

HISTORICAL IMPACTS OF GEOTHERMAL RESOURCES ON THE PEOPLE OF NORTH AMERICA

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ABSTRACT

The Indians of North America considered hot springs as a sacred place where the "Great Spirit" lived, and thus were great believers in the miraculous healing powers of the heat and mineral waters. These areas were also known as neutral ground; where warriors could travel to and rest unmolested by other tribes. Even though archeological finds date Native American presence at hot springs for over 10,000 years, there is no recorded history prior to the arrival of the Europeans in the 1500's. Many legends concerning geothermal activities are part of the Native American oral history, such as about Madame Pele, the Hawaiian goddess of volcanic fire, and the story of the battle between Skell and Llao describing the eruptions of Mt. Mazama (Crater Lake) and Mt. Shasta. Obsidian was one of the prized volcanic trading items used by the Indians for tools and weapons.

INTRODUCTION

The history of geothermal use prior to the industrial revolution, centers itself mainly in the volcanic region of western North America. A few isolated locations are also found in the middle and eastern part of the continent. The use of the geothermal resources during this period was by Paleo-Indians and Indians, the latter also referred to as Native Americans. Even though archeological finds date Native American presence at hot springs for over 10,000 years, there is no recorded history prior to the arrival of the Europeans in the 1500's. Rock paintings (pictographs) and rock carvings (petroglyphs) are their only source of writing available; however, as far as the author knows, none depict geothermal phenomena. With the discovery of these geothermal phenomena by the Europeans, the "ownership" and use changed considerably, with many becoming commercial operations. Thus, the use of geothermal springs and related phenomena have gone through three stages of development in North America: first (1) use by Indians as a sacred place, then (2) development by the early European settlers to emulate the spas of Europe, and finally (3) as a place of relaxation and fitness, and as an energy source for heating and/or cooling in modern times.

EARLY SETTLEMENTS

The time of the first human incursions into North American are subject to debate; however, it is generally accepted that it is associated with the land bridge between Siberia and Alaska, called Beringia, that was formed during the Pleistocene epoch (Figure 1). In the last stage of this glacial period, the Wisconsin or Weichsel glacial advance, so

much of the ocean's water was tied up in glaciers, that the oceans were approximately 100 m lower (Figure 2). As a result a dry land bridge formed between the Bering and Chukchi seas that was up to 2000 km wide. The land bridge probably existed from 50,000 to 40,000 ybp (years before present) and from 25,000 to 14,000 ybp. It vanished all together about 10,000 ybp (Figure 2). (Fagan, 1985).

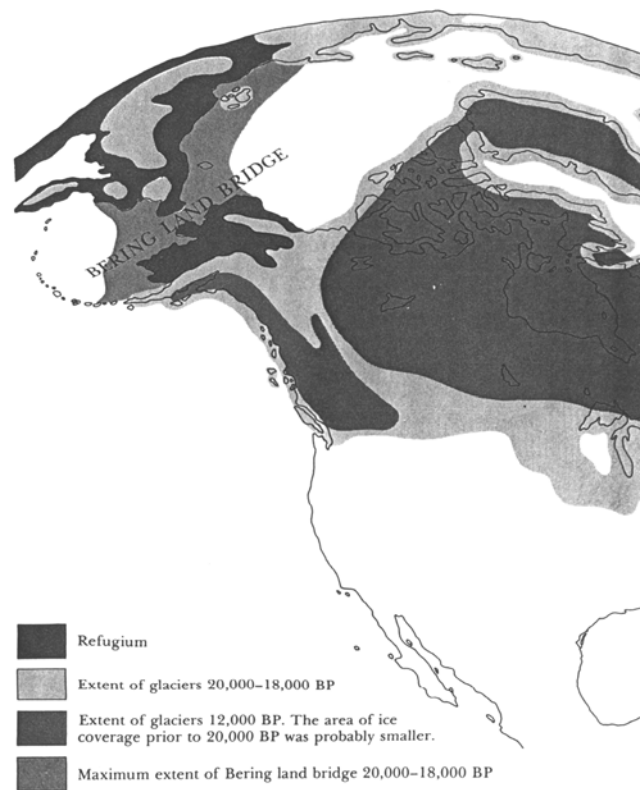


Figure 1. Bering land bridge (Beringin)(Fagan, 1985).

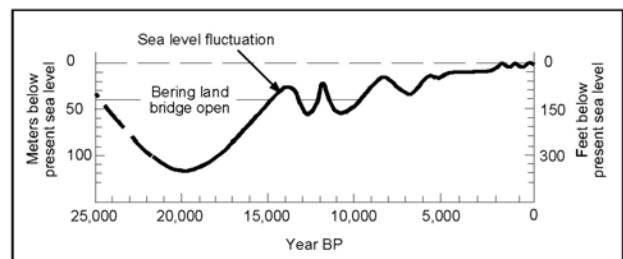


Figure 2. Beringia chronology (Fagan, 1985).

Small bands of hunters from east Asia probably followed game migrating eastward across this wide area characterized by long winters, short summers, and continual winds. However, the snow thawed in summer exposing many marsh areas and lush meadows, thus making it somewhat attractive for these migrations. This ice free summer bridge, led into the ice free interior of Alaska called Refugium (the refuge) (Jennings, 1978). It was in this area that the first Paleo-Indian site was discovered, and is the oldest dated site in North America. Old Crow Flats near the Alaska-Canada border, depending upon the reference, is dated between 40,000 and 25,000 ybp (Dumond, 1978, and Fagan, 1985).

Later on, ice free corridors did open up into the central portion of North America between the Cordilleran and Laurentide ice sheets. This corridor is estimated to have existed before 18,000 ybp and after 12,000 ybp, and emptied into the central plains around present day Edmonton, Canada. Some advanced parties of Paleo-Indian hunters, pursuing game such as mammoth and bison may have moved into the central plains as early as 25,000 to 20,000 ybp as evidenced by dated sites in the Ohio Valley (Meadowcroft Cave) and hunted remains as far south as Mexico. The dates on these sites are questionable, with the first well-attested settlement dated at 15,000 ybp (Fagan, 1985). However, significant groups of the Paleo-Indians hunters of the Llano and Folsom-Plano groups had only moved as far as Edmonton by 11,500 ybp.

The early documented sites such as Clovis and Folsom, New Mexico; Lindenmeier, Colorado; Borax Lake north of San Francisco; Tule Springs, near Las Vegas, Nevada; and Fort Rock Cave and Alvord Lake in eastern Oregon, are dated from 13,000 to 11,000 ybp and were Paleo-Indian sites. These Paleo-Indians are best known to exist in the Great Plains and the Great Basin provinces. Around 10,000 to 9,000 ybp the Paleo-Indians were replaced by the specialized hunter-gatherer cultures or Indians. Most of Canada, due to the Cordilleran ice sheet, was not occupied until about this time. Numerous sites are dated after this period, but plains and basin sites are difficult to find due to the migratory nature of the Indians in search of game. The Indians dominated North American until they were essentially replaced by the Europeans in the east around the early 1700's and in the west around the middle 1800's.

INDIAN LEGENDS

There have been a number of legends passed down orally from generation to generation by the Native Americans. Some are still recited and others were recorded by the early European settlers and survive today. Two noted legends related to volcanic phenomena, and one related to the use of a hot spring are retold here.

Hawaii - The Goddess Pele

Pele rules the volcanoes of Hawai'i, and Mankind has no power to resist her. She is Pele-honua-mea of the sacred land, as Pele-'ai-honua, eater of land, and as Ka-'ula-o-ke-ahi, the spirit of the redness of the fire. In folklore she may appear as a tall, beautiful young woman, or as an old woman, wrinkled

and bent with age, sometimes accompanied by a white dog. When enraged she may appear as a woman all aflame or as pure flame. Her personality is volcanic - unpredictable, impulsive, given to sudden rages and violence. Hers is both the power to destroy and the power to create new land (Kane, 1987).

Tradition states that Pele came, as did the Polynesian discovers, by sailing-canoe from the ancient homeland in the islands of the Tahiti group. She was supposedly driven from this ancestral home by her elder sister, goddess of the sea and of water, for seducing her husband. Her first landfall was in the northern islands of the Hawaiian archipelago. Pele needed a deep pit for her home wherein the sacred fires could be protected. Her sister followed and put out the fire, thus Pele moved southeastward along the island chain digging new craters. But each effort was flooded out by her sister (Figure 3). We thus find that on the geologically-older island of Kaua'i the craters have become wet swamps, and volcanic evidence becomes progressively more recent as we move down the island chain toward the Big Island of Hawai'i. The myth coincides with the modern geological theory of shifting plates, in which the islands are built in an assembly line as the ocean floor slid northwestward over a "hot spot" in the crust. the power to destroy and the power to create new land (Kane, 1987).



Figure 3. Madam Pele and her sister Kahalo, on Hawaii (Kane, 1987)

Since Pele's sister, Na-maka-o-Kaha'i was older, she was also more powerful, for water was believed to be more powerful than fire. The two finally locked in battle on the island of Maui, in which Pele was torn apart. A hill named

Ka-iwi-o-Pele (the bones of Pele) stands at the site of the battle and is believed to be her mortal remains. With Pele's death, her spirit was freed and elevated to godly status and took flight to the island of Hawai'i. She now has a permanent home on Mauna Loa, Earth's largest mountain.

This legend was brought home to the author during a lecture tour of several of the islands where the use of geothermal energy was discussed. Our lecture group was on Maui, the island just northwest of Hawaii. We were proposing to drill on the slopes of the volcano Hale-a-kala (last erupted in 1790, but was most active 400,000 to 800,000 years ago) and use the geothermal energy. After our presentation, an old Native Hawaiian stood up and lectured us for over an hour about volcanic geology from Pele's point of view. He warned us that drilling on Maui, would bring Pele back from the island of Hawaii and cause destruction to the residents of Maui.

Pele still lives in the hearts and minds of the native Hawaiians. Her personification is in the natural phenomena of volcanic activity. Hawaiians refer to her as Tutu Pele (an affectionate term for grandparents), and look upon her with respect. In a recent eruption where lava destroyed part of the village of Kalapana, a Hawaiian resident interviewed after losing his land said: "I love my home, live here all my life, and my family for generations. But if Tutu like take it, it's her land" (Kane, 1987). As part of the respect for Pele, older Hawaiians still offer the first 'ohelo berries picked to her, before eating any. Some still bring gifts of flowers, food and drink and set them on the rim of Halema'uma'u crater within the Kilauea caldera. They also refrain from any acts that might be disrespectful to Pele. Tourist who have taken souvenirs of rock with them home from Hawaii Volcano National Park, have often returned them to the National Park Service with a note describing misfortunes that have occurred since their removal. They hope by this action, to be released from Pele's terrible spell.

Oregon - The Battle of Llao and Skell

American Indians commonly interpreted natural catastrophes as the actions of invisible spirits who controlled the physical world. The Klamath Indians of southern Oregon devised a remarkable myth to explain the origin of Crater Lake (Harris, 1990). This legend was told to a young soldier by Lalek, an aged Klamath chief in 1865. He emphasized that the story was ancient, when his people lived in rock houses and white men ran wild in the woods. The story explains the cataclysmic eruption of Mt. Mazama, its collapse and the formation of the Crater Lake caldera about 7,700 ybp (Figure 4).

It is a story about Llao, Chief of the Below World, Skell, Chief of the Above World, and Loha, a beautiful young woman. Llao saw this woman one day when standing atop of Mt. Mazama, and begged her to return with him to his lodge in the Underworld. Even though he promised her eternal life, the maid refused to go with him. Her people would not force Loha to accept Llao's offer; thus, he thundered angrily and tried to destroy her people with fire. Skell came to the rescue by descending from heaven to the summit of Mt. Shasta (200 km south of Mt. Mazama). In the battle that followed the sky

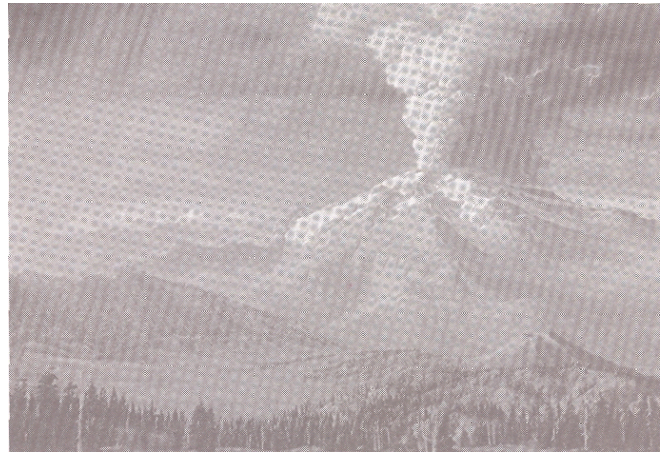


Figure 4. Mt. Mazama during eruption (P. Rockwood).

glowed and then turned dark, and the earth shook and fire flowed from Llao's mountain to burn the forests. Loha's tribe was driven from their home and forced to flee into the waters of Klamath Lake to the south.

Two brave medicine men tried to save their people by hurling themselves into the fiery mouth of the underworld. Noting their sacrifice, Skell again shook the earth, causing Llao's mountain to crash down upon him. When finally the dark clouds of ash cleared and light returned, the lofty peak was gone and was replaced by a giant hole. The curse of fire was lifted and the caldera was gradually filled with rainwater, forming Crater Lake. This myth is similar to the Greek story of Hades, god of the Underworld who pursued the Maid Persephone and carried her off to his underworld kingdom.

The Llao-Skell myth described closely the geologic events that occurred in the formation of the Crater Lake caldera. It also states correctly that Mt. Mazama did not loose its summit by blowing itself apart, but by emptying much of its underground magma reservoir, allowing the volcanic cone to collapse instead. It also describes the frequent eruptions of Mt. Shasta over the last 10,000 years, as the Klamath myth reports that Skell visited Shasta often, starting fires upon each visit. Finally, the subsequent eruption in the Crater Lake caldera forming the Wizard Island cinder cone, represents the maid Loha.

Montana - Sleeping Child

Sleeping Child Hot Springs is located in the Rocky Mountains south of Missoula, Montana. The beauty of this hot springs was first discovered by the Nez Perce Indians in the 1870's. Chief Joseph of the Nez Perce led his tribe out of the reservation and through the Lolo Pass into the Bitter Root Valley. In pursuit of Chief Joseph and his people were General Howard and a group of soldiers. Trying to avoid a confrontation, Chief Joseph split his tribe into smaller groups. One such group traveled through what is now Sleeping Child Creek and, facing a possible battle, they left their infants by the hot springs. When they returned, the infants were safe and peacefully sleeping, protected by the natural hot springs. Thus, Sleeping Child Hot Springs was named (Figure 5).

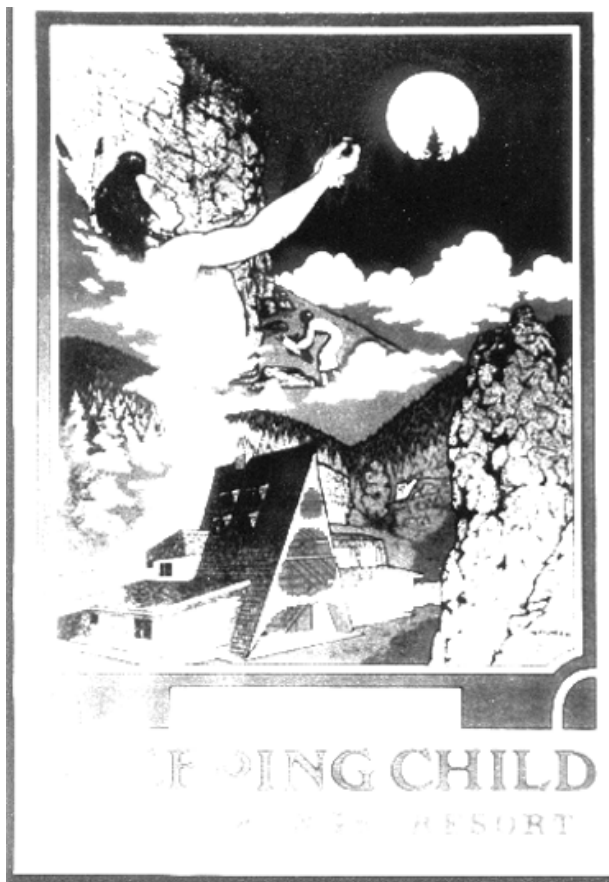


Figure 5. Poster from Sleeping Child Hot Springs.

THE INFLUENCE OF HOT SPRINGS

The Indians of the Americas considered hot springs as a sacred place where the "Great Spirit" lived, and thus were great believers in the miraculous healing powers of the heat and mineral waters. Every major hot springs in the U.S. and Canada has some record of use by the Indians. They were also known as neutral ground, where warriors could travel to and rest unmolested by other tribes. Here they would recuperate from battle. In many cases, they jealously guarded the spring and kept its existence a secret from the arriving Europeans for as long as possible. Battles were sometimes fought between Indians and settlers to preserve these rights. The early Spanish explorers such as Ponce de Leon and Hernando DeSoto were looking for the "Fountain of Youth", which may have been an exaggerated story of the healing properties of one of the hot springs (Lund, 1993).

The early European settlers in the 1700 and 1800's, found and used these natural hot springs and later realizing their commercial value, developed many into spas after the tradition in Europe. Many individual developments were successful such as at Saratoga Springs, New York; White Sulphur Springs, West Virginia; Hot Springs, Virginia; Warm Spring, Georgia; Hot Springs, Arkansas; Calistoga, California; and Harrison Hot Springs, British Columbia. However, the U.S. did not have the government, trade unions, social security

and a national health insurance program to support these developments. Thus, in spite of the benefits of spa therapy that had been proven successful in Europe and elsewhere in the world, the U.S. lagged behind in the development of these mineral springs even though some were acquired by states and the federal government. By the 1940's, the interest in spas languished, and most of the majestic resorts went into decline and closed. In recent years, the interest in hot springs soaking and physical fitness has renewed the development of spas. Since these recent developments are beyond the scope of this paper, the reader is referred to Geo-Heat Center Quarterly Bulletin (Vol. 14, No. 4, March, 1993) for further details.

Examples of some of the early uses of hot springs by Native Americans are summarized below.

Warm Springs, Georgia

Warm Springs is the most famous of Georgia's seven known warm springs. It has the largest flow of up to 58 L/s with an average temperature 31°C. The main mineral constituent is bicarbonate. For the local Creek Indians, the springs were probably a place of healing where the Indians of all tribes were allowed to bring their sick and wounded to drink the waters and bathe in the mud. The Iroquois Indians of New York State (1500 km north) used to visit the Creeks in Georgia and called this country "the land where the waters are warm." A number of trails ran through the area, maintained by the Indians and used by all travelers, many who stopped at the springs. The trails later became military and post roads, and a number of taverns with crude accommodations were set up along them, including one at Warm Springs in the early 1800's. The land was obtained by white settlers in 1825 after signing a treaty with the Lower Creek Indians. The original springs were called Meriweather Warm Springs after General David Meriweather of Revolutionary War fame. After several stages of commercial development, the springs became the site of a polio treatment center, made famous by President Franklin Delano Roosevelt.

Saratoga Springs, New York

The Saratoga Springs are located approximately 40 km north of Albany, New York and just south of the Adirondack Park. Approximately 18 springs discharge 13°C carbonated mineral water along the Saratoga fault between Whitehall and Albany, a distance of 105 km. The springs have been used for drinking and bathing in spas where it has been considered a cure for everything from skin disorders to digestive problems, and the water and carbon dioxide bottled and sold as a commercial product. The Mohawk and Iroquois Indian tribes used this area for hunting and frequented the springs, especially High Rock Spring (Figure 6). The Mohawks, a fierce warring tribe, fought to defend their hunting grounds around the springs on many occasions. They called the area Kayaderossaras. The springs were probably used by other tribes, as they lay on the path between Quebec and the Mohawk Valley. The first written record of the springs was in 1642, when the Mohawks returning from a raid on Quebec, brought with them a Jesuit priest who they had captured. They

stopped by a spring and were refreshed by the bubbling waters (Swanner, 1988). There is an unsubstantiated story of Sir William Johnson being carried to the springs in 1767 by Mohawk braves for treatment of a wound he had received in the Battle of Lake George in 1755. Probably the first settlers to visit the spring were surveyors in the 1760's. They were most likely attracted to the area by the great number of animals that frequented it as a salt lick. The spring was included in the Kayaderosseras Patent in 1771 and purchased by European settlers. After a number of different ownerships and over exploitation, a majority of the land was taken over by the State of New York and is now administered as a state park.

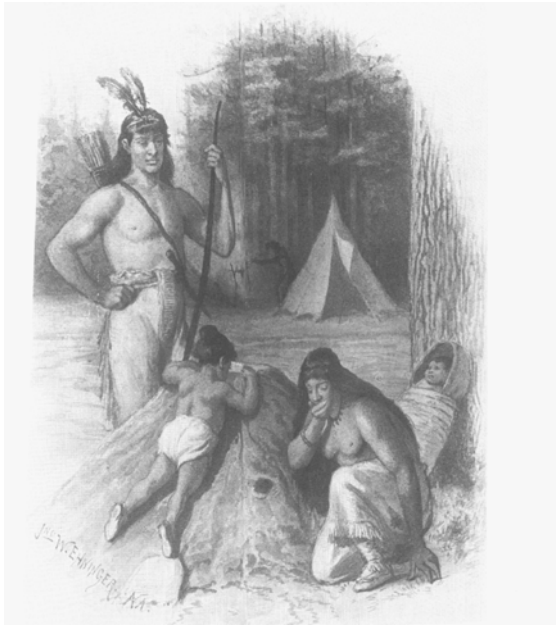


Figure 6. Mohawk Indians at High Rock Springs, NY (Swanner, 1988)

Hot Springs, Arkansas

Hot Springs, Arkansas was one of the most popular commercial spa areas in the United States, created to imitate the development of great spas in Europe - so popular that in 1832, it was made into a Federal Reservation and finally by 1921 into a National Park. It is the only national park in the U.S. created just to protect hot springs for spa use. This natural geothermal resource consists of 47 springs producing a total of about four million liters per day of 61°C water.

The National Park Service estimates that the Arkansas hot springs have been used by humans for at least 10,000 years. The "Valley of the Vapors" was an honored and sacred place to the Indians. They believed this was the home of the "Great Spirit" who brought forth the healing warmth of "Mother Earth." The waters were supposedly warmed by "His" breath. Like many hot springs of the "New World", this was neutral ground. Warriors of all tribes could rest and bath here in peace - a refuge from battle. Stone artifacts found near the springs give archeological evidence that Indians used the waters extensively. Early European explorers and settlers on the east coast pushed the Indians westward, and as a result Quapaws

and part of the Cherokee Nation wandered into the area. Legend reports that DeSoto or one of his scouts from the 1541 expedition were the first Europeans to visit the site (Figure 7). He was evidently in the areas as he claimed the territory for Spain. It is certain that French trappers, hunters, and traders were familiar with the area in the late 1700's (Bedinger, 1988).



Figure 7. DeSoto's legendary visit to the hot springs is depicted by this statue in the Fordyce Bathhouse (Bedinger, 1998).

The French actually ruled the area until 1763 when the territory west of the Mississippi was ceded back to Spain. It was again taken by France in 1800 under Napoleon Bonaparte, and finally purchased by the United States as part of the Louisiana Territory in 1803. During this period, no written record of travel to the hot springs are known; but, they were probably visited many times as evidenced by crude log cabins and huts found at the site in 1804. The spring water was first analyzed in 1804, and permanently settled starting in 1807. The first settler, Jean Emanuel Prudhomme, a plantation owner, was introduced to the springs for his health by the Natchitoches Indians, and remained in the area for a year. It became famous for curing ailments and thus the first bathhouse was opened in 1830 for visitors. The Federal Reservation followed and the development reached a peak in the early to middle 1900's. The National Park Service still exercises control over the geothermal resource and commercial development in the approximately 2000 ha park.

Thermopolis, Wyoming

Thermopolis, a Greek word for "Hot City", is located in north central Wyoming at the mouth of the Wind River Canyon, approximately 160 km south of Yellowstone National Park. At least eight hot springs in the area have created large travertine terraces along the river. The Big Horn Spring, claimed to be the largest mineral hot spring in the world, flows at 120 L/s with a temperature of 56°C.

Indians have lived in the area for at least 2000 years based on evidence associated with Legend Rock Petroglyphs in sandstone cliffs about 40 km northwest of town. The hot springs were known as having "healing water" and were known as "Bah-gue-wana" or "smoking waters" by the Shoshones. Chief Washakie of the Shoshone tribe (who later signed the treaty with the Federal Government) is reported to have had a bathhouse erected over Black Sulfur Springs at Thermopolis. Originally the Big Horn Spring was included in the Shoshone Indian Reservation Treaty of 1868. The spring became known for its "health giving properties" and the U.S. Congress was requested to set aside the area for a National Park or Reservation. In 1896, a treaty was signed between the Shoshone and Arapahoe Indians and the federal government which gave the public use of the hot springs. The condition of the treaty was that one quarter of the water of the Big Horn Spring would be set aside for free use by the public. The management of the springs was turned over to the State of Wyoming in 1897 forming Hot Springs State Park. The State Bathhouse was constructed to fulfill the condition of the treaty.

Today the State Park provides geothermal water to four commercial establishments, the Pioneer Center a retirement home for state residents, and The Gottsche Rehabilitation Center, a therapy center.

Wyoming - Yellowstone National Park

Since 1808, when John Colter described the hot springs of "Colter's Hell," attention has focused on Yellowstone. The Indians, of course, knew and used the spring for centuries. White men "discovered" many of the springs early in the 1800's, following Colter's visit. Public interest in the preservation of the many spectacular thermal features in Wyoming's northwest corner led to the establishment of Yellowstone National Park, the nation's first, in 1872.

Wyoming - Guernsey

Even though this is the location of a few small springs near the southeast corner of the Wyoming, it is probably the most famous thermal feature in the state. Although early immigrants may have heard vague tales of "Colter's Hell" and the Yellowstone country, thousands of them had actually seen the Guernsey springs. The immigrants of the famous Oregon Trail knew this spring as a welcome landmark, a place to soak sore feet and wash dusty clothes. It was appropriately named "Immigrants' Washtub." In 1858, soldiers of nearby Ft. Laramie set up a lime kiln to use the limestone from which the springs rise. The springs were then known as "Lime Kiln Springs." Today the 21°C springs serve as watering holes for cattle (Breckenridge and Hinckley, 1978).

California - Calistoga

Located approximately 120 km north of San Francisco, this resource is at the northern end of the famous Napa Valley and is also the southern end of The Geysers geothermal field. The area is noted for numerous geysers and hot springs with surface temperature near 100°C. The area was originally settled by the Pomo and Mayacmas Indians. These early

people, called Wappo by settlers, came from a wide area to use the natural hot springs, fumaroles, and heated muds to soothe aches and pains. To the Native Americans this was "Tu-la-ha-lu-si, the beautiful land"; and the hot, spongy turf was "Coo-lay-no-maock, the oven place", according to a local historian. As with many geothermal areas of the west, the Indians were the original geothermal users and appreciated this natural energy resource. They also used the local cinnabar for red war paint. Later on, this mercury ore would also be mined by white men (Archuleta, 1977).

In the early 1800's, the Spanish explorers visited the area looking for a possible mission site. Naturally, they referred to the site as "Aqua Caliente - Hot Water", as are many other geothermal areas in the southwest of the United States. These missionaries did not establish a mission here, but it is believed that they planted the first grape vines to be used for sacramental wines, and the golden mustard which even today is found in the orchards and vineyards in early spring. In 1862, Samuel Brannan established a resort and spa similar to Saratoga Hot Springs in New York. The name Calistoga resulted in a combination of California and Saratoga. The area is still a spa community today, in the heart of the Napa Valley wine country.

British Columbia - Harrison

Geothermal resources in Canada are primarily located in British Columbia where one of the most famous is Harrison Hot Springs located about 80 km east of Vancouver. The springs and resort are referred to as "The Spa of Canada." Two hot springs at 50 and 65°C are located near the south end of Lake Harrison. The Indians knew of the springs and of "Keekwully Tybee who sent up the medicine waters all hot from below." They believed the springs of boiling water - "Warum Chuck" - were of supernatural origin, and regarded the hot water in the lake with reverence and awe. They also believed that those who drank the water were given some mystic powers of endurance over their fellow men. According to some of the stories they believe the waters will boil as long as there is sickness in the land. The natives referred to the lake as "Lake Qualts", meaning hot water (Rendall, 1981).

The springs were probably discovered by Europeans in 1859, when one member of a nearly frozen group of miners sailing on the lake, toppled into the water from weakness. He was so content with the warmth, that the rest joined him. They survived and continued their journey. In the late 1800's a hotel and bath house were built adjacent to the springs. It boasted that the hot sulphur springs provided "a sure cure for paralysis, rheumatism, syphilis, diabetes, neuralgia, skin diseases, mercurial poisoning, dipsomania, and all diseases of the womb, liver, and kidneys, besides many other maladies to which human flesh is heir." The Harrison Hot Springs Hotel, without the promise of cures, is a luxury resort operating today at this location.

Alaska

Indians and Eskimos throughout Alaska, from the Seward Peninsula to the isles of southeastern Alaska, were aware of geothermal springs. Kruzgamepa Hot springs, 80 km north of

Nome, now known as Pilgrim, was utilized for bathing years before the white man arrived. People visiting Chief Shakes Hot Springs, near Wrangell in southeastern Alaska, still use the wooden cribs placed there by the Tlingit Indians prior to the Russian arrival in Alaska. Some springs held mystical powers, such as Kilo Hot Springs in north central Alaska. Hooniah or Tanakee Hot Springs, one of the best known resorts in the early part of this century in southeastern Alaska, are still used by the natives, although it is still in a primitive state (Markle, 1979).

When the Russians began colonizing Alaska, they followed the Indian's example of leaving most springs as they found them. Most of the Russian and early American settlements, were not located near a geothermal resource. This was due in part to the nomadic fur traders who did not tarry long at any one place, and travelled mainly along the coast; whereas most of the springs were located inland. In the late 1800's, with the discovery of gold, many of the hot springs were developed for use by the miners who had now moved inland. Chena, Manley and Circle hot springs are examples of those developed by miners in the Fairbanks area, and are still operating. Many others have gone into decline and are little used today.

THE INFLUENCE OF VOLCANOES

Arizona - Sunset Crater

About 900 ybp (1075 AD), the eruption of Sunset Crater east of Flagstaff spread a blanket of volcanic cinders and ash over a large part of the land occupied by the Sinagua Indians. This eruption produced a marked change in the living patterns of the area. After it produced a brief disruption, the Sunset Crater cinder fall is thought to have provided a moisture-conserving mulch that made the area more attractive to dry farmers to grow maize. The larger number of sites in the immediate post-eruptive period and the appearance of traits from other Indian tribes (Anasazi, Mogollon, and Hohokam) suggest that there was in-migration from neighboring areas at this time (Lipe, 1978).

Oregon - Mt. Mazama

Eastern Oregon was inhabited by a historic people from approximately 11000 ybp to present time. However, evidence of occupation all but disappear after the eruption of Mt. Mazama (forming Crater Lake) around 7,700 ybp. The landscape was blanketed with a layer of volcanic ash and pumice, measured over eight meters in depth in some places. There was not significant reoccupation of the area until about 5000 ybp. The characteristics of the tools, baskets and plant food resources changed markedly with this reoccupation (Aikins, 1978). The eruption of Mt. Mazama was dated by carbon-14 means based on charred sandals found buried under the pumice and ash in Ft. Rock Cave, about 100 km northeast of the mountain.

Hawaii - Kilauea

In 1790 the rule of Hawaii was being contested by several chiefs. The two main contenders were Keoua, considered a dangerous upstart by the other chiefs, and Kamehameha, the

future ruler. After several inconclusive battles on the "Big Island" of Hawaii, Keoua was returning to his home district with his army, accompanied by wives and children of the soldiers. They were walking along the flank of Kilauea volcano when part of Keoua's army was completely destroyed by a rain of hot ashes, rocks and poisonous gasses from the mountain (Figure 8). Badly shaken by this disaster, no doubt believing the Pele had turned against him, Keoua lost the will to continue the war and Kamehameha became the ruler (Kane, 1987).

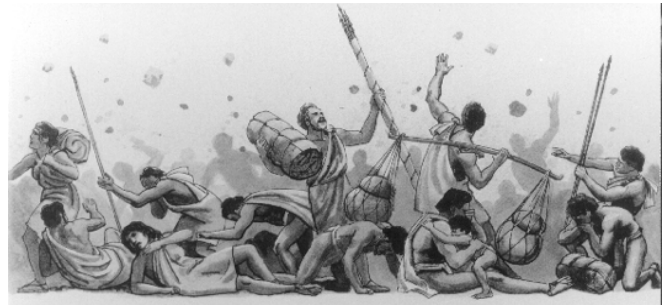


Figure 8. Keoua's army being destroyed by Kilauea's eruption (Kane, 1987).

USE OF VOLCANIC AND HOT SPRING MATERIAL

Obsidian and basalt have been formed into tools and weapons by the Indians since the first migrations into western North America. These implements and extensive middens of obsidian flakes can be found all through the west, but are now protected from "pot hunters" by federal law. Muds colored by sulfur and mercury deposits have also been used as paint for pottery, skins and rock art or writing (pictographs and petroglyphs). Obsidian hydration rates on the fresh surface of fractured pieces, have been used to date many prehistoric sites as far back as 800,000 years ago.

Arkansas - Hot Springs

Tunicas Indians of the Caddo Nation lived in the area of the present Hot Springs National Park. For centuries, they mined the very hard and even textured flintstone called novaculite (a form of silica similar to chert), in quarries adjacent to the hot springs. The Indians used it for weapons such as arrowpoints, spearheads, and for tools. Later, Europeans mined the novaculite for whetstones, and this "Arkansas Stone" is still mined outside the park - highly prized for its uniform sharpening characteristics (Bedinger, 1988).

California - Coso

Obsidian was highly prized by the Indians of California for tools and weapons due to being able to produce an extremely sharp cutting edge. Deposits of this material were available on the volcanic Great Basin side of the Sierra Nevada and traded across the mountains to the west side into the central valley. Finds of such material have been dated as early as 5000 ybp. One source, located near Coso Hot Springs (the present site of a geothermal power plant) on the present China Lake Naval Weapons Center, had inclusion of white Christobolite (amorphous silica) in the obsidian. This unique source has

been found all through the central valley. The author inspected this site in the 1960's and was amazed at the large deposit and associated midden. The author also discovered obsidian pieces from this site at nearby Little Lake attributed to the Pinto culture, estimated to be between 7000 and 2500 years old.

Similar obsidian trading from the east side of the Cascades to the west side occurred from a source in Newberry Crater of central Oregon.

Ohio - Hopewell

Over 136 kg of worked obsidian fragments were found at the Hopewell burial site in southern Ohio. These included between 250 and 500 magnificent spears probably made around 2000 ybp. Since there is no obsidian in the midwest, the source of this obsidian was traced to what is now Yellowstone National Park, about 2500 km to the northwest. Many other unusual items such as copper, mica, galena, and chlorite have also been found in these burial sites. This trade reflects the wide geographical knowledge of much of the eastern United States that some of its aboriginal inhabitants possessed. Trade helps to explain the apparent speed with which new ideas and techniques moved across long distance (Griffin, 1978).

California - Calistoga

The Indians at the north end of Napa Valley where the hot springs, geysers and fumaroles were located, traded for fish and other sea products from the coastal Indians with obsidian from the nearby Glass Mountain. In fact, Indians came from all over for the curative waters of "Coo-la-no-maock - the oven place". The Indians also came to trade for cinnabar, to be used for vermilion war paint. Later, mercury was mined here and in the Geysers geothermal field to the north. The Indians also built sweat houses over the hot pools.

CONCLUSIONS

North American Indians have a long history of association with and use of geothermal phenomena, going back at least 10,000 years. Many of these hot springs, geysers, and fumaroles were sacred places for these Native Americans, who had a special respect and understanding of the natural environment. Unfortunately, much of the oral history and legends concerning geothermal activities have been lost. We are dependent today upon archeological evidence and speculation. The present trend of hot spring users to "get back to nature" and to preserve and protect this natural resource, is not unlike the philosophy of our earliest settlers.

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