ROCKS AND ANCIENT PEOPLE IN SOUTHEASTERN NEW MEXICO

BY

BRADLEY J. VIERRA, KATE E. ZEIGLER, AND JOHN V. CAFIERO

STATISTICAL RESEARCH, INC.
AND
NEW MEXICO BUREAU OF LAND MANAGEMENT
CARLSBAD FIELD OFFICE

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Bradley J. Vierra, Kate Zeigler, and John V. Cafiero

Statistical Research, Inc.
Albuquerque, New Mexico
and

New Mexico Bureau of Land Management
Carlsbad Field Office

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Introduction and Geological Background

The immensity and stark beauty of the Pecos River valley in southeastern New Mexico has long been a source of wonder for travelers to the area. Throughout this landscape, there is a staggering variety of rock types—some dramatically exposed as outcrops and others swept into the area by the Pecos River and its tributaries. An example of the dramatic landforms that characterize the area is the Llano Estacado, or "Stockaded Plains." At approximately 32,000 square miles—an area greater than all of New England—the Llano Estacado is one of the largest mesas on the continent. The Llano Estacado stops abruptly west of the New Mexico state line at a long, steep slope formed of **caliche** caprock, the Caprock Escarpment. (*Note:* words in boldface are defined in the glossary.) This slope extends for miles from north to south, breaking the uniformity of the plains. A series of **terraces** and sand dunes to the west leads down into the Pecos River valley; this landscape varies markedly from the high-desert scenery of the Llano Estacado. On the other side of the river, additional terraces lead to the gently dipping Pecos Slope, the broad eastern flank of the Sacramento Mountains, and ultimately to ever-steeper hills and narrow, rugged canyons of limestone.

Southeastern New Mexico is renowned not only for its remarkable geology but for the long history of human occupation recorded in its vast and varied landscape—a history we are still piecing together. Many questions are still being answered: What rocks did the ancient inhabitants of the region use to make stone tools? Where did they find these materials? What remains at these locations that might help us understand the techniques they used to produce these tools?

Llano Estacado in southeastern New Mexico.

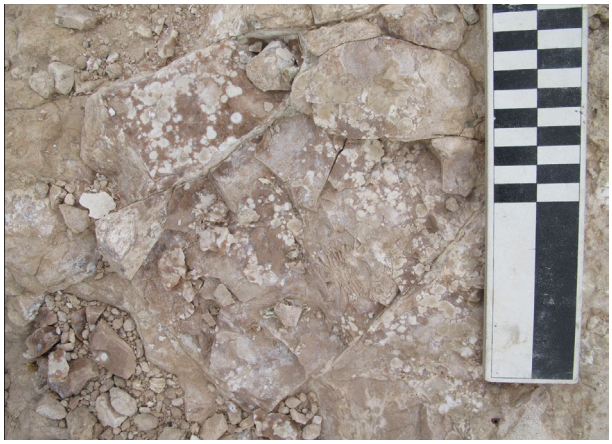
The Llano Estacado viewed from a prehistoric site in the project area.

Piecing Together the Puzzle

To get a clearer picture of how Americans lived prior to the arrival of Europeans, archaeologists must study the traces they left on the environment. Some of the most enduring of these traces are those related to the tools and other products they made out of stone. Referred to broadly by archaeologists as **lithic** technology, these items include **projectile points** (arrowheads), knives, axes, manos and metates, drills, scrapers, hammers, decorative items like pendants, and more. Studying the stone tools and tool fragments people here left behind, we can glean a great deal of information—where stone was quarried; what materials were preferred; where, when, and how it was manufactured and used; how far it traveled; the size of a particular stone-tool industry; if it was traded; and what kinds of materials it was used on. From this information, we can infer much about the lives of the people who lived here, as well as compare different lithic technologies to distinguish different cultural groups. The lifeways of a people can be reflected in the life cycles of their stone tools.

Quartzite hammerstone from the Crow Flats site.

Because rocks are such an essential source of information about the lives of **precontact** people, geology, by extension, is also important to the study of these populations. Understanding the geology of a particular region gives archaeologists an enormously helpful context for the study of stone-tool remains. For example, knowing what the sources of natural rocks (lithic raw material) of different types are in a specific region, we can infer how far each type of rock had to travel to arrive at a given archaeological site. Also, knowing how far below the ground surface bedrock lies, we can infer the likelihood of finding buried artifacts at a given site; areas where bedrock is exposed become likely raw-material sources for tools made from that particular bedrock, and



Silicified sandstone/opalized caliche outcrop that may have been a source of tool stone for prehistoric people in the area.

so on. To get a better understanding of how people used the rock resources in an area—and how that use shaped their lifeways—we need better maps of how those resources are distributed in that area.

The Bureau of Land Management, New Mexico (BLM), is responsible for archaeological sites and other cultural resources across 13.5 million acres of public land. In order to maximize the efficiency of archaeological work conducted in southeastern New Mexico lands under its jurisdiction, the BLM developed a research design to guide such work. This research design emphasizes two research needs in particular: the need to identify where the prehistoric population acquired stone to make tools and the need to better understand what exactly these people did at these locations; combining archaeology with geology, the project described in this book was conceived as a way to begin addressing these needs.

In this booklet, we will explore the ways the geology of this corner of New Mexico can tell us about its original inhabitants. First, we will set the scene with a summary of the geologic history of the region. Next, we will learn more about the types of rocks we are likely to find and how to classify them. Then we will travel to strategically chosen locations to describe the local setting and the types of rocks present now and likely available to precontact inhabitants. These locations are divided into six groups according to the bedrock or landscape feature on which they are located: the San Andres Group, the Artesia Group, the Opalized Caliche Group, the Lower Pecos River Group, the Upper Pecos River Group, and the Isolated Sites Group. In the next section, we'll learn how chipped stone tools are made and what archaeologists can read from stone artifacts. Armed with this knowledge, we'll use the data gathered during our on-the-ground survey to formulate questions and propose answers. We'll also examine the spatial patterns revealed in our survey data—how artifacts were distributed across archaeological sites—to see what they can tell us. Finally, we'll bring it all together and see what conclusions may be drawn.

Although the ancient inhabitants of southeastern New Mexico are long gone, their remains paint a picture of what they did while they occupied the area. It's like putting together the pieces of a puzzle: each bit of information helps us reconstruct a picture of life that was thousands of years in the making—or millions of years, if you consider the ancient geology.

Geological History: How the Landscape Was Made

It's hard to imagine southeastern New Mexico (the area bounded on the west by the Sacramento and Guadalupe Mountains and on the east by the Llano Estacado) as it was during the Early Permian period, 299–270.6 million years ago. At that time, New Mexico was still part of the supercontinent Pangaea, and this region was covered by an ocean. Mountains that formed during that time are now eroded (the Ancestral Rocky Mountains), but some features of the landscape remain.

By the Middle Permian period (270.6–260.4 million years ago) the Delaware Basin of west Texas and southeastern New Mexico had formed and was at its greatest depth. The San Andres **Formation** was also deposited at this time. As the **tectonism** that shaped the region subsided and sea level fell, the retreating waters deposited marine rocks in the basin. The Artesia Group was deposited along the coastline at this time.

During the Late Permian period (260.4–251.0 million years ago), sea level continued to fall, and the Delaware Basin was mostly cut off from the open ocean. The Castile and Salado Formations formed as the once-open marine basin became a restricted lagoon. Near the end of the Permian period, a short-lived rise in sea level brought marine waters back into the basin, and the Rustler Formation was deposited. The Dewey Lake Formation was deposited when the sea level fell again.

There followed nearly 20 million years of erosion during the Early and Middle Triassic periods, but **deposition** began again in the Late Triassic, when the Dockum Group, including the Santa Rosa Formation, developed. The Miocene-Pliocene–era Ogallala Formation filled in a highly eroded landscape, but its deposits were eventually cut off from their sources to the west as

Era	Period	Epoch	West of Pecos River	East of Pecos River	Delaware Basin
Cenozoic	Quaternary	Holocene	Alluvium, caliche, travertine, aeolian deposits		
		Pleistocene	Lakewood terrace Orchard Park terrace Blackdom terrace		
	Tertiary	Pliocene	Gatuna Formation Ogallala Formation		
		Miocene			
		Oligocene	*Rocks not deposited or not preserved*		
		Eocene			
		Paleocene			
Mesozoic	Cretaceous	Late			
		Middle			
		Early			
	Jurassic	Late			
		Middle			
		Early			
	Triassic	Late	Dockum Group		Dockum Group
		Middle			
		Early			
Paleozoic	Permian	Late		Dewey Lake Formation Rustler Formation Salado Formation Castile Formation	Dewey Lake Formation Rustler Formation Salado Formation Castile Formation
		Middle	Artesia Group	Artesia Group	Capitan Formation Goat Seep Formation Cherry Canyon Formation
			San Andres Formation	San Andres Formation	Cutoff Formation
		Early			

The geologic history of southeastern New Mexico is reflected in the layers of rock (stratigraphy) beneath the ground and exposed above it. This chart shows at what point in the geologic timescale (white columns to the left) each layer of bedrock was deposited. Most of the formations East of the Pecos River and in the Delaware Basin were deposited during or before the Late Permian (more than 251 million years ago).

another round of erosion began. The Gatuña Formation was deposited around the same time.

The Llano Estacado's caliche caprock developed from the end of the Pliocene era until the onset of the first Pleistocene glaciations. During this time, the High Plains region was semiarid, and streams and lakes dried up and were **deflated**, producing abundant **loess** deposits that were rich in calcium carbonate. Intermittent moist intervals and seasonal variations during that time allowed the development of early-stage caliche soils that developed over time into the thick caprock observable today.

Before the beginning of the Pleistocene, the ancestral upper Pecos-Brazos River flowed southeast (through what is now Portales) and across the Llano Estacado. In fact, this river system played a major part in the construction of the northern Llano Estacado as it carried material from the Rocky Mountains eastward onto the High Plains. The current course of the river developed when the current Pecos River watershed extended its reach northward through headward erosion (erosion at the source in the opposite direction of stream flow) and eventually captured the ancestral upper Pecos-Brazos River sometime in the early Pleistocene. The modern Pecos River has a relatively straight north–south course and lies within the Pecos Trough. We know that the modern Pecos River is younger than the Llano Estacado, because the river is inset below the Llano Estacado's current surface. The Pecos River brought down **gravel** from the north and spread it across the landscape.

The result of all this activity is the limestone bedrock and chert we find in the area today. This complex geologic sequence resulted in a variety of **knappable** rocks—some **nodules** still embedded in the bedrock, others **cobbles** concentrated along the Pecos River or strewn over the ground surface of the nearby Llano Estacado. In the next section, we will learn to identify some of these rock types.

Modern-day Pecos River.

Raw-Material Types

The ways a given ancient people used the durable resources around them—rocks, bones, shell, etc.—make up a large part of what we can know about them. Luckily, an astonishing amount of information is encoded in these remains—if one knows how to read them. Archaeology uses science and ever-improving techniques to translate these inert artifacts into increasingly clearer pictures of life in times and places for which there is no easily legible record.

Raw-Material Selection

The techniques for analyzing stone tools begin with an imaginative exercise—putting yourself in the mind of the person who made the tools. By replicating the **flint knapping** process, archaeologists gain insight into the choices facing the toolmaker and the implications of those choices. Someone wishing to make a stone tool must first determine what type of raw material would be best suited for that tool. For example, for a simple flake with a sharp cutting edge, many different kinds of rock will do, but something more specialized, like a **dart** or arrow point, requires a fine-grained material like chert that can be worked and shaped into a specific form.

In deciding which rock type to use for a given purpose, then, one way to define your choices would be to divide the rocks available to you into the fine grained and coarse grained. Fine-grained materials tend to break in a **conchoidal fracture** pattern, yielding a smooth surface and a sharp edge. Chert is a good example of a fine-grained rock. It is very useful when you want to create a sharp edge and durability is not a priority; it is best suited for cutting activities. Chert can also be easily worked into specific tool forms. Quartzite, on the other hand, is a good example of a coarse-grained rock. This type of rock can also break with a conchoidal fracture pattern, but the surface tends to be rough, and the edges tend to be dull. Quartzite is useful for creating tools with stronger, more-durable edges, but it can be more difficult to work into specific tool forms.

The choice of materials would also have been informed by availability: which materials were available within a given area and which required travel or trade. Archaeologists have developed several techniques to identify where particular stones originated. Geochemical analysis identifies the types and amounts of **trace elements** in a specific rock. This certainly works well for obsidian, which is typically associated with a unique volcanic eruption, but chert is commonly found as nodules in limestone formations that cover very broad areas, making it more difficult to isolate a distinctive trace-element signature. Therefore, another technique for identifying trace elements was developed, using ultraviolet light. Preliminary research has indicated that there may be some differences in the way cherts change colors (or exhibit **fluorescence**) when exposed to ultraviolet light. This technique is promising, but it is not without its limitations. A combination of the geochemical and ultraviolet-light techniques may help to distinguish various sources from each other. The presence of fossils in chert can also help to identify the specific geologic formation from which it was derived.

Tommy Heflin demonstrating flint knapping techniques.

Raw-Material Types

Igneous

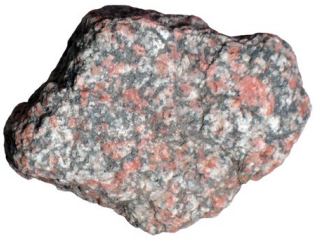
Igneous rocks are formed when lava or magma cools and hardens, either below or above ground.

Andesite: A fine-grained volcanic rock that contains the minerals feldspar, pyroxene, and amphibole. It is often gray in color and may contain some visible black or pale-pink to white crystals.

Basalt: A fine-grained volcanic rock that contains feldspar, amphibole, pyroxene, and olivine. It is often dark red to black in color and may contain holes, the remains of gas bubbles, known as vesicles (such specimens are called "vesicular basalt"). It is denser and feels heavier for its size than other volcanic rocks.

Chalcedony: A fine-grained, translucent mineral composed of microcrystalline quartz that is often found associated with hydrothermal deposits; however, it can also occur in sedimentary chert. It occurs in a variety of colors, including white, gray, red, and brown, and is often banded.

Granite: A coarse-grained igneous rock formed by magma that has cooled and crystallized below the earth's surface. It ranges in color from dark red to pink and light gray and contains quartz and feldspar, along with biotite and amphibole.



Rhyolite: A fine-grained volcanic rock that contains quartz and feldspar. It is often pale pink to gray to purplish gray in color and frequently contains visible, clear crystals of quartz.

Sedimentary

Sedimentary rocks are formed through the settling and accumulation of small particles eroded from elsewhere and carried by wind or water. The majority of the rocks on Earth are sedimentary.

Chert: A hard, fine-grained, opaque mineral composed of microcrystalline quartz that is often found associated with limestone deposits. It can also be considered a sedimentary rock and is often referred to as **flint.** Chert occurs in a wide variety of colors and textures, has a waxy luster, and fractures in a dish-shaped, conchoidal pattern, forming very sharp edges. Colors observed include white, yellow, red, brown, black, light gray, dark gray, and pale blue. Its hardness, durability, and ease of use made chert one of the most important raw materials used by prehistoric people.

Conglomerate: A sedimentary rock that contains **pebbles**, cobbles, and/or boulders of other materials held together by sandstone or some finer-grained material. Because of their structure, conglomerates tend to break unevenly and do not produce sharp edges.

Dolostone: Also known as dolomite rock, dolostone is limestone that has magnesium added to its crystalline structure. The process of dolomitization is thought to occur after the sediment has been buried and become rock. Dolostone is fine- to coarse-grained and pale-tan in color on both weathered and fresh surfaces.

Limestone: A fine- to coarse-grained sedimentary rock formed in oceanic environments. It can contain invertebrate fossil material. Limestone is frequently gray in color on weathered surfaces and can be dark gray to black on fresh surfaces. These rocks are often categorized by the amount of fossil material they contain.

Limey sandstone: Sandstone cemented together with abundant calcite cement. It implies formation near a beach or on a sand bar along a coastline and can be fine- to coarse-grained.

Mudstone: A sedimentary rock that is very fine grained. It is a hardened mud that can be green, red, purple, or tan in color.

Opalized caliche: Caliche (a layer of soil that is cemented with calcium carbonate [also known as calcrete]) that also contains varying amounts of **silica** cement. If enough silica is present, small lenses and nodules of opal will form in pore spaces in the material. The lower third of the Ogallala Formation's caprock includes areas of opalized caliche.

Petrified wood: Woody material that has been replaced with silica after burial. Petrified wood is often well-enough preserved that the grain is still partially visible. It can be brown, black, red, purple, blue, white, or multicolored.

Sandstone: A sedimentary rock with sand-sized grains. Sandstones are sometimes subdivided by the dominant composition of the grains. Fossiliferous sandstone includes fossil material, either invertebrate or vertebrate. Color variations include white, gray, tan, red, orange, and purple.

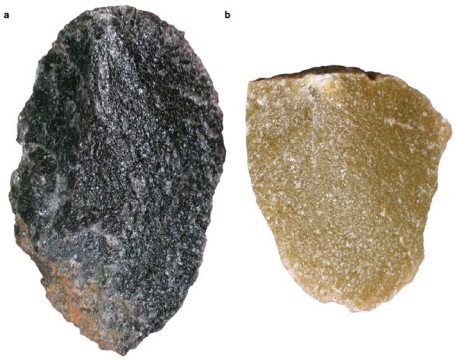
Siltstone: A sedimentary rock that is fine grained but still somewhat gritty to the touch (compared to mudstone). Colors include tan, pale orange, pink, red, and purple.

Metamorphic

A metamorphic rock is formed when heat and pressure (as occur deep beneath the ground) effect physical and chemical changes in an existing rock.

Gneiss: A medium- to coarse-grained metamorphic rock formed by the addition of heat and pressure to granite or schist. Because the minerals in gneiss separate into bands by their composition, gneisses are **foliated** (structured in successive layers) and color banded, often black and white, black and red, or gray and white.

Quartzite: A fine- to coarse-grained metamorphic rock formed from adding pressure and heat to sandstone. A very hard, dense rock that fractures conchoidally, quartzite can be recycled many times through erosion and deposition, although it is not as easy to shape as chalcedony or obsidian. Colors vary widely and include white, yellow, pink, red, dark purple, dark gray, and black.



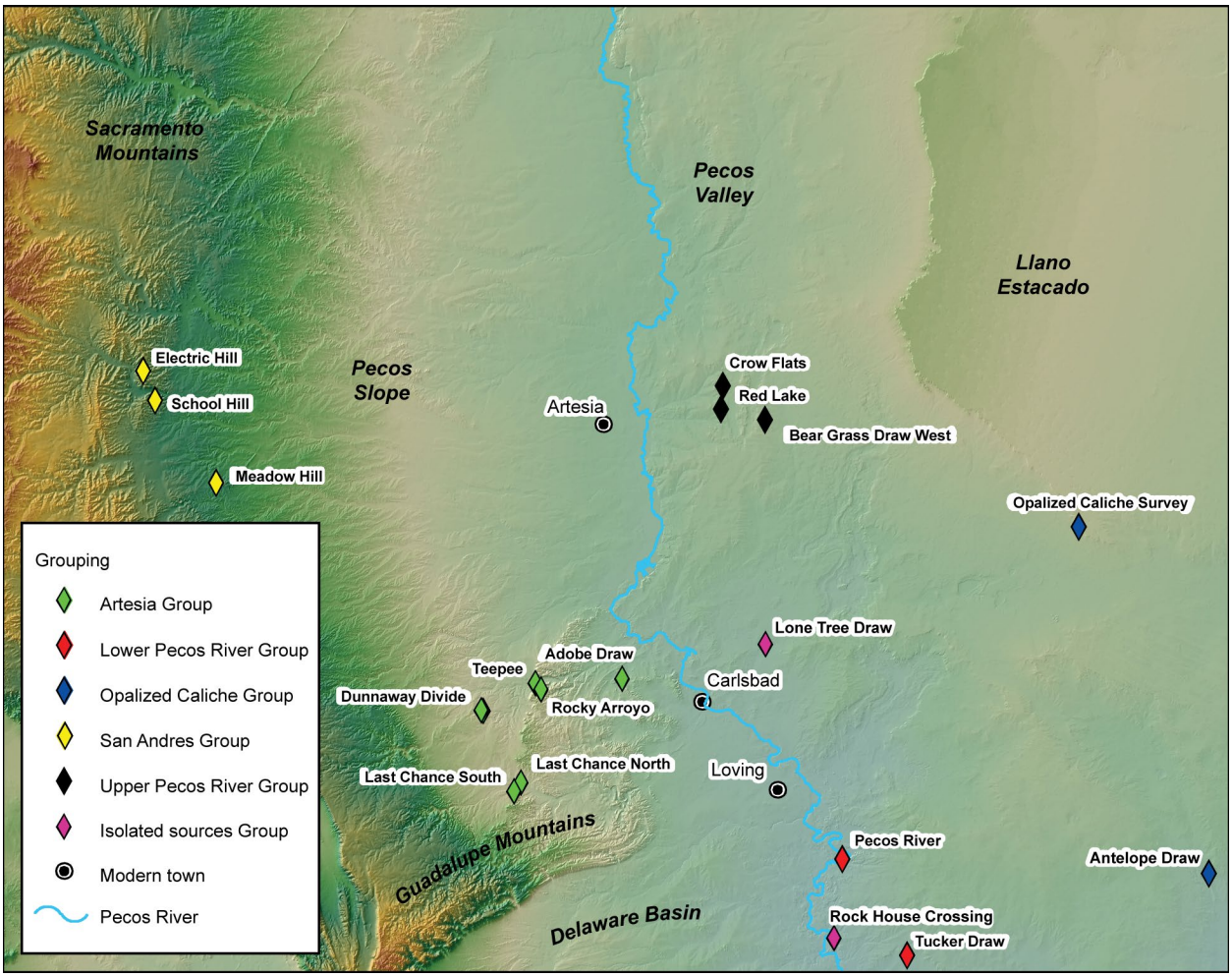
Purple (a) and mustard (b) quartzite.

Slate: A fine-grained, foliated metamorphic rock formed by the action of low heat and low pressure on a fine-grained sedimentary rock, like siltstone, mudstone, or shale. It readily splits into plates and ranges in color from pale yellow to dark gray to black.

In the next section, we will learn about the different places where the ancient peoples of the region might have gone to procure these rocks.

Rock Sources

Bearing in mind the geological history of the area, we chose a set of specific locations to study that we hoped would give us a comprehensive picture of the different types of knappable rock that were available to the prehistoric inhabitants of the region and how they were distributed across the landscape. Most of these locations are established archaeological sites or survey areas, and we recorded any artifacts present.



Shaded relief map of southeastern New Mexico showing sites and survey locations.

The Six Study Groups

At each location, the project geologists observed the bedrock exposures and landscape features and described their observations in detail. Each site or survey parcel was plotted on the 1:1,000,000-scale geologic map of New Mexico, and the geology observed in the field was then compared to the geology described on the state geologic map and in the published literature. The geologists also observed and noted the rock types of the pebbles (rocks smaller than 2½ inches in diameter) and cobbles (bigger than pebbles, but smaller than 10 inches in diameter) at each location.

The chosen locations were divided into six groups according to the bedrock or landscape feature on which they are located: the San Andres Group, the Opalized Caliche Group, the Artesia Group, the Lower Pecos River Group, the Upper Pecos River Group, and the Isolated Sources Group. The groups are discussed in order of geologic age, from oldest to youngest; so, for example, the San Andres Formation locations are discussed first, because they are on the oldest bedrock. The table below gives a summary of all the locations, which group they belong to, and what types of rock are found in each.

Rock Sources in the Area, by Study Group

Site or Area	Types of Rock
San Andres Group	
Electric Hill	"fingerprint" chert
School Hill	"fingerprint" chert, dolostone
Meadow Hill	dolostone, chert, fossiliferous chert
Opalized Caliche Group	
Antelope Draw	mudstone, sandstone, goethite, chert, slate, gneiss, quartzite, caliche nodules, banded quartzite
Opalized Caliche Locale	opalized caliche, opal
Artesia Group	
Rocky Arroyo	dolostone, some chert
Dunnaway Divide	dolostone, chert
Last Chance North	dolostone, fossiliferous sandstone, slate, limestone, limey sandstone, chert,
Last Chance South	dolostone, some chert, fusulinid fossils
Teepee	dolostone, green mudstone, gypsum-rich mudstone, dark-orange sandstone, rare chert
Adobe Draw	dolostone, chert, siltstone, mudstone
Lower Pecos River Group	
Tucker Draw	quartzite, chert, limestone, porphyritic andesite, sandstone; rare chalcedony, slate, and dolostone
Pecos River	sandstone, limestone, calcrete nodules, chert, sandstone, quartzite, pumice
Upper Pecos River Group	
Crow Flats	quartzite, chert, andesite, sandy fossiliferous limestone
Red Lake	travertine, quartzite, chert, petrified wood, travertine, sandstone, rhyolite (including possible Thunderbird rhyolite), limestone, gneiss, welded tuff, slate, porphyritic andesite, chalcedony, vein quartz
Bear Grass Draw West	caliche, quartzite, chert, andesite, rhyolite, petrified wood
Isolated Sources Group	
Rock House Crossing	fossiliferous limestone, quartzite, slate, chert
Lone Tree Draw	quartzite, chert, micrite, andesite, rhyolite with pink feldspar crystals (possibly Thunderbird rhyolite)

San Andres Group

The San Andres Group is situated in the foothills of the Sacramento Mountains, where the limestone contains a distinctive gray-banded chert. West of the town of Artesia, our chosen sites lie on outcrops of the Bonney Canyon **Member**, the middle of three members of the San Andres Formation. These locations include abundant chert in dolostone.

The Electric Hill site is on a hillside above a tributary canyon of the Rio Peñasco, just west of the elementary school at Dunken. The lower 100 m (300 feet) of the slope are composed of the Rio Bonito Member of the San Andres Formation, and the upper 33 m (100 feet) are composed of the Bonney Canyon Member of the San Andres Formation. Large nodules and discontinuous bands of chert occur at different **horizons** within a tan dolostone of the Bonney Canyon Member, approximately 13–20 m (40–60 feet) above the contact between the two members. The chert is banded with dark gray and very light gray or yellow—this type of chert is called "fingerprint chert" for its distinctive swirled banding. Chert is abundant along the producing horizons and as nodules along the canyon floor.

The School Hill site is located southwest of Electric Hill and is also on the Bonney Canyon Member. As at the Electric Hill site, the underlying Rio Bonito Member is exposed here, although not as much, and the chert-bearing horizons are at lower levels. The chert, which is also fingerprint chert, is present as large nodules and discontinuous bands about 20 m (60 feet) above the contact between the members, in a tan dolostone like that found at Electric Hill. Nodules are abundant within the dolostone and are common as weathered debris on the slopes of the hills and in the valley floors.

The Meadow Hill Survey Area is on an anticline—a part of the landscape that has folded upward into a domelike shape—southeast of Electric Hill and School Hill. The rocks exposed are entirely from the Bonney Canyon Member and are pale-gray dolostone. Small chert nodules are common, although they are generally smaller than at the other locations and only rarely exhibit the fingerprint pattern. Many of the chert nodules are fossiliferous (contain fossils) and include fossilized **foraminifera** shells and shell fragments of other invertebrates.

The Electric Hill site in the San Andres Group.

Chert in San Andres Formation limestone at the Electric Hill site.

Opalized Caliche Group

In the area of the Opalized Caliche Group, silica has migrated downward into the caliche caprock of the Llano Estacado and formed a partial cement in its lower parts, in a process of **silicification**. The amounts of silica vary along the base of the caprock, but locally there is enough silica to form opal.

The Antelope Draw site lies northwest of a small hill known locally as "Custer Mountain." The northern boundary of the survey parcel is marked by low bluffs consisting of reddish-brown mudstones (Chinle Group) beneath pinkish-orange muddy sandstones (Ogallala Formation). These are cemented with silica to varying degrees and have been highly disturbed by burrowing insects and animals and/or plant roots. Pebbles along the foot of the bluff include goethite (a common brown mineral), chert, and slate. Larger cobbles, which are much rarer, include gneiss, quartzite, caliche nodules, and banded quartzite.

The Opalized Caliche Locale, at the base of the Llano Estacado, west of Hobbs, is a zone of opalized caliche about 6 m below the top of the cliff. The silica cement here occurs very sporadically along a horizon about 1 m thick—silica is concentrated in lenses and small nodules of opal.

The Antelope Draw site in the Opalized Caliche Group.

Opalized caliche outcrop at the Antelope Draw site.

Artesia Group

The Artesia Group contains abundant dolostone, as well as chert that is eroding out of the limestone, plus surface gravels; some of the chert contains a distinctive type of fossil. These sites are on or near bedrock outcrops of various formations of the Artesia Group, including the Queen, Seven Rivers, and Yates Formations.

The Rocky Arroyo Sample Area is located where the **drainage** so named enters a narrow east–west-trending canyon. To the northeast and southeast lie exposures of the Seven Rivers Formation of the Artesia Group. The survey parcel is on the northern bank of the arroyo, where there are very pale-gray dolostone cobbles from the underlying Queen Formation and possibly dolostones from the Seven Rivers Formation that have weathered from the Seven Rivers Hills to the north and Azotea Mesa to the south. Chert pebbles were observed, but only rarely.

The Dunnaway Divide site extends across a large area of low, rolling hills of Queen Formation dolostone and conglomeratic dolostone in outcrops with numerous cobbles of rounded dolostone and occasional pebbles of chert encased in limestone. It is likely that the underlying rocks in this area dissolved at some point in the past, causing the overlying surface to break up and collapse inward. The mixture of material in the collapse zone was then re-cemented to form new rock. Both chert pebbles and dolostone cobbles have weathered free from the resulting conglomerate and are abundant on the surface.

The Last Chance North site is north of Last Chance Canyon and northeast of the Last Chance South site. It is located on a lower terrace surface near the main channel. North of the survey parcel is a higher terrace that developed on an outcrop of the Seven Rivers Formation. This terrace is at approximately the same elevation as the terrace on which Last Chance South (below) is located. At the survey parcel itself, cobbles are dolostone, fossiliferous sandstone, slate, limestone, and chert. On the older, higher terrace, cobbles and boulders of dolostone, limestone, limey sandstone, and chert are abundant.

The Last Chance South site is on the southern side of Last Chance Canyon, where it enters Azotea Mesa. The survey parcel is on a terrace surface above the main channel. The surface is a reddish brown, silty sand that is **locally deflated**, with pebbles and cobbles across the surface. The top of the terrace itself is dominated by pebbles and cobbles of dolostone; very small nodules of chert are found, but only rarely. A distinctive fossiliferous chert with abundant, very large **fusulinid** fossils (up to 1 cm each in length) is common in these deposits.

The Teepee site is located on the northern rim of Azotea Mesa, overlooking Rocky Arroyo, on the upper Seven Rivers Formation. The exposed outcrop includes beds of dolostone, green mudstone, gypsum-rich mudstone, and dark-orange sandstone. Cobble- and pebble-sized materials on the upper surface of the outcrop are predominantly tan dolostone; pebbles of chert are only rarely found.

The Adobe Draw Survey Area is located on a dipping slope of buff–to–pinkish-gray dolostone. Chert is weathering out of the dolostone surface and is uniformly a very pale blue-gray color. To the east, low hills of pale-green and pinkish-gray siltstone and mudstone crop out.

The Last Chance North site.

Typical view within the Artesia Group.

Lower Pecos River Group

The Lower Pecos River Group contains surface gravels and some rock types derived from the Guadalupe and Sacramento Mountains to the west. Lower Pecos River Group locations are near or on the lower Pecos River and reflect **terrace deposits** from that river as well as deposits from other tributaries to the west that carry limestone, dolostone, and chert from the Guadalupe and Sacramento Mountains.

The Tucker Draw site lies on low, rolling hills of reddish orange, windblown sand deposits; **gravel-lag** deposits (gravel-size rock left behind after wind has blown finer material away) cap the low rises. Pebbles and cobbles in these lag deposits are made of quartzite, chert, limestone, **porphyritic** andesite, and sandstone, with rarer instances of chalcedony, slate, dolostone.

The Pecos River Sample Location includes cobbles and pebbles on a point bar of the river. Muddy sandstone, limestone, calcrete nodules (also Ogallala Formation), chert, sandstone, quartzite, and pumice were observed.

The Lower Pecos River Sample located on the point bar of the Pecos River, north of Malaga.

The Tucker Draw site in the Lower Pecos River Group. The diversity of materials found on the site is common for gravels carried by the Pecos River.

Upper Pecos River Group

The Upper Pecos River Group sites and survey parcels lie east of Artesia; they contain surface gravels with more quartzite than the other groups, including a distinctive purple quartzite. The easternmost location most likely includes Ogallala Formation gravels left behind in the eastward retreat (erosion) of the Llano Estacado.

The Crow Flats site is east of the Pecos River and northwest of Red Lake, on very low hills capped with rounded cobbles and pebbles interspersed with broad, deflated surfaces. The surface is covered by a thin layer of sand deposited by wind. Cobbles and pebbles observed include quartzite, chert, andesite, and sandy fossiliferous limestone. Cobbles and pebbles are much less abundant at this location than at Red Lake to the south.

The Red Lake site is south of Crow Flats and just west of Red Lake, on low, rolling hills capped with abundant rounded cobbles and pebbles. There are low mounds of travertine (limestone deposited by springwater) to the north. This site contains the widest variety of rock types encountered in this project. Quartzite, chert, petrified wood, travertine, sandstone, rhyolite, sandstone, limestone, gneiss, welded tuff (volcanic rock with abundant ash fused into a more solid whole by high temperatures), slate, porphyritic andesite, chalcedony, vein quartz, and a type of rhyolite that contains distinctive pink feldspar crystals (possibly **Thunderbird rhyolite**, a type originating in the Franklin Mountains of Texas) were all observed.

The Bear Grass Draw West site is located to the east of Red Lake, on low hills capped with rounded cobbles and pebbles of varying rock types and fragments of caliche. The surface is covered by a thin deposit of windblown sand that is locally deflated. Pebbles and cobbles include quartzite, chert, andesite, rhyolite, petrified wood, and caliche nodules.

Typical view within the Upper Pecos River Group.

Cobbles on the surface of Crow Flats.

Isolated Sources Group

These are sites that are not near a well-defined **geologic unit** or **geomorphic unit** that could serve as a source of knappable materials.

The Rock House Crossing site is on an **incised** and locally deflated surface at the base of an isolated outcrop of Ogallala Formation conglomerate. The rock types here are divided by size: fossiliferous limestone, quartzite, and slate are found in cobbles, and quartzite and chert are found in pebbles. This distinctive division reflects the sorting in the adjacent outcrop of the Ogallala Formation, which is composed of a conglomerate dominated by cobbles of rounded limestone. The survey parcel itself sits on what is most likely a **pediment** surface and includes cobbles weathered from the Ogallala Formation outcrop.

The Lone Tree Draw site is in a broad, shallow drainage with many deflated areas between two long, low hills. The drainage contains small, low-density deposits of gravel lag and isolated outcrops of gypsum-rich soil. Pebbles and cobbles include quartzite, chert, micrite, andesite, and rhyolite with pink feldspar crystals (possibly Thunderbird rhyolite).

The Lone Tree Draw site appears to have been used as a source of lithic raw materials, but few usable cobbles were observed at the site.

The Rock House Crossing site in the Isolated Sources Group.

Conclusions

The types of rock at each location reflect the local bedrock geology or the underlying geomorphic unit. San Andres Group locations contain solely chert and dolostone that occur in bedrock outcrops. Sites in the Lower and Upper Pecos River Groups contain terrace deposits and pediment gravels related to erosion of the Ogallala Formation and the retreat of the Llano Estacado. Artesia Group locations are on bedrock outcrops that are dominated by dolostone from the local Artesia Group formations or on **geomorphic surfaces** that include materials from geologic units exposed upstream along with these bedrock exposures. Locations in the Isolated Sources Group reflect local geomorphic and bedrock units independent of the clusters defined above. Rocks in the Opalized Caliche Group are eroded from exposed opalized caliche just below the Ogallala Formation. The only rock type that may have come from somewhere outside the Pecos River **drainage basin** is the possible Thunderbird rhyolite, a type of rhyolite from the Franklin Mountains of Texas and not naturally found among Pecos River gravels. All other materials were derived either from local bedrock units or from gravels associated with Ogallala Formation and/or Pecos River deposits.

Archaeologists analyzed artifacts from each of these locations and gathered a lot of useful information. But before we examine the data, let's take a look at how archaeologists analyze artifacts and the different ways artifacts tell their stories.

Lithic-Artifact Analysis: Typology, Technology, and Function

Over the course of this project, archaeologists found more than 4,000 lithic (stone) artifacts. Because each of these was shaped by a human—or is a result or byproduct of human activity—it tells us something about the people who lived here (or at least passed through here). But different kinds of artifacts yield different kinds of information. The majority of the artifacts found during this project are **debitage**; they are by-products of stone-tool production rather than actual tools, so they are more informative in the aggregate than as individual artifacts. They are also less distinctive than, for example, a complete, finished projectile point (a dart, spear, or arrow point), which not only can help pinpoint its maker in terms of time and cultural group, but is easier to spot on the ground!

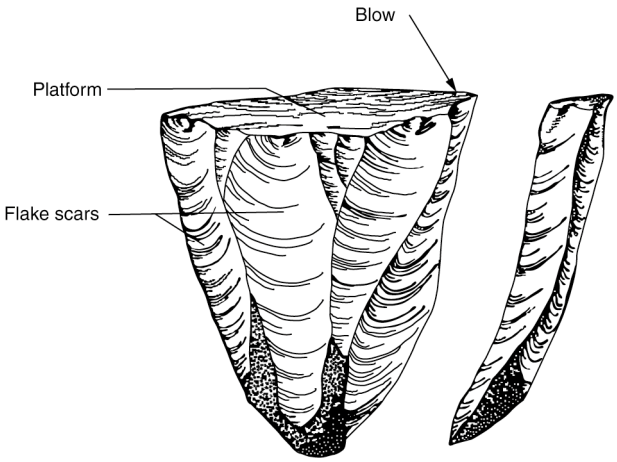
Archaeologists are often asked how they can distinguish a naturally broken rock from one that was intentionally broken by a human hand. Faced with vast areas littered with surface gravels, how do we identify the rocks that can yield information about past human activity, and how do we coax that information from them? The answer lies in archaeology's ever-improving understanding of the tool-making processes and tool-using habits of ancient peoples, gained through experimental flint knapping and detailed analyses.

Surface scatter at Crow Flats in the Upper Pecos River Group. Note the cobble uniface in the upper right-hand corner.

There are two general ways archaeologists can approach analysis. One is to simply describe the artifacts in the field and leave them in place (in-field analysis). This allows the archaeologist to collect a limited amount of information without actually disturbing the archaeological site. The other is to collect some of the artifacts and bring them back to the laboratory for more-detailed analysis. This involves collecting, analyzing, and eventually curating the artifacts at a federally approved museum.

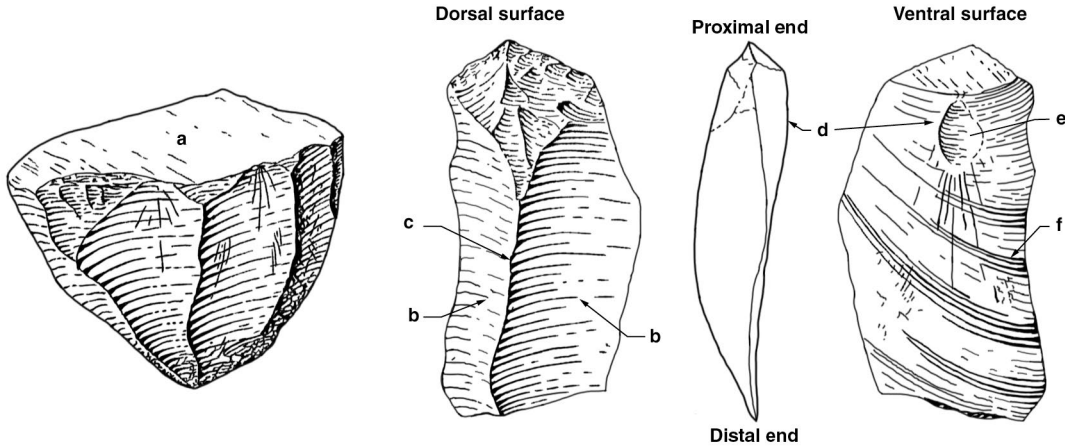
Archaeologists analyze stone artifacts with regard to three different aspects: typology, function, and technology. Typology focuses on the superficial characteristics of stone artifacts—shape, size, etc.—and classifies them accordingly. Function refers to the actual use to which a given artifact was put, which can be investigated through various kinds of laboratory analyses of wear and residues. Technology refers to the complex of tools a people used to help them survive—by hunting game, collecting wild plants, growing maize, building houses, etc.—and how those tools were made and used.

Typology involves placing artifacts into predetermined sets or categories of types. This helps ensure consistency within a given analyst's work and allows other analysts to understand exactly how the various types were defined, so that they can replicate the analysis. These types reflect not only the size and shape of an artifact, but also the manufacturing process and the point during this process at which the artifact ceased to be used and entered the archaeological record. For example, a stone artifact may be classified according to the stage it has reached in the process of making a sharp-edged cutting tool. In this process, a whole cobble is first broken in half by hitting it with a **hammerstone** to expose a broad, flat surface (the platform). The cobble thus broken (now a **core**) is hit again with the hammerstone, breaking off a smaller piece, referred to as a **flake**. (This process of striking leaves tell-tale marks on rocks, which help archaeologists distinguish artifacts from plain old rocks.) From a flake, a variety of chipped stone tools can be made. A flake that has been worked, or **retouched**, on only one side is a **uniface**; one retouched on both sides is a **biface.** A biface can be modified so that it can be hafted onto a foreshaft to make a dart or an **arrow**, and then it is referred to as a projectile point. Or it may be made into a variety of other tools.



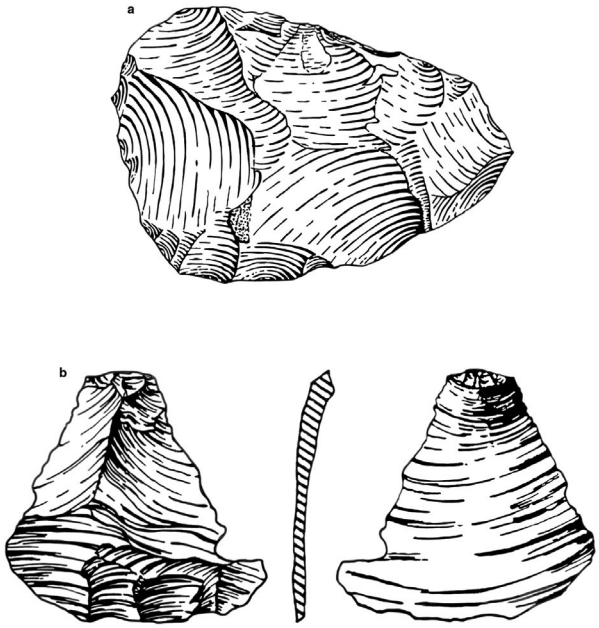
Core. Note the platform (the broad, flat surface across the top of the core where the cobble was broken in half) and the scars where flakes have been removed. (Adapted from Whittaker 1994:15.)

Quartzite core from the Crow Flats site.



a Platform **b** Flake scar **c** Arris **d** Bulb of Percussion **e** *Eraillure* **f** Lines of force

Core flake. A flake also has a platform that was once connected to a core, and the two surfaces are identified according to their former position within the core. The surface that faced outside when part of the core is the dorsal surface; it exhibits evidence of previous flake scars and, possibly, the original, weathered exterior rock surface (cortex). The formerly inside-facing (ventral) surface exhibits a bulb of percussion—a conical bulge indicating where the energy used to remove a flake was concentrated—and possibly an eraillure—a tiny scar, also the result of the impact with a hammerstone. The direction in which this energy flows is sometimes represented by a series of lines of force, or ripples, that radiate from the top (proximal) end to the bottom (distal) end of a flake. Together, these characteristics help the archaeologist to determine whether an item is natural or human-made. (Adapted from Slaughter et al. 1992:67.)



Biface (a) and biface flake (b). A flake removed during the production of a biface differs somewhat from the larger one that was removed from the core. It has a platform angle of about 45° that represents the old edge of the biface and a slight lip that protrudes onto the ventral surface that results from the use of a soft hammer, such as a piece of antler. The ventral surface also has a distinctive curvature that reflects the flake and follows the shape of the biface. Lastly, flake scars on the dorsal surface might radiate from both the proximal and distal ends, because they reflect previous flake removals along opposite sides of the biface that helped to thin it and create sharper edges. (Adapted from Slaughter et al. 1992:68 and Jackson et al. 1988:30.)

Typology helps the archaeologist classify artifacts into distinct groups. Once that classification is completed, archaeologists need to understand what the groups reflect in terms of the broader stone-tool technology. Stone-tool technology can be subdivided into several parts that help to describe the life cycle of a tool: material selection, lithic reduction (the process of making stone tools), tool use and maintenance, and discard. Viewed as a coherent whole, they can form a basis upon which archaeologists can compare and contrast different prehistoric societies.

Archaeologists formulate questions to guide their research and analysis. How did the use of stone-tool technology by hunting and gathering societies differ from that of agriculturalists? How were raw materials obtained? What kinds of tools were produced, and what were they used for? When and where were the tools eventually discarded and replaced with new ones? Such questions focus the archaeologist's attention on collecting the specific kinds of information necessary to answer them and help to determine which specific characteristics should be recorded during the analysis of each stone artifact.

Now that we know more about stone tools and how to analyze them, we can dig into the data and see what it tells us.

Results: What We Found and What That Tells Us

During this project, archaeologists recorded 4,508 artifacts while walking across the sites and survey parcels, including 472 **worked cobbles**, 384 cores, 2,572 pieces of debitage, 118 **retouched tools**, 3 **ground stone** tools, 9 hammerstones, and a quartz crystal (an additional 949 pieces of burned rock were also recorded). These stone artifacts were analyzed both in the field during the survey and in a laboratory after fieldwork was completed. Identifying specific rock types and their specific source locations can help archaeologists to answer some important questions: Who used the bedrock and surface gravels in the study area, and how were these locations linked to their residences? What kinds of stone materials were used, and what tools were produced from those materials?

To determine the composition, or lithology, of the bedrock and gravels in the study area, we analyzed more than 1,200 cobbles collected from six different locations. Limestone composed about half (56 percent) the sample; the rest was made up of chert (21 percent), quartzite (17 percent), and other materials, including igneous rocks, caliche, sandstone, and chalcedony. The cherts generally ranged in color from tans to grays, and the quartzites were tan, gray, or reddish. A specific chert with distinctive gray banding was also identified in the bedrock of the San Andres Formation. A chert that contained large fusulinid fossils was also identified. There were also quartzites of two distinctive colors: purple and mustard.

Archaeologists walking across the survey area.

A comparison of the six sample locations indicated some important similarities and differences. The Upper Pecos River Group was dominated by quartzite (47 percent) and contained less chert and limestone. These deposits were derived from the Pecos River gravels and the Ogallala Formation. Some of the cobbles collected from Bear Grass Draw West were heavily coated with caliche, indicating that they had previously been buried. Some sites, such as Dunnaway Divide in the Artesia Group, contained almost nothing but limestone (dolostone), with only occasional chert. These deposits are sitting on or near outcrops of the Queen Formation, which is predominantly dolostone, a rock type classified as limestone in our study. There were marked contrasts between samples from the Lower Pecos River Group and the Isolated Sources Group. The Tucker Draw site in the Lower Pecos River Group contained mostly chert (56 percent) and is situated on a surface scatter of gravels that may be part of a very old terrace. Chert and other siliceous materials observed in old terrace surfaces may come from Paleozoic limestones in the northern headwaters of the Pecos River or may have eroded out of the Ogallala Formation as the Llano Estacado eroded along its western edge. In contrast, the Rock House Crossing site in the Isolated Sources Group primarily contained limestone (86 percent), because it is located near outcrops of the Ogallala Formation, which contains numerous limestone cobbles.

In analyzing artifact data, it helps to think in terms of the life cycle of a stone tool, which, as previously mentioned, can be divided into the stages of raw-material selection, tool production, tool use and maintenance, and tool discard.

Surface gravels, predominantly limestone, at the Dunnaway Divide site.

Dolostone at Dunnaway Divide in the Artesia Group. Dolostone is classified as limestone in this study, which is the predominant material type for this group.

Limestone cobbles in bedrock at Rock House Crossing in the Isolated Sites Group. The sites in this group are not located near a well-defined geologic or geomorphic unit that would have been a potential source for knappable materials.

Raw-Material Selection

Procurement Strategies: Shopping for Rocks

Prehistoric New Mexicans could have collected raw materials using several different techniques. They could have collected rocks incidentally, while doing other things—for example, collecting chert rocks while hunting deer in the area. This is referred to as an **embedded procurement** strategy. Most often, individuals would collect a few pieces of rock and then return to the campsite to replace their worn-out stone tools. Raw materials could also be collected by making trips directly to the sources in order to collect a large amount of rock to bring back home—not just enough rock to meet immediate needs but enough to meet future needs, as well. This is referred to as a **direct procurement** strategy. Lastly, someone who passed by a distant chert source might have brought rocks that could be obtained by trade. This is referred to as an **indirect procurement** strategy. Unlike the other two tactics, indirect procurement limited the amount of raw material that could be obtained and most often involved receiving a finished tool, as opposed to raw material.

In general, mobile **hunter-gatherers** used embedded procurement strategies, because they traversed wide areas during their annual search for wild plants and animals. In contrast, farmers tended to live at the same locations during the year and therefore made specific trips to quarries to collect raw materials. They also often had trade relationships with other farmers in the region and exchanged pottery or possibly stone tools. But both hunter-gatherers and farmers could have employed all three procurement strategies, according to what was in their best interest.

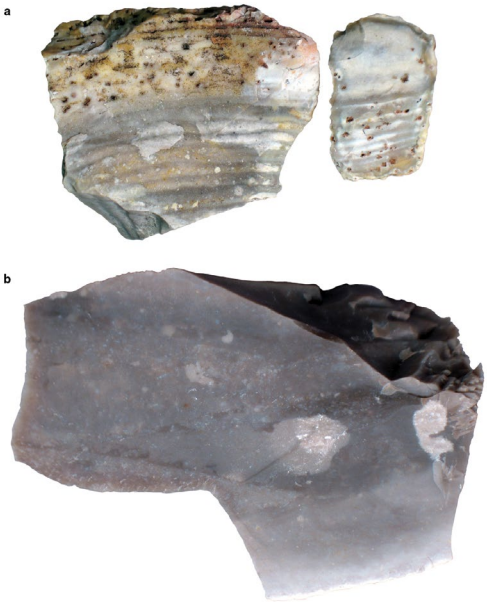
Sourcing

Chert—from which half the chipped stone artifacts we recorded were made—can be obtained from several sources in the region. As previously discussed, chert nodules that exhibit a distinctive gray banding can be found in the San Andres Formation, in the foothills of the Sacramento Mountains. Chert that contains distinctive fossils (fusulinid) can be obtained from the Cherry Canyon Sandstone in the Artesia Group. Varieties of cherts are also present in gravel deposits along the Pecos River valley and the adjacent Llano Estacado. The original sources for these materials were probably quite variable, and they were presumably derived from bedrock formations situated at great distances from their current locations.

Although some raw materials were derived from local bedrock outcrops, others traveled great distances and were eventually deposited as gravels in the study area. As noted earlier, determining exact source locations for the various rock types can pose a problem for archaeologists. We would like to be able to identify specific rock types from known source locations and then use that information to determine where people took the rocks during their annual movements, in order to get some idea of how far they traveled and where they might have moved during the year. But making such identifications isn't simple.

Fusulinid chert (exterior).

Fusulinid chert (interior).



San Andres chert (a) and Edwards Formation chert (b).

For example, let's say there are two opposing hypotheses—two ideas about where a certain group of people moved and how far—and we would like to use information about rock-source locations to test each one. The first hypothesis suggests that a certain group of people moved along a north–south-oriented path during the year while hunting herds of bison. We could look at the stone tools left behind and see whether we can identify any materials in the southern part of the area that might have been collected while they were living in the north. The problem is that some of the cherts and quartzites found in the south originate in bedrock formations in the Rocky Mountains, to the north, having been carried downriver, to the south, and deposited among the gravels along the Pecos River valley. This makes it difficult to identify which materials might have been collected from the north and which might have come from the south.

The second hypothesis suggests that this group of people traveled along an east–west-oriented path during the year and gathered wild plants and hunted game, moving from the Sacramento Mountains in the west to the Edwards Plateau in central Texas, to the east. The distinctive gray-banded chert present in the Sacramento Mountains might help us to identify any rocks that had been collected from that area, but the banding is not always present on rocks from that area. Also, a gray-colored chert that can be found there looks similar to a chert found in the Edwards Formation, in Texas, making identification even more difficult. These types of problems can make it challenging for archaeologists to link the movement of people (or artifacts) to their use of specific raw-material-source locations.

View of the Sacramento Mountains from the Electric Hill site looking southeast.

Tool Production

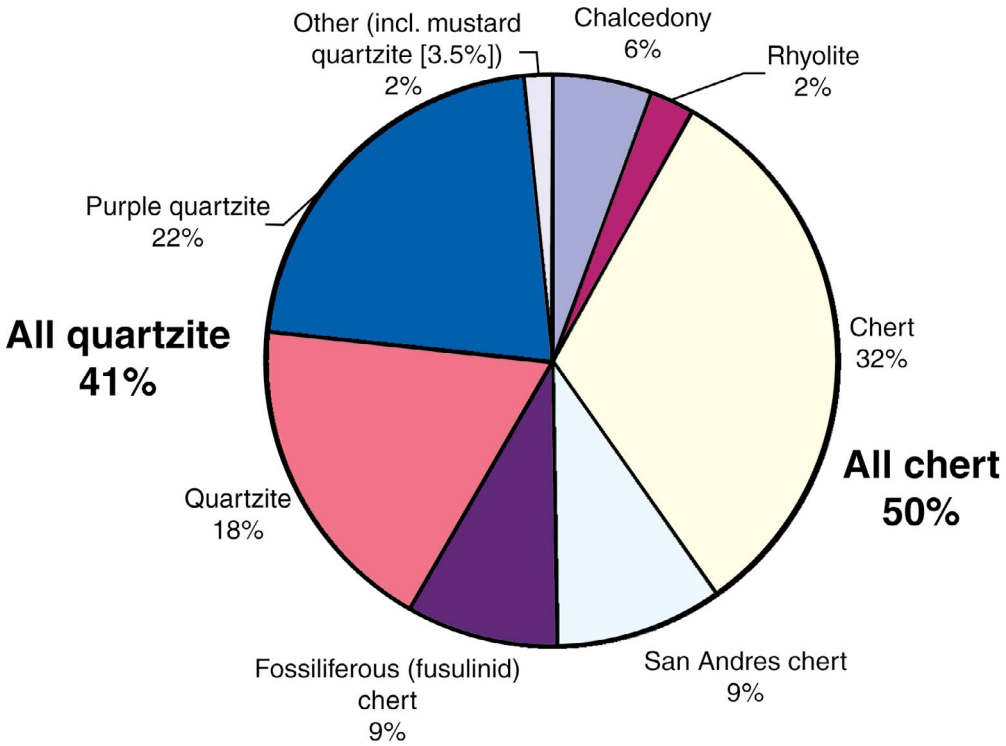
Archaeologists call the sequence of stages in stone-tool manufacture—beginning with initial core selection and preparation and continuing through the end point of final tool completion—the **reduction trajectory**. But all prehistoric tools were not subjected to the same reduction trajectory, and different raw materials were worked differently. Also, some tools could be made using only the first few stages of the production sequence—as in working a core to make a simple flake tool—whereas others required further stages—as in working a flake to create a retouched tool, such as a biface that could be used as a knife or projectile point. Simple flake tools are generally associated with farmers who lived in settled villages; bifaces are generally associated with hunter-gatherers. But tool making took place in different locations across the landscape, including at quarries and residential sites. So, the question is, what portions of the sequence were represented at the stone raw-material sources in our study area?

The working of cores to produce flakes was the primary activity at the raw-material-source locations. The graph below shows that the overall project **assemblages** consisted primarily of core flakes and that there were fewer worked cobbles and cores. Retouched tools, ground stone, and hammerstones were much less common. It is not surprising that **tested cobbles** (n = 422) were prevalent, along with a few **cobble unifaces** and **cobble bifaces**, because cobbles were readily available in the gravels, and a tested cobble reflects the simple act of picking one up and hitting it. Quartzite cobbles (60 percent) were tested and discarded more often than chert cobbles (34 percent), and quartzite was more highly represented as worked cobbles. Chert, on the other hand, was more intensively worked and included numerous examples of unidirectional (n = 25), bidirectional (n = 51), and multidirectional (n = 110) cores—that is, cores that have been worked in one direction, in two directions, and in three or more directions, respectively.

Cobble uniface on the site surface.

Flakes removed from cores are the main debitage type at the sites and survey areas we visited, and there were fewer pieces of broken shatter (or **angular debris**) and flakes removed from bifaces. Of course, it is very difficult to distinguish tool-production debris from naturally fractured rock in surface gravels, and the amount of debris may have been underestimated. Core-reduction activities focused a little more on the use of chert (50 percent) than on the use of quartzite (40 percent) materials, and tool-production activities focused mainly on the use of chert (70 percent). This provides further support to the idea that chert was worked (or reduced) more than quartzite in the surveyed locations, because it was represented by both core-reduction and tool-production activities.

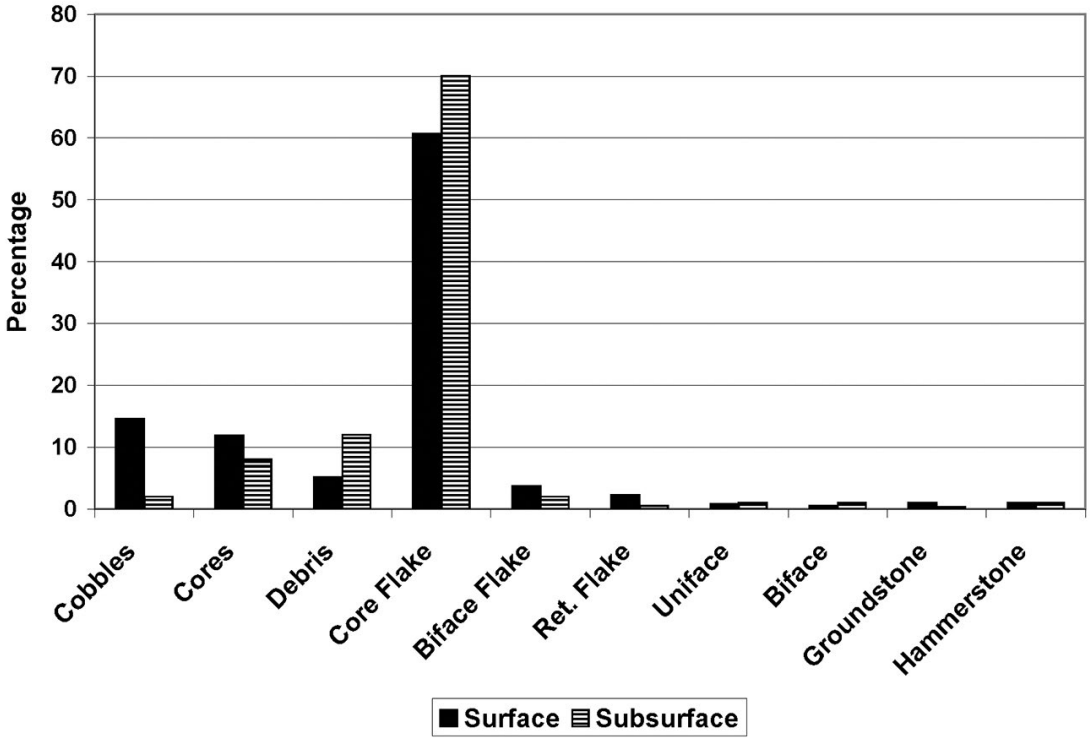
Relatively few retouched tools were recorded during the in-field analysis. Of those found, simple retouched flakes (63 percent) far outnumbered formal tools, like unifaces and bifaces. Sixty-nine percent of retouched tools were made of chert, making it the preferred material for such tools; quartzite was chosen much less often (23 percent). Overall, it appears that quartzite was used much more often for the production of flakes intended for use without further modification, whereas chert was used to produce retouched tools.



The majority of the chipped stone artifacts were made of either chert (50 percent) or quartzite (41 percent), and fewer artifacts were made of chalcedony, rhyolite, or other materials. The cherts were subdivided into three groups: generalized cherts (64 percent of all cherts), San Andres chert (19 percent of all cherts), and fossiliferous (fusulinid) chert (17 percent of all cherts). The quartzites were also subdivided into three groups: generalized quartzites (46 percent of all quartzites), purple quartzite (51 percent of all quartzites), and mustard quartzite (3.5 percent of all quartzites). Two** *milling stones* **and a** *pestle* **were made of sandstone, and the 9 hammerstones were made of either quartzite or limestone.

To determine whether sites contained artifacts beneath the surface, **test pits** were excavated. In contrast to the 4,508 stone artifacts observed above the ground, 399 buried stone artifacts were recovered from these test pits: 37 cores, 339 pieces of debitage, 21 retouched tools, and 2 hammerstones. The samples ranged in size from 2 to 108 artifacts per site or survey parcel.

Test pit at the Teepee site.



Note the difference between surface- and subsurface-artifact counts. As can be seen, relatively more debitage (core flakes and angular debris) was found beneath the surface. The increased presence of angular debris beneath the surface is to be expected. These items are extremely difficult to distinguish from naturally fractured rock when they are on the surface during in-field analysis, and field personnel tend to bias their field recording toward clearly defined flakes. Angular debris is more likely to be identified when excavated.

The majority of the cores and debitage were made of chert and quartzite, and most of the retouched tools were made of chert. Again, the debitage was dominated by core flakes and contained fewer pieces of angular debris and biface flakes. The presence or absence of natural, weathered exteriors (**cortex**) on flakes was recorded. A close examination in the laboratory of the top of each flake indicated whether it had been struck directly from a cobble with cortex or from a core without cortex. It turned out that there were relatively more quartzite flakes removed from cobbles than there were chert flakes removed from cores. This matched the data collected in the field. Of the few retouched tools recovered during the test excavations, most were retouched flakes, and all of the bifaces were made of chert, indicating the importance of this material type for producing retouched tools.

Overall, it appears that four separate reduction trajectories are represented:

1. Tested cobble to cobble uniface to flake
2. Tested cobble to flake core to flake
3. Tested cobble to bifacial core to flake
4. Split cobble to unidirectional/bidirectional/multidirectional core to flake

Trajectories 1 and 2 were primarily used to work quartzite, and Trajectories 3 and 4 were often used for chert. The bifacial cores seemed to represent very large and roughly shaped bifaces from which flakes could be removed from their broad, flat surfaces.

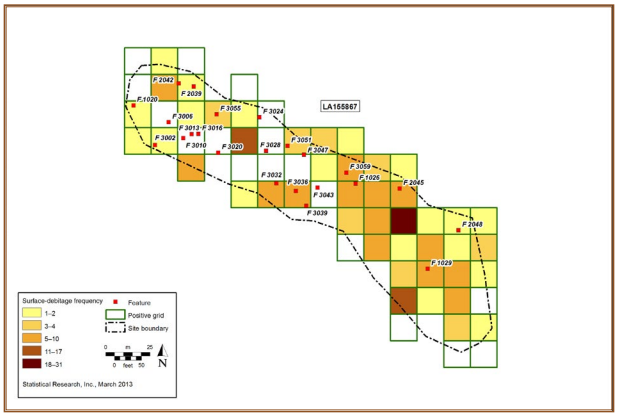
Quartzite flakes from the Crow Flats site.

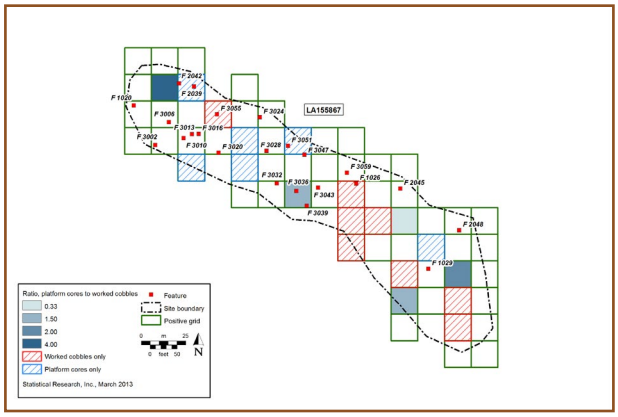
Tool Use, Maintenance, and Discard

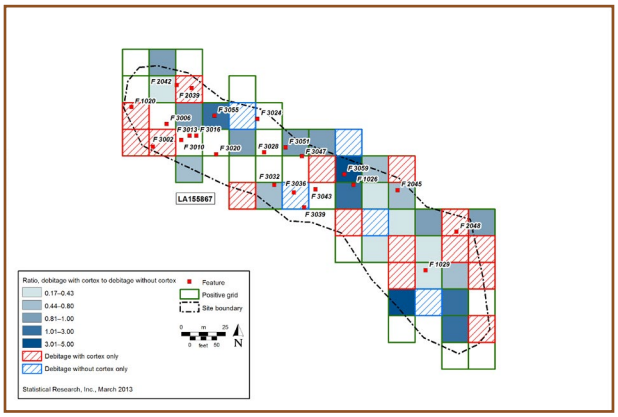
Each tool found during this survey was used for a period of time, during which it may have been resharpened before eventually being discarded. Determining the length of time between a tool's initial use and its later discard is important. Why? Because short-lived tools would naturally be discarded and replaced more frequently and therefore be more abundant at archaeological sites. In contrast, longer-lasting tools, discarded less frequently, would naturally be rarer in the archaeological record. So, how common an artifact is in an assemblage does not necessarily imply how important its use was but might simply imply the length of time that it was used.

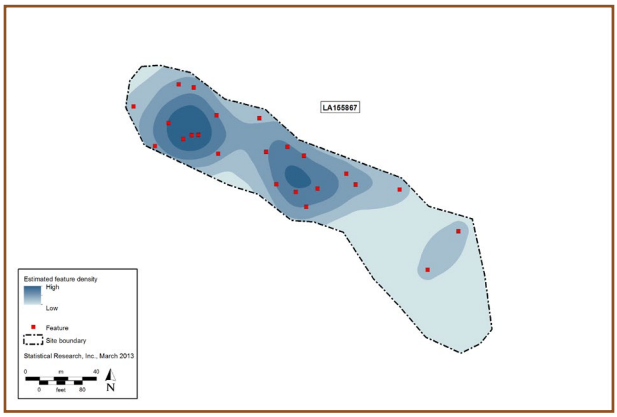
As previously noted, very few tools were actually found at the rock sources we visited. Most of them were chipped stone tools that had been used for relatively simple tasks (retouched flakes, for example), and some had been broken and discarded during the manufacturing process (bifaces, for example). It appears that most of the items manufactured at the rock sources had been removed and taken to other locations, although that may have been the case more often for artifacts made of chert than for those made of quartzite. That is, items manufactured at the sites were mostly retouched tools with longer use lives (as opposed to simpler tools with shorter use lives). In fact, we did not find any exhausted tools that had been broken and resharpened until they were no longer usable. Such items are especially informative to archaeologists, because they were presumably made of materials obtained at some distance from the site and would therefore provide some idea of the distance traveled between the raw-material source and the site where the artifact was found. But the evidence in our study seems to indicate that chert bifaces were often manufactured at the source and then taken away.

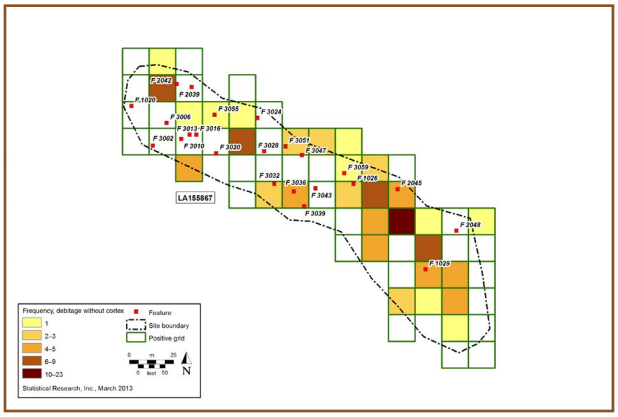
In archaeology, context is everything. *Where* an artifact is found is at least as important as *what* the artifact is. Together, the locations of all the artifacts at a given site can give us a more complete picture of how the site was used, how many times it was used, and for how long. The next section describes the results of our spatial analysis, the patterns that emerged, and what those patterns could mean.

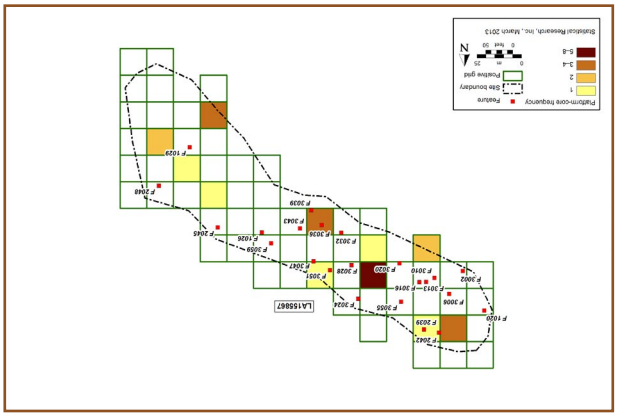












A picture is worth a thousand words. Archaeologists use maps like these (of the Last Chance North site) to visualize how each kind of artifact is distributed across a site. Isolating particular artifact types and keying them by color helps bring to light patterns that may lie hidden in numerical data.

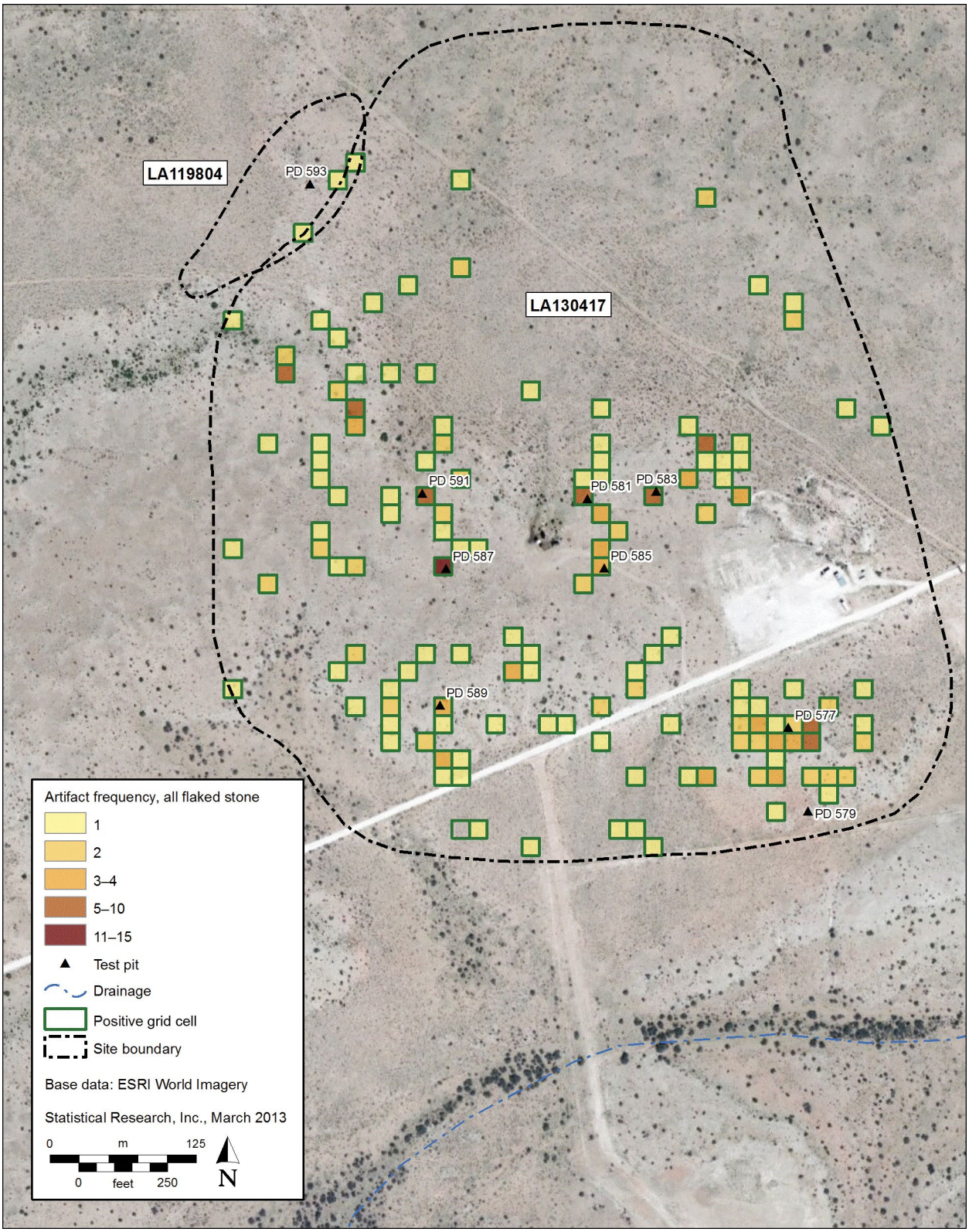
Site Structure: Three Distinct Patterns

Any given raw-material source is likely to have been periodically revisited over time, resulting in a series of successive occupations that could have overlapped with each other and extended over very large areas. How can we distinguish these occupations from each other? Probably the best way is to conduct a site-structure study—that is, collect data about the spatial distribution of artifacts and archaeological features across a site or survey parcel and see whether we there is any clustering that could represent separate occupations. To identify such spatial patterns, it is useful to map sites on a grid. Each site in the study area or survey parcel was divided into 15-by-15-m squares, and artifacts were analyzed with respect to this grid. In all, 4,717 of these grid cells were investigated, of which 824 (17.4 percent) turned out to contain artifacts.

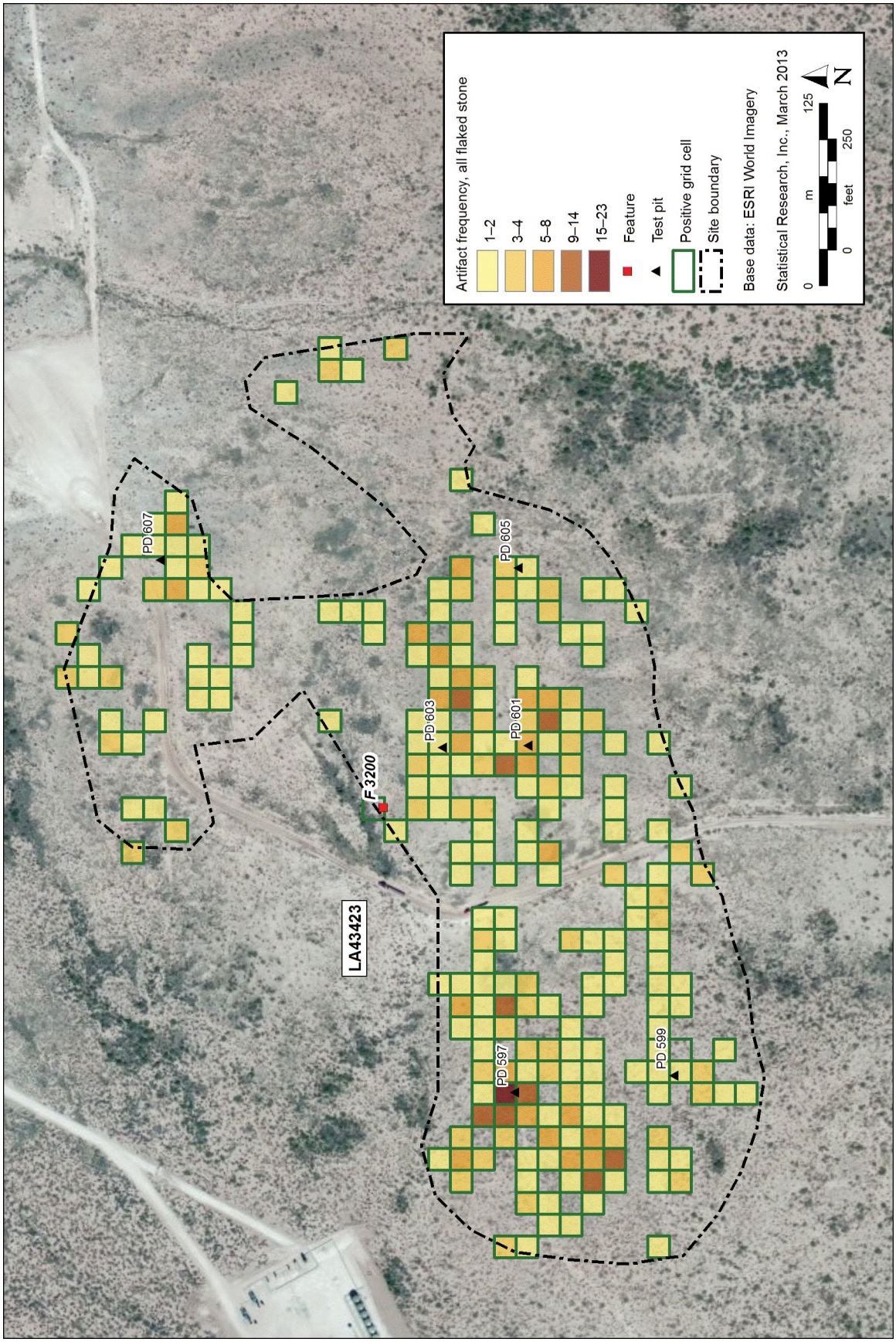
Site Structure

We identified three kinds of spatial patterns in our study of the sites and survey parcels. In the first, artifacts were scattered fairly evenly across the ground surface, with no obvious clustering. This pattern was identified at six sites and appeared to represent limited use of the site area (at the Dunnaway Divide site, for example)—in other words, single individuals working a few cobbles.

Overview of Dunnaway Divide Site.



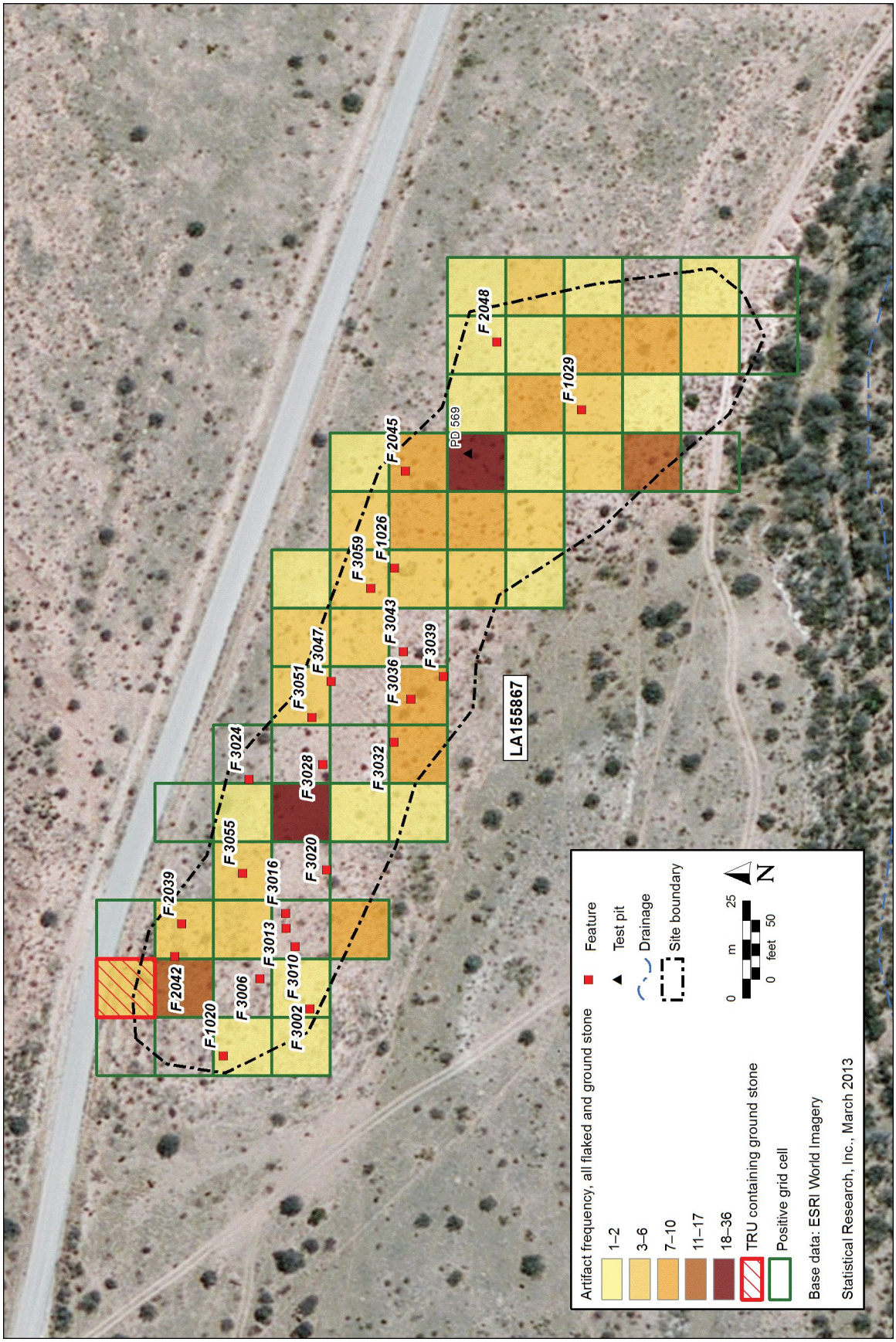
Site with no artifact clustering: Dunnaway Divide.



Site with artifact clustering: Tucker Draw.

The second pattern consisted of one or more distinct clusters of artifacts. This pattern was also seen at six sites. Presumably each cluster represents different groups coming to the site over time and working cobbles. Clusters were found directly on top of bedrock outcrops, on gravels, and on ridges or hilltops. In some cases, the clustering appeared to be the result of **deflation** or erosion artificially grouping artifacts together. In that case, the artifacts may have been sorted by size, because the smaller items would have been transported downslope and deposited at some distance from their original locations. At the Tucker Draw site, worked cobbles tended to be dispersed across the site but cores were more clustered. This could indicate that cobbles were initially worked among the gravels and then carried back to a central location for further reduction and tool production. Also, chert and quartzite artifacts were distributed differently. Most of the chert was worked in the western section of the site, while quartzite was spread relatively evenly over the entire area. This probably reflects the same pattern—quartzite cobbles were broken where they were found and discarded in place, while chert was typically moved to specific activity areas.

Overview of Tucker Draw site.



Campsite with hearths and artifact clustering: Last Chance North.

A third pattern was observed at a single site that contained numerous hearths and discrete activity areas: Last Chance North, which appeared to be a campsite that had been occupied numerous times. Artifact clusters and hearths were found mostly in the northwestern part of the site, which was probably the location of a series of households and domestic activity. Ground stone artifacts appropriate for seed processing and cores for tool production were found here, both supporting this interpretation. The southern area of the site contained evidence that cobbles had been worked there, including debitage that still retained much of its cortex. It appears that the site was divided into two distinct areas—one for domestic activities (a campsite) and the other for working cobbles (a work area).

Overview of Last Chance North site.

Conclusions: Adding a Piece to the Puzzle

BLM archaeologists working in the region have formally expressed two research needs: the need to identify where the prehistoric population acquired stone to make tools and the need to better understand what exactly these people did at these locations; this project was a step toward addressing these needs. We visited 19 different places that we know were used by prehistoric New Mexicans. By examining and describing the geology (that is, the available rock types) and archaeology (what people did with these rocks) of these places, we have helped to expand the boundaries of what we know about this land, thus providing greater context for future researchers and making their findings all the more informative.

Both the in-field and laboratory analyses provided some important insights into the nature of the 19 raw-material-source locations. Overall, chert and quartzite appeared to be the primary materials that could have been used to manufacture stone tools. Obviously, the presence of stone raw materials attracted people to the these areas, where they worked chert from bedrock outcrops or chert and quartzite from surface gravels. Chert was primarily used to produce chipped stone tools, and most of the quartzite appeared to have been used to produce simple flakes. The chert tools were subsequently taken away and used at other places, but it is unclear whether the quartzite was primarily used at these locations or was also removed.

The spatial analysis revealed three different patterns of site use. One group of sites showed little to no patterning; these sites were characterized by diffuse scatters. Another group was characterized by one or more clusters of artifacts per location. It is safe to say that sites and survey parcels in the first group experienced very little use, whereas those in the second group were occupied for extended periods of time, as evidenced by the distinct locations in which cobbles and cores were worked. The single, extensive apparent campsite, Last Chance North, was characterized by a series of occupations and could be divided into two areas. The families lived in the northern part of the site and used the southern part of the site to work cobbles. Overall, these locations represent a continuum from very short-term-use sites to seasonally occupied residences.

The difficult question to answer is, who were the people visiting these locations? The problem is that we found no diagnostic artifacts—that is, artifacts that could provide any indication of when the locations were occupied. No projectile points or pot sherds were found that could be used to roughly date the occupations, nor was there any charcoal remaining in the hearths that could be subjected to radiocarbon dating. We cannot say definitively who the people occupying these sites were. The large campsite may have been occupied seasonally by hunter-gatherers during the course of their annual movements through the region. The locations with one or more artifact clusters may have been temporarily occupied by a few farmers from the Pecos River collecting rock. The locations with only sparse scatters could have been used by people who briefly traversed the area during any time

Project geologist recording data near the Pecos River.

period. These are only preliminary interpretations—informed speculation—in need of further research. The next step in the process would be to compare and contrast these sites and survey parcels with others in the region.

But an archaeological survey doesn't have to identify who exactly occupied an area to improve our understanding of that area. In a project such as this, the archaeologist's role is relatively humble. Rather than assembling all the puzzle pieces into a satisfying, coherent whole, we simply add a piece to the greater picture, filling in some blanks but also indicating where other information is required. Our documentation of rock sources in the region will help other researchers add their own pieces. In this way—slowly, cumulatively, and cooperatively—we create a clearer and clearer picture of prehistoric life in southeastern New Mexico.

Glossary

Angular debris: Broken fragments that are the by-products of working cores.

Arrow: A stone point hafted onto an arrow shaft.

Assemblage: A collection of artifacts.

Biface: Any of a variety of stone tools that has been worked on both sides.

Caliche/calcrete: A calcium-carbonate-cemented **horizon** that forms as a result of a perfect mix of precipitation and temperature during soil formation.

Chipped stone: An artifact manufactured by removing small pieces to make a finished item.

Cobble biface: A cobble that has had flakes removed from both faces at one end.

Cobble uniface: A cobble that has had flakes removed from a single face at one end.

Cobbles: Loose gravel that is 64–256 mm (or $2^1/_2$–10 inches) in diameter.

Conchoidal fracture: The fracture of a rock along a surface that creates ripples resembling those of a mussel shell.

Core: A piece of rock from which pieces have been intentionally removed to manufacture stone tools.

Cortex: The natural weathered exterior surface of a nodule or cobble.

Dart: A stone point hafted onto the end of a spear.

Debitage: The pieces that are produced as by-products during the manufacture of stone tools.

Deflation: Scouring by wind; erosion of loose sand and other particles.

Deposition: Any of the processes by which transported material is laid down and added to the landscape or a landform.

Direct procurement: Going directly to the lithic source with the intention of collecting rocks.

Drainage: The route that water takes when it flows off a given area and into streams and rivers.

Drainage basin: A specific area that contributes water to a stream or river.

Embedded procurement: Collecting lithic materials while conducting other hunting and gathering activities.

Flake: The pieces removed from a core or tool during the manufacture of a stone tool.

Flint: A type of chert; used generically in the term "flint knapping."

Flint knapping: The suite of techniques used to shape stone into tools by striking strategically to remove material; particularly, the techniques that would have been used in prehistory.

Fluorescence: The colors observed when a rock is exposed to ultraviolet light.

Foliated: structured in successive layers

Foraminifera: Small, single-celled organisms that live in the ocean and form their shells from calcium carbonate.

Formation: A particular **geologic unit**, such as the San Andres Formation; a formation may be subdivided into **members** or, in turn, be part of a **group**.

Fusulinid: Any of a group of small, extinct marine organisms (each about the size of a grain of rice) with shells that are often found fossilized and are thus useful in geology.

Geologic unit: A distinctive unit of bedrock large enough to plot on a geologic map (see **formation**).

Geomorphic surface: A distinct portion of land surface, such as a terrace, formed by erosion, deposition, or both.

Geomorphic unit: A specific surface landform type.

Gravel or gravel lag: Unconsolidated, generally smaller rocks scattered on the surface of a landscape.

Ground stone: An stone artifact that was used as a grinding implement and/or was manufactured by grinding.

Hammerstone: A battered rock that was used as a hammer.

Horizon: A rock or soil unit that has a specific position in a stratigraphic sequence.

Hunter-gatherers: People whose livelihood depends on hunting and the gathering of wild plants.

Incised: Cut by flowing water.

Indirect procurement: Obtaining rocks or tools from someone else.

Knappable: Refers to the quality of stone material and how easily it can be worked into tools.

Lithic: Made of or having to do with stone or rock.

Locally deflated: A specific area that has been affected by deflation.

Loess: Wind-blown silty or loamy material.

Member: A distinctive subdivision of a **formation**.

Milling stone: A flat stone used to grind seeds.

Nodule: A rounded mass that is distinct from the surrounding rock.

Pebbles: Loose gravel that is 4–64 mm (or $^1/_5$–$2^1/_2$ inches) in diameter (smaller than cobbles).

Pediment: A gently dipping surface of rock or loose gravel that gets formed as a bedrock outcrop erodes and retreats.

Pestle: An oblong-shaped stone used with a vessel (called a mortar) for pounding or rubbing.

Porphyritic: Igneous rock with two significantly different crystal sizes (such as porphyritic andesite).

Precontact: prior to first contact between Native Americans and Europeans

Projectile point: A dart or arrow point.

Reduction trajectory: The sequence involved in producing a stone tool.

Retouch: The removal of smaller flakes from a primary flake (the flake struck off a core) to produce the final shape of a stone tool.

Retouched tools: Chipped stone tools that have been manufactured by retouch.

Silica: A chemical compound (silicon dioxide) which is present as a component of many minerals, including

quartz and opal; it dissolves into groundwater as minerals are weathered; contributes to cementation by binding together grains of other minerals.

Silicification: Refers to the process whereby silica enters the pore spaces in a sedimentary rock (for example, through groundwater) or whereby the cells in ancient wood are replaced by silica, creating petrified wood.

Tectonism: The deformation process that results in the structures of the earth's crust.

Terrace: a step-like landform

Terrace deposit: The rock and soil that makes up the bench along a stream or river.

Test pits: small holes, systematically arranged and placed at sites to test for the presence, depth, and extent of subsurface artifacts or other cultural material; also used to record information regarding soils.

Tested cobbles: Cobbles that have only one or two flakes removed.

Thunderbird rhyolite: A distinctive black rhyolite with pink inclusions originating in the Thunderbird Formation, Franklin Mountains, Texas.

Trace elements: Elements that make up very minor portions of a rock.

Uniface: A chipped stone artifact that has been worked on one side.

Worked cobbles: Cobbles that have been struck with a hammerstone.

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Notes

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