STAINING OF TIMBER IN THE MOUNT ST. HELENS MUDFLOWS

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ABSTRACT

A discolored ring of wood was observed in standing dead Douglas-fir trees that were in the path of the Mount St. Helens volcano mudflows. Frequently, this stain occurred only in the inner sapwood of the trees so that an outer ring of unstained wood was left. Chemical analysis confirmed that the stain was caused by iron infiltration of the wood. The hypothesis that mudflow heat inactivated translocation mechanisms in the tree and prohibited the transport of iron through the outer sapwood could not be proved.

Keywords: Staining, iron, volcano, heat, wood, Douglas-fir.

INTRODUCTION

The eruption of Mount St. Helens on May 18, 1980, caused large amounts of snow and ice on the flanks of the mountain to melt rapidly, producing flows of mud and debris that extended down river valleys far outside the eruption impact area. Many trees in the path of these mudflows were uprooted and washed downstream, but others were left standing. Some standing trees that were not immediately killed by abrasion or heat of the mudflow and that died within months of the eruption developed a dark stain in their sapwood. This stain is dark purplish to black and sometimes involves the entire sapwood zone. More frequently, however, the outer sapwood (up to 4.5 cm wide) was left unstained. At present it is not known how hot the mudflow may have been after the eruption, how this stain was formed, or why it occurred only in some standing dead trees located in the mudflows.

Although there is no published information on the occurrence of this stain in trees from the Mount St. Helens region, preliminary observations made by the Forest Research Laboratory at Oregon State University, by the State of Washington Department of Natural Resources,[2] and by the Weyerhaeuser Co.[3] indicate that:

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[1] This research was conducted while Goodell was a graduate student at Oregon State University.

[2] Personal communication, Kenneth Russel.

[3] Personal communication, Dave Overholser.

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(1) The stain is found only in standing dead trees in the mudflow zones. Living trees and downed trees that were hit by the mudflow at the same sites do not have this stain.
(2) Staining is present along the entire length of the bole, although the maximum height of the mudflow on the boles of the trees was 3 to 4.5 m.
(3) Staining apparently formed within 3 months after the eruption of the volcano.
(4) It is a nonfungal stain. The stained zone reacts strongly with hydrochloric acid/potassium ferrocyanide, indicating that iron is present (Wilcox 1964) and probably is causing the stain by reacting with tannins in the wood to form iron tannate. Bacteria were observed in the stained wood, but they may not be primarily associated with the stain.

Iron staining caused by the reaction of iron with tannins or other phenolics in wood has been well documented (Forest Products Research Laboratory 1966; Krutul and Kocon 1982). However, we are not aware of any information pertaining to an iron stain of this type forming in standing trees. The absence of this stain in the outer sapwood in many instances suggested that the translocation of the staining material through the outer sapwood had been prevented. Our objectives were:

(1) To test the hypothesis that the hot mudflow may have damaged the outer sapwood of some trees, limiting translocation of sap and staining materials to the interior sapwood; and
(2) To perform a more sensitive and accurate assay for the presence of iron in the wood and thus determine if the stain was associated with this metal.

PROCEDURE

Field data and analysis

Ten standing dead Douglas-fir trees from each of seven sites located 13 to 31 km southeast of the Mount St. Helens crater along the Muddy River Mudflow were inspected and cored with an increment borer in June 1982. Two increment cores were removed from each tree, one facing toward and the other away from the mudflow. Wood from living trees at the margin of the mudflow did not exhibit the stain; therefore, these trees were not included in our analysis.

The radial width of the outer unstained wood and of the stained wood was measured, and other data were taken on factors that may have affected heat penetration from the mudflow into the trees. In the laboratory the increment cores were treated successively with dilute hydrochloric acid (HCl) and potassium ferrocyanide ($K_4Fe(CN)_6 \cdot 3H_2O$) to test for the presence of iron (Wilcox 1964), and the width of the stained and unstained wood was again recorded.

A step-wise multiple regression analysis was performed. The width of the outer unstained wood was regressed against the following: Diameter of the trees at breast height, location of increment coring site with respect to the mudflow, presence or absence of bark at the increment coring site, thickness of bark if present, radial width of the stained wood (treated and untreated samples), distance of the site from the mouth of the crater, and the approximate distance of the tree from the nearest bank of the river at the time of sampling. Separate regressions were run for treated and untreated wood.

TABLE 1. *Step-wise multiple regression of the width of unstained wood (dependent variable) against variables which may influence penetration of mudflow heat into trees.*

Independent variables	B	Standard error B	F-significance (P-value)
Width of stained wood	−0.90	0.83 E-01	118.76 (0.0)
Tree diameter	0.44	0.72 E-01	37.23 (0.0)
Squared distance	0.34	0.72 E-02	21.93 (0.0)
Average bark thickness	−0.31	0.13	6.06 (0.015)
Presence of bark	−3.84	2.16	3.15 (0.078)
(Constant)	12.08	5.88	4.22 (0.042)
Adjusted $R^2 = 0.46$			

Microscopy, EDXA, and neutron activation analysis

Blocks of stained and contiguous unstained wood were cut from two standing dead trees in the mudflow. The samples were immediately sealed in aluminum foil to prevent drying and later lyopholized in the laboratory. These samples, along with a stained sample of veneer from a tree cut in the mudflow area, were observed under the scanning electron microscope for anatomical features that may have been related to the stain. Energy-dispersive X-ray analysis (EDXA) was also performed to determine chemical differences between stained and unstained wood. Neutron activation analysis was also performed on four wood samples from the same two trees, one unstained heartwood sample and one stained sapwood sample from each. These samples were activated in a TRIGA research reactor at the Oregon State University Radiation Center for 5 hours at 1 MW. They were stored for 3 weeks to allow the shorter-lived radioactive elements to decay to background levels. The samples were then counted for iron over a 12-hour period on a pulse height analyzer.

RESULTS

Field data and analysis

In step-wise linear regression analysis, a weak correlation ($R^2 = 0.46$) was obtained when the width of the unstained wood was regressed against the following variables (all variables significant at $\alpha = 0.05$): (1) radial width of stained wood; (2) diameter at breast height; (3) squared distance of the sites to the crater; (4) average thickness of the bark; and (5) presence or absence of bark at a particular coring site. Variables 1, 4, and 5 were negatively correlated, and variables 2 and 3 positively correlated, to the width of the unstained wood in the trees (Table 1).

Regression the width of the unstained wood after treatment with $HCl/K_4Fe(CN)_6 \cdot 3H_2O$ brought no new variables into the equation, and correlation values were lower than the 0.46 previously obtained. Dropping the independent variables of

TABLE 2. *Amounts of iron in stained and unstained samples of Douglas-fir from the Mount St. Helens mudflows.*

Tree	Sample	Iron concentration (ppm)	Statistical counting error (%)
1	Unstained heartwood	39	10
1	Stained sapwood	288	2
2	Unstained heartwood	4	14
2	Stained sapwood	122	3

tree diameter and the width of stained wood provided regressions with R^2 values of less than 0.01.

Microscopy, EDXA, and neutron activation analysis

No anatomical differences were noted between stained and unstained sections of wood, and no degradation was apparent. EDXA showed that a small amount of iron was present in all stained sections of wood removed from the standing dead trees. In unstained wood, iron was not detected by EDXA. Neither was iron detected in the stained sample of veneer; however, this sample was not as darkly stained, and although iron may have been present, it was below the detection limits (50–100 ppm) of the instrument. The neutron activation analysis showed much higher iron concentrations in the stained than in the unstained wood (Table 2).

DISCUSSION

The results of regression analysis do not support the hypothesis that mudflow heat damaged the outer sapwood of trees and limited translocation of iron through the outer sapwood.

The most significant variables in the regression analysis were the width of stained wood, tree diameter, and squared distance from the crater. The negative correlation between the width of the unstained wood and that of the stained wood indicates that the extension of staining to the interior of the tree may have been limited by the sapwood/heartwood boundary (if we assume no transport and, hence, no staining), but the correlation does not offer support for the hypothesis that mudflow heat is related to the stain. Diameter of the trees and the squared distance of the sites to the crater were both positively correlated with the amount of unstained wood. These correlations also fail to support the hypothesis because trees of larger diameter, in addition to having greater bark thickness, would have a greater volume-to-surface-area ratio and therefore should be more effectively buffered from heat damage. Trees further from the crater should also be less damaged by heat because they were further from the source.

That the average bark thickness and the presence of bark were negatively correlated to the amount of unstained wood supports the hypothesis because the presence of bark and increasing bark thickness should buffer the trees from heat damage. These two variables are not highly significant in the regression, and when regressed against the width of the unstained wood, each provides an R^2 value of less than 0.01.

It is apparent from the EDXA and NAA analyses that significant amounts of iron were present in the stained portions of the samples as compared with the background amounts of this element in the unstained wood.[4] However, we were not able to relate factors that could have influenced the mudflow heat transferred to the interior wood with a delineation of the stain in the wood. Because the temperature of the mudflow and the heat transfer into the trees do not appear to explain the variations in the stained width of the sapwood, another hypothesis is needed. One possibility is that the amount of staining simply reflects the distribution of tannin materials within the sapwood. If a large pulse of iron were translocated through the sapwood at the time of the mudflow, this iron may have bound to the tannins in the inner sapwood. In the outer sapwood the iron would have been translocated upward to lodge in the leaves and upper branch tissues, which were not analyzed in this study. The lack of stained wood in living trees in the mudflow regions suggests that damage to tree roots by the mudflow—which would have contributed to the rapid decline of the stained trees—may have been necessary for root uptake and subsequent translocation of iron present in the mudflow waters. Further research would be needed to determine if this hypothesis will explain the occurrence and distribution of the stain in these trees.

CONCLUSIONS

EDXA and staining with $HCl/K_4Fe(CN)_6 \cdot 3H_2O$ show that iron is present in darkly stained wood samples and that the reaction of this iron with wood components is the probable cause of the stain. Neutron activation analyses quantified this presence. At present, however, we have insufficient data to prove the hypothesis that mudflow heat inactivated translocation mechanisms in some trees, prohibiting transport of iron through the outer sapwood.

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[4] In the heartwood and sapwood of Douglas-fir samples taken from areas outside the mudflow zone and analyzed by NAA, iron content was less than 2 ppm (unpublished).