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THE GEOARCHAEOLOGY OF DAY CREEK CHERT:

LITHOSTRATIGRAPHY, PETROLOGY, AND THE INDIGENOUS LANDSCAPE

OF NORTHWEST OKLAHOMA AND SOUTHWEST KANSAS

A Dissertation

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

Doctor of Philosophy

By

BERKLEY BARNETT BAILEY
Norman, Oklahoma
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LITHOSTRATIGRAPHY, PETROLOGY, AND THE INDIGENOUS LANDSCAPE
OF NORTHWEST OKLAHOMA AND SOUTHWEST KANSAS

A Dissertation APPROVED FOR the
Department of Anthropology

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Finally, I owe my wife, Dr. Martha Lou McCollough the greatest gratitude. She lived through this project, remained mentally intact and, never lost faith in me.

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ABSTRACT

This research is designed to investigate the geoarchaeology of Day Creek chert. Located in the southern Great Plains of the United States, Day Creek chert supplied an important lithic raw material for prehistoric populations. Given the enormous confusion that has existed concerning the lithostratigraphic placement of the Day Creek Dolomite, emphasis has been placed on providing an accurate geologic profile contained within the Cloud Chief Formation. Factors contributing to the formation, exposure, and acquisition of Day Creek chert are addressed with commentary concerning the fluvial geomorphology and climatic variation that has waxed and waned on the Great Plains since earliest Permian Period times.

Given the variation in geomorphology of the region, due in part to variant lithostratigraphic exposures, discussion of local and allochthonous chert resources is provided. Investigation of petrological differences pertaining to Day Creek chert and allogenic chert suggests that instrumental neutron activation analysis can assist with providing a signature for unrelated lithic raw material resources.

Examination of quarries, workshops, archaeological sites, and private lithic collections suggests that Day Creek chert was heavily utilized during the Archaic Period. Subsequent occupations appear to rely more heavily on allogenic chert, suggesting changes in human behavior specific to direct acquisition, trade, and/or mobility during the Late Prehistoric Period.

Chapter I: INTRODUCTION

Using middle-range theory and methodology, as defined by Lewis R. Binford (1981, 1982:5-31, 1983, 1985:580-90, 1986:547-62), this study examines the geoarchaeology (Gladfelter 1981:343-64; Hassan 1979:267-70) of Day Creek chert. Located within the Day Creek Dolomite Bed of the Cloud Chief Formation, Day Creek chert represents a highly heterogeneous lithic raw material. The geographic placement of the lithostratigraphic outcrops of Day Creek chert, stretching from northwest Oklahoma into southwest Kansas, firmly places this chert into the hinterland, with respect to, known, high-grade, lithic raw materials found elsewhere on the Great Plains (Figure 1). I emphasized the examination of *in situ* Day Creek chert outcrops in Harper County, Oklahoma and Clark County, Kansas (Semenov 1985) (Figure 2).

The lithostratigraphies and attendant nomenclatures, which have been historically used to describe the Day Creek Dolomite, remain in serious scientific error (Bailey 1998:192-3). As a result, archaeological data incorporating lithic raw materials as a basis for trade, exchange and movement could be in error. Day Creek chert is visually very similar to other lithic raw materials throughout the Great Plains. This study is designed to contribute, through an analytical process, determination of the ultimate lithostratigraphic origin and dispersal of southern Great Plains lithic raw materials (Banks 1984:65-95, 1990).

Extensive emphasis is placed on the fact that the Day Creek Dolomite (with *in situ* Day Creek chert) is ***not*** a lateral equivalent of Alibates agatized dolomite. Furthermore, neither lithic raw material has any, Late Permian Period, lithostratigraphic relationship (Fay et al. 1962). The use of subjective lithologies (e.g., colors, textures, inclusions, etc.), by archaeologists (Torrence 1989), to detect lithic raw material source, are non-analytical and typically require reexamination. Petrological and lithological analysis proves that Day Creek

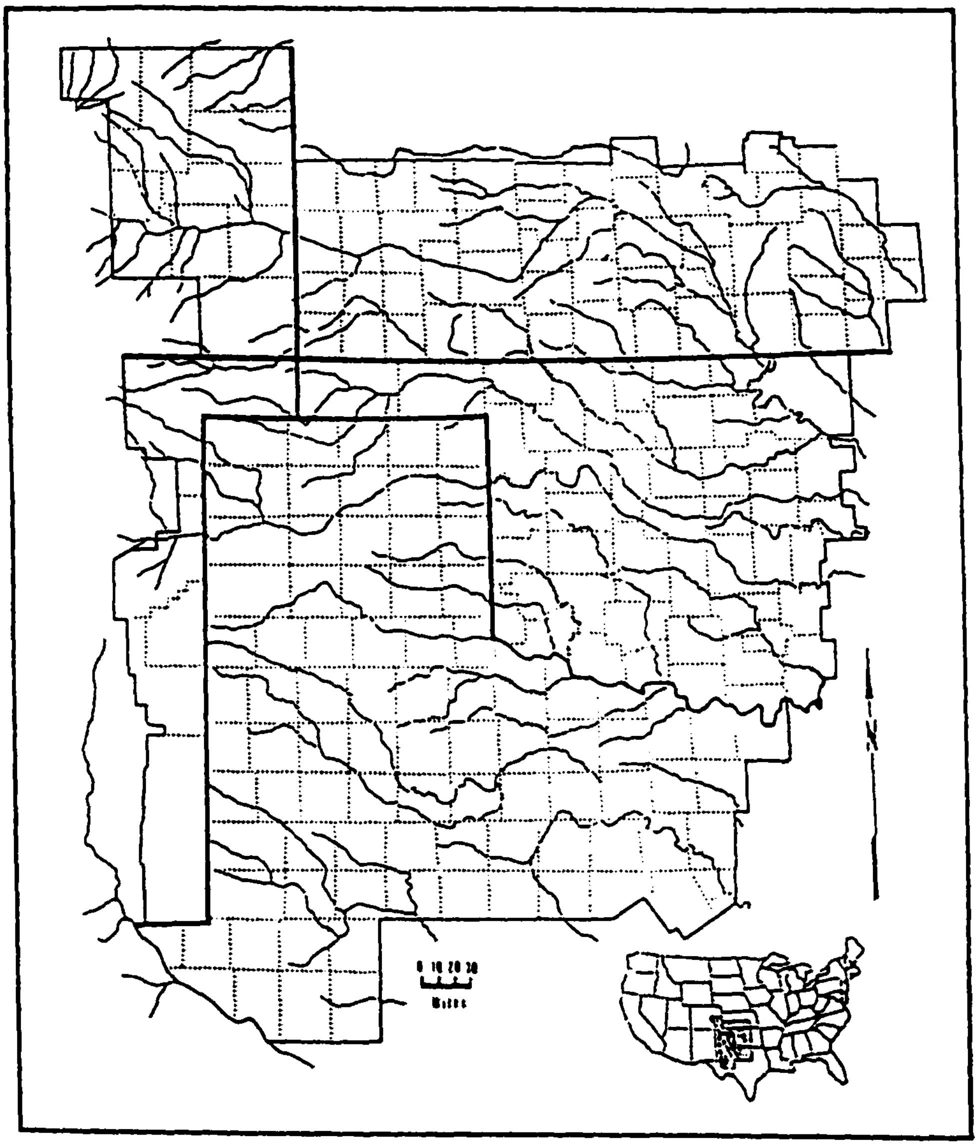

Figure 1. The Southern Great Plains Study Region (adapted from Brooks and Hofman 1989:2)

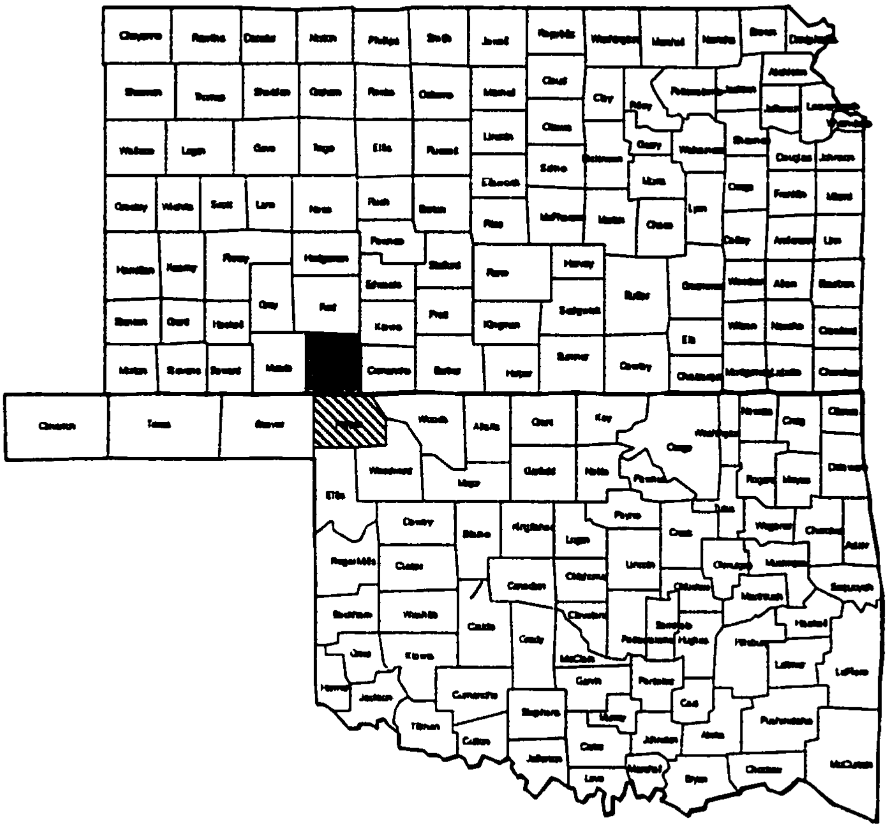

Figure 2. The location of Harper County, Oklahoma and Clark County, Kansas

chert exhibits a tremendous amount of heterogeneity and, when coupled with allochthonous lithic raw materials, becomes extremely difficult to distinguish by geologically sophisticated, analytical tools (Bakewell 1995). This situation has significant impact on the common use of lithic raw material source for the investigation of prehistoric trade, exchange (Morrow and Jefferies 1989:27-33), and/or mobility (Lurie 1989:46-56) throughout the Great Plains (Andrefsky 1994:21-34; Bailey 1990; Blikre 1993), Southwest (Baugh 1987:313-29; Baugh and Nelson 1987:313-29, 1988:74-94;), and North America (Baugh and Ericson 1994; Purdy 1984:119-127).

My use of theoretical archaeological landscape models (Fish and Kowalewski 1990a, 1990b; Rossignol and Wandsnider 1992) suggests that Day Creek chert has been extensively used for a variety of purposes, resulting in quarries and lithic raw material reduction workshops, ranging in size from square kilometers to less than a single square meter (Camilli 1989:17-26). Location and acquisition of Day Creek chert, by prehistoric and/or historic populations, are dependent on complicated environmental and behavioral factors (Lurie 1992:46-56). For example, lithic reduction strategies remain geared, differentially (Jeske 1989:34-45), toward a particular grade of Day Creek chert for specific stone tool tasks (e.g,, Calf Creek point type, Clear Fork gouge type, etc.) Based on my field observations, reduction and production of technologically complicated stone tools required the periodic use of thermal alteration before construction of task-specific tools. This reality, when viewed from the perspective of Taylor (1964), suggests an greater Archaic Period emphasis (e.g., tethered nomads, etc.), on Day Creek chert in northwest Oklahoma and southwest Kansas (Steward 1955).

It should be noted that the Day Creek chert quarries and workshops do not lend themselves to a clear placement within the southern Great Plains chronology (Richerson 1977:1-26). Therefore, limited data obtained from surveys conducted well outside of the *in* *situ* Day Creek chert are important. This information provides a temporal datum for prehistoric occupations in northwest Oklahoma and southwest Kansas.

My field observations concluded that access to high-grade Day Creek chert, during any period of prehistory, required an in depth knowledge of the extremely dynamic geomorphology of the region (Fay 1959). Northwest Oklahoma and southwest Kansas contain deeply stratified salt beds within the Blaine Formation (Fay et al. 1962). Since the Permian Period, subsurface dissolution of Blaine Formation salt beds has contributed to the evolution of the regional landscape on a *daily* basis. As a result, the present-day appearance of quarries, workshops (Sullivan et al. 1985:755-88) and, available lithic raw materials contained within the Day Creek Dolomite (Cloud Chief Formation, Fay 1959, 1965; Fay et al. 1962; Fay and Hart 1978), does not reflect Late Pleistocene/Holocene conditions (behavioral, biological, and/or geological) when the outcrops were actively mined for *in situ* Day Creek chert (Bamforth 1988; Ericson and Purdy 1984; Hofman et al. 1989; Hall 1982:391-407, 1983:15-46, 1985:95-123, 1988:203-17, 1990; Hall and Lintz 1984:129-33; Torrence 1986) and/or allogenic alluvial chert (Sappington 1984:23-34).

Additionally, it is important to note, that, following the orogeny (Tertiary Period) of the Rocky Mountains, the eastward regional geomorphology deposited extensive alluvial gravel, mixed with chert's of unknown lithostratigraphic origin. However, subjectively, many alluvial cherts are lithologically identical to known, lithostratigraphic sources. For the well-trained, region-specific, archaeologist, it is possible to identify some alluvial cherts to lithostratigraphic origin (Wyckoff 1989:405-52, 1993:35-58). Determination of lithostratigraphic source for specific types of alluvial gravel, containing allochthonous cherts, remains extremely difficult without advanced geochemical analyses (Odell 1989:159-82).

Therefore, my geoarchaeological research was primarily directed toward the lithostratigraphic investigation of Day Creek chert; beginning with its primary diagenesis

(Late Permian Period), and subsequent availability (Late Quaternary Period) for creation of chipped stone tools (Straus 1991:169-86). Extensive efforts were undertaken in the field and laboratory to locate quantitative, analytical tools which would ultimately distinguish Day Creek chert from every allochthonous chert, within the region of northwest Oklahoma and southwest Kansas. To date, the only successful quantitative tool for *signatory* determination of Day Creek chert petrologies, is through "Instrumental Neutron Activation Analysis" [INAA] (Church 1994, and references cited therein). Analytical data concerning visual and physical characteristics of Day Creek chert are addressed in this document.

For lithic raw material identification, my research proves that, *subjective*, lithological characteristics of primary cherts, within the region of the Great Plains, are not sufficient for *ultimate* determination of lithostratigraphic source (e.g., Alibates agatized dolomite, Day Creek chert, Edwards Formation flint, Baldy Hill jasper, etc.). Until we, as archaeologists, know the true, quantitative, lithostratigraphic origin of the lithic raw material resources used by prehistoric populations, our current perspectives on prehistory (e.g., trade, exchange, mobility, etc.) will remain seriously flawed (Sullivan and Rozen 1985:755-88). Clarification of the lithostratigraphic sources for lithic raw materials on the Great Plains will contribute towards a more complete understanding of prehistoric trade, mobility and exchange (Steward and Murphy 1977).

Chapter II: CURRENT ARCHAEOLOGICAL INVESTIGATIONS OF DAY CREEK CHERT WITH SPECIFIC EMPHASIS TO METHOD AND THEORY

> Theories are the key to the scientific understanding of empirical phenomena, and they are normally developed only when previous research has yielded a body of information, including empirical generalizations about the phenomena in question. A theory is then intended to prove deeper understanding by presenting those phenomena as manifestations of certain underlying processes (adapted from Binford 1981:25, Hempel 1977:244).

My choice to utilize Binford's (1981) middle-range theory approach, coupled with the theoretical archaeological landscape approach (Cowgill 1990:249-60; Fish and Kowalewski 1990; Rossignol and Wandsnider 1992), is consistent with the formation of a fundamental understanding of the archaeological record, and/or prehistoric site signature on the landscape in northwest Oklahoma and southwest Kansas (e.g., Hofman 1992, 1994)

Upon my arrival to the University of Oklahoma from the University of Alaska-Fairbanks in 1989 (Bailey 1992), I was employed as a research assistant with the Oklahoma Archeological Survey in Norman. My first assignment was to differentiate hundreds of surface-collected artifacts, according to lithic raw material, from Cedar Creek, Oklahoma (Bailey 1990; Hofman 1990:19-23). The methodology I was instructed to use was basic: If the artifacts' construction was stone and it roughly looks like a particular sample of known lithostratigraphic source, then record the sample according to subjective lithologies (e.g., lithologies congruent with Alibates agatized dolomite should all be called Alibates agatized dolomite). This methodology eventually became difficult, due to the wide range of lithologies for any lithic raw material, regardless of geographic loci. As a result, I attempted to identify the allochthonous cherts located within the regional landscapes of the Dissected Red Hills, and High Plains (Figure 3). I began this project through thorough geologic literary research, field investigations, and extensive consultations with Dr. Robert Fay (Oklahoma Geological

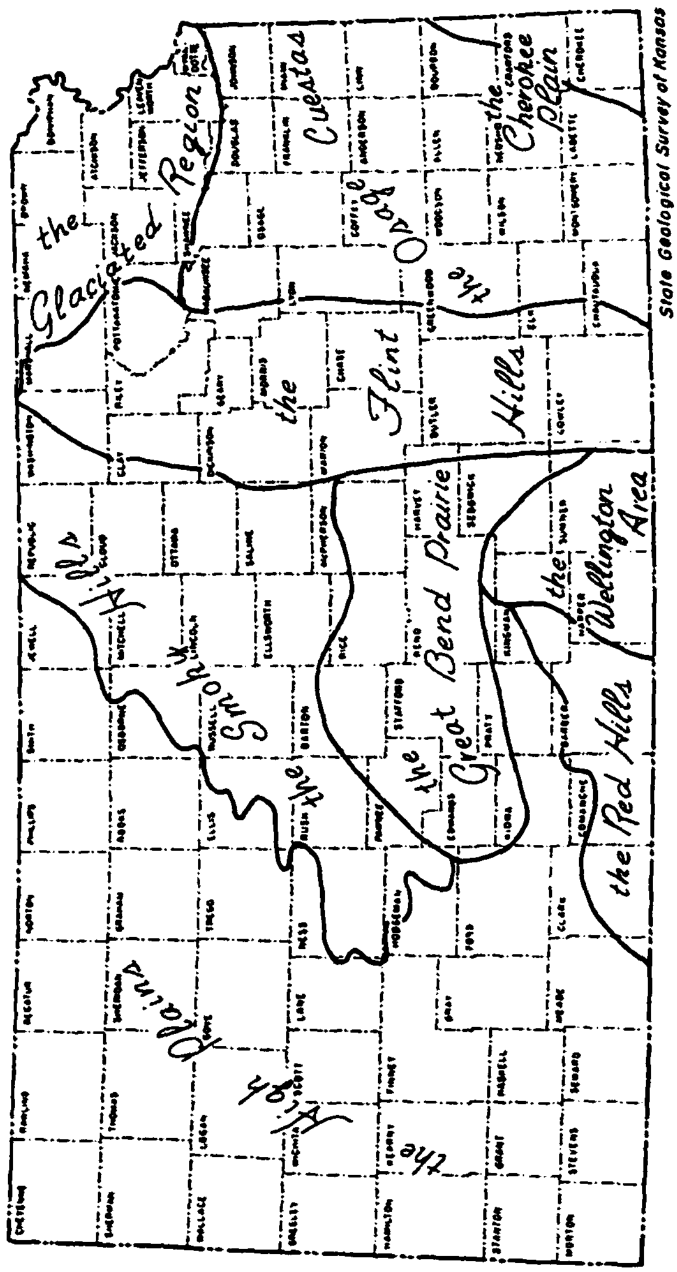

Figure 3. The Surface Geomorphology of Kansas

Survey, Norman) and Dr. David Loope (Department of Geology, University of Nebraska-Lincoln).

On March 13, 1991, this study initially began as a basic investigation of one Day Creek chert workshop in northwest Oklahoma (Salyer site [34HP40]). Upon my arrival at 34HP40, (19.31 km north of Buffalo, Oklahoma), I was impressed by the magnitude of quarries and workshops (Figure 4). Day Creek chert quarries and workshops have an immense signature on the landscape, defined by differential lithic raw material reduction strategies (Jeske 1989:28-45), which roughly follows the outcrops of the Day Creek Dolomite (Cloud Chief Formation). During pedestrian and/or equestrian surveys, I noticed that lithic reduction trajectories differed. In many instances they were associated with due to differences within the lithic raw material. It became obvious that Day Creek chert does not contain a uniform lithology (e.g., color, texture, granularity, etc.). With these observations, I am convinced that the hundreds of artifacts I classified at the Oklahoma Archeological Survey, based on lithologies alone, remain entirely in error, and do not reflect actual lithostratigraphic origins (Bailey 1990).

In 1992, I returned to the Salyer site [34HP40] and performed a detailed pedestrian survey of the location. Site 34HP40 is on report with the Oklahoma Archeological Survey, and within the site description, static archaeological site boundaries have been established. In reality, 34HP40 is much larger than suggested in the original site report. The Salyer site represents many thousands of discreet lithic reductions, distributed over an area that is in excess of six kilometers. This site also contains *in situ* Day Creek chert within the Day Creek Dolomite that, with respect to lithologies, are identical to Alibates agatized dolomite, Edwards Formation(s) chert, and Tecovas chert. (Schmid 1986:1-5; Trierweiler 1994 and references cited therein). Given the magnitude of archaeological resources in a circumscribed region, I limited my research from northern Harper County, Oklahoma into northern Clark

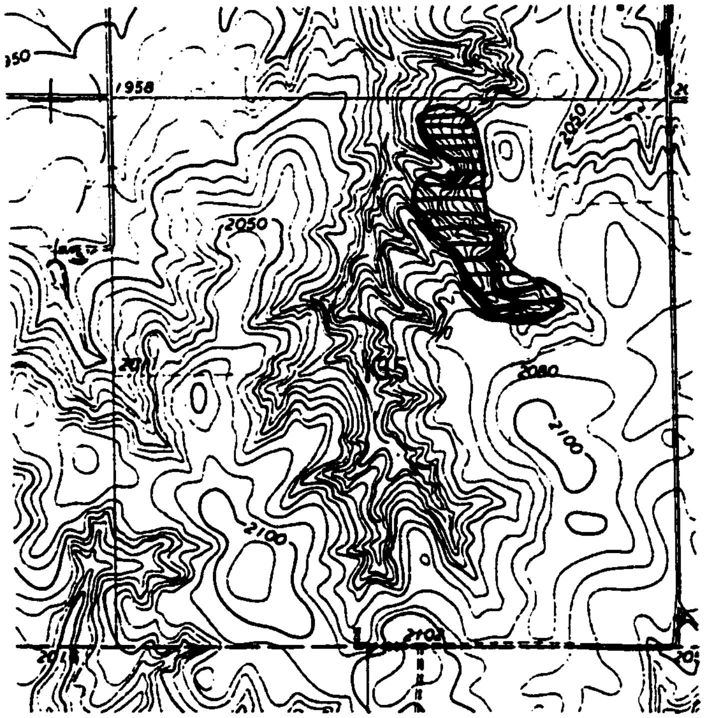

Figure 4. The Salyer Site, 34HP40 [Buffalo NW Quadrangle; Sec. 35, T. 29n, R. 23w]

County, Kansas. Additional field investigations (via vehicular, pedestrian, and equestrian transport) were conducted in Ford, Kiowa, Meade, and Comanche counties, Kansas, for the purpose of determining the areal extent of prehistoric transport of Day Creek chert away from the *in situ* Day Creek Dolomite (Cloud Chief Formation).

THE EMPLOYMENT OF ARCHAEOLOGICAL METHOD AND THEORY FOR THE INVESTIGATION OF DAY CREEK CHERT

With my complete agreement concerning Binford's (1981:31-2) observations on the European Paleolithic archaeological record, he cautions:

> I attempted to show that Paleolithic archaeology developed in a situation where a specific concern for methodological research was not seen as separate from research conducted for purposes of learning about the past. Interpretations were largely developed post hoc or after discoveries had been made in the archaeological record. These procedures largely consisted of using inferences based on assumptions regarding the formation processes operative in the past or the conditions responsible for morphological properties or patterns of association observed in the archaeological record. Once such post hoc interpretations were offered and judged "probable" or plausible they frequently became conventions whereby additional observations at new sites were interpreted. Gradually a myth was built up about the past. The myth consisted of inferences drawn from unevaluated premises and its very scale of acceptance gradually became further justification for belief in the myth. Unfortunately, this remains one of our dominant "methodologies.

It is with this caveat that I began the study of the Late Permian Cloud Chief Formation. Contained within the Day Creek Dolomite of the Cloud Chief Formation, Day Creek chert has been afforded only sporadic archaeologic investigation without any serious attempts by archaeologists to understand the evolution of geologic lithostratigraphies in northwest Oklahoma and southwest Kansas. I quickly ascertained that with reference to the southern Great Plains, early lithostratigraphic myth has transformed into modern archaeologic theoretical and methodological myth.

My goals pursuant to this research were to initiate a geoarchaeological emphasis that would resolve the underlying question about the lithostratigraphic placement of Day Creek chert in the southern Great Plains. A major component of my study was to distinguish Day Creek chert from other non related lithic raw materials and remove the myth that many lithic raw materials have a lithostratigraphic relationship. By doing so, I have attempted to extinguish the myth that purely subjective lithologies of any lithic raw materials are sufficient to determine the ultimate lithostratigraphic source for typological stone tools and/or stone tool debitage. *Subjective* lithologies transform into lithic raw material source *realities*, often resulting with the investigator claiming to understand prehistoric trade, exchange, mobility, and ultimately, human behavior (Figure 5).

Binford's (1981) middle-range research, as a theoretical foundation to my research, was therefore initiated. Stated succinctly, Binford (1981:29) cautions:

> 1. All our statements about the past are inferences relative to observations made on the contemporary archaeological record.
>
> 2. The accuracy of our inferential constructions of the past is directly dependent on the accuracy of the assumptions or premises serving as the basis of our inferential arguments.

As previously mentioned, for the past quarter century archaeological research and publications confined to the southern and central Great Plains have utilized lithic raw material source as a means to investigate exchange (Baugh et al. 1994; Frison 1991; Earle et al. 1977) and mobility (Hofman 1991:335-56 and reference cited therein).

Binford's (1981) theoretical middle-range research approach was chosen following my investigations of the lithostratigraphies of Day Creek chert and Alibates agatized dolomite. For example, both lithic raw materials continue to be characterized as *lateral equivalents* by archaeologists, yet in reality, neither lithic raw material has any geologic association with one

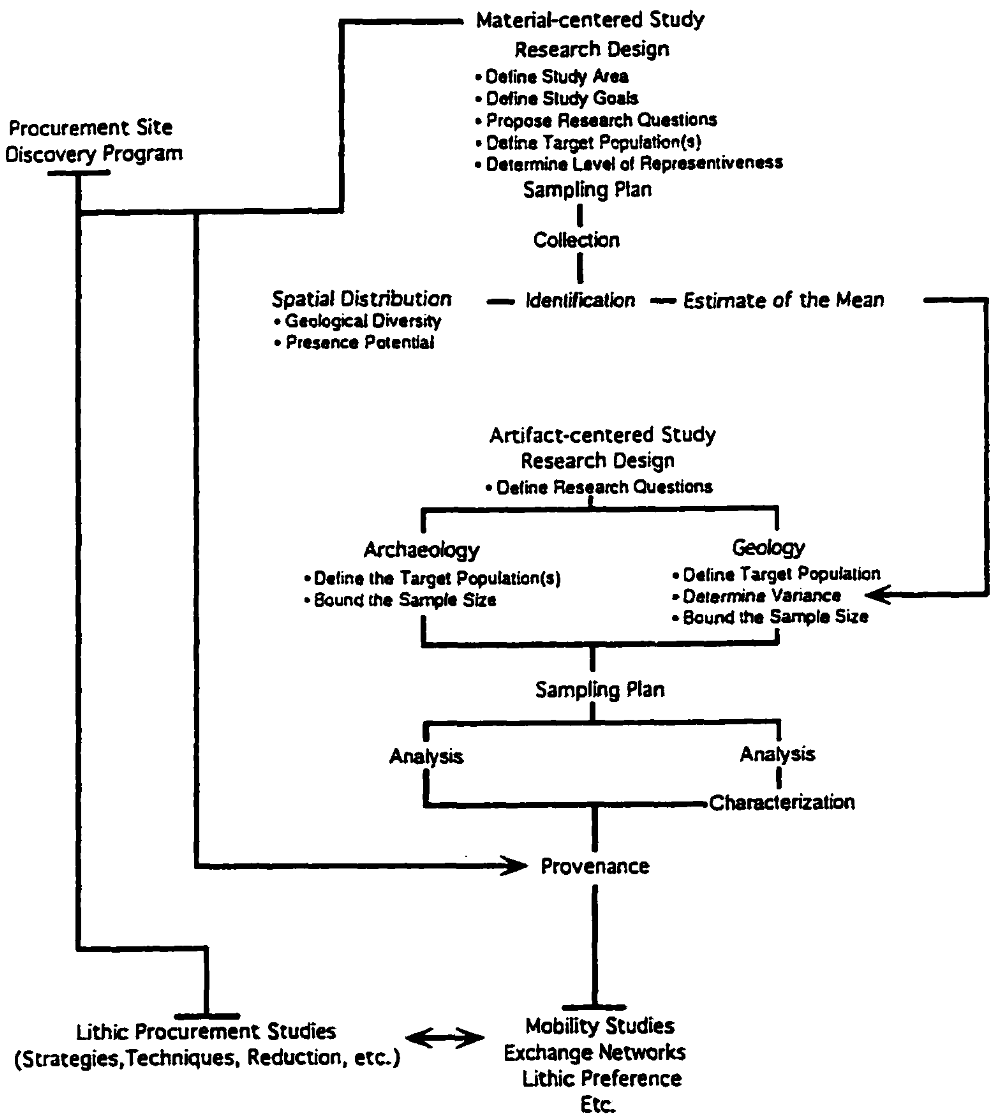

Figure 5. Generalized Flowchart for Lithic Resource Studies (adapted from Church 1994)

another; they are *not* lateral equivalents. In order for me to understand the lithic raw material resources, it required beginning with the primary geologic literary data, following its academic investigation and development for the past 130 years. Contemporary landscapes within the Dissected Red Beds and/or High Plains do not reflect prehistoric conditions when Day Creek chert was a primary source for stone tools. As I investigated the position of Day Creek chert in the Cloud Chief Formation, I learned that all aspects of the geomorphology of the region continues to rapidly evolve. Therefore, in order to understand why one outcrop of Day Creek Dolomite may show extensive prehistoric extraction of Day Creek chert, yet other loci, with identical lithostratigraphic characteristics, indicate no prehistoric utilization, I pursued a methodology that would detail the geomorphological evolution of the region since the Late Permian. The regional geomorphology of northwest Oklahoma and southwest Kansas has received cursory attention, particularly sedimentary deposits that are Quaternary in age (Hofman 1991:335-56; Wyckoff et al. 1991).

Binford's (1981) introduction of middle-range theory and methodology to the archaeological community was largely based on faunal remains. It is only the object of discussion (e.g., fauna versus lithic raw materials) that we depart from the question at hand; namely, what is the basis for our understanding of any archaeological resource and/or site? In the case of Day Creek chert, my inherent interests are to understand lithic raw material petrologies and the inclusive *determinants of patterning* (Binford 1981:32, 1985:580-90, 1986:547-62; Binford and O'Connell 1984:406-32) found at the quarry and workshop level. While Binford has reservations about formulating new ideas concerning human "behavior," I do believe that given my extensive examination of the Day Creek chert landscape in northwest Oklahoma and southwest Kansas, I can state with reasonable certainty what probable human behaviors are reflected in the quarry and workshop debris that I recorded throughout the region.

Attempts to ascertain the exact provenance of a given lithic raw material through geochemistry is certainly not a new avenue within geoarchaeological and/or stone tool typological research (e.g., Bush and Sieveking 1986:133-40; Hoard et al. 1993:698-710; Hofman 1991:335-56; Holen 1991:399-411; Holliday 1997). Metcalf et al. (1991) pursued an identical methodology that I followed for Day Creek chert. With regard to Kremmling chert procurement in Colorado [5GA1144 and 5GA1172], Metcalf et al. (adapted from 1991:7) formulated the following hypothesis:

> 1. Kremmling chert is sufficiently distinct for visual identification found in Middle Park and adjacent area sites.
>
> Data Needs. Representative sample of Kremmling chert from known sources, petrographic description of samples; identification of visual keys; comparison with samples of similar material from the area.
>
> Criteria for Acceptance. Kremmling chert contains visual or other landmarks distinctive only to the material.

With reference to Day Creek chert in northwest Oklahoma and southwest Kansas, I used an identical hypothesis as a focal point, in the same manner that Metcalf et al. (1991:1-107) hypothesized for Kremmling chert.

To this is added an initial exploration of geochemical characterization. Turnbaugh et al. (1984:129-38) attempted to track certain soapstone artifacts, via color, texture, mineralogy, thin-section petrography, and atomic-absorption spectrophotometry to their respective quarry source. The results of this investigation led Turnbaugh et al. (1984:137) to *promising results* but did not constitute the final quantitative methodologies for sourcing New England soapstone to original quarry sources.

My methodological approach, like the aforementioned Kremmling chert analysis, is to derive a geochemical *signature* for Day Creek chert which distinguishes it from known sources and/or alluvial gravel that are Tertiary and/or Quaternary in age (Sappington

1984:23-34). Therefore, I should be able to confirm the distribution, through trade, exchange, and/or direct acquisition, of Day Creek chert across the Great Plains landscape (Earle and Ericson 1977; Ericson 1984; Fish and Kowalewski 1990; Plog 1974, 1977:127-39, 1990:243-48; Rossignol and Wandsnider 1992 and references contained therein).

Temporal data concerning the majority of Day Creek chert procurement and processing is lacking (Briscoe 1979:907-22; Bryan 1950; Jochim 1989:106-11). While anecdotal clues (Leach 1984:107-18), through local private surface collections (Baker 1939:2-7; Beck and Jones 1994:304-15), have provided a rough framework towards understanding the dynamics of prehistoric use of this lithic raw material (Ahler 1986; Bailey 1983:1-6; Bamforth 1986:38-50; Reher 1991:251-84), no excavations (Redman 1987:249-65), and/or the landscape surveys (Kintigh 1990:237-42; Kowalewski 1990:33-86; Kowalewski and Fish 1990:261-77), provided sufficient quantitative data (Schlanger and Orcutt 1986:296-312) that would elucidate the principle culture(s) that created the vast workshops (Bettinger 1980:189-242; Holmes 1890, 1897, 1919; Luedtke 1984:65-76). Based on non-quantified data collected through regional surveys (Johnson 1989:119-38; Lewarch and O'Brien 1981:297-33), I am convinced that the majority of quarries and workshops date from the Archaic period (Bell 1984; Hofman 1989:25-60; Hughes 1984:109-16; Kay 1998:173-200; Kelly 1995; Schlesier 1994; Wedel 1961; West 1983:364-82; Wood 1998).

Chapter III: FLUVIAL GEOMORPHOLOGY AND CLIMATIC VARIATION ON THE SOUTHERN GREAT PLAINS

The study of fluvial systems and their combined effect on the geomorphology of a given area has long been understood as a dynamic process. Simply and succinctly stated:

> A river or drainage basin might be considered to have a heritage rather than an origin. It is like an organic form, the product of a continuous evolutionary line through time (Leopold et al. 1964:421 cited in Dolliver 1984:6).

This statement is a useful characterization of the surrounding landscape as well. Changing "surface geology, landscape and drainage network morphology, climate, vegetation and hydrology" (Dolliver 1984:5) contribute immensely to the present landform, and work in conjunction with one another to create a given geomorphology at a particular time and place. Landscape dynamics have an effect both on the occurrence of lithic raw materials and the occupants that utilized the area as part of their subsistence rounds. In the region of northwest Oklahoma and southwest Kansas, it will be shown that fluvial geomorphology played a key role in the utilization of the landscape by prehistoric populations, and in many ways, was instrumental for those inhabitants to successfully adapt to quickly changing environmental conditions (Albert and Wyckoff 1984:1-43; Alland and McCay 1973:143-78).

Although the focus here is Quaternary in time, it is necessary to briefly discuss geological events occurring from the Permian (Flügal and Reinhardt 1989:502-18) through late Tertiary. In reality, the stage that dictated the fluvial systems found currently in the Texas and Oklahoma panhandles, and southwest Kansas, was established long before the Quaternary. Subsequent geological and environmental events in the Pleistocene and Holocene have provided an extensive record of geomorphological and behavioral change in the region (Albert and Wyckoff 1984:1-43; Binford 1968:313-42; Bailey et al. 1998; Berta and Harrington 1994:33-50; Boul et al. 1980; Ferring 1990:1-625, 1992:1-40; Frison 1991).

PERMIAN THROUGH LATE TERTIARY (PLIOCENE - MIOCENE) GEOMORPHIC EVOLUTION

The area comprising the Texas panhandle, Oklahoma panhandle, and southwest Kansas is characterized by Permian deposits originating from shallow marine supratidal or subtidal shoals and lagoons (McGookay et al. 1988:1). Along the confines of these Permian lagoons, varying thicknesses of dolomites and limestones were formed, with constituent sand facies, representing shallow marine offshore bars lying conformably in a basal position (Al-Shaieb 1988:104). Constituting a facies change, deeply stratified salts and gypsums are found in off-shore shallow Permian basin environments, such as the Anadarko, Dalhart, and Palo Duro basins (McGookay et al. 1988:4). These deeply stratified salts and gypsums (e.g., Blaine Formation [Fay 1962 et al.:47-51]) are now exposed and contribute directly to the fluvial geomorphology found in the area today (Figure 6)(Al-Shaieb 1988; Clifton 1930; Cragin 1896; Dolliver 1984; Evans 1931; Fay 1959, 1965; Fay et al. 1962, 1978; Frye and Leonard 1957, 1965; Gould 1924; Gould and Lewis 1926; Greene 1936; Gustavson et al. 1980; Gustavson and Finley 1985; Myers 1959; Walker 1978).

Cretaceous rocks composed of sandstone, marine limestone and claystone mantle a highly dissected Triassic, Jurassic, and Permian terrain. In places, Cretaceous materials are entirely absent, however (Walker 1978:12-13). The highly dissected strata (through fluvial processes) were blanketed by tertiary sediments associated with the Laramide Uplift of the Sangre de Cristo and Rocky mountains (Dolliver 1984:27). This mantle forms an unconformity over underlying older strata and originally was believed to represent a "..coalescence of broad alluvial fans which spread eastward from the southern Rocky Mountains of New Mexico and Colorado ..." (Plummer 1933 cited in Walker 1978:7). In reality, however, this formation (Ogallala) is now believed to be derived from three to four sources, each representing a different genesis, and origin, of gravel and eolian materials

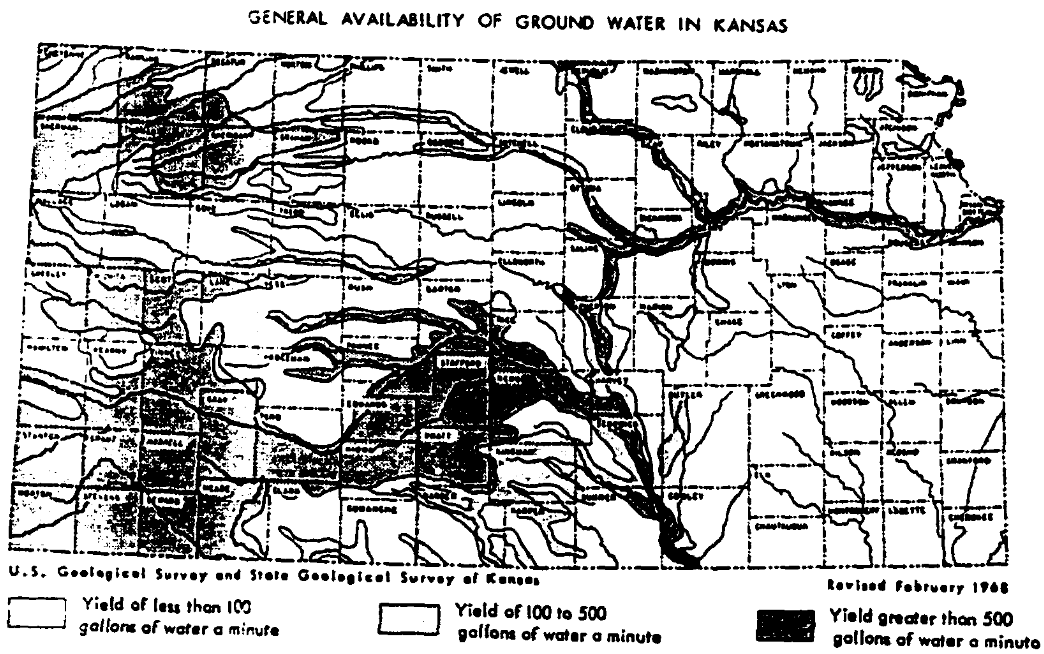

Figure 6. General Availability of Ground Water in Kansas

(Dolliver 1984).

An eolian genesis of the upper Ogallala (Upper Couch Formation) is clearly seen in the Blanco Canyon stratigraphic profile of the Llano Estacado, in the Texas panhandle, near Crosbyton, Texas (Dolliver and Holliday 1988:299). During decreased sediment accumulation, caliche soils formed, creating a distinctive caprock throughout the southern Great Plains. This caprock provides a temporal datum throughout the southern Great Plains and can be easily observed where erosion and stream dissection has removed younger deposits and/or caused lateral erosion of the sedimentary unit.

During the Pliocene, major drainage systems (Pecos, Canadian, North Canadian, and Cimarron) were initiated from the west. Dissection and the general trends of these rivers occurred, to a great extent, following the eastward dip of the Rocky Mountains, and, dissolution of subsurface salts and gypsums associated with Permian deposits (Dolliver and Holliday 1988). Solution-collapsed depressions are believed to have preceded and accompanied Ogallala deposition over the southern High Plains (Dutton et al. 1979:87; Gustavson et al. 1980:30-32; Seni 1980:5 cited in Dolliver 1984:32). Concurrent with the development of numerous subsidence basins, lateral erosion of the eastern High Plains occurred, accentuating escarpments. These events took place when the Canadian, North Canadian and Cimarron rivers were at their most incipient stage (Fay et al. 1962:87) and contributed immeasurably to the exposure of Late Permian sediments containing Day Creek chert.

Drainage systems including the Cimarron, North Canadian, Canadian, Pecos, Red and Brazos began (and continue today) to flow roughly parallel to regional and local structural elements of the Pliocene (Gustavson and Finley 1985:21). These drainage systems follow a general southeasterly course, with lateral movement along the dip of underlying beds to the southwest (Figure 7).

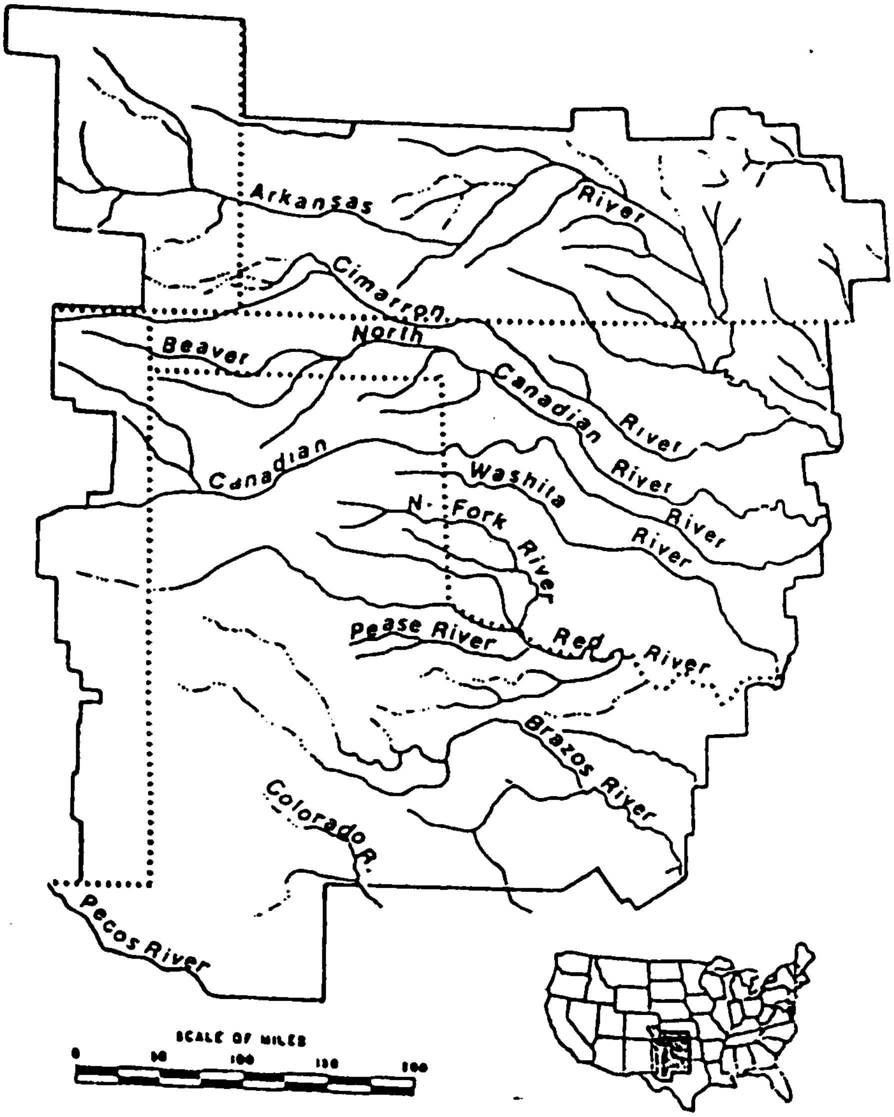

Figure 7. Primary Rivers in the Southern Great Plains (adapted from Hofman and Brooks 1989:7)

As previously mentioned, the present alignment of rivers in this region has occurred as a result of differential erosion of shales and surface subsidence following dissolution of Permian salts. Such a scenario is in evidence today near Roman Nose State Park in western Oklahoma. Currently, dissolution of gypsum in the Blaine Formation has redirected hydrological flow from the Canadian River by as much as 30%, resulting in numerous sink holes along a linear axis towards the southwest. Eventually this situation will redirect major stream flow towards the state park, resulting in stream piracy by a new meander. Such occurrences provide clear examples of river diversion from the dissolution of salts and/or gypsums, and underscores the fact that all hydrological diversion is not a simple case of stream piracy.

QUATERNARY (PLEISTOCENE) FLUVIAL DEVELOPMENTS ON THE SOUTHERN GREAT PLAINS

The Pleistocene represents a period of remarkable environmental, climatic, and biotic changes. In terms of fluvial regimes in the northern extent of the southern High Plains, climate has likely taken a leading role in geomorphological evolution. It is clear that there is a systematic relationship between climate and hydrology (Dolliver 1984:37), resulting in correlations of aggregation and degradation within fluvial systems and associated climatic events.

The Pleistocene is associated with four major cooling events that resulted in glacial advances within North America. In ascending order, they are: Nebraskan, Kansan, Illinoisan, and Wisconsinan. Such advances resulted in the deposition of coarse-grained sand and gravel in alluvium and extensive terraces by streams within fluvial valleys. Rivers in this region generally have a veneer of silt and clay with little sand and gravel on their southwest side, and thick deposits of sand and gravel on the northeast (Fay et al. 1962:85-86). These deposits provide clues for correlations of terraces, and the lateral movement of the ancient drainage through time.

Between the periods of major glaciation, four major periods of climatic warming (interglacials) occurred during the Pleistocene. They include in ascending order: Aftonian, Yarmouthian, Sangamonian, and Bradyan. All four interglacials have a corresponding soil development that aids in cross correlations over wide geographic areas and further suggests stable climatic conditions. Associated with these early interstadials, particularly during periods of maximum melting of ice during Kansan time, Pleistocene fluvial regimes eroded downward forming extensive valleys (Fay 1962:88).

Subsurface salt solution (within the Blaine Formation) with accompanying surface subsidence continued throughout the Pleistocene, and probably reached a maximum during Kansan times (600,000 BP). Currently, more than 37,000 playas and/or dolines are identified in the Texas and Oklahoma panhandles. These environments were rich in both aquatic and terrestrial micro/macro faunas, generally enabling paleontologists to reconstruct paleoenvironments. It should be noted that past reconstructions based on spring boil, playa, or doline features have remained tentative due to the extensive fluvial turbation of these lacustrine deposits. Bones, teeth, etc, are generally mixed (e.g., bioturbation, etc.) in the stratigraphic profile, and bear little relationship to the true superposition of mammalian evolution over temporal periods. With this caveat in mind, however, such deposits can still have far reaching effects for archaeologists when tools of human origin are found in direct contact with some ancient and extinct fossils; for example the Cooperton Mammoth site (Anderson 1975), and the Burnham site (Wyckoff et al. 1991:82-121).

Playas on the southern High Plains are lacustrine, and often have xeric, mesic, and aquatic communities associated with them (Wyckoff et. al. 1991:101). These natural basins also have served as traps for free falling tephra, and as a result, have been useful in determining Late Kansan to Early Yarmouthian environments when found in conjunction with a standard High Plains datum: the Pearlette Ash (Dolliver 1984:36; Frye and Leonard 1965:207; Ward 1991a:50-64, 1991b:65-72). Currently, the Pearlette ash is now defined as constituting at least five separate tephra and all are found in lacustrine settings (lake, oxbow, pond) of Early, Middle, and Late Pleistocene age (Dolliver 1984:36) and may be reworked deposits.

During Late Kansan times, fluvial systems in this region had a marked increase in deposition of coarser-grained alluvial sand and gravel. Kansan terraces indicate enhanced erosion and downcutting by major rivers and tributaries. Drainage base levels declined in part as a result of dissolution of Permian salts/gypsums. During periods of high fluvial activity, coupled with basin collapse due to dissolution of subsurface salts, downward entrenchment can be extremely fast; between 1 m every 1000 years to 6 m every 1000 years (Peterson 1988).

The Pleistocene was substantially cooler and wetter than the present environment in the southern High Plains (Porter 1983; Wendland 1978:273-287; Wendorf and Hester 1962;159-71). As previously mentioned, soil development appears to indicate relatively stable climatic regimes, in addition to less severe erosional cycles (characteristic of the Middle to Late Holocene) (Dolliver 1984:36; Lintz and Hall 1983). Post Kansan terraces and interglacial soils have undergone extensive reworking, and in some areas, paleosols, gravel, and caliche have been removed altogether.

During the Illinoisan, a period of very dry conditions and lack of fluvial deposits (Walker 1978:15), a northeasterly thickening blanket of eolian sand ("cover sands") were deposited across the Great Plains (Frye and Leonard 1957). Soils associated with the Post Illinoisan Sangamon are referred to as the Brownfield, Amarillo, Patricia, and Anvana (Reeves 1976 cited in Stafford 1984:6).

Extensive sheetwash of surrounding uplands resulted in cumulic horizons in alluvial facies. These events likely had their origin in the Illinoisan and Wisconsinan glacial periods. Fay (1965:93) indicates that one section of the Canadian River near Bridgeport, Oklahoma, has a probable Wisconsinan age channel underlain by 60 feet of gravel overlain by 40 to 50 feet of sands, and with cross-bedding possibly related to braided stream channels.

LATE PLEISTOCENE AND HOLOCENE FLUVIAL SYSTEMS

Appreciably more detailed geologic field work has been completed concerning the geomorphological evolution of the southern Great Plains during the Late Pleistocene and Holocene. In part, this resulted from the fact that the earliest peopling of the Americas took place within this time frame (Adovasio et al. 1982:97-137; Anderson 1975:130-73; Baker et al. 1957:1-20; Bamforth 1985:243-58; Figgens 1927:229-47; Frison and Bradley 1980; Hofman and Carter 1991:24-37; Holliday 1997; West 1983:364-82).

During the Wisconsinan Interstadial (Bradyan), regional climatic stabilization is indicated by the presence of the Brady soil (Walker 1978:11). Lacustrine deposits from this time period indicate relatively warmer and more humid conditions.

Germane to this discussion is the extensive work conducted at the Burnham Site [34WO73] in Woods County, Oklahoma (Flynn et al. 1988; Wyckoff et al. 1991:82-121). Purportedly of pre-Clovis origin, the site is in an ancient stream channel or lacustrine basin overlain by sedimentary and eolian deposits. The important point here is not the possible early association of humans with an extinct fauna , but rather, that the paleoenvironmental data is useful in understanding Wisconsinan environments in northwest Oklahoma from 40,000 to 11,500 years ago.

The Burnham site indicates that pre-Wisconsinan glacial maximum temperatures were cooler and wetter in summer, and warmer in winter, suggesting less seasonality. The flora and fauna indicate a rich environment of grasses and sedges accompanied by now extinct megafauna, including Pleistocene horse, bison [*Bison chaneyi*], alligator, and elephant (Wyckoff et al. 1991:103).

The data from this location fit well with the general scenario of a cooler and wetter environment during Wisconsinan times and the presence of numerous shallow playas across the landscape. In such an environmental picture, fluvial systems would, no doubt, be aggrading fine silts and clays, following the general drainage course laid out in pre-Wisconsin times. Evidence of this scenario is provided by Baker and Penteado-Orellana (1977, 1978). Geomorphological and pedological studies of the floodplain and paleochannel morphology of fluvial systems in Texas indicate alternating humid and arid intervals. Baker and Penteado-Orellana's (1977, 1978) data suggest that humid phases were characterized by fine-grained loads and high sinuosity on the flood plains during Late Wisconsinan times.

Late Pleistocene (25,000-11,000 BP) environmental data further suggest that the water table was higher, resulting in active spring conduits, which indicates that the environment contained increased moisture (Haynes and Agogino 1966:812-21). Between 11,000 and 12,000 BP, the environment is believed to have become increasingly cooler with greater effective moisture (Graham 1987:39). The flora and fauna suggests that the mean annual temperature during the Late Pleistocene was either the same (as previous environmental factors), or lower, and the winters were not extremely and sporadically cold (Graham 1987:39). During the transition from Late Pleistocene into Early Holocene (11,000-8,000 BP), moist and cool conditions ameliorated in the Llano Estacado, and, farther north towards the Texas and Oklahoma panhandles (Graham 1987:38).

Following the Late Pleistocene and Early Holocene, climatic amelioration became dramatic, entering a period commonly referred to as the Altithermal. During this period

(8,000-4,000 BP) the climate is characterized by drought conditions (6,000-4,000 BP) that had an impact on fluvial systems in the region. Eolian activity throughout this period increased (Holliday 1988) and climatic shifts brought increased seasonality to the southern Great Plains (Ferring 1990:254-55, 1992:1-40). During the Archaic, archaeological sites dating from this period indicate lower water tables which forced human populations to excavate wells for the purpose of gaining access to water. Given the dryer conditions and punctuated seasonality of this period, it would be expected that during brief increased fluvial discharge, sediment loads would be greater, leading to increased alluvium being deposited along major stream drainages and lateral tributaries. Such a situation is suggested by Nials (1977) from his research along the Cowden laterals watershed in Oklahoma. Nials' (1977) geomorphic research indicates increased cut-and-fill sequences following the Late Pleistocene, often making correlations of terraces extremely difficult. Increased sporadic discharges associated with climatic seasonality suggests channel trenching and subsequent fill by alluvium and colluvium, which in turn truncates lower deposits in the canyon. Lintz and Hall (1983) believe that with increased seasonality, frost/freeze cycles effected the jointed Rush Springs Sandstone, resulting in increased colluvial deposition within canyons that lay lateral to major stream drainages. Lintz and Hall's (1983) Carnegie Canyon, Oklahoma study provides clear and convincing evidence that Middle to Late Holocene deposition was extensive, and as Ferring (1990:263; Ferring et al. 1976) suggests, resulted in extensive alluviation of floodplains and terraces.

Alluviation during Late Holocene times, as previously mentioned, affects not only our ability to correlate lithostratigraphic units from one area to another, but also has resulted in limiting our knowledge of Archaic cultures in the vicinity of fluvial systems (Ferring 1990: 260-263). In addition, Holocene burial of archaeological sites with colluvium and eolian sand is documented (Ferring 1990:261; 1992:1-40); deposition of fine-grained sand can range anywhere from 1 to 10 m.

During the Late Holocene, increased channel trenching associated with slightly moister conditions, occurred between 2,500 and 2,000 BP (Hall 1990:328; Lintz and Hall 1983). After 2,000 BP, coarser-grained strata within alluvial settings represent intermediate magnitude floods during times of more arid climates. Based on data provided by Lintz and Hall (1983) for Carnegie Canyon, geomorphic evolution is clearly indicated. Beginning around 2,000 BP alluvial filling of the canyon decreased. The following 1,000 years appears to have been a period of high water tables and relative stable conditions, coupled with decreased sediment accumulation. The higher water table and associated molluscan fauna suggests that the Late Holocene, during this period, had a moister climate than what is found after 1,000 BP. Climatic amelioration occurred, resulting in channel trenching and extensive deposition of sands up to 2 m in thickness. This scenario is likely applicable throughout the southern Great Plains (Ferring 1990:263) during the Late Holocene.

In summary, beginning with the Permian and continuing through to the present, fluvial regimes on the southern Great Plains are dynamic. In order to gain a holistic view of any given drainage, numerous elements of the system (e.g., structural geology, climate, depositional environment, etc.) must be examined. It has become increasingly clear that fluvial systems do not follow a single linear axis of development and/or change. Depositional events that occurred in the Permian continue to effect drainage patterns of rivers in the southern Great Plains today. Pleistocene and Holocene climatic shifts have contributed to the dynamic river morphologies evident along the entire course of any drainage system. Ultimately, these same natural forces have altered and modified the availability of Day Creek chert within the primary Day Creek Dolomite outcrops and secondary regolith. It should be expected that human populations dependant on this material had to constantly reform their procurement strategies as the fluvial geomorphology, surface physiography, and climate evolved throughout the Late Pleistocene and Holocene (Buchner 1980; Butzer 1971; Carr 1994; Dalton 1977:191-209; Degarmo 1977:153-68; Driskell 1986; Earle 1980:1-26; Earle and Christenson 1980; Findlow and Bolognese 1984:77-82; Francis 1991:305-20, 1994:230-34; Gould 1929a:66-68, 1929b:90; Hall and Lintz 1984:129-33; Hardesty 1980:158-83; Henry 1989:139-56; Hofman et al. 1989).

> The Day Creek Dolomite, a uniform thin bed at its surface exposures, shows much variation in the subsurface. In some wells it is entirely anhydrite; in some it consists of two brown or pink dolomite beds separated by red shale or anhydrite; in some it is represented by thin-bedded anhydrite and red shale (Maher, 1947, p. 3). It attains its greatest thickness (120 feet) in northeastern Morton County, where it is predominantly anhydrite (Swineford 1955:92).
>
> The Day Creek 10 miles north of Freedom, Oklahoma is 3 feet thick, light-gray to white, rather coarsely crystalline to very fine-grained, and highly calcareous (Swineford 1955:85).

THE PERMIAN LITHOSTRATIGRAPHY OF NORTHWESTERN OKLAHOMA AND SOUTHWESTERN KANSAS: THE ORIGIN OF DAY CREEK CHERT IN THE DAY CREEK DOLOMITE

Different ideas have existed since the late nineteenth century concerning the lithostratigraphic relationships within the coarse topography of the Permian Dissected Red Beds in Texas, Oklahoma, and Kansas. This is particularly evident in the geologic literature concerning the panhandle regions of Texas and Oklahoma, northwest Oklahoma, and southwest Kansas. Currently little has been accomplished in terms of synthesizing data that would provide direct correlations between lithostratigraphic units within the region. As a result, publications are often found to contain entirely discordant lithostratigraphic columns that bear little relationship to one another (e.g., Fay et al. 1978 and Dolliver 1984). Major formations and their members have been delineated for the Permian System, but larger aggregates (series and groups) have continued to elude an all-encompassing lithostratigraphic nomenclature (Hedberg 1976). Reliance on early data has led some geoarchaeological and/or archaeological investigators to utilize outdated lithostratigraphic nomenclature within their respective publications (Bailey 1998). The purpose of this chapter is to trace the development of the Permian lithostratigraphy for northwest Oklahoma (Harper, Woods, and

Woodward counties) and southwest Kansas (Clark and Kiowa counties), with emphasis on the Cloud Chief Formation. This formation contains stringers of nodular chert within the Day Creek Dolomite, which, based on extensive lithic workshop debitage evident in northwest Oklahoma and southwest Kansas, was a very important source of lithic raw materials beginning 11,500 years (or more) before present (Figure 8).

THE ORIGIN OF PERMIAN SEDIMENTARY DEPOSITS IN NORTHWEST OKLAHOMA AND SOUTHWEST KANSAS

During earliest Permian times (Cimarronian Series), the area comprising the Texas and Oklahoma panhandles, along with southwest Kansas were characterized by red beds (McGookey et al. 1988:1). Shallow lagoons and deep basins (eg., Anadarko, Dalhart, and Palo Duro) were formed in which numerous lithostratigraphic formations were deposited. As these shallow marine seas waxed and waned along the confines of lagoons, varying thicknesses of dolomite and limestone were formed near shore, usually when 50% evaporation occurred (Loope and Kuntz 1987:75-79; Marshall 1961:1493-1520). Constituent sand facies developed as well, representing shallow marine off-shore bars, beach barriers, and localized backshore eolian dunes (Al-Shaieb 1988:104). In the deeper basins, farther removed from shore, when about 80 to 90% evaporation took place, stratified salt and gypsum were deposited. In the region now encompassing the Texas and Oklahoma panhandles, northeast to Clark County, Kansas, restricted marine circulation and high evaporation from the desert climate discouraged the growth of marine organisms. Without the presence of organic flora and/or fauna, the Permian environment severely inhibited the reduction of iron, which resulted in bright red hematite-cemented sediments characteristic of the coarse topography today (Kay 1965:294; Matsui 1965:221-244). Given the intensely briny environment, chert in the Upper Permian (Day Creek Dolomite) is not fossiliferous, such as that found east in the Flint Hills of Marion County, Kansas, and Kay County, Oklahoma (Haury 1985; Wise

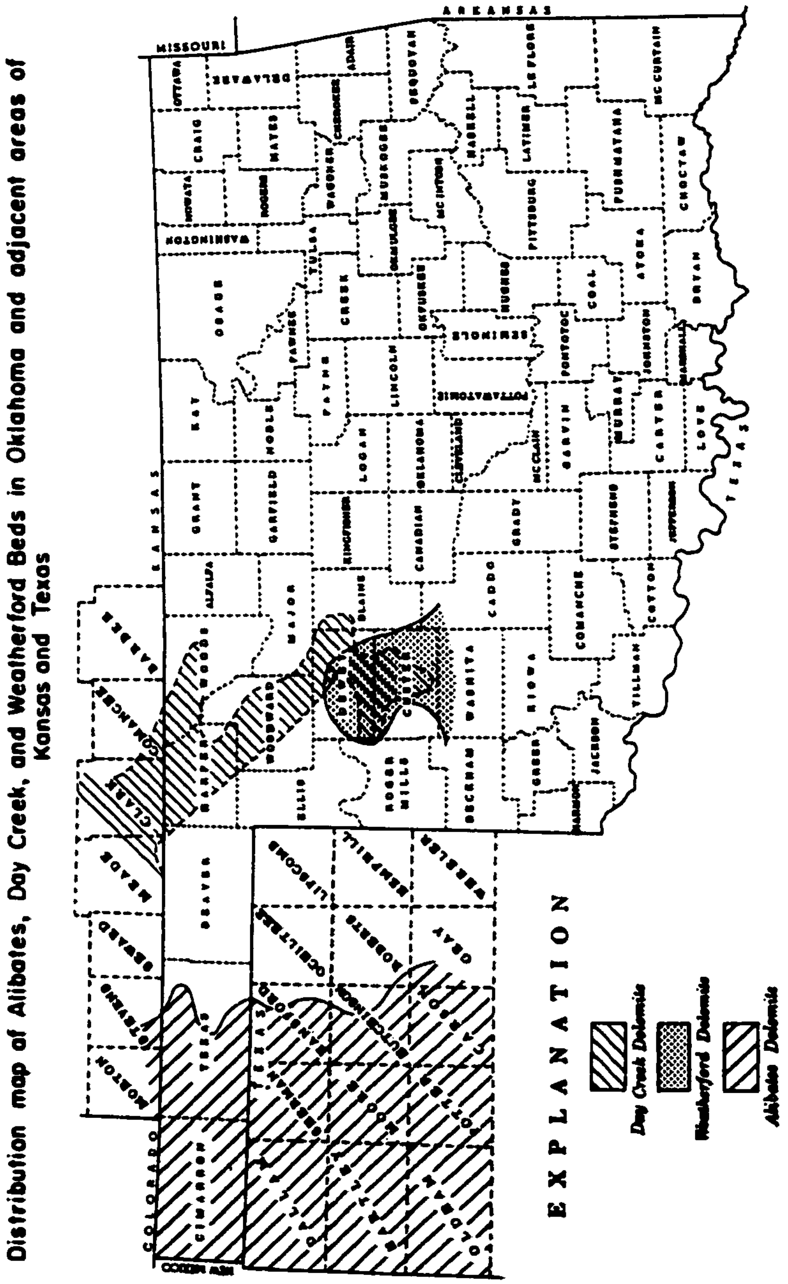

Figure 8. Distribution of Alibates Dolomite, Day Creek Dolomite, and Weatherford Beds of Oklahoma, Kansas and Texas (adapted from Fay and Hart 1978)

Weaver 1974:301-26).

Late Permian Dissected Red Beds and caprock exposures within the coarse physiography of northwest Oklahoma and southwest Kansas are a result of erosion by streams and dissolution of subsurface salt and gypsum (Blaine and lower formations). This is due to hydrological activity in Late Paleozoic Era [Late Permian: 230 to 225 mybp], Mesozoic Era [225 to 65 mybp], and Cenozoic Era [65 mybp to present] deposits (Dolliver 1984; Leopold et al. 1964; Reeves 1976:213-234; Ritter 1986). Concurrent with the development of numerous subsidence basins erosion of the eastern High Plains occurred accentuating escarpments during pre-Pleistocene times (Fay et al. 1962:86). Given depth of erosion and solution subsidence affecting the geomorphology of the region, it has been speculated that silica solutions would partly replace the Day Creek Dolomite (Cloud Chief Formation) during the Pliocene, Pleistocene, and Holocene (McBride et al. 1979). In addition, active channel trenching during the Holocene Altithermal likely served to make cryptocrystalline resources increasingly available (Holliday 1988; Holliday et al. 1992; Kay 1965; Krumbein et al. 1963; Leopold et al. 1964; Lintz et al. 1983; Mandel 1992:41-100; Porter et al. 1983; Ritter 1986; Stafford, Jr. 1981:548-565, 1984; Stephens 1965:281-292; Thornbury 1966; Walker 1978; Wyckoff 1989:405-452, 1993:35-58).

Research towards the diagenesis of chert has been refined and a new understanding is being proposed within contemporary sedimentology literature (eg., Chowns et al. 1974:129-147; Davies 1965:123-44; Dietrich et al. 1963:16-33; Folk et al. 1971:59-72; Harris 1958:1-15; Hayes 1964:34-44; Namy 1974:106-112; Siedlecka 1972:73-78). It has been demonstrated that the diagenesis of chert is primary to the limestone or dolomite parent material. Furthermore, the diagenesis of chert is believed to have a relationship to extant marine organisms within three specific temporal intervals: the Cenozoic Era, the Silurian to Cretaceous Periods, and the Late Proterozoic Era (Maliva et al. 1990:519; see Table 1).

	Sedimentary Environment		
Interval	Basal and Deep Ocean	Subtidal Shelf and Platform	Peritidal Marine
Late Proterozoic	Unknown	Present	Abundant
	CAMBRO - ORDOVICIAN TRANSITION		
Silurian to Early Cretaceous	Abundant	Abundant	Uncommon
	LATE CRETACEOUS - PALEOGENE TRANSITION		
Eocene to Present	Abundant	Uncommon	Uncommon

Table 1: Summary of the Broad Facies Distribution of Early Diagenetic Chert Through the Last 1000 Ma (adapted from Maliva et al. 1990:528)

Secondary chert (as opposed to *primary*), is thought to be *only* associated with the sedimentary deposits at the Lake Magadi region in Kenya (Surdam et al. 1976:1739-52), gravel deposits outside Omaha, Nebraska (Loope 1998: personal communication), and possibly the Table Mountain opalic chert near the Wyoming and Nebraska border (Koch et al. 1996:107-08; Surdam et al. 1972:2261-66). Discussing this geological phenomenon, Maliva et al. (1988:387-98, 1990:519-32) have determined that dissolved silica from demosponges, found in a context that is Permian in age, was deposited as a silica solution shortly before the final diagenesis of the limestone or dolomite in essence depositing the silica solution within the parent material shortly *before* final chertification. Furthermore, the source of silica within limestone and dolomite beds can be traced to biological origins that are distinguished by clear temporal parameters. Maliva et al. (1990) states:

> In the modern oceans, the removal of dissolved silica from sea water is principally a biological process carried out by diatoms, with lesser contributions from radiolaria, silicoflagellates, and sponges. Because such silica in sediments is often redistributed locally during diagenesis to form nodular or bedded chert, stratigraphic changes in the facies distribution of early diagenetic chert provide important insights into the development of biological participation in the silica cycle. The abundance of chert in upper Proterozoic peritidal carbonates suggests that at this time silica was removed from seawater principally by abiological processes operating in part at the margins of the oceans. With the evolution of demosponges near the beginning of the Cambrian Period, subtidal biogenic cherts become increasingly common, and with the Ordovician rise of radiolaria to ecological and biogeochemical prominence, sedimented skeletons became a principal sink for oceanic silica.
>
> Cherts of Silurian to Cretaceous age share many features of facies distribution and petrography but they differ from Cenozoic siliceous deposits. These differences are interpreted to reflect the mid-Cretaceous radiation of diatoms and their subsequent rise to domination of the silica cycle.

Unlike Cenozoic shelf and platform sediments, Mesozoic and Paleozoic shallow-water carbonates routinely contain nodular chert (Maliva et al. 1990:522). Continuing sedimentological research indicates that there are occasions where chert may have been deposited as a result of downward diffusion of silica within seawater; this is typically associated with peritidal carbonates. However, chert diagenesis resulting from non-skeletal precursors are "of minor importance relative to biogenic silica" (Maliva et al. (1988:387-98, 1990:528).

Maliva's et al. (1990) research has profound implications for the understanding of cherts found in Permian sediments within the southern Great Plains. Rather than being an anamorphism, silica within southern Great Plains parent materials may, in fact, represent primary constituents, rather than the common notion that all cherts in this region are secondary during lithodiagenesis. Visual identification of *secondary* chert is pronounced due to the lithologies of those samples that retain cortex. The cortex is modified through cataclasis, leaving a case-hardened clast.

LITHOSTRATIGRAPHIC HISTORY OF THE LATE PERMIAN SYSTEM AND THE CLOUD CHIEF FORMATION

With the conclusion of a brief investigation of the Permian (Late Paleozoic Era) lithostratigraphy by Professor St. John in 1886, and his subsequent publication, *Notes on the Geology of Southwestern Kansas* in 1887, additional lithostratigraphic research in southwest Kansas was not forthcoming. Following St. John (1883, 1887), much of the lithostratigraphic nomenclature concerning Permian red bed deposits was first established by F. W. Cragin (1896) (Table 2). Arriving in the region by train in 1894, Cragin set out by horse-drawn wagon to study the overall lithostratigraphy in southwest Kansas and northwest Oklahoma. Cragin (1896:3) proposed that these strata be classified into a number of formations, divisions, and series (see Hedberg 1976). Little regard was given to actual mapping, and as a result, a mixture of nomenclatures for the Permian System was proposed, having no relationship to the actual lithostratigraphies currently recognized (Hedberg 1976). It should

CLASSIFICATION OF THE ROCKS OF THE PERMIAN SYSTEM IN KANSAS

II. The Cimarron Series

DIVISIONS	FORMATIONS
	Big Basin sandstone [Quartermaster]
	Hackberry shales [Cloud Chief]
	Day Creek dolomite
Kiger	Red Bluff sandstones
	Dog Creek shales
	Cave Creek gypsums
	Flower-Pot shales
Salt Fork	Cedar Hills sandstones
	Salt Plain measures
	Harper sandstones

I. The Big Blue Series

DIVISIONS	FORMATIONS
	Wellington shales
Sumner	Geuda salt-measures
Flint Hills	Chase limestones (Prosser.)
	Neosho shales (Prosser.)

Table 2: Cragin's 1896 Classification of the Kansan Permian System (adapted from Cragin 1896:3) Note: The terms in brackets denote later modifications of the column. The name in parentheses denotes previous classifications by C. S. Prosser (1895)

be noted that Cragin was forced to assume relationships solely on the grounds of similar lithologies, since at the time of his geologic investigations, none of the Permian lithostratigraphies had been mapped in detail (Haworth 1897:53-96). Cragin (1896:1) did utilize data derived from United States military dragoon campaigns along the Red River in 1854, as well as data reported to the Secretary of War in 1855.

Cragin (1896:3) initiated the first structured lithostratigraphic column, and at the time, believed that, "The Day Creek and the Big Basin are the only formations of the Kansas Permian that seem to be absolutely *simple* terrains, or to consist of a single bed." Although Cragin's overall contributions have been well documented by Fay et al. (1962), Fay (1965), Fay et al. (1978), what is of particular importance here is Cragin's (1896:44-6) discussion of the Day Creek Dolomite (Table 2). Cragin (1896:44) states:

THE DAY CREEK DOLOMITE

> Upon the latest of the Red Bluff beds rests a persistent stratum of dolomite; varying from less than a foot to five feet or more in thickness. This is the same as the "gray, cherty, sometimes gypsiferous limestone" noticed by Professor St. John as occurring in Clark county [Kansas] at the head of Day Creek. It is true dolomite, containing the carbonate of lime an equal or even greater percentage of carbonate and magnesia, as indicated by a qualitative analysis kindly made for the writer by Prof. William Strieby of Colorado College. Though not of great thickness, it is an important member of the upper Permian of southern Kansas and northern Oklahoma owing to its persistence, which makes it a convenient horizon of reference. It may therefore be considered a formation by itself and, to distinguish it from other and less important dolomites of the Cimarron series, be called the Day Creek dolomite, after the above-named locality of its occurrence.

The drainage that Cragin (1896:44) utilized for the basis of naming the Day Creek Dolomite is currently of important economic interest to contemporary Clark County, Kansas, and specifically to individuals living in the towns of Sitka and Ashland, Kansas. The head of Day Creek is spring-fed with capillary flow surfacing from the Rush Springs

Sandstone Formation, overlain by a prominent Day Creek Dolomite escarpment. The geomorphology of the upper Day Creek drainage (cardinal flow direction: north to south) is currently defined by a steeply-sided meandering creek with multiple terraces. Portions of the terraces are used for commercial washed gravel. The coarse gravel, cobbles, and boulders (Cretaceous, Tertiary, and Quaternary in age), when inspected closely, contain extensive allochthonous [exotic] gravel and cobbles of chert, petrified wood (e.g., cedar, palm, etc.), and an assortment of quartzites, Dakota sandstone, obsidian, basalt, fossilized Late Pleistocene mammal bones, and fossilized elephant ivory. Eventually the drainage forms a slip-off slope within an expanding flood plain, with sharp cut-offs, Rush Springs Sandstone Formation bluffs, extensive eolian dunes, point bars, and swales before emptying into the Cimarron River floodplain and ultimately into the Cimarron River.

Cragin describes not only the very common colors of Day Creek chert [HUE 5B 8/2: very pale blue; HUE 5B 6/2: pale blue; HUE 5PB 7/2: pale blue; 5PB 5/2: grayish blue; 5B 9/1: bluish white; 5B 7/1: light bluish gray; and, 5B 5/1: medium bluish gray] (Munsell Rock-Color Chart 1991) associated with the Day Creek Dolomite [HUE 5YR 8/1: pinkish gray], but continues to report a far more homogeneous semi-translucent white [N9: white] lithic (chert?) of *remarkably pure aspect* (Cragin 1896:45). This lithic, named *Faresite* by Cragin (1896:46), is said to bear a resemblance to fine-grained marble, onyx, or chalcedony. Named after a prominent cattle rancher, *Henry Fares*, who lived on West Bear Creek in Clark County, Kansas, in the late nineteenth century (Ford 1939:28), no currently known samples of this material have been secured or analyzed. According to Welsh (1966:5):

> Norton (1939) described the Day Creek Dolomite as follows: In Kansas a single bed, typically about two feet thick, of fine-grain dense dolomite ... In local areas, the dolomite has been partly altered to a siliceous rock which Cragin (1896) dignified by the name of 'faresite'.
>
> Various explanations have been offered for the occurrence of

this "faresite"; one of them, by Norton (1939) is as follows:

> ..the preponderance of evidence favors the theory of replacement of dolomite by silica from percolating ground water from overlying strata, the commonest source being the sandy, conglomerate of the Tertiary Ogallala 'mortar beds.'

Given the ubiquitous nature of Day Creek Dolomite throughout the region, Cragin (1896) believed that it could occur over a wide geographic area, serving as a temporal lithostratigraphic datum for correlations of other lithostratigraphic deposits throughout the southern Great Plains.

Refinement of the Dissected Red Bed lithostratigraphies of Oklahoma and Kansas resulted from research focusing on subsurface water and petroleum reserves (Aurin 1917; Clapp 1921; Gould 1902, 1905; Greene 1936; Howell 1922; Ohern 1918; Reeves 1921; Snider 1913; Wegeman 1915). As a result of this intensive work Charles Gould (1924:322-342) proposed the first reclassification of the Permian Dissected Red Beds in Oklahoma. Gould's classifications have little in common with current classifications (e.g., Fay 1959, 1965), but what is important to note is the continual refinement of the lithostratigraphic nomenclatures of the Permian System and their relationships to areas outside of Oklahoma.

Building on his initial classification of the Oklahoma Dissected Red Beds, Gould and Lewis (1926:1-29) identified additional correlations between the Texas and Oklahoma Dissected Red Beds. It is in this publication that Gould and Lewis (1926:22-24) first proposed that the Day Creek Dolomite is a *lateral equivalent* of the Alibates Dolomite of the Texas Panhandle. Gould and Lewis (1926:23) state:

> Since the revision of the classification of the Permian red beds of Oklahoma, geologists have not been in agreement as to the place to be assigned to the Alibates. Its stratigraphic position above the Whitehorse would indicate that it is the approximate equivalent of Day Creek. On the other hand, so far as we are aware the Alibates has not yet been traced, either on the surface or by means of well logs to correlate with the Day Creek.

> Our present opinion is that Alibates is the equivalent of the Day Creek. In this respect, we agree with Clifton (1926). *We, therefore, recommend that the name Alibates be dropped* [emphasis added].

Continued reliance on Gould and Lewis' (1926) original hypothesis is found in numerous publications, particularly those archaeological in subject, by researchers seeking to correlate the Day Creek Dolomite with the Alibates agatized dolomite (Bowers 1975:18-19; Dolliver 1984:74; Hofman 1986:6; Wyckoff 1989:40). Banks (1984:74) reports "...a number of geologists.." believe Day Creek Dolomite to be a *lateral equivalent* of Alibates agatized dolomite; other researchers (Fay 1991:personal communication) discount this entirely and confirm that both are distinct and unrelated lithostratigraphic formations. Subsequently, well logs throughout the Texas and Oklahoma panhandles confirm Fay's position (Fay 1991: personal communication).

Continued disagreement about the Permian lithostratigraphies of Oklahoma resulted in additional publications during the 1930s (Clifton 1930; Evans 1931; Greene 1936; Schweer 1937). Of particular note is the identification of chert-bearing Day Creek Dolomite, in southwest Kansas, that contains lithic material similar to Alibates agatized dolomite lithologies (Evans 1931:426). However, lithology alone does not automatically confirm an Alibates agatized dolomite connection to the Day Creek chert. Coloration of chert is a complicated process of various minerals (iron oxide, copper sulfides, etc.) being held in solution during solidification, *possibly* originating through leaching of sediments in a hydrological system (Chowns et al. 1974:885-903; Dietrich et al. 1963:646-663; Folk et al. 1971:1045-1058; Franks et al. 1959:186-196; Namy 1974:1262-1268; Siedlecka 1972:812-816; Smale 1973:1077-1089; Swineford 1955:83-85). With a reliance on the study of physical properties, and a lack of sedimentary lithogeochemistry analyses of the lithic material (see Church 1994; Haury 1994:75-88), the postulated relationships between the

Alibates agatized dolomite and Day Creek chert are clearly unacceptable. This postulated connection is overwrought in the archaeological literature, and Brooks (1994:1-27) has approached the problem by reclassifying materials that share similar lithologic characteristics as combined "Alibates/Day Creek". While Brooks' position does note the lithologic similarities between the two lithic raw materials, it continues to erroneously suggest that both lithic materials are geologically equivalent.

Following Schweer's (1937) publication, research concerning the Permian Dissected Red Beds of the region waned due to their relative insignificance as a source of petroleum and natural gas (Fay 1991: personal communication). In 1959, Myers (1959:1-105) published *Geology of Harper County*, utilizing much of the nomenclature set forth by Clifton (1930), Evans (1931), Gould (1924), and Gould and Lewis (1926).

Myers' (1959:42) manuscript contains the first published lithological analysis of chert-type materials found in the Day Creek Dolomite. Myers (1959:42) states:

> Evans (1931:425-426) wrote that the Day Creek dolomite limestone is a 2-foot thick, hard, light gray limestone or dolomitic limestone, which commonly contains aggregates of smoky or reddish chert. Merrit and Ham (unpublished Oklahoma Geological Survey Report, 1942) described an outcrop of the Day Creek dolomite in the SW 1/4 Sec. 18, T. 28N., R 22W. as a 2 1/2 foot thick ledge of white, dense, crenelated dolomite with stringers and irregular masses of bluish botryoidal chalcedony. Thin section study showed that considerable quartz is present in three forms: (1) euhedral, 0.25 to 0.4 mm long, partially replaced by calcite; (2) anhedral in cavities associated with secondary calcite, with which it seems to be at least in part contemporaneous; and (3) chalcedonic\silica replacing carbonate and euhedral quartz.

Postulated relationships between this lithic raw material and Alibates agatized dolomite are not included in the discussion.

Reanalysis of the lithostratigraphies, coupled with changes to the lithostratigraphic nomenclatures, was first initiated by Fay et al. (1962). Within the publication (Fay et al.

1962), adherence to distinguishing between Lower (Leonardian Series) and Upper (Guadalupean Series) Permian deposits continued to follow previously established lithostratigraphic nomenclature, however, important refinements were proposed for certain members and formations.

Fay (1965) continued the refinement of the lithostratigraphic profile in his publication *Geology of Woods County*. Choosing for the first time to drop the Leonardian and Guadalupean Series nomenclature, Fay (1965:16) proposed that Cimarronian (Lower Permian) and Custerian (Upper Permian) be used in their place. This decision resulted from the inability to correlate contiguous sedimentary units in Oklahoma, Kansas, and Texas with those series found in the *type sites* of southwest Texas, and New Mexico (Fay 1965:16). Additional refinement of various beds (e.g., Moccasin Creek Bed) are proposed and utilized as lithostratigraphic datums to distinguish one formation from another (Fay 1965:73).

Subsequent work by Fay and Hart (1978) has resulted in the most complete understanding of northwest Oklahoma, and southwest Kansas, Permian Dissected Red Bed lithostratigraphies to date (Table 3 and Table 4). In addition to reorganizing various strata by groups (e.g., Foss Group; Upper Permian), Fay and Hart (1978:19) outlines the rationalization of dropping the former lithostratigraphic nomenclature "Quartermaster Formation." First proposed by Gould (1902:57), and then utilized as a formation by Evans (1928:708), the Quartermaster has been dropped by Fay and Hart (1978:19) due to the fact that the type "Quartermaster Formation," is actually defined by the Cloud Chief Formation and the Rush Springs Formation. The Quartermaster Formation cannot be grouped into a natural tectonic or contiguous sedimentologic unit (Bailey 1998:192-93). This is due to the fact that the Doxey Shale, and underlying Cloud Chief Formation, are grouped together, forming the Foss Group (Fay and Hart 1978:19).

The terminal Upper Permian is represented solely by the Elk City Sandstone. The

Table 3: Lithostratigraphic Column for Permian Red Beds of Northwestern Oklahoma and Southwestern Kansas (Fay and Hart 1978)

PERMIAN SYSTEM

- CUSTERIAN SERIES [Upper Permian]
  - TERMINAL UPPER PERMIAN
    - Elk City Sandstone
  - FOSS GROUP
  - Doxey Shale
  - Cloud Chief Formation
    - Big Basin Member
    - Day Creek Dolomite Bed
    - Kiger Member
    - Moccasin Creek Bed
  - WHITEHORSE GROUP
    - Rush Springs Sandstone Formation
      - Weatherford Bed
      - Old Crow Bed
    - Marlow Formation
      - Emmanuel Bed
      - Relay Creek Bed
      - Doe Creek Sandstone

- CIMARRONIAN SERIES [Lower Permian]
  - EL RENO GROUP
    - Chickasha Formation
      - Dog Creek Shale
      - Southard Dolomite Bed
      - Haskew Gypsum Bed
      - Watonga Dolomite Bed
      - Blaine Formation
      - Shimer Gypsum Bed
      - Altona Dolomite Bed
      - Nescatunga Gypsum Bed
      - Magpie Dolomite Bed
      - Kingfisher Creek Gypsum Bed
      - Medicine Lodge Gypsum Bed
      - Cedar Springs Dolomite Bed
      - Flowerpot Shale
      - Duncan Sandstone [Peace Treaty Bed]
  - HENNESSEY GROUP
    - Bison Formation
    - Salt Plains Formation
      - Kingman Siltstone
      - Fairmont Shale
  - SUMNER GROUP
    - Garber Sandstone
    - Wellington Formation

Table 4: Lithology Descriptions for Certain Permian Red Beds in Northwestern Oklahoma and Southwestern Kansas (Fay and Hart 1978)

PERMIAN SYSTEM

CUSTERIAN SERIES [Upper Permian]

TERMINAL UPPER PERMIAN

Elk City Sandstone

Orange-brown sandstone as much as 50 feet thick with prominent thin maroon shale about 14 feet thick above the base and greenish-gray siltstone and shale at base; contact with the Cretaceous (Kiowa Shale Formation) at the tope of the unit represents an unconformity.

FOSS GROUP

Doxey Shale

Red-brown shale and well-indurated siltstones approximately 195 feet thick with a 0.4 foot tan dolomite about 72 feet above the base and a greenish-gray calcitic siltstone at the base.

Cloud Chief Formation

Red-brown shale with interbedded thin orange-brown to greenish-gray sandstones, siltstones, shales and dolomites, divided into an upper *Big Basin Member*, having a maximum preserved thickness of 25 feet and a lower *Kiger Member* approximately 35 feet thick. Between them is the *Day Creek Dolomite Bed*, a 1 to 2 foot layer of compact light gray cherty dolomite that supports a prominent escarpment. At the base of the formation is the scarp-forming *Moccasin Creek Bed*, normally 2 to 4 feet thick which consists of one or two thin pink dolomites that are gradational into greenish-gray calcitic sandstones.

WHITEHORSE GROUP

Rush Springs Sandstone Formation

Orange-brown fine-grained sandstone and siltstone with interbedded red-brown shale; upper one-third is massive sandstone 80 - 90 feet thick.

Marlow Formation

Orange-brown fine-grained sandstone 100 to 115 feet thick, including 12 to 20 feet of red-brown shale at top.

CIMARRONIAN SERIES [Lower Permian]

EL RENO GROUP

Chickasha Formation

Dog Creek Shale

Primarily red-brown shale, 50 feet thick, conformable with beds above and below; upper 10 feet interbedded with fine-grained dolomites.

Blaine Formation

Alternating thick white gypsum beds and red-brown shales (70 feet thick), conformable with beds above and below.

Flowerpot Shale

Red-brown gypsiferous shale and thin greenish-gray shales with interbedded orange-brown to greenish-gray gypsiferous sandstones/siltstones; near top is 1 to 2 inch dolomite.

Cedar Hills Member

Orange-brown and thin greenish-gray fine-grained sandstone and siltstone, with interbedded red-brown shale and gypsiferous sandstone.

Bison Member

Red-brown shale and orange-brown siltstone.

type Quartermaster Formation included the Rush Springs Sandstone Formation, and overlying Cloud Chief Formation (Fay and Hart 1978:19), and therefore the name *Quartermaster Formation* has been dropped (Bailey 1998:192-93). With reference to the lithogenesis of Day Creek Dolomite, Welsh's (1966:62-3) closing comments are worth noting:

> In view of the results of this study, the following conclusions were reached:
>
> 1. The Day Creek Dolomite is a thin, persistent, stratigraphic Unit.
> 2. The Day Creek Dolomite, as classified on the basis of calcium-magnesium ratios, is slightly calcareous dolomite.
> 3. The chalcedony present is a replacement after dolomite, as shown by its automorphic boundaries against dolomite.
> 4. The calcite found in the vugs is a second generation of calcite as shown by its euhedral crystals, which have grown at the expense of surrounding material.
> 5. Dolomite has replaced calcite as shown by the automorphic boundaries of dolomite against calcite and the calcite centers of dolomite rhombs.
> 6. The dolomite has experienced at least two episodes of crystal growth as shown by the two different ranges of crystal sizes.
> 7. The wavy structure is the result of gravity sliding and folding before lithification.
> 8. The Day Creek Dolomite is of early replacement origin, post-wavy structure, pre-lithification. (Because of the fact that dolomite rhombs do not show orientation controlled by the wavy structure, the wavy structure is judged to be pre-lithification).
> 9. The sequence of events regarding the history of Day Creek Dolomite are as follows: deposition of precipitated calcium carbonate as lime mud on the bottom of a marginal depression on the shelf of an intracratonic basin; restriction of the outflow of sea water from the marginal basin; balance of inflow of normal sea water and evaporation; deposition of precipitated magnesium carbonate, calcium carbonate, and calcium sulfate onto the lime mud; gravity sliding and folding of the unconsolidated sediment; permeation of the unconsolidated sediment by magnesium carbonate; and crystallization of dolomite effecting the

replacement during lithification.

The lithostratigraphic nomenclature of the Texas and Oklahoma panhandles and southwest Kansas, have followed an evolutionary path since Cragin's (1896) initial synthesis. In hindsight, many of the proposed lithostratigraphic relationships (e.g., Gould 1902; Gould and Lewis 1926) are in error, yet they continued to be utilized by geologists until the middle 1960s (Myers 1959; Swineford 1955; Welsh 1966) and in many instances by contemporary archaeologists and geomorphologists (Banks 1984:74, 1990:92; Dolliver 1984; Holliday 1997). Research concerning the lithostratigraphic relationships of Permian Dissected Red Bed deposits throughout the region has been sporadic due to their inconsequential economic value. Current lithostratigraphic research is often associated with natural gas well drilling, hydrological studies, and large scale projects concerning the storage of nuclear waste (Dolliver 1984; McGookey et al. 1988). Research conducted with an archaeological focus in the northwest Oklahoma, and southwest Kansas, regions most often are in the form of mitigation procedures associated with the placement of natural gas pipelines, drilling rigs, and highway projects (Lopez and Keith 1979). As a result, publications concerned with the geoarchaeology and/or prehistoric/historic archaeological resources of the region tend to cite outdated literature. Examples of this situation include: (1) The continued use of the name "Quartermaster Formation" nomenclature subsequent to its removal in 1978 (e.g., Hofman and Brooks 1989:6; Holliday 1997:245-57); (2) The extrapolation that Alibates agatized dolomite is a lateral equivalent to Day Creek Dolomite (e.g., Banks 1984:74, 1990:92; Brooks 1994:13; Dolliver 1984; Hofman and Brooks 1989:6); and, as a result, (3) That the utilization of Day Creek chert was only a local occurrence that had little importance outside the immediate area in which it is found (Banks 1984:74, 1990:92; Hofman and Brooks 1989:6).

Chapter V: AVAILABLE LITHIC RAW MATERIALS FOR PRODUCING STONE TOOLS IN NORTHWEST OKLAHOMA AND SOUTHWEST KANSAS

Utilization of lithic raw material resource data is an increasingly viable and important research tool. Within much of the archaeological discourse committed to the analyses of prehistoric temporal periods on the Great Plains, socioeconomic emphasis concerning the acquisition, distribution, and exchange of lithic raw materials (Vehik and Baugh 1994:249-274 and references cited therein) have occasionally utilized the sophistication of geophysical and geochemical methodological approaches (Church 1994 and references cited therein). Coupled with these evolving methodologies are the re-evaluations of theoretical perspectives concerning the mechanisms contributing to variant prehistoric human behaviors (Binford 1983; Binford and Binford 1968; Clark 1989; Clarke 1968; Dunnell 1971; Earle and Ericson 1977; Plog 1974; Winterhalder and Smith 1981). Of immediate interest, for my research, are the archaeological signatures that prehistoric human populations deposited within the lithic raw material quarries and workshops (see Ahler 1977; Carlson and Peacock 1975; Haury 1985; Holen 1991:399-411; Vehik 1983:211-255, 1984:175-197, 1986a:13-33, 1986b:141-154, 1988:41-68; 1990:125-145; 1994:239-263; Vehik and Baugh 1994:249-274).

It should be noted that whenever discussion of lithic raw materials are the focus of any research program, primary concern should be paid to the appearance and location of both local and allochthonous chert rescources (Luedtke 1992). The primary aim of this chapter is to familiarize the reader with the mulititude of both local and allogenic cherts found in the study region. This is important. Currently, archaeological research in the study region has been sporadic and without a committment to the determination of lithostratigraphic sources of useful stone for the production of tools (Odell 1989:159-82). In addition to the mantle of Tertiary gravel blanketing the area (which does contain suitable lithic raw materials for the production of stone tools), there exists a plethora of available lithic raw materials that are transported by adjacent streams, rivers, and extinct alluvial systems. Much of this material is not Day Creek Dolomite in origin. Additionally, with the widespread dissemination of lithic raw materials across the Great Plains, nearly every lithic raw material available over many hundreds of kilometers is found in the region of northwest Oklahoma and southwest Kansas. Therefore, discussion of the most prevalant lithic raw materials is presented for the purpose of clarification (Kozlowski 1991:1-6), ultimately detailed towards the ultimate origin of lithic raw materials that share similar lithologies in the study region (e.g. Tunnell 1978) (Figure 9).

LOCALIZED PRIMARY LITHIC RAW MATERIALS

Lithic raw material sources available within the regional scope of my research tend to consist of poor lithological, stratabound Day Creek chert, allochthonous cherts within local Tertiary and Quaternary gravel (with limited areal accessibility). This often resulted in prehistoric behavior that relied on allochthonous lithic raw material sources for high quality lithic raw material. The presence and location of lithic raw materials suitable for stone tool reduction by prehistoric Native Americans in northwest Oklahoma and southwest Kansas is predicated by: (1) The accessibility to intact chert bearing strata within the Day Creek Dolomite; (2) Accessibility to colluvium resulting from mass wasting of chert-bearing strata within the Day Creek Dolomite; (3) The occurrence of regolith in floodplain valleys; (4) Redeposited alluvium associated with intermittent and permanent streams; (5) Knappable gravel sources occurring along the marginal edges of the Cimarron River; and (6) Knappable gravel naturally occurring within discontinuous point bars associated with fluvial events that have transpired since the Tertiary and/or Quaternary periods.

Materials suitable for stone tool production, and discussed herein, include Day Creek chert, Ogallala (chert, petrified wood, quartzite), Dakota quartzite, Morrison

Figure 9. Location of Lithic Raw Materials on the Southern High Plains (adapted from Drass and Turner 1989:68)

quartzite, knappable allochthonous alluvium gravel consisting of, but not limited to, chert, basalt, fossilized wood, jasper, and obsidian. Discussion of each lithic raw material (Day Creek chert withstanding) is drawn from published data provided by Banks (1984:64-95;1990:59-115). It should be noted that Banks (1973, 1983, 1984, 1990) has consistently contributed to our understanding of the regional presence, distribution, and intensity of lithic raw materials within the southern and south-central Great Plains.

DAY CREEK CHERT [Late Permian]

Within Harper County, Oklahoma and Clark County, Kansas (along the confines of various alluviums resulting from extinct paleo-drainages found throughout the Cimarron River floodplain), there exists a large amount of freely occurring Day Creek chert in regolith, ranging in size from sand particle to boulder. Most examples tend to range in size from very angular clast to large, well-rounded cobble. Many nodules tend to be poorly suited for knapping due to the cataclasis presence of fracture planes originating from alluvial and/or colluvial impact, thermal expansion/contraction (Gibbard 1986:141-49), and mechanical stress fractures originating from deformation of the Day Creek Dolomite Bed while the Day Creek chert remained *in situ* (Gibbard 1986:141-49 and references contained therein).

OGALLALA [Pliocene]

Defined by Darton (1899:734-35), the Ogallala was initially named after formational outcrops located near Ogallala, Nebraska. In recent years the presence of four distinct Ogallala formations (Kimball, Sidney, Ash Hallow, and Valentine) have been identified in Colorado and Kansas, and contain geological materials within the Potter Member that are classified as orthoquarzites, metaquartzites, chert, silicified siltstone, opalite, and petrified woods (Banks 1990:95). Ogallala quartzite cobbles with grey-brown and/or red coloration are found commonly in the region, having been reduced into stone tools by prehistoric artisans. Given the ubiquitous nature of this lithic material in the central and southern Great Plains (Franks and Swineford 1959:186-196; Frye and Leonard 1957), archaeological sites in the region typically show evidence for the use of Ogallala. Banks (1984:71) notes that within the Texas Panhandle there exist "eight different localized names for the gravel member of the Ogallala" (Byrd 1971:11), and given the confusion associated with this situation, Jack Hughes (1976:2) chose instead to refer to the material simply as *Potter Chert*.

Chert from the Ogallala Formation that assumes a brown-tan-white Opaline hue (Banks 1984:71; Swineford and Franks 1959:111-112) is commonly found throughout the Great Plains, and in particular, the caprock exposures outside Spearman, Texas (Bailey 1993:personal observation). Given the poor fracture mechanics of this material (termed *Ogallala Chert* by Jack Hughes [1976:2]), Banks (1984:72) considers it to have been used only sporadically by Archaic and later groups. Unique opalite outcrops limited in areal distribution but of a high quality are reported by Peterson (1988:286) along Palo Duro Creek in the northeastern Texas Panhandle (Banks 1990:95).

In the vicinity of Mt. Jesus in Clark County, Kansas, the presence of Ogallala quartzite cobbles mixed with sand and gravel have been documented during field work associated with this research. Often found clast size, the cobbles were used for lithic raw material, as well as hammerstones. Ogallala hammerstones litter the Day Creek Dolomite outcrops at the head of Day Creek (Clark County, Kansas). They were presumably used to dislodge and knap the chert and, when fractured beyond that use, they were sometimes reduced and made into expedient flake tools.

DAKOTA and/or MORRISON [Cretaceous]

Unfortunately, clear distinctions between the sources for Dakota Formation quartzite (Beaubien 1931), Morrison Formation quartzite (Voegeli and Hershey 1965:57), and Tesesquite quartzite (Saunders 1978:86) are unavailable (Banks 1990:94). In much the same manner as Day Creek chert, the Dakota Formation and Morrison Formation do not contain continuous outcrops of quartzites, forcing the researcher to conduct actual field investigations for identification of lithic raw material availability and the presence of discrete workshops and/or quarries. Banks (1990:94) reports that the greatest known concentrations of knappable quartzites within the Dakota Formation occur in the Black Mesa region of the western Oklahoma Panhandle (Saunders 1978), the Springfield vicinity of Colorado (Beaubien 1931), an isolated quarry site [14KY303] reported by Martin Stein (1985:101-16) in Kearny County, Kansas, and a quarry site [14MT98] reported by Kenneth Brown (1976) in Morton County, Kansas. Typically found with variations in lithologies, many of the quartzites are found to range in color from yellowish-browns, browns, and dark red to deep maroon.

The presence of Dakota and/or Morrison outcrops containing knappable quartzites have been documented north of the Cimarron River in Clark and Kiowa counties, Kansas during the course of my research. Additionally, many other sites containing this material are known from interviews with local informants in southwest Kansas. In most cases the presence of the Dakota and/or Morrison was discovered through early Euroamerican pioneers seeking good masonry stone, and later, through the use of this material for countless building sites implemented by the Works Progress Administration during the 1930s.

Significant to the identification of this material in southwest Kansas is the presence of Dakota and/or Morrison Formational elements associated with permanent spring boils. Due to the subsurface dissolution of friable materials laying in a basal position to the sandstone, surface collapse occurs and creates a suitable approach for the quarrying of the lithic raw material. Commonly, the lithologies at these sites consist of loosely cemented and poorly indurated sandstones, however, it is not infrequent to find very tightly cemented and well-indurated sandstone (orthoquartzites) immediately adjacent. Typically a very dark brown to black in color, variations consisting of yellows, yellow-browns, and deep maroons are recorded. In one particular exposure, the quartzite consists of a deep brown to maroon tightly cemented material, and has inclusions of fossilized flora (most often fern, however, grape has been recorded by Raymond McMillion during construction of his house near Englewood, Kansas in the 1920s) that are bright yellow and found throughout the orthoquartzite.

Prehistoric use of the Dakota and/or Morrison quartzites in Clark County, Kansas, is evident in many sites that were recorded during the process of my research, and indicates that the materials were used during the Paleoindian period. The oldest cultural site with an associated artifact (Clovis projectile point; proximal end) located in Clark County, Kansas, during the course of my research is fashioned from Dakota quartzite; it is deep maroon in color and contains numerous fossil fern inclusions throughout the orthoquartzite. The origin of the lithic raw material most consistent in lithology with the material used to fashion the aforementioned Clovis point is approximately 12.87 kilometers due southwest of the Paleoindian campsite (14CK421) on Bluff Creek (Clark County, Kansas) where the projectile point was initially discovered.

Artifacts fashioned from Dakota quartzite in the region of this study include examples of the diamond-beveled knife (Plains Village Tradition), spear, dart, and arrow projectile points, large non-descript utilitarian tools, manos and grinding stones of every size and description. In those areas where access to the Dakota Formation is unimpeded, literally hundreds of prehistoric pictographs have been etched into the sandstone walls, cave ceilings, and/or rock shelters (most frequently in Kiowa and Ford counties, southwest Kansas).

LOCALIZED ALLOCHTHONOUS LITHIC RAW MATERIALS

In northwest Oklahoma and southwest Kansas, the procurement of lithic raw materials for the production of stone tools can be problematic. Good knappable materials, outside of the aforementioned localities that contain Day Creek chert, Ogallala, and Dakota, are often difficult to locate and/or contain scant amounts of the cryptocrystalline necessary for making many classes of tools. In a region such as this, where lithic raw material is often scant, reliance on gravel deposits for suitable allochthonous material is reflected in most of the archaeological sites investigated; many flakes and/or tools commonly exhibit gravel cortex. Gravel associated with the Cimarron River, as well as smaller lateral drainages (most often Bluff Creek in Clark County, Kansas and Buffalo Creek in Harper County, Oklahoma), contain lithic raw material which is conducive to reduction via standard knapping trajectories. The most common problem, however, is finding gravel that is large enough to reduce. Most of the material is pebble to roughly tennis ball in size, rounded but often angular, and contains many internal fractures, making controlled reduction nearly impossible. In those instances the material tends to be fashioned into utilitarian flakes without clear diagnostic value.

My research has indicated that a plethora of lithic raw materials are available along the confines of the Cimarron River, Bluff Creek, (Clark County) Kansas, and Buffalo Creek, Oklahoma. Clast size (and larger) rounded cobbles can be found in many of the point bars and flood gravel associated with both drainages. Secondary material identified as obsidian has been found along the Cimarron River, in the vicinity of *Deep Hole* (south-central Clark County, Kansas), suggesting that sources for this lithic raw material are not necessarily related to trade and/or long distance acquisition (Rensink and Spieksma 1991:141-60). Gravel associated with fluvial systems in the region can essentially contain every description of lithologies, including, but not limited to, petrified wood, petrified bone, petrified ivory, chert, chalcedony, quartzite, jasper, sandstone, granite, and quartz. Locating pieces that are large enough to produce stone tools, however, is often difficult.

Another source for lithic raw material is found in the Tertiary gravel that blankets the region (Nials 1977). Contained therein are materials of every description and lithology, and one can often find individual pieces that are satisfactory for controlled lithic reduction. In 1994, while investigating a modern gravel quarry about 9.67 kilometers northwest of Sitka, Kansas [Clark County], washed gravel awaiting shipment was sampled for knappable material. In a short time after removing selected pieces and testing them for lithology and quality, it was clear there existed enough fine-grained lithic raw material, of sufficient size, to produce essentially any typological stone tool. The presence of high grade petrified wood and unidentified clast size chert indicates that, with little difficulty, prehistoric artisans could have mined these gravel sources and located enough lithic raw material to satisfy their needs. Interestingly, within the gravel are a large compliment of ivory, teeth, and bone that are consistent with the skeletal elements of mammoth and bison. Petrified skeletal elements sufficient in size and quality for knapping, however, are lacking.

ENTIRELY ALLOCHTHONOUS LITHIC RAW MATERIALS

Most likely resulting from the highly variable lithology, quality, and quantity of the aforementioned localized lithic raw materials in northwest Oklahoma and southwest Kansas, the region contains ample evidence of prehistoric utilization of allochthonous lithic raw materials. Procurement of allochthonous lithic raw materials, and their subsequent transport to the local area (e.g. Harper County, Oklahoma and Clark County, Kansas), can occur as a result of trade, exchange, direct acquisition, or through the discovery of a previously buried lithic cache. While it is unknown what the total inventory of allochthonous lithic raw materials coming into the prehistoric region may have been, evidence confirmed by the presence of known lithic raw materials in archaeological context indicates that allochthonous lithic raw materials arrived from loci throughout the Great Plains. Unfortunately, it is currently unclear what the ultimate variety of lithic raw materials in local gravel deposits may consist of, forcing the researcher to often assign the material as *unidentified* and/or *nonlocal*. Coupled with the fact that many researchers are ill-equipped to deal with the variant lithologies of lithic raw materials in the Great Plains and beyond, this situation has led them to assign lithostratigraphic sources such as *Alibates agatized dolomite* to material that is *Day Creek chert* or even *unidentified river gravel*. At the regional level, both the Arkansas and Cimarron rivers have downcut through hardrock and sedimentary formations, and in the process, redeposited those materials far downstream (see Wyckoff 1993:35-58 for discussion of this dynamic situation along the Canadian River). For instance, lithic raw material having its formational origin in eastern Colorado can be transported by the Arkansas River, and ultimately deposited throughout western Kansas. Given the preservation of chert, chalcedony, and jasper in the fluvial environment, and its long distance transport over time, lithic raw materials that may be *subjectively* consistent with a known allochthonous lithic raw material (such as Alibates agatized dolomite), still are not *objectively* known to actually *be* that specific lithic raw material. Too often, this leads towards the formulation of a skewed archaeological record. It was with the knowledge of this common problem that led my research to focus only on those lithic samples in the field that could be objectively identified, and verified, *in situ* at the Cloud Chief formational level (Whalen 1990:219-236).

ALIBATES AGATIZED DOLOMITE [Permian]

Simply termed *Alibates* by most archaeological researchers, this stone type has its origin in the Texas panhandle, northeast of Amarillo, Texas. Primary literary sources concerning Alibates agatized dolomite include Banks (1984:74, 1990:91-94), Bowers (1975 and references cited therein), Carroll (1941:64), Gould (1907:17), J. Hughes (1976), Wiseman (1992:167-70), and Wyckoff (1989, 1993).

Alibates agatized dolomite constitutes one of the most common lithic raw materials utilized by prehistoric populations in the southern Great Plains. Its areal movement during prehistory covers a wide geographic expanse in any cardinal direction, and as a consequence, contributes to this lithic being commonly over-identified by archaeologists in the Great Plains. However, Banks (1990:91) rightly states that, with regard to the lithology of Alibates agatized dolomite, "...the variability in physical characteristics of the raw materials is poorly known by most archaeologists and inadequately described in print." Interestingly, this statement applies to nearly all of the lithic raw materials that outcrop in the Great Plains.

Unfortunately, Alibates agatized dolomite continues to be reported as a *lateral equivalent* to Day Creek chert in most of the archaeological literature concerning lithic raw material sources and quarries on the southern Great Plains. For instance, Banks (1984:74) erroneously states:

> The Day Creek dolomite is considered by Roger Bowers (1975:17-19), and *a number of geologists* to be a lateral equivalent of the Alibates dolomite. The Day Creek produces *minor* quantities of chertified dolomite similar in color and texture to some of the less vivid and more porous varieties of the Alibates. It was in the Day Creek deposits of southern Kansas immediately north of this area that G. H. Norton (1939:1811) first hypothesized that the silicification (or chertification) in the Day Creek was a result of secondary replacement from silica sources in the Ogallala formation [emphasis added].

In a more recent article, Banks (1990:92) continues his insistence that Alibates agatized dolomite and Day Creek chert are lateral equivalents. Banks (1990:92) states:

> The Day Creek Dolomite (Cragin 1896:361-362) is a lateral equivalent of the Alibates (see Bowers 1975:17-19 for discussion). The Day Creek crops out in western Oklahoma, southwest Kansas, and in the vicinity of Two Buttes in south-east Colorado. At Two Buttes, however, chert is not

> known as a part of the lithology. In general, *the chert in Day Creek is not comparable to the Alibates in quantity, quality, or size* [emphasis added].

It should be noted that extensive research and lithological mapping of the deposits in southwest Kansas and northwest Oklahoma have confirmed, without any doubt, that Alibates agatized dolomite and the Day Creek Dolomite (with *in situ* chert) are *not* lateral equivalents. It is unclear whom Banks (1984:74) is referring to when he states that *a number of geologists* believe the Alibates agatized dolomite and Day Creek Dolomite to be lateral equivalents; on the contrary, the geological literature indicates the exact opposite (Fay 1959; Fay et al. 1962; Fay and Hart 1978). According to Banks (1984:74):

> ...it is unlikely that its [Day Creek chert] distribution would have anything other than local significance. Individuals conducting archaeological research in the areas of Day Creek exposures, however, should be aware of its possible local significance. The actual distribution of chert in the Day Creek is *unknown* [emphasis added].

Based on the aforementioned, it is not clear why Banks (1984:74) continues to contradict his position that the Day Creek Dolomite "produces minor quantities of chertified dolomite similar in color and texture to some of the less vivid and more porous varieties of the Alibates," and/or that "...the chert in Day Creek is not comparable to the Alibates in quantity, quality, or size" (Banks 1990:92). Given Banks' (1984:74) accurate statement that the "...actual distribution of chert in the Day Creek is unknown," it is unclear why Banks' remains inconsistent concerning his perspective that Day Creek Dolomite produces only minor quantities of chert similar to Alibates agatized dolomite, and/or that Day Creek chert is not comparable to Alibates agatized dolomite's lithological attributes.

It should be noted that my research has uncovered *in situ* Day Creek chert that shares exact lithologies with many different grades of Alibates agatized dolomite. However, at the archaeological site level, it is nearly impossible to distinguish one chert from the other based simply on lithologies. In the region of Harper County, Oklahoma, and Clark County, Kansas, both cherts are found within habitation sites, and occasionally, at lithic reduction workshops. Without the use of extremely sophisticated trace mineral analyses (e.g., see Church 1994), lithic raw material and/or debitage analysis assigning lithostratigraphic identifications of Day Creek chert and Alibates agatized dolomite is extremely inaccurate.

Alibates agatized dolomite can run the full gamut of lithology. Typically it tends to be a mixture of bright reds, yellows, whites, and blues. Within archaeological specimens found in Clark County, Kansas, granularity tends to be very fine, however, roughly textured specimens with inclusions and vugs of quartz are not uncommon. Lithic material samples *consistent* with the lithologies of Alibates agatized dolomite are found literally in the thousands throughout Harper County, Oklahoma and Clark County, Kansas. But, it cannot be certain that the material is Alibates agatized dolomite. Currently, there exists no standard visual characteristics that can be routinely utilized to ultimately distinguish, with certainty, Alibates agatized dolomite, Day Creek chert and/or Baldy Hill jasper.

TECOVAS [Triassic]

Information pertaining to this discussion of Tecovas is primarily derived from Banks (1984:70-72; 1990:92-94). Additional information for Tecovas and/or its lateral equivalents (including the Baldy Hill Formation of northeastern New Mexico) can be found in Gould (1907:20-29), Foster (1966:84), Lynn (1986), Mallouf (1989), McGowen et al. (1979), and Neuhäuser et al. (1987:153-159).

Covering a greater areal distribution than Alibates agatized dolomite, Tecovas constitutes a jasper that retains a wide spectrum of colors. It is, typically, considered by researchers in the Great Plains to resemble *bacon* in color, and often tends to have mottling of white, yellow, orange, and/or tan. Areal distribution of Tecovas is much wider than that found with Alibates agatized dolomite, however, the quantity of available material does not approach that of Alibates agatized dolomite. Tecovas rarely approaches sufficient raw material nodule size (unlike Alibates agatized dolomite) to be considered optimal for primary lithic raw material reduction (Banks 1990:92-93). Samples of Tecovas indicate that it could be mistaken for either Alibates agatized dolomite (Wiseman 1992:1 67-70) and/or Day Creek chert, due to the overlap of its representative lithologies. Banks (1990:92) states that "The best known sources of Tecovas are along the eastern escarpment of the Llano north of Quitaque, Texas, along the Canadian River in the same general area as the Alibates Dolomite, and at the Rotten Hill quarries near Landergin Mesa in Oldham County [Texas]."

FLORENCE [Permian]

Located in the Flint Hills of south-central Kansas and north-central Oklahoma, the presence and discussion of the Winfield, Wreford, and Florence chert-bearing formations have been detailed extensively by Haury (1979, 1984).

Banks (1990:99) considers the Flint Hills, and its "...areal extent, volume, and variability" to represent "...one of the major resource areas of chert in the United States." However, even with the overwhelming magnitude of the chert-bearing formations found in the Flint Hills, it is surprising that more extensive prehistoric quarrying and utilization of the material was not achieved (Banks 1990:99).

Archaeological research aimed at determining the prehistoric use, trade, and exchange of Florence-A chert in the region (Kay County, Oklahoma) has been extensively reported on by Cooper (1975:185-192), Sudbury (1971), and Vehik (1976:199-205) 1982:69-90; 1985a:81-98;1985b:165-232; 1986a:141-154; 1986b:13-33;1988:41-68; 1990:125-145; 1992:311-332; 1994:239-263).

The lithologies of chert specimens collected near Hardy, Oklahoma and Maple City, Kansas, are detailed by Banks (1990). Quoting Skinner (1957:42-43), Banks (1990:101) states:

> This rock is a fine-grained organic chert which was originally a calcarenite. The banding is discernible in thin-section only with low-power magnification. The banding appears to be a weathering phenomena due to alteration of hematite to limonite in fronts of penetration through ground water action. Fusilinid sections, spicules, ostracod shells, straight and curved shell fragments, etc., are characterized by coarser chert than the finer ground mass. A flattened crinoid stem plate with typical inclusions is shown in Plate 9, fig. 1.The calcite is not completely replaced by silica (Plate 9, fig. 4). Large, incompletely replaced uni-granular masses of calcite traversed by silica seems to prove a replacement origin. A tendency to linear orientation of the organic fragments is striking. The pigment consists of hematite altering to limonite and clay and is more concentrated in the more organic portions of the slides. Many impurities are visible and are apparently an allogenic residue. A few dolomolds with an occasional dolocast are present. The fossil structures are more readily detected with uncrossed nicols.

As has been discussed by Skinner (1957:42-43), the presence of fossils and banding within samples of Florence-A tends to greatly aid with its identification. Florence-A, in my opinion, is one of the few cherts that can be often, but not always, be field-assigned, based on the lithologies, to its correct classification. Aside from the presence of fossils, extensive banding that mimics the look of tree rings is another visual aid that contributes to field identification. Additionally, Florence-A is often seen in the field to have undergone extensive thermal alteration through the intentional application of heat treatment by prehistoric populations (Cooper 1975:185-192). Originally removed from the ground with a tan or even grey appearance, once Florence-A has been heat treated, it tends to become a brilliant red or pink. Heat treatment also accentuates the presence of banding found in most samples.

Chert whose origin is the Flint Hills is routinely found in northwest Oklahoma and southwest Kansas. Typically most samples are found to be heat treated, however, the presence in this region of Florence-A that has not been thermally altered is well known, too. I have seen non heat treated Florence-A in the form of a large Paleoindian Folsom preform (Frison and Bradley 1980) that had been found on the ground surface in Comanche County, southwest Kansas as well as a combination of heat treated and non heat treated Plains Village Tradition diamond beveled knives contained in a cache at Rex Schmidt Site [14KW313] in Kiowa County, Kansas (Figure 10). While the presence of Florence-A in southwest Kansas and northwest Oklahoma has been repeatedly noted during the course of my research, it should not be construed that its appearance is overwhelming.

SMOKY HILL SILICIFIED CHALK [Cretaceous]

Found within the Smoky Hill Chalk Member (Banks 1990:96; Cragin 1896:51) of the Niobrara Formation, Smoky Hill silicified chalk is commonly referred to as *Niobrara jasper* and/or *Niobrara chert* by archaeological researchers in the southern Great Plains (e.g., O'Brien 1984). Additional nomenclature for this lithic raw material includes *Graham jasper* (Wedel 1979) and *Republican River jasper* (Carlson and Peacock 1975). However, based on the lithostratigraphic position of this jasper with relation to the Niobrara formation, Holen (1983) prefers the nomenclature *Smoky Hills silicified chalk*, or for the sake of brevity and in agreement with Wedel (1986), the use of *Smoky Hill japser*.

The Smoky Hill silicified chalk forms the upper member of the Niobrara Formation and is most often found "near the eroded upper surface of the member" (Frye and Swineford 1946:23). Unweathered, the interspersed chalk, chalky shale, and bentonite beds tend to exhibit a dark gray. However when exposed to physical weathering, the beds will transform in color to pinkish, tan, orange, yellow, brown, green, and maroon. This material will often exhibit limonite and pyrite concretions, and, in addition, ample evidence for marine fossils. With regard to outcrops of Smoky Hill silicified chert in the region of northwest Kansas, Wright (1985:87) reports:

Figure 10. Location of Kiowa County, Kansas [14KW313; Rex Schmidt Site]

> The Smoky Hill (Niobrara) "jasper" is generally a banded, almost ribbon form of agatized chalky marl which often resembles a Jasp-Onyx. It outcrops in western Kansas in upper sections of the Mesozoic Era, Cretaceous System. Gulfian Series, Colorado Group, Niobrara Formation. When viewed as pieces or manufactured artifacts it often displays a character which is too complex to identify as to its origin unless you use x-ray study or happen to be a local expert.

During a 1992 visit to the Smoky Hill silicified chalk member, south of Harlan County Reservoir in south-central Nebraska, I collected numerous samples that range the entire color spectrum and exhibited widely varying degrees of suitability for knapping lithic tools. Formed through secondary silicification diagenesis, typically the material is naturally graded from very soft and light in color into dense jasper which attains brilliant hues of the aforementioned coloration. The late Mr. John Reynolds [Kansas State Historical Society] (cited in Holen 1989:6) reported that "A nearly translucent chalcedony occurs occasionally in the jasper as thin veins." Variant coloration and density is a typical property of this jasper, and in that regard Wright (1985:88) states:

> Jasper can be said to grade from pure form to marginal forms. There are sub-varieties like: *Jasp-agate*, which is a mixture of jasper and chalcedony with jasper dominant (some of the "Smoky Hill" materials had these characteristics); *Jasper*, which is never as rough as chert, but is an impure chalcedonic quartz. The colors were previously discussed. It is never quite as exotic as agate. Some of the sub-varieties are: *Jaspilite, Moss Orbicular, Banded, Striped, Ribbon*, etc. Jaspilite, for example, is bright red with alternating bands of specular hematite. Hence, the great complexity grows, and a formation like the Niobrara evidently would produce scores of different appearing materials. Another sub-variety of jasper is *Jasperine*, which is defined as merely banded brown with specific mineral traces. Other types include *Pastelite, Waxy Jasper, Pudding Stone, Algae Jasper*, and *Jasperoid*.

Smoky Hill silicified chalk's presence, as an exotic, within northwest Oklahoma and southwest Kansas lithic collections is typically only second in volume to Alibates agatized dolomite, indicating that the jasper served as a key resource to prehistoric populations from the Paleoindian to Historic periods. During my field surveys, archaeological sites dating from the Late Prehistoric Period, located in Clark and Kiowa counties, Kansas, suggest a marked preference for this lithic raw material (evidenced by lithic debitage and finished tools); tools such as the diamond-beveled knife are frequently constructed utilizing Smoky Hill jasper. Holen (1983:10) reports having found Smoky Hill silicified chalk at the Spanish Diggings quarry in east-central Wyoming. It also has a significant presence in prehistoric sites near the Missouri River in northern Nebraska, Pawnee [Skiri] village sites in east-central Nebraska (Holen 1983, 1991:399-411), and at Wichita village sites near the Arkansas River in south-central Kansas. It should be noted that these examples indicate geographic movement in excess of 160 km. Finally, I examined a Clovis projectile point consistent with Smoky Hill silicified chalk in a private lithic collection maintained by the late Mr. Elmer C. Kraft, Jr., of Altus, Oklahoma. The specimen is in excess of 15+ cm, and exhibits unusual protrusions (nipple-like) on both lateral margins near the haft limit.

EDWARDS PLATEAU CHERTS [Ordovician through Permian]

Given the fact that the Edwards Plateau chert's of central Texas constitute an extensive areal source for lithic raw materials and are contained within 13 separate Paleozoic formations (Banks 1990:59; Trierweiler 1994), a complete description of the varied materials is well beyond the scope of this discussion. It should be noted that Fay (1999:personal communication) considers Edwards Plateau chert to date from the Cretaceous. For an in depth review of Edwards Plateau cherts, consultation should be directed to Banks (1990:58-62), Fisher and Rodda (1967:52-75), Geno (1976), Hill and Vaughan (1898:193-321), Paige (1911), Pittman (1959:121-134), and Trierweiler (1994).

Dating from the Paleoindian period and found within the region of northwest Oklahoma and southwest Kansas, stone tools (most often Clovis and/or Folsom projectile point types and transverse scrapers) constructed from lithic raw materials *consistent* with Edwards chert lithologies and ultraviolet fluorescence (see Wain 1965), are common in most private lithic collections. Nevertheless it should be noted that, within the context of archaeological site investigations in the region for the purpose of my research, Edwards Formation chert was *very rarely* encountered; this includes flintknapping debris, broken or complete stone tools of any classification, as well as examples from any temporal context aside from the Paleoindian Period.

In the Fall of 1994, Dr. Lee Bement [Oklahoma Archeological Survey] reported to me that a specific source of Edwards Plateau chert from Irion County, central Texas [41IR92] (Figure 10) appeared identical (with respect to lithology) to geologically unrelated samples of Day Creek chert located in Harper County, Oklahoma and Clark County, Kansas. It was subsequently found that Edwards Formation chert from Irion County, Texas, has identical coloration with respect to Day Creek chert when both were viewed under short-wave and/or long-wave ultraviolet fluorescent radiation.

Given this situation and the problems it posed in the field concerning accurate identification of the respective cherts, a fresh sample of Irion County, Texas, chert, as well as five fresh samples of Day Creek chert, were submitted to the University of Missouri, Research Reactor Center for in depth geochemical sourcing utilizing Instrumental Neutron Activation Analysis [INAA]. Concerning the INAA procedure, Purdy (1984:120) remarks: "Activation analysis can be defined as chemical analysis by means of induced radioactivity to make use of nuclear reactions resulting in radioactive species of atoms, whose disintegration characteristics are subsequently determined and used as a basis for identifying the elements originally present in the sample." Subsequent data, collected utilizing INAA, clearly indicates that, although Irion County, Texas, chert and Day Creek chert share nearly identical *subjective* lithological appearances as well as coloration under ultraviolet fluorescent

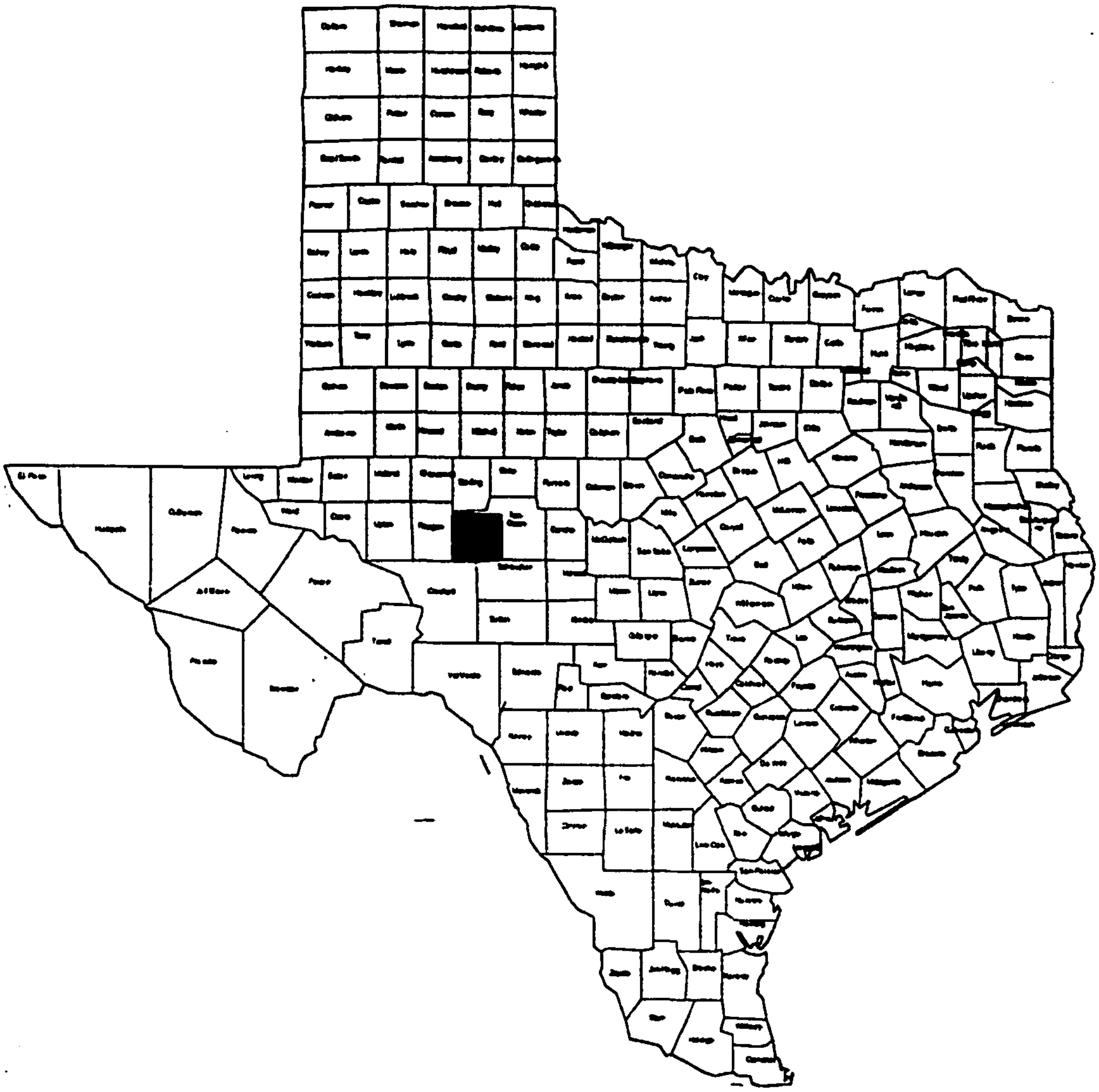

Figure 11. Location of Irion County, Central Texas Chert [41IR92; Edwards Formation]

radiation, their respective quantitative geochemical dissimilarities are clearly accentuated when analyzed using the process of INAA.

Given the aforementioned problems with accurate identification of lithic raw materials, and/or lithic sourcing of stone tools and debitage, we clearly need quantitative measures of identification between variant chert samples prior to speculating on any geological connections based on subjective criteria. Given the increasing use of lithic raw material as an analytical conduit to discuss prehistoric exchange systems in North America (Baugh and Ericson 1994), data that is subjectively collected and eventually disseminated through the archaeological literature will only increasingly, and incorrectly, skew the reality of what constitutes prehistoric exchange and/or direct acquisition of lithic raw materials on the Great Plains.

Chapter VI: PETROLOGICAL ANALYSES OF DAY CREEK CHERT AND ITS COMPARISON WITH ALLOCHTHONOUS LITHIC RAW MATERIALS FROM SURROUNDING GEOGRAPHIC REGIONS

> The dolomite [Day Creek] in the type area (sec. 33, T. 32 S., R 22 W.) is approximately 2 feet thick. Outcrops are poor and the rock is found chiefly as rubble on slopes. The wavy structure is well developed on the float blocks, and small chert nodules (generally less than 2 mm diameter) and stringers are common; they are particularly obvious in parts of the dolomite which are well weathered. Calcite-lined vugs and nodules of red very calcareous siltstone are also present. This rock is of complex origin and deserves detailed study. Up to 30 percent of the dolomite in the type area is acid-soluble and consists of globular drusy chert. Future petrographic study may indicate whether or not any of this chert is primary in origin (Swineford 1955:83-5).

With reference to the Day Creek Dolomite Bed, Swineford (1955:92) continues to state that the beds are uniformly thin and show much variation in the subsurface. Considered entirely anhydrite (in some wells), at places it consists of two brown or pink dolomite beds, at other locations is separated by red shale or anhydrite, and finally, in other places it is thin-bedded anhydrite and red shale.

Myers' (1951:42) manuscript contains the first published petrological analysis of chert-type materials found in the Day Creek Dolomite. Myers (1959:42) states:

> Evans (1931:425-426) wrote that the Day Creek dolomite limestone is a 2-foot thick, hard, light gray limestone or dolomitic limestone, which commonly contains aggregates of smoky or reddish chert. Merrit and Ham (unpublished Oklahoma Geological Survey Report, 1942) described an outcrop of the Day Creek dolomite in the SW 1/4 Sec. 18, T. 28N., R 22W., as a 2 1/2 foot thick ledge of white, dense, crenelated dolomite with stringers and irregular masses of bluish botryoidal chalcedony. Thin section study showed that considerable quartz is present in three forms: (1) euhedral, 0.25 to 0.4 mm. long, partially replaced by calcite; (2) anhedral in cavities associated with secondary calcite, with which it seems to be at least in part contemporaneous; and (3) chalcedonic\silica replacing carbonate and euhedral quartz.

As has been previously described in Chapter V, the lithological characteristics of Day

Creek chert often overlap with lithic raw materials originating from other formations found over large geographic distances within the Great Plains (e.g., Alibates agatized dolomite [Texas], Edwards Formation(s) [Texas], Frisco [Oklahoma], Knife River flint [North Dakota], Permian chert [Nebraska], Arkansas River gravel [Colorado; Kansas; Oklahoma], Cimarron River gravel [Kansas; New Mexico; Oklahoma], and, Canadian River gravel [Oklahoma; Texas]. River gravel sources are particularly troublesome since debitage often does not exhibit cortex suggesting its alluvial origin. With respect to temporal deposition Tertiary and Pleistocene gravel bars contain an array of knappable materials, resulting in the formation of lithic workshop debris that presently cannot be identified to lithostratigraphic origin (Brooks 1994:13).

Given this situation a systematic approach following a methodology pioneered by Welsh (1966) was developed to gain a more complete understanding of the Cloud Chief Formation lithostratigraphy. I placed particular emphases upon the extant Day Creek Dolomite and the discontinuous chert that is located within the bed. Pedestrian, vehicular, and equestrian field reconnaissance was initiated to research the position of *in situ* bedded Day Creek chert, as well as Day Creek chert located in regolith and other secondary environments.

My field and laboratory investigations (1991 through 1999) are pursuant to gaining a thorough understanding of the variations in lithologies and petrologies of Day Creek chert *in situ* to the lithostratigraphic Day Creek Dolomite. My intentions are to determine if the material is statistically homogeneous in relation to its physical and geochemical properties. Samples derived from the Day Creek Dolomite were secured in Harper County, Oklahoma and Clark County, Kansas (Table 5). Samples were subsequently submitted to scanning electron microscopy [SEM], ultraviolet fluorescence [UVF], and instrumental neutron activation analysis [INAA] (Church 1994). Strikingly dissimilar samples (color, texture, etc.)

SAMPLE 1

Ashland Type I
Day Creek Chert (Typical blue/grey)
Source: Bennefield Test Nodule
Harper County, Oklahoma
Buffalo NW Quadrangle, Section 35, Township 29 north, Range 23 west

SAMPLE 2

Ashland Type II
Day Creek Chert (Identical to Edwards Chert, black)
Source: The Henry Ford Site [14CK403]
Clark County, Kansas
Ashland Quadrangle, Section 10, Township 33 south, Range 23 west

SAMPLE 3

Buffalo Type I
Day Creek Chert (Identical to Alibates Agatized Dolomite, red/white/yellow/tan)
Source: The Isolated Buttes Sites
Harper County, Oklahoma
Fort Supply NE Quadrangle, Sections 11 & 13, Township 25 north, Range 22 west

SAMPLE 4

Buffalo Type II
Day Creek Chert (Identical to Tecovas, multi-colored)
Source: The Isolated Buttes Sites
Harper County, Oklahoma
Fort Supply NE Quadrangle, Section 11, Township 25 north, Range 22 west

SAMPLE 5

Buffalo Type III
Day Creek Chert (Identical to Alibates Agatized Dolomite, deep red/brown)
Source: The Isolated Buttes Sites
Harper County, Oklahoma
Fort Supply NE Quadrangle, Section 11, Township 25 north, Range 22 west

SAMPLE 6

Edwards Plateau Chert (Identical to Day Creek Chert, typical blue/grey)
Source: 41IR92
Irion County, Central Texas

Table 5. Geographic Locations of Six Samples Submitted for SEM and INAA Analysis

to routine Day Creek chert (Ashland Type II) were obtained from regolith exactly two miles west of Ashland, Kansas [Henry Ford Site; 14CK403] along an unnamed tributary of Red Hole Creek and submitted to the same analyses (Table 5, Sample 2).

Data derived from my field investigations indicates that Day Creek chert is discontinuous and, in every instance, nodular. Color, texture, and luster gradations are often entirely discordant over a single meter within a specific outcrop of Day Creek chert. I emphasized mapping and documenting extant outcrops of the chert; classifying it according to common physical properties such as system, color, texture, patination, granularity, luster, fracture, cleavage, inclusions, hardness, and nodular size. Unfortunately, Day Creek chert is never found to be fossiliferous, and as a result, cannot be analyzed through the identification of extinct marine organisms contained within the samples' silica.

Day Creek chert does not exhibit microscopic geologic structure commonly associated with confirmed secondary replacement chert found within the lithostratigraphic beds reported in Wyoming (Eugster and Surdam 1973:1115-20; Surdam et al. 1972:3361-66), gravel deposits outside Omaha, Nebraska (Loope 1998:personal communication), or Lake Magadi, Tanzania (Surdam and Eugster 1976:1739-52). However, the diagenesis of chert and/or chalcedony is controversial (Wise and Weaver 1974:301-326). The reader is directed to sedimentologic research concerning Day Creek chert conducted by Swineford (1955), Welsh (1966), and the aforementioned citations.

Swineford's (1955:83-5) research into the diagenesis and petrologies of the Day Creek Dolomite and, to a lesser extent, the Day Creek chert are well documented. With reference to petrology, Swineford (1955:83-5) proposes a lithostratigraphic origin for Day Creek chert that has since been seriously questioned and, subsequently, revised (Surdam and Eugster 1976:1739-52). In proposing a secondary source for Day Creek chert, Swineford (1955:83, 85) states:

Exposures of the Day Creek dolomite in Kansas are restricted to Clark County north of Cimarron River. In Oklahoma, however, a dolomite formation correlated with the Day Creek of Kansas crops out for about 60 miles in a southeast-trending belt in Harper and Woodward Counties (Norton, 1939, pp. 1760-1761). The formation was named by Cragin (1896, p.44) from exposures at the head of Day Creek in Clark County, Kansas, a few miles east of Ashland. The Day Creek in Kansas consists of a single bed of pale-gray to pink dense fine-grained dolomite ranging in thickness from 2 to 3 feet. At some localities the formation contains chert nodules and disseminated chert. The origin of the chert is reported to be post-Permian and is related to the Cenozoic deposits (see Norton, 1939, p. 1811). Weathered surfaces of the dolomite are characterized by intricately wavy ridges (Pl. 14A), and this character has led to its tentative correlation with the "crindly limestones" of northeastern Colorado, the Forelle limestone of Wyoming, and the Minnekahta limestone of the Black Hills (Norton, 1939, p.1812).

With reference to the Day Creek chert, Swineford (1955:85) states:

Better exposures of the Day Creek dolomite may be seen at the Kiger Creek locality in the SW1/4 SW1/4 sec. 3, T. 33 S., R. 24 W., Clark County (Pl. 13B). The dolomite here is 2.2 feet thick. The upper 1.1 foot is cherty and extremely vuggy; the middle 0.6 foot is light gray and dense, but in places slightly geodal. The lower 0.5 foot is similar to the middle, but also has yellow and purple streaks. This part is gradational downward into hard, well-cemented, dolomitic, well-sorted very fine-grained sandstone. The Day Creek dolomite is well exposed along the section road on the E. line sec. 19, T. 31 S., R. 22 W., Clark County. The total thickness at this locality is 2.3 feet; the upper two-thirds is white, and the remainder is faintly pink and purple and sandy. The upper surface of some of the dolomite in this general area has a siliceous crust, even where is underlies the basal greenish-gramontmorillonitic shales of the lower Taloga formation. This suggests that perhaps the Cenozoic deposits were not the only source of the silica. If the lower Taloga shale is bentonitic, silica may have been leached from volcanic ash and deposited at the top of the Day Creek dolomite.

In the Cen. sec. 14, T. 32 S., R. 23 W., the Day Creek dolomite is approximately 2.1 feet thick. the color is predominantly white. The Day Creek 10 miles north of Freedom, Oklahoma, is 3 feet thick, light-gray to white, rather coarsely crystalline to very fine-grained, and highly calcareous.

In agreement with Myers (1957) and Swineford (1955), Welsh (1966:44) argues for a secondary source for Day Creek chert found within the Day Creek Dolomite bed. Thin sections prepared by Welsh (1966:44)) indicate:

> The Day Creek Dolomite, in thin section, reveals fine-grain euhedral dolomite crystals, fine-grain subhedral calcite, and anhedral limonite. The minerals quartz and chalcedony are present in minor amounts, if present at all except in thin sections 12A and 13C, which contain considerable chalcedony as spherulites. Thin section 8C seems to contain the only quartz observed in all the thin sections examined. The quartz is angular to subangular indicating little or no corrosion or modification during transport. The quartz is anhedral, therefore, probably did not grow in situ. It may indicate a nearer strand line association than expected, but inasmuch as the grains are very small (less than 10 microns) it is possible that they were carried and deposited by the currents. The chalcedony spherulites present in thin sections 12A and 13C might be thought to indicate a rather active depositional interface. Thin sections 12A and 13C show that the chalcedony is in a replacement relationship by its more clearly defined boundaries against the surrounding dolomite and calcite. This observation leads to the possibility that the spherulites are replaced oolites and pisolites, indicating an active depositional interface, perhaps one such as would be found in a back reef area.

Following analysis of the petrology for Day Creek Dolomite and, to a lesser extent, Day Creek chert, Welsh (1966:45) believes that thin section 12A indicates:

> Fine grain, 10 to 60 microns, granular, chalcedonic dolomite. Dolomite is subhedral due to replacement by siliceous material, calcite in very minor amount as subhedral due to replacement by siliceous material, calcite in very minor amount as subhedral grains. Chalcedonic spherulites are numerous assuming no preferred orientation and showing no internal organization.

With reference to thin section 13C, Welsh (1966:46) states:

> Fine grain, 60 to 260 microns, granular, chalcedonic dolomite. Dolomite in very fine euhedra surrounded by chalcedony. Chalcedony spherulites are present with no apparent internal structure or inclusions.

In conclusion and in agreement with Swineford (1955), Welsh (1966:61) believes the Day Creek chert to be a secondary replacement following the diagenesis of Day Creek Dolomite [CaMgCO3: calcium/magnesium/carbonate], due to its automorphic boundaries against Day Creek Dolomite petrological samples.

Clearly, based on evidence presented in the geological literature over the past five decades, it is paramount that intensive geological research be directed at determining the ultimate origin and petrology of Day Creek chert (Bakewell 1995). Currently, arguments for either a primary or secondary diagenesis have been presented in a framework that is on the formation level and not usually directed at particular examples of chert, chalcedony and/or flint within their respective parent material. The work by Eugster and Surdam (1973), Loope (1998), Loope et al. (1990), Surdam et al. (1976), Swineford (1955), Welsh (1966), and others continues to point to the complexities of defining the petrology of any given chert and, more importantly, specific relationships between unrelated formations and the chert and/or chalcedony contained therein.

I attempted to locate an analytical tool which could be used by the archaeologist for determination of specific lithostratigraphic, unrelated lithic raw materials. With most archaeologists unwilling to sacrifice any portion of a diagnostic artifact for destructive analyses (particularly Paleoindian in origin), emphasis was placed on locating a non-destructive methodology for the determination of lithic raw material resources found in the region. Previous attempts towards this goal tend to be subjective and/or simplistic leading some in the archaeological community to believe that determination of any lithic raw material resource source is routine and without complication. On the contrary, my research indicates that the goal of establishing a theoretically sound and methodologically expedient set of procedures is exceptionally problematic. Lithic raw materials which are found to be void of extinct marine fossils do not lend themselves to an easy identification based on lithologies alone. With the use of the aforementioned scientifically advanced methods for lithic raw material identification, the net result remains the same: non-destructive procedures to identify some lithic raw materials from an archaeological context are inherently flawed. It should be strongly noted that with known lithic raw materials removed directly from the lithostratigraphic parent material, extensive overlap with unrelated lithic raw materials (also removed from their primary context) does not support the postulation of relationships based on lithologies (e.g., Alibates agatized dolomite versus Day Creek chert). For this reason intensive analyses was performed on Day Creek chert samples (N=3) through scanning electron microscopy (Table 5, Samples 1, 2, 3).

SCANNING ELECTRON MICROSCOPY

Scanning electron microprobe [SEM] analysis was conducted at the University of Oklahoma's geological laboratory on March 06, 1993. We thin-sectioned [1" x 2" covered] three non-fibrous, vitreous, subvitreous and/or waxy Day Creek chert samples [Sample 1: Day Creek chert, Ashland Type I (Table 5); Sample 2: Day Creek chert , Ashland Type II (Table 5); Sample 3: Day Creek chert, Buffalo Type I (Table 5)].

Ashland Type I (most typical lithology color [5BP 7/2] for the majority of Day Creek chert in Kansas and Oklahoma) was retrieved from Sample 1 (Table 5). A trace mineral spectrum display was obtained. Group 1 [Version 3], at a scale of 3,000 cts and with a counting time of 100 seconds (20 kV; 20 nA; 15,000X magnification) resulted in an inconclusive trace mineral spectrum display. The analysis was determined to be statistically insignificant. Immediately prior to detailed examination of one particular location on the sample, the laboratory technician scanned all three samples and found them to be highly heterogenous. All samples exhibit excellent calcite [$CaCo_3$: calcium carbonate] structure and are rich in magnesium [Mg]. Ashland Type I was found to be equally heterogenous with respect to its particular geochemistry but, more importantly, it was the only sample to contain possible traces of the sulfate "Barite" [BSE chemistry; Ba04S: barium sulfate]. It was concluded prior to additional analysis that any location on the sample Ashland Type I would produce totally incongruent results among the variant loci on the samples' surface. Detailed scanning of the sample confirmed this hypothesis (Figure 12).

The resultant analysis of Day Creek chert Ashland Type I sample indicates that the microprobe scan pinpointed an array of trace minerals. Overall, the sample had peak quantities of barium [Ba], sulfur [S], silicon [Si], iron [Fe] and iron oxide [O/Fe]. Smaller ratios of calcium [Ca] and copper [Cu] are also identified. However, it should be noted that when the technician manually microprobed the sample for variations in trace minerals, the appearance of a "Bright BSE [Barite?]" (Figure 12) inclusion was possibly evident, although never confirmed. The presence of barite [BSE: Ba04S: barite/sulfuric acid/barium salt = barium sulfate] in Day Creek chert was subsequently confirmed in the instrumental neutron activation analysis [INAA]. This may be of significant importance in the ultimate goal of finding a geochemical signature to distinguish Day Creek chert from non-related lithic raw materials; the use of Ba04S as a trace mineral marker within Day Creek chert could provide a signature for this specific lithic raw material. The Group "Barite," classed as a Sulfate, is a mineral and often is an accessory to other minerals. Furthermore, it is known to create a backdrop to brightly colored crystals. Barite color is variable (from colorless to white, blue, green, yellow and shades of red) with conchoidal fracture and vitreous luster. This would suggest that Barite may not form a common element in all submitted samples.

Utilization of the scanning electron microscope was conducted as a preliminary examination to see if the instrument would benefit my research. Under the advice of the laboratory technician, additional samples that were prepared towards utilizing scanning electron microscopy during this analyses were not extensively investigated for trace mineral

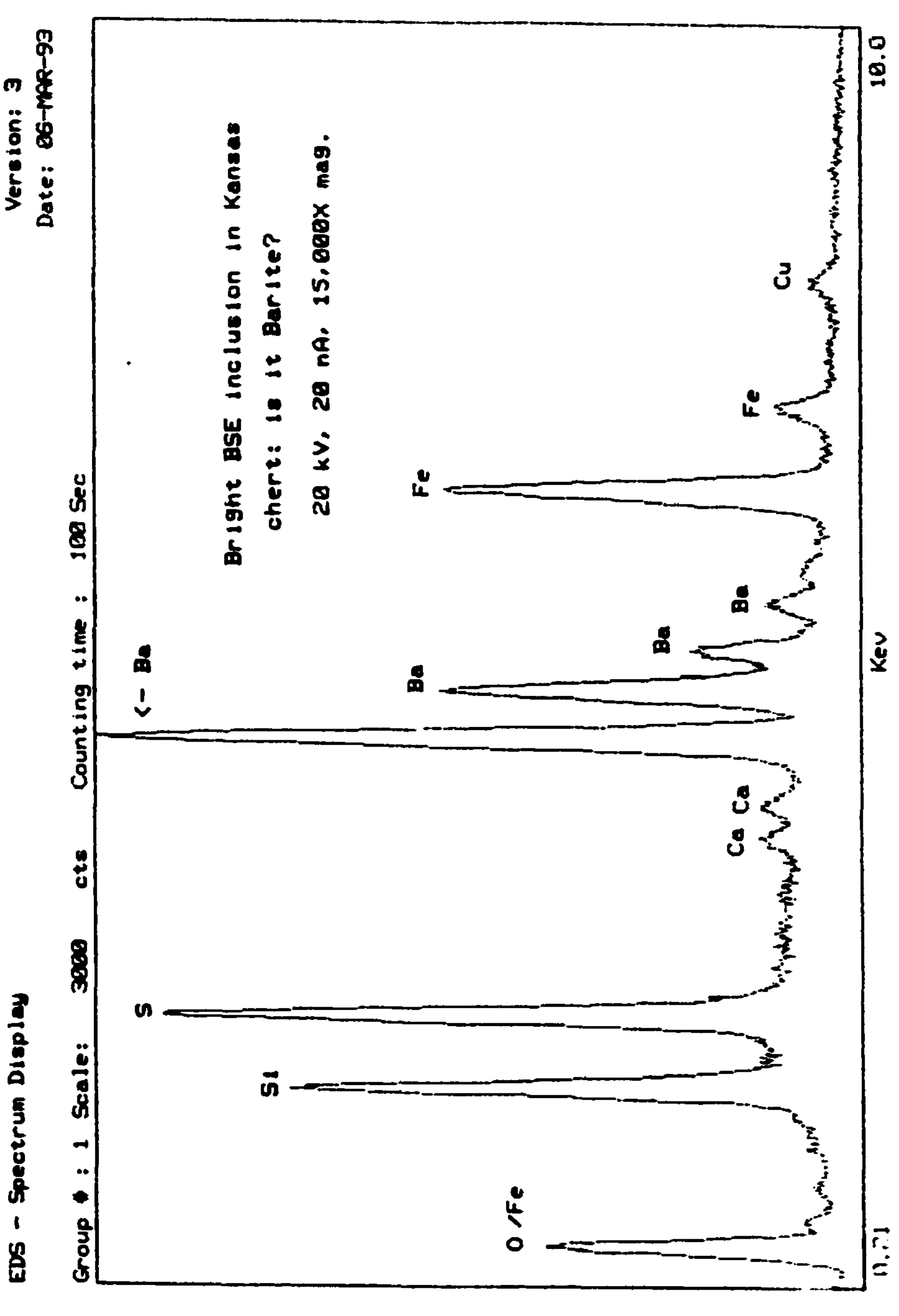

Figure 12. Results of Scanning Electron Microscopy for Sample 1 (Ashland Type I)

composition. This decision was due to the fact that the while the samples were lithologically unidentical, their trace elements were nearly identical and did not warrant additional complex analysis. The use of the SEM facilities are expensive and my analysis was not considered cost effective. We observed the routine trace mineral signature for Ashland Type II and Buffalo Type I (Table 5). We did not process and print the respective signatures for Ashland Type II or Buffalo Type I. They were verbally described to me by the technician. He indicated to me that trace mineral heterogeneity within three samples was indicated through, 1. A single sample of Ashland Type I [anhydral]; 2. Similar patterns observed within Ashland Type II (also containing excellent calcium carbonate [CaCO3] structure with magnesia/calcite [Mg/Ca], titanium oxide [O Ti] inclusions and barite [BaSO4]), and; 3. Buffalo Type I [detrital; rich in limonite (a mixture of hydrated iron oxides, anhydrite [CaO4S] and titanium oxide]. It should be noted that Ashland Type I and Ashland Type II were the only samples containing barium [Ba] and/or barium sulfate [BaO4S: BSE]. As a result, the desired goal of locating a trace mineral signature completely unique to Day Creek chert through SEM was abandoned. It was suggested by the technician that I should use the more intensive technique of instrumental neutron activation analysis as it could possibly identify distinguishing geochemical elements within Day Creek chert (and as a result produce an unique trace mineral signature).

ULTRAVIOLET FLORESCENCE

The use of ultraviolet florescence [UVF] has become increasingly popular, both in the field and laboratory, for the discrimination of specific lithic raw materials in the Great Plains (Church 1994:47). Certain electrons in the mineral absorb energy from the electrons, therefore, jumping to a higher energy state. The resulting UVF color is emitted following the aforementioned electrons jumping down to a lower energy state, resulting in a specific color of light. Wain (1965:15) states:

> It has been found that an electron travelling in its orbit must have a precise amount of energy if it is to remain in that orbit. Less energy would place it in an orbit nearer to the nucleus. An excess of energy would cause the electron to move to an orbit farther from the nucleus.
>
> All kinds of radiation, including ultraviolet, are forms of energy. When ultraviolet light is directed at most substances, the energy of the light is absorbed and turns into heat. However, some substances have an atomic structure that is affected by the particular kind of energy that is ultraviolet light. In these cases the energy from the ultraviolet light, when it strikes an electron, gives that electron extra energy which causes it to move to an orbit in a shell farther away from the nucleus (a higher energy level). Remember that an electron needs an exact amount of energy to stay in its orbit in a particular electron shell, and that any change in that amount of energy will cause the electron to move either toward the nucleus or further away from the nucleus. Now when this energy from the ultraviolet light strikes the electron and causes it to move away from the nucleus, the original orbit becomes empty and the electron shell is left with a gap which must be filled to maintain the electrical balance. An electron in an orbit closer to the nucleus would not have sufficient energy to move out, so the only way for the gap to be filled is for an electron in an orbit further from the nucleus to be pulled down into the empty orbit and thereby fill the gap left in the original shell by the loss of the first electron. A replacement electron, in moving down, gives off a definite amount of energy, and it is this energy which we see as visible light or fluorescence. The small packets of energy given up the electrons as they drop to lower levels are known as quanta. The radiated quanta are often called photons. What actually happens during fluorescence is that this process of energy exchange takes place rapidly with many, many electrons -- some absorbing energy, some giving it off, so that the visible light we see is for all practical purposes continuous and not interrupted.
>
> As you know, not all substances are fluorescent - in fact, most of them are not. In substances that do fluoresce, it has been found in most cases that a small amount of some impurity must be present in order for fluorescence to occur. Few chemically pure minerals will fluoresce at all. But on the other hand, the amount of impurity is critical and if there is too much, the fluorescence will either be diminished or completely eliminated. For example, the red fluorescent

> calcite from Franklin, New Jersey is activated by manganese, in a quantity of about 3%. It has been found that a manganese content in the calcite of more than about 5% or less than about 1% will not permit fluorescence. The amount and type of impurity present determine the color and intensity of the fluorescence. The mineral calcite seems to be particularly sensitive to impurity activation, and specimens of calcite have been found which fluoresce in practically every color. The amount of activator can be as important as the type.

Lithic raw materials demonstrate variant coloration when exposed to short and/or long wave UVF energy (Dake and DeMent 1941; Gleason 1960; Radley and Grant 1959; Wain 1965). While this methodology can assist on a totally subjective basis the identification of certain lithic raw materials, it also should be approached with extreme caution. For instance Edwards Plateau lithic raw material (Cretaceous) collected at a quarry/workshop site in Irion County, Texas (41IR92] (Figure 11) is entirely consistent with Day Creek chert (Late Permian); this includes overall natural light coloration [5B 7/1] as well as the presence, nature, and appearance of extant cortex, patination, granularity, vugs, and fracture mechanics. When Irion County, Texas chert [41IR92] and Day Creek chert [34HP40] are observed side-by-side under UVF, no distinguishing characteristics of short/long wave UVF ultimately identifies either lithic raw material. It should be noted that when both lithic raw materials are subjected to investigation through instrumental neutron activation analysis, the resultant trace mineral data indicates that Irion County, Texas chert and Day Creek chert do not share any statistically significant trace mineral element similarities. An identical situation occurs during the UVF analysis of Day Creek chert and Alibates agatized dolomite. Discrimination of Day Creek chert from Alibates agatized dolomite with short/long wave UVF is useless. Both lithic raw materials exhibit identical UVF signatures. In fact, UVF analysis of Day Creek chert can confuse this lithic raw material with other lithic raw materials located well outside the southern Great Plains (e.g., some Nebraskan Permian cherts). This is an important development given the discipline's increasing use of UVF to distinguish non-related lithic raw materials within archaeological assemblages. Aside from many lithic raw materials exhibiting exact lithological attributes, the inclusion of UTV for the purpose of distinguishing variant lithic raw materials is probably not warranted.

Concerning Day Creek chert and Alibates agatized dolomite, identical hues of yellow-green are typical with compounds composed of silicon dioxide. In relation to quartz and varieties of agate, chalcedony and/or chert, Wain (1965:47) cautions:

> Crystallized quartz is very seldom fluorescent; however the agate and chalcedony [chert] varieties will often fluoresce green or yellow-green, being activated by a slight content of uranium compounds. The fluoresce is usually best shortwave and rather slight longwave. Agate and chalcedony [chert] which fluoresce green are found in a number of localities in the western United States and Mexico.

INSTRUMENTAL NEUTRON ACTIVATION ANALYSIS

With the complete lack of any significant means to distinguish Day Creek chert from many other lithic raw materials found on the Great Plains, the use of instrumental neutron activation analysis [INAA] was initiated March 6,1995 through the laboratory facilities at the University of Missouri-Columbia. Five samples of Day Creek chert and one sample of Irion County, central Texas chert (Edwards Formation [41IR92]), were submitted for analyses (Table 5). Unfortunately, due to lack of funds INAA data concerning Alibates agatized dolomite is absent. This was a critical oversight. Day Creek chert and Alibates agatized dolomite are often identical based on subjective criteria (lithologies: coloration, granularity, patination, cortex, etc.). A full suite of INAA data concerning Alibates agatized dolomite would provide invaluable information towards legitimate discrimination of these two lithic raw materials. Similarly, Day Creek chert also overlaps, given the aforementioned subjective criteria, with samples of Texas lithic raw materials termed Georgetown flint [Edwards

Formation], Edwards chert(s) [Edwards Formation], and Edwards Formation chert located in Irion County, central Texas [41IR92]. Similarly, I have examined samples of Nebraskan Permian cherts, Nebraskan Plate chalcedony, and North Dakota Knife River flint; they all overlap with Day Creek chert's variant lithologies. Additionally, the prehistoric acquisition of chert from lag deposits associated with the Arkansas, Cimarron, North Canadian, and South Canadian river creates additional confusion concerning the exact lithostratigraphic loci of lithic raw materials found within many archaeological contexts. Aside from the presence of microscopic moss structures within Knife River flint all of the aforementioned cherts are non-fossiliferous. This situation punctuates the difficulty in obtaining an accurate discrimination of chert samples and/or their ultimate lithostratigraphic origin.

Given the problem of identifying of Day Creek chert with respect to allochthonous cherts in the region, experimentation with INAA was initiated for the purpose of delineating a distinct geochemical signature (through trace element petrologies) for Day Creek chert. Following the identification of Irion County, central Texas Edwards Formation chert [41IR92] as having a complete suite of specific Day Creek chert lithological characteristics, a single sample of this material was submitted (March 6, 1995) to the University of Missouri-Columbia for the purpose of INAA trace mineral discrimination [National Foundation Grant to MURR (DBS-9102016)]. Results of this analysis is broadly discussed in a letter, dated March 17, 1995 from Dr. Michael Glascock to Dr. Susan Vehik (Figures 13a and 13b).

Figures 14 and Figure 15 show the relative cluster analysis of numerous lithic raw materials found in the southern Great Plains. Figure 14 statistically clusters the samples with Scandium [Sc] and Lanthanum [La] . Similarly, Figure 15 statistically clusters the samples with Cerium [Ce] and Iron [Fe] . Additional information concerning this INAA analyses can be found in tables 6, 7 and 8. The clusters shown on the figures represent quantitative (based

Research Reactor Center

UNIVERSITY OF MISSOURI-COLUMBIA

March 17, 1995

Dr. Susan C. Vehik
Department of Anthropology
University of Oklahoma
Norman, OK 73019

Dear Dr. Vehik:

I have completed work on the six chert specimens that you recently submitted for analysis by NAA. As per the request in your student's letter, I compared the samples to other cherts available in our databank. A brief explanation of the analytical results is reported in this letter.

The samples arrived in December 1994 and were prepared for analysis using exactly the same procedures we described in our previous report and in recent publications by Robert Hoard. The only exception was that we are no longer able to measure the element B.

Table I presents the concentrations in parts per million for the elements measured in your six samples. Note that an entry of zero does not mean zero concentration but rather that the element was below detection in that sample. Five of the six samples were Day Creek chert. Table II presents the descriptive statistics calculated to describe the compositional characteristics of Day Creek chert.

MURR's chert databank has information for a few of the chert types against which you requested comparison. In particular, we have analyzed a large number of Edwards Group cherts including the following subgroups: Owl Creek, Gray-Brown-Green, Tan, Texas Novaculite, Heiner Lake, Fort Hood Gray, and Segovia Formation. In addition, the earlier results for Florence Formation chert were available for comparison.

Comparison of the different chert types requires transformation to logarithms in order to compensate for the fact the contributions of elements measured at thousands of ppm would overwhelm those elements measured at concentrations below one ppm. Log base-10 transformations induce a sort of normalization that puts the large and small concentration elements on a similar scale. After log transformation, principal components analysis (PCA) was performed on the logged data to identify the dimensions of greatest variance in the dataset. The latter transformation makes it easier to identify structure in the data and when working with small datasets enables the use of fewer variables (the PCS instead of the original elements) when performing probability of membership calculations. The latter are limited to one variate fewer than the number of specimens in the smallest reference group.

COLUMBIA KANSAS CITY ROLLA ST. LOUIS

Figure 13a. Discussion of Six Lithic Raw Material Samples (Table 5) Submitted for INAA analysis.

Dr. Susan C. Vehik
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The six new samples were compared to nine different reference groups by performing a Malahanobis distance calculation from specimen to each group centroid and by determining a posterior classification probability from the generalized (Mahalanobis) distance measure. The first six PCS were found to describe more than 90% of the variance in the dataset and these PCS were then used in the calculation. The results are presented in Table III which clearly indicate that the six samples (five Day Creek and one from Irion County) have a near zero probability of belonging to any of the nine groups.

A couple of graphical comparisons of the data are shown in Figures 1 and 2 where the logarithms of La vs Sc and Fe vs. Ce are graphed. Both plots support our probability calculation findings which indicate that the Day Creek chert and Irion County chert specimens are relatively easy to differentiate from the Edwards Group cherts and Florence Formation chert. The Owl Creek and Segovia Formation subgroups of the Edwards Group chert are also shown.

I hope this letter and brief report provide you with the information that you were hoping to obtain from this analysis. Thank you for your interest in our laboratory.

Best regards,

Michael D. Glascock

Michael D. Glascock
Group Leader, Archaeometry

Figure 13b. Discussion of Six Lithic Raw Material Samples (Table 5) Submitted for INAA analysis.

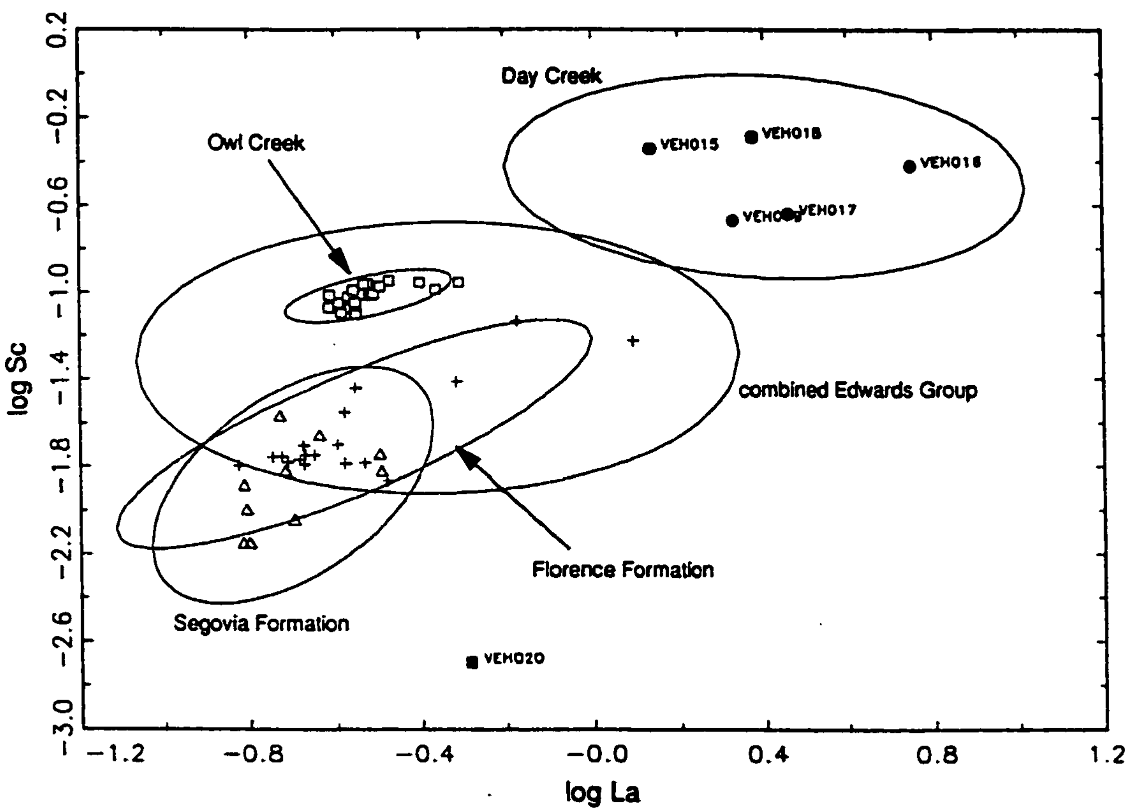

Figure 14. Statistical Clusters of Sc and La with Relationships to Great Plains Lithic Materials.

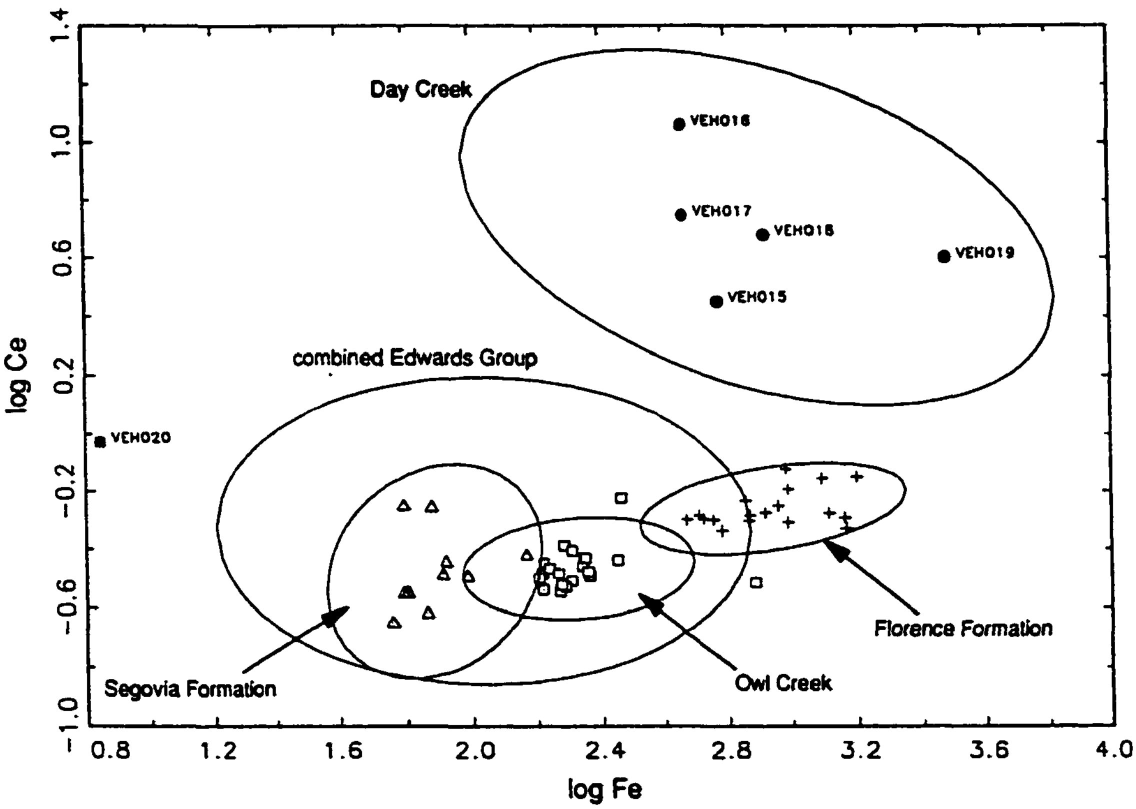

Figure 15. Statistical Clusters of Ce and Fe with Relationships to Great Plains Lithic Materials.

be found in tables 6, 7 and 8. The clusters shown on the figures represent quantitative (based on trace mineral elements) analysis. In total, 30 trace elements were detected within Day Creek chert (Tables 6 and 7). Element concentrations in parts per million in Day Creek chert were analyzed. Descriptive statistics are based on mahalanobis distance and posterior classification for two or more groups.

Day Creek chert samples were submitted on the basis that each sample represented a major lithological variant and, in addition, incorporated a north-south trajectory of lithic raw materials collected in Clark County, Kansas and carnelian samples from Harper County, Oklahoma. As stated, one isolated sample from Irion County, central Texas [41IR92] was submitted given its total lithological resemblance to Day Creek chert. While the subsequent INAA data does exhibit a loose cluster for Day Creek chert and a clear indication of non-petrological association between the Day Creek chert samples [VEH015, VEH016, VEH017, VEH018, VEH019] versus the Irion County, Texas chert [VEH020] the Day Creek chert clusters are relatively scattered (as opposed to, for instance, the Owl Creek chert cluster).

As previously mentioned, a *major* oversight with reference to this analysis was the non-submission of known examples of Alibates agatized dolomite. I had assumed that given the extensive nature of professional archaeological and/or geological research Alibates agatized dolomite has received in the past that samples of this lithic raw material would be on record with the INAA laboratory at the University of Missouri-Colombia. In order to correct this oversight future analysis using INAA with Alibates agatized dolomite samples is planned.

lithologies can mislead any researcher conducting lithic studies on samples obtained from archaeological sites. If we intend to make meaningful statements about trade, exchange, mobility and human behavior it is imperative that the most basic stage of any given lithic trajectory model be investigated; namely the petrological, lithostratigraphic and origin of

Table I. Element concentrations in parts per million in chert analyzed for Susan C. Vehik

anid	As	La	Lu	Nd	Sm	U	Yb	Ce	Co	Cr
VEH015	0.00	1.361	0.0220	2.057	0.301	0.092	0.166	2.829	0.1024	1.140
VEH016	1.21	5.623	0.0000	8.377	2.954	31.345	0.142	11.509	0.9609	4.341
VEH017	0.72	2.876	0.0000	5.443	1.695	18.050	0.078	5.576	0.0919	1.923
VEH018	1.28	2.365	0.0716	3.873	1.102	9.281	0.107	4.793	0.3141	5.272
VEH019	2.15	2.127	0.0000	3.947	1.239	13.712	0.020	4.010	0.0928	1.709
VEH020	0.00	0.521	0.0000	0.933	0.323	3.643	0.000	0.938	0.0042	0.094

anid	Cs	Eu	Fe	Hf	Rb	Sb	Sc	Sr	Ta	Tb
VEH015	0.0533	0.0687	591.7	0.2167	1.0930	0.0286	0.4553	13.86	0.0152	0.0500
VEH016	0.1530	0.0432	458.8	0.3994	2.5284	1.2066	0.3814	30.21	0.0522	0.0227
VEH017	0.0663	0.0327	461.9	0.0721	0.9980	0.0755	0.2309	6.87	0.0204	0.0212
VEH018	0.2782	0.0867	832.0	0.1808	4.2968	0.0717	0.5155	10.51	0.0440	0.0424
VEH019	0.0252	0.0107	3022.4	0.0486	0.6796	0.2481	0.2150	9.76	0.0097	0.0000
VEH020	0.0000	0.0000	7.0	0.0000	0.0000	0.0076	0.0020	0.00	0.0000	0.0000

anid	Th	Zn	Al	Ba	Ca	Dy	K	Mn	Na	V
VEH015	0.2684	0.76	1707.7	64.4	17067.6	0.2212	0.0	55.472	249.2	0.00
VEH016	1.1719	1.94	3016.8	63.1	271.5	0.1912	730.9	5.947	513.2	102.83
VEH017	0.1548	0.60	1761.6	76.7	0.0	0.0607	0.0	14.929	286.9	5.33
VEH018	0.3744	1.54	3580.3	101.5	812.0	0.2190	1247.1	12.577	486.5	18.94
VEH019	0.1318	0.82	1807.5	64.7	172.0	0.0426	553.7	36.512	298.7	7.99
VEH020	0.0000	0.00	955.9	0.0	0.0	0.0000	0.0	0.155	163.2	0.00

Note:
VEH015 is sample 1 from Day Creek
VEH016 is sample 2 from Day Creek
VEH017 is sample 3 from Day Creek
VEH018 is sample 4 from Day Creek
VEH019 is sample 5 from Day Creek
VEH020 is sample 6 from Edwards Group Chert (Irion County)

Table 6. Element Concentrations [ppm] for Samples 1, 2, 3, 4, 5, 6.

Table II. DESCRIPTIVE STATISTICS FOR DAY CREEK CHERT

Type of statistics: Arithmetic

Element	Mean	St. Dev.	% St. Dev.	No. Obs.	Minimum	Maximum
AS	1.342	0.598	44.572	4	0.716	2.155
LA	2.870	1.633	56.886	5	1.361	5.623
LU	0.047	0.035	74.941	2	0.022	0.072
ND	4.740	2.361	49.822	5	2.057	8.377
SM	1.458	0.976	66.919	5	0.301	2.954
U	14.496	11.530	79.542	5	0.092	31.345
YB	0.103	0.057	55.605	5	0.020	0.166
CE	5.743	3.379	58.836	5	2.829	11.509
CO	0.312	0.375	119.920	5	0.092	0.961
CR	2.877	1.815	63.073	5	1.140	5.272
CS	0.115	0.103	89.297	5	0.025	0.278
EU	0.048	0.030	61.738	5	0.011	0.087
FE	1073.360	1100.065	102.488	5	458.800	3022.400
HF	0.184	0.140	76.263	5	0.049	0.399
RB	1.919	1.508	78.557	5	0.680	4.297
SB	0.326	0.499	153.133	5	0.029	1.207
SC	0.360	0.134	37.153	5	0.215	0.515
SR	14.242	9.267	65.066	5	6.870	30.210
TA	0.028	0.019	66.112	5	0.010	0.052
TB	0.034	0.014	42.187	4	0.021	0.050
TH	0.420	0.431	102.604	5	0.132	1.172
ZN	1.133	0.579	51.078	5	0.604	1.943
AL	2374.780	867.217	36.518	5	1707.700	3580.300
BA	74.068	16.286	21.988	5	63.060	101.470
CA	4580.775	8329.298	181.832	4	172.000	17067.600
DY	0.147	0.088	59.902	5	0.043	0.221
K	843.900	360.247	42.688	3	553.700	1247.100
MN	25.088	20.493	81.684	5	5.947	55.472
NA	366.900	123.098	33.551	5	249.200	513.200
V	33.772	46.414	137.435	4	5.331	102.830

Table 7. Descriptive Statistics for Day Creek Chert.

Table III. MAHALANOBIS DISTANCE CALCULATION AND POSTERIOR CLASSIFICATION FOR TWO OR MORE GROUPS.

Reference groups and numbers of specimens:

1	PC-EFC1	119	combined Edwards Group cherts
2	PC-E1	20	Owl Creek chert
3	PC-E2	21	Gray-Brown-Green chert
4	PC-E3	20	Tan chart
5	PC-E4	20	Texas Novaculite chert
6	PC-E5	20	Heiner Lake Tan chert
7	PC-E6	18	Fort Hood Gray chert
8	PC-SF2	10	Segovia Formation chert
9	PC-FA	18	Florence Formation chert

Variables used: PC01 PC02 PC03 PC04 PC05 PC06

The following specimens are in the file PC-NEW

Probabilities:

ID. NO.	PC-EFC1	PC-E1	PC-E2	PC-E3	PC-E4	PC-E5	PC-E6	PC-SF2	PC-FA	BEST GP.
VEH015	0.002	0.000	0.000	0.001	0.001	0.000	0.000	0.091	0.000	8
VEH016	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.024	0.000	8
VEH017	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.077	0.000	8
VEH018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.034	0.000	8
VEH019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.253	0.000	8
VEH020	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.102	0.000	8

Summary of Probabilities for Specimens in the file PC-NEW

Probability Cutoff Values:

Group:	0.01000	0.10000	1.00000	5.00000	10.00000	20.00000	100.00000
PC-EFC1	6	0	0	0	0	0	0
PC-E1	6	0	0	0	0	0	0
PC-E2	6	0	0	0	0	0	0
PC-E3	6	0	0	0	0	0	0
PC-E4	6	0	0	0	0	0	0
PC-E5	6	0	0	0	0	0	0
PC-E6	6	0	0	0	0	0	0
PC-SF2	0	4	2	0	0	0	0
PC-FA	6	0	0	0	0	0	0

Summary of Best Classification of Projected Specimens:

Classified Into Group:

From Group:	PC-EFC1	PC-E1	PC-E2	PC-E3	PC-E4	PC-E5	PC-E6	PC-SF2	PC-FA	Total
PC-NEW	0	0	0	0	0	0	0	6	0	6
Total	0	0	0	0	0	0	0	6	0	6

Table 8. Mahalabis Distance Calculation and Posterior Classification for Two or More Groups.

every lithic raw material on the Great Plains. Lithologies alone contribute little more than confusion and, ultimately, skewed science.

Chapter VII: DAY CREEK CHERT QUARRIES TO WORKSHOPS: VARIABLE LITHIC TRAJECTORIES THROUGH TIME AND SPACE

INTRODUCTION

My main focus has remained the areal exposures of Day Creek Dolomite, and within it, the presence of Day Creek chert. Location of archaeological sites was a fortuitous addition to my primary theoretical perspective of defining exactly what Day Creek chert is. No archaeological sites had collections made from them. The following discussion is based primarily on field observations.

DESCRIPTION OF THE DAY CREEK QUARRIES IN OKLAHOMA AND KANSAS

The region of northern Harper County, Oklahoma into Clark County, Kansas is paved with the by-products of hundreds of thousands of discreet lithic removal episodes. In many places (e.g. Salyer site, 34HP40 [Figure 4]), the land surface is seen to have primary, secondary, and tertiary waste flakes carpeting an area in excess of 2 km. Surface manifestations of workshop activity indicates that Day Creek chert debris, resulting from prehistoric lithic reduction, is mostly comprised of primary and secondary waste flake removals. This appears to result from the testing of specific nodules for the presence of fracture planes, vugs, and/or large inclusions. Much of the *in situ* surface Day Creek chert is a poor quality lithic raw material resource for the construction of stone tools having a sharp cutting edge and/or small ratios of length to width in the finished form (Callahan 1979). The *in situ* surface nodules, embedded in the Day Creek Dolomite, tend to have major fracture planes arising from post Permian tectonic formational stresses and/or naturally occurring secondary thermal (e.g. prairie fires and/or freezing) modifications (Bettis 1992:119-44; Cotterell and Kamminga 1979:97-111; Lautridou et al. 1986:269-82; Sieveking and Clayton 1986:283-90). Based on my observation of surface waste cores, *peeling* of the nodule was a common prehistoric strategy for removal of the heavy cortex and probably is a behavior designed to uncover the presence of incongruities that would make further reduction meaningless (Marks and Volkman 1987:11-20; Muto 1971; Stevenson 1985:63-81; Villa 1982:276-90).

The aforementioned strategies likely produced the great majority of waste materials within the quarrying and workshop stage of reduction (Vierra 1993:141-381; Villa 1982:276-90). It is common to find shattered and broken pieces. Refitting of cores and flakes indicated that sometimes lithic raw material was not even removed from the immediate location (Villa 1990:276-90). Some Day Creek chert nodules exhibit differential patination of human derived flake scars indicating that testing and retesting of the same nodule occurred over thousands of years. Most often, these artifacts exhibit a lithic reduction trajectory aimed at the production of biface cores (Callahan 1979; Crabtree 1982; Muto 1971). In nearly every case, cessation of reduction took place once the knapper encountered significant obstacles (e.g., fracture planes and/or vugs) within the lithic raw material. These observations have been made at every Day Creek chert workshop I investigated and, furthermore, suggest reduction for the purpose of creating utilitarian flakes is probably insignificant given the presence of millions of otherwise useful waste flakes on the landscape (Callahan 1979; Muto 1971). The presence of waste flakes in Harper County, Oklahoma and Clark County, Kansas cannot be underestimated.

Lithic raw material reduction sites located to date indicate the aforementioned knapping strategies are apparent at all lithic workshop sites in both counties. I have encountered this knapping strategy at the Salyer site (34HP40) (Figure 4) in northwest Oklahoma. During field operations, 14CK312 (Figure 16, Number 1), 14CK313 (Figure 16, Number 2), 14CK314 (Figure 16, Number 3), 14CK315 (Figure 16, Number 4), 14CK316 (Figure 16, Number 5), 14CK317 (Figure 16, Number 6), and 14CK318 (Figure 16, Number 7) were located and documented in 1989 near the Day Creek drainage by Martin Stein (1989) during a Kansas State Historical Society field school in Clark County, Kansas. In most instances, these sites contain lithic raw material identified as Day Creek chert that is poorly suited for reduction into high quality formal tools because of thermal fractures, vugs, and/or stress fractures. All aforementioned sites contain thousands of primary, secondary and, to a much lesser extent, tertiary waste flakes. Diagnostic tools are lacking, leaving the assignment of cultural affiliation unavailable for all of these quarries and workshops (Hamond et al. 1977:35-65). Stein's (1989) observations essentially confirm my own experiences with the location and identification of Day Creek chert lithic reduction workshop sites in northwest Oklahoma and southwest Kansas.

In agreement with Stein (1989), based on my own fieldwork, quarry and workshop debris that did not have any cultural affiliations associated with them include, in Clark County, Kansas, the following sites: Henry Ford site (14CK403 [Figure 17; Number 1]), A-Frame site (14CK405 [Figure 17, Number 2]), Hinkle site (14CK406 [Figure 17, Number 3]), Loner site (14CK407 [Figure 17, Number 4]), Soldiers' Summit site (14CK408 [Figure 17, Number 5]), Mt. Pisgah site (14CK411 [Figure 17, Number 6]), and the Mt. Nebo site (14CK412 [Figure 17, Number 7]). All of these sites conform to a strategy of primary and secondary reduction aimed at the production of biface cores which were removed from the loci (Jelinek 1991:7-32). None of the sites contain diagnostic information that would elucidate the cultural period responsible for their creation (Jeske 1989:34-45; Kelly 1995).

The Henry Ford site (14CK403 [Figure 18]) presents an interesting divergence from the norm with reference to established lithic workshop sites. This site contains the finest lithic raw material, in terms of quality, found to date. It was not mined from any surrounding Day Creek Dolomite as the site sits in re-worked alluvium and colluvium. It is my opinion that, given the presence of a large spring boil immediately adjacent to the workshop, lithic

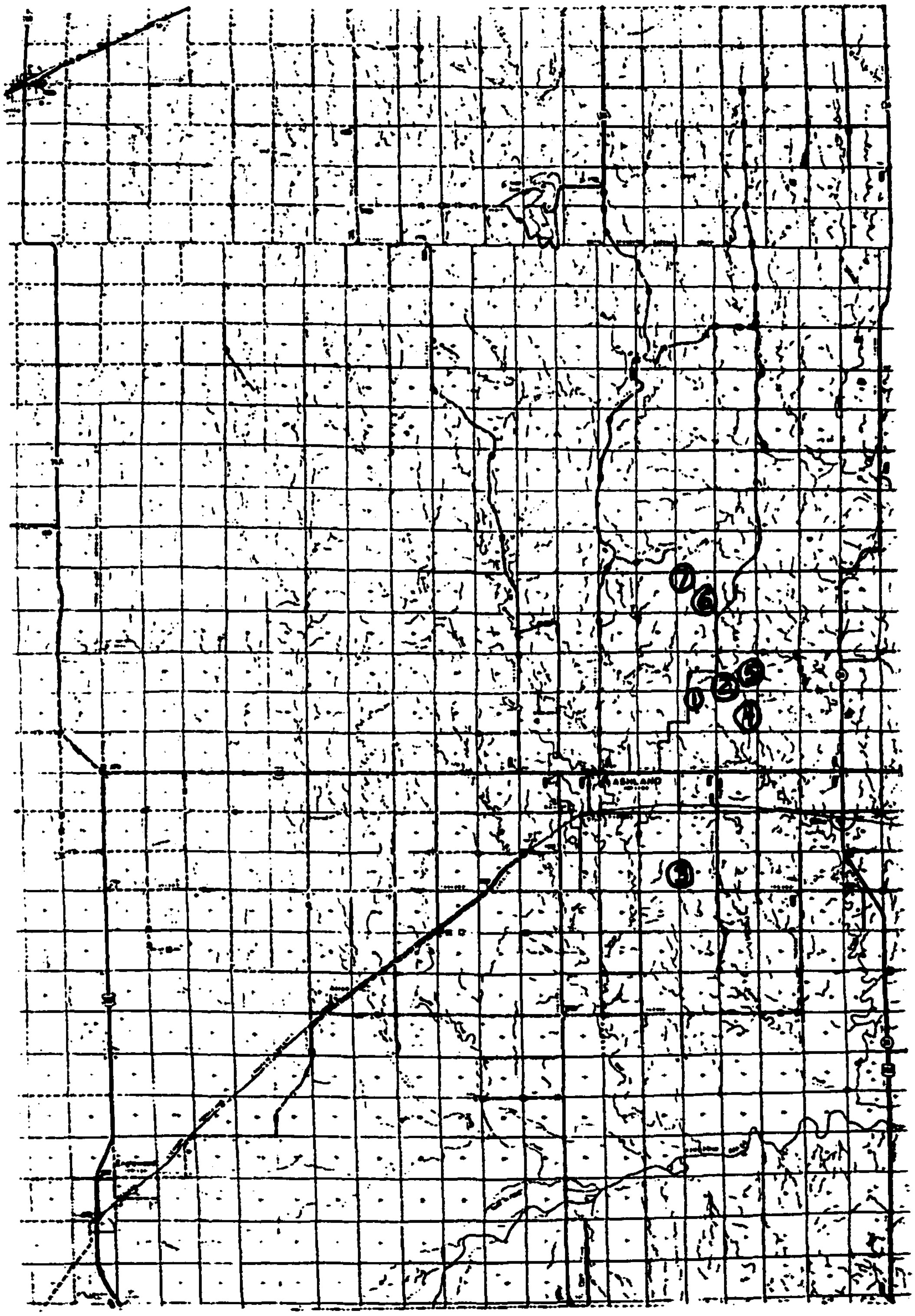

Figure 16. Location of Stein's (1989) Seven Archaeological Sites in Clark County, Kansas

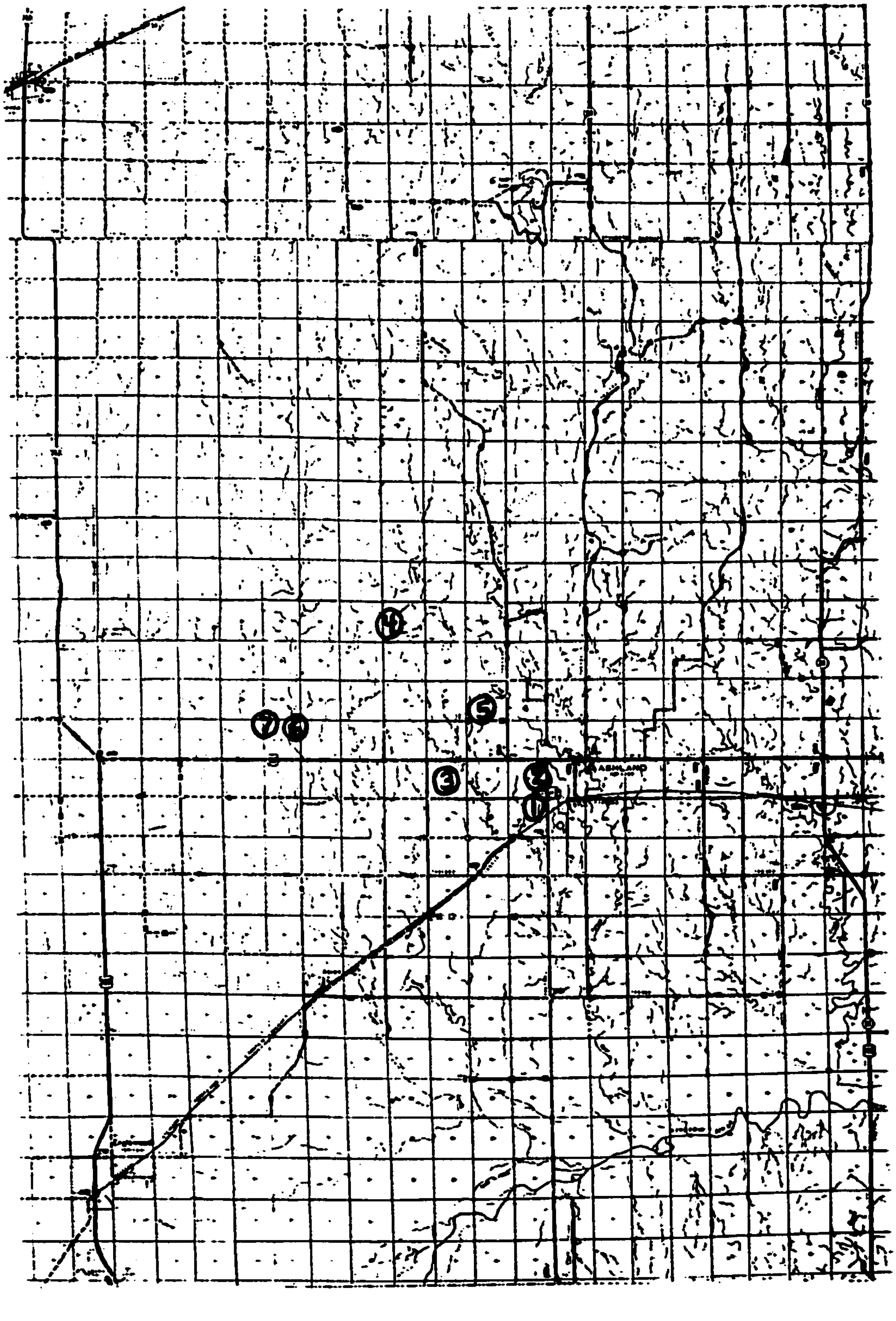

Figure 17. Location of Bailey's Seven Archaeological Sites in Clark County, Kansas

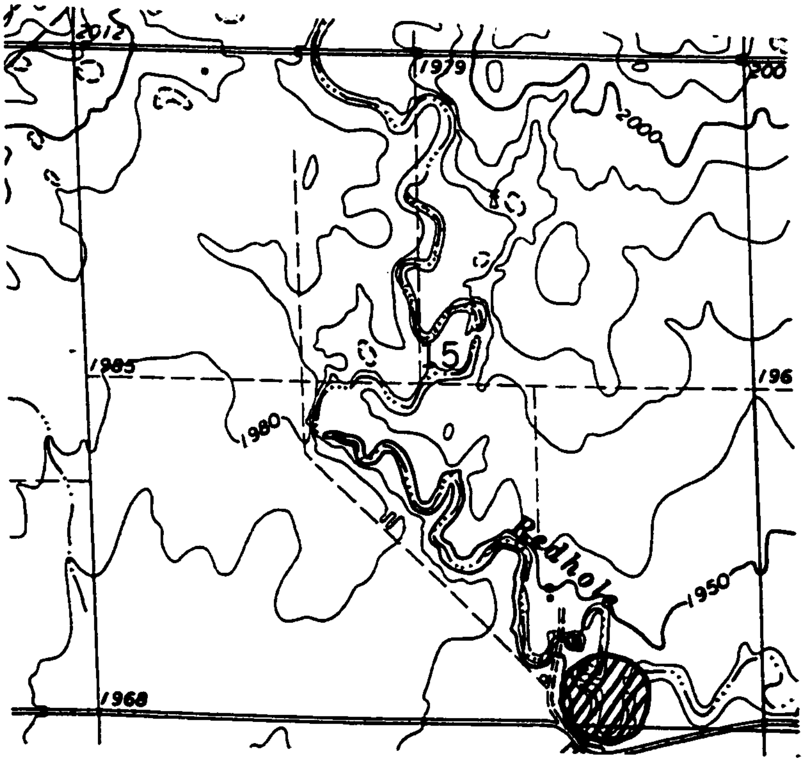

Figure 18. The Henry Ford Site, 14CK403 [Ashland Quadrangle; Sec. 10, T. 33s, R. 23w]

raw materials were transported to the site for reduction at a later period (Johnson 1989:119-38). The cortex of the primary and secondary flakes suggests that the original nodules were removed from an alluvial environment, then transported to the location because of its permanent access to excellent, drinkable water. The site sits in the Dissected Red Beds but it is close enough to the escarpment of the High Plains to reduce the salinity of the water making it much more palatable for prehistoric inhabitants. The very fine texture and coloration of the lithic raw material is not common to Day Creek chert. Rather, it tends to be a very dark blue which often turns to deep hues of brown and black. Some pieces are mottled with blue, white, brown, and black. Scattered pieces of the more common bluish/grey Day Creek chert are in abundance, too. This site is an anomaly and has been the source of countless surface collections, by current inhabitants, for many years. Today, the site contains no culturally affiliated remains. Given the absence of criteria associated with the bulk of Day Creek chert in Oklahoma and Kansas, Sample II (VEH016 [Table 5]) was submitted for INAA analysis. Results of that analysis can be found in Chapter VI and indicate that the material, based on trace mineral analyses, loosely fits the overall cluster for Day Creek chert. Its ultimate origin is unknown. However, it is clear, based on the large overall amount of debitage that 14CK403 exhibits, it was highly prized for reduction into stone tools.

In most cases, the acquisition of suitable lithic raw material for reduction into biface cores neccessitated a strategy which placed emphasis on environmentally unexposed nodules of lithic raw material (Reher 1991:251:84). In order to obtain good quality Day Creek chert for biface production, the knapper was probably forced to obtain the materials by excavation *under* the exposed Day Creek Dolomite. In this manner, the knapper could obtain significant sized nodules which do not exhibit the fracture planes which are omnipresent on the land surface. Sample 1 [VEH015; Table 5] was extracted through my use of a rock hammer and chisel (Figure 19). Instead of obtaining the nodule through the removal of material on the surface of the landscape, I initiated an adit and excavated *under* the Day Creek Dolomite until observing a soccer ball sized nodule. The nodule contained no evidence of tectonic and/or thermal modifications and, when reduced, was remarkably free of vugs and large inclusions. With a hardness measure of 7, the nodule necessitated the use of granite hammerstones for successful reduction into two large bifaces. This strategy probably explains the apparaent disregard for surface nodules and the overwhelming evidence for excavation of nodules, based on the appearance of many tons of broken Day Creek Dolomite on the land surface, adjacent to primary workshops (Smolla 1987:127-29). Workshop debris that constitutes successful reduction into biface cores typically exhibits cortex that suggests removal deep within the Day Creek Dolomite (Reher 1991:251-84). This strategy is readily apparent at the Salyer site (34HP40 [Figure 4]). Lateral removal of the Day Creek Dolomite, and the lithic reduction workshop immediately adjacent to the dolomite, indicates removal of deep *in situ* Day Creek chert nodules within the parent material (Marks et al. 1991:127-40; Whiteside 1965:307-20).

PREHISTORIC EXPLOITATION OF DAY CREEK CHERT

Several prehistoric habitation sites were located. They included 14CK307, Walnut Grove Site (14CK308), and 14CK309 all documented by Stein in 1985. Starting in 1992, I located the Salyer Site (34HP40), Blue Site (14CK401), Raymond McMillion Site (14CK409), Moccasin Site (14CK413), Roper Site (14CK416), and the Couch Site # 1 (14CK421).

Northwest Oklahoma

My research into the cultural affiliations of Day Creek chert in northwest Oklahoma

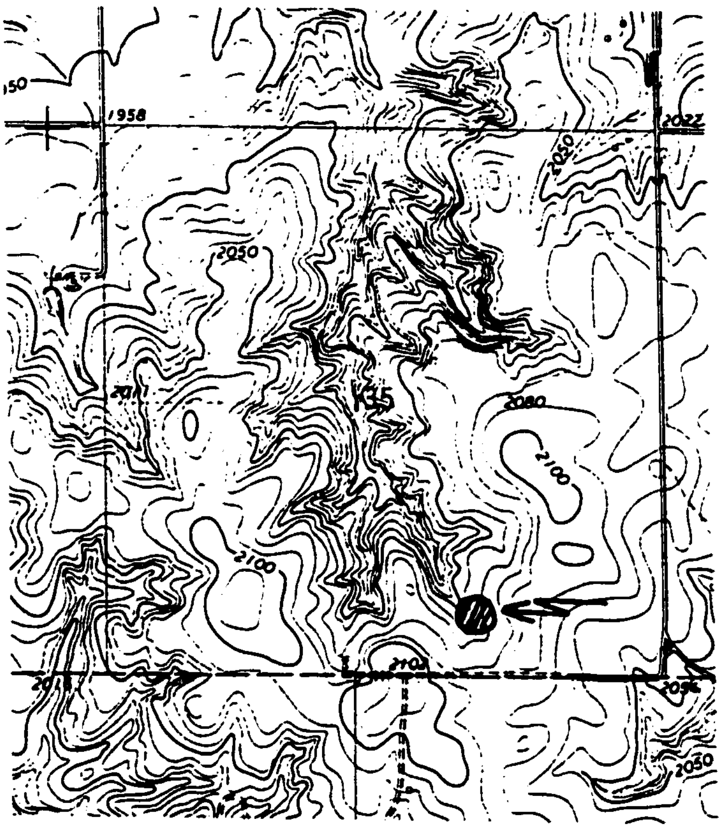

Figure 19. Location of Lithic Raw Material Procurement Site [Buffalo NW Quadrangle; Sec. 35, T. 33s, R. 23w]

was solely limited to the quarries and workshops associated with the Salyer site (34HP40).

34HP40; The Salyer Site

At the Salyer site [34HP40], located adjacent to an active spring boil in northwest Harper County, Oklahoma are *in situ* nodules of Day Creek chert (Figure 4). This site represents a complex series of workshops. As previously discussed, it is clear that the removal of nodules for initial reduction was not directed at *in situ* nodules from the *surface*, rather, the material was derived by removing large blocks of Day Creek Dolomite. Many kilos of broken dolomite litter the workshops and show indication that internal nodules had been removed while surface nodules were discarded. Once removed, the *in situ* nodules, *internal* to the Day Creek Dolomite were retrieved and reduced into transportable bifaces.

A methodology for the successful reduction of high quality Day Creek chert was investigated in 1994. I obtained a soccer ball sized nodule from the Day Creek Dolomite (Figure 19) utilizing the exact excavation and procurement strategies discussed above. Once obtained, the nodule was reduced with the assistance of Paul Bennifield from Norman, Oklahoma. Bennifield produced, from large thermally treated flakes, two exceptional bifaces that mimic a prehistoric lanceolate projectile point and a Calf Creek point preform (Wyckoff et al. 1994) Based on Bennifield's work, it is apparent that any type of tool could be produced from Day Creek chert. It should be noted that paramount to successful reduction and production of intensively prepared tools, thermal modification was apparently mandatory (Mandeville1973:177-202). Bennifield noted that even with intensive thermal modification, the reduction of bifaces necessitated granite hammerstones. Day Creek chert is exceptionally hard in tensile strength (measure of hardness of from 7 to 8), and as such, numerous hammerstones were utilized as each one was exhausted during experimentation. Evidence for thermal modification as compared to the pre-thermal treated nodule indicated increased gloss; small, almost insignificant stringers of red lines running though the otherwise blue material, and a substantial reduction in granular size from the original sample.

My surface examination of 34HP40 produced no diagnostic artifacts. The most common artifacts are end scrapers, utilized flakes, broken bifaces, and broken granite hammerstones. The site exhibits mostly primary, secondary, and biface finishing flakes. Banks 1990:92) states, "Relatively large bifaces were being manufactured at the outcrop" (Ericson 1977:109-125; Healan 1995:689-99). Allogenic chert and obsidian (Hughes and Lees 1991:38-45) recovered from among the workshop debris suggests retooling. This site represents an excellent location from which to quarry high grade chert while having a 360° sweeping view of the surrounding landscape.

Cultural affiliations were ascertained through the examination of a surface collection owned by Mr. Victor Brice Brown. Brown's family homesteaded the property following the opening of the Cherokee Strip in the 1890s. As a young man Brown occasionally found formal tools during plowing and surface collecting. Brown's collection is very small though it is demonstrative of the long time over which the Salyer site [34HP40] was occupied. His collection contains the distal portion of a Folsom point broken at the medial axis, Clear Fork gouges (Hofman 1977:105-21), broken and/or exhausted Calf Creek points (Wyckoff et al. 1994:11-68), manos and grinding stones, Day Creek chert hammerstones, and an array of arrowpoints including Fresno, Harrell, Scallorn, and Washita. When viewed in its entirety, Brown's lithic collection spans the entire prehistoric period. However, he did not identify or collect any ceramic sherds.

Southwest Kansas

As with most quarries and workshops in both Oklahoma and Kansas, definitive demarcations of the exact limits of archaeological features are entirely arbitrary in many instances. The position of Clark County, Kansas places it exactly along the axis where the High Plains meet the Dissected Red Beds. Consequently the availability of suitable drinking water (Figure 6) is much more prevalent in Clark County due to the fact that the water table cascades off of the Kiowa Shale, reducing to a minimum the amount of salinity within the water. In the region of the Dissected Red Beds, drinking water is extremely saline, and as a result, poorly suitable for human consumption. Active spring boils can be located in the Dissected Red Beds, and in those geomorphic situations, prehistoric occupations are usually evident, and at times, the locations are occupied repeatedly over time (e.g., 34HP40).

14CK307

First identified by Mr. Leon Deckert in the early 1980s, this site is classified as Middle Ceramic by the Kansas State Historical Society. Found adjacent to the Simmons Creek drainage (Figure 20, Number 1), the site is actively eroding. In 1983, Martin Stein visited the site with Deckert and mapped what at that time was a substantial cutbank of cultural debris. Today, nearly the entire site has been washed away. In 1983, Stein mentions that the exact horizontal limits were unknown, though they probably were not in excess of 0.1 h. Vertical deposition is not discussed. Artifacts collected in 1983 indicate two shell-tempered sherds (one smooth surface sherd and one cord-roughened sherd). Additionally, Stein mentions (unpublished Kansas State Historical Site report) burned bone, bone, local shell, quartzite flakes, and flakes of unidentified materials predominated.

When I visited Deckert in 1994, I re-examined his collection and found it to be consistent with Early Ceramic/Middle Ceramic cultural affiliation. I had already relocated 14CK307 in 1994 and, in addition to Late Prehistoric Period materials that Deckert collected in the early 1980s, Woodland Period artifacts were evident. This includes one very thick cord-marked ceramic sherd and the remnants of hearths. The ceramics collected by

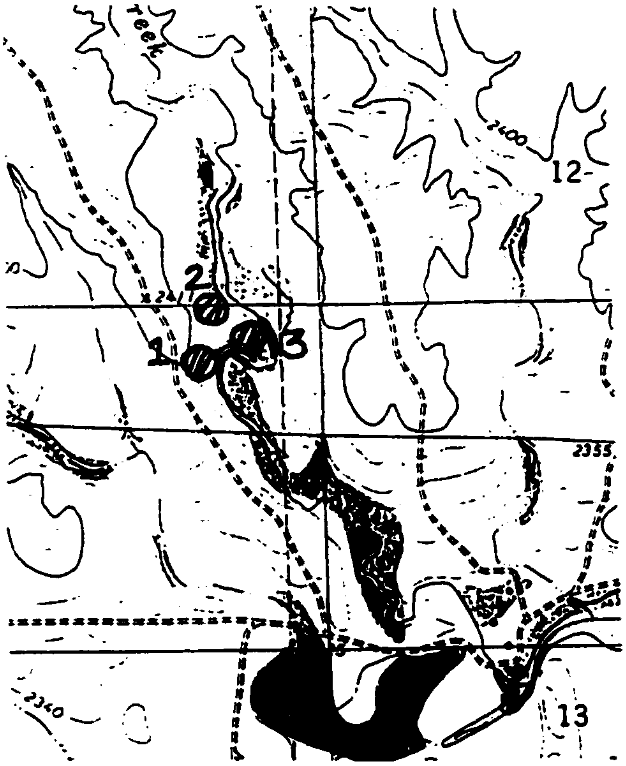

Figure 20. Loction of 14CK307 (1), 14CK308 (2), 14CK309 (3) [Simmons Creek Quadrangle; Sec. 11, T. 30s, R. 23w]

Deckert during his initial foray onto the site are comprised of Wolf Creek Plain and Borger Cordmarked (Drass and Turner 1989). They come from the upper horizon of occupation. The chert (light and dark gray flakes) were exceptionally fine examples of Day Creek chert, and are very similar to Day Creek chert workshop debris located at the Henry Ford Site (14CK403).

This site (14CK307) does contain ample prehistoric remains that could elucidate the transition between the Plains Woodland Period/Late Prehistoric Period. In Clark County, this site exhibits the only confirmed Plains Woodland Period component that I have found to date. The small cutbank that I examined and took charcoal samples from is very rich in artifacts and charcoal.

14CK408; The Walnut Grove Site

The Walnut Grove Site sits immediately to the north of 14CK307 (Figure 20, Number 2) and may constitute a continuation of 14CK307 (Figure 20, Number 1). 14CK308 exhibited nothing more than "stone chips" according to Martin Stein in 1983. Examination of Deckert's collection in 1994 indicated that Day Creek chert was probably not an exclusive lithic raw material. The Walnut Grove site was re-seeded in the 1970s, protecting it from further lateral damage by Simmons Creek (Atchinson 1972). However, the loci was trenched for the purpose of planting Black Walnut trees, and during that trenching, the majority of stone debitage was located by Deckert. The lithic material agrees with the material found at 14CK307. It is primarily composed of possible Alibates agatized dolomite and to a much lesser extent, Day Creek chert identical to the workshop debris at the Henry Ford Site (14CK403). Ceramic sherds were entirely lacking.

14CK309

Cultural affiliation for 14CK309 is unknown (Figure 20, Number 3). Given its very close proximity to 14CK307 (Figure 20, Number 1) and 14CK308 (Figure 20, Number 2), it is likely that the site is a continuation of these sites. Stein's site report of 1983 mentions he examined "..stone chips, burned and unburned bone, roofing nails, and stone types including Alibates agatized dolomite, quartzite and basalt." The site extends laterally along Simmons Creek for at least 0.4 h., following a northeasterly course that would, at one time, have made all three sites contiguous were it not for erosional and vehicular truncations along the drainage.

The Simmons Creek watershed has a plethora of old growth Black Walnut trees, witnessed by one tree that is in excess of 500 years old (Atchinson 1972). It is easy to speculate that the drainage has seen periodic use by nomadic and other semi-nomadic groups for at least that period of time; probably longer. Shovel tests, not yet on file with the Kansas State Historical Society, have indicated to me that the location is literally paved with the by-products of countless occupation (Wendland et al. 1987:461-73)

14CK401; The Blue Site

Located in 1992 along the confines of Brites Creek, northern Clark County, Kansas (Figure 21), 14CK401 represents a single occupation. The site is defined by a continuous occupation zone, 1 m (6 - 10 cm thick) below surface and extending approximately 32 m along the confines of the drainage cutbank. Activity areas are suggested by concentrations of burned and un-burned bone, canine teeth, quartzite, possible Alibates agatized dolomite, basalt, and Day Creek chert flakes. Day Creek chert predominates the observed lithic material. Most of the flakes represent secondary and tertiary waste flakes. A few sherds of cordroughened pottery have been recovered.

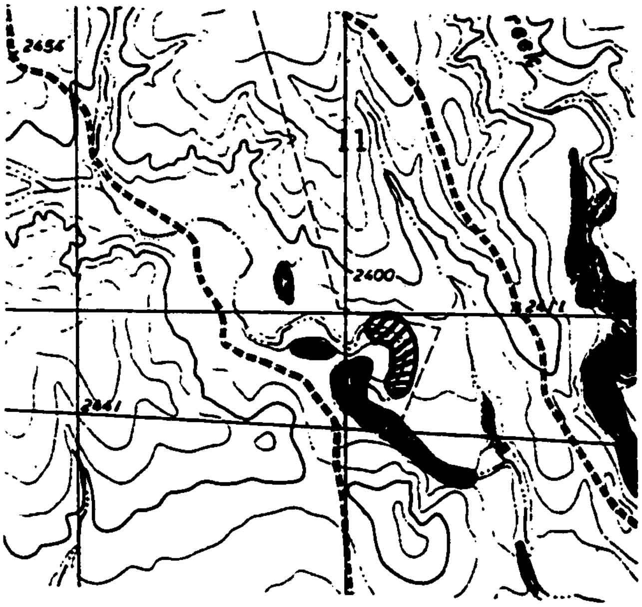

Figure 21. The Blue Site, 14CK401 [Simmons Creek Quadrangle; Sec. 11, T. 30s, R. 23w]

14CK409; The Raymond McMillion Site

The Raymond McMillion Site, 14CK409 (Figure 22) is remarkable for its variability in lithic tool types and lithic raw materials. The lithic collection (collected since 1910) contains artifact types that span the Paleoindian through the Historic periods. Mr. McMillion reported to me that during his work with tractor and plow, he would frequently uncover discreet sites complete with hearths and many stone tools. Numbering in the many hundreds, Mr. McMillion's lithic collection contains Folsom channel flakes (probably Alibates agatized dolomite), a preponderance of Archaic dart points (Day Creek chert) that Mr. McMillion pointed out were usually associated with the hearth features, and small arrow points (probable Alibates agatized dolomite and Day Creek chert). Unfortunately, Mr. McMillion did not collect pottery sherds, though he indicated he would not recognize them in the field while plowing.

Mr. McMillion's collection is probably the best indication that from a temporal frame of reference, Day Creek chert was mostly utilized by Archaic populations. His collection contains a large number of Calf Creek points. While totally exhausted and/or broken, these points are made of thermally altered Day Creek chert. They tend to be very glassy, contain stringers of light red through the otherwise white and/or blue lithic raw materials, and certain examples exhibit potlids that were deliberately avoided during construction of the point and/or knife. Scallorn, Washita, Harrell, and Fresno points tend to be constructed from Day Creek chert and material that is likely high grade Alibates agatized dolomite. The site exhibits a spectacular 360^0 view of the surrounding Cimarron River drainage, as well as the lateral drainages that empty into it. During Archaic times, it is possible that the Cimarron River ran its course much closer to the site, based on extensive alluvium south of the location. This could explain the appearance of Day Creek chert with both alluvial and natural cortex.

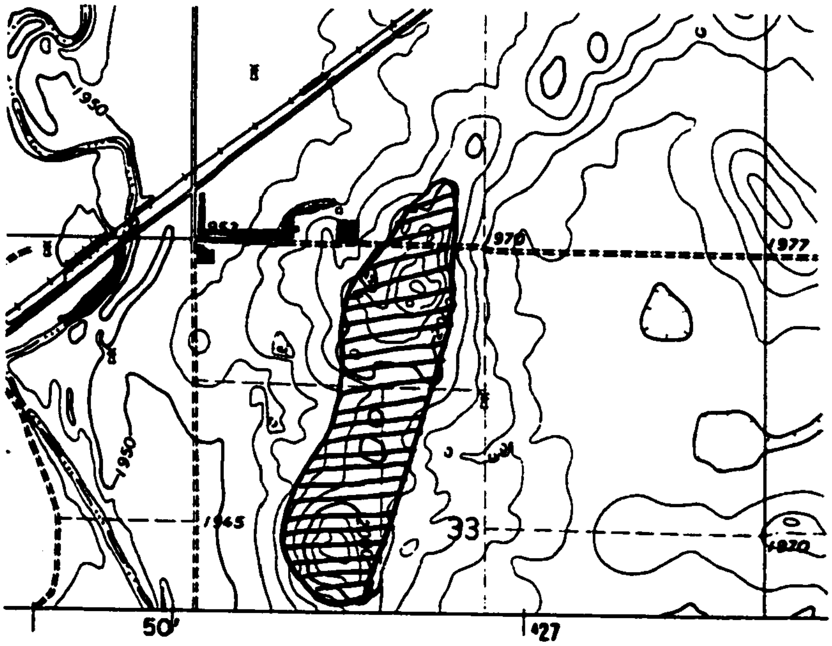

Figure 22. The Raymond McMillion Site, 14CK409 [Ashland Quadrangle; Sec. 33, T. 33s, R. 23w]

Allogenic chert (e.g., Keokuk chert and Florence-A) is evident, though not in abundance (Vehik 1982:69-90). The Keokuk chert is fashioned into a utilitarian knife while the Florence-A (both heat treated and non-heat treated) is usually confined to small arrow points. Taken as a whole, all allogenic chert described in Chapter V are the collection. Their temporal status is problematic since most are broken and lack clear temporal and/or typological affinities.

14CK413; The Moccasin Site

The Moccasin Site (Figure 23) is interpreted as an Archaic yucca processing camp. It is primarily composed of Clear Fork gouges (Hofman 1977; Hughes 1984). Located high on an upland, the site is essentially undisturbed due to its difficult access for cattle and/or bison. This site contains rich potential concerning the full range of Clear Fork gouges; from newly constructed to exhausted. Created from the typical blue/gray Day Creek chert located in the region the gouges do not exhibit thermal modification. Quarry activity is found adjacent to the processing camp.

14CK416; The Roper Site

Located on the upper terrace of a tributary to Bluff Creek (Figure 24), the Roper site is an *in situ* Late Prehistoric site. Its exposure is due to the continued erosion of the ground surface, resulting from a natural gas pipeline road. The site is situated to take advantage of a very large spring boil. Given the stabilization of the ground surface outside of the pipeline road, it is difficult to say how large this site is. Artifacts include Washita, Harrell, Fresno, and Scallorn projectile points, diamond beveled knives, an abundance of bison remains and lithic raw material debitage. The debitage is primarily composed of possible Alibates agatized dolomite, however, Day Creek chert primary and secondary debitage is abundant as well.

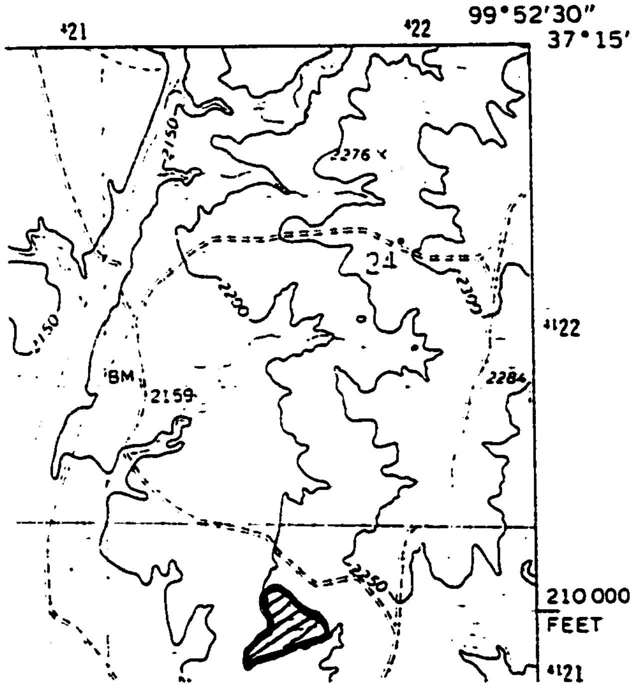

Figure 23. The Moccasin Site, 14CK413 [Ashland NW Quadrangle; Sec. 25, T. 32s, R. 24w]

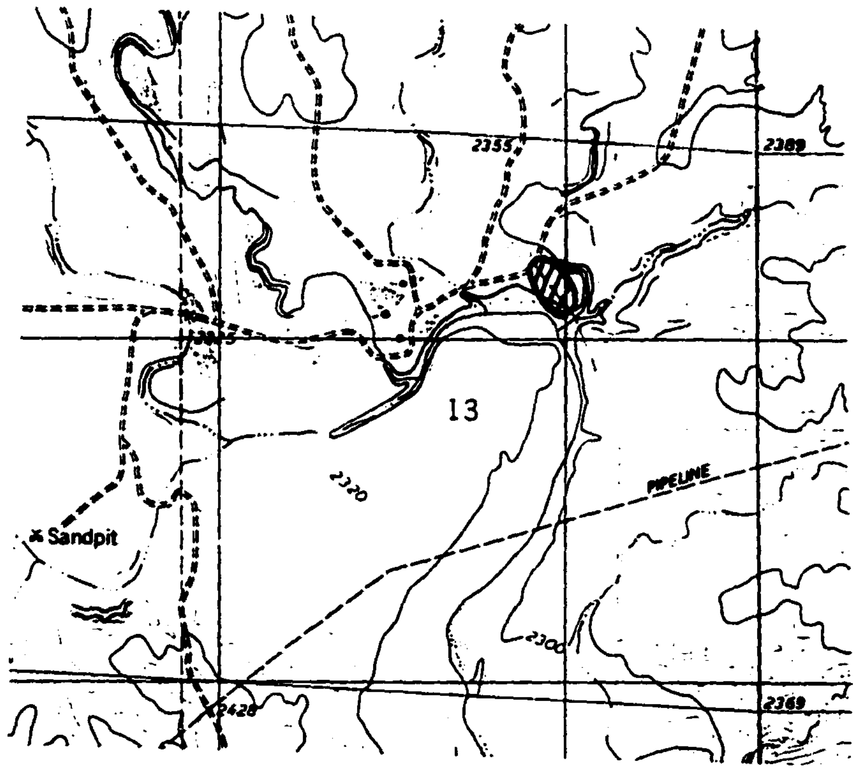

Figure 24. The Roper Site, 14CK416 [Simmons Creek Quadrangle; Sec. 13, T. 30s, R. 22w]

Small samples of Wolf Creek Plain (some with lip tabs and pinched rims), Borger Cordmarked, and unidentified smoothware (Drass and Turner 1989) have been recovered.

14CK421; Couch Site #1

The Couch Site #1 (Figure 25) is represented by the proximal portion of a quartzite Clovis point, some ivory, quartzite and Day Creek chert flakes, and burned bison bone. The site has been exposed through the placement of a pasture road and since it is found on a slope, most materials associated with it are found in secondary deposits at the bottom of the access road following a steady rain.

The Couch Site #1 is capped by a large Late Prehistoric site that is associated with a thick "A" horizon. Numerous examples of Wolf Creek Plain, Borger Cordmarked, and unidentified smoothwares are commonly found mixed with the Clovis material. The upper component of this site is defined by an abundance of diamond beveled knives which in most cases, are constructed from both quartzites and very fine-grained lithic material consistent with Alibates agatized dolomite. Day Creek chert is not well represented at this site. Following the access road down the terrace some 40 m away, a thick "A" horizon with abundant diamond beveled knives and Washita, Harrell, Fresno, and Gary points are commonly found in re-worked alluvial sediments. Given this situation, both Clovis and Late Prehistoric artifacts can be located adjacent to each other, complicating the separation of assemblages.

Summary

Based on the survey data and site inventory of lithic raw materials employed, variables such as areal distance, quality of material, and artifact typology played key roles in the ultimate decision to utilize Day Creek chert. Given data arising from the analysis of

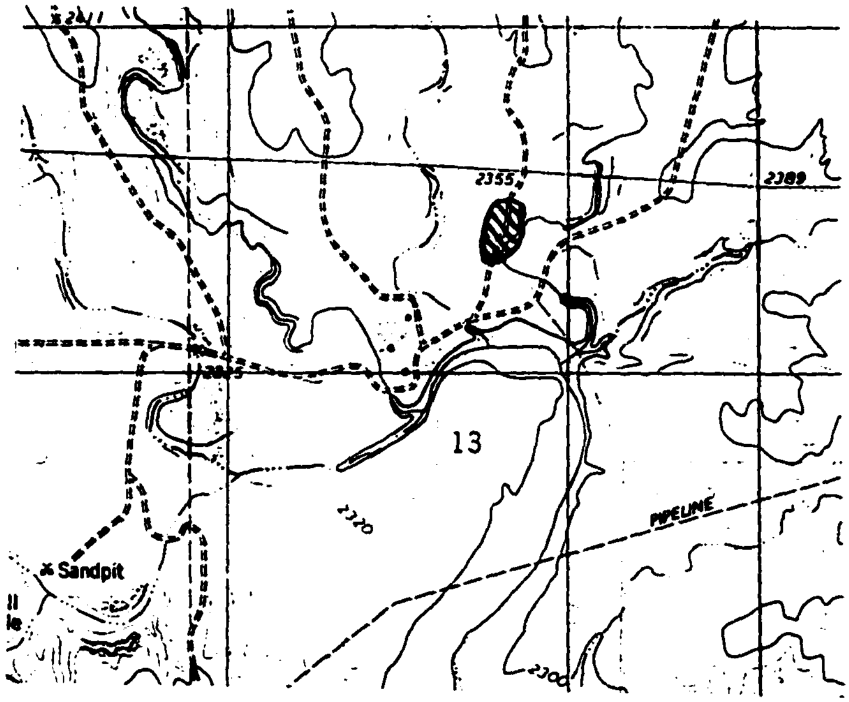

Figure 25. The Couch Site #1, 14CK421 [Simmons Creek Quadrangle; Sec. 13, T. 30s, R. 23w]

numerous private collections in the region, it is clear that these variables waxed and waned over time. For instance, there appears to be an emphasis on complicated, intensively worked tools fashioned from Day Creek chert in the Archaic Period (particularly at 14CK409) while simple, expedient tools predominate in the Plains Woodland and Late Prehistoric periods sites (e.g., 14CK307, 14CK308, and 14CK309).

The aforementioned sites contain cultural deposits that range from Paleoindian (Frison 1991; Frison and Bradley 1980; Hofman and Graham 1998:87-139), through Archaic (Hofman 1978:311-17, Hughes 1984:109-16; Kay 1998:173-200), and Plains Woodland period (Johnson and Johnson 1998:201-34; Vehik 1984:175-95), into the myriad of Late Prehistoric period type occupations (Drass 1998:415-55). Given my entire methodology was to record only those sites that were present either in alluvial deposits and/or exposed in cutbanks, I did not seek to identify sites through the use of excavation (Mueller 1975). All of the aforementioned sites in this chapter were discovered through my myopic struggle to discover Day Creek Dolomite *in situ*, and hopefully, the presence of Day Creek chert within the dolomite. Based on the lithic record maintained by Mr. Raymond McMillion at the 14CK409 site, I am able to state that all periods of prehistory are evidenced in this region of Clark County, Kansas. These data indicated that many environmental factors, aside from the geological outcrops of Day Creek chert, played an important role (Steward 1955). Sites far removed (≥ 15 km) from the source of Day Creek chert indicated that the material was also available in regolith and alluvial settings, often times of much higher quality (represented by larger nodules) than that located in the quarries proper (Love 1977:24-41). It should be noted that the exact loci of extremely high quality alluvial nodules continues to evade my attempts to locate the points of acquisition that prehistoric populations utilized for procurement of these lithic raw materials; they may simply be representative of lag deposits in extinct terraces.

Chapter VIII: SUMMARY AND CONCLUSION OF THE GEOARCHAEOLOGY OF DAY CREEK CHERT

The lithostratigraphy of Day Creek chert has followed an evolutionary path since its initial description by St. John (1887) in 1886. By 1894, F. W. Cragin (1896) had devised a rudimentary classification system that in many respects is still acknowledged today (Fay 1978). However, more important, are the many refinements that detail the Cloud Chief Formation and, within it, the Day Creek Dolomite bed (Fay 1978). Refinement of the lithostratigraphy concerning the Lower and Upper Permian Period formations within the Dissected Red Beds of northwest Oklahoma and southwest Kansas has been historically misunderstood by the archaeological community. Without a clear and precise knowledge of the current Permian lithostratigraphic system, beds such as the Day Creek chert will not foster definitive data concerning the acquisition of lithic raw materials on the Southern Great Plains. Behavioral questions such as the role of mobility in prehistory will remain skewed, leaving the researcher without quantified geological information to base his or her data. This situation is most pronounced with respect to the placement of Day Creek chert and Alibates agatized dolomite. Typically referred to as "lateral equivalents," by modern researchers (e.g., Banks 1984:65-95, 1990:91-92), neither bed within its respective formation has a contemporary geologic relationship. This fact is underscored by Gould's (1926:23) insistence that the Late Permian lithostratigraphic nomenclature should drop the name, ***Alibates agatized dolomite***, altogether. Rather than being dropped currently reference to Alibates agatized dolomite within contemporary archaeological literature is ubiquitous. Sedimentary geology continues to be based on incorrect field observations conducted by Cragin in 1896 and, although further refinements provided an entirely new classification system by Fay in 1965, contemporary archaeologists continue to utilize an outdated geologic scheme.

Day Creek chert, contained within the Day Creek Dolomite (Cloud Chief

Formation), is a distinct bed that contains nodular chert ranging in size from grain to boulder. Its sporadic appearance within the Day Creek Dolomite in northwest Oklahoma and southwest Kansas has evaded an all-encompassing means by which to delineate it from other lithic raw materials found in the Great Plains. Given its subjective lithological overlap with many other lithic raw materials from both within and outside the immediate regional outcrops, Day Creek chert most often is routinely classified as Alibates agatized dolomite in its lithic raw material form. Day Creek chert also overlaps in every respect with Edwards Formation chert located in Irion County, central Texas. Distinguishing lithic raw materials is complicated by the fact that routine laboratory procedures (such as the use of ultraviolet fluorescence) produce identical signatures among variant lithic raw materials recovered from the field. My research indicates that subjective criteria for the identification of lithic raw materials in the southern Great Plains is without merit. Aside from the formational level chert found on the southern Great Plains, Tertiary gravel containing vast amounts of allochthonous lithic raw materials is so widely spread, that the need for a quantitative method of discrimination is imperative.

Allogenic chert provided prehistoric populations with a permanent means by which to procure adequate lithic raw materials in the region. Their availability is underscored by the presence of numerous river systems which can transport the material great distances given millions of years. Active channel trenching during the Holocene altithermal likely exposed additional *in situ* lithic raw materials within their respective formations, and created point bars containing freshly uncovered allogenic chert. The availability of suitable lithic raw materials for the construction of stone tools in the region probably did not pose a significant obstacle for prehistoric artisans. Known outcrops of high grade chert, coupled with allogenic resources, could provide both informal and formal tools throughout the region.

Gaining a deeper understanding of the distinguishing characteristics between known formational chert is the goal of this research. Rather than relying on my own subjective criteria for identification of lithic raw materials, I placed emphasis on finding a quantitative means to address the problem. Field observations alone did not answer the fundamental question of ultimate geologic origin. Utilizing a methodology rooted in middle range research (Binford 1981, 1983, 1985) and contained in a theoretical framework that stresses the archaeology of regions (Fish and Kowalewski 1990; Rossignol and Wandsnider 1992), my aim is to develop tools to address the question of lithic raw material origin. Once understood, my goal is to answer fundamental questions of prehistoric behavior with respect to lithic raw material acquisition.

Following the discovery that much of the lithic raw material on the southern Great Plains remained indistinguishable, I embarked on a course that would provide me with the key trace elements contained within specific geological samples. Following the realization that ultraviolet fluorescence would not delineate one lithic raw material from another (e.g., Day Creek chert and Alibates agatized dolomite), I initiated the use of scanning electron microscopy. Unfortunately, the silica based samples that I provided the laboratory were so homogeneous in their atomic structure, it was quickly ascertained that this line of inquiry would have to be abandoned. In its stead, the use of instrumental neutron activation analysis (INAA) proved invaluable for the trace element discrimination of chert from my research samples. Although loose in comparison to other samples (e.g., Owl Creek chert), Day Creek chert clusters within its own statistical orbit from other allogenic cherts (especially the Irion County, Texas (Edwards Formation) sample). For the first time it was clear that INAA could provide the necessary means by which to distinguish totally unrelated cherts that on a subjective level, were identical in appearance. Currently, due to an oversight on my part, INAA data pertaining to Alibates agatized dolomite is unavailable and, as such, precludes any discussion concerning the statistical divergences between it and Day Creek chert. This is an important point since it is these two lithic raw materials that continue to be classified together, in the literature, on a formational level.

This research has proven that assigining lithographic source using subjective lithologies is non quantitative and quite possible erroneous. Studies such as Hofman's (1991:335-356) speculations based on Folsom mobility is called into question. Materials closely resembling Edwards Plateau cherts and/or Alibates agatized dolomite predominate within a Day Creek chert suite of lithological characteristics. Similarly, there appears to be a push towards the identification and distribution of Alibates agatized dolomite along the course of the Canadian River (Kraft 1997:106-109). My research proves that while samples similar to the aforementioned cherts can be found throughout the fluvial regimes of the southern Plains, it has not been quantified by any means except, perhaps, UVF.Discussion that the use of mobility, long distance procurement, and/or direct acquisition are extremely problematic questions when the researcher is relying solely on lithic raw materials. Given our current state of knowledge to date, allogenic cherts are not sufficiently understood to classify them to material type. Regardless, the archaeological literature is currently relying on subjective demarcations when it comes to classification..

With a firm grounding in the accurate demarcation of lithostratigraphic sedimentary beds and, a thorough understanding of the lithic raw materials found with any given region, the ability to ascertain the cultural complexities of prehistory can begin to be developed. It is important to note, that, oftentimes all we are left with in the archaeological record are the stone implements of a given culture. If we want to further elucidate the social constraints and/or the freedom of movement over circumscribed regions, we must acknowledge a primary understanding of the lithic for z given culture. Rather than utilizing an educated guess as to geologic origin, quantitative analysis of lithic raw material can objectively contribute to an understanding of direct acquisition, trade, and mobility within the archaeological record.

REFERENCES CITED

Adovasio, J. M., J. D. Gunn, J. Donahue, and R. Stuckenrath
1982 Meadowcroft Rockshelter, 1973 - 1977: A Synopsis. In, *Peopling of the New World*, edited by J.E. Ericson, R..E. Taylor, R. Berger. Ballena Press Anthropological Papers 23:(8; Part2):97-132, Los Altos.

Ahler, Stanley A.
1977 Lithic Resource Utilization Patterns in the Middle Missouri Subarea, in: Trends in Middle Missouri Prehistory: A Festchrift Honoring the Contributions of Donald J. Lehmer, edited by W. R. Wood, *Plains Anthropologist Memoir* 13-132-150.

1986 *The Knife River Flint Quarries: Excavations at Site 32DU508*. Publications of the State Historical Society of North Dakota, Bismarck.

Albert, Lois E. and Don G. Wyckoff
1984 Oklahoma Environments: Past and Present. In *Prehistory of Oklahoma*, edited by R.E. Bell, pp. 1-43. Academic Press, New York.

Alland Jr., Alexander and Bonnie McCay
1973 The Concept of Adaptation in Biological and Cultural Evolution. In *Handbook of Social and Cultural Anthropology*, edited by J.J. Honigmann, pp. 143-178. Rand McNally, Chicago.

Al-Shaieb, Z.
1988 Hydrocarbon-Limited Diagenetic Aureole at Cement-Chickasha Anticline, Oklahoma. In *Geological Society of America Centennial Field Guide; South-Central Section*, Volume 4. Boulder, Colorado.

Anderson, Adrian D.
1975 The Cooperton Mammoth: An Early Man Bone Quarry. *Great Plains Journal* 14:130-173.

Andrefsky, Jr., William
1994 Raw-Material Availability and the Organization of Technology. *American Antiquity* 59:21-34.

Atchinson, Fred D.
1972 *A Description of a Walnut Tree Stand in Western Kansas*. Unpublished Masters Thesis, Department of Agronomy, Fort Hays State College, Fort Hays, Kansas.

Aurin, F.
1917 Geology of the Redbeds of Oklahoma. *Oklahoma Geological Survey Bulletin*, Number 30. Norman.

Bailey, Berkley B.

1990 Eleven Thousand Years Revisited at Cedar Creek, Western Oklahoma. Paper presented at the 48th Plains Anthropological Conference, Oklahoma City.

1992 *The Archaeology of Hagemeister Island, Southwestern Alaska, with Special Emphasis on the Eskimo Occupations at the Qikertarpak Site [XHI-016].* Unpublished Master's Thesis, Department of Anthropology. University of Alaska, Fairbanks.

Bailey, Berkley B. (reviewer)

1998 *Paleoindian Geoarchaeology of the Southern High Plains*, by V.T. Holliday (1997). *Great Plains Research* 8(1):192-193.

Bailey, Berkley B., M. McCollough, B. Ritter, S. Miller, and E. Greenwald (editors)

1998 *Native Americans on the Great Plains.* Kendall-Hunt Publishers, Kansas City.

Bailey, Geoff

1983 Hunter-Gatherer Behaviour in Prehistory: Problems and Perspectives. In *Hunter-Gatherer Economy in Prehistory: A European Perspective*, edited by Geoff Bailey, pp. 1-6. Cambridge University Press, Cambridge.

Baker, V. and M. Penteado-Orellano

1977 Adjustment to Quaternary Climatic-Change by the Colorado River in Central Texas. *Journal of Geology* 85:395-422.

1978 Fluvial Sedimentation Conditioned by Quaternary Climatic Change in Central Texas. *Journal of Sedimentary Petroleum* 48:433-451.

Baker, William E.

1939 Flint Artifacts Relating to Cultures on the Great Plains. *The Oklahoma Prehistorian* 2:2-7.

Baker, William E., T. N. Campbell, and G. L. Evans

1957 *The Nall Site: Evidence of Early Man in the Oklahoma Panhandle.* Oklahoma Anthropological Society 5:1-20. Oklahoma City.

Bakewell, Edward F.

1995 Petrography, Geochemistry, and the Discrimination of Chert. Paper Presented at the 48th Northwest Anthropology Conference, Portland.

Bamforth, Douglas B.

1985 The Technological Organization of Paleo-Indian Small Group Bison Hunting on the Llano Estacado. *Plains Anthropologist* 30:243-258.

1986 Technological Efficiency and Tool Curation. *American Antiquity* 51:38-50.

1988 *Ecology and Human Organization on the Great Plains.* Interdisciplinary Contributions to Archaeology, Plenum Press, New York.

Banks, Larry D.

1973 A Comparative Analysis of Lithics at the Martin-Vincent Site. Ms. on file, Oklahoma Archeological Survey, Norman.

1983 Major Lithic Resources in the Jackfork and Brushy Creek Basins. In *Bug Hill: Excavation of a Multicomponent Midden Mound in the Jackfork Valley, Southeast Oklahoma*, edited by J. H. Altschul, pp. 135-154, 335-365, 390-392. New World Research Report of Investigation No. 81-1. Pollock, Louisiana.

1984 Lithic Resources and Quarries. In *Prehistory of Oklahoma*, edited by R.E. Bell, pp. 65-95. Academic Press, New York.

1990 *From Mountain Peaks to Alligator Tails: A Review of Lithic Sources in the Trans-Mississippi South, the Southern Plains, and Adjacent Southwest*. Oklahoma Anthropological Society Memoir, Number 4. Norman.

Barth, Fredrik

1969 Ecologic Relations of Ethnic Groups in Swat, North Pakistan. In *Environment and Cultural Behavior*, edited by A.P. Vayda, pp. 362-376. Natural History Press, Garden City.

Baugh, Timothy G.

1982 *Edwards I (34BK2): Southern Plains Adaptations in the Protohistoric Period*. Oklahoma Archeological Survey, Studies in Oklahoma's Past, Number 8. Norman.

1984 The Physical and Cultural Setting of the Mixed Grass Prairie. In *Archaeology of the Mixed Grass Prairie, Phase I: Quartermaster Creek*, edited by T.G. Baugh. Oklahoma Archeological Survey, Archeological Resource Survey Report 20:1-32. Norman.

1987 New Mexico Obsidian Sources and Exchange on the Southern Plains. *Journal of Field Archaeology* 14:313-329.

Baugh, Timothy G. and Jonathon E. Ericson (editors)

1994 *Preshistoric Exchange Systems in North America*. Interdisciplinary Contributions to Archaeology, Plenum Press, New York.

Baugh, Timothy G. and Fred W. Nelson

1987 New Mexico Obsidian and Exchange on the Southern Plains. *Journal of Field Archaeology* 14:313-329.

1988 Archaeological Obsidian Recovered from Selected North Dakota Sites and its Relationship to Changing Exchange Systemss in the Plains. *Journal of the North Dakota Archaeological Association* 3:74-94.

Beaubian, P.
1931 Materials in Archaeological Survey of Eastern Colorado. *Archaeological Survey of Eastern Colorado*, edited by E. Renaud, pp. 56-63. University of Denver. Denver, Colorado.

Beck, Charlotte and George T. Jones
1994 On-Site Artifact Analysis as an Alternative to Collection. *American Antiquity* 59:304-315.

Bell, Robert E. (editor)
1984 *Prehistory of Oklahoma*. Academic Press, New York.

Berta, Susan M. and John A. Harrington, Jr.
1984 Quartermaster Creek Watershed Land Cover Types: An Analysis of Current Conditions and Recent Changes. In *Archaeology of the Mixed Grass Prairie, Phase I: Quartermaster Creek*, edited by T.G. Baugh. Oklahoma Archeological Survey, Archeological Resource Survey Report 20:33-50. Norman.

Bettinger, Robert L.
1980 Explanatory/Predictive Models of Hunter-Gatherer Adaptation. In *Advances in Archaeological Method and Theory*, volume 3, edited by M.B.Schiffer, pp. 189-242. Academic Press, New York.

Bettis III, E. Arthur
1992 Soil Morphologic Properties and Weathering Zone Characteristics as Age Indicators in Holocene Alluvium in the Upper Midwest. In *Soils in Archaeology: Landscape Evolution and Human Occupation*, edited by V.T. Holliday, pp. 119-144. Smithsonian Institution Press, Washington D.C.

Binford, Lewis R.
1968 Post-Pleistocene Adaptations. In *New Perspectives in Archeology*, edited by L.R. Binford and S.R. Binford, pp. 313-342. Aldine Publishing Company, Chicago.

1981 *Bones: Ancient Men and Modern Myths*. Academic Press, New York.

1982 The Archaeology of Place. *Journal of Anthropological Archaeology* 1(1):5-31

1983 *Working at Archaeology*. Academic Press, New York.

1985 "Brand X" Versus the Recommended Product. *American Antiquity* 50:580-590.

1986 An Alyawara Day: Making Men's Knives and Beyond. *American Antiquity* 51:547-562.

Binford, Lewis R. and Sally R. Binford (editors)
1968 *New Perspectives in Archeology*. Aldine Publishing Company, Chicago.

Binford, Lewis R. and James F. O'Connell
1984 An Alyawara Day: The Stone Quarry. *Journal of Anthropological Research* 40:406-432.

Blikre, Lawrence
1993 *Cultural Implications of the Prehistoric Distribution of Sentinel Butte Flint in Western North Dakota*. Unpublished Master's Thesis, Department of Anthropology, Northern Arizona University, Flagstaff.

Boul, S.W., F.D. Hole, and R.J. McCraken
1980 *Soil Genesis and Classification*. Iowa State University Press, Ames.

Bowers, R. L.
1975 *Petrography and Petrogenesis of the Alibates Dolomite and Chert (Permian) Northern Panhandle of Texas*. M.A. thesis, Department of Geology, University of Texas at Arlington.

Briscoe, James M.
1979 Oklahoma Lithics and Lithic Resource Areas: Appendix II. In *Oklahoma Highway Archaeological Survey, 1972-1978*, edited by D.E. Lopez and K.D. Keith, pp. 907-922. Papers in Oklahoma Highway Archaeology, Number 6, Oklahoma Department of Transportation, Oklahoma City.

Brooks, Robert L.
1994 *Variability in Southern Plains Village Cultural Complexes: Archaeological Investigations at the Lonker Site in the Oklahoma Panhandle*. Bulletin of the Oklahoma Anthropological Society 43:1-27. Tulsa.

Brooks, Robert L. and Jack L. Hofman
1989 Introduction. In *From Clovis to Comanchero: Archeological Overview of the Southern Great Plains*, edited by J.L Hofman, R.L. Brooks, J.S. Hays, D.W. Owsley, R.L. Jantz, M.K. Marks, and M.H. Manhein, pp. 1-6. Arkansas Archaeological Survey Research Series, Number 35. Fayetteville.

Brown, Kenneth L.
1976 *Late Prehistoric Settlement Patterns in Southwestern Kansas: A Model*. Unpublished Master's Thesis, Department of Anthropology. University of Kansas, Lawrence.

Bryan, Kirk
1950 *Flint Quarries: The Sources of Tools and, at the same time, the Factories of the American Indian*. Papers of the Peabody Museum of American Archaeology and Ethnology, Harvard University, Volume 17, Number 3.

Buchner, Anthony P.
1980 *Cultural Responses to Altithermal (Atlantic) Climate along the Eastern Margins of the North American Grasslands: 5,500 to 3,000 B.C.* Archaeological Survey of Canada, Paper Number 97. Ottawa.

Bush, P. R. and G. de G. Sieveking

1986 Geochemistry and the Provenance of Flint Axes. In *The Scientific Study of Flint and Chert: Proceedings of the Fourth International Flint Symposium Held at Brighton Polytechnic, 10-15 April 1983*, edited by G. De G. Sieveking and M.B. Hart, pp. 133-140. Cambridge University Press, Cambridge.

Butzer, Karl W.

1971 *Environment and Archeology: An Ecological Approach to Prehistory*. Aldine Publishing Company, Hawthorne, New York.

Byrd, Clifford L.

1971 Origin and History of the Uvalde Gravel of Central Texas. *Baylor Geological Studies*, Bulletin No. 20, Baylor University, Texas.

Callahan, Errett

1979 The Basics of Biface Knapping in the Eastern Fluted Point Tradition: A Manual for Flintknappers and Lithic Analysts. *Archaeology of Eastern North America* 7:1-179.

Camilli, Eileen

1989 The Occupational History of Sites and the Interpretation of Prehistoric Technological Systems: An Example From Cedar Mesa, Utah. In *Time, Energy and Stone Tools*, edited by R. Torrence, pp. 17-26. Cambridge University Press, London.

Carlson, G. F. and C. A. Peacock

1975 Lithic Distribution in Nebraska. In *Lithic Source Notebook*. Section of Archaeology, Division of Historical and Cultural Affairs, State of Delaware, Milford.

Carr, Philip J. (editor)

1994 *The Organization of North American Prehistoric Chipped Stone Tool Technologies*. International Monographs in Prehistory Archaeological Series, Number 7. Ann Arbor, Michigan.

Carroll, H. B.

1941 The Journal of Lt. J. W. Abert From Bent's Fort to St. Louis in 1845. *Panhandle Plains Historical Review* XIV. Canyon, Texas.

Chowns, T. M. and J. E. Elkins

1974 The Origin of Quartz Geodes and Cauliflower Cherts Through the Silification of Anhydrite Nodules. *Journal of Sedimentary Petrology* 44:885-903.

Church, Tim

1994 *Lithic Resource Studies: A Sourcebook for Archaeologists*. Department of Anthropology Special Publication, Number 3. University of Tulsa, Oklahoma.

Clapp, F. G.
1921 Oklahoma's Stratigraphic Problem (The Redbeds). *Oil and Gas Journal* 65:156-64.

Clarke, David L.
1968 *Analytical Archaeology*. Methuen & Co., Ltd. London.

Clark, G. A.
1989 Romancing the Stones: Biases, Style and Lithics at La Riera. In *Alternative Approaches to Lithic Analysis*, edited by D.O. Henry and G.H. Odell, pp. 27-50. Archaeological Papers of the American Anthropological Association, Number 1. Washington D.C.

Clifton, R. L.
1930 *Permian Structure and Stratigraphy of Northwestern Oklahoma and Adjacent Areas*. American Association of Petroleum Geologists. 14:161-173.

Cooper, Laverne M.
1975 *A Study of Kay County Flint Prehistoric Quarrying, Typology, and Utilization Trends*. Bulletin of the Oklahoma Anthropological Society. 23:185-192. Oklahoma City.

Cotterell, Brian and Johan Kamminga
1979 The Mechanics of Flaking. In *Lithic Use-Wear Analysis*, pp. 97-111. Academic Press, New York.

Cowgill, George L.
1990 Toward Refining Concepts of Full-Coverage Survey. In *The Archaeology of Regions: A Case for Full-Coverage Survey*, edited by S.K. Fish and S.A. Kowalewski, pp. 249-260. Smithsonian Institution Press, Washington D.C.

Crabtree, Don E.
1982 *An Introduction to Flintknapping*, second edition. Occasional Papers of the Idaho Museum of Natural History, Number 28. Pocatello, Idaho.

Cragin, F. W.
1896 *The Permian System in Kansas*. Colorado College Studies 6:1-48.

Dake, H. C. and J. DeMent
1941 *Fluorescent Light and its Applications*. Chemical Publication Company, Inc. New York.

Dalton, George
1977 Aboriginal Economies in Stateless Societies. In *Exchange Systems in Prehistory*, edited by T.K. Earle and J.E. Ericson, pp. 191-209. Academic Press, New York.

Darton, N. H.

1899 *Preliminary Report on the Geology and Water Resources of Nebraska West of the 103rd Meridian*. U.S. Geological Survey, 19th Annual Report, Part 4. U.S. Government Printing Office, Washington, D. C.

DeGarmo, Glen D.

1977 Identification of Prehistoric Intrasettlement Exchange. In *Exchange Systems in Prehistory*, edited by T.K. Earle and J.E. Ericson, pp. 153-168. Academic Press, New York.

Dietrich, R. V., C. R. B. Hobbs, Jr., and W. D. Lowry

1963 Dolomitization Interrupted By Silicification. *Journal of Sedimentary Petrology* 33:646-663.

Dolliver, Paul N.

1984 *Cenozoic Evolution of the Canadian River Basin*. Baylor Geological Studies Bulletin 42:1-96. Waco, Texas.

Dolliver, Paul N. and Vance T. Holliday

1988 Ogallala and Post-Ogallala Sediments of the Southern High Plains, Blanco Canyon and Mt. Blanco, Texas. In *South-Central Section of the Geological Society of America: Centennial Field Guide* 4:299-304.

Drass, Richard R.

1998 The Southern Plains Villagers. In *Archaeology on the Great Plains*, edited by W. R. Wood, pp. 415-455. University of Kansas Press, Lawrence

Drass, Richard R. and Christopher L. Turner

1989 *An Archaeological Reconnaissance of the Wolf Creek Drainage Basin: Ellis County, Oklahoma*. Oklahoma Archeological Survey, Archeological Resource Survey Report, Number 35. Norman.

Driskell, Boyce N.

1986 *The Chipped Stone Tool Production/Use Cycle*. BAR International Series 305. Oxford, England.

Dunnell, Robert C.

1971 *Systematics in Prehistory*. The Free Press, New York.

1980 Evolutionary Theory and Archaeology. In *Advances in Archaeological Method and Theory*, volume 3, pp. 38-90, edited M.B. Schiffer. Academic Press, New York.

1986 Methodological Issues in Americanist Artifact Classification. In *Advances in Archaeological Method and Theory*, volume 9, pp. 149-207, edited M.B. Schiffer. Academic Press, New York.

Dutton, S., R. Finlay, W. Galloway, T. Gustavson, C. Hanford, and M. Presley
1979 *Geology and Geohydrology of the Palo Duro Basin, Texas Panhandle.* Texas Bureau of Economic Geology, Geological Circular 79:1-99. Austin.

Earle, Timothy K.
1980 A Model of Subsistence Change. In *Modeling Change in Prehistoric Subsistence Economies*, edited by T.K. Earle and A.L. Christenson, pp. 1-26. Academic Press, New York.

Earle, Timothy K. and Andrew L. Christenson (editors)
1980 *Modeling Change in Prehistoric Subsistence Economies*. Academic Press, New York.

Earle, Timothy K. and Jonathon E. Erickson
1977 Exchange Systems in Archaeological Perspective. In *Exchange Systems in Prehistory*, edited by T.K. Earle and J.E. Ericson, pp. 3-12. Academic Press, New York.

Earle, Timothy K. and Jonathon E. Ericson (editors)
1977 *Exchange Systems in Prehistory*. Academic Press, New York.

Ericson, Jonathon E.
1977 Egalitarian Exchange Systems in California: A Preliminary View. In *Exchange Systems in Prehistory*, edited by T.K. Earle and J.E. Ericson, pp. 109-125. Academic Press, New York.

1984 Toward the Analysis of Lithic Production Systems. In *Prehistoric Quarries and Lithic Production*, edited by J.E. Ericson and B.A. Purdy, pp. 1-9. Cambridge University Press, Cambridge.

Ericson, Jonathon E. and Barbara A. Purdy (editors)
1984 *Prehistoric Quarries and Lithic Production*. Cambridge University Press, Cambridge.

Eugster, Hans P. and Ronald C. Surdam
1973 Depositional Environment of the Green River Formation of Wyoming: A Preliminary Report. *Geological Society of America Bulletin* 84 (4):1115-1120.

Evans, Noel
1931 *Stratigraphy of Permian Beds of Northwestern Oklahoma*. American Association of Petroleum Geologists 15:405-440. Tulsa.

Fay, Robert O.
1959 *Pleistocene Course of the South Canadian River in Central Western Oklahoma*. Oklahoma Geological Survey, Oklahoma Geology Notes 19:3-12. Norman.

1965 *Geology and Mineral Resources of Woods County*. Oklahoma Geological Society 106:1-189. Norman.

1991 Personal Communication to Berkley B. Bailey. Norman, Oklahoma.

1999 Personal Communication to Berkley B. Bailey. Lincoln, Nebraska.

Fay, Robert O., W. E. Ham, J. Bado, and Louise Jordan
1962 *Geology and Mineral Resources of Blaine County*. Oklahoma Geological Survey 89:1-258. Norman.

Fay, Robert O. and D. Hart, Jr.
1978 *Geology and Mineral Resources (Exclusive of Petroleum) of Custer County, Oklahoma*. Oklahoma Geological Survey 114:1-88. Norman.

Ferring, C. Reid
1990 Archaeological Geology of the Southern Plains. In *Archaeological Geology of North America*, edited by N. Tasca and J. Donahue, pp. 1-625. Geological Society of America. Boulder, Colorado.

1992 Alluvial Pedology and Geoarchaeology Research. In *Soils in Archaeology: Landscape Evolution and Human Occupation*, edited by V.T. Holliday, pp. 1-40. Smithsonian Institution Press, Washington D.C.

Ferring, C. Reid, Daniel J. Crouch, and Towana D. Spivey
1976 *An Archaeological Reconnaissance of the Salt Plains Area of Northwestern Oklahoma*. Contributions of the Museum of the Great Plains, Number 4. Lawton.

Figgens, J. E.
1927 The Antiquity of Man in America. *Natural History* 27:229-247.

Findlow, F. J. and M. Bolognese
1984 Economic Aspects of Prehistoric Quarry Use: A Case Study in the American Southwest. In *Prehistoric Quarries and Lithic Production*, edited by J.E. Ericson and B.A. Purdy, pp. 77-82. Cambridge University Press, Cambridge.

Fish, Suzanne K. and Stephen A. Kowalewski (editors)
1990a *The Archaeology of Regions: A Case for Full-Coverage Survey*. Smithsonian Institution Press, Washington D.C.

1990b Introduction. In *The Archaeology of Regions: A Case for Full-Coverage Survey*, edited by S.K. Fish and S.A. Kowalewski, pp. 1-6. Smithsonian Institution Press, Washington D.C.

Fisher, W. C. and P. V. Rodda
1967 Stratigraphy and Genesis of Dolomite, Edwards Formation (Lower Cretaceous) of Texas. In *Proceedings of the Third Forum on Geology of Industrial Minerals*. State Geological Survey of Kansas, Special Session Publication 34:52-75.

Flügal, Erik and Joachim Reinhardt
1989 Uppermost Permian Reefs in Skyros (Greece) and Sichuan (China): Implications of the Late Permian Extinction Event. *Palaios: Internatinoal Journal of Society for Sedimentary Geology* 4 (6):502-518.

Flynn, Peggy, D. Wyckoff, B. Carter, D. Wakefield, L. Martin, and L. Todd

1988 Beyond Clovis: A Glimpse from the Burnham Site? Paper presented at the 46th Annual Plains Conference. Wichita.

Folk, Robert L. and J. Stuart Pittman

1971 Length-Slow Chalcedony: A New Testament for Vanished Evaporates. *Journal of Sedimentary Petrology* 41:1045-1058.

Ford, Alonzo "The Kid"

1939 *Notes on Early Clark County, Kansas: The Clark County Chapter of the Kansas State Historical Society* 1:1-97. Ashland.

Foster, Roy W.

1966 Oil and Gas in Colfax County. *Seventeenth Field Conference Guidebook, Taos-Raton-Spanish Peaks Country.* New Mexico Geological Society.

Francis, Julie E.

1991 Lithic Resources on the Northwestern High Plains: Problems and Perspectives in Analysis and Interpretation. In *Raw Material Economies among Prehistoric Hunter-Gatherers*, edited by A. Montet-White and S. Holen, pp. 305-320. University of Kansas, Publications in Anthropology, Number 19. Lawrence.

1994 Fear and Loathing in Wyoming: Documentation and Evaluation of Lithic Procurement Sites. In *Lithic Resource Studies: A Sourcebook for Archaeologists.* Lithic Technology Special Publication 3:230-234. Department of Anthropology, University of Tulsa, Oklahoma.

Franks, Paul C. and Ada Swineford

1959 Character and Genesis of Massive Opal in Kimball Member, Ogallala Formation, Scott County, Kansas. *Journal of Sedimentary Petrology* 29:186-196.

Frison, George C.

1991 *Prehistoric Hunters of the High Plains*. 2nd edition. Academic Press, San Diego, California.

Frison, George C. and Bruce A, Bradley

1980 *Folsom Tools and Technology at the Hanson Site, Wyoming*. University of New Mexico Press, Albuquerque.

Frye, John C. and A. B. Leonard

1957 *Studies of Cenozoic Geology Along Eastern Margins of the Texas High Plains, Armstrong to Howard Counties*. Texas Bureau of Economic Geology, Report of Investigations 39:1-46. Austin.

1965 Quaternary of the Southern Great Plains. In *Quaternary of the United States*, edited by H. E. Wright, Jr. and D. G. Frey, pp. 203-16. Princeton University, New Jersey.

Geno, K. R.

1976 *Origin and Distribution of Chert in the Edwards Limestone (Lower Cretaceous), Central Texas*. B.S. Thesis, Department of Geology, Baylor University, Waco, Texas.

Gibbard, P. L.

1986 Flint Gravels in the Quaternary of Southeast England. In *The Scientific Study of Flint and Chert: Proceedings of the Fourth International Flint Symposium Held at Brighton Polytechnic, 10-15 April 1983*, edited by G. De G. Sieveking and M.B. Hart, pp. 141-149. Cambridge University Press, Cambridge.

Gladfelter, Bruce G.

1981 Developments and Directions in Geoarchaeology. In *Advances in Archaeological Method and Theory*, volume 4, pp. 344-358, edited by M.B. Schiffer. Academic Press, New York.

Gleason S.

1960 *Ultraviolet Guide to Minerals*. Von Nostrand Publishing, Chicago.

Gould, Charles N.

1902 *General Geology of Oklahoma*. Second Biennial Report, Department of Geology and Natural History, Territory of Oklahoma, pp. 17-74. Norman.

1905 *Geology and Water Resources of Oklahoma*. U.S. Geological Survey Water Supply Paper 148:1-178. Washington D.C.

1907 *Geology and Water Resources of the Western Portion of the Panhandle of Texas*. U.S. Geological Survey, Water Supply Paper No. 191. Washington, D.C.

1924 *A New Classification of the Permian Redbeds of Southwestern Oklahoma*. American Association of Petroleum Geologists 8:322-341. Tulsa.

1929a *On the Recent Finding of Another Flint Arrowhead in the Pleistocene at Frederick, Oklahoma*. Journal of the Washington Academy of Sciences 19:66-68. Washington D.C.

1929b *Fossil Bones and Artifacts at Frederick, Oklahoma*. Oklahoma Academy of Science Proceedings 9:90. Norman.

Gould, Charles N. and Frank E. Lewis

1926 *The Permian of Western Oklahoma and The Panhandle of Texas*. Oklahoma Geological Survey Circular 13:1-29. Norman.

Graham, Russell W.

1987 Paleoenvironments of the Southwestern Plains. In *Late Quaternary Mammalian Biogeography and Environments of the Great Plains and Prairies*, edited by R. Graham, H.A. Semken, Jr., and M.A. Graham, pp. 24-86. Illinois State Museum Scientific Papers, volume 22. Springfield.

Greene, Darsie A.
1936 *Permian and Pennsylvanian Sediments Exposed in Central and West-Central Oklahoma.* American Association of Petroleum Geologists Bulletin 20:1454-1475. Tulsa.

Gustavson, Thomas C., R. Finlay, and K. McGillis
1980 *Regional Dissolution of Permian Salts in the Anadarko, Dalhart, and Palo Duro Basins of the Texas Panhandle.* Texas Bureau of Economic Geology, Report of Investigations 106:1-40. Austin.

Gustavson, Thomas C. and R. Finley
1985 *Late Cenozoic Geomorphic Evolution of the Texas Panhandle and Northeastern New Mexico.* Case Studies of Structural Controls on Regional Drainage Development, Bureau of Economic Geology, University of Texas, Austin.

Hall, Stephen A.
1982 Late Holocene Paleoecology of the Southern High Plains. *Quaternary Research* 17:391-407.

1983 Geology and Holocene Sediments and Buried Trees of Carnegie Canyon. In *The Geomorphology and Archaeology of Carnegie Canyon, Ft. Cobb Laterals Watershed, Caddo Co., Oklahoma,* edited by C. Lintz and S.A. Hall. Oklahoma Conservation Commission, Archaeological Research Report 10:15-46, Oklahoma City.

1985 Quaternary Pollen Analysis and Vegetational History of the Southwest. In *Pollen Records of Late Quaternary North American Sediments,* edited by V.M. Bryant, Jr., and R.G. Holloway, pp. 95-123. American Association for Stratigraphic Polynologists Foundation.

1988 Environment and Archaeology of the Central Osage Plains. *Plains Anthropologist* 33:203-217.

1990 Holocene Landscapes of the San Juan Basin, New Mexico: Geomorphic, Climatic, and Cultural Dynamics. In *Archaeological Geology of North America,* edited by N. Tasca and J. Donahue. Geological Society of America, Colorado.

Hall, Stephen A. and Christopher Lintz
1984 Buried Trees, Water Table Fluctuations, and 3,000 years of Changing Climate in West-Central Oklahoma. *Quaternary Research* 22:129-133.

Hammond, Norman, A. Aspinall, S. Feather, J. Hazelden, T. Gazard and S. Agrell
1977 Maya Jade: Source Location and Analysis. In *Prehistoric Exchange Systems,* edited by T.K. Earle and J.E. Ericson, pp. 35-65. Academic Press, New York.

Hardesty, Donald L.
1980 The Use of General Ecological Principles in Archaeology. In *Advances in Archaeological Method and Theory*, volume 3, pp. 158-183, edited by M.B. Schiffer. Academic Press, New York.

Harris, Arthur H.
1985 *Late Pleistocene Vertebrate Paleoecology of the West*. University of Texas Press, Austin.

Hassan, Fekri A.
1979 Geoarchaeology: The Geologist and Archaeology. *American Antiquity* 44:267-270.

Haury, Cherie E.
1979 Characterization of the Chert Resources of the El Dorado Project Area. *Finding, Managing, and Studying Prehistoric Cultural Resources at El Dorado Lake, Kansas (Phase I)*, edited by G. R. Leaf, pp. 207-227. University of Kansas Museum of Anthropology Research Series, Number 2. Lawrence.

1984 Prehistoric Utilization of Chert Resources in the Southern Flint Hills of Kansas. *Prehistoric Chert Exploitation*, edited by B. M. Butler and E. E. May. Studies from the Midcontinent Center for Archeological Investigations, Occasional Papers 2. Southern Illinois University, Carbondale.

1985 *Availability, Procurement, and Use of Chert Resources by the Late Archaic Populations in the Southern Flint Hills*. Unpublished Masters Thesis, Department of Anthropology, University of Kansas, Lawrence.

1994 Defining Lithic Procurement Terminology. In *Lithic Resource Studies: A Sourcebook for Archaeologists*, edited by T. Church, pp. 26-229. Lithic Technology Special Publication, Number 3. Department of Anthropology, University of Tulsa, Oklahoma.

Haworth, Erasmus
1897 *The University Geological Survey of Kansas*, volume 2. Kansas State Printing Company, Topeka.

Haynes Jr., C. Vance and G. Agogino
1966 Prehistoric Springs and Geochronology of the Clovis Site. *American Antiquity* 31:812-821.

Healan, Dan M.
1995 Identifying Lithic Reduction Loci with Size-Graded Macrodebitage: A Multivariate Approach. *American Antiquity* 60:689-699.

Hedberg, Hollis D. (editor)
1976 *International Stratigraphic Guide: A Guide to Stratigraphic Classification, Terminology, and Procedure*. John Wiley & Sons, New York.

Hempel, C. G.

1977 Formulation and Formalization of Scientific Theories. In *The Structure of Scientific Theories* (2nd Edition), edited by F. Suppe, pp. 244-265. University of Illinois Press, Urbana.

Henry, Donald O.

1989 Correlations Between Reduction Strategies and Settlement Patterns. In *Alternative Approaches to Lithic Analysis*, edited by D.O. Henry and G.H. Odell, pp. 139-156. Archaeological Papers of the American Anthropological Association, Number 1. Washington D.C.

Hill, R. T. and T. W. Vaughan

1898 Geology of the Edwards Plateau and Rio Grande Plain Adjacent to Austin and San Antonio, Texas with Reference to the Occurrence of Underground Water. *U.S. Geological Survey 18th Annual Report*, Part 2:193-321.

Hoard, R. J., J. R. Bozell, S. R. Holen, M. D. Glasscock, H. Neff, and J. M. Elam

1993 Source Determination of White River Group Silicates from Two Archaeological Sites in the Great Plains. *American Antiquity* 58:698-710.

Hofman, Jack L.

1977 A Technological Analysis of Clear Fork Gouge Production. *Bulletin of the Oklahoma Anthropological Society* 26:105-121.

1978 An Alternative View of Some Southern Plains Archaic Stage Characteristics. *Plains Anthropologist* 23:311-317.

1989a Prehistoric Culture History - Hunters and Gatherers in the Southern Great Plains. In *From Clovis to Comanchero: Archeological Overview of the Southern Great Plains*, edited by J.L Hofman, R.L. Brooks, J.S. Hays, D.W. Owsley, R.L. Jantz, M.K. Marks, and M.H. Manheim, pp. 25-60. Arkansas Archaeological Survey Research Series, Number 35. Fayetteville.

1989b Protohistoric Culture History on the Southern Great Plains. In *From Clovis to Comanchero: Archeological Overview of the Southern Great Plains*, edited by J.L Hofman, R.L. Brooks, J.S. Hays, D.W. Owsley, R.L. Jantz, M.K. Marks, and M.H. Manheim, pp. 91-100. Arkansas Archaeological Survey Research Series, Number 35. Fayetteville.

1990 Cedar Creek: A Folsom Locality in Southwestern Oklahoma. *Current Research in the Pleistocene* 7:19-23.

1991 Folsom Land Use: Projectile Point Variability as a Key to Mobility. In *Raw Material Economies among Prehistoric Hunter-Gatherers*, edited by A. Montet-White and S. Holen, pp. 335-356. University of Kansas, Publications in Anthropology, Number 19. Lawrence.

1992 Recognition and Interpretation of Folsom Technological Variability on the Southern Plains. In *Ice Age Hunters of the Rockies*, edited by D.J. Stanford and J.S. Day, pp. 193-224. University Press of Colorado, Boulder.

1994 Paleoindian Aggregations on the Great Plains. *Journal of Anthropological Archaeology* 13:341-370.

Hofman, Jack L., R. Brooks, J. Hays, D. Owsley, R. Jantz, M. Marks, and M. Manheim (eds)
1989 *From Clovis to Comanchero: Archaeological Overview of the Southern Great Plains*, Arkansas Archaeological Survey Research Series, Number 35. Fayetteville.

Hofman, Jack L. and Brian J. Carter
1991 The Waugh Site: A Folsom-Bison Association in Northwestern Oklahoma. In *Guidebook, 9th Annual Meeting, South-Central Friends of the Pleistocene: A Prehistory of the Plains Border Region, Woodward, Oklahoma, May 17-19, 1991*, pp. 24-37. Agronomy Department, Oklahoma State University, Stillwater.

Hofman, Jack L. and Russell W. Graham
1998 The Paleo-Indian Cultures of the Great Plains. In *Archaeology on the Great Plains*, pp. 87-139. University of Kansas Press, Lawrence.

Holen, Steven R.
1983 Lower Loup Lithic Procurement Strategy at the Gray Site, 25CX1. M.A., Department of Anthropology, University of Nebraska, Lincoln.

1991 Bison Hunting Territories and Lithic Acquisition among the Pawnee: An Ethnohistoric and Archaeological Study. In *Raw Material Economies among Prehistoric Hunter-Gatherers*, edited by A. Montet-White and S. Holen, pp. 399-411. University of Kansas, Publications in Anthropology, Number 19. Lawrence.

Holliday, Vance T.
1988 *Late Pleistocene and Holocene Stratigraphy, Southern High Plains Texas*, volume 4, South-Central Section of the Geological Society of American, Centennial Field Guide. Boulder, Colorado.

1992 Soil Formation, Time, and Archaeology. In *Soils in Archaeology: Landscape Evolution and Human Occupation*, edited by V.T. Holliday, pp. 101-118. Smithsonian Institution Press, Washington D.C.

1997 *Paleoindian Geoarchaeology of the Southern High Plains*. University of Texas Press, Austin.

Holmes, W. H.
1890 A Quarry Workshop of the Flaked-Stone Implement Makers in the District of Columbia. *American Anthropologist* 3:1-26.

1897 *Stone Implements of the Potomac-Chesapeake Tidewater Province*. Bureau of American Ethnology, 15th Annual Report. Washington D.C.

1919 Acquirement of Minerals. In *Handbook of American Aboriginal American Antiquities, Part I: Introductory, The Lithic Industries*. Bureau of American Ethnology, Bulletin 60. Washington D.C.

Howell, J.
1922 Some Structural Factors in the Accumulation of Oil in Southwestern Oklahoma. *Economic Geologist* 17:1-23.

Hughes, David T.
1984 The Foragers: Western Oklahoma. In *Prehistory of Oklahoma*, edited by R.E. Bell, pp. 109-116. Academic Press, New York.

Hughes, Jack
1976 A Review of Some References to Flint Sources in the Texas Panhandle. *Archaeological Research Laboratory, Kilgore Research Center, West Texas State University*, Canyon.

Hughes, Richard E. and William B. Lees
1991 Provenance Analysis of Obsidian from Two Late Prehistoric Archaeological Sites in Kansas. *Transactions of the Kansas Academy of Science* 94(1-2):38-45.

Jeske, Robert
1989 Economies in Raw Material Use by Prehistoric Hunter-Gatherers. In *Time, Energy and Stone Tools*, edited by Robert Torrence, pp. 34-45. Cambridge University Press, London.

Jelinek, Arthur J.
1991 Observations on Reduction Patterns and Raw Materials in Some Middle Paleolithic Industries in the Perigord. In *Raw Material Economies among Prehistoric Hunter-Gatherers*, edited by A. Montet-White and S. Holen, pp. 7-32. University of Kansas, Publications in Anthropology, Number 19. Lawrence.

Jochim, Michael A.
1989 Optimization and Stone Tool Studies: Problems and Potential. In *Time, Energy and Stone Tools*, edited by R. Torrence, pp. 106-111. Cambridge University Press, London.

Johnson, Jay K.
1989 The Utility of Production Trajectory Modeling as a Framework for Regional Analysis. In *Alternative Approaches to Lithic Analysis*, edited by D.O. Henry and G.H. Odell, pp. 119-138. Archaeological Papers of the American Anthropological Association, Number 1. Washington D.C.

Johnson, Ann M. and Alfred E. Johnson
1998 The Plains Woodland. In *Archaeology on the Great Plains*, edited by W.R. Wood, pp. 201-234. University of Kansas Press, Lawrence.

Kay, Marvin

1998 The Central and Southern Plains Archaic. In *Archaeology on the Great Plains*, edited by W. R. Wood, pp. 173-200. University Press of Kansas, Lawrence.

Kay, Michael

1965 *Stratigraphy and Life History*. John Wiley and Sons, Inc., New York.

Kelly, Robert L.

1995 *The Foraging Spectrum: Diversity in Hunter-Gatherer Lifeways*. Smithsonian Institution Press, Washington D.C.

Kintigh, Keith W.

1990 Comments on the Case for Full-Coverage Survey. In *The Archaeology of Regions: A Case for Full-Coverage Survey*, edited by S.K. Fish and S.A. Kowalewski, pp. 237-242. Smithsonian Institution Press, Washington D.C.

Koch, Amy, James Miller, Michael Glascock, and Robert Hoard

1996 *Geoarchaeological Investigatons at the Lyman Site (25SF53) and Other Cultural Resources Related to Table Mountain Quarry Near the Nebraska/Wyoming Border*. Nebraska Department of Roads and the Federal Highway Administration, Project HES-92-1(113), Lincoln.

Kowalewski, Stephen A.

1990 Merits of Full-Coverage Survey: Examples from the Valley of Oaxaca, Mexico. In *The Archaeology of Regions: A Case for Full-Coverage Survey*, edited by S.K. Fish and S.A. Kowalewski, pp. 33-86. Smithsonian Institution Press, Washington D.C.

Kowalewski, Stephen A. and Suzanne K. Fish

1990 Conclusions. In *The Archaeology of Regions: A Case for Full-Coverage Survey*, edited by S.K. Fish and S.A. Kowalewski, pp. 261-277. Smithsonian Institution Press, Washington D.C.

Kozlowski, Janusz K.

1991 Paleolithic Quarry Sites. In *Raw Material Economies among Prehistoric Hunter-Gatherers*, edited by A. Montet-White and S. Holen, pp. 1-6. University of Kansas, Publications in Anthropology, Number 19. Lawrence.

Krumbein, W.C. and L.L. Sloss

1963 *Stratigraphy and Sedimentation*. W.H. Freeman and Company, San Francisco.

Lautridou, J. P., F. Letavernier, K. Lindé, B. Etlicher, and J. C. Ozouf

1986 Porosity and Frost Susceptibility of Flints and Chalk: Laboratory Experiments, Comparison of 'Glacial' and 'Periglacial' Surface Texture of Flint Materials, and Field Investigations. In *The Scientific Study of Flint and Chert: Proceedings of the Fourth International Flint Symposium Held at Brighton Polytechnic, 10-15 April 1983*, edited by G. De G. Sieveking and M.B. Hart, pp. 269-282. Cambridge University Press, Cambridge.

Leach, H. M.
1984 Jigsaw: Reconstructive Lithic Technology. In *Prehistoric Quarries and Lithic Production*, edited by J.E. Ericson and B.A. Purdy, pp. 107-118. Cambridge University Press, Cambridge.

Leopold, L. B., G. Wolman, and J. Miller
1964 *Fluvial Processes in Geomorphology*. W.H. Freeman and Company, San Francisco.

Lewarch, Donald E. and Michael J. O'Brien
1981 The Expanding Role of Surface Assemblages in Archaeological Research. In *Advances in Archaeological Method and Theory*, volume 4, pp. 297-333, edited by M.B. Schiffer. Academic Press, New York.

Lintz, Christopher R. and Stephen Hall
1983 *The Geomorphology and Archaeology of Carnegie Canyon, Oklahoma*. Oklahoma Conservation Commission, Archaeological Research Report, Number 10. Oklahoma City.

Loope, David B.
1999 Personal Communication to Berkley B. Bailey. Lincoln, Nebraska.

Loope, David B. and G. B. Kuntz
1987 Evidence of Evaporite Growth within Marine Limestones of the Upper Member of the Hermosa Formation (Pennsylvanian), Cataract Canyon, Southeastern Utah. *In* Campbell, J. A. (editor), *Cataract Canyon: Four Corners Geological Society Guidebook, 10th Field Conference*, p. 75-79.

Loope, David B. and David K. Watkins
1989 Pennsylvanian Fossils Replaced by Red Chert: Early Oxidation of Pyritic Precursors. *Journal of Sedimentary Petrology* 59 (3):375-389.

Loope, David B., George A. Sanderson, and George J. Verville
1990 Abandonment of the Name "Elephant Canyon Formation" in Southeastern Utah: Physical and Temporal Implications. *The Mountain Geologist* 27:119-130.

Lopez, David E. and Kenneth D. Keith
1979 *Oklahoma Highway Archaeological Survey, 1972-1978*. Papers in Highway Archaeology, Number 6. Oklahoma Department of Transportation, Oklahoma City.

Love, Thomas F.
1977 Ecological Niche Theory in Sociocultural Anthropology: A Conceptual Framework and an Application. *American Ethnologist* 4:24-41.

Luedtke, Barbara E.
1992 *An Archaeologist's Guide to Chert and Flint*. Institute of Archaeology, University of California, Archaeological Research Tools, Number 7. Los Angeles.

1984 Lithic Material Demand and Quarry Production. In *Prehistoric Quarries and Lithic Production*, edited by J.E. Ericson and B.A. Purdy, pp. 65-76. Cambridge University Press, Cambridge.

Lurie, Rochelle

1989 Lithic Technology and Mobility Strategies: The Koster Site Middle Archaic. In *Time, Energy and Stone Tools*, edited by R. Torrence, pp. 46-56. Cambridge University Press, London.

Lynn, A. R.

1986 Tecovas Lithic Resources in the Texas Panhandle. Manuscipt on file at West Texas State University, Canyon, Texas.

Maliva, Robert G. and Raymond Siever

1988 Mechanism and Controls of Silicification of Fossils in Limestone. *Journal of Geology* 96:387-398.

Maliva, Robert G., Andrew H. Knoll, and Raymond Siever

1989 Secular Change in Chert Distribution: A Reflection of Evolving Biological Participation in the Silica Cycle. *Palaios: Society for Sedimentary Geology* 4 (6):519-532.

Mallouf, Robert J.

1981 A Clovis Quarry Workshop in the Callahan Divide: The Yellow Hawk Site, Taylor County, Texas. *Plains Anthropologist* 34:81-103.

Mandeville, M. D.

1973 A Consideration of the Thermal Pretreatment of Chert. *Plains Anthropologist* 18:177-202.

Mandel, Rolfe D.

1992 Soils and Holocene Landscape Evolution in Central and Southwestern Kansas: Implications for Archaeological Research. In *Soils in Archaeology: Landscape Evolution and Human Occupation*, edited by V.T. Holliday, pp. 41-100. Smithsonian Institution Press, Washington D.C.

Marshall, Royal R.

1961 Devitrification of Natural Glass. *Geological Society of Amercia Bulletin* 72 (10):1493-1520.

Marks, Anthony E., Jeff Shokler, and João Zilhão

1991 Raw Material Usage in the Paleolithic: The Effects of Local Availability on Selection and Economy. In *Raw Material Economies among Prehistoric Hunter-Gatherers*, edited by A. Montet-White and S. Holen, pp. 127-140. University of Kansas, Publications in Anthropology, Number 19. Lawrence.

Marks, Anthony E. and Phillip Volkman
1987 Technological Variability and Change Seen Through Core Reconstruction. In *The Human Uses of Flint and Chert: Proceedings of the Fourth International Flint Symposium Held in Brighton Polytechnic, 10-15 April 1983*, edited by G. De G. Sieveking and M.H. Newcomer, pp. 11-20. Cambridge University Press, Cambridge.

Matsui, Takeshi
1965 On the Relic Red Soils of Japan. In *Quaternary Soils: Proceedings Volume 9, VII Congress*, edited by R.B. Morrison and H.E. Wright, pp. 221-244. International Association for Quaternary Research, Desert Research Institute. University of Nevada, Reno.

McBride, Earle F. (comp.)
1979 *Silica in Sediments: Nodular and Bedded Chert*, (Selected Papers Reprinted from Journal of Sedimentary Petrology). Society of Economic Paleontologists and Mineralogists, Reprint Series, Number 8. Tulsa, Oklahoma.

McGookey, Douglas A., Thomas C. Gustavson, and Ann D. Hoadley
1988 *Regional Structural Cross Sections, Mid-Permian to Quaternary Strata, Texas Panhandle and Eastern New Mexico: Distribution of Evaporates and Areas of Evaporite Dissolution and Collapse*. Bureau of Economic Geology, University of Texas Press, Austin.

McGowen, J. H., G. E. Granata and S. J. Seni
1979 *Depositional Framework of the Lower Dockum Group (Triassic) Texas Panhandle*. University of Texas, Austin. Bureau of Economic Geology Report of Investigations 97.

McKern, W. C.
1939 The Midwestern Taxonomic Method as an Aid to Archaeological Culture Study. *American Antiquity* 4:302-313.

Metcalf, Michael D., Ronald J. Rood, Patrick K. O'Brien, and Bret R. Overturf
1991 *Kremmling Chert Procurement in the Middle Park Area, Colorado: 5GA1144 and 5GA1172*. Metcalf Archaeological Consultants, Inc. Eagle, Colorado.

Morrow, Carol A. and Richard W. Jefferies
1989 Trade or Embedded Procurement?: A Test Case From Southern Illinois. In *Time, Energy and Stone Tools*, edited by R. Torrence, pp. 27-33. Cambridge University Press, London.

Mueller, John W. (editor)
1975 *Sampling in Archaeology*. University of Arizona Press, Tucson.

Muto, Guy R.
1971 *A Technological Analysis of the Early Stages in the Manufacture of Lithic Artifacts*. Unpublished Master's Thesis, Department of Anthropology, Idaho State University, Pocatello.

Myers, Arthur J.
1959 *Geology of Harper County, Oklahoma*. Oklahoma Geological Survey Bulletin 80:1-100. Norman.

Namy, Jerome N.
1974 Early Diagenetic Chert in the Marble Falls Group (Pennsylvanian) of Central Texas. *Journal of Sedimentary Petrology* 44:1262-1268.

Neuhauser, Kenneth R., Spencer G. Lucas, J.Stephen De Albuquerque, Robert J. Louden, Steven N. Hayden, Kenneth K. Kietzke, Wayne Oakes, and David D. Marais
1987 Stromatolites of the Morrison Formation (Upper Jurassic), Union County, New Mexico: A Preliminary Report. *New Mexico Geological Society Guidebook, 38th Field Conference*. Northeastern New Mexico State University, Albuquerque.

Nials, Fred L.
1977 *Geology of Reservoir Area, Cowden Laterals Watershed: Site Number 8*. Unpublished manuscript submitted to the Oklahoma Conservation Commission, pp. 1-59. Norman.

Norton, George H.
1939 *Permian Redbeds of Kansas*. Bulletin of the American Association of Petroleum Geologists 23:1751-1819.

O'Brien, Patricia J.
1984 *Archeology in Kansas*. University of Kansas Museum of Natural History, Public Education Series Number 9. Lawrence.

Odell, George H.
1989 Fitting Analytical Techniques to Prehistoric Problems with Lithic Data. In *Alternative Approaches to Lithic Analysis*, edited by D.O. Henry and G.H. Odell, pp. 159-182. Archaeological Papers of the American Anthropological Association, Number 1. Washington D.C.

Ohern, D.
1918 *A Contribution to the Stratigraphy of the Redbeds*. American Association of Petroleum Geologists Bulletin, Number 30.

Owen, Mark T.
1979 *The Paluxy Sand in North-Central Texas*. Baylor Geological Studies Bulletin 36:1-36. Waco, Texas.

Paige, S.
1911 *Mineral Resources of the Llano-Burnet Region, Texas with an Account of the Pre-Cambrian Geology*. U.S. Geological Survey Bulletin 450, U.S. Government Printing Office, Washington, D.C.

Perino, G. and J. Caffey
1980 *The Eufaula Lake Project, A Cultural Resource Survey and Assessment*. Museum of the Red River, Idabel, Oklahoma.

Peterson, A.
1988 *Prairie Hinterland: The Archaeology of Palo Duro Creek*. Unpublished manuscript submitted to the Palo Duro River Authority. Archaeological Research Incorporated, Austin, Texas.

Pittman, J. S., Jr.
1959 Silica in Edwards Limestone, Travis County, Texas. *Silica in Sediments*, edited by H.A. Ireland. Society of Economic Paleontologists and Mineralogists, Special Publication 7. Tulsa, Oklahoma.

Plog, Fred T.
1974 *The Study of Prehistoric Change*. Academic Press, New York.

1977 Modeling Economic Exchange. In *Exchange Systems in Prehistory*, edited by T.K. Earle and J.E. Ericson, pp. 127-139. Academic Press, New York.

1990 Some Thoughts on Full-Coverage Survey. In *The Archaeology of Regions: A Case for Full-Coverage Survey*, edited by S.K. Fish and S.A. Kowalewski, pp. 243-248. Smithsonian Institution Press, Washington D.C.

Plummer, E.
1933 Cenozoic Systems in Texas. In *The Geology of Texas: Stratigraphy*, volume 1. University of Texas Bulletin 3232:1-1007. Austin.

Porter, Stephen C. (editor)
1983 *Late Quaternary Environments of the United States: Volume 1, The Late Pleistocene*. University of Minnesota Press, Minneapolis, Minnesota.

Prosser, Charles S.
1895 Classification of the Upper Paleozoic Rocks of Cenral Kansas. *Journal of Geology* (3) 6-7.

Purdy, Barbara A.
1984 Quarry Studies: Technological and Chronological Significance. In *Prehistoric Quarries and Lithic Production*, edited by J.E. Ericson and B.A. Purdy, pp. 119-127. Cambridge University Press, Cambridge.

Radley, J. A. and J. Grant
1959 *Fluoresence Analysis in Ultra-Violet Light*. Chapman & Hall, Ltd. London.

Redman, Charles L.
1987 Surface Collection, Sampling, and Research Design: A Retrospective. *American Antiquity* 52:249-265.

Reeves, C. C., Jr.
1976 *Quaternary Stratigraphy and Geologic History of the Southern High Plains, Texas and New Mexico in Quaternary Stratigraphy of North America*, edited by W. C. Mahanay et al., pp. 213-234. Dowden, Hutchinson and Ross, Inc., Strodsburg, Pennsylvania.

Reeves, F.
1921 Geology of the Cement Oil Field. *Transcripts of the American Institute for Mineralogical and Meteorological Engineering* 65:114-17.

Reher, Charles A.
1991 Large Scale Lithic Quarries and Regional Transport Systems on the High Plains of Eastern Wyoming: Spanish Diggings Revisited. In *Raw Material Economies among Prehistoric Hunter-Gatherers*, edited by A. Montet-White and S. Holen, pp. 251-284. University of Kansas, Publications in Anthropology, Number 19. Lawrence.

Rensink, E., J. Kolen, and A. Spieksma
1991 Patterns of Raw Material Distribution in the Upper Pleistocene of Northwestern and Central Europe. In *Raw Material Economies among Prehistoric Hunter-Gatherers*, edited by A. Montet-White and S. Holen, pp. 141-160. University of Kansas, Publications in Anthropology, Number 19. Lawrence.

Richerson, Peter J.
1977 Ecology and Human Ecology: A Comparison of Theories in the Biological and Social Sciences. *American Ethnologist* 4:1-26.

Ritter, Dale F.
1986 *Process Geomorphology*. William C. Brown Publishers, Dubuque, Iowa.

Rossignol, Jacqueline and LuAnn Wandsnider (editors)
1992 *Space, Time, and Archaeological Landscapes*. Plenum Press, New York.

Sappington, R. L.
1984 Procurement Without Quarry Production: Examples from Southwestern Idaho. In *Prehistoric Quarries and Lithic Production*, edited by J.E. Ericson and B.A. Purdy, pp. 23-34. Cambridge University Press, Cambridge.

Saunders, Roger S.
1978 *Archeological Resources of Black Mesa State Park, Cimarron County, Oklahoma*. Oklahoma Archeological Survey, Archeological Resources Survey Report, Number 7. Norman.

Schlanger, Sarah H. and Janet D. Orcutt
1986 Site Surface Characteristics and Functional Inferences. *American Antiquity* 51:296-312.

Schlesier, Karl H. (editor)
1994 *Plains Indians, A.D. 500 - 1500: The Archaeological Past of Historic Groups*. University of Oklahoma Press, Norman.

Schmid, F.
1986 Flint Stratigraphy and its Relationship to Archaeology. In *The Scientific Study of Flint and Chert: Proceedings of the Fourth International Flint Symposium Held at Brighton Polytechnic, 10-15 April 1983*, edited by G. De G. Sieveking and M.B. Hart, pp. 1-5. Cambridge University Press, Cambridge.

Schweer, H.
1937 Discussion. In *Unconformity at base of Whitehorse Formation, Oklahoma*. American Association of Petroleum Geologists Bulletin 21:1553-1555.

Semenov, S. A.
1985 *Prehistoric Technology: An Experimental Study of the Oldest Tools and Artefacts From Traces of Manufacture and Wear*, translated by M.W. Thompson. Barnes & Noble Books, Totowa, New Jersey.

Seni, Steven J.
1980 *Sand-body Geometry and Depositional Systems. Ogallala Formation, Texas*. Texas Bureau of Economic Geology, Report of Investigations 105:1-36. Austin.

Siedlecka, Anna
1972 Length-Slow Chalcedony and Relics of Sulphates - Evidences of Evaporitic Environments in the Upper Carboniferous and Permian Beds of Bear Island, Svalbard. *Journal of Sedimentary Petrology* 42:812-816.

Sieveking G. de G. and C. J. Clayton
1986 Frost Shatter and the Structure of Frozen Flint. In *The Scientific Study of Flint and Chert: Proceedings of the Fourth International Flint Symposium Held at Brighton Polytechnic, 10-15 April 1983*, edited by G. De G. Sieveking and M.B. Hart, pp. 283-290. Cambridge University Press, Cambridge.

Skinner, H. C.
1957 Two Artifact Flints of Oklahoma. *Bulletin of the Oklahoma Anthropological Society* 5:39-43.

Smale, David
1973 Silcretes and Associated Silica Diagenesis in Southern Africa and Australia. *Journal of Sedimentary Petrology* 43:1077-1089.

Smolla, Günter
1987 Prehistoric Flint Mining: The History of Research - A Review. In *The Human Uses of Flint and Chert: Proceedings of the Fourth International Flint Symposium Held in Brighton Polytechnic, 10-15 April 1983*, edited by G. De G. Sieveking and M.H. Newcomer, pp. 127-129. Cambridge University Press, Cambridge.

Snider, L.
1913 *The Gypsum and Salt of Oklahoma*. Oklahoma Geological Survey Bulletin, Number 11. Norman.

St. John, Orestes H.
1883 *Sketch of the Geology of Kansas*. Kansas State Board of Agriculture, Biennial Report 3:571-599. Topeka.

1887 *Notes on the Geology of Southwestern Kansas*. Kansas State Board of Agriculture, Biennial Report 5:132-152. Topeka.

Stafford, Jr., Thomas W.
1981 Alluvial Geology and Archaeological Potential of the Texas Southern High Plains. *American Antiquity* 46:548-565.

1984 *Quaternary Stratigraphy, Geochronology, and Carbon Isotope Geology of the Alluvial Deposits in the Texas Panhandle*. Unpublished Ph.D. dissertation, Department of Geosciences, University of Arizona, Tucson.

Stein, Martin
1985 The Schmidt Quartzite Quarry (14KY303): A Source of Stone in the Arkansas River Valley. *Journal of the Kansas Anthropological Association* 5(3):101-116.

1989 KAA Survey Completed in Clark County. *Kansas Preservation* 12 (1):5-6.

Stephens, C. G.
1965 Soil Stratigraphy and its Applications to Correlation of Quaternary Deposits and Landforms and to Soil Science - A Review of Australian Experience. In *Quaternary Soils: Proceedings*, Volume 9, edited by R.B. Morrison and H.E. Wright, pp. 281-292. International Association for Quaternary Research, Desert Research Institute, University of Nevada, Reno.

Stevenson, Marc G.
1985 The Formation of Artifact Assemblages at Workshop/Habitation Sites: Models From Peace Point in Northern Alberta. *American Antiquity* 50:63-81.

Steward, Julian H.
1955 *Theory of Culture Change*. University of Illinois Press, Urbana.

Steward, Julian H. and Robert F. Murphy (editors)
1977 *Evolution and Ecology: Essays on Social Transformation*. University of Illinois Press, Urbana.

Straus, Lawrence G.
1991 The Role of Raw Materials in Upper Paleolithic and Mesolithic Stone Artifact Assemblage Variability in Southwest Europe. In *Raw Material Economies among Prehistoric Hunter-Gatherers*, edited by A. Montet-White and S. Holen, pp. 169-186. University of Kansas, Publications in Anthropology, Number 19. Lawrence.

Sudbury, B.
1971 A Brief Study of Kay County Flint. *Oklahoma Anthropological Society Newsletter* 19(4):3-9.

Sullivan III., Andrew P., and Kenneth C. Rozen
1985 Debitage Analysis and Archaeological Interpretation. *American Antiquity* 50:755-788.

Surdam, Ronald C. and Hans P. Eugster
1976 Mineral Reactions in the Sedimentary Deposits of the Lake Magadi Region, Kenya. *Geological Society of America Bulletin* 87:1739-1752.

Surdam, Ronald C., Hans P. Eugster, and R. H. Mariner
1972 Magadi-Type Chert in Jurassic and Eocene to Pleistocene Rocks, Wyoming. *Geological Society of America Bulletin* 83 (8):2261-2266.

Swineford, Ada
1955 *Petrography of Upper Permian Rocks in South-Central Kansas*. Kansas State Geological Survey Bulletin 111:1-179. Topeka.

Swineford, Ada and Paul C. Franks
1959 Opal in the Ogallaha Formation in Kansas. Silica in Sediments (A Symposium with Discussion), edited by H. A. Ireland. *Society for Economic Paleontologists and Mineralogists, Special Publication* No. 7:111-112. Tulsa, Oklahoma.

Taylor, Walter W.
1964 Tethered Nomadism and Water Territoriality: An Hypothesis. *Acts of the 35th International Congress of Americanists*, pp. 197-203, Mexico City.

Thornbury, William D.
1966 *Principles of Geomorphology*. John Wiley & Sons, Inc., New York.

Torrence, Robin (editor)
1989 *Time, Energy and Stone Tools*. Cambridge University Press, London.

Trierweiler, W. Nicolas
1994 Archaeological Investigations on 571 Prehistoric Sites at Fort Hood, Bell and Cowgell Counties, Texas. U.S. Army Fort Hood Archaeological Resource Management Series, Research Report 31. Fort Hood, Texas.

Turnbaugh, W. A., S. P. Turnbaugh, and T. H. Keifer
1984 Characterization of Selected Soapstone Sources in Southern New England. In *Prehistoric Quarries and Lithic Production*, edited by J.E. Ericson and B.A. Purdy, pp. 129 - 138. Cambridge University Press, Cambridge.

Tunnell, C.
1978 *The Gibson Lithic Cache from West Texas*. Office of the State Archeologist Report No. 30, Texas Historical Commission, Austin.

Vehik, Susan C.
1982 Kay County Chert Distributions in North-Central Oklahoma During the Plains Village Period. In *Southern Plains Archaeology*. Papers in Anthropology, University of Oklahoma 23:69-90. Norman.

1983 Middle Woodland Mortuary Practices along the Northeastern Periphery of the Great Plains: A Consideration of Hopewellian Interaction. *Midcontinental Journal of Archaeology* 8:211-255.

1984 The Woodland Occupations. In *Prehistory of Oklahoma*, edited by R.E. Bell, pp. 175-195. Academic Press, New York.

1985 Late Prehistoric Settlement Strategy and Exploitation of Florence-A Chert. *Lithic Resource Procurement: Proceedings from the Second Conference on Prehistoric Chert Exploitation*, edited by S. Vehik, pp. 81-98. Occasional Papers No. 4, Center for Archaeological Investigation, Southern Illinois University, Carbondale.

1986a Oñate's Expedition to the Southern Plains: Routes, Destinations, and Implications for Late Prehistoric Cultural Adaptations, *Plains Anthropologist* 31:13-33.

1986b The Effect of Trade on Resource Procurement Behavior: A Late Prehistoric Example from the Southern Plains, in: Current Trends in Southern Plains Archaeology, edited by T. Baugh, *Plains Anthropologist, Memoir* 21:141-154.

1988 Late Prehistoric Exchange on the Southern Plains and its Periphery. *Midcontinental Journal of Archaeology* 13:41-68.

1990 Late Prehistoric Plains Trade and Economic Specialization. *Plains Anthropologist* 35:125-145.

1994 Cultural Continuity and Discontinuity in the Southern Praires and Cross Timbers. In *Plains Indians, A.D. 500-1500: The Archaeological Past of Historic Groups*, edited bt K. H. Schlesier, pp. 239-263. University of Oklahoma Press, Norman.

Vehik, Susan and Timothy Baugh
1994 Prehistoric Plains Trade. In *Prehistoric Exchange Systems in North America.* Edited by T. Baugh and J. Ericson, pp. 249-267. Plenum Press, New York.

Vierra, Bradley J.
1993 Explaining Long-Term Changes in Lithic Procurement and Reduction Strategies. In *Across the Colorado Plateau: Anthropological Studies for the Transwestern Pipeline Expansion Project*, edited by B.J. Vierra, T.W. Burchett, K.L. Brown, M.E. Brown, P.T. Kay and C.J. Phagan, pp. 141-381, volume 23. Office of Contract Archaeology and Maxwell Museum of Anthropology, University of New Mexico, Albuquerque.

Villa, Paola
1982 Conjoinable Pieces and Site Formation Processes. *American Antiquity* 47:276-290.

Voegeli Jr., Paul T. and Loyd A. Hershey
1965 Geology and Ground Water Resources of Prowers County, Colorado. *Geological Survey Water-Supply Paper* no. 1772, Washington, D.C.: U.S. Geological Survey.

Wain, D.
1965 *The Story of Florescence*. Markum Press, Chicago.

Walker, Jimmy R.
1978 *Geomorphic Evolution of the Southern High Plains*. Baylor Geological Studies Bulletin 36:1-32. Waco, Texas.

Walker, Theodore R.
1962 Reversible Nature of Chert-Carbonate Replacement in Sedimentary Rocks. *Geological Society of America Bulletin* 73 (2):237-242.

Ward III, Phillip A.
1991a Glass Shard Uranium Fission-Track Ages of Volcanic Ash Deposits in the Southern High Plains Border Region. In *Guidebook, 9th Annual Meeting, South-Central Friends of the Pleistocene: A Prehistory of the Plains Border Region, Woodward, Oklahoma, May 17-19, 1991*, pp. 50-64. Agronomy Department, Oklahoma State University, Stillwater.

1991b Preliminary Correlation of Southern High Plains Border Volcanic Ashes. In *Guidebook, 9th Annual Meeting, South-Central Friends of the Pleistocene: A Prehistory of the Plains Border Region, Woodward, Oklahoma, May 17-19, 1991*, pp. 65-72. Agronomy Department, Oklahoma State University, Stillwater.

Wedel, Waldo R.
1961 *Prehistoric Man on the Great Plains*. University of Oklahoma Press, Norman.

1986 *Central Plains Prehistory: Holocene Environments and Culture Change in the Republican River Basin*. University of Nebraska Press, Lincoln.

Wegeman, C.
1915 *The Duncan Gas Field.* U.S. Geological Survey Bulletin 621D:1-44. Washington D.C.

Welsh, James P.
1966 *The Origin of the Day Creek Dolomite (Permian) of Kansas*. Unpublished Master's Thesis, Department of Geology, Wichita State University. Wichita, Kansas.

Wendland, Wayne M.
1978 Holocene Man in North America: The Ecological Setting and Climatic Background. *Plains Anthropologist* 23:273-287.

Wendland, Wayne M., Ann Benn, and Holmes A. Semken, Jr.
1987 Evaluation of Climatic Changes on the North American Great Plains Determined from Faunal Evidence. In *Late Quaternary Mammalian Biogeography and Environments of the Great Plains and Prairies*, edited by R. Graham, H.A. Semken, Jr., and M.A. Graham, pp. 461-473. Illinois State Museum Scientific Papers, volume 22. Springfield.

Wendorf, F. and J. Hester
1962 Early Man's Utilization of the Great Plains Environment. *American Antiquity* 26:159-171.

West, F.
1983 The Antiquity of Man in America. In *Late Quaternary Environments of the United States: The Late Pleistocene*, volume 1, edited by S.C. Porter, pp. 364-382. University of Minnesota Press, Minneapolis.

Whalen, Michael E.
1990 Sampling Versus Full-Coverage Survey: An Example from Western Texas. In *The Archaeology of Regions: A Case for Full-Coverage Survey*, edited by S.K. Fish and S.A. Kowalewski, pp. 219-236. Smithsonian Institution Press, Washington D.C.

Whiteside, E. D.
1965 Genesis of Soil Profiles in Quaternary Deposits of Central North America. In *Quaternary Soils: Proceedings*, edited by R.B. Morrison and H.E. Wright, 9:307-320. International Association for Quaternary Research, Desert Research Institute, University of Nevada, Reno.

Winterhalder, Bruce and Eric A. Smith (editors)
1981 *Hunter-Gatherer Foraging Strategies: Ethnographic and Archeological Analyses.* University of Chicago Press, Chicago.

Wise, Jr., Sherwood W. and Fred M. Weaver
1974 Chertification of Oceanic Sediments. *Special Publications of the International Association of Sediment* 1:301-326.

Wiseman, Regge N.

1992 The Other End of the Network: Alibates Material West of the Plains/Pueblo Frontier. *Plains Anthropologist* 37:167-170.

Wood, W. Raymond (editor)

1998 *Archaeology of the Great Plains*. University of Kansas Press, Lawrence.

Wright, C. M.

1985 The Complex Aspects of the "Smoky Hill Jasper," now know as Niobarite. *Journal of the Kansas Anthropological Association* 5(3):87-90.

Wyckoff, Don G.

1989 An Introductory Study of Alibates Gravel Occurrences along Western Oklahoma's Canadian River. In *In The Light of Past Experience: Papers in Honor of Jack, T. Hughes*. Panhandle Archeological Society Publication 5:405-452.

1993 Gravel Sources of Knappable Alibates Silicified Dolomite. *Geoarchaeology: An International Journal* 8:35-58.

Wyckoff, D., R. Brackenridge, K. Buehler, B. Carter, W. Dort, Jr., L. Martin, J. Theler, and L. Todd

1991 Interdisciplinary Research at the Burnham Site (34W073) Woods County, Oklahoma. In *Guidebook, 9th Annual Meeting, South-Central Friends of the Pleistocene: A Prehistory of the Plains Border Region, Woodward, Oklahoma, May 17-19, 1991*, pp. 82-121. Agronomy Department, Oklahoma State University, Stillwater.

Wyckoff, Don G. and Don Shockey (editors)

1994 Bulletin of the Oklahoma Anthropological Society Volume XL for 1991. Oklahoma Anthropological Society, Norman.

Wyckoff, Don G., William L. Neal, and Marjorie Duncan

1994 *The Primrose Site, 34MR65, Murray County, Oklahoma.* Bulletin of the Oklahoma Anthropological Society Volume XL for 1991. Norman.