identified by the National Historic Landmark Status Report in 1990 were incompatible alterations, moved buildings, and alterations to exteriors, porches, window, roofs, and interiors. In theory, it is the job of the State Park to maintain and protect the authenticity of Bodie's structures. Yet as Jack Gyer, Curator of the Yosemite Museum Collection noted in his National Landmark Inspection Visit Report of 1977, "This concept of stabilizing and holding to the last physical evidence of an era in the State's history is adventurous and exciting for visitors yet poses the problem of a delicate balance for management." The very nature of a ghost town assumes a state of abandonment and deterioration, and the dilapidated condition is considered an intrinsic quality of the ghost town. Yet, although the town of Bodie wears its dilapidation with dignity, free from commercialization, how can the structural fabric be protected against a devastating climate without betraying change? This thesis may provide a few suggestions to answer this question.

Brief History of Bodie as a Mining Town, its discovery and growth

There is a plethora of information on the history of Bodie as a mining town. Most of these references are excellent sources of the town's long history as a productive mining district, its developmental evolution of mining technologies, the reputed violence and dangerous characters exemplifying the harsh life in the hard-rock mining community, or the folklore associated with the "Bad Man from Bodie." Nothing has been written about the history of the built environment. I will give a brief overview of the history of the town as it relates to its architecture, as an illustration of its quintessential boom and bust cycles that converted a potentially prosperous mining town into an abandoned ghost town within a relatively short period of time.

Bodie's history as a mining boom town is short lived. The first claim was staked by Waterman S. Body in 1859. Although Body died in a snowstorm that year, a small group of miners working claims in the basin paid their respects by naming the mining district after him in 1860, putting Bodie on the map. The period between 1860 and 1863 showed little more than fifteen or twenty claims working within the area, and the camp was scattered with a few tents and small wooden structures. The camp was still in a rather undeveloped state, with transient miners drifting in and out of the area as the various claims changed hands. Population grew slowly but steadily, with the construction of more wooden structures. By the beginning of 1863, real estate prices started to rise as the townsite was surveyed. The following year saw twenty additional frame and adobe buildings, and the lots and town streets were marked out with stakes.¹³ Some intermittent mining started during this period and continued until 1874. Soon thereafter, there was a three year depression in the mining and probably not more than 100 people living in the town.

The first big strike was made in Bodie in 1877, initiating an excitement in and about Bodie that lasted through the early 1880s. News spread widely and rapidly that there were rich diggings at Bodie. The Bodie Weekly Standard mentioned in November of 1877, the glad noise of the "click of the hammer and the buzz of the saw from morning till night."¹⁴ It has been speculated that by December of 1877, 500 to 1,000 people inhabited the town, marking the start of the Bodie Rush. In addition to the profitable mines in operation from 1877 to 1882, a speculative fever swept Bodie as people started to populate the town. Headlines in the Bodie Standard exclaim "Don't Rush In," as the rush that autumn had been greater than was expected and "there was not adequate preparation made for their reception; and now it is impossible-

the historic period are excellent and may be eligible under Criterion D." Huston et al., 31.

¹³ From J. Ross Browne's visit to Bodie in September, 1864. His trip appeared in the *Harper's New Monthly Magazine* 31 in 1865.

¹⁴ Bodie Standard, 7 November 1877: 3/4.

owing to the lack of lumber."¹⁵ Real estate became a valuable investment, another way to get rich quick.

Economically, things looked good for Bodie during this period. More two-story structures and permanent buildings were being constructed of brick and stone. A lot in the center of town in 1878 was worth over \$1,000.¹⁶ The San Francisco Examiner was referring to Bodie as a mining city. In April of 1878, the Bodie Standard boasts, "In short, it is a lively, pushing place; fine commodious buildings going up: eligible lots commanding a good price, and the place generally wearing a look of prosperity and permanency, for the citizens seem plainly to say we have come to stay."¹⁷ As building surged ahead, the town consisted of over 250 commercial and residential structures in the center of town and an additional 100 along the ridge just south of Bodie Bluff.¹⁸ The majority of these buildings were not very elaborate, and made entirely of wood.¹⁹ Included in the commercial structures that lined the one mile long Main Street were as many as fifty saloons, a match of brothels and dance halls, a dozen lawyers, a few physicians offices, a score of restaurants, several hotels, and various residences. By the end of 1878, Bodie had increased to over 600 structures and a population of over 5,000.²⁰ By September of the following year, there were approximately 10,000

¹⁵ Bodie Standard, 19 December 1877: 2/1. The Reno Journal stated on the 18th of Dec. that Johnnie Boyd left for Bodie with 13,500 feet of lumber and 3,500 shingles. The Reno Lumber Company made monthly shipments to Bodie thereafter. Ibid., 26 December 1877: 2/3.

¹⁶ Ibid., 6 March 1878: 3/5.

¹⁷ Ibid., 24 April 1878: 2/3.

¹⁸ "Many of the denizens of Bodie are unaware that a town of very respectable dimensions exists on High Peak Hill, in the immediate vicinity of the mines. This town is made up from the workmen in the mines, who prefer to eat and sleep in the immediate vicinity of their work to taking the tramp down to Bodie and the climb back two or three times a day....There are probably 75 or 100 buildings on the hill, outside of the hoisting works with their accessory black-smith shops and other necessary structures. Many of the houses are occupied by miners and their families, but the larger ones are devoted to the uses of boarding houses." Ibid., 11 December 1878: 6/2.

¹⁹ The Engineering and Mining Journal in 1878 states, "The houses are of the usual undressed lumber and canvas-lined variety so common in all new mining camps, with here and there a more pretentious painted front. *The Engineering and Mining Journal* 26, no. 17 (Oct. 26, 1878): 296.

²⁰ Ibid., 25 December 1878: 2/5.

persons living in Bodie inhabiting over 2,000 buildings in town and another 1,000 on the hill [Figure 2.4b].²¹

Despite the quick increase in Bodie's population and construction, the boom period only lasted three years. As the decade came to a close, the townspeople slowly deserted as production declined in the 40-50 previously profitable mines. The real estate market was stagnating in the summer of 1880 and new construction was halted.²² Vacant buildings were moved to other districts, and abandoned houses and vacancy signs were increasing in occurrence.

The years from 1882 to 1889 demonstrate Bodie's decline. By the end of 1883, all but six or seven of the larger mines had closed and by 1887 the Standard and Bodie mines consolidated and were the only mines able to operate profitably for the next twenty years. Miners moved on as opportunity ran out, decreasing the town's population from 3,000 in 1882 to fewer than 2,500 in 1883, with a continual decline to 1,500 by the time the Standard and Bodie mines consolidated. With only 15 stamps operating in 1889, and production at only 4% of 1881 levels, the population had once again halved, and there were almost three times as many vacant buildings as inhabitants. Bodie was starting to take on a dilapidated look with numerous vacant wood-constructed buildings posing a major fire hazard.²³

Unlike some of Bodie's counterparts, the mostly wood-constructed and heated town managed to elude any major fires during its boom and decline, until July 28 of 1892. In the early morning, a disastrous fire swept over Main Street, decimating over sixty structures within the business section. The town rebuilt quickly, but a majority of the replacement buildings

²¹ This figure is disputable. An 1880 U.S. Bureau of the Census, Table XIV numbers Bodie's inhabitants as 6,000, although local newspapers and some historians claim that the town's population was 7,000, and even 10,000.

²² Despite the halted construction, The Bodie Railway and Lumber Company was formed to tap a tract of 12,000 timbered acres south of Mono Lake the same year. The Mono Lake sawmill, opened in August was capable of producing 15 million feet of lumber and 100,000 cords of wood per year. The rail line was completed in December, 1881. J.E. Ransom, "Old Timer Relives Days when Railroad Was Built in the Sky" California Highway Patrolman 13, no. 7 (1881): 16-17, 121,124,128-130.

²³ Public concern over the fire issue led the local newspapers to press for better fire prevention. As a result, within the following two years, Bodie had two companies of firemen, a system of hydrants throughout the town, and a special fire tax to support the salary of a fire inspector and for equipment upkeep.

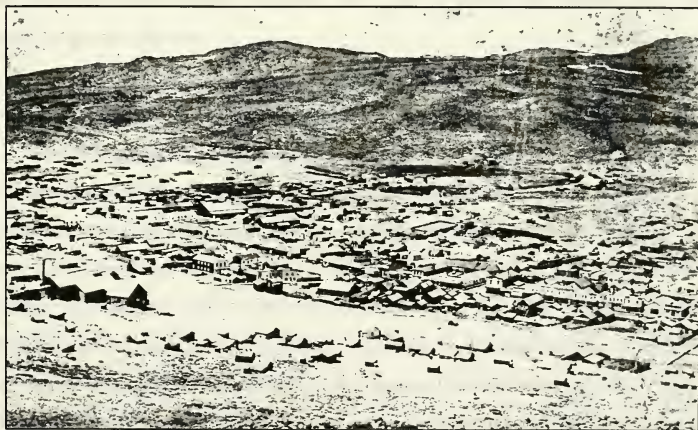


Figure 2.4a. Recent Photograph of Bodie looking South-West. Photo taken 27 Aug. 1997 by P.D. Schulz.

Figure 2.4b. Historic Photograph of Bodie looking South-West. Courtesy California Department of Parks and Recreation Photographic Archives.

were moved from peripheral areas of town. For the next few years, the town remained stagnant with the Standard Mill still in operation. In 1918, the Bodie Railway and Lumber Company removed their tracks, making the acquisition of building materials and cord wood for heat more difficult. By the 1920s, Bodie's appearance as a ghost town was taking distinct shape and although it still had residents, tourists were beginning to pass through in hopes of experiencing "the wild West" first hand.

The final blow came in June of 1932, when Bodie experienced the worst fire in the town's history. The flames consumed nearly 90 percent of the remaining buildings, hastening the end of Bodie as a living town. There was no rebuilding after this fire. What the fire hadn't reduced to ashes represents what still exists today. 1942 marks the year of near abandonment, but the structures that remain are a vestige of the district's several boom and bust cycles, each leaving visible traces of its industry and technology, commerce, occupation, and social life. The State of California acquired the town in 1962, and has managed the property as a State Historic Park since that year.

The Rapid Erection of the Buildings

Bodie's history as a mining town represents the quintessential experience of many mining towns in the West. The built environment that resulted from the rapid rise and fall of population, the scarcity of materials, and the overdriving desire to "get rich quick" can be seen in the buildings that survive today. The National Register nomination refers to the wooden buildings as exhibiting "vernacular Victorian characteristics in their form and detailing, with Italianate brackets, boxed eaves, and decorative millwork."²⁴ But few buildings exhibit more than the most rudimentary millwork detailing and most bear no resemblance to formal Victorian ideals of construction and design. One might expect that a Western community that was so directly tied to the Industrial Revolution might make use of the advancing technology such as

²⁴ Huston et al., 23.

balloon-framed construction techniques or exhibit the stylistic trends of contemporary cities in the West.²⁵

Bodie was not unique in its use of single wall construction, nor in its tacked-on aesthetic in place of a formal architectural style. Such patterns were evidently once commonplace in mining towns in the West, as well as other isolated communities across the country.²⁶ The use of single wall construction within the isolated and itinerant community allowed for rapid erection, as it required fewer materials and was thus cheaper than available alternatives.

In the first years after gold was discovered on Bodie Bluff, the residents were few, and the habitations were probably dug-out shelters, tents, or small adobe dwellings. Transience was a contrivance of these early prospectors, therefore very little emphasis was placed on the construction of dwellings. Their original placement was probably of a haphazard fashion, located adjacent to individual mining claims.²⁷ The majority of prospectors in Bodie were single men, who had few needs other than a small shelter, in which to sleep, considering that other necessities could be obtained from the local restaurants and saloons. Their “flimsy and “shoddily constructed” habitations, as they have been referred to by some historians, were determined by an immediate need for shelter, and by the lack of time, interest and money to invest in what might only be a temporary place of residence. It was not known how long any particular mine would be profitable, and this uncertainty was felt at every level of the mining

²⁵ Except for the false-front commercial buildings on Main Street (most of them are now gone), these outside influences had little impact.

²⁶ Several references are made of “single-wall construction” or “box construction” in areas such as the Ozarks, Nevada, the South, and the Great Basin. Jean Sizemore, *Ozark Vernacular Houses* (Fayetteville: The University of Arkansas Press, 1994), 156-159; Steve Mitchell, Donald R. Brown, and Michael L. Swanda, “Board Shanty: Box Construction in White County, Arkansas” *Pioneer America Society Transactions* 10 (1987): 9-16; Howard Wight Marshall, *Paradise Valley, Nevada* (Tucson: The University of Arizona Press, 1995), 30-36; Diane Tebbets, “Traditional Houses of Independence County, Arkansas” *Pioneer America* 10 no.1 (1978): 37-55; Michael Ann Williams, “Pride and Prejudice” *Winterthur Portfolio* 25, no. 4 (Winter 1990): 217-230; Thomas Carter, “Building Communities,” *Common Ground* 37, no. 2/3 (Summer/Fall, 1998): 54; and Deborah Lyn Randall, “Park City, Utah: An Architectural History of Mining Town Housing, 1869 To 1907” (Master’s Thesis, University of Utah, 1985).

²⁷ Ruins of stone shelters can be found in Milk Ranch Canyon, Taylor Gulch, Silver Hill, Queen Bee Hill, and other parts of the district. Wedertz, 73.

resident's life. As word spread that a claim was producing ore, thousands of expectant miners and laborers would pour in from all over, creating additional tension derived from economic competition and social instability. The miner's ties to the community were not strong, as large groups of hardened itinerant men and women migrated into town from other declining camps in California and Nevada. Their primary interest was in making a quick dollar, not in creating a settled, safe livable place.

Bodie's isolation aroused further instability in the initial growth of the town. But as the mines continued to produce, and people were staying around, the hard setting forced the people to respond to its needs in a more deliberate way. In even a mild Bodie winter, temperatures dropped to subzero levels, and the common canvas tents were dangerously inadequate. More substantial wood houses would be required to withstand the winters, bringing income to carpenters, lumber dealers, and to the freighter who brought the lumber in.²⁸ In demand from the influx of population, lumber for construction and cordwood for heating homes and powering the steam hoisting and milling operation were consumed at an enormous rate. A new industry of lumber supply resulted, and eventually a Railway and Lumber Company was formed to access timber from south of Mono Lake and neighboring regions such as Bridgeport and Benton.²⁹

Even though there was a gradual transition from the initial squatters' dwellings to frame houses, the latter were only a slight improvement over the former. The buildings were constructed of white pine, a soft wood native to the surrounding area. They were of milled wood, with wood shingles and gable roofs. The exterior siding was often not more than an

²⁸ "Lumber- As will be noticed by reference to our advertising columns, under the heading of 'New To-day,' it will be seen that the Bridgeport saw mill is prepared to receive orders for lumber, which will be delivered in Bodie at the moderate price of \$45 per thousand. The roads are now good, and it is probable that we shall not see a time this Summer when it will be cheaper, and it is therefore a good time for those who intend to build or use lumber to lay in a supply. Mill and mining timbers are made a specialty at this mill. Mr. J.J. Welch, at Bryant & Co.'s store, Bodie, is agent for the Bridgeport mill, and orders will be received by him." *Bodie Standard*, 17 July 1878: 7/1.

²⁹ Earlier sawmills built to supply the Monoville mines were located on the slopes of the Eastern Sierras and along Mill Creek and Lee Vining Creek, at least 20 miles from Bodie. Other mills were eventually located in

inch thick, made of board and batten, and anything else that could be scavenged throughout the region. The most frequent size for the dwellings were a 12' x 20', hall/parlor plan built with single-wall construction techniques [Figures 2.5a & 2.5b].

As the residents became more settled, and families grew and incomes increased, successive shed additions were made to the initial residences, with little regard to aesthetics or structural compatibility [Figure 2.6]. In the book *Instant Cities*, Gunther Barth talks about the overriding demand for practical solutions in mining architecture and states that “functional and pragmatic considerations dominated [in building construction] and there was little concern about appearances.” Only after Bodie had proven itself a sustainable city in the late 1870s did aesthetic concerns drive the construction of more permanent brick and stone buildings. As the town developed, there was an increased need for additional service professions to support the mining industry, bringing in doctors, lawyers, educators, et al., who brought in their families. The presence of women then, played an additional role in the changing attitude of Bodie’s appearance. Evidence of their influence can be seen in some of the remaining houses such as decorative wallpapers, organized room arrangements, and the presence of kitchens.

The majority of buildings, even after the boom period, were of single wall construction, with the exception of the most prominent commercial buildings along Main Street which had balloon-framed false front facades [Figure 2.7]. During the boom, there were a number of two story wood structures built, but less than ten of these remain today. The use of single-wall construction in Bodie was just as commonplace in the Western mining town as its boom to bust cycle. Had Bodie not suffered a downturn of mining activity, it might have grown to the size and success of various other modern mining towns within the region. Yet with the improvements consequential of a thriving and modifying city, the integrity of Bodie’s single-wall buildings would have been compromised to furred-in or stud-wall alterations. What makes Bodie unique is not that it was the only town to implement single wall

Bridgeport and Benton. The Mono Lake sawmill, opened in August 1881, was capable of producing 15 million feet of lumber and 100,000 cords of wood per year. Wedertz, 154, 159-161.

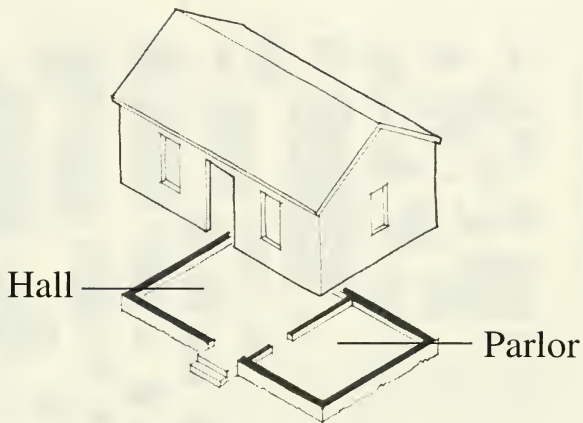


Figure 2.5a. Diagram of typical Hall/Parlor style house. Most common form of original buildings in Bodie.

Figure 2.5b. Photograph of North-East elevation of Kelley building along Green Street. Photo taken 3 Sept., 1998 by A. S. Morrison.



Figure 2.7. Diagram of all Bodie Buildings showing construction materials. Shaded area indicated predominance of single-wall construction. (Building footprints are drawn to scale, but not in spatial relation to each other.)

construction, but rather one of the few remaining collections of this building type that has transgressed virtually untouched to the end of the twentieth century. This is what makes Bodie an ideal laboratory for understanding not only the industrial and social aspects of life in a Western mining town, but more importantly, the use and techniques of single-wall construction as a common building practice across America.³⁰

Single Wall Construction Techniques

The predominance of single wall construction in early mining towns is illustrated as early as 1878, when an observer of Bodie describes the town as:

“all of the buildings in Bodie are constructed after the usual method of mining camp structures. The floor is close to the ground, the walls are of one-inch boards with battens over the cracks and the roof is steep and covered with shingles. The interior is covered with muslin to which is pasted wall paper. The sheet iron stove pipe goes through the roof with a sheet iron flashing to prevent fires and one bathes in a basin with water from the town well. The sanitary arrangements are provided in the structure known as a privy located some distance from the house and a very trying place with the thermometer standing at 20 degrees below zero.”³¹

So what is this “usual method of mining camp structures,” and how is it different from other building techniques of the same period? In short, single wall construction is a vernacular construction technique that is derived from plank construction from New England and the Midwest, but allows for the rapid erection of buildings by relatively unskilled workmen. Very little has been written about single wall construction to date, largely due to the fact that until recently little was written about any form of modest, vernacular construction trends in general, and that many of the single-wall structures have been altered by the use of boxed-in frames to thicken and insulate the exterior walls.

³⁰ Descriptions of pioneer's homes and single-wall construction technique were published in popular journals as early as 1858. *American Agriculturist* 17 no. 3 (March 1858) 73-74; *The Country Gentleman* 19 no.9 (February 27, 1862): 146; and *American Agriculturist* 49 no.11 (Nov. 1890): 555.

³¹ Herbert L. Smith. “The Bodie Era: The Chronicles of the Last Old Time Mining Camp,” Typescript at California State Library, n.d., 12.

Bodie's single-wall buildings vary occasionally, but predominantly fall under a uniform building technique. As previously mentioned, the model size for the original residences was 12' x 20'. With the exception of a few more elaborate buildings, the structures do not have foundations. Many of the residences have partial dug-out root cellars below with either stone or wood retaining walls. The buildings rise from 4 x 6" (in some instances 2 x 4") plates that rest directly on the ground. The plates are usually on edge (although some are flat), and lapped at the corners. 2 x 4" floor joists sit on top of the plates and support the 1 x 3" to 1 x 6" floor boards (frequently tongue & groove). There are no corner posts or vertical members of any kind, other than the vertical siding that connects the bottom plate to a flat 2 x 4" top plate. The exterior siding is of random width (usually 1 x 12") with 1" battens covering the cracks. The top plates are also lapped at the corner, or sometimes they are mitered at the corner joints and nailed together with cut nails [Figures 2.8 & 2.9].

The roofs are of very simple form as well. 2 x 4" Rafters meet at the ridge with no ridge member supporting them. Except in very few cases are there ceiling joists tying the heels of the rafters together. Only in some of the larger structures such as barns is there any attempt at a truss system. The rafters rest on the flat 2 x 4" top plates and are either miter-cut over the plates or bird-mouthed to fit onto the plate. The dimensions and angles of these cuts vary somewhat. Roof sheathing is usually 1" thick boards, that are usually continuous. On top of the sheathing are wood shingles to keep the water out, or in several cases recycled and flattened out tin can shingles. In some instances, the tin can shingles are used as an exterior siding as well [Figures 2.10a & 2.10b].

The interior walls used to subdivide the rooms give little structural support to the system. They consist of vertical boards of varying widths nailed to a 2 x 4" ceiling joist, their lower ends toe-nailed to the floor. The tops of the wall boards are often left untrimmed. The interior of most of the buildings were first lined with muslin or other cloth and then papered with decorative wall papers [Figures 2.11a & 2.11b]. The ceilings are normally of suspended

TONG SING WO SECTION LOOKING NORTH

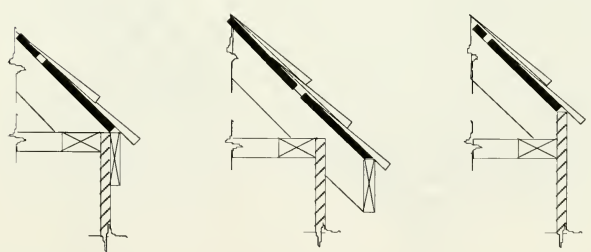
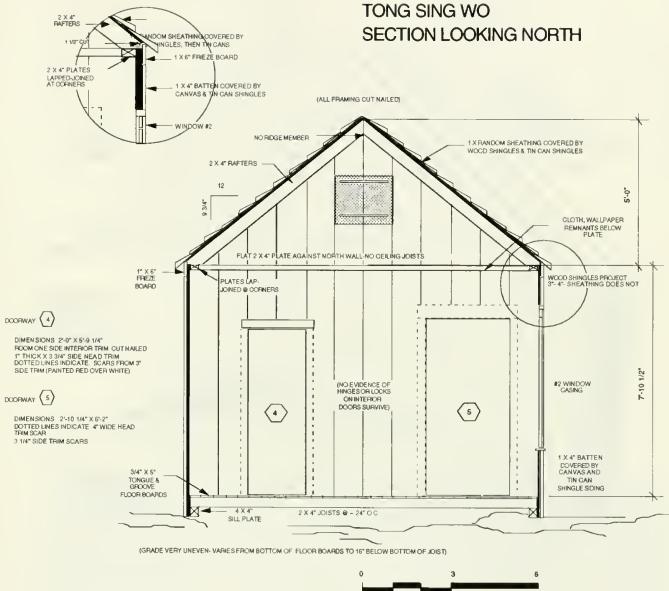


Figure 2.8. Illustration of typical single-wall construction techniques. Diagrams on bottom of three different roof-wall connections.

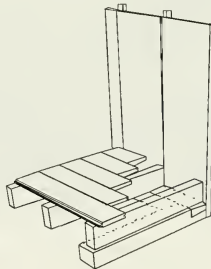
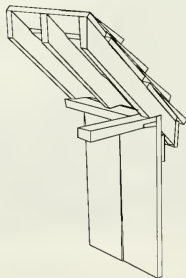
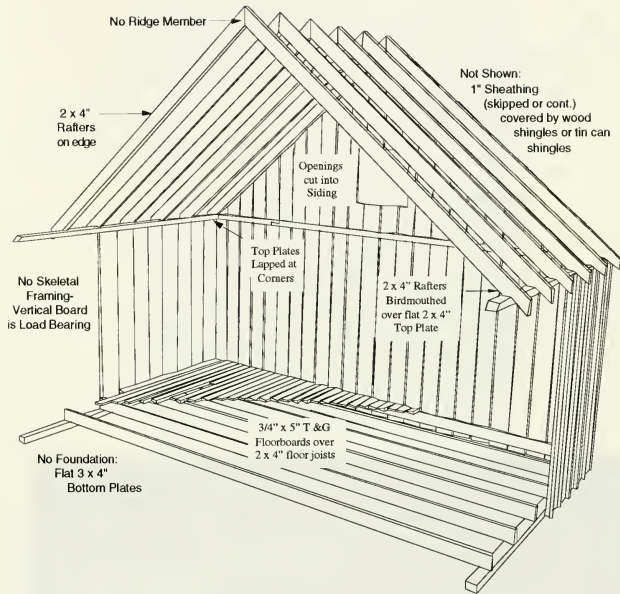


Figure 2.9. Diagram of typical single-wall construction techniques. Note lack of skeletal frame.

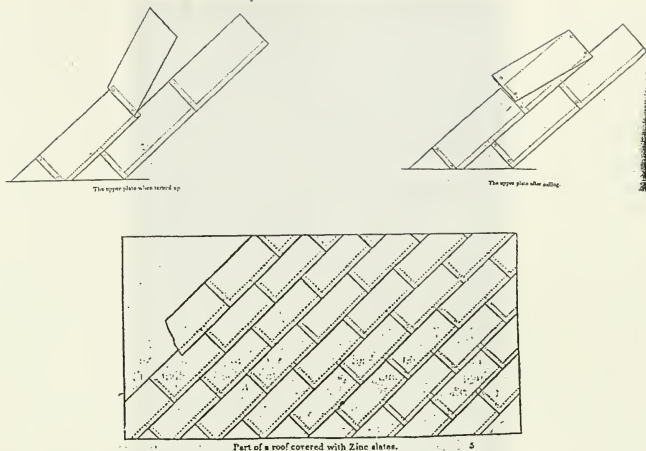


Figure 2.10a Diagram of technique for connecting metal shingles together. From Zinc Mining Company, Zinc Roofing. A Description of The Latest and Most Approved Systems of Zinc Roofing. (Liege, Belgium: "Vielle Montagne," January, 1850), 28-29.

Figure 2.10b. Photograph showing use of tin can shingles. South-East elevation of Tin Cabin. Photo taken 12 Aug., 1997 by P.D. Schulz.



Figure 2.11a. Photo of interior wall showing tops untrimmed & use of wallpaper.

Figure 2.11b. Photo showing insulation techniques; canvas, muslin , and newspaper.

cloth, again covered with wallpaper. Because single-wall construction has no interior structural frame, there is no room for the service of insulation. Once again, the miners used what they could find to exclude inclement weather. The insertion of builder's paper, scraps of cloth, newspaper, or rags made from clothes stuffed between boards or in open joints or cracks was common. There is a plethora of tin can lids nailed over knot holes as well. The use of recycled materials is prevalent at Bodie, which is illustrative of a frugal and resourceful lifestyle [Figures 2.12a].

The exterior siding is only one inch thick, but on some buildings, additional siding was added over the original: a response to the long, harsh winters. Such augmentations frequently consist of additional layers of vertical boards nailed over the original in place of battens, with new battens then added to the new exterior. There are also occurrences of shiplap siding and horizontal drop siding, especially on primary facades. In several cases, horizontal siding was used on the primary facade only, with board and batten on the side and rear walls.

The door and window openings were cut out after the walls were constructed, and infilled with ready-made sills and door frames. Some of the window sashes show evidence of a local craftsman's work, with the muntins pre-cut, then fitted together with wooden pegs or bottle corks to suit individual openings. The windows are mostly six-over-six sash. Few houses used chimneys, as wood burning stoves were used for cooking and heating. Many of these stoves are still present in the abandoned houses, but for those that are missing, evidence of flue pipes penetrating the roof sheathing tell where the stoves were originally placed.

As the inhabitants remained, certain alterations were made to the original structures. "L" shaped-additions were common of the more elaborate buildings, where a separate gabled room would be added off one side of the original Hall/Parlor structure. In this case, the framing for the new roof addition would be laid directly on top of the sheathing of the original building, a term coined as "California addition" [Figure 2.12b]. With an "L" addition, the walls of the new room are butt-up against the exterior of the old, and no effort is made to tie the



Figure 2.12a. Photo showing use of recycled materials. Building O, Rm. 5, East wall; tin can seal over knot holes. Photo taken 13 June, 1996 by P.D. Schulz.

Figure 2.12b. Photo showing "California Addition;" new roof is constructed directly on top of the original without removing shingles. Selhorn building over Rm. 2 looking North. Photo taken 29 July, 1997 by P.D. Schulz.

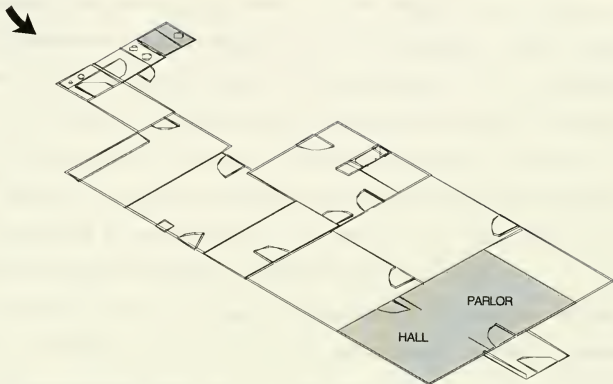
two structures together by use of rabbits or grooves. All connections are simply nailed together, with each successive addition layered on top of the previous. In the less prosperous households, less crafted shed additions were made. The rafters for these rooms were also laid on top of the previous roof, and in some instances, the shingles or tin covering were never removed [Figure 2.13a & 2.13b]. The less-skilled workmen, more than likely the owners of the houses themselves, paid little attention to the slope of each successive shed roof, thereby creating areas of pooling water and unnecessary loads that compromise the stability of the building as a system.

One rather interesting phenomenon of Bodie is the way in which successive additions were tacked on to the previous additions of a slightly larger size, sometimes taking on a snake-like form, until eventually reaching the outhouse that had originated nearly 20' independent from the original structure. This phenomenon is referred to by California State Archeologist, Peter Schulz as “additive vernacular” [Figure 2.14a & 2.14b]. The buildings that best display this “additive” system are most often the buildings with the most structural failures. The more complex the connections of the rooms, the more opportunity there is for improper loads and water (or cold) penetration; a reality that the miners were well aware of based on the frequent presence of cotton, newspaper, or other items stuffed between the joints.

Widespread Use of Single-Wall Construction

The use of single-wall construction was a logical choice for the inhabitants of Bodie, as it was quick and economical to build. The construction was simple, and mill sawn lumber was cheap and readily available. Because the small houses have no real foundations or skeletal frames, the walls could be constructed whole on the ground and then stood up to form a room, similar to a house built of cards. In Charles Martin’s study of a Kentucky community, *Hollybush*, he describes this type of building as “box” frame construction because of the descriptive shape of the structure (“box” construction is a term used predominantly in the

Photo Taken from
Here Looking West
Toward High Peak



Additive Vernacular

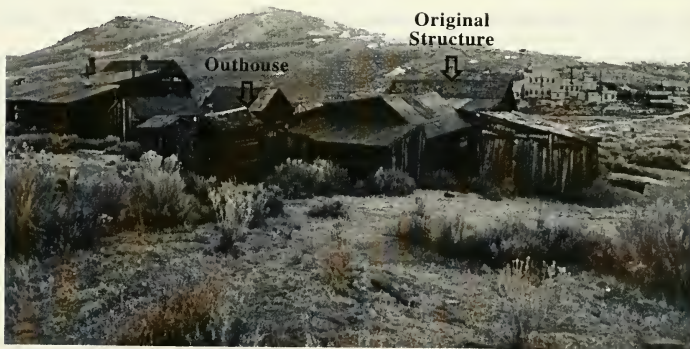


Figure 2.14a. Isometric Diagram of Reddy showing “additive vernacular.”

Figure 2.14b. Photograph of Reddy looking North-East. Photo taken 28 April, 1997 by P.D. Schulz.

South). Other authors, such as Walter R. Nelson and Dell Upton, make references to single wall construction in their writings, and according to Upton, single wall construction was an economical reinterpretation of plank framing in parts of the United States. Nelson describes plank frame houses as being built of vertical one to two inch boards of 12 to 24 inch widths attached to a heavy frame. The vertical boards were generally either mortised, rabbeted, or nailed to the sills and plates of the frame. Clapboards were attached to the exterior of the building. This type of construction differs from single wall construction in that a single-wall house is supported by the exterior siding, with the absence of an internal frame, and the connections of the single wall buildings are realized by the means of nails.

The precedent for the use of single wall construction at Bodie is clear. Its ease of fabrication and installation coupled with its low cost of erection relative to alternative construction practices available made single wall construction represented a minimal investment of both time and money; a sensible solution for structures that were meant to be temporary. Single wall construction was a logical outgrowth of plank framing, a building technique the miners may have brought with them from New England or other Eastern communities. Gunther Barth, in his book, *Instant Cities*, considers the use of imitation of Eastern and European models as a practical solution because they took less time to create. He also suggests that they provided familiar forms to masses of heterogeneous people seeking some type of identity in a new environment.³² Innovation and experimentation were limited to the bounds of familiar traditions and transmitted stereotypes.³³

³² Bodie was an ethnically diverse community and a rather cosmopolitan place. Many, if not most, of its miners were Cornish, and a large part of its shopkeepers, craftsmen, and laborers were Italians, Germans, Jews, Chinese and Irish. Paiute Indians worked as woodcutters and casual laborers. The Mexican population was represented, but few Black people lived in Bodie. Felton et al., 16.

³³ Deborah Lyn Randall, "Park City, Utah: An Architectural History of Mining Town Housing, 1869 to 1907" (Master's Thesis, University of Utah, December 1985), 5.

Park Objectives and Maintenance Philosophy

The California Department of Parks and Recreation have been managing the town of Bodie for the past 37 years as a National Monument and a State Historical Park. Throughout the past three decades, the State of California has attempted to maintain the structures at Bodie in a state that they call “arrested decay.” But just what exactly does “arrested decay” mean, and what are they intending to “arrest?” Clearly when the State acquired the property in the early 1960s, it was evident that some of the buildings were in a state of excessive disrepair, and in need of some sort of stabilization. It is the history of the park’s maintenance decisions that has led me to write this thesis. I am fascinated by the changing philosophies regarding appropriate “stabilization and repairs,” that the park has undergone in order to politically fit under the term “arrested decay.” Some avid Ruskinians might argue that the park’s current procedure of replacing historic fabric might fall into a more appropriate category of “creeping reconstruction.” It is my interest to analyze not only how the structures are failing physically, but also how the park may “stabilize” or “arrest” the buildings that will not compromise the integrity of the historic fabric.

The delicate balance of maintenance and preservation philosophy has long been felt. While reviewing various maintenance records and paperwork on Bodie, I have heard a strong argument for the preservation of buildings as they stood when acquired in 1962, yet there is equal commentary on the ever pressing problem of rapidly deteriorating fabric and building collapse.

In 1956, \$200,000 was appropriated in the State Park budget for the acquisition of the old mining town of Bodie as a historical monument. Prior to this date, several studies were made by the California Division of Beaches and Parks Department of Natural Resources as to the potentialities and recommendation for the town, including a Master Plan and Operations guidelines for the potential park. With that, it was recommended that:

“The key to the preservation and interpretation of Bodie is relatively simple. It should remain entirely a ghost town, with no attempt to revive its population, except for whatever personnel is needed for protection, operation, interpretation, and the use of the visiting public... It would be a mistake to restore the old town. Leaning buildings, broken windows, and sagging roofs are here an asset and must be retained if the ghost town atmosphere is to be retained. Stabilization of remaining buildings will be important, however, to keep them from disappearing entirely. To crystallize Bodie for all time exactly as it is when we acquire it would be the principle to follow.”³⁴

A field investigation of Bodie was conducted from June to September 1958. The detailed study of the area dealt with the state of repair or disrepair of the existing buildings and a report was composed of the analysis of the possible inclusion of Bodie into the State Park System.³⁵ In the study, it was stated that the town should be considered primarily a historical monument, and as such would undergo little change in the outward appearance of the town. It was understood and suggested, however, that stabilization and preservation of the buildings was necessary .

In 1955, Clyde L. Newlin, District III Superintendent wrote a letter to the District Chief regarding recommendations for the Master Plan and operations of Bodie. He believed that the buildings should not be restored, but rather stabilized to “retain the general appearance, the status quo.” He didn’t state specifically how the building would be “stabilized,” but said that they “should be stabilized structurally and retain all exterior appearance and charm of the authentic ghost town,” and that any material used should be of “proper character.” He specified that all wood surfaces should be treated with clear cuprelignum or another good grade preservative.³⁶ His recommendations for maintenance included “keeping the overall picture

³⁴ Aubrey Neasham, Historian to Newton B. Drury, Parks Chief, Regarding the Proposed Bodie State Historical Monument, (State of California Division of Beaches and Parks Department of Natural Resources, 27 February 1956), 2.

³⁵ It was documented that there was a total of 112 buildings still standing within the boundaries of the potential park, including sheds, outhouses, garages, houses and business buildings. 86 of the buildings were houses; of these 17 could be repaired and made livable—9 with a nominal amount of repair and 8 with extensive repairs. Nine buildings, other than houses, were recommended to be retained as they are. Of those nine, 3 would be used at once—the school, big red barn and brick building next to IOOF Hall. The buildings selected to be stabilized totaled 33, making a total of 50 to be considered for display. “Report on State Park Potentialities of Old Town of Bodie,” 13.

intact as of the present time,” and that it “should be one of retention and no changes whatsoever.”

According to Newlin, the initial stabilization would be on a progressive plan, taking structures and facilities on a priority basis, which could be accomplished by hiring two men. The appropriate materials and the stabilization of the buildings would be done in a manner needed in each individual case. Consequently, the maintenance program at Bodie has taken Newlin’s recommendations to heart, as this is the process by which the repairs have been made to date. Until recently however, little attention has been paid to the proper recordation of the stabilization efforts, or more importantly, the condition of the buildings before changes were made.

When Bodie first became a State Historic Park, Jack Evans made a resume of the Houses, consisting of a list of major buildings with comments. A more complete survey was completed by Arsenio and Backstrand, whose inventory included a single black and white photograph taken of the primary facade and a rough exterior footprint of each building. Other than this initial documentation, very little graphic documentation exists.³⁷

One of the first comprehensive stabilization efforts was done in the mid-1970s by Buck R. Nelson. Under Nelson’s supervision, some of the buildings within the core of the park were restored and modified to create year-round housing for the park personnel who maintain the area.³⁸ He attended to the immediate problems of fire protection, and the protection of the buildings from vandals, souvenir collectors and traffic. To alleviate the damage caused by

³⁷ In December of 1962, HABS/HAER surveyed the site and have minimal records and photographs of 13 buildings, including the Methodist Church, the Bank Vault, the Railroad Station, the Johl House on Main Street, the Jail, Schoolhouse, Wheaton & Hollis Hotel, D.V. Cain and J.S. Cain Houses, the Parr House, Murphy, the Boone Store, and the Miner’s Union Hall. Five of the buildings have measured drawings.

³⁸ Approximately 24 buildings are used by the State Park to house park employees and collection and provide office, work and storage space. Interior alterations were carried out on seven historic residences to create year-round and seasonal living quarters for park rangers. Work included new insulation and interior sheetrock walls, new plumbing and electrical wiring and fixtures. Similar alterations were carried out on the rear addition of the schoolhouse to house and catalog the park’s archival collections and to the red barn to provide office, work, and storage space. Approximately 17 other buildings in town are used to store vehicles, building materials, and other items. Because these alterations have had little effect on the building exteriors, and their integrity remains

excessive traffic, Main Street was blocked off, and a peripheral road was built around the town to the West that serviced a parking lot and public restrooms. Several of the structures were boarded up with recycled corrugated sheet metal or wire mesh to preclude entry into the potentially dangerous structures [Figure 2.15 a & 2.15b]. The sheet metal has helped to some degree to keep water out of the structures as well. The buildings were treated with fire retardant, but after the first winter and summer this practice was discontinued.³⁹

Nelson understood the difficulties of stabilization appropriateness well. After the initial barriers were placed in areas of hazard to the park visitor, he initiated weed control within the building areas, treated the wood with a wood preservative, and braced the buildings against wind, snow, and rain. He accomplished the bracing by inserting 2 x 4" shoring and cross-bracing on buildings that showed signs of structural weakness. His shoring still holds many of the buildings together today [Figure 2.15c]. The first few years of this stabilization effort was slow due to a shortage of money and personnel, not to mention the short working season (usually from the middle of June to the first of September). For buildings that required additional repairs, materials for their stabilization were collected from similar structures to Bodie's as they were dismantled all over California, and collected for reuse as funds and storage would allow. Nelson was careful to stabilize each building as deemed necessary, paying close attention to the conditions unique to each building.⁴⁰

Although the evocative nature of the collapsing buildings, scattered relics, mine shafts, and waste dumps make up the intangible quality that defines Bodie's historic significance, the

in character with Bodie's ghost town qualities, these buildings are still considered to contribute to the district. Huston et al., 10.

³⁹ It was found that this procedure was damaging the wood, causing the fibers of the white pine to disintegrate. Piles of wood slivers were found at the bases of the buildings. Buck R. Nelson, "Bodie, California: A Ghost Town Stabilized" (Paper presented at the Ghost Towns and Mining Camps Preservation conferences in Boise, Idaho, May 1974 and in Flagstaff, Arizona, April 1975, and the Developing Historic Districts in Small Towns and Cities Workshop in Salt Lake City, Utah, March 1975), Washington: The Preservation Press National Trust for Historic Preservation, 1977), 7.

⁴⁰ The Selhorn House was stabilized from the inside with sheets of plywood used as a diaphragm on the walls, whereas the Swazey Saloon, a two-story structure, was first braced from the inside, but later had to be reinforced from the outside as well. Some of the buildings, like the outhouses were small enough that Nelson used a 6-

structures require some form of preservation or stabilization to guarantee their sustainability for future generations. To date, some rather compromising alterations have been done in the name of preservation. But how much intervention is appropriate to fall within the goal of leaving the park in a state of “arrested decay?” Nelson asserts the contradiction best in 1975:

“Stabilizing while attempting to retain a ghost town appearance often presents problems of appropriateness. The buildings must be protected and, of course, the public, but the question arises: Where does one draw the line on the proper approach to take: Interiors must be protected from further deterioration from winter rains and snow. But roofs would lose their weathered look if reshingled. The answer in this instance may be a hidden roof immediately below the old roof, but such an approach is expensive. If the siding of the building is replaced to protect the building and visitor, one again loses integrity. On the other hand, if one does not replace deteriorated materials, how long will the basic historic fabric remain?”⁴¹

Regardless of one’s personal beliefs regarding the appropriateness of stabilizing or replacing historic fabric of the deteriorating buildings, the fact remains that the State Park’s maintenance plan to date has played a major role in the preservation of the remaining buildings and the historic landscape in the Bodie townsite. The National Historic Landmark Documentation makes an argument for the State Park presence at Bodie:

“Although the romanticized image of a ghost town would seem to indicate a condition of abandonment, a lack of human intervention, and an absence of people, the best-preserved and most well-known ghost towns are often managed by public agencies and attract numerous visitors. Without preservation action and protection against vandalism, most abandoned mining towns have collapsed and decayed into barely recognizable ruins or have been plundered for relics, equipment, and building materials. Thus, the little that remains in the truly abandoned and unprotected ghost towns often has less power to evoke the feelings and associations than the areas that have been preserved and interpreted for the public.”⁴²

inch by 6-inch piece of wood anchored in concrete behind the door. Other structures required larger amounts of work and material to bolster their original frames. *Ibid.*, 7.

⁴¹ *Ibid.*, 7.

⁴² Huston et al., 51.



Figure 2.15a & 2.15b. McMillan West, Window 4, exterior. Photo taken 8 July, 1997; Andrews, Window 6, exterior. Photo taken 22 May, 1997 by P.D. Schulz.

Figure 2.15c. Tong Sing Wo, Room 1, looking North with Nelson's shoring. Photo taken 16 August, 1996 by D.H. Chang.

CHAPTER THREE

ANALYSIS OF STRUCTURAL FAILURES

The ongoing condition of a ghost town is determined by its construction materials, length of abandonment, weather, isolation, and by the presence or absence of resident caretakers.¹ At Bodie, the presence of year-round Park personnel is aimed to protect the remaining structures. The Department has also attempted to prolong their life spans by undertaking a number of stabilization projects. Many of the methods used were defined in the last chapter. Yet despite the presence of park staff, Bodie remains one of the World's most endangered historic monuments.² This situation results from the fact that the buildings were initially constructed with insufficient bracing and a structural framework inadequate to withstand the region's environmental stresses. The majority of the buildings are in a state of structural failure. This chapter will classify the structural failures found in the single wall buildings at Bodie through an investigation of the forces, stresses, and environmental factors that have caused these failures through time. These data will serve as the foundation for the intervention strategies that will be introduced in the following chapter.

Structure as a System

The primary purpose of a structure is to provide shelter and to resist deformation. If not properly maintained, structures have a life span that is subject to limitation by various inescapable factors. Gravity, the forces of nature, and human neglect are among those factors that contribute to gradual demise. As defined by S.Y. Harris, a structure is the result of several

¹ Ann Huston, Leo R. Barker, and David Quitevis, "Draft Bodie National Landmark Documentation" (National Register Programs Division, Western Regional Office, National Park Service, San Francisco: October 10, 1991), 51.

² Bodie made the World Monuments Watch's list of the 100 most endangered sites for 1998-1999. World Monuments Watch Home Page available from <http://www.worldmonuments.org/watch.html>; Internet; accessed 21 April 1999.

subsystems, and the functional failure of any one of those systems can jeopardize the overall structure.³ Bodie exhibits failures in three subsystems which compromise the building's ability to resist deformation and effectively provide shelter.

Primarily, failures are found in the building's dominant Structural System: the joining of all structural elements, including the foundation, the load bearing walls, floor, top and bottom plates, joists and rafters, roof, entryways, and the connections between these members. Aside from the Structural System are two closure systems that function to prevent the penetration of inclement weather and preclude its damaging effects. The first (Vertical Closure System) includes the nonstructural components of the exterior wall such as siding, wall ties, interior surface substrate, windows, doors, etc. The second (Horizontal Closure System) is essentially comprised of the roof and all related elements such as the sheathing, flashing, gutters, and downspouts that deflect water and climate away from the structure. The proper function of these three systems will become evident after the causes of the structural failures of single-wall construction at Bodie have been identified [Figure 3.1].

Following extended personal inspection and after analyzing thousands of photographs of the single-wall buildings at Bodie, I have categorized the building failures into three general types; those caused by problems with the soil, those caused by stresses from loads to the building, and those caused by failures in the construction materials.

Structural Failures Due to Soil

When analyzing a structure for soil-related problems, one must consider several factors. These factors include the nature of the site upon which the structure was built, the nature of the materials of the foundation, the influences to which the materials and foundation

³ Samuel Y. Harris identifies the six subsystems as Structure (minimize deformation), Vertical Closure (provide barrier), Horizontal Closure (collect and transport precipitation), Climate stabilization (maintain homeostasis of heat, humidity, and oxygen), Hydraulic (distribute water and collect waste), and Energy (distribute power and collect by-products). Samuel Y. Harris, "A Systems Approach to Building Assessment" Standards for Preservation and Rehabilitation *American Society for Testing and Materials* STP 1258 (1996): 141.

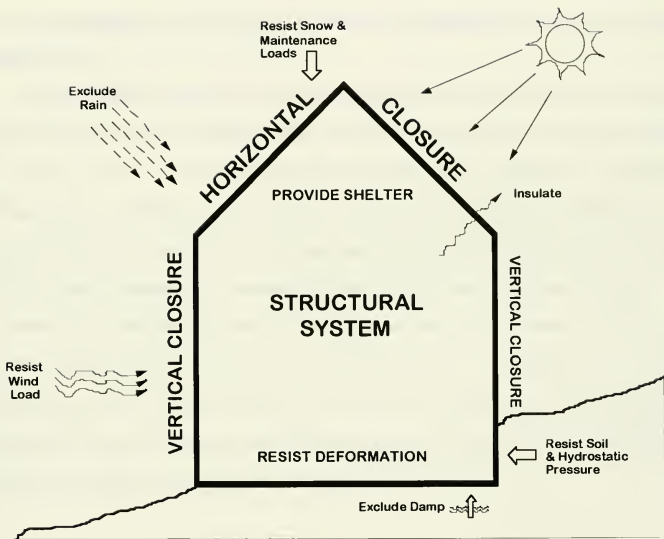


Figure 3.1. Diagram Showing how a structure works as a system made up of subsystems. The three subsystems that exhibit failures in the Bodie buildings are the Horizontal Closure System, the Vertical Closure System, and the Structural System.

are subjected, and the loading on the soil beneath the foundation.⁴ Considering that the majority of the buildings in Bodie were constructed without proper foundations, and the structures themselves are relatively light and so do not transmit extreme loads to the underlying soil, we must also look at the nature of the soil itself, and the stresses it places on the buildings in order to understand why the buildings have deformed so significantly over a relatively short period of time.

The adage that “only a foolish man builds his house upon sand” holds true at Bodie. Due to the sandy and unconsolidated nature of the soil in the Bodie region, several buildings show signs of failure due to foundation settlement or soil movement. Although the surrounding hills contain deposits of hard rock, the majority of the single-wall buildings were constructed on lower slopes or the valley floor that is primarily comprised of grayish yellow sandy clay with a percentage of intermingled small to large rock throughout its depth.⁵ To exacerbate the soil problems, the townsite is bisected by a creek that meanders in a north-south direction through the basin. At one point, this creek served as a tailings pond for the early stamp mills and the later cyanide mills on the western and northern slopes of Bodie Bluff.⁶ The siliceous nature of the soil and the high moisture content within the bowl around the creek both affect the stability of the single-wall buildings within the town.

⁴ Martin E. Weaver, *Conserving Buildings*, rev. ed. (New York: Preservation Press, 1997), 239.

⁵ Hard-rock mining activity was concentrated on the Bodie Bluff-Silver Hill ridge, which is comprised of Tertiary (Miocene) dacitic and andesitic lavas, tuff, and breccias, which have radiometric (potassium-argon) age determinations of approximately 8-13 million years before present. Gold and silver-bearing quartz veins cut the andesitic intrusives. Most of the Bodie Creek drainage and the surrounding hills are overlain by unconsolidated sediment, of Pleistocene-Holocene age, which was probably deposited about 3 million years ago. This material includes windblown sand and volcanic ash, alluvial deposits, and colluvial talus. The fine volcanic sediment is thought to be derived from eruptions of the Mono Craters and other localities from the south, as explosive volcanism occurred in those areas as recently as several thousands of years ago. F. J. Kleinhampl, W.E. Davis, M.L. Silberman, C.W. Chesterman, R.H. Chapman, and C.H. Gray, “Aeromagnetic and Limited Gravity Studies of the Generalized Geology of the Bodie Hills Region, Nevada and California” (Geological Survey Bulletin 1384, U.S. Department of the Interior, Washington, D.C.: 1975), 17, cited in Felton et al., 7; and Roger A. Calloway, R. Gregg Albright, David L. Felton, James West, and Ken Pierce, “Bodie State Historic Park, Resource Management Plan, General Development Plan and Environmental Impact Report” (California Department of Parks and Recreation, Sacramento: September 1979), 23; cited in Huston et al., 4.

⁶ Huston et al., 6.

I found five soil-related failures present within the single-wall buildings at Bodie [Figure 3.2]. I have categorized them as either settlement problems or movement problems. There are three basic types of settlement problems: vertical sinking (uniform settlement), tilt, and slumping (non-uniform settlement).⁷ The two movement problems are erosion build-up and heaving. Although some of these problems are more serious than others, in combination with other structural problems, they may contribute to a building's eventual collapse. Each of these soil-related problems will be characterized and evaluated in detail.

Settlement Related Problems

The first of the soil-related failures is vertical sinking (uniform settlement) of the structure [Figure 3.3a]. This problem is characterized by the structure moving vertically into the soft ground. Vertical sinking is minimal in Bodie (little more than a few inches), and occurs in the buildings situated in the lowest regions of the bowl, in areas near the creek or on marshy land. Four remaining structures that are sinking vertically are the Grey house, the Sled Shed (Old Barn), Building E1, and the Chinese house. These are small unadorned structures that indicate a tendency for lower-class dwellings to be constructed in the poorer-soiled areas of town (in contrast to the more elaborate, wealthy homes on the hill). Had the houses and small shops along Bonanza Street within the Red Light District and Chinatown survived the fire, there might be more evidence of vertical sinking within those structures as well. Very few structures survive in these low-flat and marshy areas.

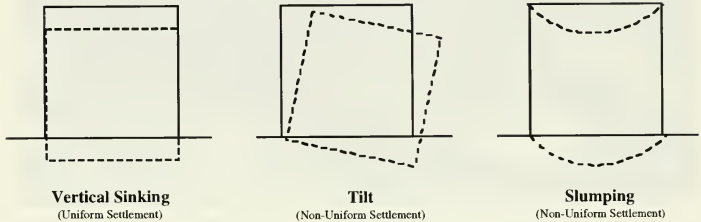
Vertical sinking is a result of settlement due to the natural influence of gravity. When a structure is placed upon the ground, the structure moves downward until resisted by an equal and opposite upward reaction.⁸ Since the buildings in Bodie were constructed on soft compressible soil, the buildings sink vertically until the soil is compressed to a stable point.

⁷ The categorizations in parenthesis are from C.B. Crawford, "Foundation Movements" *Canadian Building Digest* 148 (April 1972): 148-2-4.

⁸ Weaver, 239.

Structural Failures Due To Soil

Settlement Related Problems



Soil Movement Problems

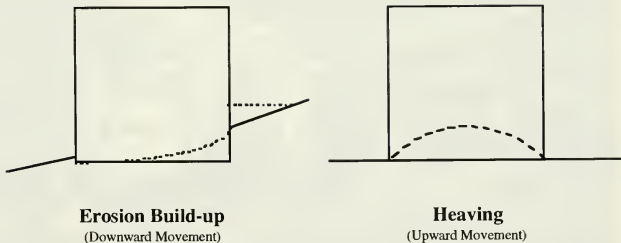


Figure 3.2. There are five types of failures due to soil. The first three are settlement problems, the last two are related to the movement of the soil.

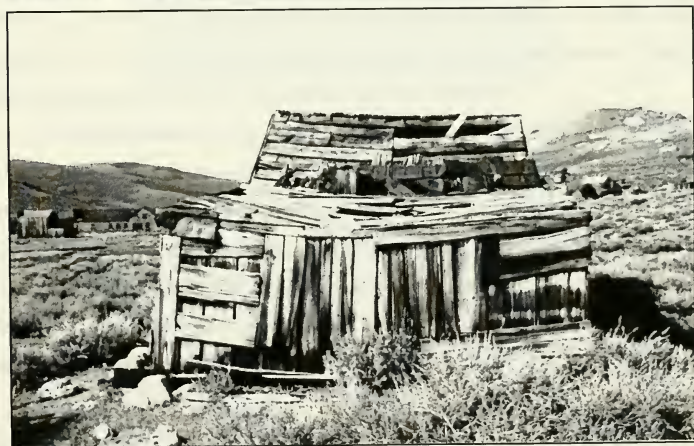
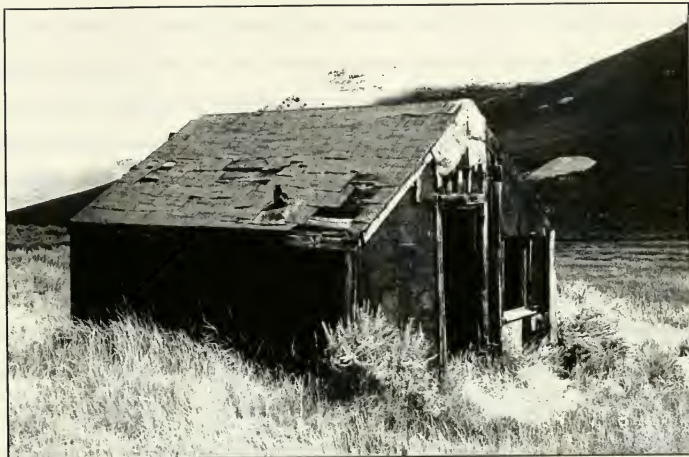


Figure 3.3a. Photo illustrating vertical sinking. South-West elevation of Chinese House. Taken 3 Sept., 1998 by A.S. Morrison.

Figure 3.3b. Photo illustrating slumping. South elevation of Campana. Taken 20 June, 1996 by P.D. Schulz.

This compression is generally caused by the constant dead load of the building upon fine-grained soils, and proceeds until the water is squeezed out from the pores of the clay. Here, considering the buildings are constructed of a lightweight material, compression may be a result of the fine grained soils reaching such a high saturation point that it acts like a liquid, moving the buildings up and down.

The second soil-related failure is tilt [Figure 3.4a]. Tilting is the non-uniform sinking in a diagonal direction. Within reason, the tilting action of this type of soil settlement alone does not greatly compromise the stability of the building, as the rigid structural system remains undeformed. This type of settlement is more common than vertical sinking in the single-wall residences in Bodie, and highly prevalent among the remaining outhouses.

Tilting of the Bodie buildings is an effect of differential settlement, or in the case of the outhouses, the structures sinking unevenly into the privy holes. Differential settlement may be favored by several factors: variations in soil compressibility, differences in building loads, variations in the moisture content of the soil, or variations in the depth and location of freezing and thawing phenomena in the soil under and around the foundations.⁹

In several instances, the load on the soil is uneven despite the weight of the building.¹⁰ Some of the smaller structures reveal tilt to an exaggerated degree. Among the outhouses, the smaller, lighter structures allow for greater rotation when the soil walls of the privy weaken and sediment moves into the void, causing the outhouse to sink diagonally. Such a weakening occurs when subterranean water removes the fine material from the soil or when organic elements such as nightsoil or wood retaining walls decompose, creating voids in the substructure.¹¹ Each structure exhibiting failures due to tilt will have to be analyzed

⁹ Crawford, "Foundation Movements," 148-2, 148-4.

¹⁰ Large movements can also occur from shrinking or swelling of clay subsoil resulting from stresses unrelated to foundation pressure. Fine grained clay soils may be subjected to extremely high stresses due to air drying or vegetation. Shrinkage may take place throughout the full depth of rooting and the depth of the active layer depends on both climatic conditions and vegetation. Drought-resistant vegetation growing in semi-arid climates may have roots extending deeper than 20 feet. *Ibid.*, 148-3, 148-4.

¹¹ Weaver, 241.



Figure 3.4a. Photo illustrating Tilt. Building O Privy taken 22 Sept., 1995 by P.D. Schulz.
Figure 3.4b. Photo illustrating Heaving. Murphy, Rm. 4 taken 30 April, 1997 by author.

individually to ascertain whether the cause is a variation in building loads or differences in the moisture content or compressibility of the soil.

The third and most detrimental settlement-related failure is slumping [Figure 3.3b]. Slumping is characterized as uneven settlement of a structure into the subsoil that creates additional stress on the joints, causing angular distortion that may cause cracks or structural failure. Slumping has the same causes as tilt, but differing results due to the size of the structure. This form of failure is initiated by the sinking of the building in one corner, or in the center of a load-bearing wall. In turn, the distortion of the vertical structural system forces the horizontal members to bend or, if strained too much, to disconnect from the wall entirely. The disconnection of the horizontal members from the vertical members weakens the rigidity of the single-wall building, which is its sole defense against deformation and structural failure.

This type of soil-related failure is most common in the larger structures, due mainly to the fact that the buildings are too large to merely tilt, or sink diagonally without compromising the rigidity of the structure. Some of the more complex structures in the town, or those that exhibit the “additive vernacular” phenomenon show signs of slumping due to differential settlement. This is most likely due to the compiled loads of additional framing members as they are stacked on top of the previous structure, thereby creating uneven weight under the areas of connection. Since the loading upon the foundation is uneven, the buildings slowly rotate in the direction of the heavier load. Differential movements under the single-wall buildings, which were constructed without sound foundations, are unavoidable in a region with sandy subsoil. So perhaps the best solution is to accept the large differential movements and to stiffen the joints to accommodate them.¹²

¹² Crawford, “Foundation Movements,” 148-4.

Soil Movements

The final two types of soil-related failures have to do with the movement of the soil. The first is erosion build-up against the structures, and the second is heaving underneath the building floors. Both of these problems are due to the nature of the topography, soil composition, and extreme seasonal changes.

Erosion build-up is characterized as loose topsoil accumulating against one side of a building. This problem obviously occurs only in the buildings that were constructed on a slope.¹³ The build-up of top soil, which consists of mostly small to midsize gravel and some sand, occurs as a result of the natural process of the erosion of the hillside adjacent to the buildings. In this arid and highly-alkaline landscape there is little vegetation to obstruct the gravitational flow of soil downslope.¹⁴ Movement of the earth may be a result of the gradual settlement of the numerous old mine shafts and dumps, or the washing away of tailings piles that scatter the hillsides from top to bottom. The loosened soil is carried down the hillside into the valley, and hence piles against the sides of the buildings during heavy rain or wind storms that are prevalent during the summer and early fall months.¹⁵

The accumulated soil against the exterior of the single wall buildings presents excess load at the base of the wall that contributes to the deformation of the structural envelope and may lead to the collapse of some of the upslope wall, especially on smaller additions. These types of failures will be addressed in the following section, but this illustrates how the single

¹³ The elevation is 8,374 feet and the ground rises gently from that point on either side. To the northeast of the Bodie bowl is Bodie Bluff at an elevation of 9,000 feet. Immediately east of the townsite is High Peak (Standard Hill) at elevation 8,820 feet. The mineralized zone stretches along a ridge approximately 2 1/2 miles, from Bodie Bluff and High Peak southward to Silver Hill (elev. 8,640 feet), Queen Bee Hill (elev. 8,720 feet), and Sugarloaf Peak (elev. 8,665 feet). Bodie Mountain and Potato Peak are to the northwest and are 10,201 and 10,226 feet in elevation respectively.

¹⁴ Bodie's natural vegetation consists of sagebrush (*Artemisia tridentata*, *A. archbuscula*, *A. cana*), rabbitbrush (*Chrysothamnus nauseosus*, *C. viscidiflorus*), bitterbrush (*Purshia tridentata*, *P. alundulosa*), and various species of grass, with occasional strands of aspen and pinyon pine (Pinyon-Juniper Woodland Biotic Community). Other plants that are typical of a Sagebrush Scrub Community are blackbush (*Coleogyne ramosissima*), saltbushes (*Atriplex confertifolia*, *A. canescens*), and horsebrush (*Tetradymai spinosa*). Felton et al., 3.

wall buildings work as a system, and increased loads on any one of the systems will lead to the failure of the structure as a whole. There are signs of attempted erosion-control on High Peak, just to the east of the townsite as one ascends Green Street to the old train depot at the top of the hill. This is in the form of a mesh cloth stretched between two short stakes to catch the downward movement of loose soil. The effectiveness of this erosion control is questionable, and its date of erection is unknown. The stresses due to erosion would be more effectively ameliorated by the removal of excess soil buildup around the bases of the buildings on a periodic basis.

The second soil-related failure caused by the movement of soil is heaving [Figure 3.4b]. Heaving is characterized by the upward movement of the soil beneath a structure: the floorboards may lift, bulge, or break as a result of an increase in reaction from beneath. Relatively few buildings show problems of heaving. All of the buildings that exhibit heaving problems were structures built without foundations; with the bottom plates set directly on the ground. Heaving occurs in the presence of water, and in particular, in the presence of frozen water. The movement of the building depends on the subsequent wetting and drying of the soils. When water is drawn up from the water table and freezes, causing a volume expansion, frost heaving under light structures may result in considerable damage.¹⁶ This phenomenon is particularly evident when fine-grained soils such as silts and clays or even dirty sands and gravel freeze.¹⁷ This type of thermal load is particularly insidious because it is not visible, and

¹⁵ Due to the elevation, Bodie has brief spring, summer, and fall seasons which last from mid-June to the middle of September. The climate can be severe during these months, with temperatures rising above 100 degrees Fahrenheit in July and August, with frequent rain and thunder storms.

¹⁶ Crawford, "Foundation Movements," 148-4.

¹⁷ Archeologists have studied the geological and climatic changes within the region and nearby areas over the last 10,000 years to understand the local variations in the terrain and how the environment affected the early communities of the region. They believe that the Bodie region was not glaciated during the most recent (Wisconsin) glacial maximum, but there was indication that ice-covered areas existed about 20 miles to the west of Bodie during this interval. This situation would probably have created periglacial conditions in areas of high elevation such as Bodie. Geological and archeological evidence suggested that the climate of the Great Basin province has not remained constant during the post-glacial (Holocene) interval. Rather, paleoclimatic interpretations present a gradual shift from a cool, subhumid era (Anathermal) to an arid situation (Altitheamal) which occurred about 7,000 to 8,000 years ago over much of the Great Basin. The relatively dry Altitheamal Period was followed by a slightly cooler, more humid climatic pattern (Meditheamal) around 3,000 to 4,000

neglect of such loads can create fracture and deterioration of the structural members, thereby compromising the stability of the flooring system.

Structural Failures Due to Stresses Induced by Loads

The second general category of structural failures includes those that result from stresses due to loads. The three types of structural failures evident in the single-wall buildings are roof collapse, racking (or shearing), and wall collapse [Figure 3.5a]. These failures are a result of vertical loads, lateral (horizontal) loads, or a combination of multiple loads (buckling), respectively. Vertical (gravity) loads come from either the dead load of the building components themselves, or live loads such as the weight of snow or ponded rain. Gravity loads are applied to the roof and floor systems and are transferred to vertical elements such as walls that deliver the load to the foundation.¹⁸ Structural failures due to horizontal loads are the result of wind. The combination of vertical load and material weakness cause the vertical members to buckle, leading to the collapse of a load-bearing wall.

Vertical Loads (Roof Collapse)

The first major failure from stresses due to vertical load is roof collapse. This is a natural failure as a result of gravity and excess vertical loads on the roof system. The function of the roof is to deflect the prevailing weather away from the building, and to act as a structural tie between the vertical elements (walls) as a means of resisting deformation. When the forces imposed upon the members exceed their capacity, failure results, as evidenced by too much deflection, or by total collapse.

There are two roof systems utilized with the single-wall structures at Bodie, and although the two tend to collapse in different manners, their sources for collapse are the same

years before present. This shift corresponds with a rebirth of lakes and small glaciers (sometimes referred to as the "neoglacial"). Felton et al., 7.

¹⁸ Eliot W. Goldstein, *Timber Construction for Architects and Builders* (New York: McGraw Hill, 1999), 1.

[Figure 3.5b]. The most prominent type of roof system is the gable roof, in which the rafters meet at the ridge, usually at an angle less than 45° without the support of a ridge member.¹⁹ The other is the shed addition roof, constructed most often as a result of a later, but immediate, need for additional space. The most common roof failure occurs in the separation of the connection between the original structure and one of these tacked-on shed additions. I will first illustrate the dynamics of vertical loads on the shed-type of roof (the simpler form of roof collapse).

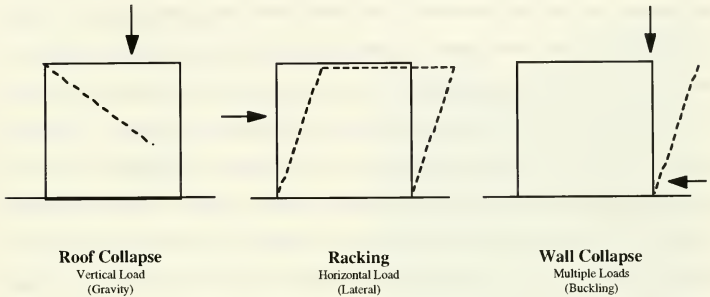
In the case of a shed roof, the rafters sit on top of a plate or ledger that has been nailed to the exterior wall of the original structure, and extends at a moderate slope to meet the top plate of the new opposing wall. Occasionally, the rafters will extend over the previous gable roof creating the “California Addition” framing system described in the previous chapter. Where a small shed roof is supported by a plate nailed to the exterior wall, there may be no rafters used at all, as the sheathing alone acts in their place. (These are the structures with the highest incidence of collapsed roofs.) In this case (as with the rafters supported at the ends on two wall plates), the rafter or wooden board used as sheathing is acting as a beam. The stress induced by an imposing vertical load on a single beam is different than that of the same load on a pair of gabled rafters. Failure in the shed roof will happen in one of two ways; either the wooden beams will fracture from the fatigue of continuous bending stress, or the roof will collapse as a unit from the failure of the connection (joints) with the vertical members.

When the rafter acts as a beam and is supported by vertical members at each end without support in the center, it is subject to stresses of tension as well as compression.²⁰ The

¹⁹ Range of roof pitches = 27-45° (6:12 to 12:12), average = 9:12; shed roofs 2:12 to 4:12.

²⁰ The structural members of the roof channel the loads on the building to the ground through two elementary actions: pulling and pushing. When a material is pulled, it is said to be in tension. When a material is pushed it is said to be in compression. When a straight element becomes curved under load, it develops beam action and the more curved it becomes, the larger its bending stresses. When a beam's ends curve up, as in a beam supported at its ends, its lower fibers are in tension and its upper fibers in compression. The tiny changes in length due to tension and compression when divided by the original length of the element are called strains. The pull or push on an element, divided by the area it is applied to, is called stress. The loads stress the structure, which strains under stress. Mario Salvadori, *Why Buildings Stand Up* (New York: W.W. Norton & Company, 1980), 60, 81.

Structural Failures Due to Stresses Induced by Loads



Vertical Load to Two Roof Systems

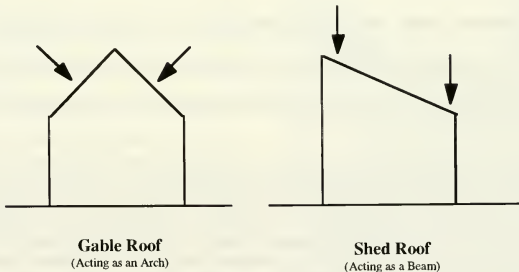


Figure 3.5a. Diagram showing three types of failures due to loads.
Figure 3.5b. Diagram comparing the forces of load on two types of roof systems.

weight of a vertical load placed on the shed roofs forces the beams to displace, or bend downward [Figure 3.6a]. (This property of wood deforming under load is referred to as creep.) The deflection of wooden members will increase with changes in load, moisture content, and temperature (shed roofs always have a shallower pitch than the adjacent gable roof-which means they are less efficient at shedding live loads). Due to the elastic nature of the wooden roof members, under short term loading, the deformation will disappear upon removal of the load.²¹ However, considering the fact that Bodie receives snowfall for more than half of the year, the structures are under load for a long enough duration that the wooden members permanently deform.²² After a number of loadings and unloadings with the seasonal changes at Bodie, the deformed wooden members reach their maximum straining point. As a result, a fracture will form between the points of inflection, causing the roof to collapse in the middle of the beams.²³ Hence, the shed roofs that are constructed with 2 x 4" rafters on edge deflect less than the additions that were constructed solely out of 1" sheathing and shingles, and the shed roofs with a shorter expanse have collapsed with less regularity than the ones with longer members.²⁴

If the roof collapses at the connection between the original building and the shed addition, then the failure occurs as a result of the loosening of the connection joint between the two rooms [Figure 3.6b]. This is caused by thermal stresses to the wooden members and the

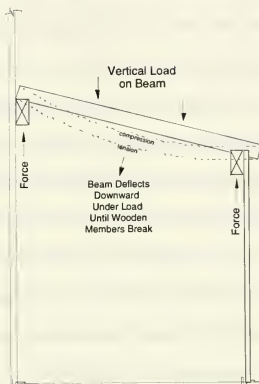
²¹ The structural behavior of wood under load is a function of load duration. Deflection under load is proportional to the load and is said to be linearly elastic (under short term loading). If the deflection is larger than the proportional deflection you expect under long-term loading, then the material is overstressed, and is acting plastically (i.e., nonrecoverable). Goldstein, 2.14; and Matthys Levy and Mario Salvadori, *Why Buildings Fall Down* (New York: W.W. Norton & Company, 1987), 282.

²² Bodie has very severe winter weather, with temperatures of 30 to 40 degrees below zero and snow drifts up to 20 feet. Other reports indicate snowfall reaching up to 8-10 feet. The problem of ponded water is of concern in the roofs that have very little slope. Deflection from the weight of the water will create ponding and will eventually increase the volume of water to the point of roof collapse. This is particularly evident in areas that contain "additive vernacular" additions where little attention was paid to the direction of the slopes of the subsequent additions.

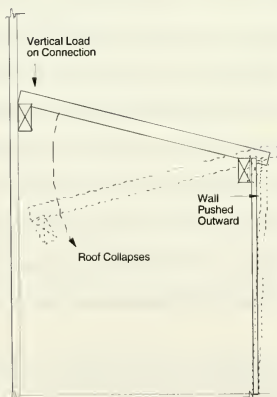
²³ The two points in the beam at which the curvature changes from down to up are called points of inflection. The short length near these points have no curvature and develop no bending stresses. Salvadori, *Why Buildings Stand Up*, 82.

²⁴ Deep beams are stiffer than shallow beams. The beam stiffness diminishes dramatically with increases in length; doubling the length of a beam makes it sixteen times more flexible. *Ibid.*, 81.

Material Failure



Connection Failure



Figures 3.6a & 3.6b. Diagrams of failures of shed roof; material failure & connection failure.

connection devices (nails), exacerbated by excess gravitational load (collected snow or ponding water) to that connection. Bernard M. Fielden explains the failure to the joints as a result of wood creep caused by tensile stresses and a variation of humidity. When the wood is subjected to bending stresses the longitudinal fibers are stretched by tension and squashed by compression, so that when repeated continuously, the wood deteriorates in a manner similar to fatigue in metal. In the areas where the wood is subject to tension, the timber lengthens, and may split at the clefts created during seasoning. Metal nails will loosen their hold (or bend) and as time goes on the wood fibers contract and leave a void into which atmospheric damp penetrates and condensation occurs, causing corrosion of the nails.²⁵ The weakened connection between the exterior wall and the shed addition can no longer withstand the static load of piled snow or ponded water, and thus collapses under the vertical stress.

Stress induced on the gable roofs are caused by the same vertical loads, but the nature of the structural system undergoes strain in different locales, transpiring failure in a distinct manner. The main distinction between the shed roof and the gable roof systems is that, unlike the shed roof's tendency to act as a beam, the two rafters of the gable roof system (set against each other without a center support) constitute a simple arch. Whereas the beam supported vertically at both its ends only exerts thrust vertically, the arch created by the gabled rafters each thrusts the other horizontally as well.²⁶ Gravity loads to the gabled roofs produce bending stresses similar to those of the shed roofs, but the beam action (or bending) is in the direction perpendicular to the inclined rafter span. Naturally, (when not supported at the ridge by a wall or separate ridge member) this force pushes the sloped rafters outward at their supports.²⁷ If the connection of the rafters to the top plate of the supporting wall weakens or breaks, then the result is a deformed building in the shape of a trapezoid, and the roof members are forced past

²⁵Bernard M. Fielden, *Conservation of Historic Buildings*, rev. softcover ed. (Great Britain: St Edmundsbury Press, 1982, reprint; Oxford: Reed Educational and Professional Publishing, 1997), 52.

²⁶Edward Allen, *How Buildings Work; The Natural Order of Architecture* (New York: Oxford University Press, 1995), 176.

²⁷James Ambrose, *Simplified Design of Building Structures*, 3d ed. (New York: John Wiley & Sons, 1995), 24.

the supporting wall (or will fall short of its support). The roof may collapse, even if the gable retains its shape [Figure 3.7a & 3.7b].

Lateral Loads (Racking/Shearing)

In addition to gravitational loads that act vertically, structural failures are caused by stresses imposed to the buildings laterally. The predominant source of lateral forces is excessive wind loads.²⁸ Wind loads not only act laterally, but also in an upward motion, potentially lifting a roof off its frame. Both the lateral forces and the upward forces of the wind have compromised the single-wall structures at Bodie. Lateral forces are reflected in the racking (or shearing) of the buildings into parallelogram shapes, whereas upward forces have caused deficiency in the horizontal closure system as evidenced by uplifted nails, missing shingles, or missing sheathing [Figure 3.8a]. Almost all of the structures show signs (or had shown signs prior to maintenance) of one of these wind-induced failures.

Single wall buildings cannot be considered independent of their environment. The buildings in Bodie are greatly affected by wind pressures and gusts due to the large, open, relatively flat valley area that provides very few obstructions or shielding. Constant lateral forces (wind pressure) can lead to the deformation of the structure, and the small, lightweight buildings are particularly vulnerable to the unexpected forces imposed upon them by dynamic wind gusts.

The first form of failure related to lateral wind loads is racking. This type of failure is characteristic of the longitudinal shearing of the structural members (at the connection points) such that the entire unit deforms into a parallelogram. The duration and force of wind pressure on the structure and the stiffness of the joints have the greatest influence on the effect of

²⁸ When winter comes, the adjoining bluffs promote wind gusts that come down on the valley and may reach 100 miles per hour. Huston, 3.

Structural Failures Due to Stresses Induced by Loads

Failures in Gable Roof

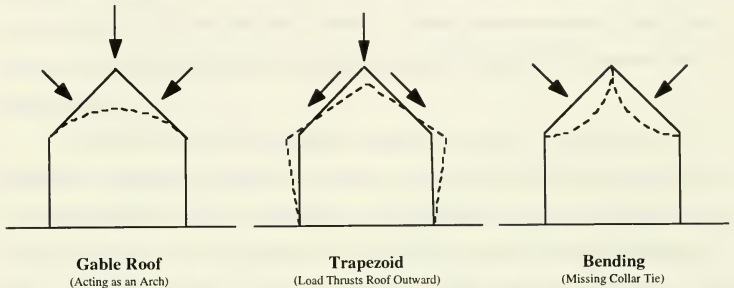


Figure 3.7a. Diagram of failures due to loads in gable roof. Rafters act as an arch.
Figure 3.7b. Photograph illustrating deformation of structure into trapezoid. Members buckle due to lack of ridge member and collar ties. Lester Bell House Barn, looking North. Photo taken 3 Sept., 1998 by A.S. Morrison.

shearing.²⁹ Shearing is a result of pressure and suction on the single-wall buildings. The wind exerts a pressure on the windward face of the rectangular structures when the building obstructs the air flow. Air is a fluid, and therefore the particles are forced to go around the building when stopped by the building's face. The particles flow back together again on the opposite (leeward) side of the structure, creating a negative pressure or suction [Figure 3.8a]. The total wind force to the single-wall buildings is the sum of the windward pressure and the leeward suction.³⁰

The Bodie structures are particularly susceptible to racking or shearing due to their lightweight construction. Unlike their masonry counterparts, the single-wall buildings have very little deadweight. Instead, the buildings gain their stability from the construction system acting as a stiff box. If the connections are not rigid enough, then the building will rack as a result of the continual pressure and suction on the face of the envelope [Figure 3.8b]. The Bodie structures that most clearly exhibit compounded failures as a result of shearing are those whose shapes are irregular. Buildings with "L" additions are more adversely affected by the lateral loads because the separate wings move independently. This in turn causes them to tear apart at the inside corners where the two wings meet [Figure 3.9a].³¹ Simpler structures, however, could be stabilized from further deformation by stiffening the box. (In contrast, past maintenance crews at Bodie have sometimes stabilized the racked structures by simply propping a pole against the exterior of the buildings on the leeward side.)

Continual (static) wind forces will produce one type of force on the buildings, whereas a sudden (dynamic) wind gust will cause an entirely different force. A weight applied dynamically can be equivalent to twice its static weight.³² Wind gusting is a serious problem at Bodie, resulting in failures of the horizontal closure system. The sudden wind gusts convert

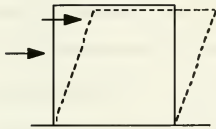
²⁹ Wind pressure is determined from the equation $P_v = 0.00256 v^2$, where P_v is the resulting pressure in pounds per square foot (psf) from wind at a speed of v miles per hour (mph). Lines of equal velocity- "wind contours"- indicate the basic wind speed. Goldstein, 9.3.

³⁰ Salvadori, Why Buildings Stand Up, 50.

³¹ Goldstein, 9.9.

³² Levy, 280.

Lateral & Upward Loads

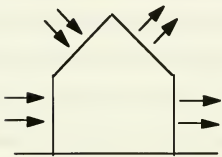


Racking/ Shearing
Lateral Movement
(Static Load)



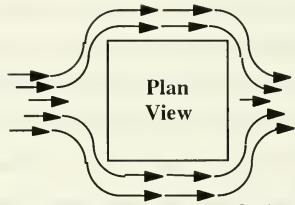
Missing Sheathing/ Shingles
Upward Movement
(Dynamic Load)

Loads from Wind



Pressure
(Windward Side)

Suction
(Leeward Side)



Pressure
(Windward Side)

Suction
(Leeward Side)



Figures 3.8a & 3.8b. Diagram of load induced by wind. Photograph of result of shear stresses on Owen. South Elevation taken 21 May, 1997 by P.D. Schulz.

the shingles into levers causing nails to uplift from the roofs, the shingles to blow off, or in some instances, the sheathing itself to blow [Figure 3.9b]. The absence of these critical elements to the closure system then allows snow and water to penetrate the buildings, creating additional damage internally.

Unlike the vertical forces of gravity loads, the forces caused by wind come from all angles. Wind loads change value rapidly and even abruptly. The damage due to wind is a product of the roof angle and the maximum force of the wind gust. On a 45° roof, there is suction to the leeward side and pressure to the windward side, whereas a flatter roof pitch will create suction of both the leeward and windward sides. Shingle loss on the windward side results from a net uplift of the wind due to the fact that the air under the roof exerts more pressure than the piling up of air blowing over the roof. Normally, the air pressure has time to equalize that of the interior when the speed of wind is constant. However, a dynamic gust of wind allows no time for this equalization, causing damaging stresses that result in the uplifting of nails, shingles, and the like.³³

Combination Loads (Wall Collapse)

Wind pressure may not create significant damage alone, other than a weakening of the joints or the deformation the single-wall form. The real damage occurs when wind is a factor in conjunction with other loads (such as vertical loads from snow and rain), even though a gust of wind may be the most common final strain that causes collapse. The last category of structural failures created by loads will look at the result of a combination of vertical and horizontal loads such as those that result in the collapse of a load-bearing wall [Figure 3.10a].

Before a wall collapses, it shows signs of the buckling of its vertical members under load. Buckling is defined as the bending of a straight element under compression. Mario Salvadori states that buckling is one of the main causes of structural failure. “Buckling

³³ Esmond Reid, *Understanding Buildings; A Multidisciplinary Approach* (Cambridge: The MIT Press 1998), 41.

failure," he writes, "is very sudden; whenever a structure under load chooses the easy path of bending rather than the foreseen path of compression, the structure may fail."³⁴ In the case of the single-wall buildings in Bodie, the exterior board and batten siding functions as the load-bearing vertical elements that hold up the roof. Therefore, the forces that the roof collects are passed down the siding on their way to the ground. In this case, the siding is working in compression, much like a column or vertical beam would in other forms of construction. The structural compromise of utilizing siding as vertical members in single-wall construction is that the boards that are bearing the compressive load are little more than one to two inches thick. This thickness is significantly insufficient for some of these structures, considering the load capable of buckling a column (its critical load) is dependent upon the slenderness of the material. (In other words, the thinner the vertical member, the higher the potentiality of bending occurs under vertical load.)

Several of the walls in the Bodie buildings have collapsed [Figure 3.10b]. Most of these buildings exhibit other structural failures as well. When vertical loads to a single-wall structure reach a maximum, then the vertical force transferred onto the thin walls will cause them to buckle. If these loads exceed the material's modulus of elasticity³⁵ (the maximum to which the material will bend without fracture), then the vertical members will break, causing the wall to collapse. Or, if constant wind loads create lateral forces in conjunction with the buckling members, the weakened joints may sever, and the wall will collapse laterally. This too may be the case with an introduction of soil movements (erosion buildup against the exterior of the hill-facing wall) as described in the first section. The forces of nature are strong

³⁴ According to Mario Salvadori, buckling is a consequence of the basic "least work law" of nature. That, as an increased load as applied to the top of a column, the load will first come down by compressing and shortening the column. Since loads always tend to settle in their lowest balanced position, this type of lowering of the load would go on indefinitely, were it not for the fact that at a certain value of the load, the column can lower it further in two ways: either by continuing to shorten in compression or by bending out. Salvadori, *Why Buildings Stand Up*, 88.

³⁵ The strain e of a material (a pure number) under a stress f is measured by dividing its elongation d (lengthening or shortening) by its lengths l . The two quantities f and e describe the two essential structural properties of a material. Their ratio $E = f/e$, called the *modulus of elasticity*, is typical of each material; its value describes uniquely its toughness under load. Levy, 279.



Figure 3.9a. Photograph illustrating deformation of "L" additions due to lateral loads. South-West Elevation, Building "D" taken 2 Sept., 1998 by A.S. Morrison.

Figure 3.9b. Photograph illustrating damage due to dynamic wind loads; uplifted nails and missing sheathing/shingles. South elevation roof, Campana taken 10 June, 1996 by P.D. Schulz.

Structural Failures Due to Stresses Induced by Loads

Combination of Loads

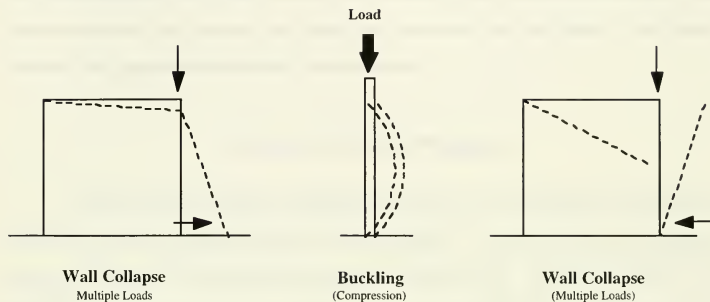


Figure 3.10a. Diagram of buckling and wall collapse (combination of loads)
Figure 3.10b. Photograph of wall collapse. South-East elevation Building "N" taken 13 June, 1996 by Lee Motz.

in the case of vertical and lateral loads. Due to the severe seasonal changes and high speed winds, the poorly-built single wall structures in Bodie are particularly susceptible to collapse due to environmental loads. But ultimately, the stability of the buildings are contingent upon the performance of the materials from which they were built, and the failure of the material singularly will jeopardize the integrity of the entire unit.

Failures in Building Materials

“A given structural system is fundamentally affected—even completely determined, in most cases—by the materials employed in its realization.”³⁶ In the case of the single-wall structures in Bodie, the predominant building material is wood. The sustainability of the buildings therefore, depends upon the ability of the wooden members to endure the forces of nature. Each material used as a structural element has certain material and chemical properties that dictate its performance over time. This performance may be predicted given certain conditions.³⁷ A fairly safe prediction for the single-wall structures in Bodie is that, when subjected unprotected to a climate which is variable and extreme, the sustainability of the structural system is only as certain as the physical lifespan that the material will allow.

Several factors made wood an excellent building material for the quickly-constructed miner's dwellings. Yet, wood is an organic material that, when subjected to harsh climates, deteriorates exponentially through time. The failure of the wooden members of the single wall buildings can be seen at various levels. Failures found in the wood are on a macro-scale, such as the bending (creep) or even fracture of the wooden members (physical failures), as well as a micro-scale, as seen in the weathering of the material itself, discoloration, or deterioration due to excessive moisture (chemical failures).

³⁶ John Fitchen, *Building Construction Before Mechanization*, 5th ed. (Cambridge: the MIT Press, 1994), 21.

³⁷ Harris (1996) explains that the properties of a given material or element constitute a characteristic profile that is unique to that substance and is replicable among like elements and materials. He specifies that the performance of a given material or element in specific conditions is predictable based on the profile alone. This

Physical Failure of Materials

The first type of material failure found in the single-wall buildings is bowing and fracturing [Figures 3.11a & 3.11b]. These two seemingly distinct failures are categorized together because they are both caused by the physical weakening of wood fibers, rather than chemical deterioration of the material (as with weathering, discoloration or rot). The structural performance of wooden members has been discussed somewhat in the section pertaining to failures due to loads, but this section will look at the physical failures of the wooden member as a material, and not as a member of a structural system.

There are many reasons why wood was a suitable material for construction in Bodie. In addition to being readily available, cheap,³⁸ and amenable to rapid construction, wood is made of a lightweight material that could be easily transported and handled on site. Despite its lightweight density, wood is a remarkably resilient material with great tensile, compressive and flexural strength.³⁹ But as described in the section relating to failures due to loads, under prolonged load, the elastic nature of the wood will become plastic, and permanent (or residual) deformation will occur.⁴⁰ If the wood is stressed beyond its yield point (the point at which permanent deformation occurs), the wood will fracture. When a wood joint fails under tension, it does so by ripping along the grain, which demonstrates its resistance to longitudinal shear. The areas of critical weakness are at the connections, which are subject to concentrated tension.⁴¹

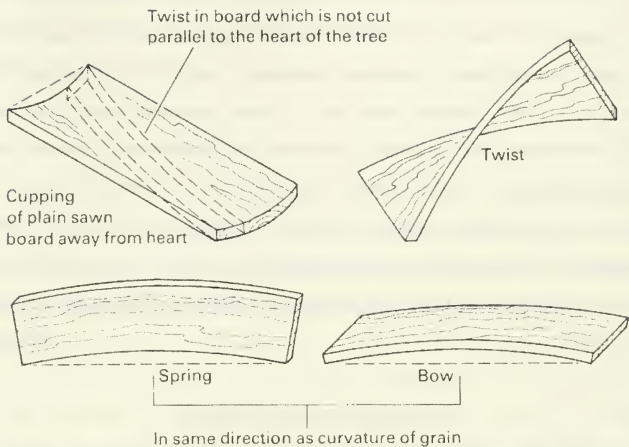
expectation is founded on scientific predictability of actions and reactions rather than merely the empirical accumulation of experience. Harris, "A Systems Approach to Building Assessment," 138.

³⁸ Wood was cheap relative to alternate construction materials, but the fact that it was brought in from neighboring areas suggests an additional cost. The cost of construction materials in Bodie has not been seriously investigated to date.

³⁹ A material's strength in tension or compression is determined by testing how much load each unit area can resist before breaking. Such unit load, measured in pounds per square inch, or psi (N/mm^2), is called the ultimate strength of the material. Levy, 279.

⁴⁰ The elasticity comes from the cellulose; the plasticity, from the lignin. Goldstein, 2.14.

⁴¹ Wood is generally less resistant along the grain than across it. Most species of timber are highly resistant to shear across the grain, but are notably less able to withstand this kind of stress in the longitudinal direction. Fitchen, 67.



Figures 3.11a & 3.11b. Diagram and Photograph of types of material failure (physical). Photograph of South Elevation siding west of Win. 3, Building "N." Taken 14 June, 1996 by P. D. Schulz.

As demonstrated in the section relating to failures due to loads, the tensile capacity of a wooden structure is often limited by the strength of its joints rather than by the strength of the material itself, and to the difference in structural responses of applied forces relative to the alignment of its grain (anisotropic nature).⁴² The most common failures of the wooden members is caused by the splitting of the wood at its connections. The birdmouth notches cut into the ends of the rafters to fit over the top plates compromise the strength of the wooden members. Also, since the tractability of the wooden members facilitates the use of simple fasteners such as nails, the joints do not maintain good structural performance. The stresses to the wood are concentrated on these joints, which tend to work loose due to moisture concentration.

Chemical Failure of Materials

Aside from structural failures of the wooden material, the continual exposure to the harsh climate has affected the fabric on a micro (chemical) level as well. The second type of material failure has resulted from prolonged exposure to the environment without protection, which include discoloration and weathering. There are several processes that will lead to the structural disintegration and destruction of wood such as thermal decay, hydrolysis, oxidation caused by ultraviolet light, rot, fungi, insects, and “weathering.”⁴³ The decay of the wood in Bodie is not caused by fungi or insects, as one might expect, as the necessary conditions present in the high, arid environment are insufficient to cultivate such activity. The other processes- oxidation, thermal decay, and “weathering”- however, are evident in abundance. All of the buildings in Bodie show signs of weathering, yet the rate at which the unfinished

⁴² Timber strengths (in both tension and compression) range from about 150 kg/cm² to 400 kg/cm² for both hardwoods and softwoods. The dimensional stability and the strength of timber are sensitive to changes in moisture content, and long-term loadings producing time-dependent deformation (creep). Timber is also notorious for exhibiting a broad range of properties due to knots and splits. Robert Mark, ed., *Architectural Technology up to the Scientific Revolution* (Cambridge: The MIT Press., 1995), 8.

⁴³ Frederick A. Stahl, *A Guide to the Maintenance, Repair, and Alteration of Historic Buildings* (New York: Van Nostrand Reinhold Company, 1984), 79.

wood erodes varies widely within the town depending on the direct exposure to climate, the severity of that exposure, and the characteristics of the wood.⁴⁴

Discoloration of the wooden members is either due to the rot of the material, or from the combined effects of sunlight, water, and biological organisms. After nearly a century of exposure to the elements, the unfinished wood of the Bodie buildings has changed color and physical appearance; the once colorful town has transformed into a monolithic landscape of golden-sunbrowned structures that is characteristic of wood when its water-soluble extractives rise to the surface and are altered by sunlight and water.⁴⁵ Discoloration (particularly in patches or streaks along the grain) is also an indicator of rot caused by the frequent and periodic changes of the wood from dampness to dryness. Several of the single-wall structures show signs of Wet Rot (or Black Rot) in areas that have been subjected to prolonged exposure to moisture (such as the bases of the buildings, especially on the northern sides, that are shielded from direct sun exposure). Wet Rot grows in extremely damp conditions with 40-50% wood moisture content and cannot extend beyond these areas as other types of rots can. The areas around the bases of the structure (the attacked wood) is characterized by a very dark brown and black appearance with cracks predominantly along the grain (the wood appears “burned”) [Figure 3.12a].⁴⁶

⁴⁴ These characteristics include the wood’s density, growth rings per inch, percent earlywood and latewood, and growth ring orientation. “In general, unfinished softwoods erode at a rate of about 0.25 inches per century, while the rate for hard-woods is about 0.125 inches per century. Wood in regions with higher annual rainfall and temperatures weathers faster than wood in areas with lower rainfall and temperature. Wood weathers fastest on a building’s southern exposure, somewhat slower on the western and eastern exposures, and slowest of all on the northern exposure. Quartersawn hardwood lumber and vertical- or edge- grained softwood lumber weathers more evenly than plain-sawn hardwood lumber and flat-or slash-grained softwood lumber, largely because the bands of softer, more easily eroded earlywood are substantially wider in the latter.” Goldstein, 3.11.

⁴⁵ Light-colored woods tend to darken, while darker woods lighten. Ultraviolet light breaks down lignin, the natural adhesive that binds wood fibers, which are made largely of cellulose. Within a few months, the wood turns a pleasing silvery gray as more and more of the lignin and extractives are washed away by rain, leaving behind a surface of light-colored cellulose. In most regions of the United States, however, the silvery gray color is temporary, and the wood deepens to dark gray, black, or brown as mildew colonizes its surface. Ibid.

⁴⁶ Rot only occurs when five conditions exist in sufficient quantities: oxygen, moisture, heat, fungi, and the timber itself. The rate of deterioration varies depending on the moisture content, temperature level, levels of extractives in the timber, and the presence and toxicity of inject retardants. Harris, “A Systems Approach to Building Assessment,” 138; and Weaver, 26.

Another form of deterioration of the wood on a chemical level is the natural “weathering” of the wood, triggered by the breakdown of its materials. This breakdown, when left to proceed un-interrupted will lead to the failure of the materials, and hence the structural system of the single-wall buildings. “Weathering” is a combination of alternating swelling and shrinking of the material (thermal expansion and contraction), combined with photodegradation of the wood surfaces from exposure to sunlight and ultraviolet radiation. One advantage to the structures in Bodie is that the park encourages the natural weathering of the materials. The erosion of the surface exposes newer surfaces of the wood at its depth which adds color and enhances the appearance of the picturesque mining landscape. The weathered appearance of the buildings marks the passage of time, evoking a romantic appreciation of the aged ghost town [Figures 3.13a & 3.13b].

Despite the romantic appeal of the weathered surfaces, the fact remains that the physical and chemical deterioration of the material compromises the strength of the structure as a system. One final chemical failure of the predominant construction material is loss of strength due to high moisture content in the wood.⁴⁷ Timber is a natural moisture-mover. The direct contact of the wooden sills and siding to the soil surrounding the buildings allow water to penetrate the wood through capillary suction. Due to the prolonged winter season, snow is in contact with the surface of the siding (especially on the northern side), exposing the wood to a high concentration of moisture as well. Failures of the wood fibers under load is induced once the sun returns and the wood dries out too rapidly.⁴⁸ The repeated cycles of expansion related to hydration and dehydration leaches out the lignin which causes the fibers of the wood to

⁴⁷ For every 1% increase in moisture content, static bending strength (commencing at oven-dry weight) is reduced 2%; the modulus of rupture is reduced 4%; and compression strength parallel to the grain is reduced 6%. Weaver, 20-21.

⁴⁸ Shrinkage occurs in the wood as the moisture content is lowered. Because wood is an anisotropic material, the wood does not shrink equally in all directions. Shrinkage tangential to the growth rings is largest. It shrinks about half as much radially, and only negligibly in length. The differences in shrinkage rates means that certain cross sections of timber are less dimensionally stable than others, the most stable being “quarter sawn” or “edge grain” sections where the growth rings are perpendicular to the long sides. “Flat sawn” or “tangentially sawn” sections are the least stable where the long sides are tangential to the growth rings and tend to cup with their outer edges curling outward. *Ibid.*, 19.

loosen. The loosened fibers eventually lift from the surface and the grain raises, only to be removed from the face by rain, wind, and freeze/thaw actions [Figure 3.12b].⁴⁹ A vertical member, weakened by environmental factors, loses strength under load and is more susceptible to failure due to buckling. The deterioration of the siding further compromises the structure in that the warped boards allow wind, rain, and snow to penetrate the vertical closure system, potentially creating additional damage to the interior of the structure.

This chapter has described how the single-wall structures work as a system, and that the compromise of any one of the subsystems can cause the entire structure to fail. If the buildings are not properly stabilized, as to prevent future failures, then the horizontal and vertical closure systems will be compromised, and the structure will no longer be able to perform its function of providing shelter and resisting deformation. The following chapter will address various intervention strategies to help minimize future structural failures based on the findings of the analysis performed in this chapter.

⁴⁹ Goldstein, 3.11.



Figure 3.12a. Photo showing chemical failure of wood. Discoloration along bottom of wall due to black rot. Rm. 2, West wall, Selhorn taken 29, July, 1997 by P.D. Schulz.
Figure 3.12b. Photograph of “weathering” of wood. East Elevation of McDonald taken 3 Sept., 1998 by A.S. Morrison.



Figures 3.13a & 3.13b. The weathered appearance of the buildings marks the passage of time.

CHAPTER FOUR

INTERVENTION STRATEGIES

Like all things, with the passage of time the face of a building will begin to weather, and if left unattended will eventually collapse. It is possible, however to suspend the point at which a building might collapse. The deterioration of a building is a function of its physical properties and the environment,¹ and by altering the state of either of these elements, the deterioration process may be slowed down. The different types of structural failures (mechanical, chemical, thermal, hydraulic, etc.) of the single-wall buildings in Bodie were outlined in the last chapter. Based on an understanding of the causes of these failures (soil, loads, material), intervention strategies can be established to counteract the forces that are initiating those problems. This chapter will evaluate the effectiveness of various stabilization methods and recommend procedures that introduce the smallest degree of alteration of the historic fabric.

Considering that the failures of the structural system of the single-wall buildings fall into a specific profile, the performance and duration of the system can be predicted based on that profile and an understanding of the environment. According to S. Y. Harris, the deterioration of a building is a measure of the capacity of a system to undergo spontaneous change, and can be charted over time as a declining *S* curve. The mathematical characteristics of the *S* curve are that the curve accelerates to a point of contraflexure then decelerates, with the lower range of the curve asymptotic to the ordinate. In terms of building history, Harris subdivides the *S* curve into three phases of deterioration: the incipient, accelerating and decelerating deterioration [Figure 4.1a].

¹ The deterioration process is referred to a mechanism that in turn is a function of physical properties and the environment within which the properties are operating, that is, mechanism = f (properties, environment). The mechanism is a description of the rate of deterioration. The magnitude of deterioration is, therefore, a measure of the operating mechanism over time. Samuel Y. Harris, "A Systems Approach to Building Assessment,"

Incipient deterioration is the first phase of the decay curve, and begins immediately following the construction of the building. The deterioration in this phase is active at the suboptimal level and continues gradually until the point at which the first major subsystem fails. Most buildings that are lived in and are maintained can sustain this phase for many years. The accelerating deterioration phase begins with the failure of the first major subsystem and extends to the point of zero utility. Left unimpeded, the building may collapse in this phase. The state that follows functional failure of the building is the decelerating deterioration phase and primarily relates to historic ruins (marked by the point of contraflexure in the *S* curve). The rate of deterioration once a building reaches this phase is relatively slow and the condition remains generally stable.²

Harris' *S* curve model is applicable to Bodie's single-wall buildings in that there are structures that fall into a wide range of points within the curve. Some of the buildings that are lived in by park staff, or that had occupants for a longer period of time fall within the incipient phase of deterioration and require less maintenance. A few of the buildings have passed the point of collapse and now lie in ruin within the decelerated deterioration phase. The majority of the buildings, however linger between the end of the incipient phase and accelerating deterioration phase, awaiting the failure of one of the major subsystems. This point within the life-cycle of the building, at which the functional aspect of the system fails is the half-life of the system (the point of contraflexure in the decay curve).

In keeping with the stated directive of "leaving the park in a state of arrested decay," the Department intends to maintain the buildings at their half-life point. This philosophy will dictate the intervention strategies in as much as the significance of the park is derived from sustaining a large number of buildings at a relatively modest state versus rehabilitating only a few at a significantly higher state of repair.

Standards for Preservation and Rehabilitation *American Society for Testing and Materials* STP 1258 (1996): 137-148.

² *Ibid.*, 139.

Prioritization of Structural Failures

In order to determine what aspects of the buildings require intervention, and at what point intervention should take place, one must first prioritize the various failures on an exigency basis. The previous chapter defined the three subsystems that exhibit failures as the structural system, the horizontal closure system, and the vertical closure system. The failure of any one of these subsystems define the failure of the building to resist deformation and to provide shelter. The failure of any one subsystem *may* jeopardize the integrity of the building as a system, but will not necessarily induce collapse. Considering that the minimum requirement is to maintain the buildings at the level of their half-lives, certain allowances can be made in the stabilization of the structures, such that the intervention of one subsystem may take precedence over the intervention of another.

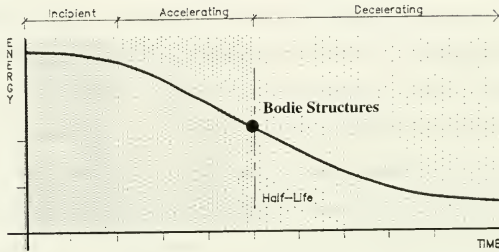
Based on Harris' definition of the effective life-span for the three subsystems, I have determined the exigency of a failure to be calculated as the minimum duration of the subsystem's ability to effectively meet its requirement of functionality. In other words, intervention of the horizontal closure system, with an effective lifespan of only 20 years, supersedes the stabilization of the vertical closure system or the structural system, each with a 40 year and 100 year lifespan, respectively [Figure 4.1b].³ Prioritization was additionally weighed according to the level of contributory damage due to the failure of any one of the subsystems. For example, the failure of the horizontal closure system renders more potential damage to the other two subsystems through the infiltration of water and other environmental elements, than say, the racking of the structural system, which may merely disfigure the box without contributing additional damage to the structure as a system.⁴

³ Numbers for the effective life-spans derived from Figures 2 a-c in Harris' article (1996). Ibid., 142.

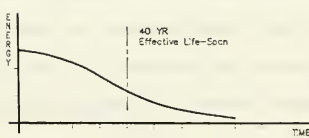
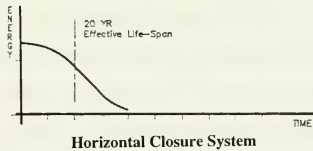
⁴ According to Harris, this can be described as the priority of intervention going to those systems that are closest to dysfunction or that are at a stage of accelerating deterioration. Prioritization, therefore is based on the rate of change rather than the absolute magnitude of damage. Ibid., 142.

Rates of Continued Decay

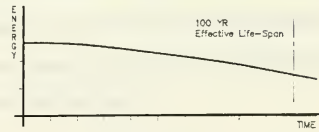
Deterioration Curve



Effective Life Spans of Subsystems



Vertical Closure System



Structural System

Figure 4.1a. Samuel Y. Harris' decay curve showing incipient, accelerating, and decelerating stages. The Bodie buildings are maintained at their "half-life" point.

Figure 4.1b. Three sub-systems showing signs of deterioration in the single wall buildings in Bodie. The effective lifespan of the structural system is far longer than the horizontal closure system and vertical closure system. Harris, 139,142.

Intervention Strategies

Starting with the horizontal closure system, then looking at the vertical closure and structural systems, this section will weigh varying approaches to intervention of the different structural failures. There are always five fundamental approaches (options) to intervening in the deterioration curve: doing nothing, mitigation, reconstitution, substitution, and acceleration [Figure 4.2].⁵ The first two approaches adjust the rate of the decay curve, and when implemented, do not alter the historic fabric. In contrast, the latter three approaches effectively alter the fabric or structure in some way that in turn changes (transports) the curve. With each failure, the option to do nothing is a viable solution, particularly keeping in mind that Bodie gains its integrity from its appearance as a ghost town (implying a natural decay of the buildings). An alternate option-unlikely ever to be recommended within a National Historic Landmark- is acceleration. Accelerating the curve (controlled demolition) is only an option in the case of public safety, when a building had transgressed past the point of contraflexure, and leveling the building is the only method to prevent a catastrophic collapse.

For the purpose of this paper, each of the other three options (mitigation, reconstitution, substitution) will be assessed in comparison with each of the structural failures to ascertain an appropriate solution for intervention in regard to the single-wall structures in Bodie. Mitigation is a way of moderating the quality or condition of the force (or its intensity) that causes the structural failures. Reconstitution, on the other hand, is an alteration or stabilization of the element or parts that make up or compose the structure itself. Substitution is just that: the introduction of a different material or system altogether.⁶

⁵ Ibid., 145.

⁶ Substitution in turn introduces a different deterioration mechanism and a different curve. Anytime one trades a presumably unacceptable mechanism for another presumably acceptable approach, the alternate mechanism is just as subject to deterioration as the replaced. Ibid., 145.

Mitigation

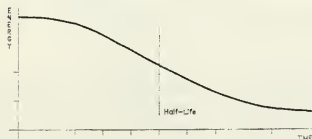
Reconstitution

Substitution

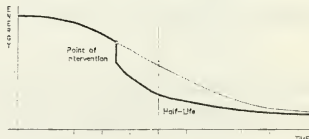


Vertical Load (Roof Collapse)	Remove Load/ Internal Cross Bracing	Stiffen Joints Sister Rafters	Replace Rafters/ Roof Members
Bending (Creep)	Remove Excess Loads	Sister Rafters/ Joints	Internal Shoring to Support Beams
Missing Shingles/ Sheathing	Wind Bread Nail Loose Shingles	Cover Holes with Like Materials- (Recycled Tin Cans)	Replace Shingles/Sheathing with New
Buckling	Remove Excess Loads	Thicken Vertical Members- Add Structural Posts	Replace Vertical Material with New
Material Failure	Remove Source of Moisture-Debris Buildup	Consolidants, Epoxies, Wire, Bolts	Replacement of Material
Missing Doors/Windows	Check Stability of Doors & Windows Regularly	Re-hang Doors & Windows; Calk Broken Glass	Cover Doors w/ Sheet Metal, Wood Replace Glass
Racking	Wind Break	External Bracing Tighten Joints	Cable & Turnbuckle
Differential Settlement	Infill Dirt/ Buildup Dirt	Stiffen Joints to Avoid Deformation	Concealed Foundation; concrete
Heaving	Erosion Control Remove Excess Buildup of Soil	Excavate Under Structure	New Foundation

Horizontal Closure
 Vertical Closure
 Structural System



Do Nothing



Acceleration

Figure 4.2. Chart outlining the five intervention strategies for failures found in each of the three sub-systems. Each intervention strategy alters the deterioration curve.

Horizontal Closure

The three failures that affect the horizontal closure system are vertical loads that cause roof collapse, the bending (creep) of the rafter members, and missing shingles and sheathing due to lateral wind loads.

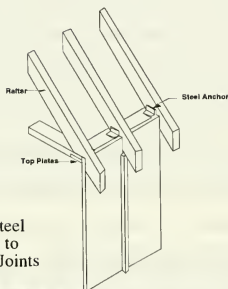
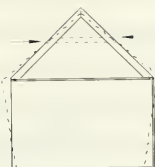
To mitigate roof collapse, the source of the excess load must be removed. In other words, the snow must be removed from the roof, and areas of pooling water must be alleviated. A second option is reconstitution of the roofing system. The best prevention for roof collapse is the tightening of the joints. The structure gains its stability as a system from its stiffness as a box. Moment-resisting joints give the structure monolithicity and greater resistance to forces.⁷ The best support for the gabled roofs is some form of lateral bracing at the top of the walls [Figure 4.3a]. Some of the structures make use of horizontal ties across the building in the form of ceiling joists (or nailers for cloth ceilings). This makes the two rafters work against each other to produce an equilibrium of horizontal forces internal to the structure.⁸ This is why the Bodie buildings that made use of such joists are generally in far better shape than the structures that were simply built as a shell with no cross-bracing whatsoever. This type of bracing also helps stabilize the structures from shear forces due to wind. Therefore the broken or weak joints must be reconstituted by securing the connections with nails, or with other connectors, or in areas where the wooden members have split or broken, existing rafters could be sistered with new members [Figure 4.3b]. An alternate option is reconstituting the fabric of the roof members by use of rods and epoxies.⁹ This would have the benefit of avoiding installation of visible non historic - elements.

⁷ Joints that prevent the relative rotation of adjoining elements are said to be rigid or moment-resisting joints. Although these joints resist lateral forces, they increase the value of stresses caused by changes in temperature and soil settlements. Matthys Levy, and Mario Salvadori, *Why Buildings Fall Down* (New York: W.W. Norton, 1987), 299.

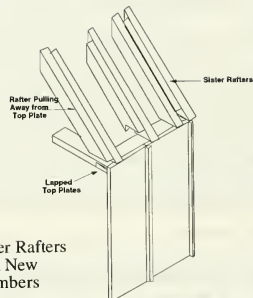
⁸ James Ambrose, *Simplified Design of Building Structures*, 3d ed. (New York: John Wiley & Sons, 1995), 24.

⁹ There are several products available for the use of wood adhesives and fillers. Frederick Stahl recommends calcium caseinate, which is powerful and has been used for centuries. For filling irregular cavities, he suggests the use of Aerolite 300. Frederick A. Stahl, *A Guide to the Maintenance, Repair, and Alteration of Historic Buildings*, (New York: Van Nostrand Reinhold Company, 1984), 80.

Insert Collar Tie
To Resist
Deformation



Insert Steel
Anchor to
Stiffen Joints



Sister Rafters
with New
Members



Figure 4.3a. Diagrams of intervention strategies for broken joints.
Figure 4.3b. Photograph showing failure of connection. Bldg. "P" Rm. 1, NW corner taken
6 Aug., 1996 by P.D. Schulz.

This is not recommended due to the fact that the goal is to preserve the structures, not to restore them. The cost of application far outweighs the visual benefit.

When the roof members bend under load and do not regain their initial state, the horizontal closure of the structure is compromised. Gaps formed from the bent, twisted, or cracked sheathing allow water to penetrate to the interior, which causes additional damage to the structure. Considering that bending (creep) is caused by excessive load to the elastic material, the most rational means to mitigate deflection is to remove the excessive load. This would require removing the snow from the roofs of the Bodie buildings; a task that would no doubt require a significant reallocation of manpower at times of the year when extra staff is least available and Bodie is least accessible [figures 4.4a & 4.4b]. Rafters that have already deflected to the point of plasticity could be reconstituted with sister rafters that would share the work of transmitting the load to the ground. The most costly approach, and perhaps the least aesthetically pleasing solution is to construct an internal shoring system under the deflected rafter members. The shoring would substitute for the rafters and walls in holding the building up, acting much like a skeletal system [Figures 4.5a & 4.5b].

Another cause for the failure of the horizontal closure system to function properly is the loss of shingles and/or sheathing. This type of failure is also due to excessive loads, but rather than vertical load, the stress is induced from lateral wind loads. This type of load is much more challenging to mitigate. In some circumstances, it is possible to create windbreaks to mitigate such situation, but given the size of the town and the need to maintain its integrity of setting, this seems totally impractical here. A more practical intervention to mitigate the loss of shingles or sheathing is to simply nail down the loose nails and shingles that have been pried up by the wind [Figure 4.6a]. An approach to the reconstitution of the horizontal closure system that would be in keeping with the nature of the park would be to cover and holes in the roof with similar materials, much like the miners would have. There is always the option of substitution of the missing roof covering as a unit. This approach requires the removal of

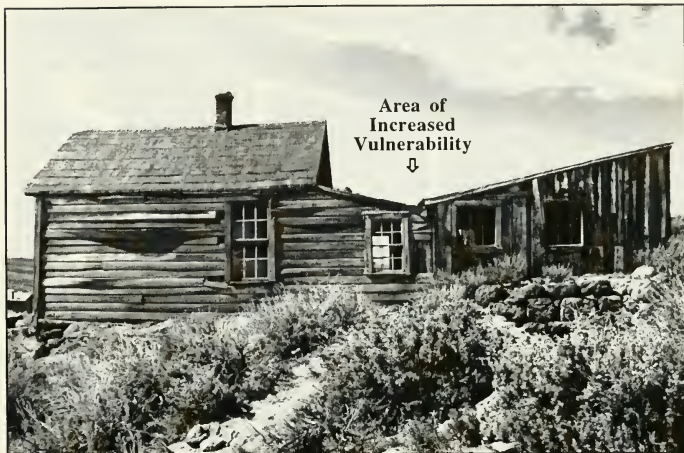


Figure 4.4a. Photograph illustrating incompatible additions and area of increased vulnerability to vertical loads. North Elevation of Metzger taken 23 May, 1996 by P.D. Schulz.

Figure 4.4b. Photograph of Andrews looking North-West showing extreme weather conditions. Photo taken 1988 by J. Brad Sturdivant.

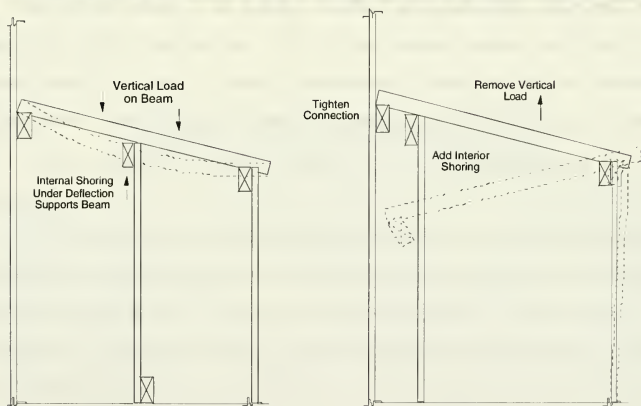


Figure 4.5a. Photograph showing shoring technique for deflected roof members (Cross bracing in photo for lateral movement) Andrews, Rm. 4- South wall taken 22 May, 1997 by P.D. Schulz.

Figure 4.5b. Diagram illustrating intervention strategies for deflected roof members and roof collapse.

existing fabric and installation of new sheathing and shingles. Several Bodie buildings have already undergone this treatment. One advantage of such intervention is that it replaces a failing system with a sound one and so protects the interior from accelerating deterioration. Also, the new roof can be expected to remain functional without attention for several years. The visual downside of this approach is that- at least for the first year or two- the replacement roof (even though made in kind) is readily discernible as new and so detracts from the atmosphere of arrested decay. The other disadvantage of this intervention strategy is the wholesale loss of historic fabric, a practice that has been criticized as leading to creeping reconstruction [Figure 4.6b].

Vertical Closure

The vertical closure of the building includes the nonstructural components of the building including the siding, wall ties, interior surface substrate, windows, and doors. These elements function as a system to prevent the penetration of inclement weather and preclude its damaging effects. Three failures that inhibit the vertical closure from performing its function are the buckling of the wall boards, the failure of the material, and missing doors and windows.

As with roof collapse and bending of the roof material, one must remove the source of load in order to mitigate buckling. Both the vertical load (excessive snow and water) and the lateral loads (erosion build up, excessive wind) must be removed. Routine checks of the structures must be made and soil build-up against the building's uphill wall should be cleared away. Excessive snow should be removed from the roof to lighten the load to the slender vertical members. In order to help strengthen the buckling vertical members, the wall boards can be reconstituted by thickening the outer envelope (adding an additional layer of vertical or horizontal siding). A comparable yet more honest reconstitution would be to insert an internal structural system in the form of shoring that could be furred against the interior of the buckling

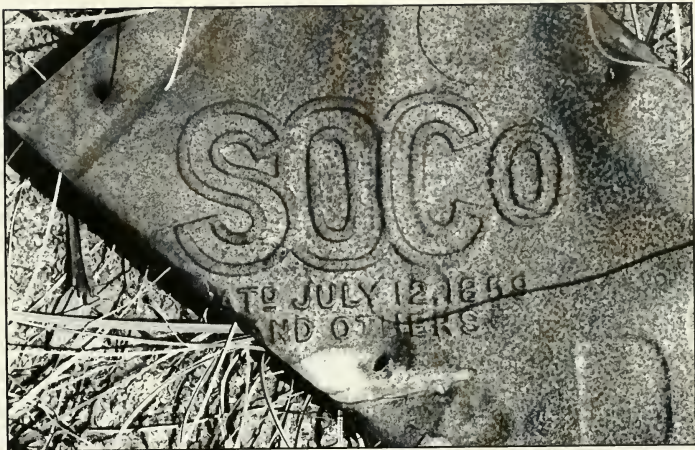


Figure 4.6a. Recycled tin can shingle w/ trademark blown off sheathing above Door 4, exterior, Building "C" taken 15, Aug., 1997 by P.D. Schulz.

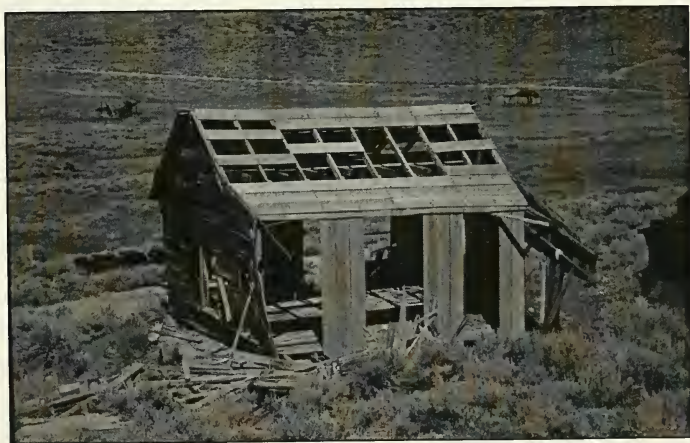
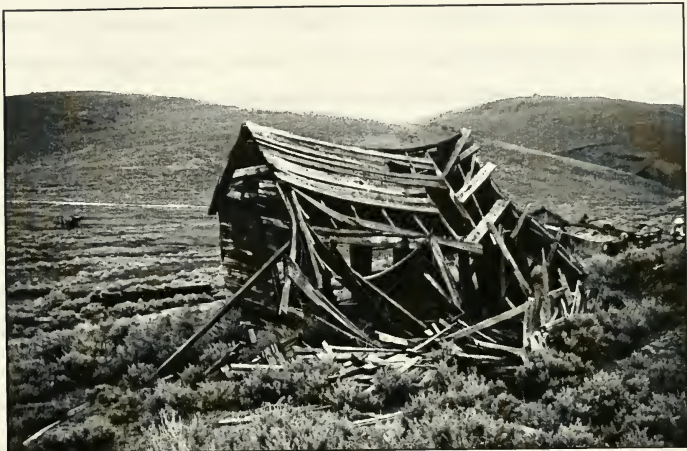
Figure 4.6b. Replaced roof with new material protects the interior of the structure, but compromises the integrity of the park and leads to creeping reconstruction. West elevation, Building "E1" taken 2 Sept., 1998 by A.S. Morrison.

wall. The shoring would share the compressive load with the slender siding as well as stiffen the outer envelope. The third intervention strategy (substitution) would require the removal and replacement of the buckled members with new members of greater strength. This approach has already been utilized by park maintenance staff. Once again, although the new siding defers the deterioration curve, it also compromises the historic integrity of the buildings due to the replacement of original fabric [Figures 4.7a & 4.7b].

A second source of failure in the vertical closure system is due to the failure of the material (fabric). The chemical or mechanical failure of the wooden members weakens the outer envelope of the structure, allowing moisture to penetrate the interior. Rising damp, wet rot, and defects such as twisting, bending, shrinkage, or missing knot holes constitute chemical or mechanical failures. There is no way to stop the natural weathering of the wood, but a few measures can be taken to retard its rate of deterioration. The simplest method of mitigating material deterioration is the removal of the rot inducers. Snow piled up against the exterior of the buildings should be cleared away as to prevent unnecessary contact with moisture, and debris piled up in the interiors of the structures should be removed to preclude the entrapment of moisture as well. There are numerous consolidants and epoxies that can be applied to the wood as a means of reconstituting the fabric. A more appropriate intervention is the application of wood preservatives, water repellents, and fire retardants to lessen the damage of the environment to the wood.¹⁰ If the wooden members are damaged beyond repair, and their failure is compromising the vertical closure of the building, then the material should be substituted with a new (not different) material.

Several of the buildings have missing doors and/or windows which accelerates the deterioration of the interior fabric. This problem can be mitigated by routinely checking the

¹⁰As previously noted, the use of wood preservatives and fire retardants had been tried and discontinued as it was found that they damaged the wood, causing the fibers of the white pine to disintegrate. Buck R. Nelson, "Bodie, California: A Ghost Town Stabilized" (Paper presented at the Ghost Towns and Mining Camps Preservation conferences in Boise, Idaho, May 1974 and in Flagstaff, Arizona, April 1975, and the Developing Historic Districts in Small Towns and Cities Workshop in Salt Lake City, Utah, March 1975), Washington: The Preservation Press National Trust for Historic Preservation, 1977), 7.



Figures 4.7a & 4.7b. Building "N" before and during reconstruction of collapsed wall.

stability of the doors and windows, and repairing those that are loose. If a door has fallen off its hinges, or the glass in the window is broken, then these items should be reconstituted. Fallen doors should be rehung where possible (or permanently fixed to jambs) and broken or loose glass should be sealed with a clear caulk. In instances where the original door or sash is not present around the structure, then the fenestration should be sealed with scrap metal or wooden boards. The structures that have fallen to a state of disrepair beyond their "half-lives" can withstand not having their openings completely sealed, as the ruins have already reached the decelerated deterioration stage and additional damage to the interior is minimal (most of these structures are not currently sealed and are merely enclosed with wire mesh or scrap metal). However, the buildings that have maintained a high state of integrity on the interior should be protected from further damage, and could make use of clear Plexiglas over large openings in the vertical closure to preclude the penetration of inclement weather but allow the visitors to see inside.

Structural System

The final subsystem that must be considered is the structural system. The failures that compromise the structural integrity of the single-wall buildings in Bodie are racking, differential settlement, and heaving. These failures cause the building to disfigure, but without the presence of failures in the horizontal or vertical closure systems, they will rarely cause it to collapse.

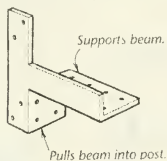
Racking is caused by excess lateral wind loads. The only mitigation for this form of longitudinal shearing is to lessen the magnitude of the lateral force. The only means of lessening the force is by creating a wind shield. Since this would be incompatible with maintaining Bodie's integrity of setting, it is not a recommended intervention. A better solution to counteract racking is to stiffen the structural box. This can be done in two ways: reconstituting the connections (joints), or bracing the structures externally. Steel plates can be used to reinforce the structural connections. Angle braces can reconstitute the monolithicity of

the joint, or a combination plate can be used for joints under both tension and compression [Figure 4.8a]. The stabilization of these joints will counteract the lateral forces imposing stress onto the structure, thereby mitigating further shearing of the building. The park personnel have in the past braced the structures externally by propping a pole against the leeward side to the wind. This is a functional alternative and in a small way adds to the intrigue of the “arrested” town. This is a very economical option [Figure 4.8b].

In structures that already exhibit pronounced racking, the substitution of a different system may be necessary to keep the structure from further deformation. When rafters and joists shear under stress, the ends become disconnected, causing the walls to lean outward as the house pulls apart under the weight of the roof. In the case of the Bodie, it is not necessary to pull the skewed walls back into true alignment because much of the appeal of the abandoned town comes from its deformed and odd-shaped buildings. However, the mechanics utilized in correcting leaning walls and swayback roofs can be utilized as an efficient stabilization method for racked structures. Instead of expecting the fragile buildings to continue to carry their own weight under compression, the substitution of a turnbuckle and cable system can stabilize the structure by transferring the weight to tension cables. The cables should be attached diagonally from the top plate to the opposite bottom plate to resist lateral forces. A turnbuckle can also be left in permanently as a wall tie where collar ties and knee braces are needed.¹¹ The advantage to using a turnbuckle and cable system in the single-wall buildings is that they effectively stabilize the structures against racking and sagging roofs, but they are also distinct in appearance as not to be confused with original construction [Figure 4.9]. This form of intervention is in keeping with the Secretary of Interior’s Standards for rehabilitation of historic structures.

¹¹ A complete description of truing up the house frame and correcting leaning walls and swayback roofs is outlined in George Nash’s book, *Renovating Old Houses* (Newtown, CT: Taunton Press, 1992), 125-129.

Combination plate for joints under both tension and compression



Use this type of plate for joints under tension.

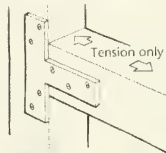
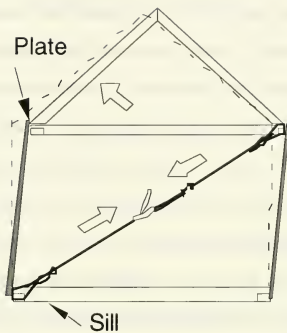


Figure 4.8a. Diagram of combination plate and "T" plates to be used to stiffen joints from Nash, 122.

Figure 4.8b. Photograph of Swazey Hotel on Main Street showing pole propped up against outside of structure on the leeward side to resist racking. Taken 2 Sept., 1998 by A.S. Morrison.

Use of a Come-along to pull the structure together.

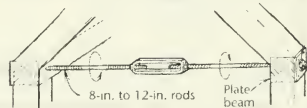


Cable & turnbuckle
Resists lateral forces

Pulling chain attaches to hook eye with clevis pin, slip hook or grab hook.



Turnbuckle as wall tie (left in permanently)



Diagrams of turnbuckles
from Nash, 127.

Cable & turnbuckles
left in permanently to
stiffen box. Resists
vertical and lateral
loads

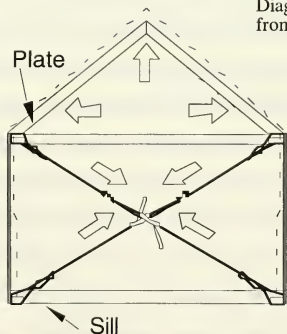


Figure 4.9. Diagrams showing use of come-along, and cable & turnbuckles to stiffen box.

The second failure that compromises the structural system is differential settlement. The best way to mitigate uneven settlement is to infill dirt and build up the foundation area under the areas that have settled to bring the structure back to plumb. As with other structural deformations, an alternative intervention is to reconstitute the connections. Stiffening the joints with steel plates, sistered rafters, or inserted collar ties will allow less movement of the structural system if a section of the building begins to settle. This intervention would most effectively preclude deformation if used in conjunction with a built-up subsoil to prevent the possibility of uneven settlement. The most comprehensive stabilization measure is to substitute an entirely new foundation under the buildings. To conceal the new foundation system, it would be necessary to excavate beneath the existing floor, supporting the structure with temporary jacks while new piles are placed.¹² The piles could be made out of wood piers or concrete. Any new foundation that was inserted would have to be properly concealed from public view [Figure 4.10].

The final failure that compromises the structural system is heaving. This failure is evident in so few of the buildings in Bodie, that the intervention should be minimal. The optimum mitigation strategy is to mitigate the movement of soil under the structures. This could be in the form of erosion control on uphill slopes, or by simply removing excess buildup of soil around the buildings such that any drainage runoff or loose soil gravitate away from the foundation. This would require routine inspection of soil movement and a certain degree of soil removal. For buildings that already exhibit problems with heaving, a more direct intervention is necessary. Floor boards may need to be removed for the excavation of built-up dirt from the subfloor. The optimum intervention would be to substitute the current foundation system on grade for one that allows for the free movement of air and soil beneath the floor. This would require extensive excavation, and potentially the placement of piles or posts to support the bottom plates. This intervention runs the risk of other structural failures,

¹² The maintenance crew at Bodie now use pressure treated wood plates set on grade (concealed on exterior by bottom of wall boards).

however, if the excavated walls were not adequately constructed, such that their collapse may cause differential settlement or other soil movement problems.

Methods for Jacking the House

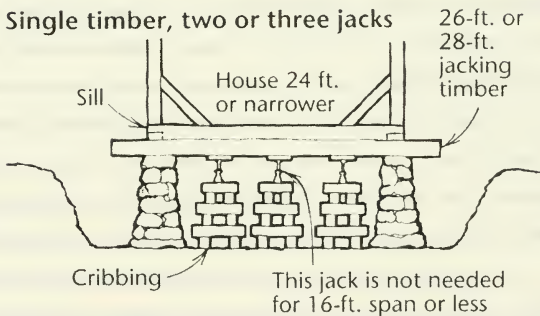


Figure 4.10. Diagram showing method for jacking up a house if excavation is needed to prevent heaving, replace foundations, etc. Nash, 85.

Conclusion

All things, with the passage of time, show signs of age and eventually die. The single-wall buildings in Bodie are a testament to this. Through a systematic analysis of the remaining single-wall structures, several structural failures were found. These include failures induced by the soil, stresses induced by loads, and failures in the construction materials. The nature of the failures are largely caused by the frugal construction technique and the inclement environment; which together pose a challenging preservation question. How does one preserve a large-scale historic landscape when, although the structures are threatened by a severe climate, were initially constructed to be temporary?

The State of California has addressed this question in their General Plan for the Park; that due to the nature its significance as a National Historic Landmark and World Monument, that the park will be maintained in a state of “arrested decay.” This approach to preservation not only secures the scenic setting of the nineteenth century mining frontier, but also serves as a viable method of maintaining the large number of buildings as a collection, as opposed to restoring only a few of the structures to a pristine degree. Based on the large-scale maintenance demands for the collection of buildings, the structures can be maintained at the point of their half-lives. The period at which an individual structures reaches its half-life point should be used to measure the appropriate time for and degree of intervention.

Five intervention strategies were assessed for each structural failure, including doing nothing, mitigation, reconstitution, substitution, and acceleration. A building-by-building survey would be necessary to ascertain which of the intervention strategies would be most appropriate for any individual structure, however, this thesis may be used as a guide for prioritizing the intervention strategies. For example, immediate stabilization needs should be addressed based on the potential threat to the building as a structural system and by that system’s rate of deterioration, rather than by the magnitude of the failure alone.

Once it has been determined that intervention should take place on one of the single-wall buildings, then a few basic guidelines should be followed. First, before any changes are made to the buildings (however minor), the structure should be fully documented with photographs and measured drawings and the repair work completed should be recorded in detail for future researchers. Secondly, the intervention strategy should only address the problem that is immediately imposing failure to the structure as a system. The cause for the structural failures are not always easy to recognize, and in several cases, more than one problem is evident. Chapter Three, “Structural Failures,” systematically breaks down the various failures and their causes in an intelligible manner to be used as a field guide for diagnosing the failures accurately. If the problem is diagnosed correctly, then the selected strategy for stabilization or repair may be made with the least amount of detriment to the historic fabric (and in the most cost-efficient manner).

The preservation of Bodie is a long-term goal for the State of California, and therefore the cumulative maintenance costs must be taken into consideration. Relative costs for each of the intervention options must be weighed against each other and adjusted for the potential duration of the structure’s lifespan. Keeping in mind that the structures only need to be maintained at the point of their half-lives (“arrested decay”), then it is safe to say that high end restoration is not appropriate for this site. In most cases, it is better to mitigate against the structural failure, than to replace its members after-the-fact. Also, in most case, little is required for stabilization or reconstitution, as indicated earlier in this chapter.

It is generally recognized in the preservation community that it is “better to preserve than to restore,” and “better to repair than to replace.” Therefore, the replacement (substitution)of the historic fabric is discouraged in order to protect Bodie’s historic integrity, and to the elude the criticism of “creeping reconstruction.” In some cases, however, this may be the last option for stabilization before the building collapses. As with all significant historic sites, the guidelines of the Secretary of Interior’s Standards should be followed. Under the

guidelines for the Preservation of Historic Structures, the materials and features of the buildings must be retained, the deteriorated historic materials should be stabilized (including structural reinforcement), and the replacement of materials should be limited (and replaced in kind). Of course, all new material should be discernible and properly documented.

This thesis and recommendations are meant to serve as a guide to understanding the failures of the single-wall structures, and are by no means guaranteed to protect the structures from future damage. The intervention strategies will however, aide in prolonging the lifespans of the structures as a collection. The large collection of remaining single-wall buildings in Bodie serves not only as an ideal laboratory to study building failures, but also as one of the last vestiges of California's early mining life that turned to ghost town. As the term "ghost town" suggests, it is certain that these single wall structures will eventually fall to ruin, and perhaps should be allowed to do so. As John Ruskin states in his book, *The Seven Lamps of Architecture*, "A ruin is a ruin, no more, no less, what is gone is gone, and cannot be recaptured...Monuments that are meant to die should be allowed to die with dignity."

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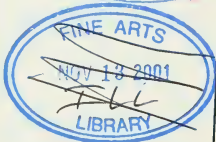
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