4-15-2013

Petrified Wood Survey of Land Adjacent to Petrified Forest National Park, AZ

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Abstract

An intensive survey was conducted on HNZ land, a subsidiary of Hunt Inc., which owns the mineral rights to land located adjacent to the Petrified Forest National Park, Arizona, United States. The purpose of the survey was to log the position and characteristics of petrified wood to better protect the fossils from thieves and to assess the value of Hunt lands. A monetary value was assigned to each log based on color, condition, size, and other mitigating characteristics. Two broad categories of fossil logs were found on the land, alabaster and rainbow. Mineral composition and oxygen isotopes were analyzed to better understand the conditions under which these two categories were fossilized.

Background Information

The Chinle Formation is the rock unit found in the Petrified Forest National Park and on HNZ (a subsidiary of Hunt Consolidated) land. It was deposited in the late Triassic Period and is dated from 230 to about 205 million years ago. As Pangaea split apart, major rifting of the continent of Laurasia developed a volcanic arc with the Chinle Formation deposited in a back arc basin.

The Petrified Forest is well known for its beautifully colored high desert badlands of erosional remnants of sands and muds but when it was first forming, it was a land of tropical forest and abundant vegetation. Muds and sands were carried by rivers from the highlands and deposited in fluvial, floodplain, delta, and lake environments of the Chinle depositional basin, entombing and preserving many fossils, specifically petrified wood. As logs of wood were taken downstream they were buried in sediment and underwent petrification. The petrification process begins as silica, pyrite, or calcite crystallizes within cells. There are many species of tree fossils found in the Chinle Formation, but for the purposes of this project, the wood was divided into two categories, alabaster and rainbow logs. Alabaster logs are tan, white, or brown in color and are less commercially valuable than rainbow logs, which are red, purple, or orange.

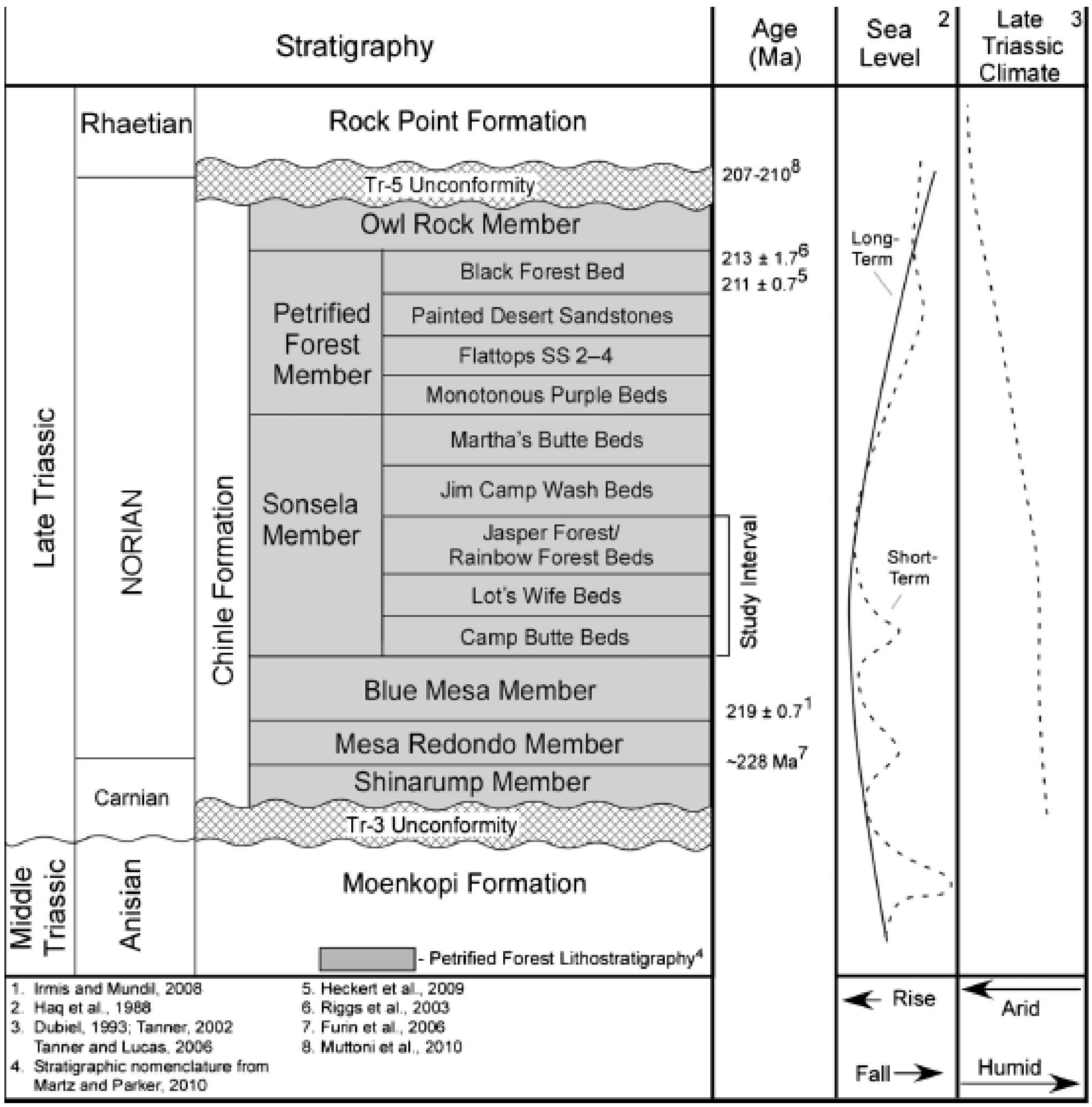

Figure 1 Stratigraphic column of the Late Triassic (from Trendell et al., 2012)

The lithology of the Chinle Formation is mostly multi-colored fluvial sandstone and mudstone beds. The upper Triassic Chinle Formation is exposed in the Colorado Plateau and covers areas of eastern New Mexico, southwestern Colorado, Eastern Utah, and Arizona. The Petrified Forest member is made up of yellowish sandstones, flattops, and reddish mudstones. Flattops are prominent sandstone layers within the Petrified Forest Formation and they are numbered 2, 3, and 4. These more resistant layers are yellowish with blocky weathering. The conglomerates in the formation are reworked pedogenic clasts of chert (Martz et al., 2010). Sedimentary structures include trough and planar cross bedding.

The Sonsela member contains layers of siliceous conglomeratic sandstones and interbedded mudstones. It is divided into five units (bottom to top): Camp Butte beds, Lot's Wife beds, Jasper Forest/Rainbow Forest beds, Jim Camp Wash beds, and Martha's Butte beds. Martha's Butte beds consist of interbedded ledge forming sandstones and easily weathered, slope forming sandstones and mudstones. These mudstones are either gray or dark purple (Martz et al., 2010). Jim Camp Wash beds are also grayer and less resistant to "hoodoo" weathering formed when a small stone or boulder acts as a resistant caprock and protects underlying softer rock from erosion, as is common in the badland topography. The Jasper Forest and Rainbow Forest beds are essential equivalent so they are grouped together.

Jasper beds and Rainbow Forest beds are texturally mature beds with siliceous conglomeritic sandstone. The gravel-sized clasts are dominated by chert, quartzite, and reworked volcanic casts of Triassic age (Martz et al., 2010). There is abundant red "jasperized" petrified wood along with white or orange "non jasperized" wood. The upper part of Lot's wife is dominated by light gray and reddish sandstone, purple and bluish mudstone, and muddy sands. There are a few beds of resistant, ledge forming sandstones. The lower part is pinkish with medium to coarse grained cross bedded sandstones (Martz et al., 2010). The Camp Butte Bed is similar to the Rainbow Forest and Jasper Forest beds as it is light colored and texturally mature siliceous sandstone dominated by trough cross bedding and lesser planar cross bedding. It is a discontinuous bed that is interbedded with uppermost Blue Mesa and the lower part of Lot's wife. It also contains conglomerate sized clasts of reworked mudstones from Blue Mesa Member. Chert and some volcanic clasts may be present (Martz et al., 2010). The Sonsela Member- Petrified Forest Member contact is distinguished by the purple mudstone beds at the top of Martha's Butte and the red mudstones of Flattop 2. This mudstone grades laterally into a conglomerate at the base of Flattop 2 and contains orange and white "non jasperized" petrified wood (Martz et al., 2010).

Petrified wood is scattered geographically in the Chinle Formation, but concentrated in the Jasper and Rainbow Forest beds of the Sonsela Member and at the bottom of the Petrified Forest Member. Petrified wood in this study was found mainly in the Sonsela Member.

Petrified Wood Survey

Seven grids were surveyed on HNZ lands, located adjacent to the Petrified Forest National Park. The grids were surveyed by four crew members, each person walking at 150 ft. spacing. Fossil locations were logged with a Trimble GPS, which has 1 to 3 meter accuracy after processing. Characteristics of logs recorded directly into the GPS and were designated following Heckert (1991) in *Petrified Wood Resources of the New Mexico and Arizona Land Company in Navajo and Apache Counties.* The log attributes were as follows:

-Grouping type (clustered/single)

- Number of logs

-Log type (Rainbow, Alabaster, Other)

- Description (Color, Hardness, Significant Features)

- Surrounding Material

- Log Location (Latitude, Longitude)
- Length (ft.)
- Maximum and Minimum Diameter (in.)
- Surface Location (Buried, Partially Buried, Mixture)
- Buried Percentage from ground view
- Weight of Logs Removed (calculated post survey) (lbs)
- Log Condition (Good, Bad, Fair, Varied) (Damaged, Undamaged)
- Log Size (Small, Medium, Large)
- Log Sectioning (Full, Partial Section, Varied)
- Log Description

After the survey was completed, the logs were assigned a value based on size, color, and condition. To estimate the weight of logs in clusters, an average length, maximum diameter and minimum diameter of the logs were needed to calculate the volume of the logs and for a single log the length, maximum and minimum diameter were used to determine volume. The following formula was implemented (Singleton, Assessment *of a Petrified Log*):

$$V=\pi r^2 h= x \text{ amount in.}^3$$

$$\pi r^2 h(16.387)(2.65)/453.59237$$

Where:

- Silica which is the main mineral takes on a density equal to quartz, 2.65g/cc or (168lb./ ft.^{3})
- X amount in.^{3}= 16.387 cc/in^3
- 1 pound= 453.59237 grams

Once the weight was calculated for a single log, and the maximum and minimum weights summed for clustered logs, a value was given to each log. For the Rainbow or "Other" types of logs a value of .50 cents per pound to 5 dollars per pound was assigned and 25 cents to 1 dollar per pound for Alabaster type wood. These values were more or less depending on size and condition. Larger logs are worth more than smaller logs and damaged logs are worth less than undamaged. A damaged log is one that cannot be cut and polished into artwork. The estimated values were calculated by total weight * value per pound.

Logs were categorized as small or large depending on the following parameters: Small (.75 ft. length, 50-445 lb.), Medium (1.5ft, 445-790 lb.) and Large (2ft+, 790+ lbs.) logs. Given their size they were then assigned the following prices (Gray):

- Smaller alabaster logs: $0.25/lb. - $0.50/lb.
- Medium alabaster logs: $0.25/lb.- $0.50/lb.
- Large alabaster logs: $0.50/lb.- $1.00/lb.
- Badly damaged alabaster logs: $0.25/lb.-$0.50/lb.
- Smaller rainbow logs: $0.50/lb.- $1.50/lb.
- Medium rainbow logs: $1.00/lb.- $2.50/lb.
- Large rainbow logs: $5.00/lb.- $7.00/lb.
- Badly damaged small and medium rainbow logs: $0.50/lb.- $1.00/lb.
- Badly damaged large rainbow logs: $0.50/lb.- $5.00/lb.

The finished product of the survey was a catalog that showed the estimated value of petrified wood in each map grid. Each log found was given its own catalog page, which reported its position, attribute table, estimated value, and sample photos. A catalog was of photos taken during the survey was presented separately. As a continuation of research on the area, two samples of petrified wood were analyzed for compositional differences between two different types of fossil wood preservations.

Mineral Analysis of Petrified Wood

One each alabaster log and rainbow log sample was chosen based on differences observed by gross examination. The rainbow sample was more massive with distinct preserved cell structure. The alabaster specimen was more granular with quartz veins. Cell structure is easily seen with a microscope but mineral composition is variable. Composition and oxygen isotopes were analyzed.

Figure 2 Alabaster Sample

Figure 3 Rainbow Sample

The samples were cut into pieces 0.00635 m thick with a saw. The length and width of the samples were no more than 0.0254 meters. The scanning electron microscope at SMU is known as Leo 1450VPSE and is produced by the company Zeiss. Samples were placed on a stage that could be rotated in the x, y, and z direction. The parameters were set at a target voltage of 15 kV, the beam current was 30 μ Amps, the spot size was 500. The detector used was QBSD and a VP mode was used with a target pressure of 20 Pa. Once a spot was selected on the computer, an image was collected for 50 seconds, and with 32 seconds for the mineral analysis. The rainbow sample consisted entirely of quartz. The alabaster sample was composed mostly of quartz but there was one dark streak very high in carbon. In Figure 2, the red square shows where the elemental analysis was taken. This spot was chosen because the flaky grain appeared like a preserved cell wall and it was very high in carbon. It is unusual to see organic remains in a petrified wood fossil as most organic material is replaced by quartz. The dark vein highlighted in Figure 1, is mostly surrounded by the quartz but was exposed on the broken surface of the sample. The samples were also analyzed with XRD but no differences were found between the samples; both analyses indicated quartz.

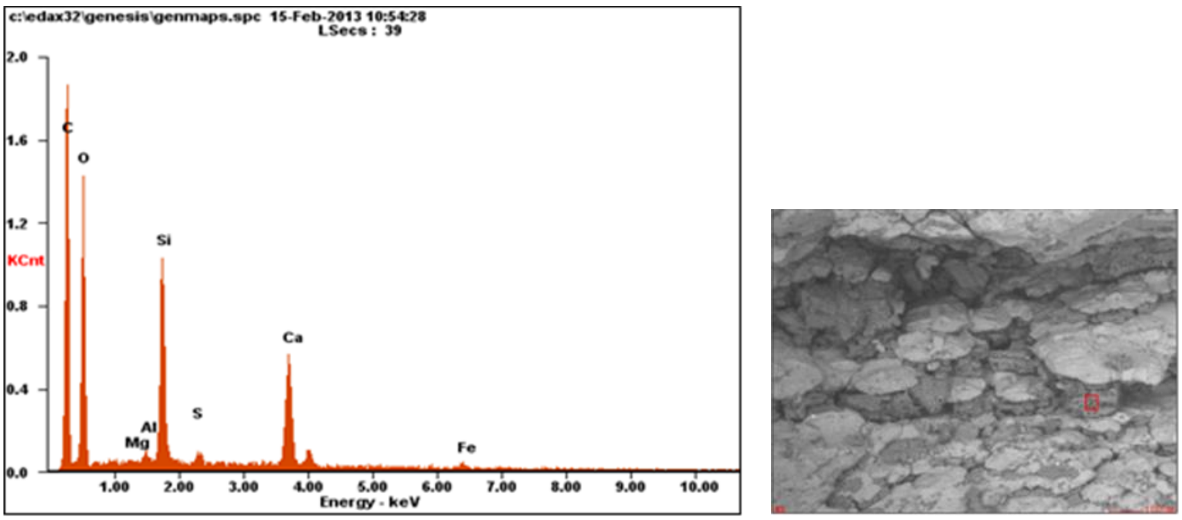

Figure 4 Alabaster Mineral Analysis. Different shades of gray indicate some compositional differences.

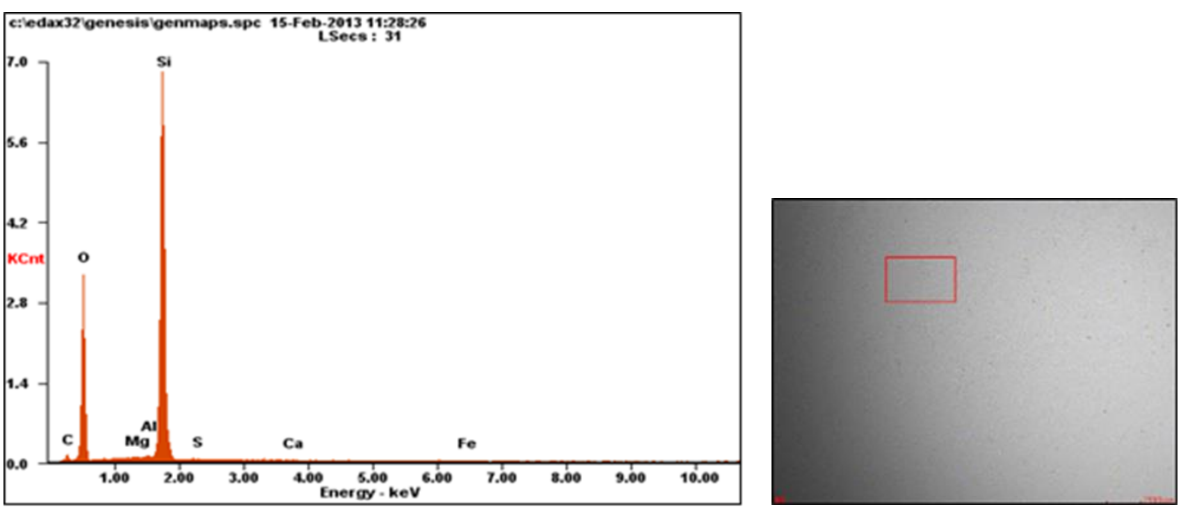

Figure 5 Rainbow Mineral Analysis, gray color indicates no mineral differences.

The carbon in the alabaster sample was analyzed for carbon isotopes. Four pieces were extracted with a knife and a chisel by me (Figure 5) and the carbon processed for me on the organic carbon line at SMU. The values for carbon isotopes averaged -23.7 PDB. This value is typical for C3

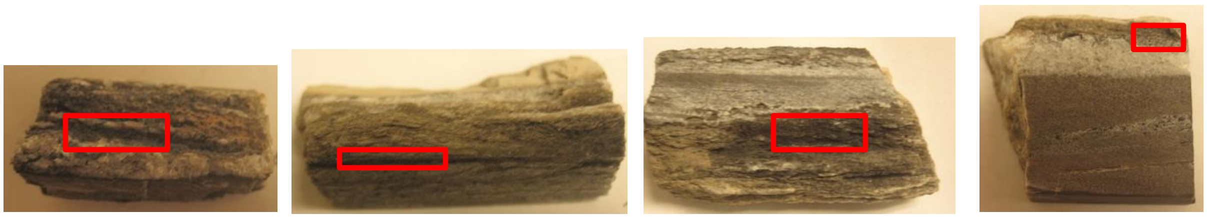

Figure 6 From left to right, samples 4, 3, 2, 1. The red squares are where samples were collected for Carbon 13 isotopes.

plants in the Triassic Period (Corso et al. 2011). Oxygen isotopes of both samples were analyzed on the silicate line. Samples, were crushed and sifted to obtain particles of 250 μm. The alabaster was sample was treated in a 10% solution of sodium fluoride to dissolve any carbonate in the sample. The samples were then sifted again and both samples were placed separately in vials. After being prepared, they were run on the silicate line at SMU for me and the $\delta^{18}O$ for the alabaster log was 26.9, 26.7. The value for the rainbow sample was 27.6, 27.8, shown in Table 1. It is interesting that these values would be different, since they were located in such close proximity to each other. These oxygen isotope values are typical for an area that experienced a humid environment and a monsoon season (Managave et al 2011). The heavier oxygen isotopes could indicate the rainbow logs were deposited in a more humid environment.

Types of logs	$\delta^{18}O$
Alabaster	26.9, 26.7
Rainbow	27.6, 27.8

Table 1 Isotope values

Conclusion

Petrified Wood occurs abundantly in the Sonsela member of the Chinle Formation. Different categories of fossil preservation result from varying depositional environments and subsequent groundwater characteristics. The Rainbow logs were subject to a higher degree of silification whereas the alabaster logs were not replaced completely by quartz. The variation in preservation is likely related to flow of groundwater through sediments of varying permeability.

Knowing where to find these fossils and exactly what variety of fossilizations to expect in an area is important because these fossils have commercial value. The estimated worth of Hunt lands based on the survey was more than expected and most fossils were in good condition, meaning they can be cut and polished. For future surveys of this area, alabaster logs are expected to dominate on southern grid squares, and rainbow logs will predominate in the northern grid squares.

Acknowledgements

Special thanks to HNZ who supplied the fossils that I used for my research, also thank you to all those that took part in the survey and completed the catalog, Brian Boutte, Matthew Bob, Ruth Bezys, Kelly Tomlinson, Emily Weaver, and Neeraj Sirdeshmukh. All those working in the stable isotope lab, Kurt Ferguson who helped me to run the carbon line, Ian Richards who ran the samples on the silicate, and Robert Gregory for his guidance. Also, thanks to Roy Beavers who ran the samples on the SEM and XRD machine at SMU. Of course a big thanks to my mentor Louis Jacobs who has guided me through completion of my engaged learning project.

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