Geologic Map of the Cañon Largo Watershed on the Jicarilla Apache Nation, Rio Arriba and Sandoval Counties, New Mexico

By

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Scale 1:50,000

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View looking southeast across *Pinus edulis*-dominated Eocene-aged sedimentary rocks of the San Jose Formation (map unit **Tsju**) in the upper Cañada Larga watershed towards the Sierra Nacimiento, approximately 14 km (9 mi) distant. The San Jose Formation comprises large portions of the map area and often comprises interbedded sandstones and mudstones as seen in the foreground hoodoo. Though uplifted approximately 2 km (1 mi) since their deposition, these sedimentary units exhibit shallow dips of <7° on most of the map area, indicating minimal compressive deformation. Photograph taken in the southeastern map area at approximately 36.22°N, 107.05°W NAD83 (NE1/4 Section 16, Township 23N, Range 02W).

EXECUTIVE SUMMARY

Located in the east-central San Juan Basin, the area included in the "Geologic Map of the Cañon Largo Watershed on the Jicarilla Apache Nation, Rio Arriba and Sandoval Counties, New Mexico" occupies key locations for understanding the geologic history of the San Juan Basin. We refine previous mapping, which produced a robust geologic map of the bedrock geology of Paleogene sedimentary units of the area (Hobbs & Pearthree, 2021), and focus efforts on accurately mapping surficial units that occupy valley bottoms and plains within the map area and are undergoing infrastructure-altering erosion and sedimentation. This map includes parts of the central basin platform and Nacimiento Uplift-affected portions of the San Juan Basin, a broken-foreland structural basin formed during the Laramide Orogeny. The majority of the quadrangle is located on or near the San Juan Basin's synclinal axis, leading to opposing shallow dip directions in bedrock units throughout most of the map area. Eocene siliciclastic sedimentary rocks comprise most of the bedrock in the map area. Three Oligocene trachybasalt dikes cover <1 km^2 (<0.4 mi^2) in the northeastern map area. Loosely consolidated to unconsolidated Pleistocene deposits exist as sand sheets, stabilized eolian dunes, and valley-floor alluvium throughout the quadrangle. Holocene deposits include sheetwash alluvium and valley-floor alluvium throughout the map area and minor eolian dunes in the valleys of Cañon Largo and its larger tributaries.

The depositional history of the map comprises three broadly defined episodes. First, Paleogene deposition of fluvial siliciclastic sediments concurrent with the Laramide Orogeny produced the Nacimiento Formation and San Jose Formation, preserved in broad outcrops across the map. Second, Pleistocene and Holocene deposition of eolian sands produced the broad sand sheets which predominate in the western map area, while sheetwash and alluvial processes led to the gravels and sands that comprise the unconsolidated deposits found throughout the quadrangle's valleys and canyon floors. Finally, modern geologic processes in the quadrangle are dominated by arroyo incision and the removal of earlier Quaternary sediments via erosion. The final episode and the processes therein are the primary cause for the *Study to Address Erosion and Sedimentation in the Cañon Largo Watershed on the Jicarilla Apache Nation, Rio Arriba and Sandoval Counties, New Mexico*, for which this geologic map and report were prepared.

Deformation structures in the map area that are mappable at the 1:50,000 scale include a fault in the southwestern map area and the broad syncline that defines the San Juan Basin axis, which bisects the map from north to south, defined in this map by the opposing dip directions on the east and west sides of the map.

Landforms in the quadrangle include plains, arroyos, canyons, and mesas. Vegetation includes that typical of US EPA Level III ecoregions 21d (Southern Rockies Foothill Woodlands and Shrublands), 21f (Sedimentary Mid-Elevation Forests), 22i

(Arizona/New Mexico Plateau San Juan/Chaco Tablelands and Mesas), and 22n (Arizona/New Mexico Plateau Near-Rockies Valleys and Mesas; Griffith et al., 2006; USEPA, 2006).

INTRODUCTION

This report accompanies the "Geologic Map of the Cañon Largo Watershed on the Jicarilla Apache Nation, Rio Arriba and Sandoval Counties, New Mexico." Its purpose is to discuss the geologic setting of the map area, explain the geologic history of the map area, and identify and explain significant stratigraphic and geomorphic relationships discovered during the course of mapping. This report presents several fundamental geological aspects of the map, including the geographic and physiographic settings, climate, and previous geological work. Then it describes the geologic map units and their depositional settings by age in greater detail than is possible on the map sheet. The structural geology and geomorphology of the area are also discussed. Figures and tables are included throughout the report, and an appendix is presented at the end of this document.

MOTIVATION

This map was created in partial fulfillment of requirements laid out in the contract between the New Mexico Bureau of Geology and Mineral Resources and the Jicarilla Apache Nation for the *Study to Address Erosion and Sedimentation in the Cañon Largo Watershed on the Jicarilla Apache Nation, Rio Arriba and Sandoval Counties, New Mexico*. The goal of that study is to identify areas at risk of sedimentation and erosion on the southern Jicarilla Apache Nation. To reach that goal, a geological map of the area was necessary.

The majority of observed and predicted sedimentation and erosion in the study occurs in Quaternary-aged surficial geologic units; therefore, mapping focused primarily on surficial materials. Contacts, orientation, and descriptions of bedrock units are accurate nonetheless. This map is also used as an analytics modeling layer in the geological and engineering hazard analyses and maps that are included in the study. A 22 km^2 (8.5 mi^2) portion of the headwaters of Cañada Larga was mapped at the 1:24,000 scale by Merrick & Woodward (1982); the remaining approximately 2,100 km^2 (810 mi^2) of the study area was previously unmapped except at the 1:250,000 scale (Manley et al., 1987) and 1:100,000 scale (Mytton, 1983; Hobbs & Pearthree, 2021). The smaller-scale maps of Manley et al. (1987), Mytton (1983), and Hobbs & Pearthree (2021) lack sufficient surficial unit detail to meet the needs of this study.

Exposures of Cenozoic strata and Quaternary surficial deposits in the mesas, canyons, and arroyos throughout the study area provide the opportunity to reconstruct the geologic history of this portion of the Colorado Plateau on the Jicarilla Apache Nation. In addition to the erosion and sedimentation study goals for this map, this product also offers new mapping, data, descriptions, and interpretations of the geochronology, stratigraphy, and deformation history of the study area.

CLIMATE

The study area, like most of the San Juan Basin, has a cold semi-arid climate (Koppen Classification *Bsk*). Mean annual temperatures are 7.7°C (45.8°F) at Lindrith in the eastern map area (elevation 2,210 m [7,240 ft]). The mean annual precipitation is 37 cm (14.5 in) at Lindrith. Like much of the Colorado Plateau, the study area has pronounced seasonality of precipitation, with 40% of the annual precipitation occurring in July, August, and September. All climate data listed above are from the Lindrith station (ID# 294960) in the National Weather Service Cooperative Network and averaged over the years 1971–2016 (Western Regional Climate Center, 2021).

GEOGRAPHIC AND TECTONIC SETTING

"The Geologic Map of the Cañon Largo Watershed on the Jicarilla Apache Nation, Rio Arriba and Sandoval Counties, New Mexico," covers approximately 2,092 km^2 (808 mi^2) in northwestern New Mexico. Approximately 67% of the map area is within Rio Arriba County, while 33% is within Sandoval County. The map area (Figure 1) comprises approximately 69% lands of the Jicarilla Apache Nation, while the remaining lands are private (approximately 19%) or administered by the U.S. Bureau of Land Management (approximately 8%), U.S. Forest Service (approximately 2%), Navajo Nation (approximately 1%), or the State of New Mexico (approximately 1%). Lands outside the Jicarilla Apache Nation are included in this map area because they are within the larger Cañon Largo watershed and, therefore, must be considered for a complete understanding of the geology, hydrology, and erosion/sedimentation potential of the area. Some Jicarilla Apache Nation lands outside the Cañon Largo watershed are included within the map area due to the fact that the contract called for study both in the Cañon Largo watershed and "on the southern Jicarilla Apache Nation". These areas comprise 3% of the total map area in the southeast corner of the map east of the Continental Divide. Elevations in the map area range from 2,485 m (8,151 ft) above sea level (ASL) at an unnamed peak on the Continental Divide in the Tapicito Creek drainage on the northeastern map boundary to 1,943 m (6,374 ft) ASL at Tapicito Creek's junction with the western map boundary. The map area includes approximately 89 km (55 mi) of the Continental Divide, which forms most of the eastern border of the map. The most significant drainages in the map area are Cañon Largo, an intermittent and ephemeral tributary to the San Juan River, and its tributaries Cañada Larga, Cañon de los Ojitos, and Tapicito Creek, all of which are intermittent and/or ephemeral.

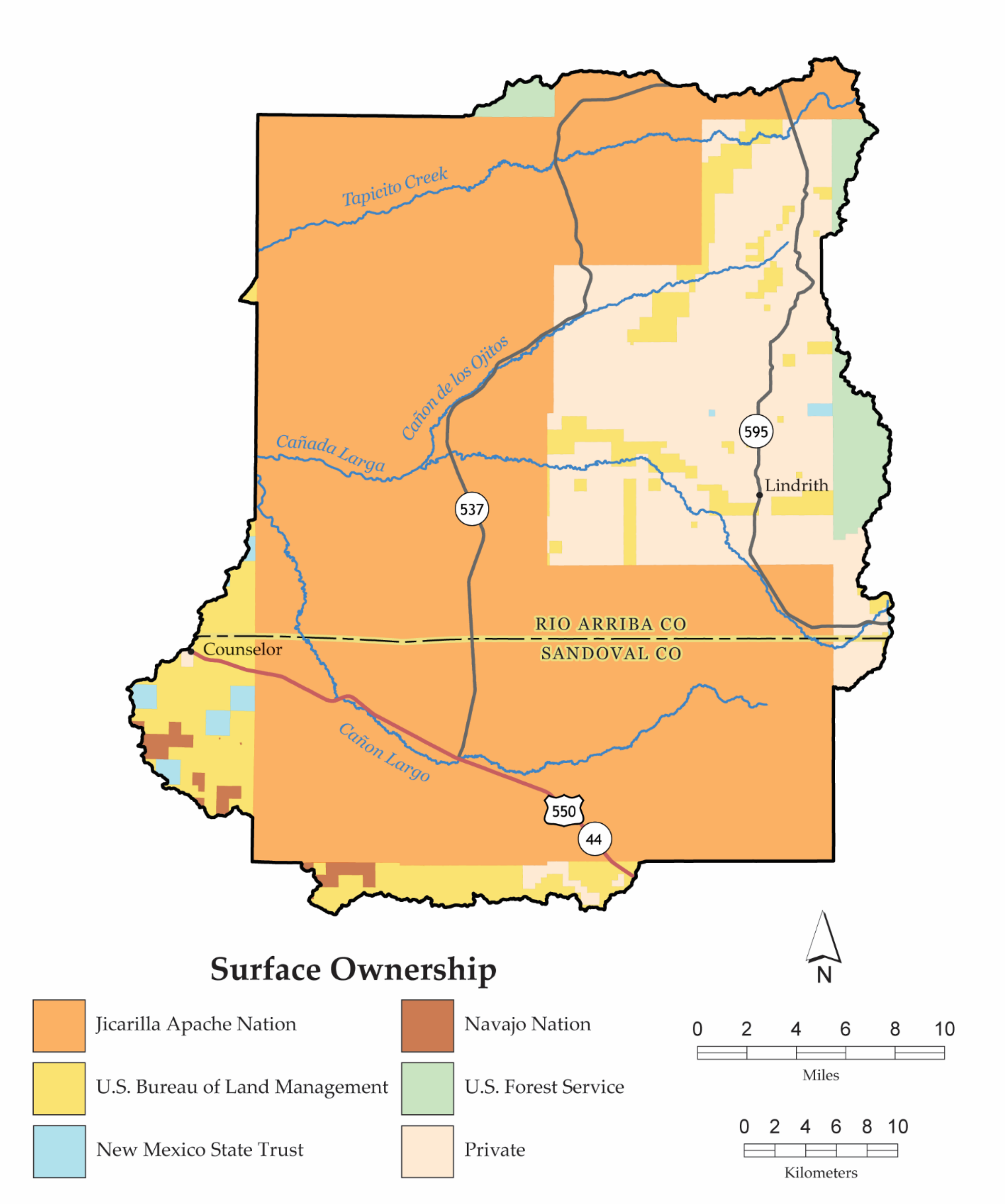

Figure 1—Map showing major drainages, highways, and land ownership in the map area.

The largest communities in the map area are Counselor and Lindrith. The human population is low and concentrated near Lindrith, with an estimated 275 people living within the map area as of 2018 (CIESIN, 2018). Three public paved highways exist in the map area: U.S. Highway 550 is a 4-lane divided highway crossing the southwestern map area; New Mexico State Road 537 is a 2-lane highway bisecting the central map area; and New Mexico State Road 595 is a 2-lane highway in the eastern map area. There are several hundred kilometers of improved (graded and graveled) unpaved roads, and thousands of kilometers of unimproved unpaved roads throughout the map area.

The map area lies entirely within the Colorado Plateau physiographic province, a region of relatively little faulting and folding compared to surrounding provinces. The Colorado Plateau's characteristic lack of abundant tectonic deformation features is manifest in this map by low dip angles and the presence of few known faults throughout the area. Like the rest of the Colorado Plateau, broad tectonic uplift in the study area occurred during the Cenozoic Era, leading to the high elevations that persist across the map area. The synclinal axis of the San Juan Basin, a structural basin in the southeastern section of the Colorado Plateau, passes through the map area. Laramide deformation led to overturned Cretaceous and Paleogene sedimentary units in drag folds on the San Juan Basin-bounding Nacimiento Fault approximately 6 km (4 mi) east of the map area, but Laramide structural deformation at the surface within the quadrangle is limited to shallow folding of bedrock units.

PREVIOUS WORK

Early geologic investigations in the vicinity of the southern Jicarilla Apache Nation were done by Dane (1946), Simpson (1948; 1950), Baltz (1953; 1967), Baltz & West (1962; 1967), and Fassett (1974). One 7.5′ x 7.5′ geologic map in the area was produced at the 1:24,000 scale (Merrick & Woodward, 1982). Mytton (1983) produced a geologic map of portions of this map area focusing on Cretaceous coal-bearing formations at the 1:100,000 scale. Since publication of those maps, significant advances in the understanding of the quadrangle's geology have been provided by Smith (1992a, 1992b), Williamson (1996), Cather et al. (2019), and Flynn et al. (2020). Throughout the 20th and 21st centuries, paleontological investigations have yielded Eocene-aged mammal, reptile, and plant fossils from within or immediately adjacent to the map area, particularly from the San Jose Formation (*e.g.*, Bown & Kihm, 1981; Lucas et al., 1981; Flanagan, 1986; Ma, 1998; Lichtig & Lucas, 2015). The San Juan Basin generally, and this map area specifically, are major producers of hydrocarbons, with over 40,000 wells drilled basin-wide. The geology, economy, and history of oil and gas production in the area are well summarized by Fassett (2010) and Hart (2021).

MAPPING METHODS

The procedures used to produce this geologic map are divided into four phases, all of which employ digital methods and the input of geological data directly into a Geographic Information System database by the authors. The first phase involved the authors identifying geologic units and likely contacts on aerial digital photographs and hillshade models derived from 1-meter LiDAR digital terrain models with the aid of previously published maps and reports. Aerial photographs include imagery from Google Earth and NAIP, though stereophotogrammetric pairs were most heavily utilized. Stereo Analyst for ArcGIS 10.8 software was used to draw contacts, faults, and dikes. The second phase involved identification and field-checking specific areas for contact accuracy, lithologic character, sample collection, and stratigraphic relationships. This phase includes recording pertinent points and lines using a handheld GPS unit. The third phase involved updating the locations of contacts and faults and revising lithologic identification based on field checks in the second phase. Finally, the map was simplified for the purpose of 1:50,000-scale final layout.

STRATIGRAPHY

"The Geologic Map of the Cañon Largo Watershed on the Jicarilla Apache Nation, Rio Arriba and Sandoval Counties, New Mexico" contains predominately sedimentary rocks and unconsolidated sediments. We discuss the bedrock units in ascending chronologic order, followed by surficial sediments and the quadrangle's one igneous unit.

Paleogene Sedimentary Strata

The oldest and stratigraphically lowest sedimentary rocks in the map area are those of the Nacimiento Formation, a thick succession of channel sandstones, overbank sandstones, floodplain mudstones, and paleosols. While this formation contains several members and is hundreds of meters thick in toto, only the upper few meters of the youngest member, the Escavada Member, are present in the map area.

The Escavada Member of the Nacimiento Formation is overlain by a disconformity or a slight angular unconformity. Atop this disconformable contact is the San Jose Formation (Figures 2 and 3), an Eocene unit containing fluvial sandstones and floodplain mudstones. The fluvial siliciclastic sediments of the San Jose Formation were derived from uplifts to the north and east of the San Juan Basin; lithologic composition and paleocurrent indicators suggest that the formation records basin-internal drainage reorganization during Eocene deposition (Smith, 1992a). The San Jose Formation is the uppermost bedrock sedimentary unit preserved in the map area and is overlain disconformably by unlithified Quaternary surficial sediments.

Figure 2—Sandstone cliff in the Eocene San Jose Formation at approximately 36.376°N, 107.245°W NAD83. The yellowish sandstone forming 75% of this cliff is likely the "persistent sandstone" of the Llaves Member of the San Jose Formation of Baltz (1967); however, for simplicity this outcrop and others like it in the map area are included in map unit **Ŧsju** (upper San Jose Formation, undivided). The cliff is approximately 18 m (59 ft) tall. Photograph taken October 31, 2021. May not be used without permission of the Jicarilla Apache Nation.

Figure 3—Sandstones and mudstones of the Regina Member of the San Jose Formation at Gallo Canyon (approximately 36.234°N, 107.448°W NAD83) on the western border of the map.

Quaternary Sediments

Unconsolidated surficial sediments in the map area are divided into 16 units. We do not propose formal names for these units; instead, we use informal descriptive names and map unit label abbreviations. The numerical ages of most units are unknown; we present units here in their likely chronologic order based on observed field relationships. Twelve charcoal samples collected from alluvial units yielded likely depositional ages of those units. Those sample locations are listed on the map sheet and are summarized in Table 1. Full analytical reports of those samples are included in Appendix A.

Table 1—Summary ^{14}C Ages From Charcoal Within Surficial Sediments in Map Area					
Sample Name	**Age (BP)**	**Latitude (°N)**	**Longitude (°W)**	**Depth below surface**	**Map unit**
JAN21-01	3,700	36.494481	-107.197067	410 cm (161 in)	Qao
JAN21-07	1,480	36.459912	-107.312239	300 cm (118 in)	Qao
JANC-02	2,030	36.22864	-107.380353	400 cm (158 in)	Qao
JANC-03	4,720	36.253817	-107.382444	200 cm (161 in)	Qao
JANC-11	1,560	36.320341	-107.220894	400 cm (79 in)	Qao
JANC-01	8,000	36.304107	-107.204801	400 cm (158 in)	Qao
JAN21-02	820	36.321576	-107.219529	360 cm (142 in)	Qay
JAN21-03	950	36.321576	-107.219529	195 cm (77 in)	Qay
JAN21-04	1,380	36.321685	-107.218415	60 cm (24 in)	Qay
JANC-08	500	36.323808	-107.406811	70 cm (28 in)	Qay
JANC-09	560	36.323534	-107.405494	190 cm (75 in)	Qay/Qf?
JAN21-05	5,810	36.362208	-107.248347	400 cm (158 in)	Qsw

Note: Margins of error can be found in the report provided in Appendix A. Geographic coordinates recorded with a handheld GPS in NAD83 datum; typical error is ±4 m (±13.1 ft). All analyses performed at Beta Analytics, Inc.

Eolian sheet sands (map unit **Qes**, Figure 4) occupy high landscape positions relative to other Quaternary units. Eolian sheet sands are found overlying bedrock. This unit formed during episodes of major eolian transport and deposition of locally derived sand and silt. Dune forms are dominated by longitudinal and parabolic dunes whose orientation suggest a mean sediment transport direction of 069°. We interpret this unit to have been deposited during climate-controlled episodes of less-abundant vegetation and increased sand transport in large drainages in and upwind of the map area. At least six paleosols at some localities within this unit suggest as many episodes of decreased eolian activity and likely stabilization of dune sands during the deposition cycle. There are no known large active linear or parabolic dunes in the quadrangle, and this unit is currently stabilized with vegetation and pedogenic development. Gravels at the base of this unit are too coarse-grained to have been deposited via eolian processes and warrant further study.

Figure 4—Cross-sectional outcrop of map unit **Qes** (eolian sheet sands) at approximately 36.234°N, 107.247°W NAD83. Where exposed in fresh outcrops, meter-scale cross-beds, like those in the center of this photograph, indicate a general northeasterly transport direction. Note the meter-scale pedogenic alteration at the surface, indicating an episode of depositional quiescence. The geologist in the photograph is 180 cm (71 in) tall. Photograph taken November 16, 2021. May not be used without permission of the Jicarilla Apache Nation.

Sheetwash alluvium (map unit **Qsw**) is found throughout the map area at the bases of eroding slopes and in moderately sloping plains where alluvial channels have not developed. This unit forms downslope of actively eroding slopes; the removal of sedimentary material from bedrock units is necessary to create the sheetwash flood deposits contained within **Qsw**. **Qsw** is an active depositional unit; deposition on this unit was observed and quantified by the authors during the study. Some areas of former sheetwash deposition are no longer active; these areas are separated from active areas with the map unit label **Qswo** (older sheetwash alluvium).

Modern to historic eolian deposits, derived from sand-bed arroyos and within valley floors (map unit **Qea**, Figure 5), are separated from map unit **Qes** based on their geomorphic position (**Qea** is found within valley floors as opposed to **Qes** being found capping broad uplands), lithologic composition (**Qea** is less mature than **Qes**), and activity (active dunes are common within **Qea** but absent within **Qes.**) This unit forms from the eolian reworking of sand and silt from large sand-bed drainages in the map area, especially along the larger drainages of Cañon Largo, Cañada Larga, and Tapicito Creek. Active dunes are up to 7 m (23 ft) tall and have an average sediment transport direction of 074°. Dunes in this unit are substantial enough to reroute and/or dam modern drainages. A review of historic aerial photographs shows variation in eolian activity and vegetation on dunes within this unit between 1997 and 2018, the causes of which were not examined for this study.

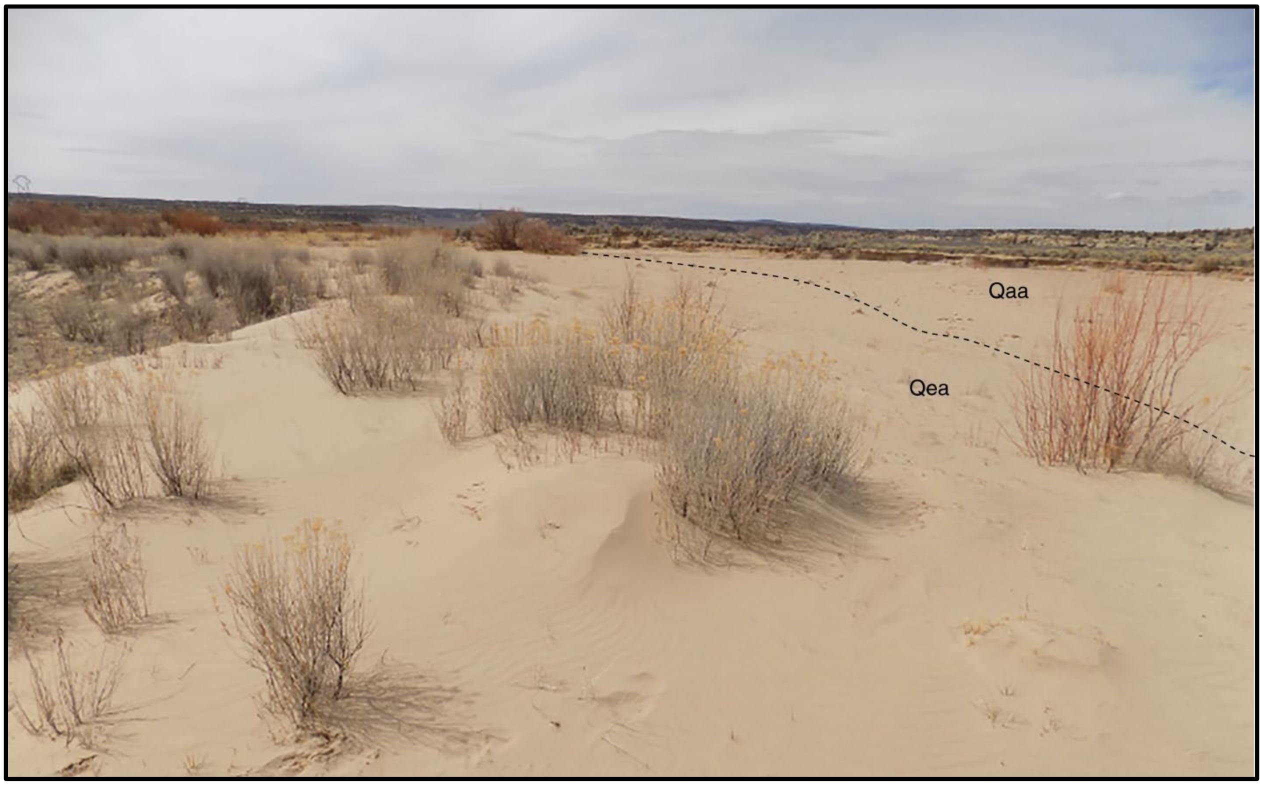

Figure 5—Photograph showing relationships between map units **Qea** and **Qaa**. These units are both active in modern arroyos and valley bottoms and often display complex intertonguing relationships. The eolian sand in unit **Qea** here has the same lithologic composition as that in the nearby alluvial channel mapped as **Qaa**, and sand grains within **Qea** here show no noticeable rounding or frosting relative to **Qar** sands. The dune in the foreground is approximately 2 m (7 ft) tall and appears to have prevented leftward lateral migration of the alluvial channel; the ground to the left of the dune is approximately 50 cm (20 in) lower than the active channel to the right. Photograph taken April 1, 2021 in Cañada Larga at approximately 36.323°N, 107.393°W NAD83. May not be used without permission of the Jicarilla Apache Nation.

Quaternary alluvium in the quadrangle is subdivided into older alluvium (map unit **Qao**), younger alluvium (map unit **Qay**), and active alluvium (map unit **Qaa**). All were deposited in intermittent and/or ephemeral streams contained within valleys and are lithologically similar. Map unit **Qao** is geomorphically higher than map units **Qay** and **Qaa** and represents alluvial deposition before the more recent incision of the alluvial system. Map unit **Qay** is inset into **Qao** by 1.5–7 m (5–23 ft), and its surface is 1.5–2.5 m (5–8 ft) higher than the active arroyo bed. Map unit **Qaa** is in or immediately above active channels and shows evidence of deposition during the historic timeframe (Figures 6 and 7). In valleys or reaches where all three alluvial units (**Qao**, **Qay**, and **Qaa**) are present, there is a slight coarsening through time; i.e., **Qaa** is coarser than **Qay**, which itself is coarser than **Qao**. All three are sand-dominated.

Figure 6—Three alluvial units in Cañada Larga at approximately 36.321°N, 107.224°W NAD83. The oldest unit, **Qao**, forms the highest bluff on the left. Inset into **Qao** is **Qay**, forming the medium cliff in the center and right. The youngest and lowest alluvial unit, **Qaa**, forms the mostly unvegetated area in the foreground. Photograph taken August 24, 2021. May not be used without permission of the Jicarilla Apache Nation.

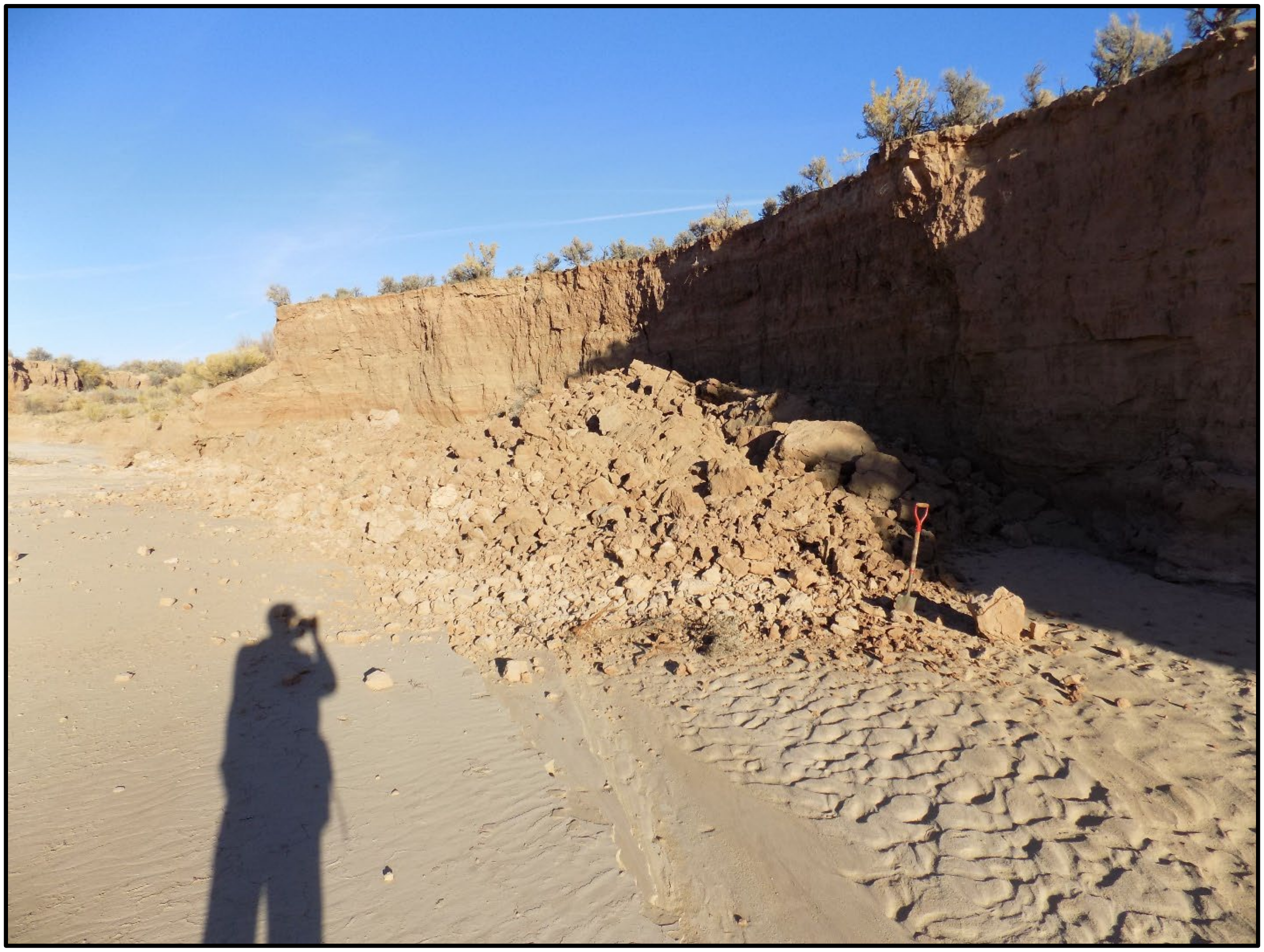

Figure 7—Recent collapse of 6-m-high bluff of Qao in Cañada Larga at approximately 36.321°N, 107.222°W NAD83. The process of lateral migration of the active stream channel, as evidenced by features like this, is decreasing the amount of map units Qao and Qay in the map area. Shovel is 1.3 m (4.3 ft) long. Photograph taken November 1, 2021. May not be used without permission of the Jicarilla Apache Nation.

Intrusive igneous dikes

Three dikes are present at Tapicito Ridge in the northeastern map area. These dikes represent the southernmost extension of the Dulce dike swarm of Lipman & Zimmerer (2019). Given their position in the same dike swarm and the proximity to Lipman & Zimmerer's (2019) described samples, we assume that these dikes are of similar lithologic composition, age, and character as the Oligocene trachybasalts they describe near Dulce, New Mexico, approximately 25 km (16 mi) north of the northern boundary of this map.

DESCRIPTION OF MAP UNITS

QUATERNARY

Anthropogenic Units

af **artificial fill (present to ca. 0.1 ka)**—Accumulations of clay, silt, and sand for the construction of dams, berms, roads, and well pads. Deposits of clay, silt, sand, and pebbles on the upstream sides of dams. The thickness is 1–5 m (3.3–16.4 ft).

ad **disturbed ground (present to ca. 0.1 ka)**—Disturbed ground and soil dump areas mapped where the original topography or geomorphic expression is obscured or significantly altered. Includes a 50 ha (123 acre) soil reclamation facility on Highway 537 on the north side of Cañon de los Ojitos. Where used for infrastructure, like electric power transformer stations or well pads, this map unit is sometimes capped with trucked-in gravel of different lithologic composition than other gravels found in situ within the map area. The thickness is <1 m (<3.3 ft).

Valley-Floor Units

Qaa **active alluvium (present to historic)**—Stream-deposited clay, silt, sand, and gravel within channels of active ephemeral and intermittent streams. This deposit occupies the lowest geomorphic position in any alluvially active valley. Mineral composition and grain rounding are influenced by, and largely inherited from, the bedrock composition of the drainage basin in which the deposit is found; deposits typically have the composition of feldspathic arenite or feldspathic wacke. A typical deposit consists of light-yellowish-brown, light-brown, or light-gray unconsolidated sand and silty sand with subordinate pebbly silty sand, sandy silt, and silty clay. The average sand grain size is slightly larger than that of the older alluvial units (map units Qay and/or Qao) in the same reach of the valley. The deposit contains trace pebble- through boulder-sized, rounded to spherical mud clasts. In Tapicito Creek, the deposit contains pebbles through cobbles of subangular to subrounded trachybasalt derived from dikes at Tapicito Ridge. In addition, the deposit sometimes contains rounded cobbles through boulders of quartzite, granite, gneiss, schist, and/or metapelite assumed to have been transported downstream from road crossings, where it was placed as non-locally sourced aggregate. The deposit contains anthropogenic detritus at the surface and in cross-sectional outcrop at a depth of up to 2 m (6.6 ft), including common litter, asphalt macadam, wire fencing, fenceposts, rubber tires, and household appliances. Bedforms include trough cross-bedding, ripple cross-bedding, ripple laminations, graded bedding, scour-and-fill structures, and plane bedding. In cross section, horizontal-plane bedding is the predominant bedform. Waning-stage mud films often overlie this unit but are rarely, if ever, preserved; muds at the surface are presumably removed during the early stages of subsequent streamflow events. This unit includes minor eolian dunes that are too small to map at the 1:50,000 scale; these dunes are up to 2 m (6.6 ft) high and are rare but present in cross-sectional outcrops. This unit does not effervesce in 10% HCl. The unit is predominantly unvegetated; primary successional grasses and forbs are present but rare. Perpendicular to the down-valley direction, the topographic profile atop this unit is horizontal. The observed thickness is 3 m (9.8 ft); the total thickness is unknown.

Qay **young alluvium (historic to ca. 1.4 ka)**—Stream-deposited clay, silt, sand, and gravel in valley floors that compose the first alluvial terrace above the active stream bed. Where present, this unit occupies the second-lowest geomorphic position in the valley. Mineral composition and grain rounding are influenced by, and largely inherited from, the bedrock composition of the drainage basin in which the deposit is found; deposits typically have the composition of feldspathic arenite or feldspathic wacke. A typical deposit consists of light-yellowish-brown, light-brown, or light-gray; poorly consolidated to unconsolidated sand and silty sand with subordinate pebbly silty sand, sandy silt, and silty clay. The average sand grain size is typically slightly finer than **Qaa** but slightly coarser than **Qao** in the same reach of the valley. In Tapicito Creek, the deposit contains pebbles through cobbles of subangular to subrounded trachybasalt derived from dikes at Tapicito Ridge. In Tapicito Creek and Cañon de los Ojitos, this unit contains trace anthropogenic detritus up to 1 m (3.3 ft) below the surface, including glass bottles and rubber tires. Bedforms include cross-bedding, ripple cross-bedding, ripple laminations, graded bedding, scour-and-fill structures, and plane bedding. In cross section, horizontal-plane beds comprise approximately 90% of observed bedforms. Bed thickness varies from laminated (<1 cm [<0.4 in]) to thick (>30 cm [>11.8 in]). Thin beds are the most dominant. Reddish-brown to light-reddish-brown paleosols up to 80 cm (31.5 in) thick with columnar peds, weak horizonation, and root traces are present but rare. Loosely to moderately consolidated; forms vertical faces up to 2.5 m (8.2 ft) tall. There is a distinct contact with underlying units. There is a gradational contact with surrounding fans and colluvial deposits. Where present in the same valley as older alluvium (unit **Qao**), this unit is inset by 1.5–7 m (4.9–23 ft) in a lower geomorphic position. Radiocarbon dates from charcoal collected within this unit on the Jicarilla Apache Nation range from 0.5–1.38 ka. The unit displays weak effervescence in 10% HCl at depths of 10–20 cm (3.9–7.9 in) below the surface. Surfaces of this unit typically contain grama grass (*Bouteloua sp.*), galleta grass (*Hilaria jamesii*), saltbrush (*Artiplex canescens*), big sagebrush (*Artemisia tridentata*), and chamisa (*Ericameria nauseosa*), with subordinate saltcedar (*Tamarix ramosissima*) and cottonwood (*Populus sp.*). Bar-and-swale topography up to 30 cm (11.8 in) tall is plainly evident on some surfaces. The unit includes minor amounts of debris fans, canyon-mouth fans, colluvium, eolian dunes, and sheetwash deposits. Perpendicular to the down-valley direction, the topographic profile atop this unit is horizontal. The observed thickness is 1.5–2.5 m (4.9–8.2 ft); the total thickness is unknown.

Qao **older alluvium (Holocene)**—Clay, silt, sand, and gravel that underlie terraces 3.5–9 m (11.4–29.5 ft) above the active stream bed. Sediment is in laminated to thick tabular to lenticular beds with cross-beds, ripple cross-beds, graded bedding, scour-and-fill structures, and horizontal-plane beds. In cross section, horizontal plane beds comprise approximately 80% of observed bedforms and trough cross-beds comprise approximately 15% of observed bedforms. Mineral composition and grain rounding are influenced by, and largely inherited from, the bedrock composition of the drainage basin in which the deposit is found; deposits typically have the composition of feldspathic wacke with subordinate feldspathic arenite. The average sand grain size is finer than that of the younger alluvial units (map units Qay and/or Qaa) in the same reach of the valley. A typical deposit consists of brown, light-brown, or yellowish-brown, loosely to moderately consolidated silty sand with subordinate silty clay, pebbly silty sand, sandy silt, and trace sandy gravel. Reddish-brown to light-reddish-brown paleosols with columnar peds and root traces are common; Stage II calcic horizons are present in some of these paleosols. This unit forms vertical faces up to 10 m (32.8 ft) tall. Where observed, this unit has a distinct contact with underlying units (typically Paleogene sandstones). There is a gradational contact with surrounding fans and colluvial deposits. This unit occupies the highest landscape position out of all alluvial units in the map area. Radiocarbon dates from charcoal collected within this unit on the Jicarilla Apache Nation range from 1.48–8.0 ka. This unit displays moderate effervescence in 10% HCl at depths of 10–30 cm (3.9–11.8 in). The surface of this unit typically contains plant communities dominated by big sagebrush (*Artemisia tridentata*), chamisa (*Ericameria nauseosa*), and saltbrush (*Artiplex canescens*), with rare cottonwood (*Populus sp.*), juniper (*Juniperus sp.*), piñon (*Pinus edulis*), cane cholla (*Cylindropuntia imbricata*), and prickly pear (*Opuntia sp.*). The unit includes debris fans, canyon-mouth fans, colluvium, and minor sheetwash alluvium. The surface topography is muted. This unit is differentiated from map unit Qay (young alluvium) by higher geomorphic position, slightly finer-grained texture, slightly darker color in outcrop, and a different plant community. Since the 19th century, this unit has been incised by up to 10 m (32.8 ft). Perpendicular to the down-valley direction, the topographic profile atop this unit is horizontal. The observed thickness is 7–10 m (23–32.8 ft); the total thickness is unknown.

Qaoa combination of Qao and Qaa (present to Holocene)—Combined map units where **Qaa** and **Qao** share a contact but are too small to map separately at the 1:50,000 scale. Does not include map unit **Qay**.

Qaoya combination of Qao, Qay, and Qaa (present to Holocene)—Combined map units where **Qao**, **Qay**, and **Qaa** share contacts but are too small to map separately at the 1:50,000 scale.

Qaoy combination of Qao and Qay (historic to Holocene)—Combined map units where **Qao** and **Qay** share a contact but are too small to map separately at the 1:50,000 scale. Does not include map unit **Qaa**.

Qaya combination of Qay and Qaa (present to ca. 1.4 ka)—Combined map units where **Qay** and **Qay** share a contact but are too small to map separately at the 1:50,000 scale. Does not include map unit **Qao**.

Other Alluvial Units

Qsw sheetwash deposits (present to Holocene)—Unconsolidated to weakly consolidated clay, silt, sand, and gravel. This unit includes minor colluvium on the toes of slopes. This unit may include mudflows, poorly sorted debris flow deposits, and associated debris flow levees at the foot of slopes. At the base of slopes, this unit includes locally-derived clay, silt, sand, and mud, whose composition and texture are controlled by the composition of upslope bedrock outcrops. In these settings, the unit often includes coalesced alluvial sediment aprons that grade upslope into colluvial aprons. Where this unit is found on broad upland flats, it consists of alluvially reworked eolian sands. In these settings, it comprises weakly consolidated, light-brown to light-yellowish-brown, poorly to moderately sorted clay, silt, and sand in poorly expressed very thin to medium horizontal-plane beds. In cross section, this unit exhibits poorly expressed plane bedding or no visible bedding. Cut-and-fill structures are not observed. Root traces and buried in situ vegetation are more common in this unit than in valley-floor units. This unit grades laterally into adjacent map units. In steep, narrow drainages, this unit consists of brown, light-brown, or yellowish-brown; cobbly, pebbly, and bouldery; medium- to very coarse-grained sand with minor sandy silt and trace sandy gravel. Reddish-brown paleosols are present in most outcrops. The surface of this unit usually contains a soil marked by a 30–50-cm-thick (11.8–19.7 in) Btw horizon. Weak effervescence in 10% HCl indicates the presence of calcium carbonate. Flow paths on the surface are non-parallel. Areas of recent deposition host grasses at the surface, while less recently active areas host roughly equal proportions of saltbrush (*Artiplex canescens*) and big sagebrush (*Artemisia tridentata*), with subordinate grasses, Mormon tea (*Ephedra sp.*), broom snakeweed (*Gutierrezia sarothrae*), prickly pear (*Opuntia sp.*), and cane cholla (*Cylindropuntia imbricata*). In upland areas, the contact with the underlying unit often is gradational and may be obscured by pedogenic or paleo-pedogenic alteration. Where found at the base of slopes, the lower contact is often distinct and marked by a scour surface. The contacts with adjacent units are gradational and this unit interfingers with alluvium. One radiocarbon date from charcoal found within this unit yields an age of 5.8 ka. This unit is rarely sharply incised and subdued topography is prevalent. The cross-sectional profile of the surface is not horizontal; where confined to a valley, the profile is concave-up. This unit has been incised up to 12 m (39.4 ft). The observed thickness is 1–12 m (3.3–39.4 ft); the total thickness is unknown.

Qswo **older sheetwash alluvium (Holocene to Pleistocene)**—Weakly consolidated clay, silt, sand, and gravel in a higher landscape position than map unit **Qsw**; otherwise similar lithologic description as **Qsw**. This unit appears darker and redder on orthophotographs and in outcrop and lacks any indication of recent or active deposition at the surface. The surface of the unit is smooth and hosts plant communities which include grasses, big sagebrush (*Artemisia tridentata*), and chamisa (*Ericameria nauseosa*) with rare pines and junipers. When measured, it has a concave-up topographic profile that is perpendicular to flow direction. The observed thickness is 2–8 m (6.6–26.2 ft); the total thickness is unknown.

Fan Deposits

Qf **fan deposits (present to Holocene)**—Unconsolidated to weakly consolidated silty sand, sand, and pebbly sand with trace cobbles. The lithologic composition is inherited from the bedrock composition of drainages upstream of the deposit. Internal structures include massive horizontal-plane beds, lenticular beds, cut-and-fill structures, and pebble imbrication. The sand is typically light-brown or yellowish-brown. The weakly developed topsoil includes a Btw horizon and is up to 50 cm (19.7 in) thick. There are up to 120 cm (47.2 in) of channel and swale topography on the surface of this deposit. In aerial photographs, active avulsions and deposition can be observed within this unit between 1997 and 2017. The plant community at the surface includes grama grass (*Bouteloua sp.*), galleta grass (*Hilaria jamesii*), saltbrush (*Artiplex canescens*), big sagebrush (*Artemisia tridentata*), and chamisa (*Ericameria nauseosa*). Flow paths show radial flow directions from the apex of the fan. This unit interfingers with adjacent alluvial deposits of the same age. This unit has been incised by up to 2 m (6.6 ft). The thickness is <10 m (<32.8 ft).

Qfo **older fan deposits (Holocene)**—Loosely to weakly consolidated silty sand, sand, and pebbly sand with trace cobbles. The lithologic composition is inherited from the bedrock composition of drainages upstream of the deposit. Limited outcrop exposures preclude describing the internal structure and total thickness. This unit occupies a higher landscape position than the adjacent younger fan deposits of map unit **Qf**. The surface of this unit is also smoother than that of map unit **Qf**. Very weak to weak effervescence in 10% HCl at depths of 10–30 cm (3.9–11.8 in). No active avulsion or deposition is observed in aerial photographs. The plant community at the surface is dominated by saltbrush (*Artiplex canescens*), big sagebrush (*Artemisia tridentata*), and chamisa (*Ericameria nauseosa*). This unit interfingers with adjacent alluvial deposits of the same age. Where this unit borders younger fan deposits of map unit **Qf**, it is 1–2 m (3.3–6.6 ft) higher. The thickness is likely <12 m (<39.4 ft).

Mixed Eolian-Alluvial Units

Qea active to historic eolian deposits derived from sand-bed arroyos and within valley floors (present to 0.2 ka)—Well-sorted coarse-grained silt to medium-grained sand that is light-yellowish-brown to white and unconsolidated. Bedforms include laminated to thin cross-beds with subordinate horizontal-plane beds. Ripples and sand avalanches are seen on active deposits. The grains are subrounded to subangular and are composed of quartz, feldspars, and lithic fragments. Little to no frosting is observed. The deposits have the composition of feldspathic arenite. This unit includes coppice dunes up to 3 m (9.8 ft) tall. The deposit is frequently reworked by lateral migration of active stream channels in west-flowing drainages such as Tapicito Creek and Cañada Larga. The unit also includes minor amounts of alluvium and sheetwash around active and stabilized dunes. Where dunes block surface drainages, and in deflation blowouts, the unit includes subordinate palustrine deposits consisting of horizontal-plane laminated clay and silt. Active dunes are 1.5–7 m (4.9–23 ft) tall. Stabilized dunes typically contain sacaton grass (*Sporobolus sp.*), grama grass (*Bouteloua sp.*), cocklebur (*Xanthium sp.*), and saltbrush (*Artiplex canescens*). This unit does not react with 10% HCl. The dunes sometimes bury riparian trees and shrubs. This unit can be differentiated from map unit **Qes** (eolian sheet sands) by its lower geomorphic position, active dunes, less mature lithologic composition, lighter color, and less-developed soil. The thickness is 1–8 m (3.3–26.2 ft).

Qeao inactive stabilized eolian deposits derived from sand-bed arroyos and within valley floors (Holocene)—Well-sorted, coarse-grained silt to medium-grained sand that is light-yellowish-brown and unconsolidated. No known cross-sectional exposures exist in the map area. The grains are subrounded to subangular and are composed of quartz, feldspars, and lithic fragments. No grain frosting is observed. The deposits have the composition of feldspathic arenite. The unit is mostly found as isolated vegetated and stabilized dunes northeast of Cañon Largo in the southern map area. Stabilized dunes are 1.5–4 m (4.9–13.1 ft) tall and typically contain grasses and saltbrush (*Artiplex canescens*) with few isolated pines and junipers. The surface of the unit contains a weakly developed soil with a 10-cm-thick (3.9 in) Ah horizon and weak effervescence in 10% HCl, indicating the presence of calcium carbonate. This unit can be differentiated from map unit **Qea** by its more-developed topsoil, lack of evidence for active eolian processes, and distinct plant community. The thickness is <8 m (<26.2 ft).

Surficial Units Not Confined to Valley Floors

Qsm **mesa-top sands (Holocene)**—Weakly consolidated sand and silt in broad sheets atop small topographically-isolated mesas. The unit is composed of moderately sorted laminated to thin-bedded silt and sand with trace granules and pebbles. The sand is composed of 70–80% quartz, 30–20% feldspar, and trace lithic fragments. Pebbles include petrified wood, quartzite, and sandstone. This unit likely represents remnants of eolian sheet sands (map unit **Qes**) that have been alluvially reworked and pedogenically altered, though not transported significant distances. Very poorly exposed in outcrop. Effervesces in 10% HCl at depths of 10–30 cm (3.9–11.8 in). This unit can be identified in orthophotographs based on landscape position, lack of recognizable dune forms, smooth surface, and redder color than **Qes**. The unit supports plant communities dominated by grasses, big sagebrush (*Artemisia tridentata*), and chamisa (*Ericameria nauseosa*); few woody trees are present except in the easternmost high-elevation outcrops in the central map area where pines and junipers are present in addition to the aforementioned plant species. The thickness is unknown but presumed to be <12 m (<39 ft) thick based on outcrop character and inferred origin.

Qes **eolian sheet sands (early Holocene to Pleistocene)**—Unconsolidated to weakly consolidated sand in broad sheets and stabilized dunes. Younger deposits consist of linear or parabolic dunes composed of very fine- to fine-grained sand that is white to pink, well-sorted, cross-bedded, and quartz arenitic to feldspathic arenitic (80–95% quartz in the sand size class). Older deposits are more common and consist of stabilized longitudinal dunes and sand sheets on upland areas composed of coarse-grained silt to medium-grained sand that is light-brown, pale-brown, and very pale-brown; loosely consolidated; moderately sorted to well-sorted; and subrounded. The bedding is disturbed to the point of obscurity in lower portions of the unit. The upper 30 cm (11.8 in) of this unit is noneffervescent in HCl; lower paleosols within the unit are effervescent, indicating the presence of calcium carbonate. At least six stratigraphically distinct paleosols are present in older deposits; these comprise pale-brown to strong-brown, poorly sorted to moderately sorted clay to medium-grained sand, silty sand, sandy silt, and clayey silt; massive horizons with block ped structures; and up to Stage II pedogenic carbonate horizons with few carbonate nodules and filamental coatings. In general, lower paleosols are darker (lower Munsell color value), finer-grained, and more likely to contain blocky peds, pedogenic carbonate, and thin clay cutans on ped faces. The unit has a distinct contact with underlying units, though this contact is sometimes overprinted by a paleosol. In approximately 50% of outcrop locations, this unit overlies a 2–7-m-thick deposit of subangular to rounded (predominately subrounded) sandy gravel with trace pebbles and cobbles. The gravel comprises, in decreasing abundance, quartzite, chert, quartz, crystalline metamorphic rocks, petrified wood, and intermediate to felsic volcanic rocks, including ignimbrites. Gravel outcrops are rare, but gravels are often seen as float or lag on slopes below outcrops of this map unit. Gravels are included within map unit **Qes** because of their association with that unit and because their outcrop areas are too small to map separately at the 1:50,000 scale. Stabilized dunes are typified by big sagebrush (*Artemisia tridentata*)-dominated plant communities, with subordinate ricegrass (*Achnatherum hymenoides*), grama grass (*Bouteloua sp.*), saltbrush (*Artiplex canescens*), chamisa (*Ericameria nauseosa*), broom snakeweed (*Gutierrezia sarothrae*), and Mormon tea (*Ephedra sp.*). Pine (*Pinus sp.*) and juniper (*Juniperus sp.*) are nearly entirely absent on this deposit. The unit is generally poorly exposed and only well-exposed in active headcuts and construction trenches for pipelines and roads. The average sediment eolian transport azimuth is 069° as determined by dune morphologies in aerial imagery. Stabilized longitudinal dunes are up to 10 m (32.8 ft) tall. The thickness is 4–15 m (13.1–49.2 ft).

Mass-Wasting Deposits

Qls **landslide deposits (Holocene)**—The composition is inherited from the bedrock composition at the head of landslides, which primarily comprises sandstones and mudstones of the Paleogene San Jose Formation and includes back-rotated Toreva blocks. This unit mostly occurs in steep-walled canyons in the San Jose Formation. In a large rotational landslide on the north side of Tapicito Creek, this unit includes sands and silts accumulated in a sag at the base of the headscarp. The thickness is not measured but is likely 5–20 m (16–66 ft).

PALEOGENE

Igneous Rocks

Ꝑi **intrusive dikes of the Dulce dike swarm of Lipman & Zimmerer (2019) (ca. 25.0 Ma)**—Light-gray to gray trachybasalt and basaltic trachyandesite dikes that intrude Eocene-aged San Jose Formation mudstones and sandstones on Tapicito Ridge in the northern map area. Dike orientation is subvertical. Dikes in the map area are up to 5.5 km (3.1 mi) long and 1–8 m (3.3–26.2 ft) thick. They contain phenocrysts of olivine and clinopyroxene with mica and amphibole present in the groundmass. The dikes often form resistant ridges with >30 m (>98 ft) of topographic relief above the surrounding landscapes.

Siliciclastic Rocks

₱sju Regina, Llaves, and Tapicitos Members of the San Jose Formation, undivided (Eocene)—This unit contains interfingering rocks fitting the lithologic descriptions of the Regina, Llaves, and Tapicito Members of the San Jose Formation as described by Baltz (1967) and Smith (1992a). Because of complex lateral gradational changes observed in the map area, these units are difficult to map in a sensible way. Below, we provide lithologic descriptions for the mudstone-dominated and the sandstone-dominated portions of this map unit. The total thickness in the map area is up to 450 m (1,476 ft).

Mudstone-dominated portions: Reddish-brown, light-reddish-brown, light-reddish-gray, and light-brown mudstone with subordinate reddish-yellow, yellow, yellowish-brown, and light-red sandstone and conglomerate. Both mudstones and sandstones are slope-formers. Mudstones are moderately to well-consolidated, non-fissile silty claystones, sandy silty claystones, and siltstones. The bedding is generally obscured by weathering and by the crumbly nature of the units. The sandstones are poorly consolidated, medium- to coarse-grained, subangular to angular, thin- to medium-bedded, cross-bedded feldspathic arenites and feldspathic wackes with trace conglomerate lenses. The conglomerates contain subangular to subrounded pebbles of crystalline igneous and metamorphic rocks with subordinate chert, quartzite, and limestone. The sand bodies within this unit are 1–10 m (3.3–32.8 ft) thick. The mudstones and sandstones grade laterally and vertically with each other and with the subjacent and adjacent sandstone-dominated portions of the Regina, Llaves, and Tapicitos Members of the San Jose Formation. Overlies the Cuba Mesa Member of the San Jose Formation.

Sandstone-dominated portions: Reddish-yellow, light-red, very pale-brown, yellow, and brownish-yellow; cross-bedded; medium- to very coarse-grained; moderately sorted; subangular sandstone and conglomerate with lesser reddish-brown, yellowish-brown, pale-olive, and gray mudstone. Primarily forms cliffs. The sandstones are poorly to well-consolidated, medium- to coarse-grained, subangular to angular, thin- to thick-bedded, cross-bedded and plane-bedded feldspathic arenites and feldspathic wackes with trace conglomerate lenses. The conglomerates contain subangular to subrounded pebbles of crystalline igneous and metamorphic rocks with subordinate chert, quartzite, and limestone. Individual sand bodies are 2–30 m (6.6–98.4 ft)thick but are amalgamated into thicker sand bodies. The mudstones and sandstones grade laterally and vertically with each other and with the subjacent and adjacent map unit (mudstone-dominated portions of the Regina, Llaves, and Tapicitos Members of the San Jose Formation). Defined here as a lithostratigraphic unit with varying ages. Overlies the Cuba Mesa Member of the San Jose Formation.

Pesjc Cuba Mesa Member of the San Jose Formation (Eocene)—White to yellow, rusty-weathering sandstone, pebbly sandstone, and trace conglomerate with lenses of light-gray to reddish-gray mudstone and silty mudstone. Sandstones are medium- to very coarse-grained, moderately sorted, angular to very angular feldspathic arenites. The sand composition is 40–55% quartz, 45–55% feldspar, and 5–15% lithics. Pebbles include phaneritic igneous rocks, quartzite, gneissic rocks, chert, and trace limestone. Sandstone bedforms include tabular cross-beds, horizontal-plane beds, scour-and-fill structures, contorted beds, and massive beds. Molds of trees are common throughout, especially in the bases of sandstone beds that overlie mudstones. The sandstones form prominent and continuous cliffs. The mudstones are lens-shaped, slope-forming, discontinuous over kilometers, and may grade into sandstones over meters. The unit contains vertebrate fossils from the Wasatchian North American Stage (50.3–55.4 Ma). The contact with the underlying Nacimiento Formation is disconformable to slightly angular unconformable. There is a conformable and/or intertounguing contact with the overlying member of the San Jose Formation. The total thickness is 210 m (689 ft) in the southwestern corner of the map area; only the upper 60 m (196 ft) are exposed in limited outcrops in Tapicito Creek and Cañada Larga at the western boundary of the map.

Pene Escavada Member of the Nacimiento Formation (Paleocene)—White to gray sandstone and mudstone. Sandstones are very fine- to medium-grained, poorly to moderately sorted, angular to subrounded (primarily subangular), feldspathic arenites and feldspathic wackes. Sandstone beds are rarely visible; those observed are thin to medium horizontal-plane beds and tabular cross-beds. Mudstones include silty claystone, clayey siltstone, and clayey sandy siltstone. Bedding is difficult to observe in Escavada Member mudstones. The contact with the overlying San Jose Formation is disconformable; a slight (2–5°) angular unconformity exists atop the Escavada Member just south of the map area. The lower contact does not exist within the map area. The total thickness is up to 90 m (295 ft), but only the upper 20 m (66 ft) are exposed in the far southwestern corner of the map area.

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APPENDIX A.

Beta Analytic, Inc.
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ISO/IEC 17025:2017-Accredited Testing Laboratory

January 11, 2022

Dr. Kevin Hobbs
New Mexico Bureau of Geology
801 Leroy Place
Socorro, NM 87801
United States

RE: Radiocarbon Dating Results

Dear Dr. Hobbs,

Enclosed are the radiocarbon dating results for nine samples recently sent to us. As usual, the method of analysis is listed on the report with the results and calibration data is provided where applicable. The Conventional Radiocarbon Ages have all been corrected for total fractionation effects and where applicable, calibration was performed using 2020 calibration databases (cited on the graph pages).

The web directory containing the table of results and PDF download also contains pictures, a cvs spreadsheet download option and a quality assurance report containing expected vs. measured values for 3-5 working standards analyzed simultaneously with your samples.

Reported results are accredited to ISO/IEC 17025:2017 Testing Accreditation PJLA #59423 standards and all chemistry was performed here in our laboratory and counted in our own accelerators here. Since Beta is not a teaching laboratory, only graduates trained to strict protocols of the ISO/IEC 17025:2017 Testing Accreditation PJLA #59423 program participated in the analyses.

As always Conventional Radiocarbon Ages and sigmas are rounded to the nearest 10 years per the conventions of the 1977 International Radiocarbon Conference. When counting statistics produce sigmas lower than +/- 30 years, a conservative +/- 30 BP is cited for the result unless otherwise requested. The reported d13C values were measured separately in an IRMS (isotope ratio mass spectrometer). They are NOT the AMS d13C which would include fractionation effects from natural, chemistry and AMS induced sources.

When interpreting the results, please consider any communications you may have had with us regarding the samples.

Our invoice has been sent separately. Thank you for your prior efforts in arranging payment. As always, if you have any questions or would like to discuss the results, don't hesitate to contact us.

Sincerely,

Chris Patrick

Digital signature on file

Chris Patrick
Vice President of Laboratory Operations

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ISO/IEC 17025:2017-Accredited Testing Laboratory

REPORT OF RADIOCARBON DATING ANALYSES

Kevin Hobbs	Report Date: January 11, 2022
New Mexico Bureau of Geology	Material Received: December 16, 2021

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes	
Beta - 613539	**JANC-08**	**500 +/- 30 BP**	IRMS δ13C: -23.5 o/oo

(95.4%) **1399 - 1450 cal AD** **(551 - 500 cal BP)**

Submitter Material:	Charcoal
Pretreatment:	(charred material) acid/alkali/acid
Analyzed Material:	Charred material
Analysis Service:	AMS-Standard delivery
Percent Modern Carbon:	93.97 +/- 0.35 pMC
Fraction Modern Carbon:	0.9397 +/- 0.0035
D14C:	-60.35 +/- 3.51 o/oo
Δ14C:	-68.49 +/- 3.51 o/oo (1950:2022)
Measured Radiocarbon Age:	(without d13C correction): 480 +/- 30 BP
Calibration:	BetaCal4.20: HPD method: INTCAL20

Results are ISO/IEC-17025:2017 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB. References for calendar calibrations are cited at the bottom of calibration graph pages.

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REPORT OF RADIOCARBON DATING ANALYSES

Kevin Hobbs | Report Date: January 11, 2022

New Mexico Bureau of Geology | Material Received: December 16, 2021

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes	
Beta - 613540	**JAN21-07**	**1480 +/- 30 BP**	IRMS δ13C: -20.0 o/oo

(95.4%) **550 - 644 cal AD** **(1400 - 1306 cal BP)**

Submitter Material: Charcoal
Pretreatment: (charred material) acid/alkali/acid
Analyzed Material: Charred material
Analysis Service: AMS-Standard delivery
Percent Modern Carbon: 83.17 +/- 0.31 pMC
Fraction Modern Carbon: 0.8317 +/- 0.0031
D14C: -168.27 +/- 3.11 o/oo
Δ14C: -175.48 +/- 3.11 o/oo (1950:2022)
Measured Radiocarbon Age: (without d13C correction): 1400 +/- 30 BP
Calibration: BetaCal4.20: HPD method: INTCAL20

Results are ISO/IEC-17025:2017 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB. References for calendar calibrations are cited at the bottom of calibration graph pages.

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REPORT OF RADIOCARBON DATING ANALYSES

Kevin Hobbs
New Mexico Bureau of Geology

Report Date: January 11, 2022
Material Received: December 16, 2021

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes	
Beta - 613541	**JANC-09**	**560 +/- 30 BP**	IRMS δ13C: -23.5 o/oo

(48.5%)	**1312 - 1362 cal AD**	**(638 - 588 cal BP)**
(46.9%)	**1386 - 1428 cal AD**	**(564 - 522 cal BP)**

Submitter Material: Charcoal
Pretreatment: (charred material) acid/alkali/acid
Analyzed Material: Charred material
Analysis Service: AMS-Standard delivery
Percent Modern Carbon: 93.27 +/- 0.35 pMC
Fraction Modern Carbon: 0.9327 +/- 0.0035
D14C: -67.34 +/- 3.48 o/oo
Δ14C: -75.43 +/- 3.48 o/oo (1950:2022)
Measured Radiocarbon Age: (without d13C correction): 530 +/- 30 BP
Calibration: BetaCal4.20: HPD method: INTCAL20

Results are ISO/IEC-17025:2017 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB. References for calendar calibrations are cited at the bottom of calibration graph pages.

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REPORT OF RADIOCARBON DATING ANALYSES

Kevin Hobbs
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Report Date: January 11, 2022
Material Received: December 16, 2021

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes	
Beta - 613542	**JAN21-01**	**3700 +/- 30 BP**	IRMS δ13C: -24.9 o/oo

(82.1%)	**2150 - 2019 cal BC**	**(4099 - 3968 cal BP)**
(9.7%)	**2199 - 2166 cal BC**	**(4148 - 4115 cal BP)**
(3.6%)	**1996 - 1980 cal BC**	**(3945 - 3929 cal BP)**

Submitter Material: Charcoal
Pretreatment: (charred material) acid/alkali/acid
Analyzed Material: Charred material
Analysis Service: AMS-Standard delivery
Percent Modern Carbon: 63.09 +/- 0.24 pMC
Fraction Modern Carbon: 0.6309 +/- 0.0024
D14C: -369.10 +/- 2.36 o/oo
Δ14C: -374.57 +/- 2.36 o/oo (1950:2022)
Measured Radiocarbon Age: (without d13C correction): 3700 +/- 30 BP
Calibration: BetaCal4.20: HPD method: INTCAL20

Results are ISO/IEC-17025:2017 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB. References for calendar calibrations are cited at the bottom of calibration graph pages.

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REPORT OF RADIOCARBON DATING ANALYSES

Kevin Hobbs — Report Date: January 11, 2022

New Mexico Bureau of Geology — Material Received: December 16, 2021

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes	
Beta - 613543	**JAN21-03**	**950 +/- 30 BP**	IRMS δ13C: -23.8 o/oo

(95.4%) **1028 - 1162 cal AD** **(922 - 788 cal BP)**

Submitter Material:	Charcoal
Pretreatment:	(charred material) acid/alkali/acid
Analyzed Material:	Charred material
Analysis Service:	AMS-Standard delivery
Percent Modern Carbon:	88.85 +/- 0.33 pMC
Fraction Modern Carbon:	0.8885 +/- 0.0033
D14C:	-111.54 +/- 3.32 o/oo
Δ14C:	-119.24 +/- 3.32 o/oo (1950:2022)
Measured Radiocarbon Age:	(without d13C correction): 930 +/- 30 BP
Calibration:	BetaCal4.20: HPD method: INTCAL20

Results are ISO/IEC-17025:2017 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB. References for calendar calibrations are cited at the bottom of calibration graph pages.

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REPORT OF RADIOCARBON DATING ANALYSES

Kevin Hobbs

New Mexico Bureau of Geology

Report Date: January 11, 2022

Material Received: December 16, 2021

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes	
Beta - 613544	**JAN21-05**	**5810 +/- 30 BP**	IRMS δ13C: -22.3 o/oo

(93.3%)	**4726 - 4549 cal BC**	**(6675 - 6498 cal BP)**
(2.1%)	**4775 - 4760 cal BC**	**(6724 - 6709 cal BP)**

Submitter Material: Charcoal
Pretreatment: (charred material) acid/alkali/acid
Analyzed Material: Charred material
Analysis Service: AMS-Standard delivery
Percent Modern Carbon: 48.52 +/- 0.18 pMC
Fraction Modern Carbon: 0.4852 +/- 0.0018
D14C: -514.84 +/- 1.81 o/oo
Δ14C: -519.05 +/- 1.81 o/oo (1950:2022)
Measured Radiocarbon Age: (without d13C correction): 5770 +/- 30 BP
Calibration: BetaCal4.20: HPD method: INTCAL20

Results are ISO/IEC-17025:2017 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB. References for calendar calibrations are cited at the bottom of calibration graph pages.

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Beta Analytic TESTING LABORATORY

ISO/IEC 17025:2017-Accredited Testing Laboratory

REPORT OF RADIOCARBON DATING ANALYSES

Kevin Hobbs

New Mexico Bureau of Geology

Report Date: January 11, 2022

Material Received: December 16, 2021

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes	
Beta - 613545	**JAN21-02**	**820 +/- 30 BP**	IRMS δ13C: -23.3 o/oo

(95.4%) **1175 - 1273 cal AD** **(775 - 677 cal BP)**

Submitter Material: Charcoal
Pretreatment: (charred material) acid/alkali/acid
Analyzed Material: Charred material
Analysis Service: AMS-Standard delivery
Percent Modern Carbon: 90.30 +/- 0.34 pMC
Fraction Modern Carbon: 0.9030 +/- 0.0034
D14C: -97.04 +/- 3.37 o/oo
Δ14C: -104.87 +/- 3.37 o/oo (1950:2022)
Measured Radiocarbon Age: (without d13C correction): 790 +/- 30 BP
Calibration: BetaCal4.20: HPD method: INTCAL20

Results are ISO/IEC-17025:2017 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB. References for calendar calibrations are cited at the bottom of calibration graph pages.

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REPORT OF RADIOCARBON DATING ANALYSES

Kevin Hobbs	Report Date: January 11, 2022
New Mexico Bureau of Geology	Material Received: December 16, 2021

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes	
Beta - 613546	**JANC-11**	**1560 +/- 30 BP**	IRMS δ13C: -20.7 o/oo

(95.4%) **425 - 575 cal AD** **(1525 - 1375 cal BP)**

Submitter Material: Charcoal
Pretreatment: (charred material) acid/alkali/acid
Analyzed Material: Charred material
Analysis Service: AMS-Standard delivery
Percent Modern Carbon: 82.35 +/- 0.31 pMC
Fraction Modern Carbon: 0.8235 +/- 0.0031
D14C: -176.51 +/- 3.08 o/oo
Δ14C: -183.65 +/- 3.08 o/oo (1950:2022)
Measured Radiocarbon Age: (without d13C correction): 1490 +/- 30 BP
Calibration: BetaCal4.20: HPD method: INTCAL20

Results are ISO/IEC-17025:2017 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB. References for calendar calibrations are cited at the bottom of calibration graph pages.

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REPORT OF RADIOCARBON DATING ANALYSES

Kevin Hobbs	Report Date: January 11, 2022
New Mexico Bureau of Geology	Material Received: December 16, 2021

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes	
Beta - 613547	**JAN21-04**	**1380 +/- 30 BP**	IRMS δ13C: -22.4 o/oo

(93.4%)	**602 - 678 cal AD**	**(1348 - 1272 cal BP)**
(2.0%)	**750 - 758 cal AD**	**(1200 - 1192 cal BP)**

Submitter Material: Charcoal
Pretreatment: (charred material) acid/alkali/acid
Analyzed Material: Charred material
Analysis Service: AMS-Standard delivery
Percent Modern Carbon: 84.22 +/- 0.31 pMC
Fraction Modern Carbon: 0.8422 +/- 0.0031
D14C: -157.85 +/- 3.15 o/oo
Δ14C: -165.15 +/- 3.15 o/oo (1950:2022)
Measured Radiocarbon Age: (without d13C correction): 1340 +/- 30 BP
Calibration: BetaCal4.20: HPD method: INTCAL20

Results are ISO/IEC-17025:2017 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB. References for calendar calibrations are cited at the bottom of calibration graph pages.

Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL20)

(Variables: d13C = -23.5 o/oo)

Laboratory number **Beta-613539**

Conventional radiocarbon age **500 ± 30 BP**

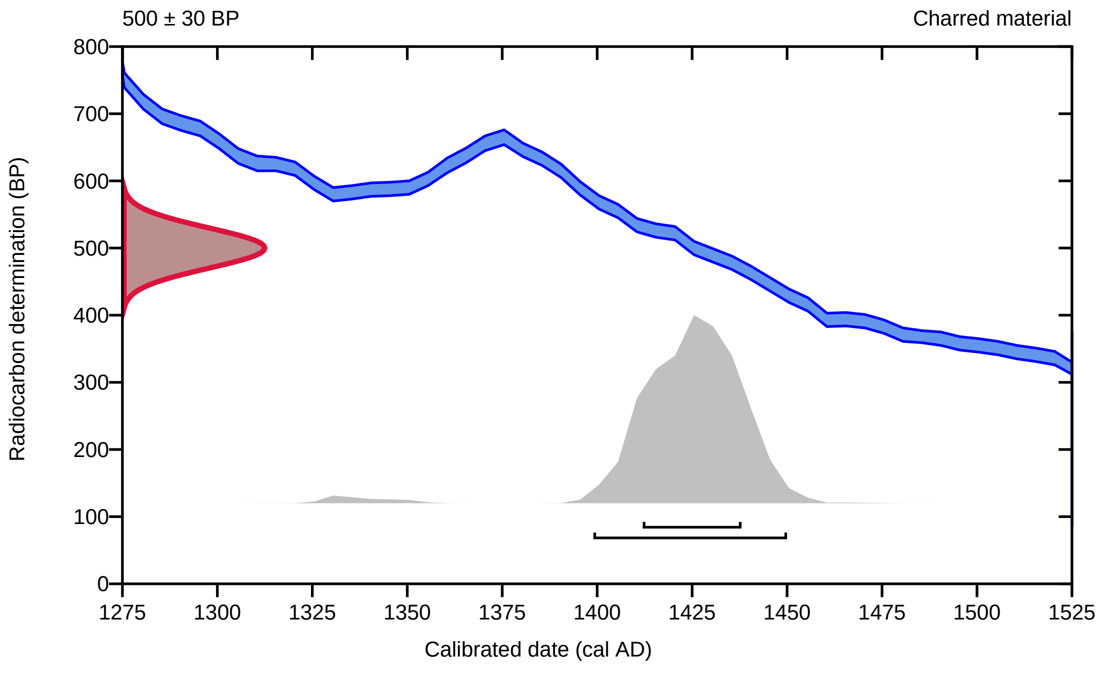
95.4% probability

(95.4%) 1399 - 1450 cal AD (551 - 500 cal BP)

68.2% probability

(68.2%) 1412 - 1438 cal AD (538 - 512 cal BP)

JANC-08



Database used

INTCAL20

References

References to Probability Method

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

References to Database INTCAL20

Reimer, et al., 2020, Radiocarbon 62(4):725-757.

Beta Analytic Radiocarbon Dating Laboratory

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Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL20)

(Variables: d13C = -20.0 o/oo)

Laboratory number **Beta-613540**

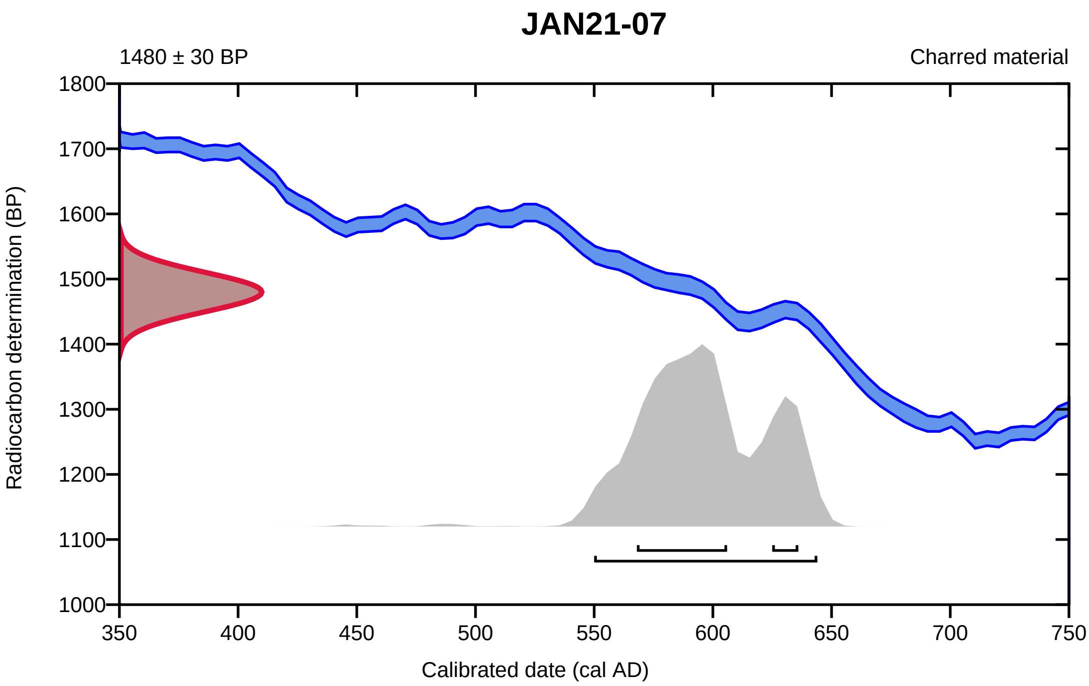
Conventional radiocarbon age **1480 ± 30 BP**

95.4% probability

(95.4%)	550 - 644 cal AD	(1400 - 1306 cal BP)

68.2% probability

(55.8%)	568 - 606 cal AD	(1382 - 1344 cal BP)
(12.4%)	625 - 636 cal AD	(1325 - 1314 cal BP)



Database used

INTCAL20

References

References to Probability Method

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

References to Database INTCAL20

Reimer, et al., 2020, Radiocarbon 62(4):725-757.

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Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL20)

(Variables: d13C = -23.5 o/oo)

Laboratory number **Beta-613541**

Conventional radiocarbon age **560 ± 30 BP**

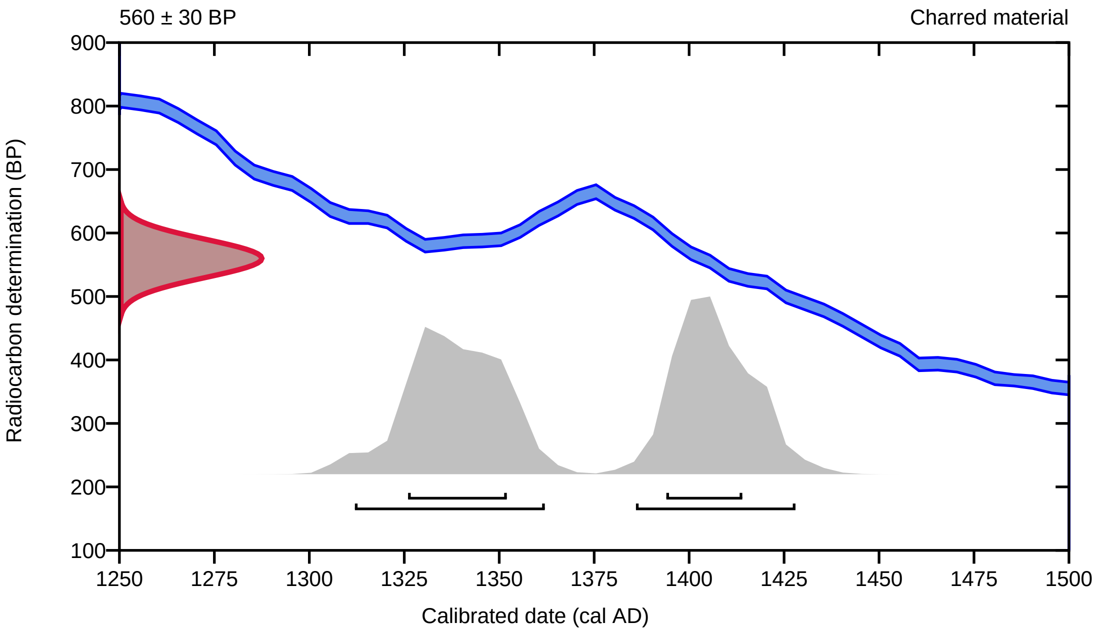
95.4% probability

(48.5%)	1312 - 1362 cal AD	(638 - 588 cal BP)
(46.9%)	1386 - 1428 cal AD	(564 - 522 cal BP)

68.2% probability

(35.4%)	1326 - 1352 cal AD	(624 - 598 cal BP)
(32.8%)	1394 - 1414 cal AD	(556 - 536 cal BP)

JANC-09



Database used
INTCAL20

References
References to Probability Method
Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.
References to Database INTCAL20
Reimer, et al., 2020, Radiocarbon 62(4):725-757.

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BetaCal 4.20

Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL20)

(Variables: d13C = -24.9 o/oo)

Laboratory number **Beta-613542**

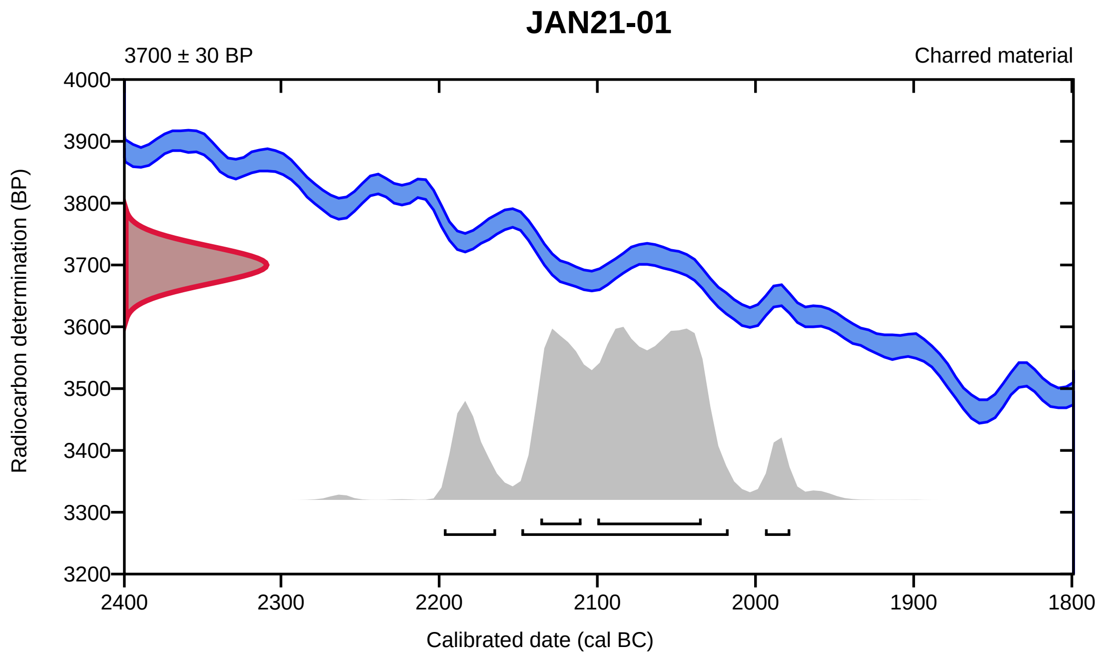
Conventional radiocarbon age **3700 ± 30 BP**

95.4% probability

(82.1%)	2150 - 2019 cal BC	(4099 - 3968 cal BP)
(9.7%)	2199 - 2166 cal BC	(4148 - 4115 cal BP)
(3.6%)	1996 - 1980 cal BC	(3945 - 3929 cal BP)

68.2% probability

(49.3%)	2102 - 2036 cal BC	(4051 - 3985 cal BP)
(18.9%)	2138 - 2112 cal BC	(4087 - 4061 cal BP)



Database used

INTCAL20

References

References to Probability Method

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

References to Database INTCAL20

Reimer, et al., 2020, Radiocarbon 62(4):725-757.

Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL20)

(Variables: d13C = -23.8 o/oo)

Laboratory number **Beta-613543**

Conventional radiocarbon age **950 ± 30 BP**

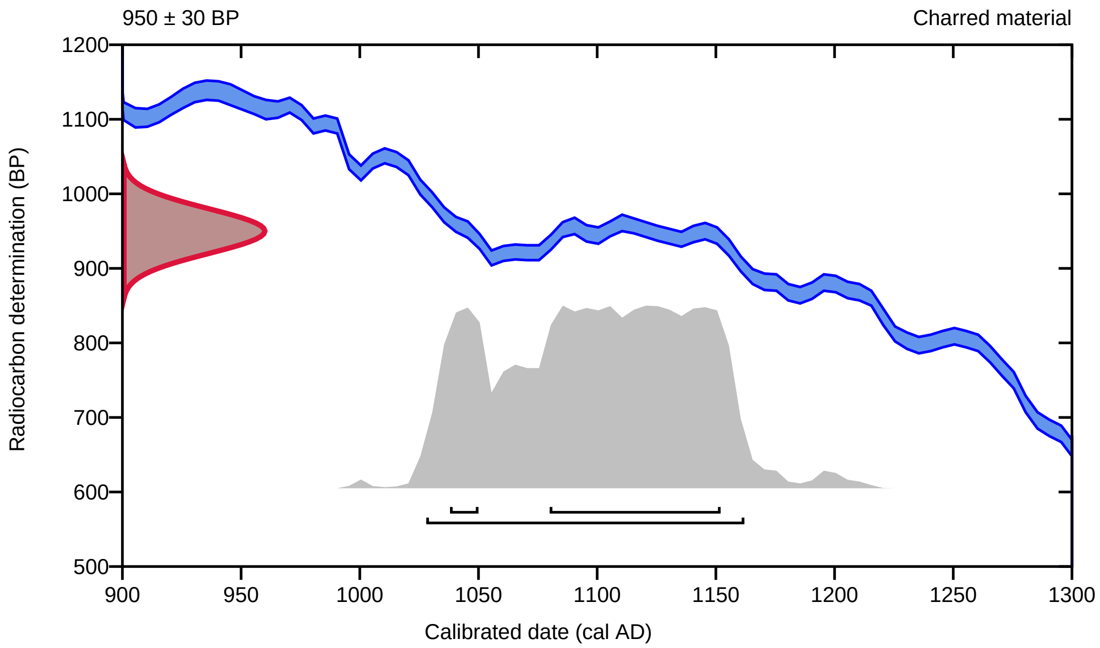
95.4% probability

(95.4%)	1028 - 1162 cal AD	(922 - 788 cal BP)

68.2% probability

(58.9%)	1080 - 1152 cal AD	(870 - 798 cal BP)
(9.3%)	1038 - 1050 cal AD	(912 - 900 cal BP)

JAN21-03



Database used

INTCAL20

References

References to Probability Method

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

References to Database INTCAL20

Reimer, et al., 2020, Radiocarbon 62(4):725-757.

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BetaCal 4.20

Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL20)

(Variables: d13C = -22.3 o/oo)

Laboratory number **Beta-613544**

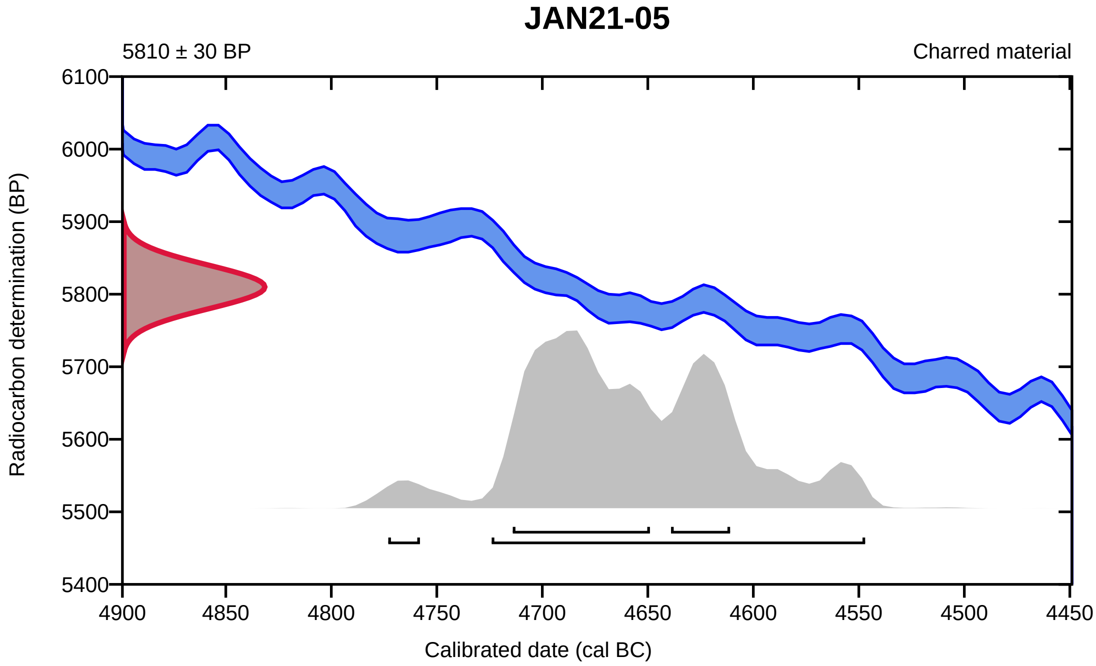
Conventional radiocarbon age **5810 ± 30 BP**

95.4% probability

(93.3%)	4726 - 4549 cal BC	(6675 - 6498 cal BP)
(2.1%)	4775 - 4760 cal BC	(6724 - 6709 cal BP)

68.2% probability

(48.7%)	4716 - 4651 cal BC	(6665 - 6600 cal BP)
(19.5%)	4641 - 4613 cal BC	(6590 - 6562 cal BP)



Database used

INTCAL20

References

References to Probability Method

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

References to Database INTCAL20

Reimer, et al., 2020, Radiocarbon 62(4):725-757.

BetaCal 4.20

Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL20)

(Variables: d13C = -23.3 o/oo)

Laboratory number **Beta-613545**

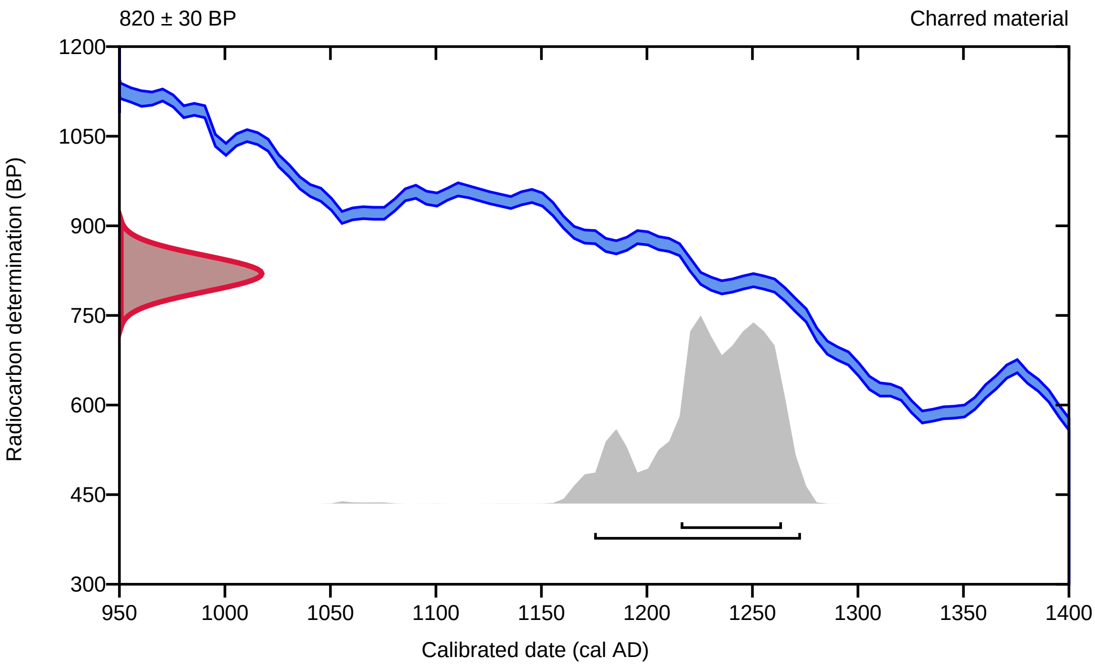
Conventional radiocarbon age **820 ± 30 BP**

95.4% probability

(95.4%) 1175 - 1273 cal AD (775 - 677 cal BP)

68.2% probability

(68.2%) 1216 - 1264 cal AD (734 - 686 cal BP)



Database used

INTCAL20

References

References to Probability Method

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

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BetaCal 4.20

Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL20)

(Variables: d13C = -20.7 o/oo)

Laboratory number **Beta-613546**

Conventional radiocarbon age **1560 ± 30 BP**

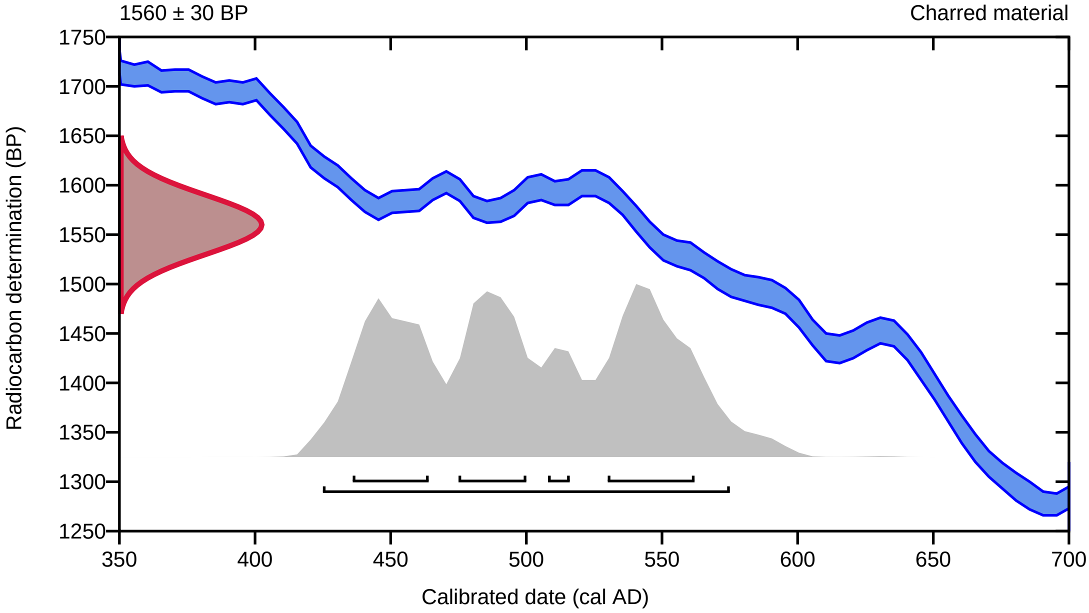
95.4% probability

(95.4%)	425 - 575 cal AD	(1525 - 1375 cal BP)

68.2% probability

(23.4%)	530 - 562 cal AD	(1420 - 1388 cal BP)
(20.8%)	436 - 464 cal AD	(1514 - 1486 cal BP)
(19.2%)	475 - 500 cal AD	(1475 - 1450 cal BP)
(4.8%)	508 - 516 cal AD	(1442 - 1434 cal BP)

JANC-11



Database used
INTCAL20

References
References to Probability Method

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

References to Database INTCAL20

Reimer, et al., 2020, Radiocarbon 62(4):725-757.

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Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL20)

(Variables: d13C = -22.4 o/oo)

Laboratory number **Beta-613547**

Conventional radiocarbon age **1380 ± 30 BP**

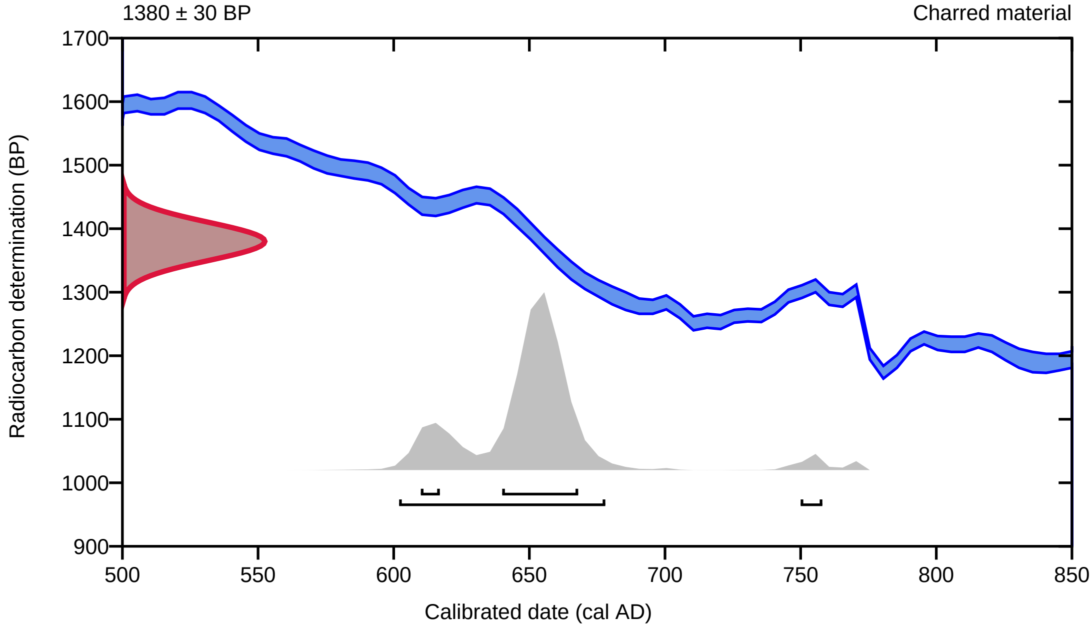
95.4% probability

(93.4%)	602 - 678 cal AD	(1348 - 1272 cal BP)
(2%)	750 - 758 cal AD	(1200 - 1192 cal BP)

68.2% probability

(62.6%)	640 - 668 cal AD	(1310 - 1282 cal BP)
(5.6%)	610 - 617 cal AD	(1340 - 1333 cal BP)

JAN21-04



Database used

INTCAL20

References

References to Probability Method

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

References to Database INTCAL20

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ISO/IEC 17025:2017-Accredited Testing Laboratory

April 12, 2021

Dr. Kevin Hobbs
New Mexico Bureau of Geology
801 Leroy Place
Socorro, NM 87801
United States

RE: Radiocarbon Dating Results

Dear Dr. Hobbs,

Enclosed are the radiocarbon dating results for five samples recently sent to us. As usual, the method of analysis is listed on the report with the results and calibration data is provided where applicable. The Conventional Radiocarbon Ages have all been corrected for total fractionation effects and where applicable, calibration was performed using 2020 calibration databases (cited on the graph pages).

The web directory containing the table of results and PDF download also contains pictures, a cvs spreadsheet download option and a quality assurance report containing expected vs. measured values for 3-5 working standards analyzed simultaneously with your samples.

Reported results are accredited to ISO/IEC 17025:2017 Testing Accreditation PJLA #59423 standards and all chemistry was performed here in our laboratory and counted in our own accelerators here. Since Beta is not a teaching laboratory, only graduates trained to strict protocols of the ISO/IEC 17025:2017 Testing Accreditation PJLA #59423 program participated in the analyses.

As always Conventional Radiocarbon Ages and sigmas are rounded to the nearest 10 years per the conventions of the 1977 International Radiocarbon Conference. When counting statistics produce sigmas lower than +/- 30 years, a conservative +/- 30 BP is cited for the result unless otherwise requested. The reported d13C values were measured separately in an IRMS (isotope ratio mass spectrometer). They are NOT the AMS d13C which would include fractionation effects from natural, chemistry and AMS induced sources.

When interpreting the results, please consider any communications you may have had with us regarding the samples.

The cost of analysis was previously invoiced. As always, if you have any questions or would like to discuss the results, don't hesitate to contact us.

Sincerely,

Chris Patrick

Digital signature on file

Chris Patrick
Vice President of Laboratory Operations

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REPORT OF RADIOCARBON DATING ANALYSES

Kevin Hobbs
New Mexico Bureau of Geology

Report Date: April 12, 2021
Material Received: March 26, 2021

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes	
Beta - 587936	**JANC-01**	**8000 +/- 50 BP**	IRMS δ13C: NA

(91.5%)	**7060 - 6746 cal BC**	**(9009 - 8695 cal BP)**
(3.9%)	**6725 - 6699 cal BC**	**(8674 - 8648 cal BP)**

Submitter Material: Charcoal
Pretreatment: (charred material) acid/alkali/acid
Analyzed Material: Charred material
Analysis Service: AMS-Micro-sample Analysis; Standard delivery
Percent Modern Carbon: 36.94 +/- 0.23 pMC
Fraction Modern Carbon: 0.3694 +/-
D14C: -630.61 +/- 2.30 o/oo
∆14C: -633.77 +/- 2.30 o/oo (1950:2021)
Measured Radiocarbon Age: (without d13C correction): NA
Calibration: BetaCal4.20: HPD method: INTCAL20

Results are ISO/IEC-17025:2017 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB-1. References for calendar calibrations are cited at the bottom of calibration graph pages.

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ISO/IEC 17025:2017-Accredited Testing Laboratory

REPORT OF RADIOCARBON DATING ANALYSES

Kevin Hobbs — Report Date: April 12, 2021

New Mexico Bureau of Geology — Material Received: March 26, 2021

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes	
Beta - 587937	**JANC-02**	**2030 +/- 30 BP**	IRMS δ13C: -20.2 o/oo

(94.8%)	**107 cal BC - 68 cal AD**	**(2056 - 1882 cal BP)**
(0.6%)	**147 - 140 cal BC**	**(2096 - 2089 cal BP)**

Submitter Material:	Charcoal
Pretreatment:	(charred material) acid/alkali/acid
Analyzed Material:	Charred material
Analysis Service:	AMS-Standard delivery
Percent Modern Carbon:	77.67 +/- 0.29 pMC
Fraction Modern Carbon:	0.7767 +/- 0.0029
D14C:	-223.31 +/- 2.90 o/oo
Δ14C:	-229.95 +/- 2.90 o/oo (1950:2021)
Measured Radiocarbon Age:	(without d13C correction): 1950 +/- 30 BP
Calibration:	BetaCal4.20: HPD method: INTCAL20

Results are ISO/IEC-17025:2017 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB-1. References for calendar calibrations are cited at the bottom of calibration graph pages.

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ISO/IEC 17025:2017-Accredited Testing Laboratory

REPORT OF RADIOCARBON DATING ANALYSES

Kevin Hobbs — Report Date: April 12, 2021

New Mexico Bureau of Geology — Material Received: March 26, 2021

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes	
Beta - 587938	**JANC-03**	**4720 +/- 30 BP**	IRMS δ13C: -23.0 o/oo

(45.1%)	**3462 - 3375 cal BC**	**(5411 - 5324 cal BP)**
(27.2%)	**3628 - 3558 cal BC**	**(5577 - 5507 cal BP)**
(23.0%)	**3536 - 3492 cal BC**	**(5485 - 5441 cal BP)**

Submitter Material: Charcoal
Pretreatment: (charred material) acid/alkali/acid
Analyzed Material: Charred material
Analysis Service: AMS-Standard delivery
Percent Modern Carbon: 55.57 +/- 0.21 pMC
Fraction Modern Carbon: 0.5557 +/- 0.0021
D14C: -444.33 +/- 2.08 o/oo
Δ14C: -449.08 +/- 2.08 o/oo (1950:2021)
Measured Radiocarbon Age: (without d13C correction): 4690 +/- 30 BP
Calibration: BetaCal4.20: HPD method: INTCAL20

Results are ISO/IEC-17025:2017 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the 14C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. d13C values are on the material itself (not the AMS d13C). d13C and d15N values are relative to VPDB-1. References for calendar calibrations are cited at the bottom of calibration graph pages.

Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL20)

(Variables: d13C = N/A)

Laboratory number **Beta-587936**

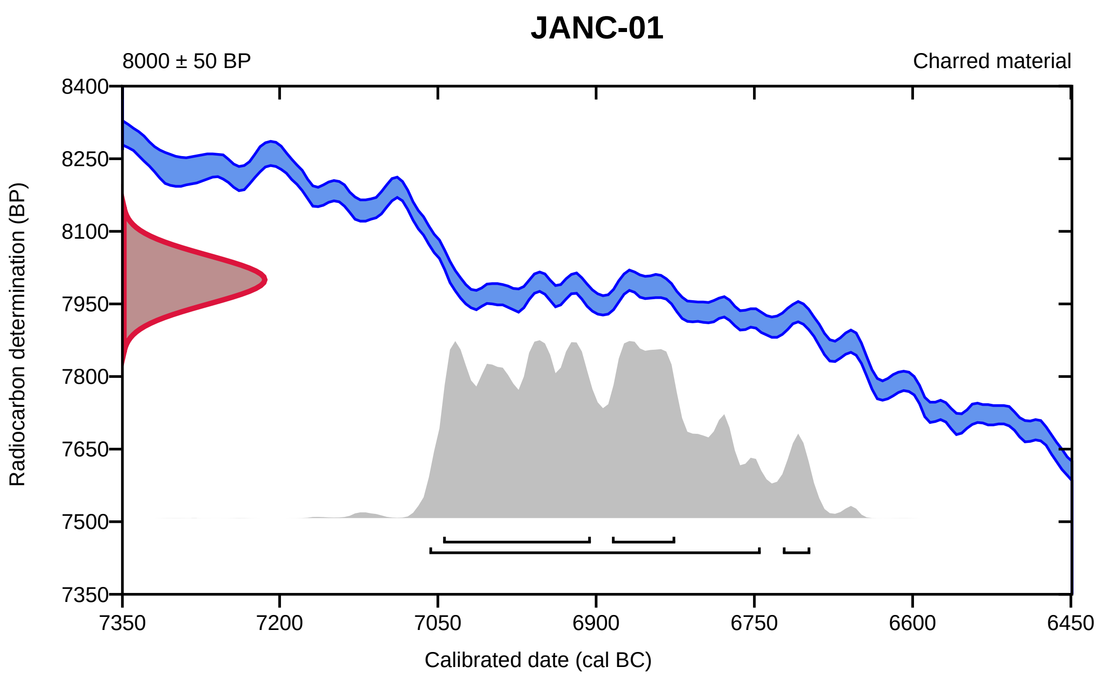
Conventional radiocarbon age **8000 ± 50 BP**

95.4% probability

(91.5%)	7060 - 6746 cal BC	(9009 - 8695 cal BP)
(3.9%)	6725 - 6699 cal BC	(8674 - 8648 cal BP)

68.2% probability

(46.7%)	7047 - 6907 cal BC	(8996 - 8856 cal BP)
(21.5%)	6887 - 6827 cal BC	(8836 - 8776 cal BP)



Database used

INTCAL20

References

References to Probability Method

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

References to Database INTCAL20

Reimer, et al., 2020, Radiocarbon 62(4):725-757.

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Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL20)

(Variables: d13C = -20.2 o/oo)

Laboratory number **Beta-587937**

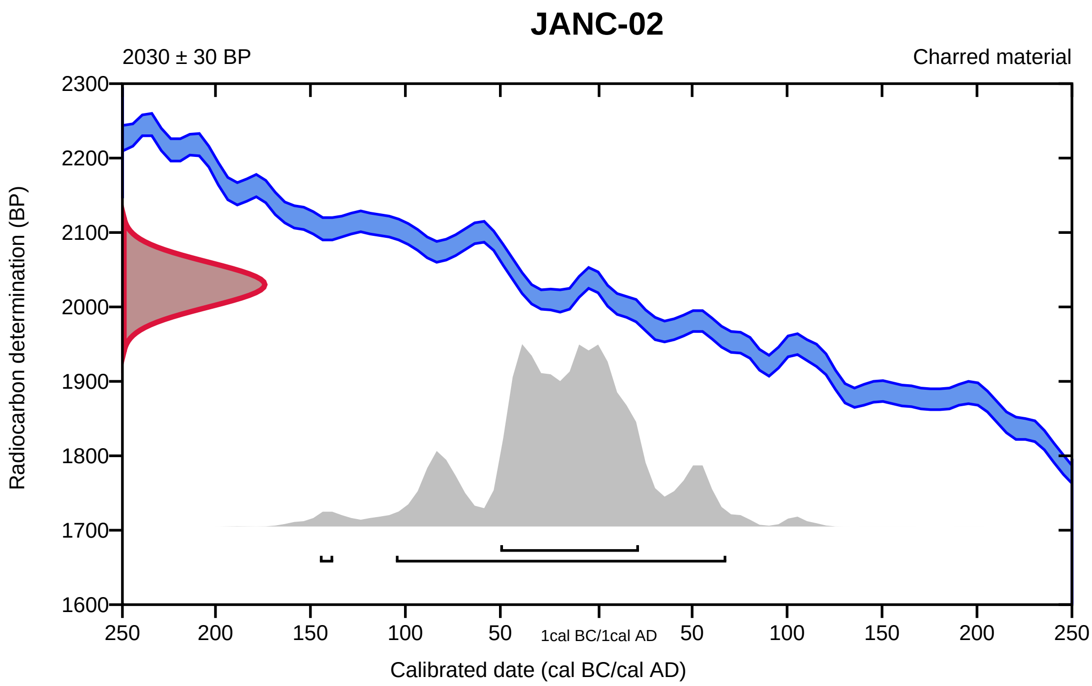
Conventional radiocarbon age **2030 ± 30 BP**

95.4% probability

(94.8%)	107 cal BC - 68 cal AD	(2056 - 1882 cal BP)
(0.6%)	147 - 140 cal BC	(2096 - 2089 cal BP)

68.2% probability

(68.2%)	52 cal BC - 22 cal AD	(2001 - 1928 cal BP)



Database used

INTCAL20

References

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Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. Radiocarbon, 51(1), 337-360.

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Calibration of Radiocarbon Age to Calendar Years

(High Probability Density Range Method (HPD): INTCAL20)

(Variables: d13C = -23.0 o/oo)

Laboratory number **Beta-587938**

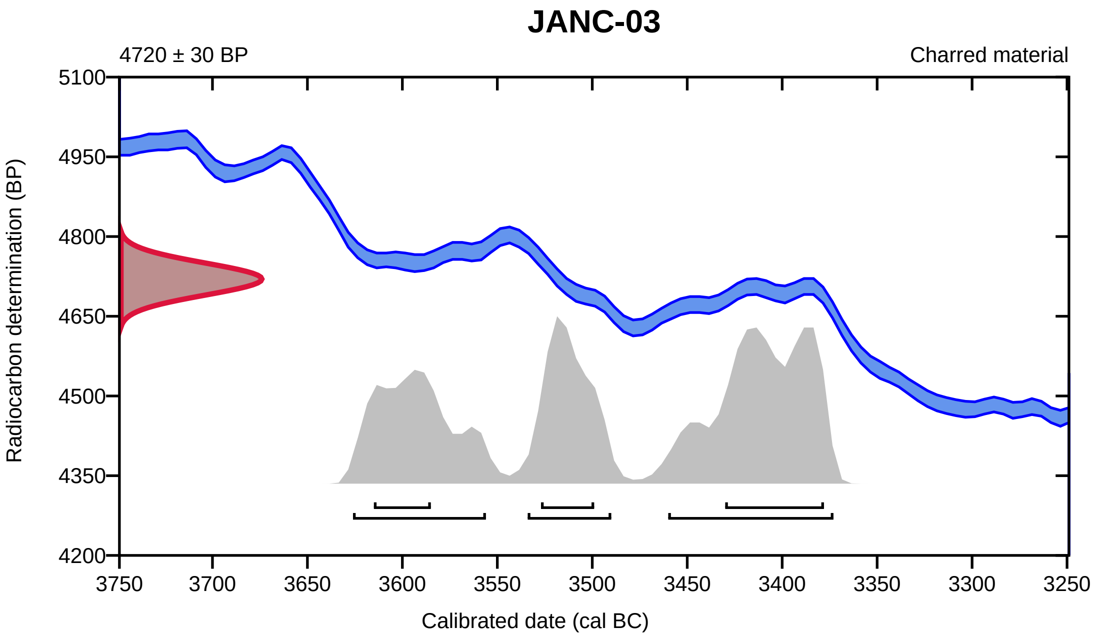
Conventional radiocarbon age **4720 ± 30 BP**

95.4% probability

(45.1%)	3462 - 3375 cal BC	(5411 - 5324 cal BP)
(27.2%)	3628 - 3558 cal BC	(5577 - 5507 cal BP)
(23%)	3536 - 3492 cal BC	(5485 - 5441 cal BP)

68.2% probability

(35.5%)	3432 - 3380 cal BC	(5381 - 5329 cal BP)
(18.5%)	3529 - 3501 cal BC	(5478 - 5450 cal BP)
(14.2%)	3617 - 3587 cal BC	(5566 - 5536 cal BP)



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