OFFICE OF
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CITY OF DEADWOOD SOUTH DAKOTA

Mike Runge
Archivist
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MEMORANDUM

Date: December 19, 2022

To: Deadwood Historic Preservation Commission

From: Mike Runge, City Archivist

Re: **2022 Deadwood Fire History Project and Final Report – INFOMATIONAL NO ACTION NEEDED**

On December 19, 2022, Dr. Peter Brown of the Rocky Mountain Tree-Ring Research in Fort Collins, Colorado submitted the enclosed report and two exhibit quality wood cuts to fulfill the requirements outlined in the 2022 Deadwood Fire History Project. These samples consisted of wood cross sections of tree stumps that contained multiple fire scars. According to Brown's report,

"Occasionally a fire will get hot enough to kill a portion of a tree's growing tissue (the cambium) and form what is called a "fire scar". In this case the fire doesn't kill the tree itself, and the fire scar shows up as a distinctive injury in the annual tree rings as the tree continues to grow. Fire scars can be dated to the exact year they formed – and even the season of formation – using dendrochronological methods."

A total of 45 wood samples were collected within the Deadwood city limits during Brown's weeklong site visit in October of 2022 (see Image #01). The samples were then sanded and cross dated to the Black Hill's ponderosa pine master chronology.

"Ring patterns match between trees since climate affects growth of all the trees in a local area in more or less the same way – narrow rings during stressful years and wide rings during good years."

Based on Brown's report, the oldest fire scar occurred in 1487. Coincidentally, this stump had a pith or birth date of 1452 (see Image #02). Many of the other fire dates coincided with other fire history sites throughout the Black Hills including the 1785 fire that destroyed an estimated 1 million acres. Brown also determined that many of Deadwood's fires occurred in the late summer or early fall based on the size of the affected growth ring.

The report provides inciteful information pertaining to the regularity of forest fires within Deadwood Gulch as related to the Black Hills. Based on this study, the median interval between fires in Deadwood Gulch from 1551 to 1819 was 27 years. However, from 1840 to 1891 the median interval increased to 6 years, due to the increased occupation of the Black Hills by indigenous and Euro-American settlers. It is unknown if these fires were accidental or purposeful. As related to this report, a total of 21 different fires were identified during this project, the oldest being 1487 and recent 2002.

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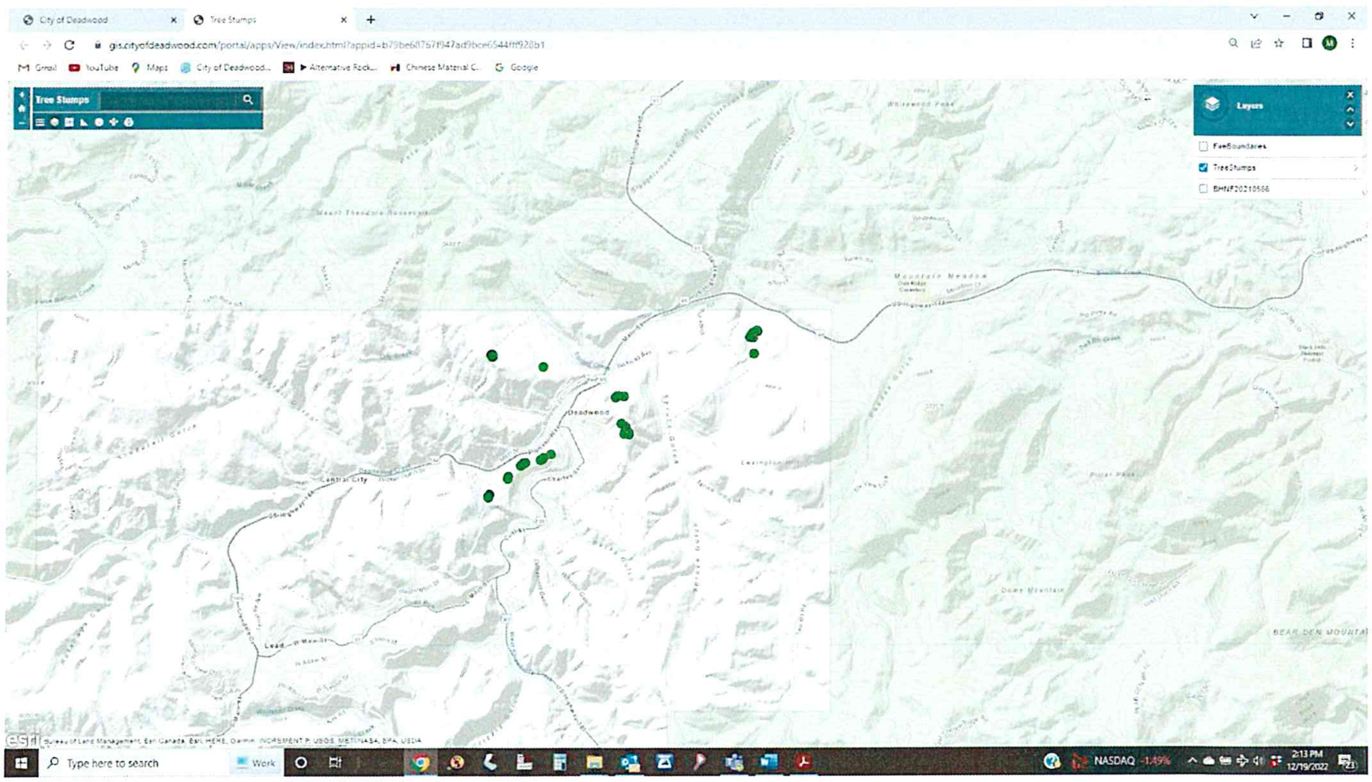

Image #01 Map showing the locations of the sampled stumps within the Deadwood city limits.

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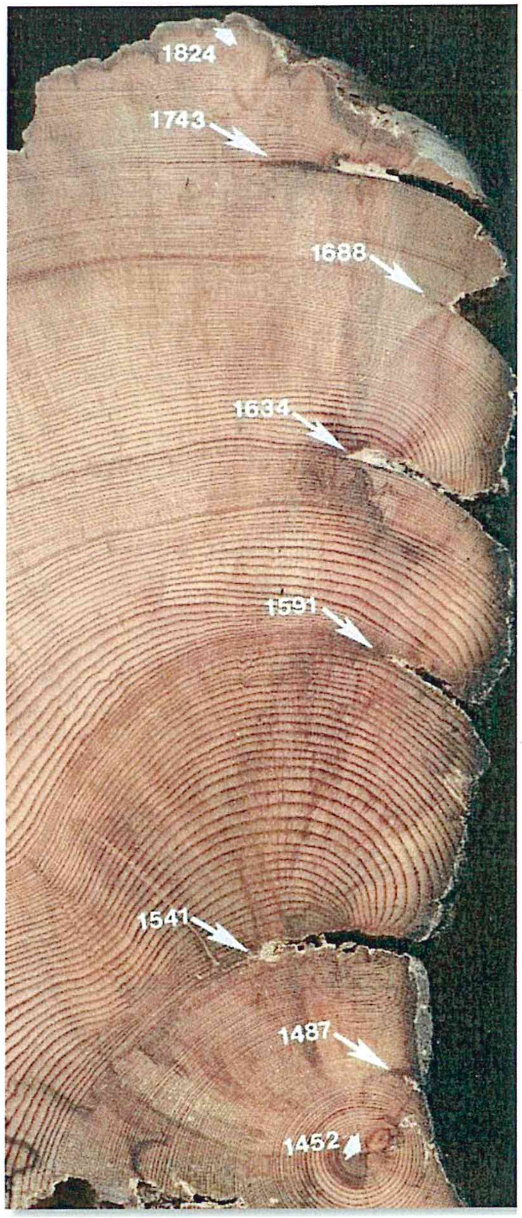

Image #02 Close up cross section DED-43. This was the earliest sample collected during the project.

A Forest Fire History of Deadwood

Final Report to the City of Deadwood, South Dakota

December 8, 2022

Peter M. Brown, Ph.D.
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2901 Moore Lane, Fort Collins, Colorado 80526
(970) 229-9557; rmtrr.org

Introduction

Wildfire has been a central ecological disturbance process in ponderosa pine forests of the Black Hills for hundreds if not thousands of years (Brown 2006). For wildfires to occur, three things have to be present: 1) fuel to burn, in the form of vegetation; 2) the fuel has to be dry enough to ignite and burn; and 3) there has to be some sort of ignition source – either lightning or humans – to get the fire started. Ponderosa pine forests throughout western North America are in what fire ecologists and managers like to think of as the "Goldilocks" zone (Heyerdahl et al. 2011); everything is just right for fires to occur fairly often. Ponderosa pine forests tend to be fairly productive – in contrast to, for example, lower elevation dry forests such as piñon-juniper woodlands in the Southwest or dry desert shrublands in the Great Basin – and they grow in areas with often dry summers – in contrast to higher elevation forests such as subalpine spruce-fir forests that tend to be much wetter and with snowpacks that often last into the early summer.

There is also a balance between how often fires occur and how hot they get: the more often they burn results in less fuel to burn in subsequent fires, and thus fire intensity tends to be lower. Fire behavior in past forests largely ranged from relatively frequent, low-intensity *surface fires* burning through grass, forbs, shrubs, and leaf and needle litter on the ground, to much less frequent but much higher intensity *crown fires* burning through tree canopies. Fire fighters often refer to these as "cool" vs. "hot" fires. Historically in ponderosa pine forests, fires tended to occur relatively frequently – on average every 10 to 30 years or so in the Black Hills depending on elevation and location – and mostly low intensity with flame lengths of only a few feet (Brown 2006).

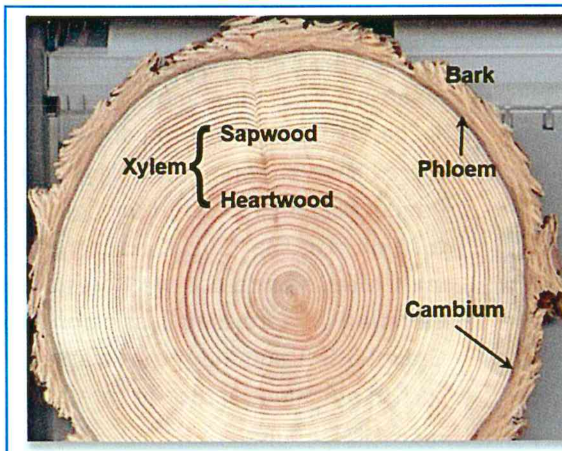
Fire Intensity versus Fire Severity

Intensity is measured at the time the fire occurs, how "hot" the fire gets. Technically this is the amount of heat released (measured in BTUs) but can be estimated in the field by measures such as flame length and rate of spread. **Severity** is the amount of damage the fire causes. In forest fires this is usually measured as the amount of trees killed by the fire. Crown fires cause extensive areas of tree mortality while surface fires usually don't kill many mature trees, especially in historical ponderosa pine forests.

Mature ponderosa pine trees typically survive these frequent, low intensity surface fires as a result of their ecological adaptations to fire. Wildfire kills a tree in one of two ways: either by killing all of the growing tissue (the "cambium") near the base of the tree's stem – also referred to as "girdling" the tree - or as a crown fire that kills most or all of the tree canopy. Mature ponderosa pine trees have characteristics that protect themselves from both of these factors. They have both thick bark - often 2 to 3 inches thick - that protects the cambium underneath the bark from getting too hot, and by "self-pruning" lower branches such that their canopies are raised above the flames burning through surface fuels. Note, however, that these factors only protect mature trees from being killed. Young seedlings and saplings – with canopies that go all the way to ground and with thinner bark – can be killed by even very low intensity fires (Battaglia et al. 2009). Historically, when fires were burning every 10 to 30 years, the vast majority of seedlings and saplings were thinned out before they had a chance to reach maturity. This limited the number of mature trees over time, resulting in largely open forests consisting of individual trees of variable sizes and ages (Brown and Cook 2006). However, after active fire suppression began in the early 1900s by Forest Service and other land management agencies, wildfire was no longer a check on the numbers of seedlings and saplings, resulting in the much denser stands present in many areas today. And more critically, this shift to much younger and smaller trees has also resulted in a shift in fire behavior from the low-intensity surface fires of the past to large areas of high-intensity crown fires as we've seen in recent fires across the Black Hills.

Deadwood's Fire History

Occasionally a fire will get hot enough to kill a portion of a tree's growing tissue (the cambium) and form what is called a "fire scar" (Figure 1). In this case the fire doesn't kill the tree itself, and the fire scar shows up as a distinctive injury in the annual tree rings as the tree continues to grow. Fire scars can be dated to the exact year they formed – and even the season of formation – using dendrochronological methods. Dendrochronology – tree-ring research – uses variability in annual growth rates caused by varying annual climate conditions to "crossdate" ring patterns between trees. Ring patterns match between trees since climate affects growth of all the trees in a local area in more or less the same way – narrow rings during stressful years and wide rings during good years. A dendrochronological study starts by examining ring patterns from living trees where we know the date of the outermost ring, and then works backwards to develop a "chronology" of ring patterns for older and older periods. Living trees are sampled using an increment borer that removes a 4 to 5mm diameter core from the tree without harming the tree, while dead wood is usually sampled with a chainsaw to remove a cross section, often referred to as a "cookie". Dendrochronological methods also permit dating of dead wood such as from stumps or timbers used in construction of a building, where we have no idea when the tree was cut, and often outer portions of the wood – the bark and sapwood - have decayed away.



Some Wood Anatomy:

Xylem: The technical name for wood.
Sapwood: Portion of xylem where water and nutrients flow from soil up the stem to the leaves. Sapwood is not resistant to decay and erodes within a few decades after tree death.
Heartwood: portion of xylem where tannins and other "waste" products from respiration are deposited; the heartwood is very resistant to decay and can persist for many decades especially in ponderosa pine trees.
Phloem: Between bark and xylem, the tissue where sugars produced by photosynthesis move down the stem from leaves to provide new substrate for growth.
Cambium: The growing tissue that forms new xylem to the inside and new phloem to the outside.
Pith: The center tissue of the stem.

Figure 1. Cross section sample DED 13 with two fire scars from historic fires in the Deadwood area. The first fire to scar the tree was the September, 1959, Deadwood Fire and the second was the 2002 Grizzly Gulch Fire. After each of these fires killed portions of the cambium, the tree continued to grow and formed "woundwood" that covers the injury. This cross section was removed from a stump cut in 2011, and the earliest date for the center of the tree was 1885. Note also the thick bark, characteristic of ponderosa pine. Thick bark is generally able to protect the cambium from injury by fire, and did for most of this tree's circumference except for the fire scar areas. For a higher resolution version of this image, please go to https://flic.kr/p/2o4uCmD.

Once crossdated, fire scars provide an annual history of fires that occurred in an area. That is what we have done for this study of the fire history of the City of Deadwood (Figure 2). We searched for and sampled mainly stumps from various areas around Deadwood to obtain the longest records we could find (Figure 3; see also Methods text box below for more details of sampling and analysis). Deadwood has had a long history of timber harvest starting in the earliest days after non-Indigenous settlement beginning in 1875, but because the heartwood of ponderosa lasts long in the environment we were still able to find stumps of trees that were felled in the late 1800s and early 1900s.

The fire history provides a window into both pre-historic fires in and around Deadwood going back several centuries as well as more recent ones. We collected cross sections from two trees that recorded fire scars and three that died during the 1959 Deadwood Fire. We also found fire scars from the more recent 2002 Grizzly Gulch Fire on three trees (Figures 1 and 2). The oldest fire scar we found was recorded in 1487, on what was also the oldest tree we found, with a center date of 1452 (Figure 4). Many of the fire dates also are found in other fire history sites throughout the Black Hills (Brown 2006). For example, fires in 1785 has been found in over 80% of the sites sampled across the Hills, and it is estimated that probably at least one million acres burned during this year. These extensive fire years probably were not single fire starts but caused by multiple ignitions during regional drought years when climate conditions were conducive for widespread wildfires to occur (Brown 2006). Most of the fire scars we found occurred either late in the ring for the particular year or just after growth had ceased for the summer, suggesting that all occurred in either August or September. This fits with historic fires in Deadwood, most of which occurred in early September after summer rains failed to develop. In addition to the fire scars, we also found in several samples abrupt growth "releases" – large increases in growth –

starting around the late 1870s that probably were the result of timber harvest (Figure 5). These trees were likely growing in relatively dense stand conditions and, after timber harvest of neighboring trees, saw a release from competition and thus an increase in their annual growth rates.

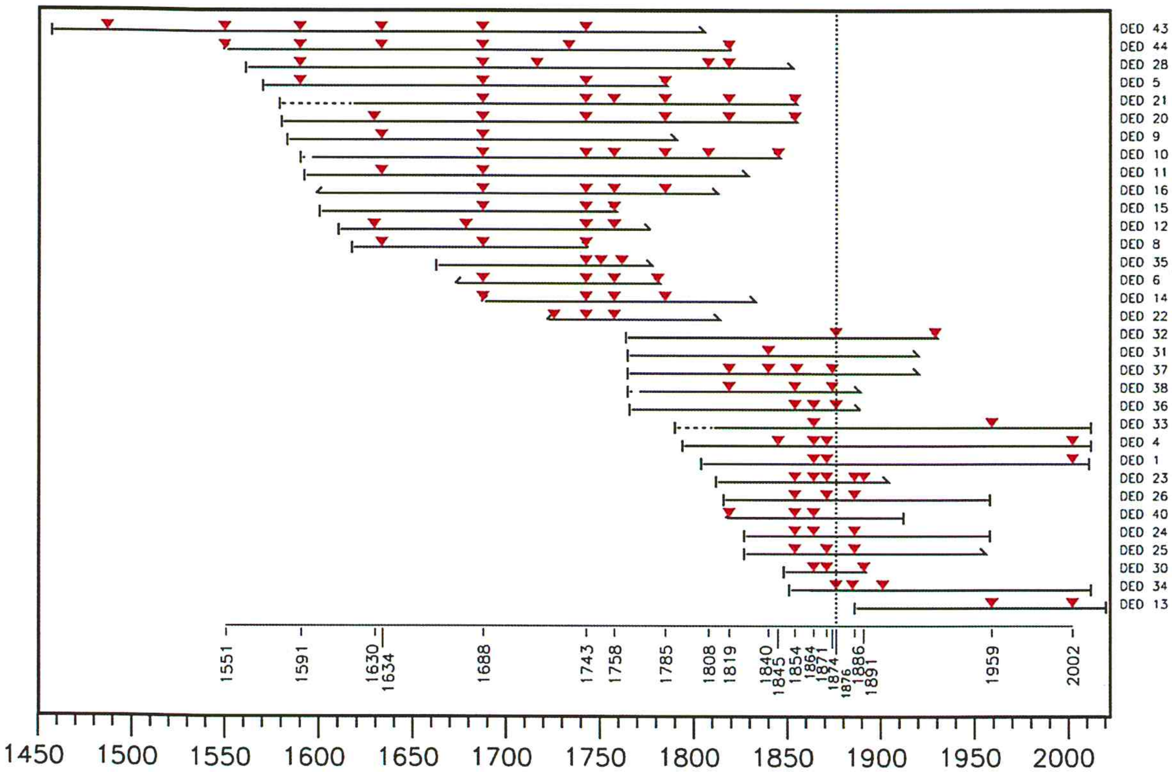


Figure 2. Fire chronology for Deadwood. Each of the horizontal lines represents the time span of an individual tree (samples IDs on the right) with dates of fire scars represented by red triangles. Dates at the bottom are fire scar dates recorded on at least two trees. Vertical tic lines to left on each tree represent pith dates while slanted lines represent inside dates (i.e., pith was not present on the cross section sample). Vertical tic lines to the right on each tree represent bark or death dates, while slanted lines represent outside dates (i.e., not death dates). Note that all of the oldest trees (above DED 22) were stumps likely harvested in the late 1800s but bark and sapwood have decayed and we cannot be sure of when exactly they died. The vertical dashed line is at 1874, after which Deadwood is founded.

Fire frequency varied through the fire history. From 1551 to 1819, the median interval between fires was 27 years, but from 1840 to 1891 the median interval increased to 6 years. This pattern has been found elsewhere in the Black Hills (Brown 2006) and thought to perhaps relate to increased occupation of the Black Hills in the middle to late 1800s by the Lakota. As mentioned in the introduction, the third component necessary for a wildfire to occur is an ignition source. Lightning is common during summer thunder storms in the Black Hills, but human activities would have supplemented ignitions during certain times and places. Prior to the middle 1800s the Lakota were primarily Plains peoples, but with increased pressures from Euro-American settlement throughout the Plains areas beginning at this time they may have started to use the Hills more as refuge and for resource use. An increase in human land use and associated ignitions both accidental and purposeful during this period may well be the reason fire frequency increased in the Deadwood area, as it did in other areas of the Black Hills.

There were several fires recorded in the trees surrounding Deadwood after settlement that apparently have no written record associated with them. Fire scars were recorded on several stumps in 1876, 1886, and 1891. However, the only recorded fire I have been able to find during this early period is the well known September 1879 fire that burned down much of the town that existed at that time. Interestingly this date was not found in any of the trees sampled. It is possible that the 1879 fire was isolated to the town only and did not burn any distance into the surrounding forest. Conversely, apparently the fires that burned in the surrounding forest during the years recorded by fire scars did not cause enough damage to town infrastructure as to warrant a mention in the historic record.

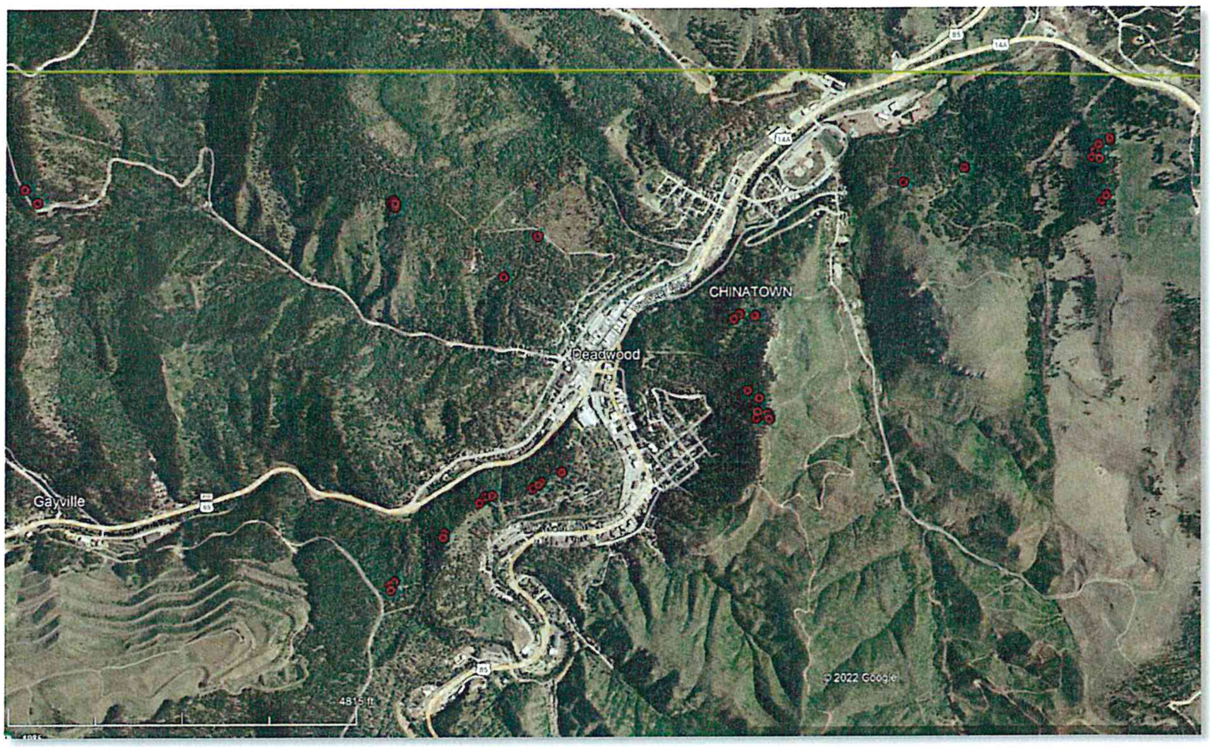


Figure 3. Locations of trees (red dots) sampled around Deadwood for the fire history study.

Implications of the Fire History for Deadwood Fire Management

A principle message from the fire history is that fire in ponderosa pine forests of the Black Hills is inevitable; it's not a question of *if* future wildfires will occur, but *when* fire will occur, and - perhaps more importantly – what kind of fire it will be. Wildfires were and always will be common in these forests because of the ideal balance between fuel amounts and fuel drying. The third factor, an ignition source, can be controlled to some extent by controlling human activities, but there is also always lightning as a potential source that will always be present.

A key question is what type of fire behavior to expect, whether low-intensity surface fire or high-intensity crown fire. Of course, the main factors affecting these varying fire behaviors are both how much fuel may be present in the form of trees and shrubs, but perhaps more importantly the arrangement of those fuels and how fire burns through it. Firewise efforts and other work to create defensible space around structures and other infrastructure are critical to modifying fire behavior once a fire gets started. These efforts should both reduce fuel amounts by thinning trees but also by rearranging fuel structures such that surface and canopy fuels are separated; in this case fire can stay in surface fuels and not climb up into tree canopies where it can be much more difficult to control. Combined efforts between City, State, and Federal agencies and private landowners to thin forests and modify fuels are central to creating broad scale patterns of conditions that affect real changes in how fire moves across the landscape. Wildfires will continue to burn in the future forests surrounding Deadwood, but by learning to live with fire, its impacts can be better managed for and anticipated.

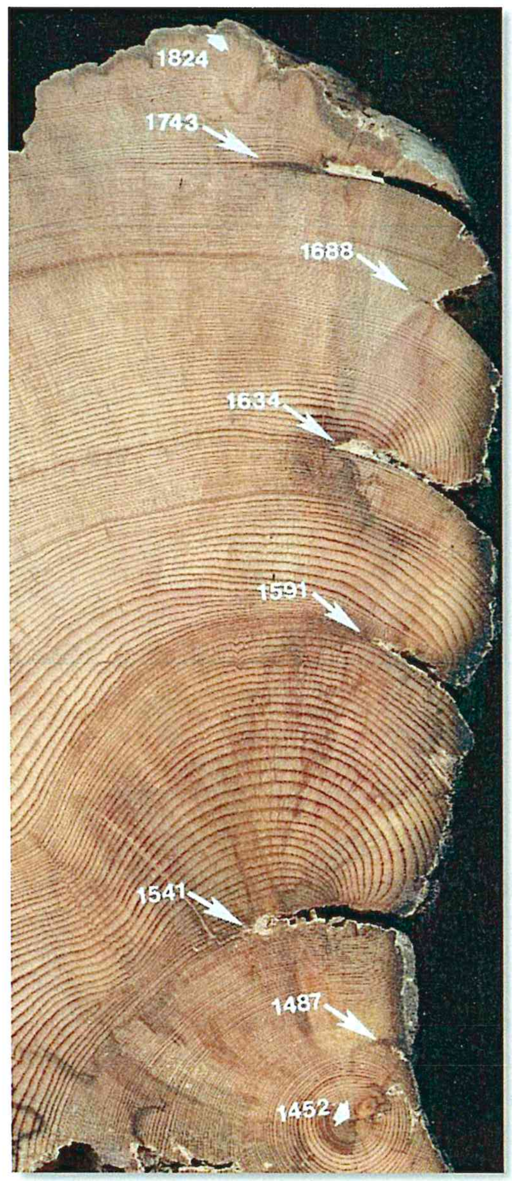
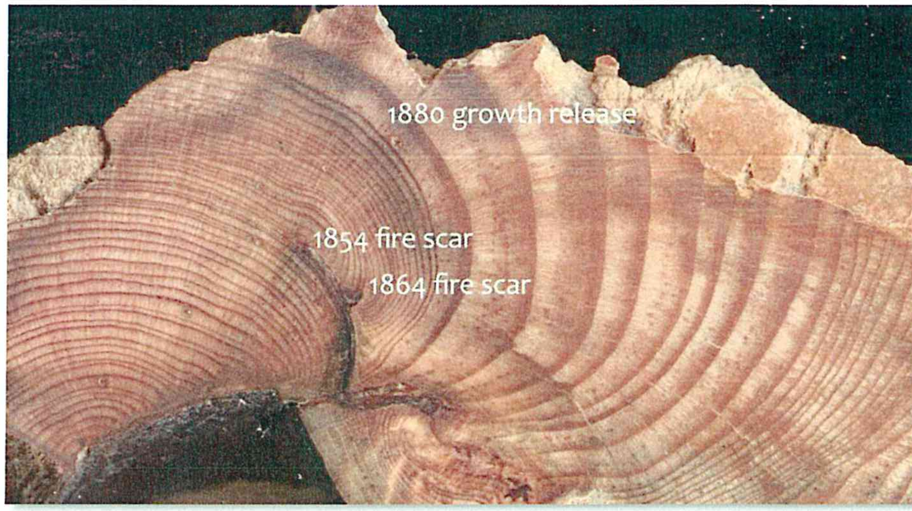


Figure 4. Cross section sample DED 43. This was the oldest tree found, with a pith date of 1452. Note that bark and sapwood are decayed from this cross section, which consists of only the heartwood of the tree. The outermost date recorded on the tree was 1824, but it was likely cut in the late 1800s for timber. This tree was located on the ridge between Deadwood and Whitewood Creeks in the middle of town. For a higher resolution version of this image, please go to https://flic.kr/p/2o4JgEr.

Figure 5. Cross section sample DED 40 with abrupt growth release starting in 1880. This is likely a response to surrounding timber harvest and reduced competition from neighboring trees.



Methods

Fire scar sampling took place between October 16 to 20, 2022. We searched for fire-scarred stumps, snags, or logs and removed cross section samples using a chainsaw. Samples were wrapped in stretch wrap for transport, and notes collected on sample location, type of sample, and number of visible scars. A total of 45 cross sections were collected from 44 trees. In addition, several larger living trees were cored with increment borers to assist in crossdating the dead trees.

Samples were returned to laboratory facilities at Rocky Mountain Tree-Ring Research in Fort Collins, Colorado. Samples were glued to backing boards and stabilized for sanding. Samples were surfaced using a combination of electric planer, belt sanders, and hand sanding to 400 grit sandpaper to be able to see cell structure in tree rings. Standard crossdating procedures including visual crossdating and skeleton plots were then used to date annual rings and fire scars recorded within them. Thirty-three of the trees were able to be dated, while dating was not possible on the other 11. Dates for fire scars also include position within the annual ring: E = first third of the earlywood; M = second third of the earlywood; L = latter third of the earlywood; A = latewood; D = dormant period between two rings; U = unknown position owing to damage to scar, tight rings, etc. Data were compiled, graphed, and analyzed using program FHAES, Fire History Analysis and Exploration System (https://www.frames.gov/fhaes/home).

Acknowledgments

We thank the City of Deadwood for funding this project, and especially Michael Runge, City Archivist, for his enthusiasm for this research. Mike and Emmett Brown assisted with field sampling, and Emmett helped with sample preparation.

References

Battaglia, M., Smith, F.W. and Shepperd, W.D., 2009. Predicting mortality of ponderosa pine regeneration after prescribed fire in the Black Hills, South Dakota, USA. International Journal of Wildland Fire, 18(2), pp.176-190.

Brown, P.M. 2006. Climate effects on fire regimes and tree recruitment in Black Hills ponderosa pine forests. Ecology 87:2500-2510.

Brown, P.M., and B. Cook. 2006. Early settlement forest structure in Black Hills ponderosa pine forests. Forest Ecology and Management 223:284-290.

Heyerdahl, E.K., P.M. Brown, S.G. Kitchen, and M.H. Weber. 2011. Multicentury fire and forest histories across forest types in Utah and eastern Nevada. General Technical Report 261 WWW. Fort Collins, CO: USDA, Forest Service, Rocky Mountain Research Station.