The Kiln Conference at Crow Canyon: 
A Summary Report 1991 to 1996

by

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Kiln Conference Introduction

Purpose of the Kiln Conference is to examine Ancestral Puebloan pottery firing technology from a wide range of interests including potters, archaeologists, ethnobotanists and native Americans.

First Kiln Conference was held in February, 1991.
Sponsored by Crow Canyon Archaeological Center and the Museum of New Mexico, Office of Archaeological Studies. Megg Heath, Eric Blinman, C. Dean Wilson

For many years prehistoric kiln were overlooked possibly due to the prevailing ethnographic model.
1) Puebloan people of today are direct descendants of prehistoric / Anasazi peoples.
2) Today most Puebloan potters do surface firings, using manure, coal, sometimes wood, which leave little or no evidence. Any evidence is easily obliterated.
3) If the Ancestral Pueblo fired like their descendants there would be little or no evidence today.

Slab lined thermal features were reported quite early on; 1878. (Holmes, Hayden survey)
Morris and Shepard, 1939 and later Reed, 1958, questioned the use of thermal features in pottery firing.

1973: First published report: the Kiln Site, Cedar Mesa, Southeast Utah. - Helm
1984: Detailed report on Late Anasazi Pottery Kilns in the Yellowjacket District, Southwestern Colorado. The 1980's saw widespread investigation and survey connected with energy development.
1992: Research design for further research on excavating kilns, an outcome of Kiln Conference - Blinman.
1993 Excavations of kilns at Mesa Verde National Park; pipeline project - Brisbin, Ives.

Today numerous kiln features are recognized, there are 29 totalled: 25 in southwest Colorado and northwest New Mexico, 2 in southeast Utah and 2 in Santa Fe.
Pit kiln are constant in form (Rectangular trench, approximately 1 meter by 1.5 to 10 meters in length), construction (lined with upright stone slabs), and location (often on the edge of a mesa, in a shallow drainage, perpendicular to prevailing winds).
In cross section they are also similar; the bottom most level is a thick layer of charcoal or ash. Interpreted as a prefire. Above that an irregular layer of sandstone slabs, blocks or cobbles. This is interpreted as the pottery setting. The uppermost level is a layer of charcoal, ash, clay and colluvial fill, in which sometimes sherds are found. This has been interpreted as the main fire, misfired pottery and / or cover sherds and smothing agent.

By combining archaeological knowledge gained from recent excavations of kiln features with insight experiences of potters and replicators (Clint Swink) the Kiln Conference provides a unique setting for conducting experiments in understanding Ancestral Puebloan firing technology.
Paul Ermigiotti, Crow Canyon Archaeological Center,

Crow Canyon Archaeological Center, Cortez, Colorado, hosted the Kiln Conference annually from 1991 to 1996. This report records the development of the conference and includes descriptive and interpretive summaries of the results.

Introduction
Since its inception the Kiln Conference has been sponsored by Crow Canyon Archaeological Center and the Museum of New Mexico, Office of Archaeological Studies. The purpose of the conference, as proposed by C. Dean Wilson of the Museum and Megg Heath, Director of Education at Crow Canyon, was to examine various aspects of prehistoric Anasazi pottery firing technology. The conference would incorporate archaeological data from excavated kiln sites, results from ceramic research analysis, modern pottery replication studies, information from contemporary Native American pottery firings, and botanical data concerning fuel wood use. The insights gained from these various studies were and continue to be used in subsequent archaeological research.

The Puebloan people of the upper Rio Grande and Zuni in New Mexico, and the Hopi mesas of Arizona are the direct descendants of the ancestral Puebloan or Anasazi peoples. Today most Puebloan potters fire their wares using a surface firing, fueled by animal manure, sometimes wood and, or coal. Surface firings usually leave little or no evidence of the activity. Evidence of this type of firing would be easily obliterated after a short time. If the ancestral Puebloan potters fired like their descendants, there would be scant testimony for this stage of production today. Until fairly recently prehistoric kilns were largely overlooked, possibly due to this prevailing ethnographic model.

Sandstone-slab lined thermal features were reported by William Holmes, of the Hayden Survey, as early as 1878 (Purcell 1993). Morris (1919) and later Reed (1958) also commented on these features and considered their possible use in pottery firing (Purcell 1993). The first published report to argue for the use of an excavated thermal feature as a pottery firing kiln was by Helm (1973) from a site in southeast Utah. In 1984 a detailed report on trench kilns in southwest Colorado was published by Fuller. As an outcome of the first two Kiln Conferences, Eric Blinman, M.N.M., O.A.S. proposed a research design for further excavation of slab-lined thermal features as kilns (Blinman 1992). In 1992, during a monitoring survey for a water pipeline replacement project at Mesa Verde National Park, nine trench kilns were located. Excavations of these features by Brisbin and Ives at Mesa Verde provided the most extensive look at kiln stratigraphy to date. The detailed stratigraphic sequences recorded in these excavations, combined with experimental firings conducted by Clint Swink, artist and replicator, have produced results in pottery replication that are the most consistent with the archaeological record. To date, twenty-seven thermal features interpreted as kilns have been reported in the San Juan River basin and two in the Northern Rio Grande valley, New Mexico (Brisbin and Swink 1996).

Trench kilns are consistent in form and construction. They are rectangular or sub-rectangular in shape and are approximately 1 to 1.5 meters wide and can vary in length from 1.5 to 8.5 meters. The
walls are typically lined with upright sandstone slabs. The kilns are often located on the sloping edge of a mesa, across a shallow drainage, and are located some distance from habitation sites. The thermal features also appear to be similar in cross section. The bottom most stratum is a thick layer of charcoal, interpreted as a prefire or the primary fuel. Above the charcoal is an irregular layer of sandstone slabs, blocks or cobbles. This is interpreted as the pottery setting or kiln furniture. The upper most level is a layer of charcoal, ash, clay and colluvial fill in which pottery sherds or wasters are found. This has been interpreted as the main fire or secondary fuel, evidence of misfired pottery and/or cover sherds, and a smothering agent.

**Kiln Conference I**  

Kilns:
Prior to the first conference, two trench kilns models were constructed that approximated what has been seen in the archaeological record. The kilns were located in a small drainage that feeds into Crow Canyon. They were situated roughly perpendicular to this drainage.

Kiln A was approximately 1.5 by 1.25 meters and 23 to 36 cm deep. This kiln was oriented with its long axis running on a line northeast/southwest from magnetic north. The walls were lined with sandstone-slabs and slightly sloped. Kiln B was approximately 1.6 by 1.2 meters and 25 to 30 cm deep, and was oriented with its long axis running north to south. The walls were sloped and sandstone slab-lined.

Strategy Session:
The goals of this project, postulated problems, and potential solutions were discussed. The objectives were to:

- produce reasonable replicas of prehistoric pottery using locally available materials,
- control the firing atmosphere to produce black-on-white pottery,
- examine fuel use and consumption.

Ethnographic and experimental firing literature indicates that in open or shallow pit firings there are usually two stages. First, a preliminary or prefire is lit to dry the ground and heat the vessels. A second fire, usually of short duration with very intense heat, is used to fire the vessels. Vessels are usually protected from direct flames by cover sherds or thin metal. Vessels are supported on metal grates, tin cans, or rocks (Shepard 1980). This information was used as a start for the prehistoric model (Ermigiotti and Hovezak 1991, Revised 1994).

It was suggested that the location of the vessels and ceramic tiles placed in the kilns should be mapped. Thermocouples would be placed in various areas of the kiln and observations of firing conditions and temperatures would be made at regular intervals. After firing, observations of vessels would be made and kiln conditions described.

Karen Adams, Crow Canyon ethnobotanist, suggested using equal amounts of pinon pine and juniper
wood as fuel. Although the record of plant remains in prehistoric kilns is limited, samples show these conifers are predominant. Quantities of corn cobs could also be used as fuel. The amount of fuel wood would be recorded by weight before firing in hopes of understanding prehistoric fuel consumption (Adams 1991).

Firing 1: Kiln A
Clint Swink, local prehistoric pottery replicator, was designated kiln master for this firing. The role of the kiln master is to design the firing regime. Swink, who had done more than one hundred firings commented that the results of each firing can be different and there is always something to be learned.

A fire was built in both kilns the evening before the pottery firing to thoroughly dry the kiln. This was especially important because traces of snow still lingered and the ground was muddy in places. In the morning, a prefire was built to preheat the kiln, remove moisture from the sandstone wall liners, and heat the vessels. After this fire had burned down, the kiln was cleaned of charcoal and embers. Shortly after 10:00 a.m., the vessels (15) were loaded in the center of the kiln and tiles of varied clays were scattered throughout. This covered only about 50 percent of the kiln floor. Organic painted pottery was placed in the west end, and mineral painted pottery in the east end. Small, split pieces of juniper were placed between the mineral painted vessels. Twelve thermocouples were placed in different parts of the kiln to record temperature. Vessels were covered by sherds. Wood (split, fireplace size, approximately 18 inches long) was cribbed directly over the vessels. All juniper was used in the west end and the east end had approximately 50% pinon and 50% juniper. The fuel was lighted from the top at 11:40 a.m. The firing lasted two hours and 40 minutes. A maximum temperature of 800° C was reached in approximately 30 minutes at the east end of the kiln. (Temperature profile 91:1, A). One thermocouple, and some small pieces of fuel, placed under an inverted bowl reached a temperature of 600° C. One hour into the firing, the west end of the kiln was smothered with fine ash in an effort to avoid oxidizing organic-painted white wares. Two hours into the firing, vessels were removed from the east end of the kiln. A rapid temperature drop was recorded where the pots were removed and a gradual decrease where the pots were ash smothered.

All of the vessels were more oxidized than is typically seen in prehistoric samples (Toll, Wilson, Blinman 1991). These vessels had orange to buff colored surfaces and were soft and friable. However, the pottery in the area covered with ash showed less oxidation. A total of 61 kgs of fuel was used, 24 kg of this in the prefire. Fuel brake down was 39 kg juniper, 20 kg pinyon and 2 kg juniper bark (Hovezak 1994).

Firing 2: Kiln B
Based on the results of the first firing, and stratigraphic descriptions of prehistoric kilns, this firing was designed by Eric Blinman, Museum of New Mexico, and Dabney Ford of the National Park Service. This firing differed from the first in that a layer of split juniper wood was placed under the stone slabs used as kiln furniture. It was hoped this might help maintain a neutral (not reduced or oxidized) atmosphere in the late stages of the fire. Eighteen vessels and various test tiles were placed in the kiln. The quantity of wood was increased and the fuel consisted of 50 percent pinon and 50 percent juniper. The fuel was lit from the bottom at 3:25 p.m. Additional fuel was added after 30
minutes. Fifty corn cobs and juniper bark were also added (Hovezak 1994). Temperatures of more than 800°C were reached after one hour. At one hour and 25 minutes into the firing, ash was used to smother portions of the fire and prevent oxidation. One thermocouple recorded a high temperature of 1000°C after three hours. Temperatures were still above 500°C after five hours (Temperature profile 91:2, B). The vessels were not removed until the following morning.

Most of the vessels in Firing 2 were less oxidized than those from Firing 1, but still more oxidized than prehistoric samples. Mineral paints from this firing came out black although in some cases the paint was not well fused to the surface. Organic paint retention varied throughout. Some vessels were cracked but there was no spalling. A glaze paint was inadvertently produced when a copper-jacketed lead slug, which was present in a piece of firewood, melted and a cover sherd emerged with greenish drips similar to early glaze wares (Toll, Wilson, Blinman 1991). A total of 150 kg of fuel were used in this firing, 40 kgs in the prefire. Utilized fuel included 87 kg juniper, 54 kg pinyon, 9 kg juniper bark and fifty corn cobs (Hovezak 1994).

Firing 3: Kiln A
Kiln masters for this firing were Clint Swink and Eric Blinman. Fuel was placed below the stone slabs that support the pottery (kiln furniture), similar to Firing 2. Approximately 20 vessels and various tiles were placed in the kiln. Cover sherds were used over the vessels. Fuel consisted of equal parts of pinyon and juniper. The fire was started just before 11:00 a.m., Feb. 24. A layer of juniper bark was added after 45 minutes. The intent was to seal in heat, slow cooling, and prevent oxidation. Corn cobs were also added. Temperatures continued to climb to more than 900°C just over an hour into the firing. Fresh bark was added to holes to control the burn. After one hour and 40 minutes, a blanket of wood ashes was used to smother the fire. Temperatures stabilized at 600°C. After four hours, temperatures were still more than 500°C. (Temperature profile 91:3, A) The fire had to be opened prematurely, after four and a half hours, to allow conference participants to observe the results before returning home.

The vessels in Firing 3 were the least oxidized of those from the three firings at this conference, but were still more oxidized than prehistoric examples. The stratigraphy of this kiln was closer to that found in excavated kilns, but not close enough. (Toll, Wilson, Blinman 1991). A total of 81 kg of fuel were used, eight in the prefire. The fuel used was 40 kg junipers, 29 kg pinyon, 12 kg of juniper bark, and 50 corn cobs (Hovezak 1994).

Note: During the conference wrap-up and evaluation there were discussions about the possibility of numerous ways to achieve desirable results. Steve Williams, a participant, suggested prehistoric potters may have put a layer of sediment or clay over the firing, sealing in heat with the vessels. He believes potters would then have to dig in the soil and ash to retrieve their vessels. Most archaeologists at the conference disagreed. Given what is now known (Brisbin, Swink and others) about kiln stratigraphy, it appears that Williams was on the right track (Hovezak 1994).
Kiln Conference II

The objectives of the second Kiln Conference were the same as those for the first conference. However, the intention was to include a bit more structure in the firings to reduce variables and to better record fuel use. There would be separate firings for mineral and organic painted wares. It was suggested that those potters bringing pieces to fire also include documentation of those pieces to provide information on clay sources, temper, slip, and paint.

Prior to Kiln Conference II, a flotation sample was taken from Kiln B. The kiln had been left uncovered in an attempt to observe natural deterioration and fill processes. The range of deposition was from 2 cm to 15 cm. Much of the above floor deposit was of ash and charcoal left in the kiln after firing. Abundant vegetation had grown in the kiln bottom. Plants were identified, but did not differ significantly from those growing around the kiln. (Hovezak and Ermigiotti 1992)

Presentations:
Clint Swink: Potting in Sand Canyon, Colorado. A paper reporting the difficulty of carrying greenware to a kiln site.

Kilns:
The same kilns were used as in the previous conference with slight modifications. Kiln A, the western or up slope kiln, measured approximately 1.63 by 1.14 meters at the top and 1.32 by 0.71 meters at the bottom. The depth ranged from 30 to 35 cm. The sides were lined with sandstone slabs. The bottom was lined with broken sandstone. Kiln B measured 125 by 76 cm at the top and 1.52 by 1.15 meters at the bottom. The depth ranges from 25 to 30 cm. The sides were lined with sandstone and the bottom was excavated to sandstone bedrock.

Firing 1: Kiln A
Clint Swink was kiln master for this firing, which was designed for mineral painted wares. The intention was to see if non-carbonaceous clays will pick up carbon from the fuel and duplicate the carbon streak found in prehistoric pottery samples. Also, it was hoped this firing regime would produce two temperature peaks, one from the fuel above the vessels and the second from fuel placed below the vessels.

A prefire was built to remove moisture from the ground and heat the sandstone rock that would be used for kiln furniture. A thin sheet of metal was used to conserve heat in the kiln and to warm and dry pottery on. After the prefire had burned down, the ash and heated rocks were removed from the kiln. A layer of juniper fuel was placed on the kiln floor. Sandstone slabs were placed on top of the fuel. The stones covered nearly the entire floor. Six thermocouples were placed in the kiln, three at the level of the top of the furniture and three higher into the area of the vessels. Approximately 30 pieces were placed in this firing. To reduce breakage bowls and jars were set upside down and mugs were placed on their sides. Juniper bark was placed between pots and inside the vessels. The idea at
the time was that the bark would use up the oxygen as it reached the pots, providing a reducing atmosphere. Cover sherds were placed over the vessels. Fuel, consisting of 90 percent juniper and 10 percent pinyon, was cribbed over the vessels to about 10 inches above ground level. Fuel size was roughly 18 inches in length and split to about 2 by 2 inches. Some pieces were longer in to act as structural support for smaller fuel. The fire was ignited from the top to allow vessels to heat slowly. The firing began at noon to the accompaniment of dark clouds and thunder to the east and north. Temperatures reached 540°C in thirty minutes. At first fuel was added as needed to plug burn through holes, later holes were allowed to form and remained uncovered. These holes were thought to allow oxygen into the lower fuel which would ignite and burn. A maximum temperature of 700°C was reached after one hour. An additional layer of fuel, 14.5 kg, was added at this time. Once the fuel had burned down and an overall ash / charcoal layer was created, a 2-inch layer of juniper duff was spread around the periphery of the kiln. An area 30 by 60 cm in the center was left uncovered. This smothering occurred at three hours into the firing.

Vessels were left in the kiln overnight. Temperatures were monitored for 18 hours. There was a small, slow but steady temperature increase which is possibly due to the combustion of the bottom layer of fuel. The temperatures never went much over 700°C. (Temperature profile 92:1, A) The results of this firing were variable. Body colors ranged from grey to buff white to orange. Some of the vessels were extremely oxidized, under fired, and friable. There was little mineral paint adherence on these vessels. Swink’s vessels fired with a grey body and black paint with good retention. This firing regime worked best with Swink’s specific materials, i.e., clay, slip and a copper-based paint. A total of 251 kg of wood were used in this firing. The main firing consumed 168 kg of fuel and 83 kg in the prefire.

Firing 2: Kiln B
This firing was intended for organic painted pottery, but unpainted wares were also included. Eric Blinman was kiln master. Prefiring of the kiln and kiln furniture was similar to Firing 1. This firing also used fuel below the pottery setting. About 24 vessels were loaded into the kiln. No bark was placed inside the vessels in this firing. Cover sherds were used. Fuel was cribbed over the kiln and longer pieces were used for structure across the pit. This firing was ignited from the bottom by placing hot coals at the bottom of the northeast corner. Coals placed around the perimeter might have ignited the kiln more evenly. A single thermocouple was used to record temperature, therefore there is not a range of temperatures to compare. Temperatures seemed to rise very slowly to only 320°C after one hour. Gross refueling occurred after one hour and 40 minutes. The kiln was smothered with a fine ash layer after four hours and 25 minutes. A maximum temperature of 610°C was reached after five hours and 30 minutes. (Temperature profile 92:2, B)

The results were also extremely variable. Swink’s raw materials seemed to work best for this firing regime. Body colors were generally shades of grey with black paint. Was softer than prehistoric samples. Some of the vessels, made of Mancos shale, were extremely oxidized, orange in color and soft. A total of 195 kg were used in this firing; 68 kg in the prefire and 127 kg in the main fire.

Several important documents were published as result of suggestions, observations, and inspirations
generated from Kiln Conference I and II. Recommendations for collection of data and future excavation of trench kilns were developed at the request of archaeologist attending the conference (Blinman 1992). The results of theses discussions were incorporated in the excavation of nine thermal features encountered during a water pipeline replacement project at Mesa Verde National Park (Brisbin 1993) and now provide the clearest insight into trench kiln stratigraphy. A thesis, Pottery Kilns of the Northern San Juan Anasazi Tradition, was submitted by David Purcell as part of his M.A. requirement at Northern Arizona University. Purcell summarized the investigation of 19 trench kilns reported to date.

**Kiln Conference III**

The objectives of this conference were much the same as those of the first and second:
- to achieve a limited oxidation firing,
- to produce consistent black organic and mineral paints,
- achieve a hard, white ware with a carbon streak (dark core).

This year a separate surface firing would be conducted for grey wares. In addition it was suggested a materials type sample be initiated for all slip and body clays used in the firings.

Presentation of New Ideas and Discoveries:
Eric Blinman: Kiln Conference Review and Research Update
Lori Reed: Excavation of a Pueblo I Kiln in the Navajo Reservoir Area.
Clint Swink: Limited Oxidation Firing of Organically Painted Pottery in Anasazi Style Pit Kilns.

**Kilns:**
Kiln A was approximately 1.3 by 1 meter with a depth of 35 cm. The walls were sandstone lined.
Kiln B measured 1.2 by .9 meters with a depth of approximately 30 cm. The walls were sandstone lined. A third kiln, Kiln C, was an impromptu, above ground pit, sub-rectangular in shape. The pit was built up from a bedrock base, located in a drainage. The sides were built up with sandstone blocks and earth was heaped up around the outside. There were no dimensions recorded for this kiln.

**Firing 1: Kiln A**
Clint Swink was designated kiln master. His intention was to create a high temperature firing for organic paint. Recent excavations at Mesa Verde National Park (Brisbin 1993) yielded the most detailed and comprehensive look at prehistoric kilns to date. The excavated kilns were similar enough to suggest a common firing strategy. Swink’s recent testing was based on the repeated stratigraphic pattern discovered by Brisbin (Swink 1993). He hoped to duplicate these results.

A prefire was begun at 6:30 a.m. with large amounts of juniper wood. Fuel was heaped above ground level and additional fuel continuously added until 9:00 a.m. About 57 kgs of fuel had been burned. The kiln contained a bed of ash-covered coals which were very hot and radiating heat. The coals were
raked flat across the kiln to a depth of about 18 cm and allowed to burn until all flame and smoke had disappeared. It was hoped that heat from the coals of this “primary fuel” below and the burning fuel above the vessels would create what Swink described as a “heat sandwich.” After 2 hours and 25 minutes, the sandstone slab kiln furniture was placed on the hot coals. They were evenly spread and covered about 50 percent of the kiln. The pottery was placed in the kiln. Bowls were placed first, mouth down. Swink noted that “pottery should sit in the kiln in its strongest position.” Jars were placed upright and mugs on their sides with handles down into the coals. A total of 34 vessels were included in this fire. A number of pieces were situated so that the paint from one touched an unpainted area of another to see if organic paint would transfer. (There was no subsequent transfer.) Cover sherds were used on all vessels except one unpainted jar, which would hopefully become fire clouded. (It did not.) Thermocouple probes were installed - three below the furniture and six placed among the pots, including one inserted into a prepared hole in a bowl. Three probes were placed on top of the cover sherds. After a few minutes, as the sugars in the organic paint were heated, a pleasant aroma was produced. It was thought the paint was being set at this time. Thermocouples produced readings of 100°C in the charcoal and 300°C between the wares and cover sherds. Five juniper log spanners were placed across the kiln to support the shorter secondary fuel. The fuel, primarily juniper, was cribbed around the sides and filled in with lighter pieces of sagebrush. A dome of fuel was built over the kiln with several inches of head space above the cover sherds. It was thought this head space would generate draft and draw heat up from the hot coal of the prefire. The fuel was lit from the top at 10:45 a.m. Thermocouples in the cover sherds jumped to 800°C in a short time. The probe placed inside the bowl registered 810°C after 25 minutes. After 45 minutes, all probes registered between 650°C and 800°C. (Temperature profile 93:1, A) By this time, the fire had subsided to about ground level, and was reduced mostly to coals. Burning pieces of wood were removed so that a layer of smokeless, flameless coals covered the kiln. To limit oxidation the kiln was now capped with a covering of clean earth.

The kiln was uncovered the following morning. This firing was the best success yet, resulting in well fired vessels with body colors that ranged from light grey to white and good organic paint retention. Vessels with organic base mineral paint had poor paint adherence. It appeared from this firing that higher temperatures might be more important than the length of time of the firing. (Ediminster 1993) This firing consumed a total of 191.7 kg of fuel. Fifty-seven kg were used for the primary fire and 111.2 kg juniper plus 23.5 kg sagebrush were used in the secondary fueling. The emptied kiln appeared the closest to excavated ancient kilns.

Firing 2: Kiln B
This firing was intended for mineral painted (“carbon non-retentive”) wares. Greg Wood acted as kiln master. The design for this firing was a modified version of Firing 1, Kiln A, 1992.

A prefire was started in this kiln at 7:00 a.m., 19 kg of juniper were used. The fire was allowed to burn down. Hot coals and ash were removed. Split juniper was placed flat across the bottom of the kiln, spaced about one inch apart. The kiln furniture, sandstone slabs, were tightly packed on top of the juniper. Thirty vessels and various test tiles were loaded in the kiln. Juniper bark was placed inside bowls, mug and ladles. Bowls and ladles were placed upside down, mugs on their sides, and a canteen
and kiva jar were placed right side up. Thirty vessels and various test tiles were included. Cover sherds were used over the vessels. A juniper log spanner was placed lengthwise across the kiln. Lightweight, split juniper pieces were placed on top of the cover sherds. Stoutier, split juniper pieces were used to bridge the distance between the spanner and the kiln edge. The kiln was lit from the top. The time was 1:30 p.m. (There was a long break because of threatening clouds and lunch between kiln loading and lighting fire). After 45 minutes, fuel was added around the edges and to plug holes. After one hour and 40 minutes, a layer of juniper duff was spread around the edges of the kiln, leaving the center open. Unfortunately, no temperatures were recorded for this firing. The vessels were left in the kiln overnight.

Overall, the results were good if the Swink / Wood materials (clay, slip, and copper oxide paint) were used. Vessels were well fired and fairly hard. Body color ranged from dark to light grey. There was considerable smudging. Paints were black with good adherence. Although limited there was some cracking and spalling of vessels. There was speculation that spalling and cracking may have been caused by raindrops. It appeared higher temperatures were reached in this firing than in the one of the previous year using this same regime. Total fuel consumption was 127.5 kg, mostly juniper. Primary fuel totaled 19 kg. Secondary fuel weight totaled 108.5 kilograms.

Firing 3: Kiln C
This firing was designed to establish whether acceptable grey wares could be fired in a fairly short period of time with minimal kiln preparation and fuel consumption. Lori Reed, of Western Cultural Resource Management, designed this kiln. A prefire was used to warm the kiln. When the fuel had burned down, embers were removed. Corrugated and neck-banded jars made up the majority of the wares. A few bowls were included. Vessels were stuffed with juniper bark and placed mouth down, directly on the kiln floor. Fuel was cribbed from the kiln bottom, in a circle, around the pots and lit. Additional juniper was then stacked tent-like over the kiln top. After 35 minutes a small brown-ware jar was pulled from the fire to test “doneness.” There were no temperatures recorded. More fuel was added because, although there was good fire all around, the vessel tops were exposed. A second vessel, a small corrugated jar, was removed to test. This jar appeared to be fired; it sounded firm but “punky” or under fired when tapped. After one hour, hot coals were raked around the bottom of the remaining vessels. Cold charcoal was then used to cover the top of the vessels.

This firing did not produce the atmosphere or temperatures necessary for good black-on-white pottery but appeared adequate for utility wares. Fuel use for this firing totaled 52.1 kilograms.

Kiln Conference IV
June 3 - 5, 1994.

Over the preceding year significant progress had been made in understanding the technology of firing organic black-on-white painted pottery. One of the objectives of this year’s conference was to test this firing technology in a larger kiln that would more closely approximate the length of some of
the excavated prehistoric kilns. It was proposed that some of what has been learned through the Kiln Conference could be presented at the 1994 Pecos Conference, to be held at Mesa Verde National Park. The intent would be to demonstrate a 4-meter trench kiln firing there. Another objective of this firing would be to determine fuel cost per vessel.

Presentations:
Eric Blinman: Kiln Conference Review and Research Update
Clint Swink: State of the Art, Pecos Conference
Richard St. John: Wichita State University, An “Outsiders” Perspective
Donna Glowacki: Neutron Activation Analysis Study at University of Missouri

Kilns:
Kiln A was remodeled for this conference by lengthening it to 3 meters by 1 meter. The depth was approximately 30 centimeters. The kiln is rectangular with sloping, sandstone-lined walls and is oriented perpendicular to the drainage, its long axis runs southeast by northwest, in the hope of taking advantage of prevailing southwest winds.

Before remodeling, the sandstone slabs of the side walls of were removed and then soil checked for any signs of change in color. There was no major oxidation rind behind the slab kiln liners. There was a slight amount of mixed orange to grey earth in the walls to a depth of 3 to 4 centimeters, but overall the color was a dark brown. The natural color of the soil is a rich reddish-brown. The mixing may be due to spaces between and behind the sandstone slab wall liners where charcoal could lodge. A root located approximately 10 centimeters behind a slab on the west wall was not charred in any way. Apparently heat from the kiln, even after repeated firings, does not penetrate deeply into the soil.

Kiln B was expanded to 2 meters by 1 meter, and a depth of 30 to 33 centimeters. This rectangular kiln runs roughly north to south along the long axis and has sloping, sandstone slab-lined walls.

Firing 1: Kiln A
Clint Swink was kiln master for this firing which would use the limited oxidation regime (Swink 1993). The firing was designed for wares using carbonaceous clays, slipped with a “white” firing montmorillonite, and organic paint.

Primary fuel was lit early in the morning with the intent of creating a deep bed of charcoal which. This fire was allowed to burn down until there was no flame or smoke. At this point all volatile gases in the fuel should have burned off. The charcoal bed was approximately 15 cm deep. Sandstone slabs and blocks which would cover about 50 percent of the trench were placed on top of the coals to serve as kiln furniture.

A team of eight loaded the kiln, four placed vessels and tiles on the furniture while the others handed them the wares. The idea was to load as quickly as possible, to maintain valuable heat. Eighty-one
pieces of pottery, assorted miniatures, and test tiles were placed in the kiln. Within minutes the sweet smell of burning sugars was observed coming from the organic paint. Cover sherds were placed loosely over the vessels arrangement leaving some space for heat circulation. Twelve thermocouples were placed in the kiln, six among the vessels the others above the cover sherds. Several juniper log spanners were placed perpendicular to the long axis supporting the bulk of the secondary fuel above the cover sherd, creating head space considered necessary for oxygen exchange. At this point temperatures reached 250°C. Mostly juniper wood was used to fuel this kiln. More dead wood, as opposed to split, cured fire wood, was used for this firing than in previous years. The irregular lengths and shapes worked well in gapping the longer spaces in this large kiln. Also, it is more likely that dead wood was used by the ancients potters, who did not use metal axes. The secondary fuel was lit from the top in three places. Strong, unpredictable gusts of wind fanned the blaze. After 30 minutes, additional fuel was added to plug burn-through holes and fine-tune the fire. Although one thermocouple registered over 850°C, temperatures averaged 600°C. (Temperature profile 94:1,A) After about one hour and fifteen minutes, when the secondary fuel had been reduced to mostly flameless, smokeless embers, the kiln was ready to be smothered. Still burning pieces of fuel were removed. The entire kiln was smothered with a thick layer of loose, dry earth.

The kiln was uncovered the following morning. The results were mixed. Lower than expected temperatures did not produce very hard wares. Tightly packed fuel may have caused insufficient oxygen below the fuel dome. The atmosphere of the firing was variable. Swirling winds were a problem. Several vessels had cracked others exploded or spalled. This may have been caused by excessive vessel wall thickness in combination with too rapid a heat rise early in the firing. There had been a transfer of design from vessels to cover sherds. This was an interesting discovery. Over all, carbonaceous clays, particularly from the Dakota formation, worked best. Body colors ranged from a warm white to light grey to dark grey and there were many fire clouds. Organic paint results were good.

A total of 416 kg of wood was consumed, roughly half in the prefire and the remainder in the secondary fire. Approximately 33.3 kg of fired wares came out of the kiln. This equates to roughly 12.4 kilograms of fuel to fire 1 kilogram of pottery.

There was some dialogue over the possible social or communal implications that filling, fueling and firing such a large trench kiln would require.

Firing 2: Kiln B
This firing also adopted Swink’s “limited oxidation” strategy. Bruce Bradley wanted to test some red clay bodies and slips as well as mineral paint in this firing. The procedure used in Firing 1 was also followed in this firing. Because all thermocouples were in use in Firing 1, there are no temperature records for this fire. About 35 pots and several test tiles were fired. The overall impression of observers was temperatures were not high enough for well-fired pottery. There was some breakage. Mineral paint (iron, manganese or copper oxides) adherence was poor, even when mixed with an organic or clay binder. These paints turned a rusty brown color. Body colors ranged from light to dark grey to black. The red wares and slips ranged form orange-red to red-brown. Although the fuel
covering was lighter than in Firing 1, smudging may have resulted from too much fuel loading after
the initial conflagration or the premature collapse of the spanning timbers.

Fuel wood consumption for this firing was 280.5 kilograms. The thirty-five vessels fired produced
approximately 29.87 kg finished wares. There was roughly 9.3 kilograms of fuel used to fire 1
kilogram of pottery.

Firing 3: Surface Firing
The regime for this surface firing was designed by Clint Swink, Eric Blinman and Chris Pierce. It was
intended for grey wares which were mostly corrugated jars. An expedient “kiln structure” was built
of eight sandstone support columns rising approximately 12 inches above the ground. A prefire was
built to dry and warm the ground surface. Vessels were placed mouth down over the hot coals using
sandstone pieces to support them. Twelve vessels and several test tiles were included. Juniper log
spanners were placed from column to column. Smaller pieces of fuel were used to roof the structure.
Split fuel pieces enclosed the sides. The fire was lit from above. Wind conditions were breezy. Again,
there were no temperature recordings. Several vessels exploded in the initial stages of the fire. This
may have been due to poor vessel construction and rapid heat rise. Overall, vessels were oxidized
with body colors ranging from a buff-orange, where the mouths of the vessels were close to the
ground, to black where the vessel bottoms were near the fuel. Even though there was vessel loss, they
seemed better fired and harder than the previous two firings.

There is no archaeological evidence to support this particular firing arrangement This firing used
126.5 kg of fuel producing 6.6 kg of fired pottery. This resulted in 19.16 kilograms of fuel per
kilogram of finished pottery.

Kiln Conference V

Considering the fairly reliable results of the “limited oxidation” firing regime, perfected by Clint
Swink, it appeared that we were close to understanding how late Pueblo III organic painted pottery
could have been produced. Although close in terms of producing reasonable looking wares, there still
seem to be several unanswered questions in this complex scenario. The objectives for this year’s
conference were:
• to take a closer look at fuel consumption,
• to achieve higher temperatures in the firing,
• to test alternate firing regimes, such as surface firings for utility wares.
A new computerized temperature recording system was tried this year, with a capacity for collecting
data from 16 thermocouples.

Presentations:
Paul Ermigiotti: Kiln Conference Introduction and Review
Joel Brisbin: A Two-Part Explanation for the Location of Kilns
Jerry Fetterman: Excavation of a Trench Kiln at Indian Camp Ranch, Cortez, Colorado
Clint Swink: “Trash or Tools?” A Kiln Master’s Opinion of Five Late PII Kiln Assemblages
Greg Wood: Alternate Fuels and Kiln Configurations
William Lucius: “Cautions, Interpretations and Hopes”
Richard St. John: Firing Techniques Relating to Temperature
Steven Lakatos: Black on White Pottery Firing Features of the Northern Rio Grande Valley

Kilns:
Kiln A, the larger of the two kilns, is rectangular with slightly sloping sandstone lined walls. It measures 2.26 by 1.15 meters at ground level. The long axis of this kiln runs roughly southeast by northwest. The depth varied from approximately 33 to 37 centimeters. Kiln B rectangular with sandstone lined walls. This kiln measures 2 meters by 1 meter and is approximately 30 to 35 centimeters deep with the long axis running roughly north-south.

Firing 1: Kiln A
Clint Swink served as kiln master for this firing. Swink used the four step firing process (Swink 1993) which produce the best match with the stratigraphy in the archaeological record. This regime has previously been shown to create a limited oxidation atmosphere in the late stages of firing.

The “primary fuel” for the firing was lit just before 8:00 a.m. The purpose of this fire is to produce a bed of clean, hot, smokeless coals which would fill the kiln to half of its depth. After two and a half hours the primary fuel had burned down (there was a brief strategy session here, and Kiln B was loaded before Kiln A. Therefore, this stage may have taken longer than it should have). At this time the sandstone kiln furniture was loaded into the kiln, on top of the fuel. Swink believes thicker shelving may interfere with venting from below the vessels, making the firing less efficient. Three thermocouple probes were placed at the level of the primary fuel and shelving. At 10:45 a.m., vessels were loaded into the kiln with larger pots placed in the deeper part of the kiln. There were 77 vessels of various sizes and 12 test tiles. Cover sherds were placed over the vessels so the curvature of the cover pieces did not come into direct contact with the vessels. This created a loose setting which allowed for air to circulate but protected the pottery. Swink considers the sweet smell of burning sugars from the organic paint a good sign as it may be that the paint is being “set” at this time. The remaining six thermocouple leads were divided between the level of the vessels and just above the cover sherds. Several log spanners were placed over the setting (vessels and cover sherds), perpendicular to the long axis of the kiln. A cornmeal and juniper twig offering was made, and the kiln pyre was lit from the top at 11:25 a.m. Swink believes that lighting the kiln from the top allows for a slower temperature rise, causing less thermal shock to the vessels. There were significant problems with the temperature recording equipment in this firing. One of the thermocouples at the level of the vessels did not register. At various stages all of the thermocouples failed before the firing cycle was complete.

Twenty-five minutes after the secondary fuel was lit, additional fuel was added to “fine tune” the fire. Temperature readings clustered in the 475 to 600°C degree range. Several thermocouples located
above the vessels and cover sherds, recorded above 800°C degrees. Temperatures in the area of the primary fuel, below the vessels, slowly rose and leveled off around 700°C. (Temperature profile 95:1, A)

About one hour and thirty minutes after the secondary fuel was lit, the kiln was smothered with earth. The visual clues that indicate a fire is ready for smothering are a flameless, smokeless mound of coals, that evenly cover the setting. Pieces of fuel which could flame-up are removed. This earth smother limits oxidation within the kiln, and so the cover must be checked for settling and venting. Vents are filled as they form.

This kiln was uncovered the following morning. There are always feelings of optimism and suspense that accompany a kiln opening. The smothering agent contained a high percentage of sand, causing some settling and potential venting problems. Swink suggested that a soil with more clay and “body” would work best. The earth covering was removed to the layer of the cover sherds. The kiln was still hot to the touch. Swink believes the cover sherds create a chamber that helps reduce thermal shock.

Overall, the results of this firing were good. The body color of the vessels ranged from black to various shades of grey to white. The majority were within the range that is seen in the prehistoric record. Organic paint retention was also good. Tests using mineral paint, iron and copper, showed poor retention. Vessel hardness was good, but replicas still do not seem to be as hard as prehistoric samples. Swink stated, and all agreed, that the goal of replication is to make a usable vessel, not just one that looks good. If the vessel does not have a good ring it is not usable. There were some vessels that showed signs of cracking and spalling. The ladle handles seemed particularly susceptible to breakage. Some of the failures may have been the result of poor manufacture. Of the 77 vessels fired there were eight cracked or broken. This is roughly a 10 percent failure rate.

The depth of fill in Kiln A was measured immediately after the vessels were removed. The layer of primary fuel charcoal, from the kiln floor to the base of the sandstone kiln furniture, was approximately 20 centimeters. The total amount of fuel used in this firing was 516 kg, mostly juniper. The total weight of fired pottery was 41.75 kilograms. This equates to about 12.36 kilograms of fuel per kilogram of fired vessel.

Firing 2: Kiln B
Richard St. John, Wichita State University professor of ceramics, was kiln master for this firing. St. John was assisted by three of his students from WSU, who were part of a special project research class. This firing would try to achieve high temperatures by raising the height of the roof of the secondary fuel and slowing the collapse of the roof. Cover sherds would not be used in this firing. The falling charcoal from the roof would completely submerge the pottery so excess oxygen would be eliminated. Vessels would be pulled from the fire, hot, rather than smothering the kiln to stop oxidation of the vessels.

The primary fuel fire was lit at 8:20 a.m. to create a good bed of hot coals similar to Firing 1. When the primary fuel had burned down to a smokeless, flameless bed of embers, the coals were leveled out
and the kiln was loaded. Thermocouple probes were placed on this bed of coals and just below the kiln furniture to see if there was an elevation in temperature from this fuel, after the secondary fuel was lit. These recordings indicated that this did indeed occur. The kiln furniture was placed in the kiln toward the center leaving some space around the edges. At 10:15 a.m., 37 vessels and 13 tiles were loaded in the kiln. Five thermocouples were placed at the level of the vessels. No cover sherds were used to protect the vessels. As vessels warmed, the smell of burning sugars from the organic paints was present.

In creating the secondary fuel roof, columns of sandstone were stacked (8 to 12 inches) at ground level on the long ends of the kiln. This was to elevate the fuel well above the vessels to allow draft that would increase temperatures. A freshly cut juniper or green timber spanner was placed on top of this stone support, and ran the length of the kiln. Shorter pieces of fuel were placed perpendicular to the main support forming a fuel tent. After allowing time for the vessels to slowly heat, the fuel was lit from above at 11:00 a.m. Within twenty-five minutes, temperatures at the level of the vessels reached 800°C. The primary fuel level was 650°C. After 40 minutes, fuel was burning down and all temperatures stabilized around 800°C. (Temperature profile 95:2, B) In broad daylight the pots could be seen glowing red. At 11:55 a.m., coals were raked over the vessels to limit oxidation. About one hour after the fuel was lit, St. John began removing pieces from the kiln. Long iron tongs were used to remove the vessels. This caused some problems and several pieces were cracked. There were objections to the use of iron utensils, because prehistoric potters would have had only wooden poles.

The results of this firing were variable. Fairly good temperatures were reached, but vessels from this firing are still not as hard as in prehistoric samples. As a result of this firing, it can be clearly shown that primary fuel temperatures do rise again after the secondary fuel is lit. A high percentage of vessels experienced breakage. This could be due to several factors including thermal shock and/or removing fragile pieces with metal tongs. This increased breakage raises the question of whether the use of cover sherds could reduce some of the loss? Of the 37 vessels fired there were nine that experienced some breakage, this is about a 24 percent failure rate.

Vessel body colors, overall, were good, but did range from white to shades of grey and buff. It appears that removing hot vessels from the fire can halt the oxidation process. Organic paint adherence was good. In some cases the paint appeared faded but this may be due to application.

The total amount of fuel used in this firing was 494 kg, mostly juniper. The total weight of fired vessels was 14.68 kilograms. This equates to approximately 33.65 kilograms of fuel per kilogram of fired pottery.

Firing 3: Surface Firing
Paul Ermigotti and Mike Yeatts conducted a series of three consecutive open surface firings. These firings were designed to examine whether or not acceptable prehistoric cooking wares could be produced using a contemporary Pueblo Indian surface firing as a prototype. The surface firings were conducted mid-afternoon in an area cleared of vegetation, on the floor of a shallow drainage. Unfortunately, there was no temperature recording equipment available for these firings, nor was fuel
use recorded.

The first firing was prefaced with a small prefire to heat the ground surface and the vessels. Mostly smaller pieces of juniper and twigs were used. When the fuel had been reduced to mostly charcoal, flaming embers were moved aside and three small sandstone pieces were set on the bed to support the vessels. One neck-banded grey ware jar was placed on the sandstone supports, mouth down. Corn cobs were placed tepee like around the vessel, then finely split juniper was placed similarly over this. The fire was lit and additional fuel was added as needed. The duration of this fire was about 25 minutes. The corn cobs were not totally consumed but the most of the wood had burnt down. The vessel was black in color, due to reduction atmosphere. This was acceptable. The vessel had cracked and there was a blown out spall on the side. This can be attributed to rough handling by the potters in the early stages of the firing. Overall the vessel was of acceptable hardness.

The second firing was built on the bed of coals produced by the first firing. A small neck-banded pitcher and a bird effigy jar were placed on several sandstone supports, mouth down. Fuel, mostly deadwood, was cribbed around the vessels this time. A few thin pieces of wood and juniper bark were placed tepee like over this. The fire was lit and in less than 15 minutes the fuel had collapsed, the vessels were visible and glowing cherry red. Coals were raked over exposed portions of the vessels. As the fuel collapsed further, the vessels were allowed to “cool” in the charcoal bed. The vessels were removed 25 minutes after being placed in the fire with good results. The body colors ranged from grey to slightly buff with some prominent fire clouds. The vessels were slightly more oxidized than in the last fire. Vessel hardness was acceptable for cooking wares.

For the third surface firing three vessels were placed similarly on the bed of coals created by the first two fires. The vessels included a corrugated and a neck banded jar, and a red ware bowl. Fresh pine needles and juniper bark were placed inside the red ware bowl in hopes of producing a smudged interior. Fuel of arm-sized thickness was cribbed around the vessels. A tepee of split juniper was placed over this. At the time the fire was lit, the wind picked up significantly. Juniper bark was lavishly added to slow the fire. As the fuel collapsed the vessels, especially the bowl, were visible. Coals were raked to keep the wares covered. The bowl was removed from the fire and the grey wares were smothered with a sandy soil after 30 minutes.

In this firing the bowl turned an orange to buff color. The rim and much of the interior were smudged black. Cracks created in forming the vessel were present. The bowl was not as hard as seen in prehistoric samples. The jars were mostly white in color with random fire clouds. These body colors would be welcome in a painted white ware firing. The vessels were fairly hard and would make acceptable cooking wares.

It was agreed surface firings would leave little trace in the archaeological record. These test firings did raise the question of whether it is possible to produce suitable white wares without the use of the trench kiln. The question remains, were grey wares produced in separate firings?
Kiln Conference VI
August 23-25, 1996

The 1996 conference was overshadowed by severe drought in the Four-Corners area. The conference was rescheduled from the original June dates due to a county wide fire ban issued by the Fire Marshal.

It was suggested by an ad hoc steering committee that the conference review proposals for firing demonstrations or experiments prior to the event. The goals the sixth conference developed from the proposals submitted. They were:

• to achieve and sustain higher temperatures than in previous firings in these kilns using an alternate fuel arrangement system,
• to leave the fire open without smothering,
• to not use cover sherds,
• to consistently record temperatures between firings,
• the demonstration of an upper Rio Grande style pit kiln,
• to determine whether or not trench kilns are a more efficient firing technology, as defined by fuel costs, than open surface firings.

This year’s conference was fortunate to have had the involvement of several potters from Native American communities.

Presentations:
Eric Blinman: A Brief History of Research on Ancient Firing Technology in the Four Corners Area
William Lucius: Observations on Experimental Firing Techniques
Richard St. John, Dean Wallace: Wichita State University Research Team Test Results
Steve Lakatos: Upper Rio Grande Pit Kiln Firing Experiments
Clint Swink: Firing Freckles and Hot Spots as Evidence of Cover Sherd Use in Late Pueblo III Pottery Kilns, and A Comparison of Organic Paint Sources for Pottery
Greg Wood: The Thermal Behavior of Clay Minerals
Nancy Olsen: Toughness Tests and Time Investment Studies
Larry Sitney: Anasazi Pottery Firing Technology, Los Alamos Firing Experiments

Kilns:
Two of the kilns used, A and B, were the same as in the 1995 conference firings, but with some slight modifications. A bag wall was built across the northwest end of Kiln A to shorten the length and create a kiln chamber 1.8 m long, 1.2 m wide and 30 cm average depth. Kiln B measured 2 m in length, 1 m wide and 25 to 30 cm deep. To elevate the level of fuel above the kiln two stone structures were built at both ends of Kiln B. These structures were referred to as “risers” and had the appearance of a step pyramid. The center was highest, about 40 cm above the ground surface, and dropping to 20 cm on each side.

A third kiln was created to simulate those excavated near Santa Fe, New Mexico (Post and Lakatos...
This kiln, Kiln C, was dug into the native soil making a shallow, oval pit about 1 m by 1.4 m and 15 to 20 cm deep. The dish-shaped pit was unlined. About 30 quartzite cobbles were used as kiln furniture.

Firing 1: Kiln B
Richard St. John and Dean Wallace of Wichita State University served as kiln masters for this firing. They headed up a Kansas research team made up of art and anthropology students who spent a semester investigating materials and firing techniques related to black-on-white pottery. The primary goal of this firing was to achieve high temperatures using a fuel arrangement that would draw air into the kiln. The technique is referred to as “drafting.” This firing would not use cover sherds, it was believed by the team that the limited archaeological evidence failed to support their use. This firing would not attempt to limit oxidation in the final stage of the process by smothering the kiln with earth. The vessels would be pulled from the kiln after all fuel had been reduced to ashy white charcoal and the pottery appeared to be the right color.

A kiln drying fire was lit at 7:50 a.m. It had rained the evening before and humidity was quite high. Two sandstone risers, one at each end of the kiln, were constructed for the purpose of elevating the log spanners used in supporting the secondary fuel structure. Fuel, pinyon and juniper, was added as needed to the primary fire for the next two hours to produce a good, thick bed of hot coals. Kiln furniture, sandstone slabs, were placed on top of the coals when the fuel had been reduced to flameless embers. The slabs were loosely spaced to allow heat to rise from the charcoal bed. Eight thermocouple probes were placed in the kiln, three probes at the level of the kiln furniture and primary fuel, and the remainder at the level of the vessels. To evaluate heat work three sets of three pyrometric cone packs were set to “witness” the fire. The cone pack sets were placed in the center of the kiln and at each end. Large cones were chosen and ran in even numbers from 020 to 04. The cone packs were covered with an inverted bowl for protection.

Three hours after the initial fire was lit sixty-six vessels and forty test tiles were loaded into the kiln. Larger bowls, ollas, dippers and mugs were placed first. A second layer of smaller bowls were stacked on top, face down, protecting the vessels underneath. Secondary fuel placement made this firing unique. Three sturdy green timbers were placed atop the stone risers spanning the length of the kiln. The center ridge pole was highest. This created considerable head room, about 30 cm, above the vessels. Split pieces of juniper averaging a meter in length and 10 to 15 cm in diameter was stacked up against the spanners, allowing ample space between each piece. This created a structure that resembled an “A-frame.” The vessels were allowed to warm in the kiln before the fuel was lit. When an oven thermometer, mounted on a pole, determined the temperatures at the level of the vessels was above 100°C, the secondary fuel was lit. It was after noon at this point. The spacing of the fuel made a very open fire and the vessels were plainly visible during most of the fire. Fuel was steadily added as needed for almost two hours. The kiln masters wanted to sustain high temperatures for an extended length of time. The drafting technique appeared to work well. Unfortunately, due to a computer problem all temperature results from the thermocouples were lost. After the spanners had burned through the remainder of the fuel was allowed to burn down to flameless, white coals which mostly covered the vessels. At this stage, with the aid of long poles, the vessels were carefully
removed from the kiln.

The results of this firing were variable and somewhat controversial. While it was generally agreed that head space above the level of the vessels and the secondary fuel source is crucial in encouraging air circulation, there is no evidence for the stone structures, "risers," in the archaeological record. The greatest disappointment was the loss of recorded temperatures during the fire. The cones did provide valuable data. Although cones do not actually measure temperature, they show the combined effects of time and temperature. Typically the faster the firing, the higher the temperature required to bend the cone and the longer the firing the lower the temperature needed to bend the cone. Generally it takes 15 to 25 minutes for a cone to bend once it starts melting (Orion Ceramic Foundation). The north end of the kiln reached cone 012, the center 014, and the south end cone 016. This puts the range of temperatures between 770 and 880°C over a three hour period which is a rather low temperature range. While cones may or may not be a reliable way to record what is happening in an open firing they are a standard used around the world to measure how much heat has been absorbed by the ware.

There was a wide range in vessel hardness. A majority of the vessels were soft and friable, but a few were well fired and rang when tapped. Of the 66 vessels, 18 showed cracks or breakage. That is about a 27% failure rate. Most of these vessels experienced rim cracks resulting from cooling too rapidly after being pulled from the fire. Body colors overall were white to light gray. Paint retention also varied; an even application of organic paint produced a good black while thin organic paint application or mineral paint mixtures produced poor results.

The fuel consumption for this firing was very high. A total of 790 kg of wood was used, mostly pinyon pine and juniper. The three spanners, of a nonnative species, were cut green to burn slowly, weighed 92 kilograms. It is hard to determine exactly what percents were used in the primary and secondary fires. The fired vessels and tiles produced approximately 35 kg of finished wares. There was roughly 22.5 kilograms of fuel used to produce 1 kilogram of pottery.

Firing 2: Kiln C
Steven Lakatos of the Museum of New Mexico, Office of Archaeological Studies was kiln master for this firing which was to evaluate the effectiveness of the limited oxidation atmosphere firing model in pit kilns similar to those found at Las Campanas near Santa Fe, New Mexico. The four stage firing consisting of a primary fuel fire, setting, secondary fuel firing and earth smother (Swink 1993) was being tested to determine whether the technology for firing black-on-white pottery might have been similar in the northern Rio Grande Valley even though materials and kiln construction were different.

The primary fuel fire was started at 9:20 a.m. Additional fuel was added as needed to create a hot bed of coals. Approximately 30 quartzite cobbles, 10 to 15 cm in diameter were added to the coals for heating. These were to be used as kiln furniture which reflected what was found in archaeological excavations. When the coals had been reduced to a white, flameless state thermocouple probes and vessels were placed in the kiln. This was about one-and-a-half hours after the initial fire was lit.
Twenty-two vessels and six test tiles made up this firing. Six thermocouple probes were used to record temperatures; three at the level of the primary fuel and cobbles, the other three higher up in the level of the vessels. No cover sherds were used to protect the vessels. The fuel, mostly juniper in .5 to 1.5 meter lengths, was loosely cribbed up and around the pit 3 or 4 courses, additional fuel was placed across the top. This created a very open arrangement which would allow an ample draft to the interior. In a very short time all of the thermocouples registered 200°C. The secondary fire was lit at 11:20 a.m. Temperatures rapidly moved into the range of 650°C to 800°C, peaking at 840°C in little over twenty minutes. As the wood collapsed some fuel was added and the coals were raked to cover the vessels. At 1:00 p.m. the kiln was smothered with earth to stop the oxidation process.

Shortly over two hours after the kiln was smothered the covering was removed and the vessels exposed. The pottery was hot to the touch but not in jeopardy of damage from thermal shock. Overall, the results were favorable. Two pieces experience hairline stress cracks. The failure rate was less than one percent. The vessels were fairly well fired but softer then in prehistoric samples. Some vessels were lightly oxidized, the majority being light gray to off-white. Organic paint retention was good.

Total fuel wood consumption for this firing was 109 kilograms. A little under half of that was used in the primary fire. Six kilograms of fired wares were produced. Fuel cost was roughly 18 kg wood to 1 kg finished ware.

This firing provided evidence that thermal features excavated in the Las Campanas area near Santa Fe, New Mexico may have been used similarly to Northern San Juan region trench kilns. Lakatos suggested several changes in social patterns might account for the differences in the shape of the kilns. The smaller pit kilns of the Santa Fe area may have been used on a household level versus the community level which has been suggested for the larger trench kilns. Another observation was it would be difficult to fire large white ware ollas in the shallow pit kiln as they would protrude above the level of the kiln. This is reflected in the Santa Fe black-on-white tradition which contains few ollas and mostly bowls.

Firing 3: Kiln A

The purpose of this firing was to provide a standard for comparison against the other firings during this conference. The four stage, limited oxidation atmosphere firing regime (Swink 1993) would be used in a stone-lined trench kiln. The kiln masters were Eric Blinman and Paul Ermigotti. A bag wall was created across the width of the existing kiln to reduce the area needed for the small number of vessels available for this firing.

The primary fuel fire was lit at 10:00 a.m., fuel was added as needed and allowed to burn for an hour and a half to produce the necessary hot, flameless bed of coals. The sandstone slab kiln furniture was placed on the bed of coals covering about 80% of the area. Blinman said this coverage best models the archaeological record. After allowing the slabs to be heated, 63 vessels and 36 test tiles were loaded into the kiln. Nearly half of the vessels in this firing were mugs. Vessels were arranged in a single level on the furniture. Eight thermocouple probes were placed in this firing but disappointingly,
they were tied into the same computer system which failed to record temperatures in Firing 1, Kiln B. Two sets of pyrometric cone packs were also placed in the kiln and ran consecutively from cone 018 to 014. Cover sherds were used to protect the vessels from thermal shock from above. There was at this stage a series of failures from spalling where vessels were suspended over hot coals and not supported, or protected, by the kiln furniture. These vessels may have been improperly dried.

Several juniper spanners, 1.5 meters long, were placed across the width of the kiln. Shorter lengths of juniper were used to build a fairly tightly packed dome of fuel above the kiln. The secondary fuel was ignited at 1:00 p.m. Observations taken from the computer screen placed temperatures in the range of 700° C after about 45 minutes. A high reading of 850° C was observed after an hour. When the fuel layer had burned, collapsed on the setting, and been reduced to smokeless, flameless coals the kiln was smothered with earth. The smothering occurred one hour and fifteen minutes after the secondary fuel was lit. The kiln was left to cool overnight and uncovered the next morning.

The short duration of this firing seemed to produce less than satisfactory high temperatures. Many of the vessels were slightly under fired and not as hard as archaeological samples. None of the pyrometric cones showed any signs of bending. Body colors on a majority of the vessels showed the results of a slightly oxidizing atmosphere and ranged from a warm white to buff. The edges of the kiln were more reduced. Paint adherence varied greatly depending what was used. Cleome (beeplant) produced good blacks. Samples that experimented with other organic paints including pine sap or those using minerals showed poor paint adherence. This firing had a high rate of breakage and spalling, 11 vessels, mostly resulting from thermal shock which occurred just after the wares were loaded in the hot kiln.

A total of 219 kilograms of fuel was used in this firing. Approximately one-third of that was primary fuel; 145 kg was used in the secondary fueling. The total weight of fired wares was 25.6 kilograms, therefore roughly 8.5 kg of fuel was used to produce a kilogram of finished ware though more fuel may have resulted in better fired vessels.

Firing 4: Surface Firing

A series of three firings were planned to address the issue of whether or not trench kilns are a more efficient firing technology than open surface fires. Over the years of the conference there has been no systematic data collected on temperatures achieved or amount of fuel used in surface firings using wood. Unfortunately, due to time constraints only one firing occurred. Paul Ermigioti designed the firing sequence based on contemporary Pueblo models.

A prefire, covering an area less than one square meter, was built on level ground. Seventeen kg of juniper, pine and other kindling were used in this stage. The purpose was to heat the ground and create a good, hot beds of coals. Several vessels were warmed next to this fire. After the fire had burned down, six cobbles were placed on the coals. Several pieces of broken pottery, “cover sherds,” were placed on the cobbles to serve as vessel supports and shields from the direct heat of the coals. Seven vessels were stacked on top of the furniture, including a grey ware jar, a painted red ware
mug, and five organic painted black-on-white test samples. Five thermocouple probes were located in the setting. One probe was below the vessels at the level of the cobbles. Two probes were placed inside vessels and two were placed above the vessels. A few strategic cover sherds were employed, then juniper fuel was cribbed and stacked tepee style around the vessels. One kilogram of dry corn cobs was also used as fuel. The fire was ignited at 11:30 a.m., and temperatures within the vessels jumped to 500 - 700°C range within five minutes. A high temperature of 820°C was reached approximately 15 minutes into the firing. This temperature is certainly comparable with any of those reached in the trench kilns. The red ware mug was pulled from the fire as the fuel began to collapse, in the hope of maintaining oxidizing conditions for this vessel. Thermal shock was too great for the mug which developed vertical cracks down from the rim. The body color of this vessel turned from a beautiful red with fire clouds to a brownish red as the vessel cooled. The fired color of the manganese/beeplant paint was poor, also a brownish red.

As temperatures dropped close to 400°C and the fuel continued to collapse around the vessels, earth was mounded around the wares to smother the fire and limit oxidation. The vessels were uncovered two and a half hours later.

The results of this firing were mixed but positive. Most of the vessels showed some smudging or fire clouds. The vessels were adequately fired and the small grey ware jar was considered serviceable as a cooking ware. The black-on-white wares ranged in body colors from smudged to buff/orange patches to grey and white. Organic paint was black with good retention, but when mixed with minerals it produced a rust color which rubbed off. One vessel spalled from a draft of cooler air. The failure rate was 28%, but this could have been lower if the redware vessel had not been pulled from the fire and all were protected from drafts of wind.

A total of 33 kilograms of fuel was used in this firing; 17 kg in the prefiring and 16 in the primary fire. Upon examination, the corn cobs in this hot fire were reduced to about one quarter of their original size and extremely fragile. The corn cobs, unless only partially burned, would probably leave little evidence. This firing produced 1.5 kilograms of finished wares. About 11.3 kg of fuel were used for firing one kilogram of pottery.

Conclusion and Future Goals
The Kiln Conference at Crow Canyon has brought together participants with widely varied interests and knowledge with clay as the common denominator. As such the Conference has provided a unique opportunity for archaeologists and non-archaeologists to contribute to an understanding of the past. Incorporating archaeological data from excavated kiln sites in the Southwest with experimental pottery replication studies has produced many insights into ancient firing technology. Although experimental research has closely approximated kiln stratigraphy and vessel appearance, we do not yet know how closely this model duplicates prehistoric practices. Some aspects of the process are still imperfectly understood (Blinman 1996).

The geologic formations of the San Juan River Basin in the Four Corners area contain numerous sources for obtaining clay. Only a limited number of clays have been sampled for experimental
pursposes, and of these, still fewer have been chosen for characteristics believed desirable for producing black-on-white pottery. Carbonaceous shale clays deposited between sandstone strata, particularly from the Dakota formation, have been chosen most often by replicators for the ware body. These clays have a high shrinkage rate and must be modified with tempering materials of crushed sherds or grog, sand and finely crushed igneous rock. Montmorillinitic clays from the Morrison formation have yielded the best results as slip clays for organic paints.

One of the larger issues recognized in the production of white wares is the difficulty in achieving the correct atmosphere in the firing. This requires a delicate balance between an oxidized and reduced atmosphere which creates the white body color yet retains vessel strength originating from the carbon in the vessel wall. The most consistent results have been achieved largely through the efforts of Clint Swink, working with Joel Brisbin after the excavation of kilns at Mesa Verde National Park. Swink’s four stage limited oxidation firing sequence [primary fire, the setting, (which is the kiln furniture, vessels and cover sherds), secondary fire and smothering agent] most closely approximates what has been found in the archaeological record. So far the limited oxidation firings produces the best results with organic painted white wares. Since most of the experimental firings at the Kiln Conference over the last few years have centered on organic painted white wares, there is still a great need for testing mineral paints on white wares. Additional experimentation on grey ware and red ware firings is also needed.

Achieving vessel strength and paste hardness in replicas that is consistent with ancient samples seems to be a problem. Many replicas seem to be rather soft and porous. Producing sufficiently high temperatures as well as proper atmosphere is crucial to achieving desired results. Temperatures in the range of 700-850°C have been typical of firings in trench kilns at Crow Canyon and may be too low. Anna Shepard (1980) and Owen Rye (1981) both state that temperatures in open firings, using wood, are unlikely to exceed 1000°C. The placement of kilns which allow for maximum air flow is an important consideration. Firings of replicators Clint Swink and Greg Wood, who have situated their kilns in a location which increase the effects of drafting, have consistently resulted in higher temperatures and harder wares. Conditions such as high relative humidity as well as moisture content of the fuel may also reduce temperatures. Unfortunately the Kiln Conference firings have been dictated by the calender rather than when conditions were optimal.

Archaeobotanical evidence suggest that Utah juniper and Pinyon pine were the primary fuels used in the firing of prehistoric pottery. These fuels have been most heavily used in our firings. Other woody shrubs, corn cobs and stalks may also have been employed but very limited quantities of these have been used in our experiments. If one considers that the ancients had only stone axes or mauls for cutting, then dead wood, particularly juniper, may have been the fuel of choice. Dry, dead juniper burns hot and has the advantage of breaking up easily with a heavy blow. Chopping and splitting dry pine is a difficult task even with the sharpest metal axe. Estimates for fuel needed in a trench kiln to produce one kilogram of finished pottery has averaged between 18 and 22 kilograms. Most of the native Pueblo potters who observed these firings have commented on the large amount of fuel used. Because prehistoric kilns are typically a considerable distance from contemporary habitation sites, it may be an indication of the large amounts of fuel needed to fire these kilns. Firings may have been
executed near fuel sources. There is a question as to whether it was more convenient to transport unfired pottery to the kiln, located near the fuel source, rather than carry fuel to fire close to the pueblo. Fuel consumption studies may have implications for understanding possible resource depletion.

One of the greatest weaknesses of Kiln Conference research has been the inconsistent collection of data. Several firings have either no temperature data or fuel use records for comparison to other firings. This lack of data has occurred both through technical and human failure. Data to determine whether or not trench kilns are a more efficient firing technology than open surface fires is an issue that needs to be addressed.

Native American involvement in the Kiln Conference has been a high priority from the onset. The organizers had long hoped to address the difference in technology between contemporary Pueblo potters and their ancestors of 800 years ago. In 1996, with support from a Dr. Scholl’s Foundation grant, several steps were taken to encourage the participation of native American potters. In April of that year a presentation was given on kiln research and prehistoric pottery traditions to Indian potters at a symposium; Pueblo Pottery Arts. In June a follow-up workshop was given for interested native potters at the Pojoaque Pueblo Cultural Center, north of Santa Fe. The workshop introduced raw materials and construction techniques of prehistoric pottery. The participants were then invited to the Kiln Conference and encouraged to share their perspectives on the experience. When asked for their views on the connection to the technology of ancient pueblan pottery; the overall response has been the importance of the clay and the potter’s relationship with “Clay Mother.” The most important aspect of the technology, whether ancient or contemporary, is being able to listen to what the clay and the fire tells the potter. All of the Pueblo potters questioned the excessive amount of fuel used in our experiments.

A great deal has been learned about ancient Pueblo trench kilns and the firing of black-on-white pottery through replication experiments. The Kiln Conference has played an important role in this learning process. Tremendous potential exists for future studies. Possible applications for pottery replication studies include the ability of researchers to be able to conduct production cost and performance experiments on replica vessels. It is the hope of the author that this conference and future experimentation will continue to contribute to our understanding of ancestral Puebloan pottery technology.

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Temperature Profiles

The intent of these graphs is to portray the most meaningful thermal information about each firing in a simplified but uniform way. The experimental firing procedures differed greatly over the six year period, 1991 to 1996. The number of thermocouple probes used to compile these profiles ranged from one to twelve for each firing. Some failures of thermocouples did occur. Placement of the probes also varied. There are no records available for firings 2 and 3 in 1993, firing 2 in 1994, firing 3 in 1995, and firings 1 and 3 in 1996.

The dark grey areas in the graphs represent the major concentration of readings from the thermocouple probes. They are interpreted as temperatures most closely associated with the vessel mass. In some instances, the precise location of the probes was not clear, therefore some subjective interpretation was necessary to help define the limits of the area.

The broader light grey areas represent the readings from all probes and portray minimum and maximum temperatures. These readings include short term fluctuations and temperature extremes that may have been a result of wind, shifting fuel, venting, and/or smothering.

Temperature recording began after vessels were loaded in the kiln except for 1993:1, A, 1994:1, A, 1995:1, A and 1995:2, B. Pre and primary fire temperatures were not recorded except for 1995:2, B.
KILN CONFERENCE I (1991)

Firing 1, Kiln A

12 Thermocouple probes; half of kiln smothered with wood ash
KILN CONFERENCE I (1991)

Firing 3, Kiln A

12 Thermocouples; wood ash smother
KILN CONFERENCE II (1992)

Firing 1, Kiln A  1 of 3

12 Thermocouples; kiln periphery covered with juniper duff

![Graph of kiln firing temperatures over time](image)
KILN CONFERENCE II (1992)

Firing 1, Kiln A  3 of 3

Elapsed time in hours
Firing 1, Kiln A

12 Thermocouples; earth smother, limited oxidation, vessels removed following morning
Firing 1, Kiln A

12 Thermocouples; earth smother, limited oxidation
KILN CONFERENCE V (1995)

Firing 1, Kiln A

8 Thermocouples, 5 burn out; earth smother, limited oxidation
Firing 2, Kiln B

1 Thermocouple; ash smother
KILN CONFERENCE I (1991)

Firing 2, Kiln B

12 Thermocouples: ash smother
Firing 2, Kiln B

8 Thermocouples; no smother, vessels pulled hot
Firing 2, Kiln C

6 Thermocouple probes, earth smother, limited oxidation
KILN CONFERENCE VI (1996)

Firing 4, Surface

6 Thermocouple probes, earth smother, one vessel removed before smothering