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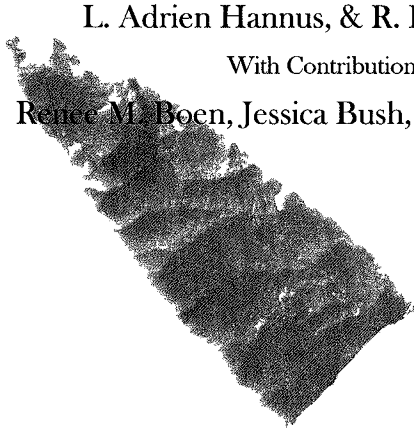
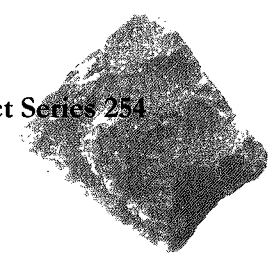
The Archeology, History, and Geomorphology of the Ray Long Site (39FA65), Angostura Reservoir, Fall River County, South Dakota

Manuscript III

Cultural Resources Report
& Appendices

Austin A. Buhta, Bruce A. Bradley, Marvin Kay,
L. Adrien Hannus, & R. Peter Winham
With Contributions By
Renee M. Boen, Jessica Bush, & Heidi Sieverding





Archeological Contract Series 254

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2032 South Grange Avenue
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Prepared for:
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Rapid City Field Office, 515 9th Street, Room 101
Rapid City, South Dakota 57701

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U.S. Department of the Interior, Bureau of Reclamation

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L. Adrien Hannus, Ph.D.
(Principal Investigator)

November 2013

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Cover Image: Composite photograph of Angostura projectile point Specimen Nos. 4 (proximal base) and 280 (distal tip) recovered by Richard Wheeler from Area A of the Ray Long site (39FA65).

FOREWORD

This volume includes a discussion by Bruce Bradley that further defines the Angostura point and a piece written by Marvin Kay that presents the results of a microwear study of the Ray Long site artifacts. Bradley's expertise is lithic technology while Kay's is microwear studies, tool reuse and maintainability.

At my request, Kay and Bradley examined the available material from Richard P. Wheeler's original work at the Ray Long site as well as data recovered during fieldwork at the site by Augustana College in the 1980s and 1990s. The intention was to achieve greater specificity regarding Wheeler's definition of materials from the Ray Long site with the hope of correcting the confusion that has surrounded the identification of the Angostura point type. Bradley and Kay first examined the collections separately, and later together, during a collaborative session in 1998 at Augustana College; they were joined at Augustana by R. Peter Winham and me.

Drafts of Bradley's and Kay's earlier reports (ca. 1998) have been revised and updated for inclusion in this manuscript. Prior to losing funding for the write-up in the early 2000s, the outline of a joint manuscript was begun. While their work is presented here as separate efforts, much of the analysis and resulting ideas were a collaborative effort, resulting in some overlap where material is cogent to both discussions.

L. Adrien Hannus, Director
Archeology Laboratory, Augustana College

ABSTRACT

This manuscript represents the third of three reports detailing the results of historical, archeological, and geomorphological research conducted at the Ray Long site (39FA65), Angostura Reservoir, Fall River County, South Dakota. Due to an alluring combination of antiquity, preservation, and the presence of a poorly understood cultural technocomplex, the Ray Long site has been the subject of archeological scrutiny and intermittent investigations for over six decades. Ray Long is best known as the type-site for the Angostura complex, an enigmatic Paleoindian group that occupied the Plains around 9,000 years ago. However, archeological and radiocarbon evidence indicate that the site was inhabited by other groups who both predate and postdate the Angostura occupation. This manuscript, Manuscript III, includes a detailed reevaluation of the Angostura cultural technocomplex and a discussion of Angostura and the Ray Long site in the broader context of Northern Plains prehistory.

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The Angostura Point Type Defined

Bruce A. Bradley

Introduction

This paper was originally written for inclusion in a Ray Long site report in 1998. Since then, a thorough analysis and definition of Angostura points, based on evidence primarily from southern Colorado, has been published by Bonnie Pitblado (2007:311-337). This excellent study includes far more than the materials from the Ray Long site, but nevertheless agrees with the definition proposed in this paper. In fact, it lends significant support to the author's perception of what the Angostura point type is, and goes much further in interpretation. The one curious aspect is that Pitblado's interpretation indicates that Angostura remains at the Ray Long site are outliers in terms of ecological distribution and probable subsistence practices. Such is the nature of historical accident that sees the establishment of site and point types.

Over fifty years ago, Marie Wormington (1957:141) admonished archeologists not to identify projectile points as *Angostura* unless they "...have the same shape and general thickness and the [oblique] parallel flaking that characterizes those from the type station." Although the author agrees with this advice, the problem has been the lack of a tight definition and the apparent mixing of a number of time periods and technologies in the Ray Long materials. This led to the unfortunate situation where almost any diagonal-flaked projectile point was classified as Angostura or Angostura-like (see Perino 1985; Pettipas 1970; Prewitt 1981; Sollberger and Hester 1972; Suhm and Jelks 1962; Thoms 1993). Pitblado (2007) has now rectified the situation with a discrete point definition, based on technological and morphological traits.

Many circumstances influence the size, shape and form of finished projectile points as found by archeologists. Raw material and the flaking process, as well as intent and skill of the knapper, greatly affect the outcome. Use, breakage, and reuse potentially alter, sometimes significantly, the original point configuration (see Kay, pages 32-33). Finally, post-depositional processes may also alter the piece. By the time items are studied, they may look greatly different than the size, shape, or form intended by the knapper.

Great strides have been made in the past couple of decades in coming to grips with some of these influences. It is now common practice to evaluate specific raw material qualities and availability. Knapping technologies are much better understood, and evidence of mistakes and flaws that may have influenced size and shape is frequently identified. Experimental studies and use-wear analyses have contributed significantly to the interpretation of the use history of specific pieces and classes of artifacts (see Kay, pages 18-36). Most archeologists now carefully consider the context of finds in relation to depositional and erosional processes.

In view of all of these advances, classifications of assemblages of artifacts, as well as individual types, are being continually reevaluated and reassessed. The typological approaches typical of stone tool analyses and interpretations are being expanded, enhanced and refined. As a result, the author reassessed the Angostura point type by carefully reexamining all of the materials that have been recovered from the type locality, the Ray Long site (39FA65). The results were then compared to the outcomes of Pitblado's (2007) study. This reassessment was necessary because of information acquired during more recent investigations at the Ray Long site by the Archeology Laboratory, Augustana College (ALAC), as well as what the author views as a mistaken original classification and subsequent misidentification of projectile points from many other sites and regions as Angostura (see Hofman and Graham 1998:114 and Thoms 1993 for insightful critiques).

The problems with Angostura extend beyond nomenclature to issues of preferential selection of quartzite,[1] manufacturing technology, life history and tool use. To address these fundamental questions, the original Ray Long collections were reexamined, including Richard P. Wheeler's records and related collections; further investigations were also undertaken at the Ray Long site (see Ray Long site Manuscripts I [Hannus et al. 2012] and II [Buhta et al. 2012]). These renewed efforts address site geomorphology; the Late Paleoindian antiquity of Angostura and earlier units; and independent techno-functional evaluations that draw upon different but complementary perspectives of the Ray Long and related sites' artifacts.

All available artifacts and illustrations from the Ray Long site, as well as other collections, were examined. While the majority of the "Angostura" artifacts recovered by Wheeler are now missing, illustrations and photographs were obtained, and new casts made of the few extant pieces. Using Wheeler's description of the Angostura point, the author examined the available specimens and more tightly defined this point type – which is considered a definite type, clearly distinct from Agate Basin.[2] Using this definition, 11 specimens from the Ray Long excavations (1948-1996) were considered Angostura. These also conform to the more rigorous definition proposed by Pitblado (2007).

Wheeler's illustration of Angostura points (1995:Figure 47) includes eight of these points, as well as four items not now considered Angostura. Excluded from his illustration is a drill, reworked from an Angostura point recovered from the surface of Area C. In addition, two of the points recovered on the surface of Area B in 1985 are Angostura. In Wheeler's unpublished photograph of Angostura points (Figure 1), he has dropped all but two of the four non-Angostura specimens – clearly Wheeler and this author are interpreting the material in a very similar way.

[1] The use of the term *quartzite* in this chapter includes metamorphic types as well as silicified sandstones.

[2] The differences between Angostura and Agate Basin are many but, primarily, it is the production technologies that distinguish them. Agate Basin points were made with highly controlled bifacial thinning, frequently extending across the entire faces of the preform; this created a relatively thin, flat cross-section. Selective, non-patterned pressure flaking was then used to produce the final shape, which also tended to increase the width-to-thickness ratio. Angostura preforms were made with percussion that usually travelled just past the midline, maintaining a proportional thickness (width-to-thickness) of between 3:1 and 4:1. Pressure finishing was patterned, serial, and oblique, and maintained the width-to-thickness ratio.

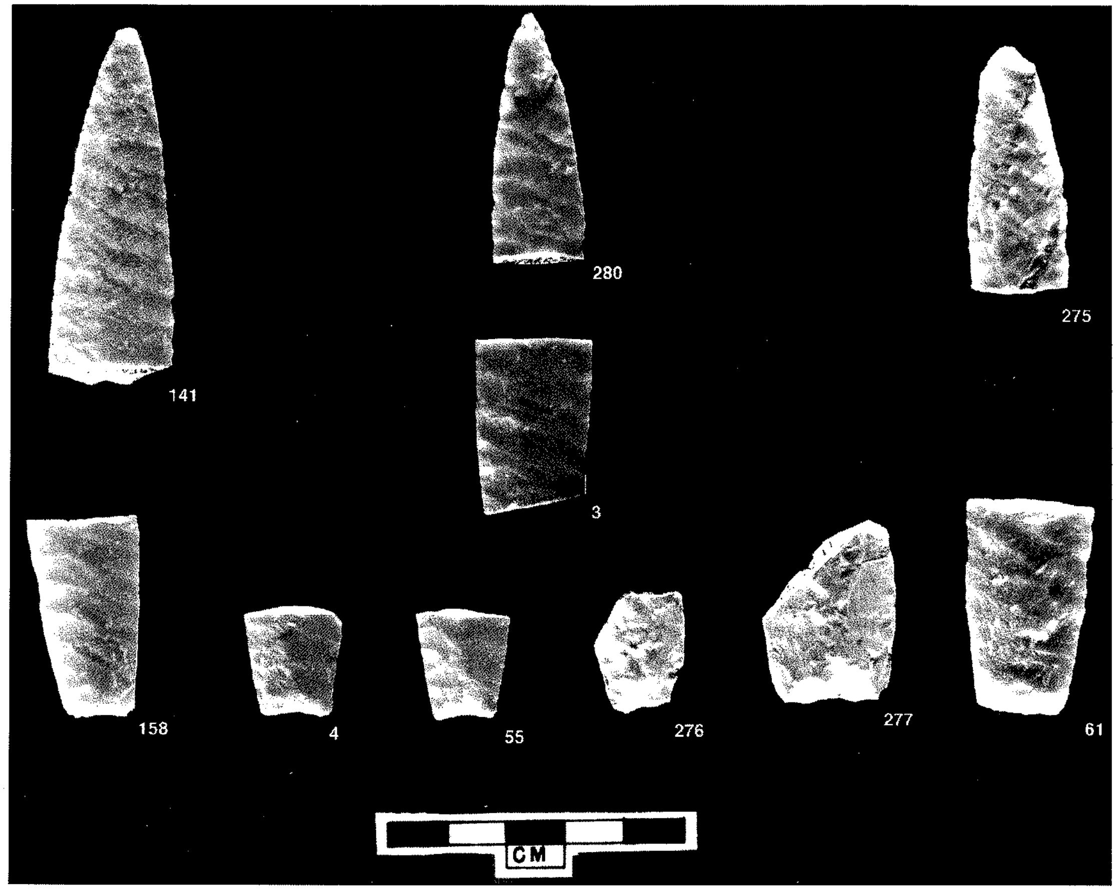

Figure 1. Wheeler's unpublished plate. Items 276 and 277 are not classified as Angostura points in this study.

TYPOLOGY AND TECHNOLOGY OF RAY LONG BIFACIAL ARTIFACTS

The limited sample of bifacially flaked artifacts from the Ray Long site makes a complete reconstruction of the manufacture of Angostura points impossible. Although the collection includes what might be termed middle phase bifaces (Figure 2: No. 2 [Wheeler 1995:Figure 43a], No. 166 [Wheeler 1995:Figure 48a], No. 193 [Wheeler 1995:Figure 48b], No. 206/83 [Wheeler 1995:Figure 43d], and No. 282 [Wheeler 1995:Figure 48d]), these do not seem to represent point preforms. An additional four pieces (Figure 3: No. 5 [Wheeler 1995:Figure 43f], No. 6 [Wheeler 1995:Figure 43c], No. 102 [Wheeler 1995:Figure 43g], and No. 114 [Wheeler 1995:Figure 43e]) could be blanks intended to be made into points, but these were not available for study, nor is it clear they were associated with finished points. The descriptions, therefore, are confined to the final flaking and finishing processes.

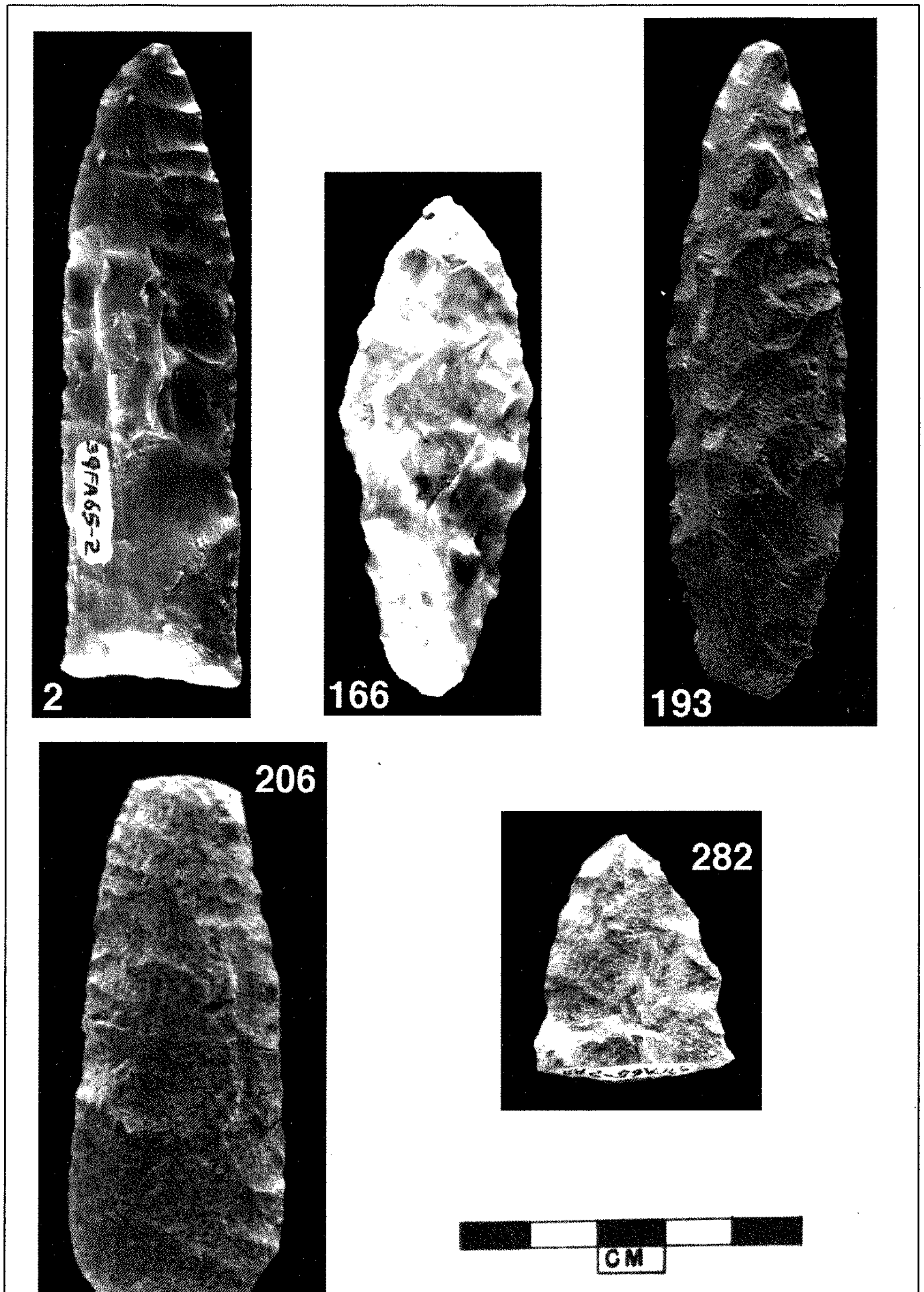

Figure 2. Middle to late phase bifaces from the Ray Long site, 39FA65.

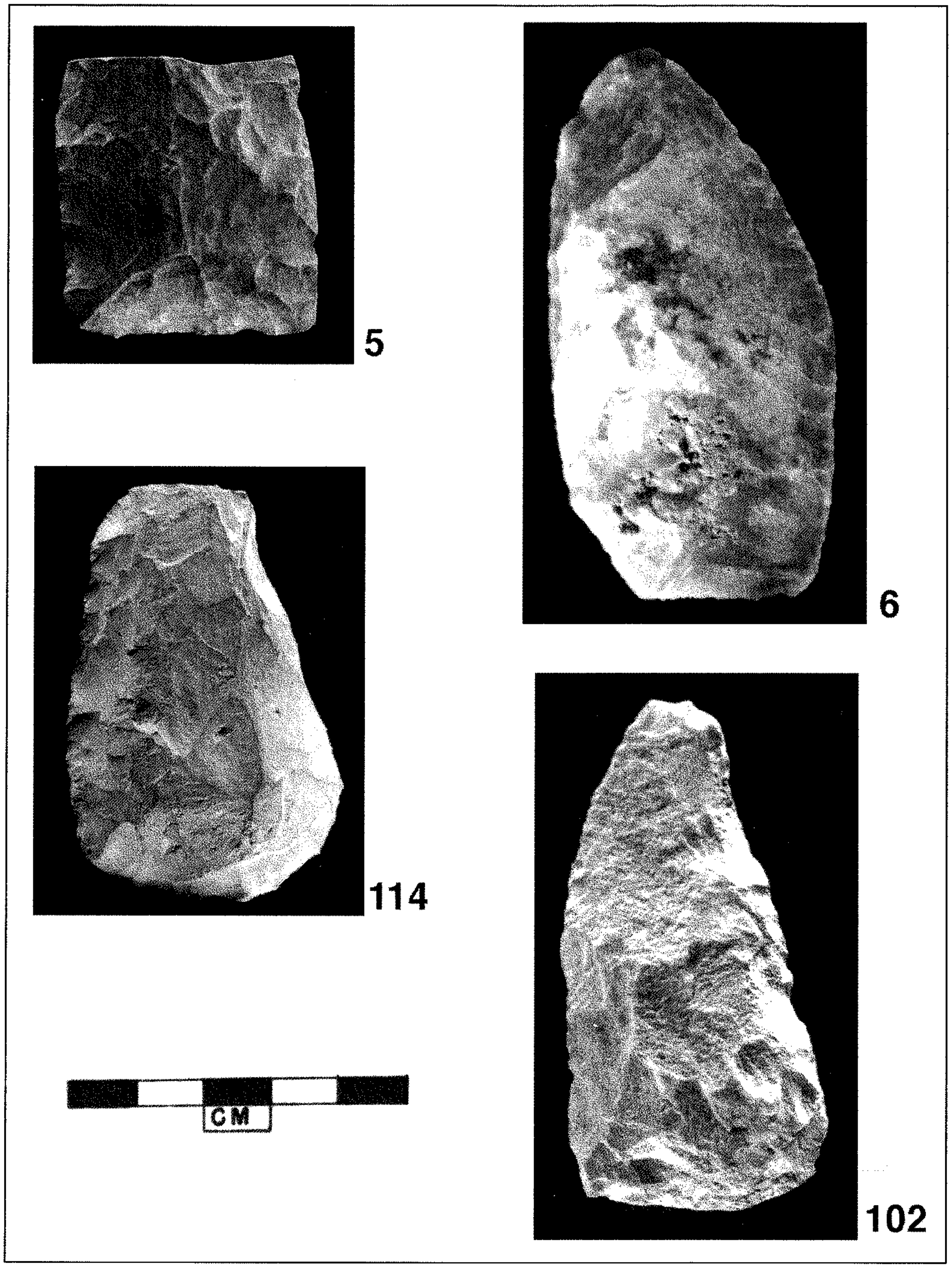

Figure 3. Possible point blanks from the Ray Long site, 39FA65.

All but one of the Ray Long Angostura points were made from quartzite of varying textures. The author's experience with this stone type (especially from Spanish Diggings in southeastern Wyoming and sources in the southern Black Hills) suggests that serial oblique pressure flaking is an ideal method to consistently produce sharp, even projectile points from this material. These quartzites tend to be strong but brittle. This combination of qualities often results in step fracture terminations on thin pressure flake removals (for an example on an Agate Basin point see Frison and Stanford 1982:Figure 2.50Ai) unless there is a fairly straight and even ridge for flake formation to follow. The best way to accomplish this consistently is to remove flakes in a serial pattern (flakes are removed sequentially adjacent to each other in one direction). This also is best accomplished at a diagonal to the midline of the piece, taking maximum advantage of the surface curve.

This serial oblique technique is direction-dependent as well, especially in the first sequence across a biface surface. If the flaking pattern is upper left to lower right, the sequence of removal is usually tip to base on the right side and base to tip on the left. This is a function of ridge formation at the sides of the subsequent flake scars (Figure 4).

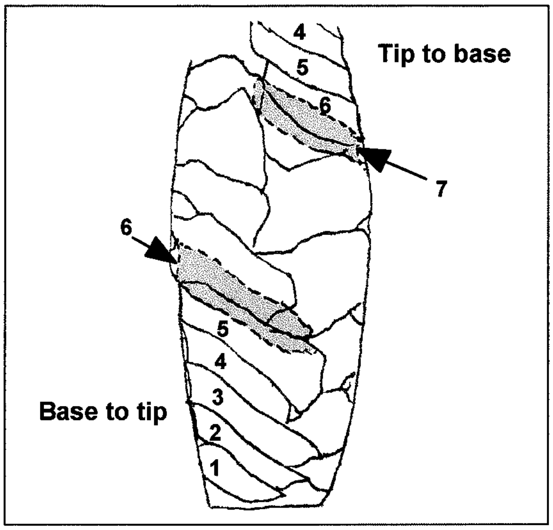

Figure 4. Idealized flake scar pattern, Angostura point.

Another effect of this serial pressure flaking technique is the removal of lipped platform flakes. Lipping leaves the biface edge extremely sharp without dull or steep remnants between the flake removals. An edge formed in this manner needs little to no retouch to be straight and very sharp. These lipped flakes are also distinctive of this technique.

If exactly the same technique is used (including the diagonal direction of force application) but the sequence is reversed, the leading edge of the pressure flakes does not have an even ridge to form along, often resulting in expanding flakes and step terminations. Even when successfully accomplished, the resulting flake scar pattern tends not to be diagonal.

Once a diagonal pattern is well-established, it is possible to reverse the sequence direction or remove non-serial flakes, but there is no advantage to this nor does it seem to have been practiced on Angostura points from Ray Long.

The typical or normal diagonal pressure flaking process and the possible relationship between strong, brittle materials (such as some quartzites, basalts and obsidian) and the method are described above. The following descriptions of the individual pieces from Ray Long will refer to this idealized process and when present will simply be called typical. Only the exceptions to the ideal will be individually described.

Two factors should be considered for these descriptions: 1) most of the actual pieces were not available and the descriptions are based on casts, photographs, or drawings, and 2) quartzite is a difficult material on which to see shallow pressure flake scars, especially the detail of which adjacent flake scars were first. To help view the flake scar patterns, the points were impressed into opaque modeling compound. The flake scars show as positives (as if the flakes were refitted) and the sequences become more apparent.

ANGOSTURA POINT SPECIMEN DESCRIPTIONS

Specimen 3

This specimen exhibits typical flaking. It is missing from the collections. Assignment is based on the photograph (Figure 5).

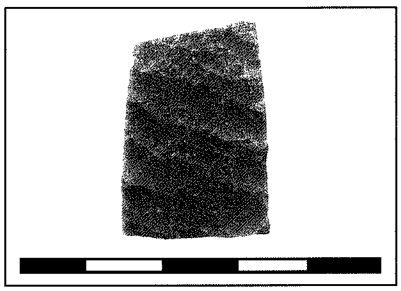

Figure 5. Scale photograph of Specimen 3 (scale is in cm).

Specimen 55

This specimen exhibits typical flaking. It is missing from the collections. Assignment is based on the photograph (Figure 6).

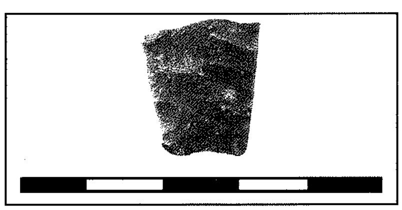

Figure 6. Scale photograph of Specimen 55 (scale is in cm).

Specimen 61

This Angostura point base has typical parallel oblique serial flaking on both faces (Figure 7). The cross-section is slightly plano-convex with flaking on the convex face being very narrow and mostly meeting at the midline. Flaking of the flatter face is wider and less well-controlled, with several step fractures. This piece exhibits some noninvasive pressure retouch. It has a straight base. There is an impact bend break.

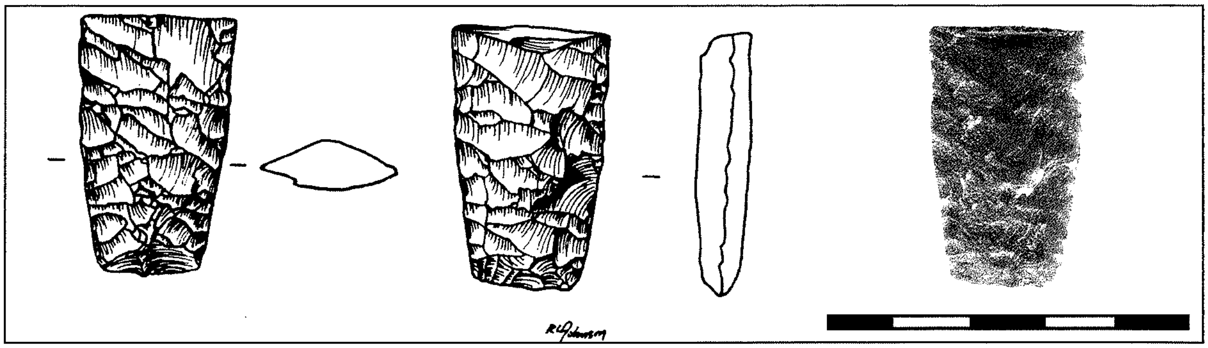

Figure 7. Scale line drawing (left) and photograph (right) of Specimen 61 (scale is in cm).

Specimen 80

This piece is an Angostura drill (Figure 8). It shows typical parallel oblique serial pressure on both faces. There is a good description in Wheeler (1995:401) but Bradley disagrees that it was a reworked Angostura point. Technologically it is Angostura, but the serial flaking is continuous from base to near the tip on one face on the left lateral margin and was accomplished **after** the bit beveling was done. The same seems to be true on the opposite face but a small break in the sequence near where the beveling of the drill bit begins makes this less apparent. The surface flaking does, however, follow the beveling. If this is a reworked point, the reworking was all over, not just the bevel, and the original point would have been larger and wider than any of the other finished specimens.

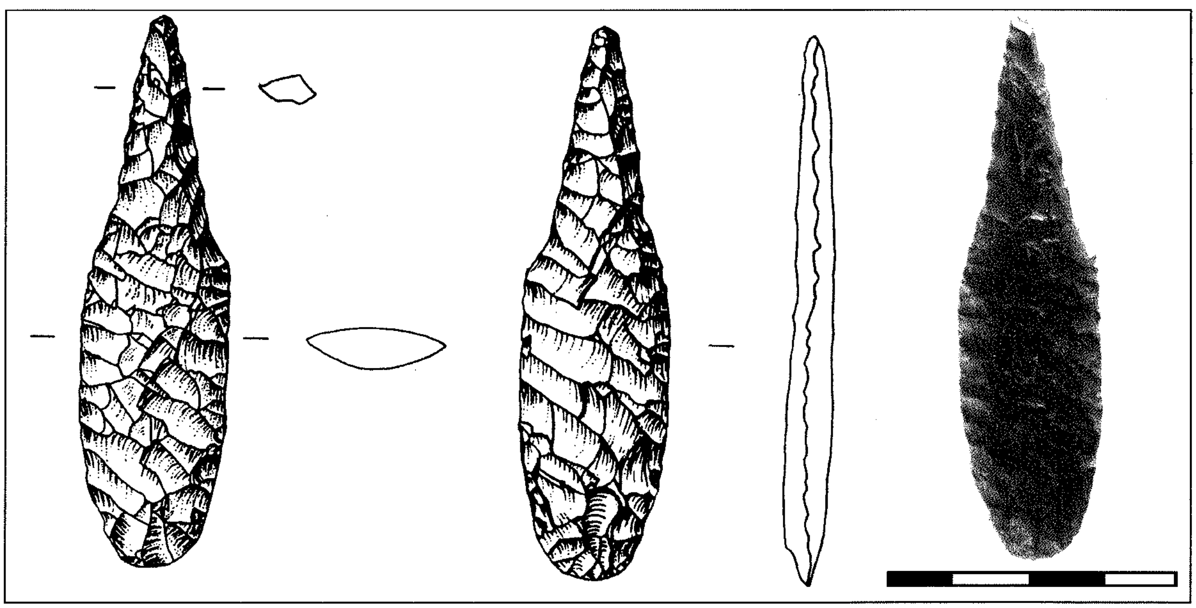

Figure 8. Scale line drawing (left) and photograph (right) of Specimen 80 (scale is in cm).

Specimen 141

This specimen is an Angostura point distal fragment (just less than one-half) (Figure 9). It is quartzite (based on the photo). Only finishing pressure flaking is present. There is well-controlled oblique serial flaking. The left side sequence is base to tip; the right side sequence is tip to base. Flaking is mostly transmedial with the last two flaking sequences on the same face. This is the best example of an unreworked distal fragment. (Note: line drawing from cast. Tip broken [and lost] prior to photograph).

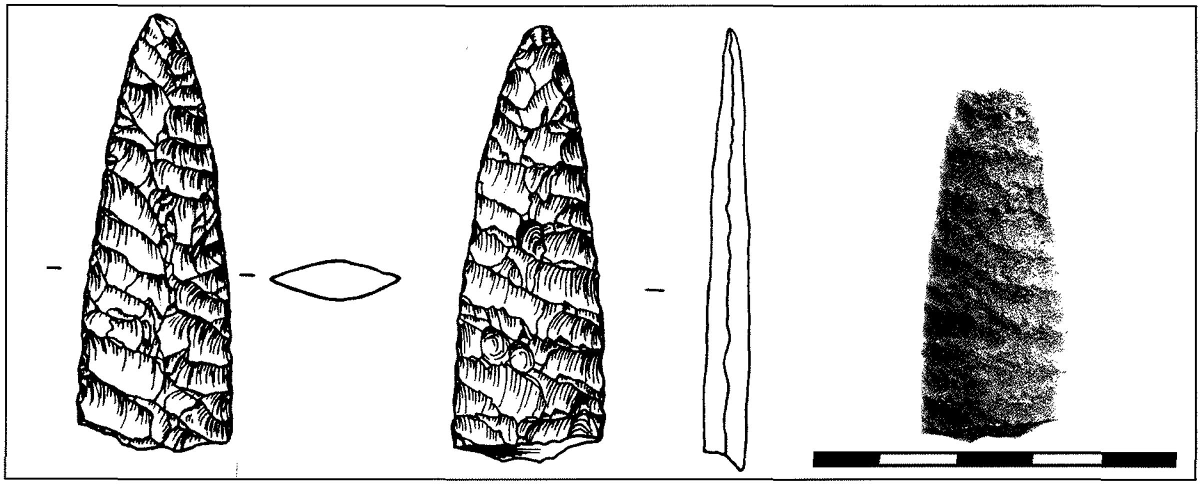

Figure 9. Scale line drawing (left) and photograph (right) of Specimen 141 (scale is in cm).

Specimen 158

This Angostura point base exhibits well-controlled oblique serial flaking with the left side sequence from base toward tip and the right side tip toward base (Figure 10). Some flake scars run past the midline but none run completely across the face as described by Wheeler (1995:414). The base is very slightly indented. There is no perceptible margin retouch. The snap-break is possibly radial.

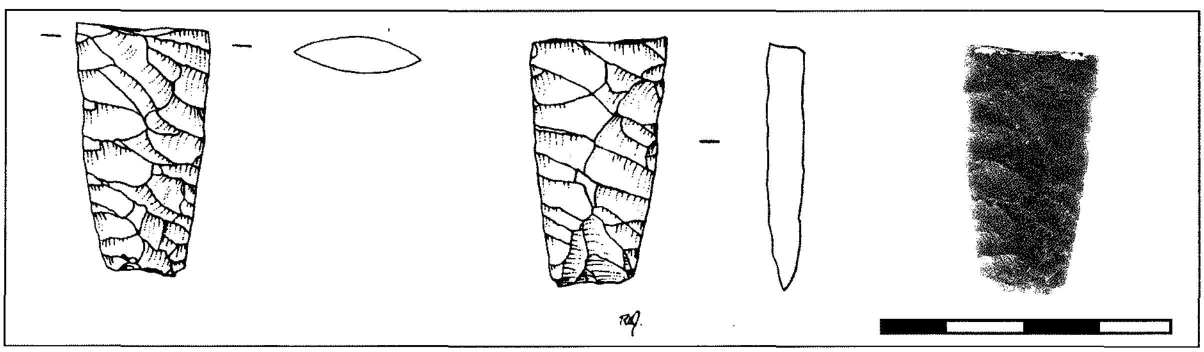

Figure 10. Scale line drawing (left) and photograph (right) of Specimen 158 (scale is in cm).

Specimen 275

This typical specimen is missing from the collections. Assignment as Angostura is based on the photograph (Figure 11).

Figure 11. Scale photograph of Specimen 275 (scale is in cm).

Specimen 280

This typical specimen is missing from the collections. Based on its size and slightly irregular flaking pattern, this could be a fragment of an unfinished point. Another sequence of pressure flaking could have regularized the pattern and brought its size into a more normal range. Assignment as Angostura is based on the photograph (Figure 12).

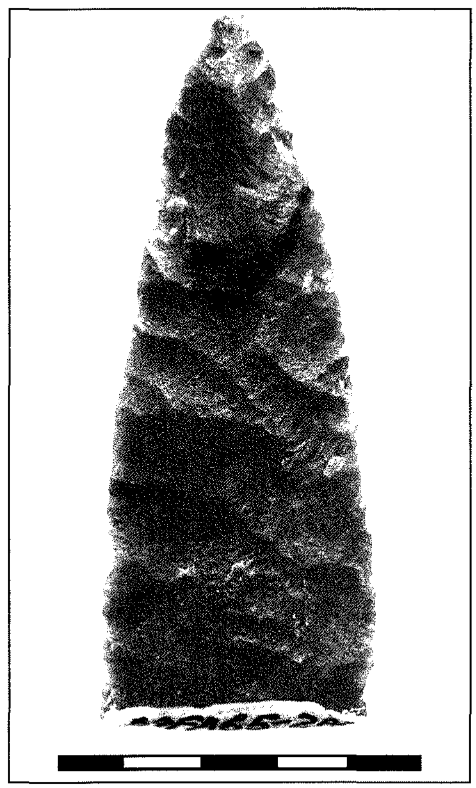

Figure 12. Scale photograph of Specimen 280 (scale is in cm).

Specimen 4

This typical specimen is missing from the collections. Assignment as Angostura is based on the photograph (Figure 13).

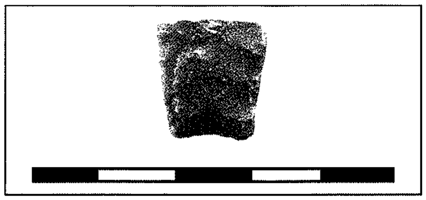

Figure 13. Scale photograph of Specimen 4 (scale is in cm).

Specimen 85-1

This piece exhibits a mix of flaking patterns although it generally conforms to the serial parallel sequence (Figure 14). The orientations of flake scars near the base are variable but as they progress toward the tip they become typically oblique. The author thinks this break in pattern is a product of increasing narrowness of the point and relative thickening (see discussion on 'typical' Angostura point technology, pages 6-7). Basal flaking on one face was done last. It has an impact-snap break.

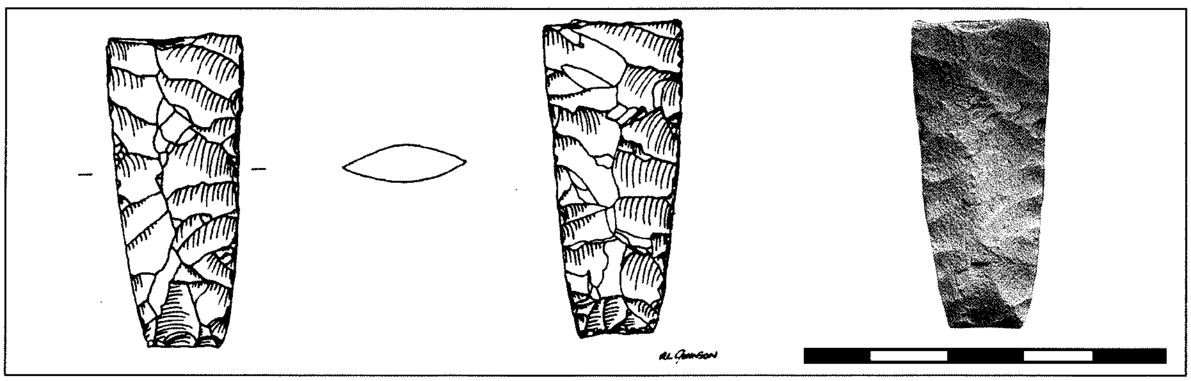

Figure 14. Scale line drawing (left) and photograph (right) of Specimen 85-1 (scale is in cm).

Specimen 85-2

This piece is an Angostura point (Figure 15). This specimen is either Flat Top chert or West Horse Creek chert. There is a percussion flake remnant on one face. The irregular serial oblique flaking on this face is a tip to base sequence on the left side, probably as adjustment to the percussion flake scar. On the same face, opposite side, a step fracture also broke the regularity of the flaking pattern. There is a bevel retouch near the tip of the right side. There is typical but irregular serial flaking on the other face. An attempt had been made to remove a deep step fracture near the left margin by a deep pressure flake from the right margin, producing the irregular flaking pattern. There is more than usual retouch, especially near the tip, with a slight beveling of the right margin. There is a snap-break of unknown origin. Bradley suspects that the knapper was having trouble dealing with this raw material or specific piece. The flaking qualities are enough different from quartzite that adjustment to this stone involved knapping "mistakes."

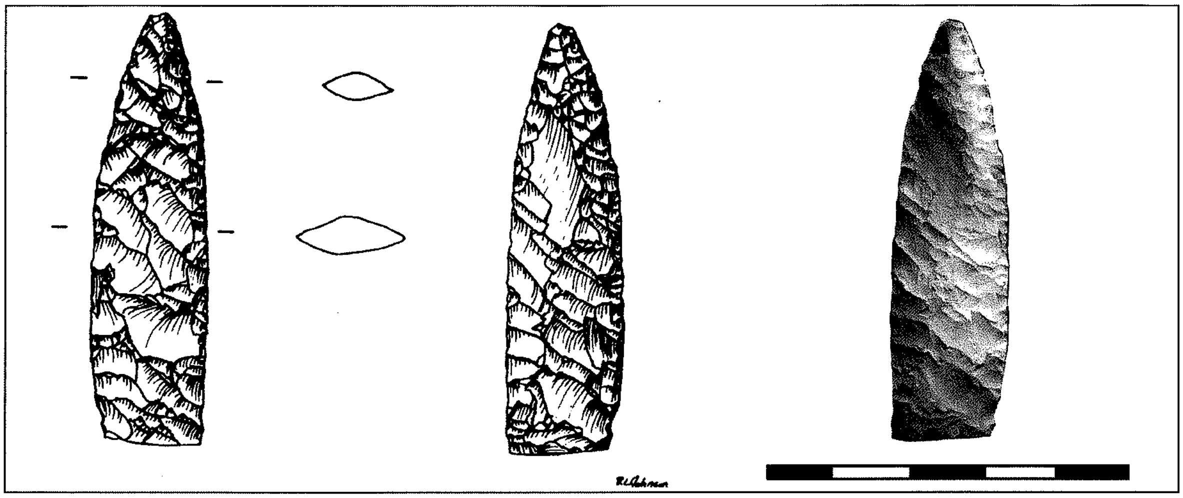

Figure 15. Scale line drawing (left) and photograph (right) of Specimen 85-2 (scale is in cm).

CONTEXT OF ANGOSTURA PROJECTILE POINTS

The provenience/context of the 11 specimens identified as *Angostura*, which exhibit the distinctive flaking technology, is summarized in Table 1.

Table 1. Provenience/Context of Angostura Points from the Ray Long Site (39FA65).

Specimen No.	Context	Comments
3	Surface	Collected 8-6-48 (Figure 5)
4	Surface	Collected 8-6-48 (Figure 13)
55	Area A - Sq. B2-L3. Depth 4.4 ft. (Feature 3). 3213.1 ft. amsl	Collected 8-27-48 (Figure 6)
141	Area A - Sq. R5-B2, 3.6 ft. from R5 - B1, 4.3 ft. from R6-B1; 3.5 ft. below stake L3 (Feature 9).	Collected 8-17-49 (Figure 9)
158	Area A - Sq. L2-B2 Feature 8, 1.7 ft. from L2-B1, 0.2 ft. from line L2-B1 to L1-B1; 4.1 ft. below stake L3, about 3 ft. below surface. 3217.1 ft. MSL (surveyed 11/4/49)	Collected 8-16-49 (Figure 10) Associations - general occupational level and especially that of Features 4 (lower fire place) and 3 (point base). A large quartzite chip (showing possible use) to east 0.3 ft.
275	Area A - Sq. BF-R6 Feature 15, 2.575 ft. back of F1 line and 1.95 ft. left of R7 line. Depth 3217.82 ft. amsl	Collected 7-10-50 (Figure 11)
280	Area A - Sq. BF-L1 Feature 13. 2.9 ft. left of right front corner, 1.15 ft. back of front wall of section. Depth 3217.48 ft. amsl	Collected 7-8-50 (Figure 12)
61	Area B - Surface	1948 (Figure 7)
85-1	Area B - Surface	1985 (Figure 14)
85-2	Area B - Surface	1985 (Figure 15)
80	Area C - Surface	Collected 8-23-48 (Figure 8)

It should be noted that the only Angostura points recovered from in situ contexts came from 39FA65-Area A. The distribution of the Angostura points across Area A (Figure 16) is widespread, suggesting a single occupation. Other than these points, the cultural materials from the occupation zone in Area A consist of scattered flaking debitage, worked stone (Cat. No. 106), a possible graver (Cat. No. 128), a mineralized bone fragment (Cat. No. 139), a worked flake (Cat. No. 159), two other point fragments (Cat. Nos. 276 and 277) - possibly blanks (from Feature 19), a scraper in two fragments (Cat. Nos. 278 and 279), a fossil belemnite fragment (Cat. No. 297), a sandstone fragment/palette(?) (Cat. No. 298), burned bone fragments - Feature 19 (Cat. No. 356), and a pebble/hand-hammer (Cat. No. 357). Wheeler summarizes the excavations at Area A as uncovering ten hearths and three possible workshop areas (Wheeler 1995:431).

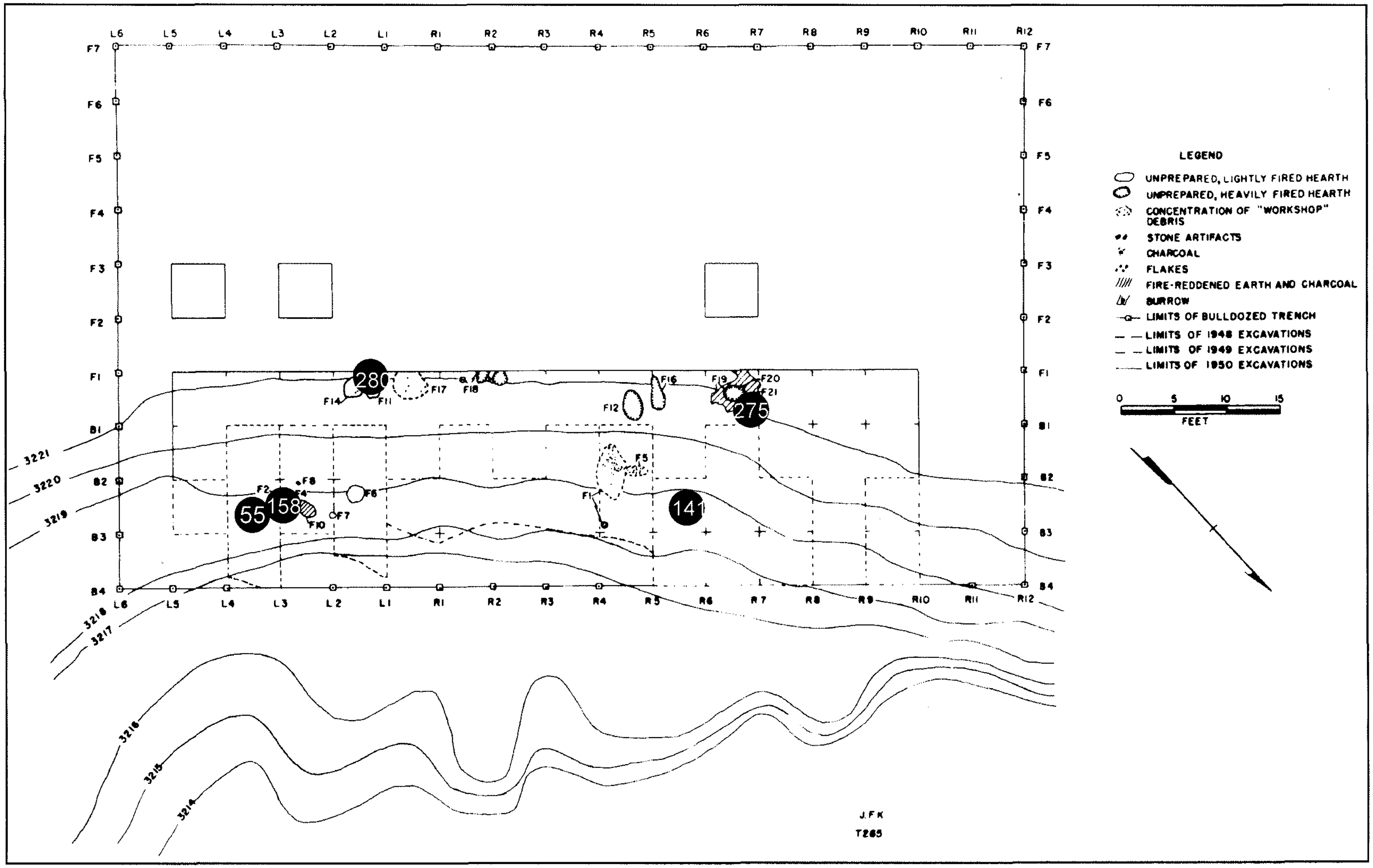

Figure 16. In situ Angostura points (Specimen Nos. 55, 141, 158, 275, 280), Ray Long site (39FA65) – Area A (adapted from Wheeler 1995:Figure 50).

Angostura Point Typology

The Ray Long Angostura points are long lanceolate forms that evenly curve to a sharp tip and taper to a straight to slightly concave base from about the middle of their length. Flake scar patterns are consistently serial, parallel oblique running from upper left to lower right. Flake scars may run past the midline toward the center of the point but tend to meet near the midline near the base. Flake removal sequence is mostly from base to tip on the left side (with point viewed tip up) and tip to base on the right. There is little to no margin retouch except on one example where steep noninvasive pressure flaking produced a slight bibevel near the tip. Only one specimen retains part of a percussion flake scar. Although most pieces are evenly lenticular in cross section, there is a tendency toward slightly plano-convex cross sections as well. Projectile point margins from the greatest width to the base are ground smooth.

Verbal descriptions of this sort must necessarily be imprecise. What does evenly curved to the tip or tapered to the base actually look like? What is a lens-shaped cross section? The best way to answer these questions is to simply examine the illustrations of the artifacts. Unfortunately, there is not a single, complete specimen of an Angostura point from the Ray Long site. To try to illustrate the size and form of a Ray Long Angostura point, the author made a best guess at reconstructing a whole point from the available fragments (Figure 17). To be sure, this is very imprecise and subject to ready manipulation; however, the resulting composite probably is an accurate representation of an original. This composite point corresponds well to Pitblado's (2007) type definition. In differentiating Angostura with Jimmy Allen specimens, the main trait she found useful was the maximum width to basal width (see Pitblado 2007:322, Figure 10.4). The composite point has a maximum width of 223 mm and a basal width of 146 mm. When plotted on Pitblado's graph, it falls right in the middle of the Angostura point distribution. Note that this graph only supports comparisons between Angostura and Jimmy Allen – not other types.

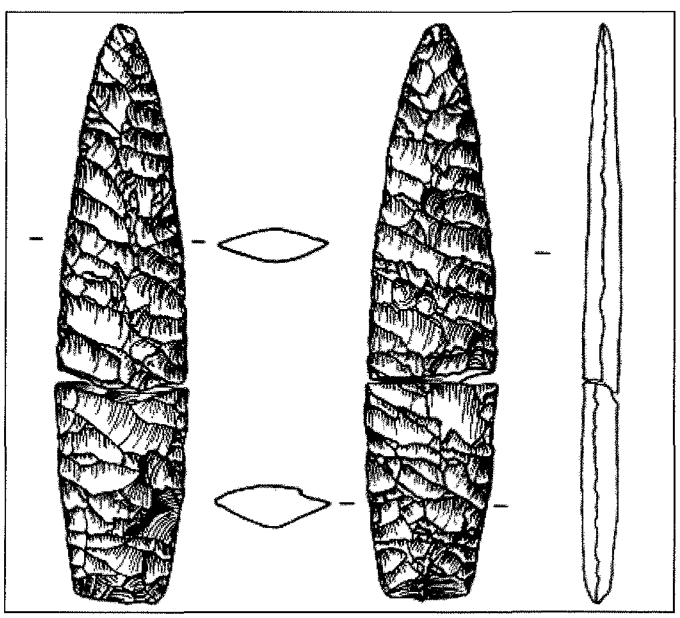

Figure 17. Composite Angostura point from the Ray Long site.

Angostura points were finished by the dulling of the proximal lateral edges from the widest point, including the base. This type of edge grinding relates to manufacture or optional maintenance rather than use. Margin dulling better prepares the edge for prehension or hafting. This can be felt and seen. A microscope is only necessary to note its characteristics; its presence can be detected without a microscope. Theoretically, edge grinding could occur in any direction. However, the examples are uniform in being scored parallel to the edge, which is also consistent with the author's experimental approach. The likely reason for this uniformity is that parallel scoring of an edge dulls it without further step fractures. Step fractures would leave the edge more brittle and less-suited for either further reduction or hafting. The resulting edge is broad and dull; microscopically, parallel divots and finer striae are visible (see Kay, page 26).

As Kay's microwear analysis demonstrates, intentional edge grinding is the most uniform and essential observation for bifaces more generally. On points, the lateral grinding generally extends across the proximal, or basal, end and onto both adjacent edges. It is the principal way to identify the haft element. Since haft grinding obscures the negative bulbs produced in the final pressure flaking, it would have been the last step in point manufacture. Haft element grinding is present on one distal point fragment or tip (Specimen 85-2), as well as Specimens 85-1 and 158. The consistent approach (i.e., the parallel approach) to lateral grinding for point manufacture minimizes the likelihood of edge step fractures. This consideration was important in that it made sense as an appropriate motor habit exercised throughout the manufacture process. Edge grinding was part of a deliberate, prudent strategy for the manufacture and maintenance of Paleoindian lanceolates more generally. Identical lateral grinding occurs on the Ray Long fluted lanceolate (Hannus et al. 2012:60-61), and is common on Clovis points (Kay 1996). The goal always seems to have been to guarantee a high state of maintainability (Bleed 1986).

The quartzite lanceolate base fragments primarily exhibit grinding, and appear to have been broken in either use or in retooling. Transverse breaks due to bending, or snapping caused by the unequal application of force to one or the other end, are generally present. These bending breaks are common, secondary effects of impact damage to projectile points and typically occur in the haft binding. However, they can also result from a knife blade being levered against a bone. The use-wear evidence indicates that either situation is plausible (see Kay, pages 29-33). Each also appears to be a reject; none is large enough to have been further reworked. Not a single point specimen would be classed as usable. They appear to be at the end of their use-lives and were likely rejects.

SUMMARY AND CONCLUSIONS

The Angostura point type was first described by Hughes under the type name "Long" as "large lanceolate specimens with narrow, straight to concave bases, fine, sometimes oblique flaking; and ground edges near bases" (Hughes 1949:270). Wheeler described the Angostura point as "a large, slender lanceolate point, the symmetrical sides of which incurve to the tip and taper to the narrow base forward from the base about two-fifths to one half of the total distance from base to tip" (Wheeler 1995:415). Wheeler goes on to note that "the base is either shallowly concave or irregularly straight." The Angostura point type was more widely published in Wormington's (1949) third edition of *Ancient Man in North America,* still under the type name *Long*. In the fourth edition of her book, Wormington (1957:139) adopts the name Angostura for the type but illustrates a specimen that does not match the type description and is not from the type-site. This circumstance contributed to the ensuing confusion surrounding the (mis)identification of Angostura points.

This author's definition of Angostura points clearly conforms to Hughes's (1949) and Wheeler's (1995:449-450) initial descriptions and Pitblado's (2007) more detailed definition of a basally ground lanceolate, whose parallel oblique flaking is oriented mostly from upper left to lower right. Basal shape varies from straight to slightly concave. As a matter of tool form and semantics, this author's definition differs from Pitblado's in that, for the Ray Long specimens, final point pressure flaking is *always* parallel oblique, as opposed to "sometimes."[3] In the author's estimation, the bifacial parallel oblique flaking represents a technological solution to pressure flaking quartzite and other strong but brittle materials, proceeding in a serial fashion. This technique also produces straight, razor sharp edge results that require no further preparation and, on brittle materials, is more resistant to damage than it would be on chert or flint. Earlier analogues also occur on silicified sandstone and quartzite points in the Rocky Mountains (Davis 1993; Davis et al. 1988; 1989; 1998; Frison and Walker 2007:42, Figure 3.8e). This pressure flaking technique is not exclusively Late Paleoindian in age or restricted to brittle stones; however, its origin does seem to have been in the Rockies or Great Basin. The technique was well-suited to the stones selected for Angostura points at the Ray Long site. For later examples of the use of this technique see Benedict (1981:67, 80-81; 1985:62-63; 1990:63; 1996:45) and McCracken et al. (1978:128).

[3] However, this is admittedly based on the examination of an extremely small sample-size.

When the Ends Are the Means: Retooling Angostura

Marvin Kay

Introduction

This techno-functional analysis of the *Angostura* projectile point considers the original artifacts from the Ray Long site (39FA65, the type-site for Angostura), related collections, and the records of Richard P. Wheeler, who initially defined Angostura. The study also addresses samples from ALAC's more recent investigations of the Ray Long site, which consist mostly of flakes and ground stone fragments not related to the central question of Angostura (see Appendix M).

Wheeler's interest was primarily in the parallel oblique flaked lanceolate points from Ray Long. The Angostura surface at Ray Long has been radiocarbon dated by AMS to ca. 9000 RCYBP, or ca. 8250 B.C. (see Buhta et al. 2012:2-5) as calibrated with CALIB 6.0 and the INTCAL09 calibration curve (Reimer et al. 2009). As such, it is among the later manifestations of parallel oblique flaked points found more commonly in the Rockies, and is Late Paleoindian in age.

Implications about Angostura and, more generally, about Late Paleoindian weaponry and social geography are developed by advancing William Henry Holmes's (1894:Diagram 1) century-old methodology now known as *chaîne opératoire* in European Paleolithic studies and its American counterpart the flow-chart model (Johnson 1993; see also Bleed 2001 for a general overview). This evaluation addresses the intended result of stone tool production and toolstone preferences following Holmes's principles. It extends Holmes's method in ways the author would hope he might have approved by considering microscopic wear traces. The latter develop evidence of tool use and use-life primarily from experimental replication of tool forms, flaking patterns, and use of the replicas. Realistic experimentation is integral to use-wear assessments of artifacts by providing an empirical comparison of how tools satisfied engineering design requirements. In the case of chipped stone projectiles, engineering design contends with two opposing issues that governed retention, everything else being equal: tool function balanced against anticipated maintenance upon use and breakage (Kay 1996; see also Ahler and Geib 2000). When maintenance cost exceeds the benefit of continued, intended use, the artifact is likely to be either recycled or discarded. These functional prerequisites of use and maintenance govern the forms and sizes of recovered artifacts far more so, in the author's opinion, than would be expected by the mental template of a traditional artifact type.

Thus, in this assessment the author argues that Angostura is but one example, albeit a particularly egregious one, of an archeological tendency either to overstate the heuristic value or, worse, the validity of conventionally defined point types. In a nut shell, when archeologists address "idiosyncratic knapping habits and the level of knapping skill of individual stoneworkers" to define initial artifact appearance plus other factors that affect artifact form "over the course of its useful life" (Bamforth 1991a:310), they often put the cart before the horse, to mix metaphors. In most instances, the impression is that higher quality, or finer-grained, toolstone was preferred, if only because it likely enhanced individual knapping skill. Yet, the finely executed parallel oblique flaking of many Late Paleoindian projectile points often is on relatively coarse-grained quartzite, even when finer-grained toolstones seemingly were as available. This paradox demands an explanation. This study supports the argument that keenly sharp and exceptionally durable edges produced by parallel oblique flaking of quartzite satisfied functional tool design prerequisites in ways well-suited to point use and especially so to maintenance; and that quartzite-dominated technology may represent diffusion or population movement from a western intermontane adaptive strategy (Frison 1991, 1992; Frison and Walker 2007; Pitblado 1998, 2007) onto the Northern Plains.

The author was fortunate to share insights with Bruce A. Bradley, as both worked together on the Ray Long collections. Working with Bradley was a bonus; especially so because quartzite is among the more difficult lithic materials for high-magnification use-wear analysis and required innovations to get the most possible good from the microscopic examinations.

This assessment begins with a summary of the studied sample, continues with a discussion of microwear methods and results, and is followed by descriptions of the production chain, or Angostura flow-chart. The assessment starts with the bifacial preforms from which Angostura points were fashioned; then considers the points themselves, their use, reworking or recycling. The obvious implication is that Wheeler's concept of the Angostura point type as developed at the Ray Long site addresses lanceolate points at the end of their use life, not the beginning. Wheeler's all-too-common mistake has been transmogrified since into a concept he would not recognize much less appreciate. Simply put, Angostura has been mugged by archeological practice.

MICROWEAR STUDIES

Analyzed Ray Long site artifacts include six specimens from ALAC's 1985 excavations, 22 specimens from ALAC's 1995-1996 excavations, and seven specimens from Wheeler's 1948-1950 excavations. Sixteen surface specimens from Sioux and Dawes counties, Nebraska, previously examined by Wheeler (1995) and considered to relate to an Angostura occupation, were included too (Table 2; see also Appendix M). An Angostura point replica, a bifluted point base from Ray Long, and a Clovis point from the Lange/Ferguson site (39SH33) were also examined, making the total number of specimens 54. Metric data were tabulated for the projectile points (Table 3).

The study specimens include three points and a preform from ALAC's 1985 excavations at Ray Long. Fifteen flakes and nine sandstone fragments from ALAC's 1985-1996 excavations are included in Table 1 but are described in Appendix M since they are not central to the question of Angostura. The study sample also includes three bifacial preforms and four lanceolate points recovered from eroded but sealed accretional surfaces of the Ray Long alluvial fan by Jack T. Hughes (1949) or Wheeler (1954, 1995) plus three bifacial preforms and 13 lanceolate points from Wheeler's collections of six and 10 specimens, respectively, from Sioux and Dawes counties, Nebraska.

In addition to these artifacts, a cast of one item and a photograph of another were examined. Both specimens are of quartzite, exhibit parallel-oblique flaking, and are consistent in size and shape with the author's concept of Angostura.

Table 2. Microwear Study Sample.

Group 1: 39FA65-Area B (ALAC 1985)

Specimen ID No.	Field ID No.	Material	Description	Figure	Microwear (Inconclusive results left blank)
1	85-3-C	Quartzite	Point	21d	
2	85-6-E	Quartzite	Flake	M7a	
3	85-2-B	Chert	Point	21a	Soft to medium hard
4	85-4-D	Quartzite	Preform	20b	
5	85-5-T	Quartzite	Flake	M7d	Medium hard
7	85-1-A	Quartzite	Point	25d	

Group 2: 39FA65-Area B (ALAC 1995-1996)

Specimen ID No.	Field ID No.	Material	Description	Figure	Microwear (Inconclusive results left blank)
26	9N2W-E	Quartzite	Flake		
27	9N2W-E	Quartzite	Flake		
28	10N3W-D	Sandstone	Debitage		Metal
29	10N3W-D	Sandstone	Debitage		
30	10N3W-D	Quartzite	Flake		Negative
31	10N3W-D	Sandstone	Debitage		
32	9N2W-D	Sandstone	Debitage		
33	9N2W-D	TRSS	Flake		Metal
34	9N2W-D	Sandstone	Debitage		
35	9N2W-D	Tongue River silicified sediment (TRSS)	Flake	M7c	Negative
36	9N2W-D	Sandstone	Debitage		
37	10N3W-F	TRSS	Flake	M7e	Metal
38	10N3W-F	Quartzite	Flake		
39	10N2W-D	Sandstone	Debitage		
40	12N2W-C	Sandstone	Groundstone		Hard
41	9N3EW-D	Quartzite	Flake	M7b	
42	9N2W-E	Quartzite	Flake		
43	9N1W-N	TRSS	Flake		Negative
44	8N2W-D	Sandstone	Groundstone	M8	Hard
45	8N2W-E	Quartzite	Flake	M7f	
46	8N1W-A/B	Quartzite	Flake		
47	8N3W-E	Quartzite	Flake		

Table 2 (continued).

Group 3: Wheeler Excavations 1948-1950 - Areas B and C, Surface

Specimen ID No.	Field ID No.	Material	Description	Figure	Microwear (Inconclusive results left blank)
48	39FA65-83 4275334 Area C	Quartzite	Preform	20e	
49	39FA65-2 427515 Shippee 8-6-1948	Petrified wood	Preform	23e	
50	39FA65-193 427556 Area B (by stake N7E2)	Quartzite	Preform	20d	
51	39FA65-60 427522 Area B	Chert?	Point	23d	Soft to medium hard

Group 4: Wheeler Excavations 1948-1950 - Area A

Specimen ID No.	Field ID No.	Material	Description	Figure	Microwear (Inconclusive results left blank)
52	39FA65-61 427523X	Quartzite	Point	22e	Negative
53	39FA65-158 427545X	Quartzite	Point	22f	
54	39FA65-80 427532	Quartzite	Point	21c	

Table 2 (continued).

Group 5: Surface Collection from Sioux and Dawes Counties, Nebraska

Specimen ID No.	Field ID No.	Material	Description	Figure	Microwear (Inconclusive results left blank)
8	S7441	Quartzite	Point	23f	Medium hard
10	S7461	Quartzite	Point unground base	21b, 27	Medium hard
11	D7416	Quartzite	Preform	20c	
12	D7419	Quartzite	Preform	18b	
13	D7411	TRSS	Point reworked base	23a, 24	Soft to medium hard
14	D7418	Quartzite	Preform	20a	
15	D7541	Quartzite	Point	25a	
16	S7470	Quartzite	Point	18c	
17	S7600	Quartzite	Point	23b	
18	S7421	Quartzite	Point unground base	25c	
19	S7353	Quartzite	Point	23c	Ambiguous
20	DW2 61-45	Quartzite	Point	22c	
21	D7370	Quartzite	Point	22a	
22	D7400	Quartzite	Point	25b, 26	Soft to medium hard
23	D2 199-47	Quartzite	Point	22d	
24	D7410	Quartzite	Point	18d	

Group 6: Lange-Ferguson Site (39SH33)

Specimen ID No.	Field ID No.	Material	Description	Figure	Microwear (Inconclusive results left blank)
25	L-84-1	Chert (black)	Clovis Point		

Group 7: 39FA65-Area B (ALAC 1995)

Specimen ID No.	Field ID No.	Material	Description	Figure	Microwear
6	9N-2W	silicified sediment	Clovis/Folsom Point	18a	Negative

Group 8: Bruce Bradley Angostura Point Replica (made in 1994)

Specimen ID No.	Field ID No.	Material	Description	Figure	Microwear
9	L-9.94	Knife River flint (KRF)	Point Replica	19a, 19b	Hard

Table 3. Projectile Point Metric Data - All Specimens (Total = 21).

Specimen ID No.	Location	Completeness	Weight (g)	Length (mm)	Haft length (mm)	Width (mm)	Thickness (mm)	Width/ Thickness Ratio
3	39FA65-Area B 1985	Distal	7.238	59.38		16.22	6.76	2.4
54	39FA65-Area A 1948-1950	Complete	12.67	76.7	43	21	6.8	3.08
52	39FA65-Area A 1948-1950	Medial	8.16	36.6	35.45	21.9	6.65	3.29
53	39FA65-Area A 1948-1950	Proximal	4.326	34	28	19	5.4	3.518
1	39FA65-Area B 1985	Medial	4.946	23.5		25.2	5.74	4.39
7	39FA65-Area B 1985	Proximal	6.721	44.13	44	19.33	6.44	3
51	39FA65-Area B 1948-1950	Complete	13.5	67.6	30.9	24.4	8	3.05
21	Dawes Co, NE	Proximal	6.227	33.41		22.31	8.19	2.72
10	Sioux Co, NE	Distal	13.65	83.63	41	23.84	7.19	3.32
20	Dawes Co, NE	Proximal	2.778	20.01		19.81	5.89	3.36
8	Sioux Co, NE	Complete	18.591	91.4	26	19.57	9.84	1.99
19	Sioux Co, NE	Complete	13.458	63.48	27	21.05	8.29	2.54
13	Dawes Co, NE	Proximal	18.761	68.38	32	26.45	9.3	2.84
16	Sioux Co, NE	Medial	8.943	34.6		24.62	8.02	3.07
22	Dawes Co, NE	Proximal	9.341	43.36	34	23.15	7.24	3.2
17	Sioux Co, NE	Proximal	12.286	61.12	40	23.55	7.23	3.26
15	Dawes Co, NE	Proximal	2.909	18.78		20.83	6.16	3.38
23	Dawes Co, NE	Proximal	3.001	20.26		21.59	6.07	3.56
24	Dawes Co, NE	Proximal	1.973	15.06		20.45	5.63	3.63
18	Sioux Co, NE	Proximal	3.813	28.31		16.51	7.21	2.29
6	39FA65-Area B 1995 (Clovis/Folsom)	Proximal	2.298	16.39		25.09	5.57	4.5

One Ray Long site bifluted point base, excavated in 1995, comes from stratigraphically sealed deposits below the Angostura component and figures only indirectly in the Angostura analysis (Table 2, Group 7). Sharing attributes of both Clovis and Folsom points, this specimen is too incomplete to make a foolproof distinction. It is described in Appendix M in comparison to the Lange/Ferguson Clovis specimen (Table 2, Group 6).

Discounting the two fluted points, the study sample (see Table 2, above) is evaluated as a single – albeit diverse – assemblage. All pieces other than the bifacial cast were subjected to the microwear analysis. Bifacial artifacts were measured for length, width, thickness, and maximum potential haft length (see Table 3 for projectile points).

MICROWEAR METHODOLOGY

For the purposes of this analysis, each specimen was assigned an individual identification number and its field ID label was listed along with its formal description. Each specimen was weighed to the nearest 0.001 g, photographed on both faces after being coated (or "smoked") with water soluble ammonium chloride that enhanced flaking or other surface details, and, as needed, ultrasonically cleaned in an ammonium-based detergent and water solution. (The bifacial cast was not photographed because "smoking" with ammonium chloride might have damaged it, nor were the small reduction flakes and sandstone fragments).

The ultrasonic cleaning removed all remaining, easily dislodged sediment and any oils that would obscure microscopic details. No attempt was made to unglue the bonds on refitted specimens, which were examined in the state in which they were received. The microscopic examination was on the ventral surface and all edges of the unifacial artifacts, and on the edges and one or both surfaces of the bifacial artifacts. The approximate location of microscopic details was noted on the artifact photographs, and when subjected to photomicroscopy, the photomicrograph orientation was also noted on these artifact photographs.

A differential-interference binocular microscope with polarized light Nomarski optics was used at intermediate magnifications of 100 to 400 diameters. This microscope is ideally suited for this analysis because it provides a high resolution, three-dimensional image of microtopography. Most artifact surface scans for polishes, residues and striae were done at 100 diameters and then further evaluations were made at either 200 or 400 diameters, and photomicrographed as needed. Microscopic evaluations at lesser magnifications (10-40X) concerned gross details of edge damage, crushing and rounding or the intentional grinding (and probable reworking) of point bases; these evaluations included the artifact cast.

The analysis followed the general traceological approach of S. A. Semenov (1964), and paid special attention to the orientation and crosscutting sequences of striae, the presence of abrasive particles, other evidence of the direction of use of a tool, or prehension, or hafting potential, and possible contact material. The methodology and appropriate experimental analogs are further explained elsewhere (Kay 1996, 1997b; Root et al. 1999). If there is a difference with Semenov's classic study, it is in the recognition of additive, soluble inorganic residues to tool surfaces and edges during use or due to prehension or hafting. These additive residues are common features and appear to be impervious to further cleaning. They permanently bond to an artifact surface.

Clearly denoting the orientation and direction of their formation are the filling in of striae, crystallization on the trailing edge of the residue, and to a lesser degree desiccation cracking.

The analysis was done in two phases. The earlier preceded a several-day joint evaluation by Bruce A. Bradley (experimental replication of stone tools) and the author (stone tool use-wear). We largely agreed in the overall techno-functional judgments; the later phase included several Ray Long specimens loaned by Dennis Stanford and only examined by the author.

MICROWEAR RESULTS

Quartzite and sandstone artifacts are difficult to analyze for microscopic wear traces. Conchoidal fracture (see Cotterell and Kamminga 1990; Field 1965 for general discussions) of individual quartz grains may be confused with use scratches, or striations. Nevertheless, because quartzite and basalt artifacts and tool replicas do display wear traces that crosscut or extend beyond the gross details of conchoidal microflaking (see Kay 1996, 1997a, 1997b), the author expected, and indeed found, use-wear even on the quartzite and sandstone artifacts. But, because of quartz grain fracturing, 27 of 34 (>79 percent) quartzite artifacts and 6 of 8 (75 percent) sandstone artifacts were inconclusive for use-wear when viewed at intermediate magnifications, as opposed to only 1 of 9 (11 percent) non-quartzite or non-sandstone artifacts (see Table 2). At lower and intermediate magnifications it was possible to accurately assess lateral edge grinding for the quartzite bifaces that include 12 points. Of these points, 11 were in other respects inconclusive for wear traces. The bifluted lanceolate base (Specimen 6-Figure 18a) of silicified sediment presented no analytical problems but has no use-wear other than lateral edge grinding.

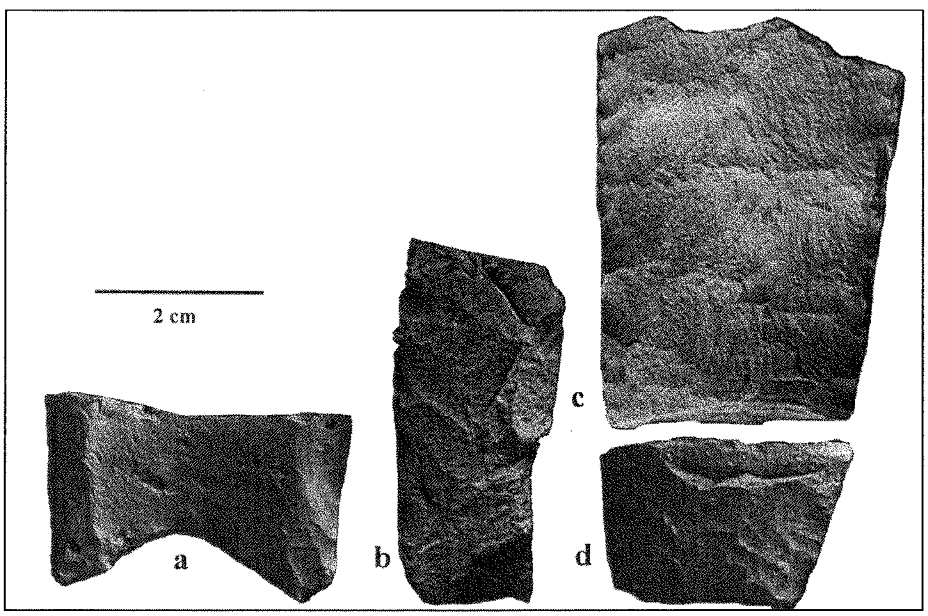

Figure 18. Projectile point (a, c, d) and preform (b) fragments: a) Specimen No. 6; b) Specimen No. 12; c) Specimen No. 16; d) Specimen No. 24 (see Table 2 for provenience data for all specimens).

Edge grinding of this kind relates not to use but to manufacture or optional maintenance. Either it better facilitates flaking (by deliberately flattening and roughening the striking platform), or dulls the edge for prehension or hafting and it can be felt as well as seen. One does not need a microscope to note its presence, but only its characteristics. In theory, edge grinding could be in any direction. The examples, however, are uniform in being scored parallel to the edge, which is also consistent with Bruce Bradley's approach in creating an experimental Angostura point replica. Bradley's experiments identify the likely reason for this uniformity: parallel scoring of an edge dulls it without further step fractures. Step fractures would make the edge more brittle and less-suited for either further reduction or hafting. The result is a broad, dull edge that microscopically has parallel divots and finer striae, as noted on the point replica (Specimen 9-Figure 19b).

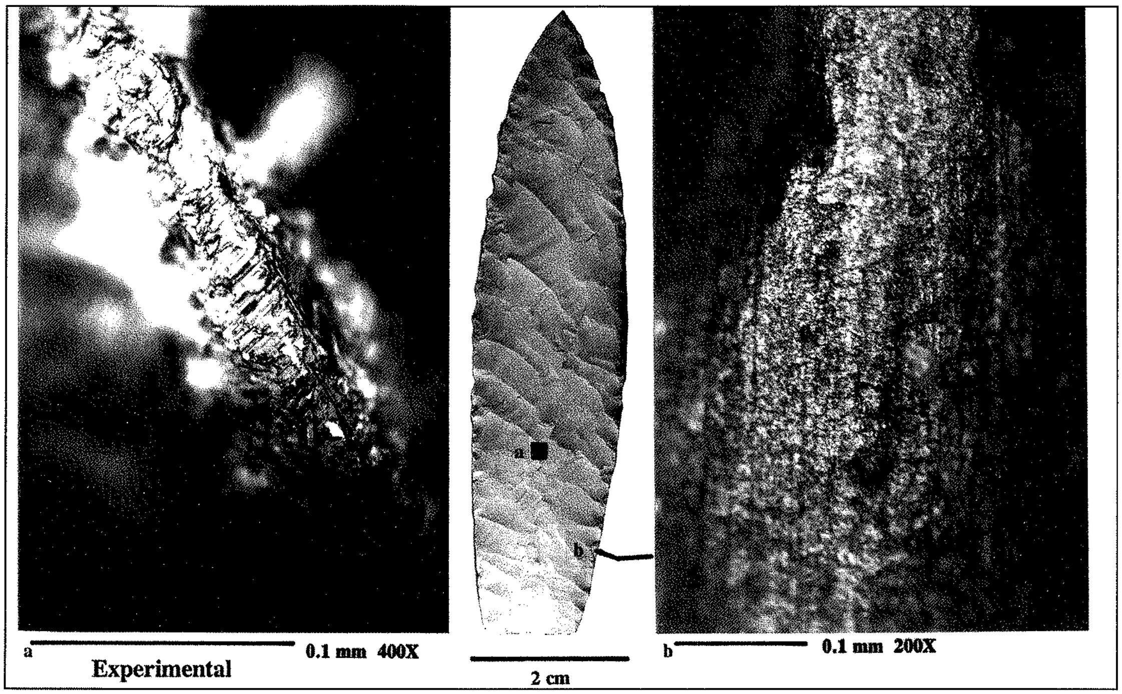

Figure 19. Oriented photomicrographs of manufacture details of experimental replica created by Bruce Bradley (Specimen No. 9): a) striated residue apparently due to contact with leather backing; b) abrasive wear caused by lateral grinding of the base.

This replica is interesting also for insights into the formation of striated residues not related to either hafting technique or use. The best example is shown in Figure 19a, but this residue occurred at several places on the surface of the replica. During manufacture, the replica was held against a leather pad or backing that apparently was responsible for the residue.

The analysis partitioned the sample into functional artifact groups. The unifacial or ground stone implements and their debitage are described in Appendix M along with the bifluted point. The likely Angostura bifacial preforms and points are described as follows.

Bifacial Artifacts: Preforms

The preforms are more crudely percussion flaked, rarely if ever have pressure flaking, and are significantly larger than the pressure flaked, finished points. Two distinct preform shapes are evident. Six (Specimen 12-Figure 18b and Specimens 4, 11, 14, 48, 50 - Figure 20) are of quartzite, mostly have a convex base, and are oval in outline. Because they are mostly of the same material and share a grossly similar outline, they are likely to be part of the production sequence of parallel oblique flaked points (Figures 21 and 22). The other is represented by a single specimen (Specimen 49-Figure 23e) of petrified wood, and has a square base and rough, parallel sides. Hughes (1949:270) described it as a "rather large, crude Plainview point," following Krieger's (1944) evaluation. But it displays no use-wear and shares critical flaking details with horizontally flaked points (see Specimens 51 and 8 - Figures 23d and 23f).

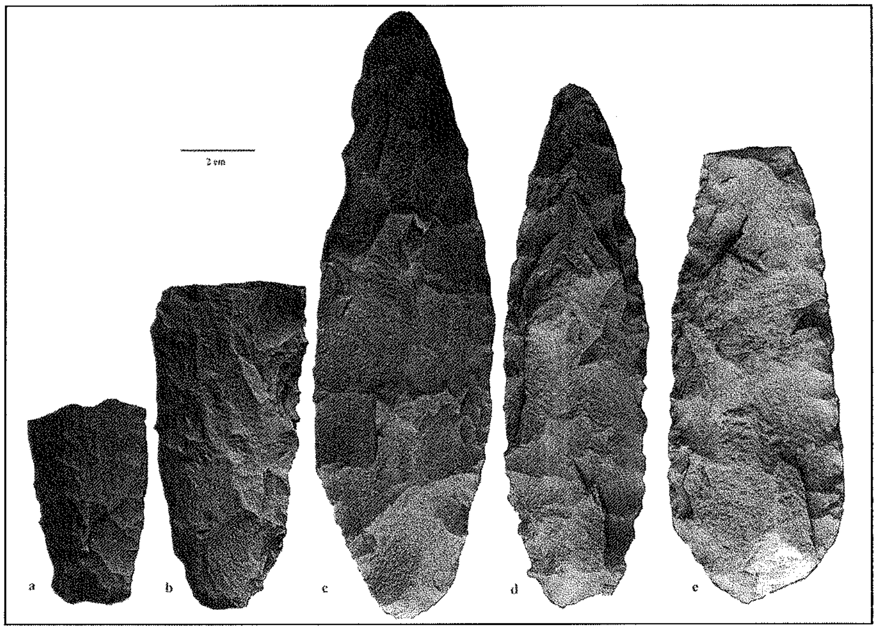

Figure 20. Quartzite point preforms: a) Specimen No. 14; b) Specimen No. 4; c) Specimen No. 11; d) Specimen No. 50; e) Specimen No. 48.

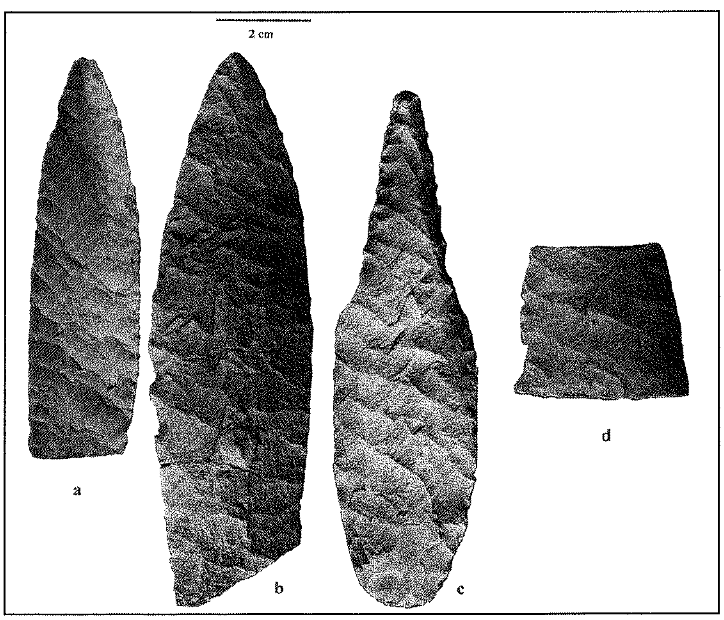

Figure 21. Parallel oblique flaked points (a, chert; b-d, quartzite): a) Specimen No. 3; b) Specimen No. 10; c) Specimen No. 54; d) Specimen No. 1.

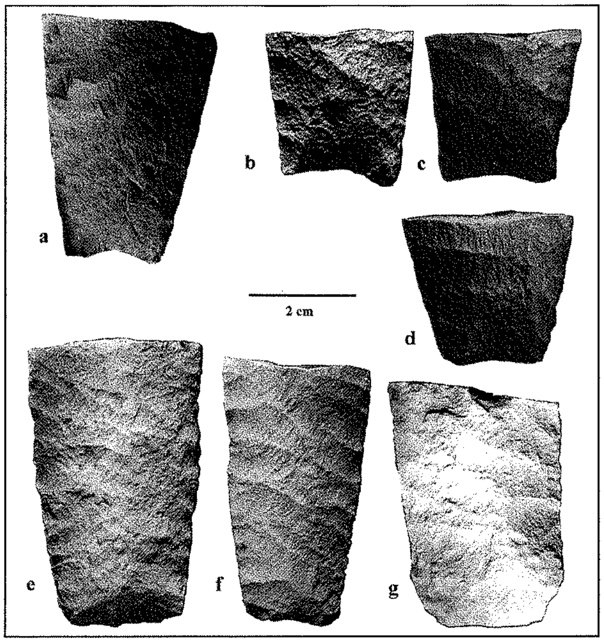

Figure 22. Quartzite point bases (note all but d are parallel oblique flaked; b and g are from the Buster Hill site (39MD145): a) Specimen No. 21; b) Specimen No. P4; c) Specimen No. 20; d) Specimen No. 23; e) Specimen No. 52; f) Specimen No. 53; g) Specimen No. P5.

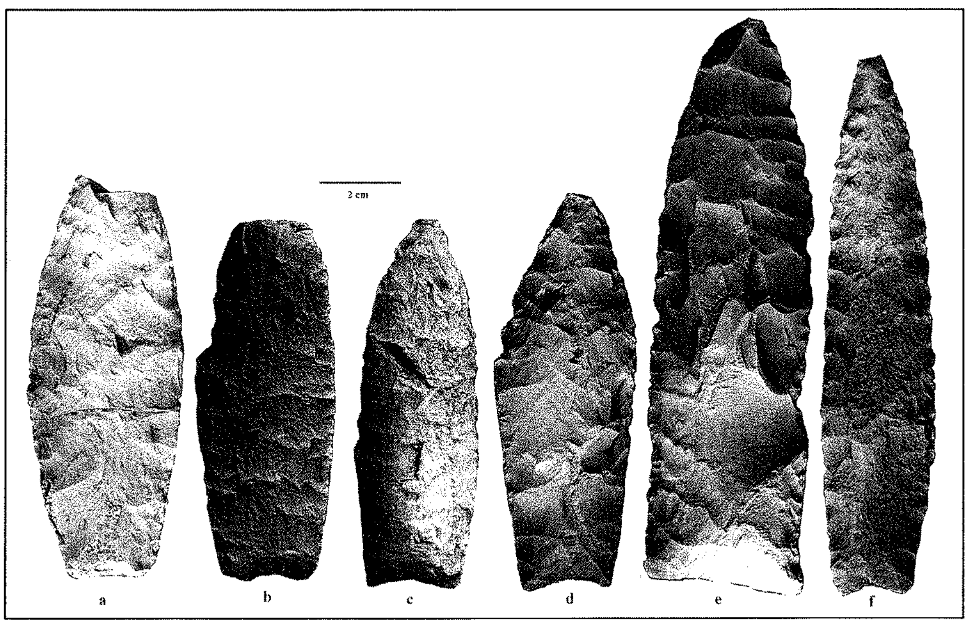

Figure 23. Horizontal flaked points (a-d, f) and preform (e) (a, TRSS; d, chert; b, c, f, quartzite; e, petrified wood): a) Specimen No. 13; b) Specimen No. 17; c) Specimen No. 19; d) Specimen No. 51; e) Specimen No. 49; f) Specimen No. 8.

One might not expect preform usage (Kay 1984:176-177) but, according to wear traces on Folsom technology (Kay, unpublished), they were used – if only occasionally. For the quartzite preforms, however, the use-wear evidence is ambiguous at best – and applies only for one specimen. From a microwear perspective, this preform fragment (Specimen 4-Figure 20b) is actually one of the better quartzite artifacts because of its relatively few quartz grains and more amorphous silica matrix, which is where to look for wear traces. Striae are not in this silica matrix on the artifact's faces nor its broken end, but are parallel to and only at the edges of the artifact. These could be due to use as a simple cutting tool. Post-depositional metal streaks are also along the edges, and the striae are as likely to have been caused by a metal object as by use.

Use-wear is inconclusive for all others due to quartz grain fracturing. On the largest preform (Specimen 11-Figure 20c), the edges are rounded. There are no striae. Rounding indicates contact with a soft material – perhaps animal hide.

Intentional edge grinding is present on two fragmentary specimens. One was ground on only one side (Specimen 14-Figure 20a). The lack of grinding on the opposite edge was due to either specimen breakage or its removal in further flaking. On the other, lateral grinding could be observed only on one side because of breakage (Specimen 12-Figure 18b). In these two instances, the lateral grinding is likely to have been a step in preparing striking platforms for further reduction in biface manufacture.

Bifacial Artifacts: Points

Intentional edge grinding is the most uniform and perhaps, surprisingly, essential observation for bifaces generally. On points, this lateral grinding mostly extends across the proximal, or base, end and onto both adjacent edges. It is the prime way to identify the haft element. Haft grinding would have been the last step in point manufacture as it obscures the negative bulbs of percussion produced in the final pressure flaking. Haft element grinding is present on at least 14 of the 20 points in the Angostura sample; arguably it also occurs on three other specimens – two medial point segments (Specimens 16 and 1-Figures 18c and 21d) and one distal point fragment, or tip (Specimen 3-Figure 21a).

Edge grinding occurs on a TRSS, horizontal flaked point proximal fragment (Specimen 13-Figure 23a and Figure 24), but not on its base, which is highly unusual and instructive. Its edge grinding is actually well up from the base and continues to the broken tip. The fracture at the opposite end is due to heat or thermal failure. The specimen likely was being reworked. The base was newly created from the tip end. Reversing the ends corrected earlier breakage. It was rejected due to thermal fracture, which may have been an unsuccessful attempt to rework the tip. From this perspective, its edge grinding denotes the original (and now

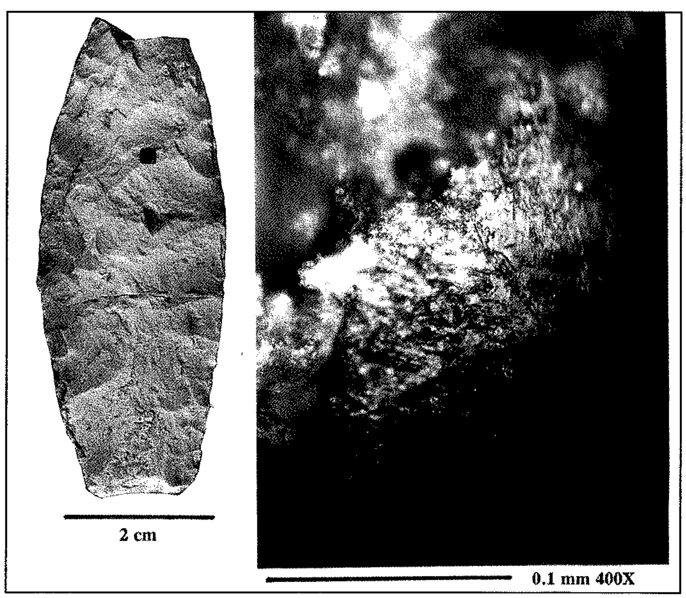

Figure 24. Oriented photomicrograph of striated residue due to use as a projectile point and then as a knife (Specimen 13).

distal) basal end and clearly occurred late in tool manufacture. Its wear traces (Figure 24) are additive and have a clear sequencing of striae parallel to the longitudinal axis crosscut by striae transverse and obliquely oriented to it.

These occur and are best expressed along the midline of the blade, and are deeply invasive. Its use-wear is consistent with experimental analogs (Kay 1996) and follows a basic division in initial tool function as a projectile, resharpening (that removed edge-related wear traces), and alternative, ad hoc use as a knife point. The most critical wear trace observation in this respect is sequencing of striae, identified by their crosscutting relations.

Projectile impact striae originate at the tip and generally parallel the tool's longitudinal axis. Striae transverse to the longitudinal axis of the tool are consistent with usage as a knife and originate at the blade edges rather than the tip. When impact striae are either crosscut by, or themselves crosscut striae that are transverse to the longitudinal axis, it is possible to determine the order of contrastive tool usage. A reasonable explanation, for this specimen, would be use as a projectile point and then as a knife. This distinction may relate to the presence or absence of basal grinding for the parallel oblique and horizontal flaked points, as tool use evidence is virtually identical. Examples with ground bases display wear traces typical of initial usage as projectile points. Two each are horizontal flaked quartzite (Specimens 8 and 22-Figures 23f and 25b) and either horizontal or parallel oblique flaked chert (Specimens 3 and 51-Figures 21a and 23d) points.

One of the quartzite specimens (Specimen 22-Figure 25b) broke on impact and then continued to be used as a knife (Figure 26). One of the chert specimens is horizontal flaked (Specimen 51-Figure 23d) and appears to have had its ends reversed, although it is possible the wear traces relate to haft instability; the other is parallel oblique flaked (Specimen 3-Figure 21a) and shows a sequence of alternate usage that begins as a projectile, then a knife, and then a projectile point again. A fifth tool, of quartzite and without basal grinding but parallel oblique flaked (Specimen 10-Figure 21b), presents a logical contrast, as it was initially used as a knife and then as a projectile point (Figure 27).

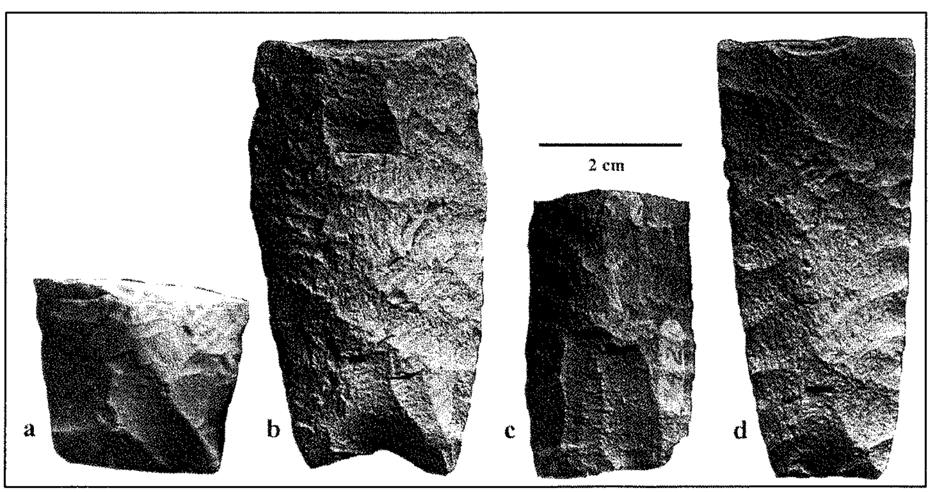

Figure 25. Impact fractures on reworked point bases: a) Specimen No. 15; b) Specimen No. 22; c) Specimen No. 18; d) Specimen No. 7.

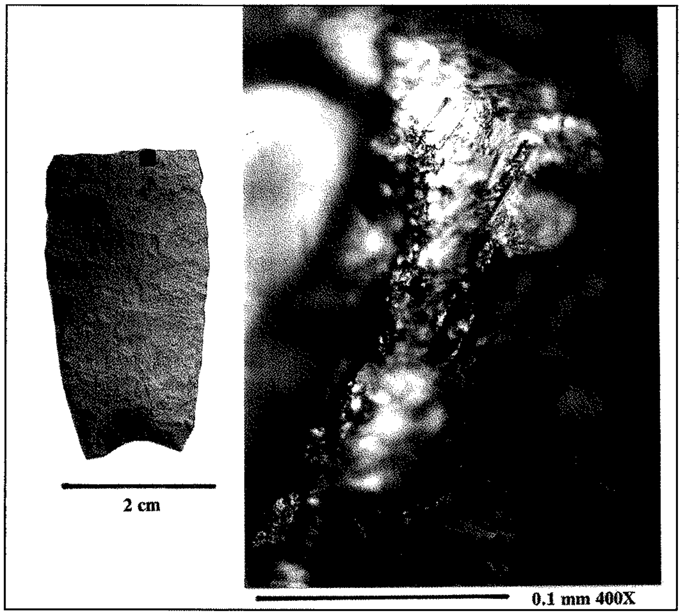

Figure 26. Oriented photomicrograph of sequential use-wear at the edge of broken point (Specimen No. 22). Note the striae slightly oblique to the longitudinal axis of the tool that are probably due to impact, and that are crosscut by striae perpendicular to them that are likely due to use as a cutting tool.

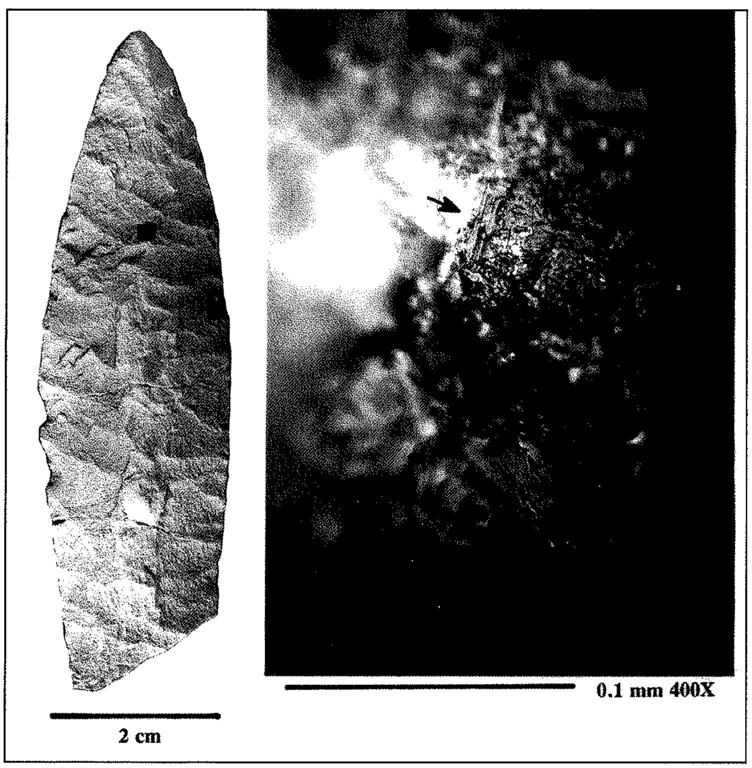

Figure 27. Oriented photomicrograph of sequential use-wear near the midline of point (Specimen No. 10). The arrow points to potential impact striae that crosscut striae due to usage as a knife.

Macroscopic evidence of projectile point usage normally is indicated by impact fractures to the tip, as seen on three ground-base horizontal flaked quartzite specimens (Specimens 17, 19 and 8-Figure 23b, c, and f) and one chert parallel oblique flaked tip (Specimen 3-Figure 21a). In contrast, at least four points (Specimens 7, 15, 18 and 22-Figure 25), of which at least three (Specimens 15, 22 and 7-Figure 25a, b, and d) are horizontal flaked, have unambiguous negative impact scars that originate at the proximal end of a usually ground base, or what originally would have been the broken tip end. On one of these (Specimen 18-Figure 25c), the impact fractured tip was reworked as a new base but without lateral edge grinding. One of the quartzite specimens (Specimen 22-Figure 25b) broke on impact and then continued to be used as a knife (Figure 26).

On two other parallel oblique flaked ground bases (Specimens 52 and 53-Figure 22e, f), impact fractures are also apparent at the proximal end. Microscopic repair by grinding that overrides impact-related step fractures is apparent. Thus, if only for five of these six broken specimens, edge grinding was part of the optional maintenance needed to rework the points by reversing their ends and fashioning a new base. Basal repair of these lanceolates by *reversing* the ends actually appears to have been quite common, although we do not know the exact number. Only one parallel oblique flaked specimen (Specimen 54-Figure 21c) can be categorically regarded as not having a reworked proximal edge, but its clearly reworked tip was recycled as a drill or perforator as Hughes (1949:270) stated. Its deeply convex base displays no step fractures and is broadly ground. Its convex base contrasts with the straight to concave bases of the other points. Hughes (1949:270) regarded its basal configuration as anomalous. Yet, the base is consistent with its likely preforms; it may be the only original one in the sample.

IMPLICATIONS

The obvious implication of the consistent approach (i.e., the "Bradley" approach) to lateral grinding for point manufacture *and* repair is to minimize the likelihood of edge step fractures. This consideration was important in that it allowed for extended maintenance of the tools, which clearly was desired, and also made sense as an appropriate motor habit exercised throughout the manufacture process. Edge grinding was part of a deliberate, well-thought-out strategy for manufacture and maintenance of Paleoindian lanceolates more generally.

Identical lateral grinding occurs on the Ray Long fluted lanceolate and is common on Clovis points (Kay 1996). The objective always appears to have been to ensure a high state of reliability (Bleed 1986) for these armatures, even were it doubtful a specialist was required to accomplish this operation. The repair option was literally built into their initial design. As long as there was sufficient length to attach a reworked point to a foreshaft, optional maintenance by reworking the base or reversing the ends would proceed with little if any alteration to point width and thickness. Thus, we would expect maximum width/thickness ratios to be reliable measures of initial engineering design criteria for these lanceolates, and useful for comparisons.

When a lanceolate would no longer be considered repairable, and would likely be discarded, may be judged from the lengths of both individual point specimens and probable haft elements (identified by the lateral extent of basal grinding). The minimum effective length for retooling the ground base points must have been no less than about 68 mm, the length of the lanceolate with reversed ends and a thermally fractured new tip (Specimen 13-Figure 23a). No ground base point fragment comes anywhere close to this 68 mm value for retooling. The only specimen

(Specimen 8-Figure 23f) to exceed this value is both impact-fractured and much narrower than most of the other ground base points. It seems a likely reject too, but primarily because its blade width would not easily have allowed further resharpening. With one exception (Specimen 7-Figure 25d), each basal fragment is less than the average ground haft lengths of 34.25 mm for the four more-or-less complete points or of 35.4 mm for five proximal point fragments with perverse impact fractures.

The lanceolate base fragments (Figures 18d, 22, and 25) of quartzite exhibit grinding primarily, and seemingly were broken in either use or in retooling. Most have transverse breaks due to bending, or snapping caused by the unequal application of force to one or the other end. These bending breaks are common, secondary effects of impact damage to projectile points and typically occur in the haft binding. But they can also happen when a knife blade is levered against a bone. Either situation would be plausible given the use-wear evidence. Each also appears to be a reject, in that none is large enough to have been further reworked. Not a single point specimen would be classed as usable. All appear to be at the end of their use-lives and were likely rejects.

Not all, however, exhibit basal edge grinding. The one used initially as a knife, and then as a point (Specimen 10-see Figure 21b), was not. The mostly ground-base specimens were initially used as projectile points.

Variability in Paleoindian point forms has long been recognized (cf., Davis 1954; Holder and Wike 1949; Hughes 1949) although we are still at some pains to explain it. The points in this study sample had extended use-lives and what appears to have been a deliberate engineering design strategy to prolong maintenance. Breakage did not foreclose further use. The likelihood of breakage followed by repair principally by reversing the broken ends seems to have been built into the original lanceolate design of the point type. These were often broken, reworked, and used again. Undoubtedly, these tools were highly valued and were maintained until further retooling was impractical or impossible. Width and thickness stayed much the same throughout a point's use-life. The threshold for rejection and discard was a maximum length less than 68 mm. The collection is replete with examples of this kind. Indeed, it seems that not one point in the sample set measuring less than 68 mm in length was actually regarded as anything other than a functional reject, or one at the absolute end of its use-life.

Comparative Point Specimens

The points from the Angostura type site, Ray Long, were also compared to several other collections from South Dakota, Nebraska, and Montana. The author examined these collections except for those from two sites in Medicine Creek Reservoir, Nebraska. Pertaining especially to Ray Long, but also applicable to the others, is that the few complete specimens are eclipsed by fragmented ones. Breakage occurred during manufacture, use, and further optional maintenance.

The Buster Hill site (39MD145), also in the Black Hills of South Dakota, produced comparative materials (Kay 1997a) in deposits dating to 7690 ± 210 RCYBP (Hannus et al. 1997:11.1). Using CALIB 6.0 and the INTCAL09 calibration curve (Reimer et al. 2009), the date produced a calibrated range of 9015-8045 cal B.P., or 7066-6096 B.C. at two standard deviations. If this date reflects the Angostura occupation at Buster Hill, it is more recent than the Ray Long Angostura occupation, which dates around 8250 B.C. Four points from Buster Hill had originally been classified as Angostura (Figure 28, Specimens P2, P5, P10 and P11). Kay and Bradley's reevaluation classified three additional points as Angostura, two of which had been previously classified as James Allen (Figure 28, Specimens P4, and P6/9) and one that had been unclassified (Figure 28, Specimen P74); all but one are of quartzite. Specimen P2 is very wide and produced on jasper. At least one has clearly reversed ends (Specimen P5-Figure 22g).

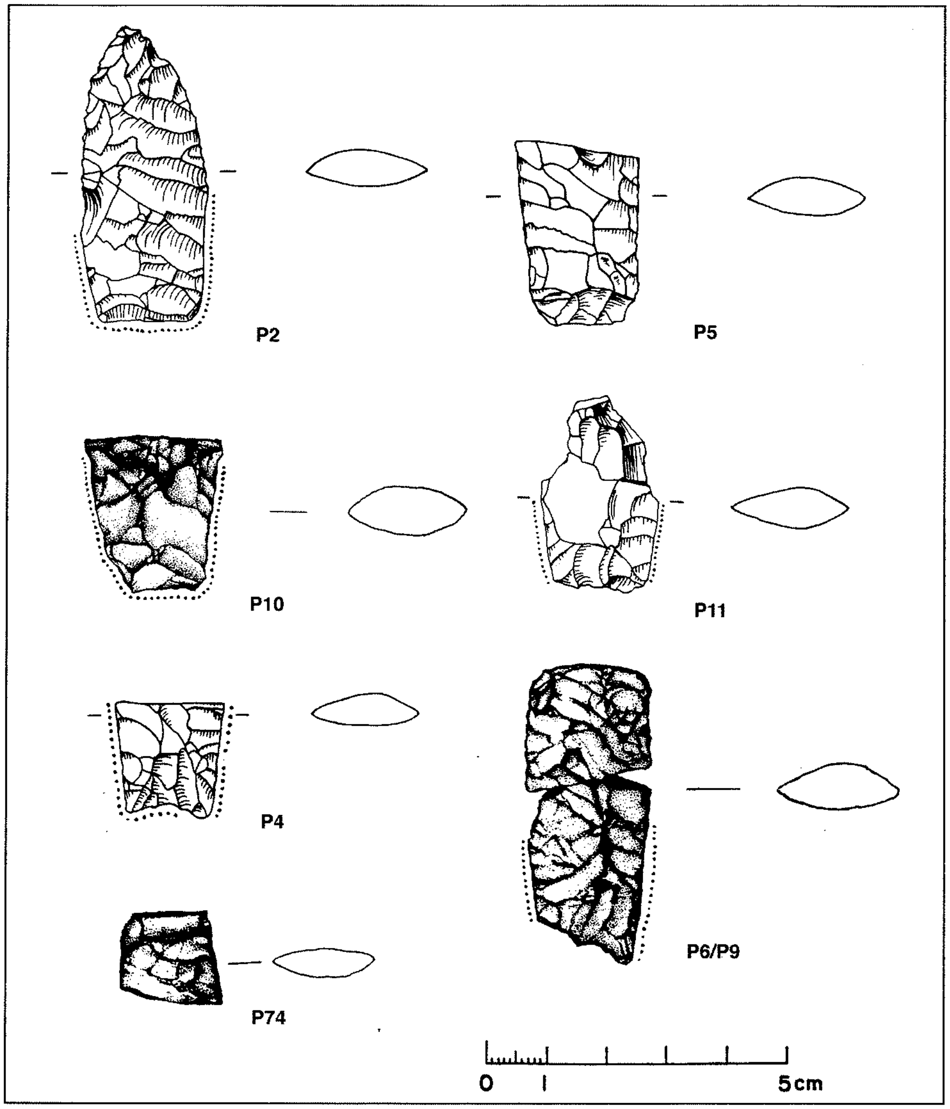

Figure 28. Projectile points examined from the Buster Hill site (39MD145) (from Hannus et al. 1997:Figures 13.3, 13.5, and 13.23).

Measurements for these Buster Hill point fragments are provided in Table 4. All but Specimens 4 and 74 are significantly thicker than the Ray Long Angostura points, with the width/thickness ratio generally under 3.0, whereas all but one of the Ray Long specimens has a width/thickness ratio *over* 3.0. Classifying these specimens as Angostura would expand the range of variation of the type. Based on the fragmentary nature of the Buster Hill sample and the lack of secure association, such a classification may not be advisable at this time.

Table 4. Select Projectile Point Measurements from the Buster Hill Site (39MD145).

Specimen No.	Completeness	Length (mm)	Width (mm)	Thickness (mm)	Width/ Thickness Ratio
2	Complete	49.74	21.70	7.32	2.96
4	Proximal	19.28	18.30	6.16	2.97
5	Proximal	30.79	20.42	7.22	2.83
6/9	Proximal	51.00	21.48	8.48	2.53
10	Proximal	26.00	22.94	8.64	2.65
11	Proximal	33.38	19.71	7.32	2.69
74	Midsection	16.15	17.55	4.95	3.54

Five of the seven Buster Hill specimens qualified for Pitblado's (2007:321) discriminant functional analysis designed to distinguish Angostura projectile point types from Jimmy Allen points; Specimens 74 and 6/9 could not be included in the analysis because they lack complete bases. According to the formula, all of the five analyzed specimens fit Pitblado's classification of Angostura.

Also of generally smaller effective minimum size are Alder complex, Ruby Valley points that date to 9400 RCYBP and come from the Barton Gulch site (24MA171), in western Montana (Davis et al. 1988, 1989, 1998). The Ruby Valley points clearly share the same technology as Angostura (Figure 29). Their raw materials are also dominated by quartzite. In many instances they would be indistinguishable from Angostura, as would similar but unnamed specimens from Canyon Ferry Reservoir (24LC611), a second western Montana site that the author examined when analyzing the Ruby Valley points from Barton Gulch.

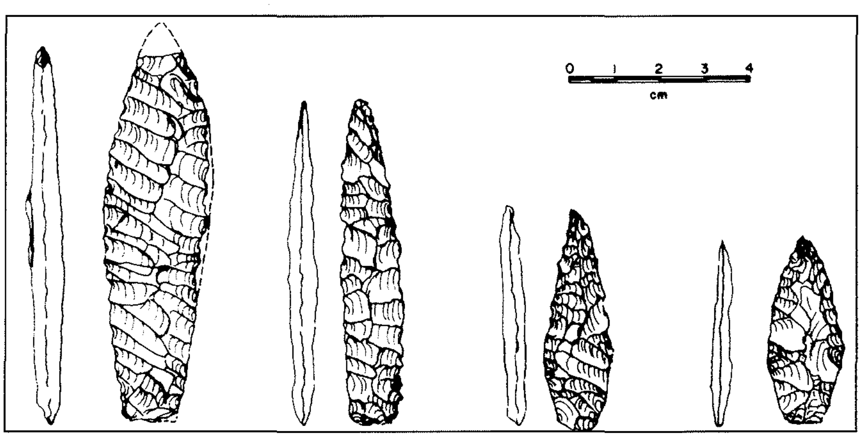

Figure 29. Alder complex Ruby Valley projectile points from the Barton Gulch site (from Davis et al. 1989:Figure 1).

Other parallel obliquely flaked point fragments that are similar to, if not actually being, Angostura come from the investigations of Medicine Creek Reservoir, Frontier County, Nebraska. Two unprovenienced specimens, of quartzite, are from the Allen site (Bamforth 1991b:391). A third specimen, of green-brown jasper, comes from Zone III, the uppermost Paleoindian component, of the Lime Creek site (Davis 1962:47 and Figures 20C, 28; see also Davis 1953, 1954; Davis and Schultz 1952). The Lime Creek specimen (Figure 30) was found in the same stratum as two other lanceolates originally described as Plainview and Milnesand by E. Mott Davis.

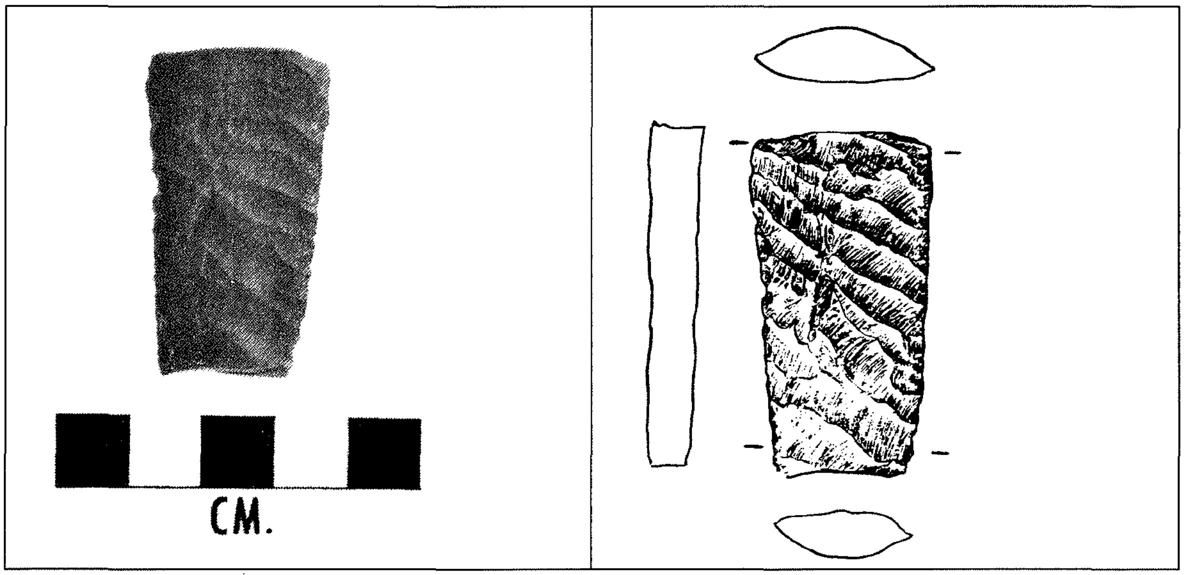

Figure 30. Lime Creek specimen (from Davis 1962:Figures 20c and 28).

A Synthesis: Angostura and Ray Long in the Context of North American Late Paleoindian Archeology

Twenty-one years ago, in response to concerns over wave-action destroying portions of the Ray Long site (39FA65), Reclamation entered into a cooperative agreement with ALAC to further investigate the site area. The agreement, which has since been revised and amended, had both research and management objectives. The research objective centered on the resolution of questions originally raised by Richard P. Wheeler as a result of the 1948-1950 Smithsonian Institution (SI) River Basin Survey (RBS) excavations at the Ray Long site. The unanswered questions concerned the stratigraphy and geomorphology of the site as well as the relationship of the Angostura complex chronologically and culturally to the broader Paleoindian tradition. The management objective focused on an assessment of ways to stabilize and protect the site from further erosional damage and how to implement a plan that would only minimally impact any remaining archeological deposits.

What follows is a summary of ALAC's research results from fieldwork at the Ray Long site (see also Buhta et al. 2012; Hannus et al. 2012), a discussion concerning the definition of the Angostura complex, an overview of the future of the Ray Long site from a management perspective, and a series of avenues for further exploration.

Ray Long Site Research: A Summary and Synthesis

Between 1948 and 1950, Richard Wheeler oversaw excavations at the Ray Long site as part of the SI's broader RBS initiative. The results of Wheeler's research at Ray Long were published in 1995 (Wheeler 1995:372-450) and subsequently summarized by ALAC as part of the present study (Buhta et al. 2012:40-49). ALAC's involvement at the site began with limited test excavations in 1985 (Hannus 1986), continued intermittently between 1992 and 2000, and culminated with additional investigations in 2010 (Buhta et al. 2012; Hannus et al. 1993, 2012). The South Dakota State Historical Society, Archaeological Research Center (ARC), Rapid City, South Dakota, briefly visited the Ray Long site in 1987 and excavated one test unit (Haug 1987:3). However, the exact location of the excavation unit and the results of the testing were not published. The results of the previous investigations at Ray Long are summarized and compared below. For more detailed discussions, refer to the above-listed reports.

Wheeler (1995) identified three distinct localities at the Ray Long site: Areas A, B, and C (see Buhta et al. 2012:41 – Figure 21). Areas A and B were further explored by ALAC; Area C was destroyed by reservoir wave-action prior to ALAC's work at the site. The three site localities are individually addressed below.

Area A Findings

The most conclusive evidence of the Angostura occupation at Ray Long comes from Wheeler's investigations at Area A of the site (see Wheeler 1995:427-440). This is the only portion of the site from which diagnostic Angostura projectile point fragments were recovered from buried, datable contexts; Angostura artifacts from Areas B and C were documented on the surface.

Area A is the easternmost of the three localities at Ray Long and is situated on the upper midsection of the alluvial fan landform about 630 ft southeast of Area B and 830 ft southeast of Area C (Wheeler 1995:395). Investigations at Area A were initiated by Wheeler in 1948 and RBS work continued there in both 1949 and 1950. RBS crews excavated 46 complete and eight partial 5-ft-x-5-ft (ca. 1.5-m-x-1.5-m) units at Area A (see Buhta et al. 2012:41 – Figure 22). These excavations resulted in the documentation of 13 settlement features, including 10 unprepared hearths and three lithic workshop loci (Table 5).

Table 5. Summary of Settlement Features Documented During RBS Investigations at Area A, Site 39FA65.

Feature No.*	Feature Type/ Description	Feature Provenience	Radiocarbon Date(s) Obtained?	Reference
1	Lithic workshop loci	Units B2R3, B3R3, B2R4, and B3R4; 4.48 ft (1.37 m) below surface	No, but charcoal lots are curated under catalog nos. 34, 44, and 45 at SI MSC	Wheeler 1995:434
2	Unprepared heavily fired hearth	Units B3L4 and B3L3; 4.66 ft (1.42 m) below surface	No, but charcoal lot is curated under catalog no. 127 at SI MSC	Wheeler 1995:432-433
4	Unprepared lightly fired hearth	Units B3L4 and B3L3; 5.46 ft (1.66 m) below surface; Angostura point base 0.2 ft (0.06 m) above feature	No, but charcoal lots are curated under catalog nos. 57, 59, and 157 at SI MSC	Wheeler 1995:432
5	Lithic workshop loci	Unit B2R4; 4.38 ft (1.34 m) below surface	No, but charcoal lot is curated under catalog no. 36 at SI MSC	Wheeler 1995:434
6	Unprepared lightly fired hearth	Unit B3L2; 4.66 ft (1.42 m) below surface	No	Wheeler 1995:432
7	Unprepared lightly fired hearth	Units B3L2 and B3L3; 4.97 ft (1.51 m) below surface	No	Wheeler 1995:432
11	Unprepared lightly fired hearth	Unit B1L2; 4.92 ft (1.50 m) below surface	No	Wheeler 1995:432
12	Unprepared heavily fired hearth	Unit B1R4; 4.48 ft (1.37 m) below surface; many lithic flakes recovered from fill	No	Wheeler 1995:432-433
14	Unprepared lightly fired hearth	Unit B1L2; 5.02 ft (1.53 m) below surface; Angostura point tip found on hearth	No	Wheeler 1995:432
16	Unprepared heavily fired hearth	Units B1R4 and B1R5; 4.55 ft (1.39 m) below surface; several flakes found in fill	No	Wheeler 1995:432-433
17	Lithic workshop loci	Unit B1L1; 4.99 ft (1.52 m) below surface	No	Wheeler 1995:434
18	Unprepared heavily fired hearth	Units B1R1 and B1R2; 6.0 ft (1.83 m) below surface	No	Wheeler 1995:432-433
19	Unprepared heavily fired hearth	Unit B1R6; 5.16 ft (1.57 m) below surface; Angostura point tip found 0.48 ft (0.15 m) above hearth and 2 Angostura bases found in hearth fill	No	Wheeler 1995:432-433

*** Wheeler also assigned feature numbers to in situ Angostura point fragments; however, only settlement features are tabulated here.**

Artifacts recovered from Area A include 29 complete and fragmentary tools, 1,097 pieces of lithic debitage, and one lot of unidentifiable burned bone fragments (Table 6). The majority of the lithic reduction material consists of small and minute waste flakes, 1,066 of which are of various colors of fine-grained and very fine-grained quartzite, the material from which most of the Angostura points from the site were produced (Wheeler 1995:434). Also collected from Area A were 42 charcoal samples from various contexts. One sample was collected from talus screening, two samples were collected from bulk soils (one from the upper soil stratigraphic unit and one from the lower), and 39 samples were collected from hearths and additional localities within the 1948/1949 excavation grid. Only one of the collected samples – the bulk sample from the lower soil stratigraphic unit in which the Angostura material was documented – was submitted for radiocarbon assay; it yielded a date of 9380 ± 500 RCYBP (Wheeler 1995:440). The additional charcoal samples collected are curated at the SI's Museum Support Center (MSC), including samples from the upper soil stratigraphic unit (Catalog No. 381) and the fill of hearth Feature 2 (Catalog No. 127) (see Buhta et al. 2012:48).

Table 6. Summary of Artifacts Documented During RBS Investigations at Area A, Site 39FA65.

Artifact Type	Artifact Count	Artifact Provenience*	Notes	Reference
Lithic flake	1,097	Surface and Units	1,066 are of fine-grained quartzite of the type used to produce the majority of Angostura points from the site	Wheeler 1995:434
Lithic tool	29	Surface and Units	Includes 9 Angostura point fragments; 2 knives; 1 drill possibly reworked from an Angostura point; 9 scrapers; 3 utilized flakes; 2 choppers; 1 engraver; 1 hammerstone; and 1 palette	Wheeler 1995:435-439

*** See Buhta et al. 2012: Appendix K for complete catalog specifics**

Seven of the nine Angostura point fragments documented by Wheeler were recovered in situ from intact, buried contexts. Several of these were directly associated with datable settlement features (see Table 5, above).

ALAC investigated Area A in 1994 and again in 1998 (Hannus et al. 2012:27-29, 74-80). Four 1-m-x-1-m units were opened adjacent to the SI RBS excavation grid in Area A in 1994. Three of the four units investigated were devoid of cultural material; the fourth unit yielded one small, unidentifiable bone fragment and one small tertiary flake of fine-grained quartzite (Table 7; see Hannus et al. 2012:29).

In 1998, excavations at Area A were more extensive. It was felt that Area A warranted further attention because it was the only locality at 39FA65 to have yielded in situ Angostura material. A 15-m-x-5-m grid was established so that it partially overlapped the SI's 1948-1950 excavation area; the grid included the four units originally opened in 1994. A total of 15 1-m-x-1-m units were opened in the grid, and five backhoe trenches were also excavated in and adjacent to the area (see Hannus et al. 2012:74 – Figure 97).

Table 7. Summary of Artifacts Documented During ALAC Investigations at Area A, Site 39FA65.*

Artifact Type	Artifact Count	Artifact Provenience	Notes	Reference
Lithic flake	7	Surface and Units 2N 2E, 9N 0E, 11N 0E, and 14N 3E	6 are of fine-grained quartzite of the type used to produce the majority of Angostura points from the site	Hannus et al. 2012:29, 75-76
Faunal	1	Unit 14N 3E	Unidentifiable fragment	Hannus et al. 2012:29

*** See Hannus et al. 2012: Appendix I for complete catalog specifics**

Despite increased efforts at Area A in 1998, excavations yielded equally as little as in 1994. Of the 15 units excavated during the 1998 field season, 10 were sterile. The remaining five units yielded a total of five fine-grained quartzite tertiary flakes and two ephemeral, unprepared hearth features (Table 8; see Table 7). This material was all documented at between 1.62 and 1.69 mbs at the transition between the clay-sand facies and coarse clast facies soil stratigraphic units estimated by Mandel (2012:23 – Figures 6 and 7) to be the Angostura occupation surface. Although this surface lies at a depth of 1.54 mbs in the Trench I profile that Mandel documented adjacent to the Area A grid, it extends into the grid area at a slightly lower depth.

Table 8. Summary of Settlement Features Documented During ALAC Investigations at Area A, Site 39FA65.

Feature No.	Feature Type/ Description	Feature Provenience	Radiocarbon Date(s) Obtained?	Reference
98-1	Unprepared lightly fired hearth. Shallow and amorphous w/scattered charcoal flecks and staining	Units 11N 0E and 11N 1E; 1.33-1.36 m below surface. Associated with 2 quartzite flakes.	8970 ± 50 (Sample No. 1A [GX-24603] AMS-dated charcoal); additional samples collected	Hannus et al. 2012:75-78
98-2	Unprepared lightly fired hearth	Unit 13N 0E; 1.33-1.34 m below surface. About 2 m southeast of F98-1.	No, but charcoal sample was collected from the feature fill	Hannus et al. 2012:29, 75-79

In addition to the AMS date obtained for Feature 98-1, ALAC collected four charcoal samples from Area A for AMS dating. Two of these samples were taken from the wall of trench 2A, which was cut across the Area A grid, at depths of 2.02 mbs (Sample No. 5 – GX-24607) and 1.84 mbs (Sample No. 6 – GX-24608), respectively. The other two samples were collected from Units 12N 0E (1.66 mbs [Sample No. 2A – GX-24604]) and 2N 2E (1.67 mbs [Sample No. 3A – GX-24605]) in close vertical and horizontal proximity to Wheeler's Features 19 and 17. Three of these samples yielded dates (Sample No. 2A: 8880 ± 50; Sample No. 3A: 9060 ± 50; and Sample No. 5: 9040 ± 50) that correspond well with Wheeler's original date for the Angostura occupation of Ray Long. Sample No. 6 yielded a date of 11,300 ± 80 from a depth of 18 cm *above* that of Sample 5; clearly this must have been a contaminated sample (see Buhta et al. 2012:11-12).

Area B Findings

Area B is the most extensively investigated of the three localities at Ray Long. RBS crews spent portions of the 1949 and 1950 field seasons investigating Area B (see Buhta et al. 2012:43-45 and Wheeler 1995:405-427) and ALAC conducted excavations at this locality in 1985 (Hannus 1986), 1992 (Hannus et al. 1993), 1993-1996, and 2010 (Hannus et al. 2012:20-73, 104-114). ARC also excavated a test unit at Area B during a brief visit in 1987 (Haug 1987:3).

Area B is situated near the distal end of the alluvial fan landform about 630 ft northwest of Area A and about 250 ft due east of Area C (Wheeler 1995:395). Investigations at Area B were initiated by Wheeler in 1949 and RBS work continued there in 1950. RBS crews excavated 18 complete, 30 "nearly complete," and six partial 5-ft-x-5-ft (ca. 1.5-m-x-1.5-m) units in two adjacent large bulldozer trenches (SI Trenches 1 and 2) (see Buhta et al. 2012:44 – Figure 23). These excavations resulted in the documentation of 12 settlement features, including 11 unprepared hearths and one large, amorphous burned area (Table 9).

Table 9. Summary of Cultural Features Documented During RBS Investigations at Area B, Site 39FA65.

Feature No.	Feature Type/ Description	Feature Provenience	Radiocarbon Date(s) Obtained?	Reference
2	Unprepared hearth	SI Trench 1, NW¼ of Unit N6; 3,199.2 ft (975.12 m) amsl; associated with a mano, 2 small flakes, and a charred mass of vegetal material	No but charcoal lot from F2 is curated under catalog no. 181 at SI MSC	Wheeler 1995:410-411
9	Unprepared hearth	SI Trench 1, NE¼ of Unit N5 E4; 3,199.19 ft (975.11 m) amsl	No	Wheeler 1995:409
10	Unprepared hearth	SI Trench 1, NW¼ of Unit N3 E3, SW¼ of Unit N4 E3, and parts of two other units to west; 3,197.82 ft (974.70 m) amsl	No but charcoal lot from F10 is curated under catalog no. 469 at SI MSC	Wheeler 1995:410
11	Large amorphous burned area (Wheeler felt this to be a disturbed hearth)	SI Trench 1, Unit N6 E3 (likely extends into N6 E4); associated with a mano; no absolute depth listed	No but charcoal lot from F11 is curated under catalog no. 507 at SI MSC	Wheeler 1995:411
12	Unprepared hearth	SI Trench 1, NE¼ of Unit N6 E1; 3,199.22 ft (975.12 m) amsl	No	Wheeler 1995:409
13	Unprepared hearth	SI Trench 1, Unit N3 E4; 3,198.26 ft (974.83 m) amsl	No	Wheeler 1995:410
14	Unprepared hearth	SI Trench 1, Unit N3 E3; 3,197.82 ft (974.70 m) amsl; associated with 1 lithic flake	Yes – one date: 7073 ± 300	Wheeler 1995:411
15	Unprepared hearth	SI Trench 1, Units N6 E5 and N7 E5; 3,200.84 ft (975.62 m) amsl	No	Wheeler 1995:410
16	Unprepared hearth	SI Trench 2, NW¼ of Unit N12 E8; 3,208.5 ft (977.95 m) amsl	No	Wheeler 1995:410
17	Unprepared hearth	SI Trench 2, E½ of Unit N12 E8; 3,208.4 ft (977.92 m) amsl	No	Wheeler 1995:410
19	Unprepared hearth	SI Trench 2, Unit N11 E8; 3,208.3 ft (977.89 m) amsl	No	Wheeler 1995:410
20	Unprepared hearth	SI Trench 2, Units N11 E7 and N12 E7; 3,208.55 ft (977.97 m) amsl	No	Wheeler 1995:411

Artifacts recovered from Area B by RBS crews include 45 complete and fragmentary tools, 161 pieces of lithic debitage, 5 small cores, and 3+ small unidentifiable bone fragments (Table 10; Wheeler 1995:411-426). All of the lithic reduction material consists of small and minute waste flakes, 128 of which are of various colors of fine-grained and very fine-grained quartzite, the material from which most of the Angostura points from the site were produced (Wheeler 1995:411). The tool assemblage from Area B consists of three incomplete Angostura projectile points, three biface preforms (which Wheeler interprets to be Angostura projectile point preforms), three bifacial knives, two distal drill tips, one complete drill, 12 scrapers, seven utilized flakes, three choppers, one hammerstone, two palette fragments, three metate fragments, and five manos (Wheeler 1995:412-426).

Table 10. Summary of Artifacts Documented During RBS Investigations at Area B, Site 39FA65.

Artifact Type	Artifact Count	Artifact Provenience*	Notes	Reference
Lithic core	5	Surface and SI Trench 1 (catalog only lists 2 specimens)	1 brown medium-grained quartzite, 2 chert, 1 moss agate, and 1 fine-grained quartzite	Wheeler 1995:411-412
Lithic flake	161	SI Trenches 1 and 2	128 are of fine-grained quartzite of the type used to produce the majority of Angostura points from the site	Wheeler 1995:411-412
Lithic tool	45	Surface and Units N7 E2, N10 E8, N2 E1, N7 E3, N12 E8, N6, and N8 E4	Includes 3 Angostura projectile point fragments; 3 biface preforms; 3 knives; 1 drill and 2 distal drill tips; 12 scrapers; 7 utilized flakes; 3 choppers; 1 hammerstone; 2 palette fragments; 3 metate fragments; and 5 manos	Wheeler 1995:412-426
Faunal	3+	SI Trench 2	3 small and several tiny unidentifiable fragments	Wheeler 1995:426

*** See Buhta et al. 2012: Appendix K for complete catalog specifics**

Also collected from Area B were 18 lots of charcoal and a mass of charred vegetal material consisting of small branches and grass stems. Two of the collected samples were submitted for radiocarbon assay. The first sample, collected from a 4-inch-thick (ca. 10.2-cm) lens of charcoal in Unit N7 E4 of Trench 1 at a depth of 1.8 ft (0.55 m) below surface, yielded a date of 7715 ± 740 RCYBP (Wheeler 1995:427). The second sample, collected from the fill of hearth Feature 14 in Unit N3 E3 of Trench 1, approximately 20 ft (ca. 6.1 m) southwest of the provenience of dated charcoal sample 1, yielded a date of 7073 ± 300 RCYBP (Wheeler 1995:427; see Buhta et al. 2012:45).

In SI Trench 1, all identified features and the vast majority of artifacts were documented between 3,197.82 and 3,199.63 ft (974.70-975.25 m) amsl, or within a 1.81-ft (0.55-m) range. Each was located within what Wheeler (1995:407) described as a zone of light gray brown massive weathered clay shale ("cs") with many pieces of limonite, gypsum, and flecks of charcoal.

In SI Trench 2, all features except one were documented stratigraphically between 3,208.20 and 3,208.55 ft (977.86-977.97 m) amsl, or a span of only 0.35 ft (0.11 m). Wheeler (1995:408) described this matrix as an undulating, discontinuous charcoal lens within a zone of light yellowish gray sandy clay ("sc").

The soil stratigraphic units containing the bulk of cultural deposits in SI Trenches 1 and 2, as described above, are clearly different from one another. Of the 11 settlement features documented by Wheeler in Area B, only two of them, Features 2 and 14, were documented in association with artifacts. These features, located in Trench 1, are separated stratigraphically by 1.38 ft (0.42 m) but lie within the same soil stratigraphic unit – described by Wheeler (1995:407) as the "cs" zone. Overall, however, features documented within SI Trenches 1 and 2 vary from one another stratigraphically as much as 10.73 ft (3.27 m), or an average of 9.65 ft (2.94 m).

ALAC's investigations at Area B spanned seven field seasons between 1985 and 2010. During that time, eight backhoe trenches (Trenches A-C, E-F, and portions of G, L, and M) were opened, one 1-m-x-1-m unit was excavated in the wall of Trench M, one 1-m-x-1-m unit was excavated along the western scarp edge of the site just west of SI Trench 1, and a grid block consisting of 15 contiguous 1-m-x-1-m units just east of SI Trench 2 was excavated. A total of 18 ephemeral hearth features, characteristically similar to those identified by Wheeler, were documented during ALAC's seven field seasons at Area B. In addition to these features, 45 artifacts, most of which were surface specimens, were documented. Among these artifacts were three Angostura projectile point fragments; all were identified surficially in a deflated area east of SI Trenches 1 and 2 and ALAC's block B grid. Only one other artifact, a bifluted projectile point base, is culturally diagnostic, and although it was discovered buried in the block B grid, there is reason to believe that it was removed from its original context prior to discovery (see Hannus et al. 2012:57-61). The complete artifact assemblage from ALAC's investigations at Area B includes 32 flakes, two pieces of shatter, one mammal bone fragment (possible pronghorn), and 10 complete or fragmentary lithic tools (Table 11; see Hannus et al. 2012). Seven additional artifacts were documented elsewhere on the surface of the site in 2010; however, these are not from the Area B locality (see Hannus et al. 2012:105 – Figure 132).

Table 11. Summary of Artifacts Documented During ALAC Investigations at Area B, Site 39FA65.*

Artifact Type	Artifact Count	Artifact Provenience*	Notes	Reference
Lithic reduction detritus	34	Surface and Units XU-1, 8N 1W, 8N 2W, 8N 3W, 8N 5W, 8N 6W, 9N 1W, 9N 2W, 9N 4W, and 10N 3W	32 are flakes and 2 are shatter; 11 specimens were surface collected	Hannus 1986; Hannus et al. 1993; Hannus et al. 2012
Faunal	1	Unit XU-1 backdirt pile	Unidentifiable mammal fragment (possible pronghorn)	Hannus et al. 2012
Lithic tool	10	Surface and Units 9N 3W/9N 4W, 9N 2W	1 mano and 1 fluted point base recovered in situ from grid block; 3 Angostura point fragments, 1 scraper, 3 biface fragments, and 3 knife fragments recovered from surface	Hannus 1986; Hannus et al. 1993; Hannus et al. 2012

*** See Hannus et al. 2012: Appendix I for complete catalog specifics**

In general, each of the 18 settlement features documented in Area B by ALAC fit the description of Wheeler's (1995:409-411) unprepared hearths – generally small to medium-sized, shallow, amorphous-to-roughly-circular zones of reddened or burned soil with flecks of charcoal scattered in-and-around the basins. One was recorded in Unit XU93-1, four were recorded in Trench F, and the remaining 13 were recorded in the block B grid. Table 12 provides a list of these features with absolute elevational data that, where possible, are correlated with soil stratigraphic units profiled by Mandel (2012). It is critical to note that, because of the westward-sloping nature of the fan (nearly a 5 percent grade) in this locality, absolute elevational data and soil stratigraphic units are not necessarily consistent across Area B.

Table 12. Summary of Settlement Features Documented During ALAC Investigations at Area B, Site 39FA65.

Feature No.	Feature Type/ Description	Feature Provenience	Radiocarbon Date(s) Obtained?*	Reference
85-1	Ephemeral, unprepared hearth (soil staining and charcoal concentration)	Trench F; 3,206.56 ft (977.31 m) amsl; likely correlates with soil stratigraphic Unit 8 in the block B grid	10,400 ± 360 (Sample No. I-14245 – date from charcoal)	Hannus 1986:12
85-2	Ephemeral, unprepared hearth (soil staining and charcoal concentration)	Trench F; lies directly atop F85-1; likely correlates with soil stratigraphic Unit 8 in the block B grid	9549 ± 540 (Sample No. I-14240 – date from charcoal)	Hannus 1986:12
85-3	Ephemeral, unprepared hearth (soil staining and charcoal concentration)	Trench F; lies directly below F85-1; likely correlates with soil stratigraphic Unit 8 in the block B grid	11,000 ± 310 (Sample No. I-14241 – date from charcoal)	Hannus 1986:12
85-4	Ephemeral, unprepared hearth (soil staining and charcoal concentration)	Trench F; 3,209.32 ft (978.20 m) amsl; may correlate with soil stratigraphic Unit 3 in the block B grid	8950 ± 140 (Sample No. I-14239 – date from charcoal)	Hannus 1986:12
93-1	Ephemeral, unprepared hearth (soil staining and charcoal concentration)	Trench M (and SI Trench 1), XU93-1; 3,199.20 ft (975.11 m) amsl; 0.43 ft (0.13 m) below zone containing most of artifacts and features in SI Trench 1; in Wheeler's "clay-shale" soil stratigraphic unit	8545 ± 65 (Sample No. I-18881 – AMS date from charcoal)	Hannus et al. 2012:25-26
94-2	Ephemeral, unprepared hearth (soil staining and charcoal concentration)	Unit 9N 6W; 3,206.36 ft (977.30 m) amsl; soil stratigraphic Units 8/9	No	Hannus et al. 2012:38-40
94-3	Ephemeral, unprepared hearth (soil staining and charcoal concentration)	Unit 9N 6W; 3,206.33 ft (977.29 m) amsl; soil stratigraphic Units 8/9	No	Hannus et al. 2012:40-41
94-4	Ephemeral, unprepared hearth (soil staining and charcoal concentration)	Units 9N 3W and 9N 4W; 3,207.12 ft (977.53 m) amsl; soil stratigraphic Unit 7 (base); adjacent to mano	9150 ± 230 (Sample No. I-17779 – AMS date from charcoal)	Hannus et al. 2012:41-44
94-5	Ephemeral, unprepared hearth (soil staining and charcoal concentration)	Unit 8N 3W; 3,206.76 ft (977.42 m) amsl; soil stratigraphic Unit 7	No	Hannus et al. 2012:43-44

Table 12 (continued).

Feature No.	Feature Type/ Description	Feature Provenience	Radiocarbon Date(s) Obtained?*	Reference
95-2	Ephemeral, unprepared hearth (soil staining and charcoal concentration)	Unit 10N 2W; 3,206.50 ft (977.34 m) amsl; soil stratigraphic Unit 8	8993 ± 87 (Sample No. I-18480 – AMS date from charcoal)	Hannus et al. 2012:57-58
95-3	Ephemeral, unprepared hearth (soil staining and charcoal concentration)	Unit 9N 2W; 3,206.50 ft (977.34 m) amsl; soil stratigraphic Units 8/9	7862 ± 88 (Sample No. I-18481 – AMS date from charcoal)	Hannus et al. 2012:58-59
95-4	Ephemeral, unprepared hearth (soil staining and charcoal concentration)	Unit 10N 2W; 3,206.00 ft (977.19 m) amsl; soil stratigraphic Units 9/10	No	Hannus et al. 2012:59-60
96-1	Ephemeral, unprepared hearth (soil staining and charcoal concentration)	Unit 9N 3W; 3,206.27 ft (977.27 m) amsl; soil stratigraphic Units 8/9	No	Hannus et al. 2012:67
96-2	Ephemeral, unprepared hearth (soil staining and charcoal concentration)	Unit 8N 6W; 3,206.00 ft (977.19 m) amsl; soil stratigraphic Units 8/9	No	Hannus et al. 2012:68
96-3	Ephemeral, unprepared hearth (soil staining and charcoal concentration)	Unit 8N 2W; 3,207.09 ft (977.52 m) amsl; soil stratigraphic Unit 7	No	Hannus et al. 2012:69-72
96-4	Ephemeral, unprepared hearth (soil staining and charcoal concentration)	Unit 8N 5W; 3,205.12 ft (976.92 m) amsl; soil stratigraphic Unit 11 (top)	No	Hannus et al. 2012:72-73
10-1	Ephemeral, unprepared hearth (soil staining and charcoal concentration)	Unit 9N 6W; 3,205.48 ft (977.03 m) amsl; soil stratigraphic Unit 10	9150 ± 25 (Sample No. A1695 – AMS date from charcoal)	Hannus et al. 2012:111-112, 114
10-2	Ephemeral, unprepared hearth (soil staining and charcoal concentration)	Unit 9N 6W; 3,205.15 ft (976.93 m) amsl; soil stratigraphic Unit 11	No	Hannus et al. 2012:112-113

*** See Buhta et al. 2012:1-16 for detailed discussion on radiocarbon dates from these and other features**

Three of the sixteen units excavated at Area B (Units 8N 4W, 9N 5W, and 10N 1W) were sterile. Of the remaining 13 units, four (XU93-1, 9N 3W, 9N 6W, and 10N 2W) were devoid of artifacts but contained features and three (8N 1W, 9N 1W, and 10N 3W) yielded artifacts but contained no features; the remainder (8N 2W, 8N 3W, 8N 5W, 8N 6W, 9N 2W, and 9N 4W) yielded artifacts as well as features (Table 13).

Eleven soil stratigraphic units were identified in Area B, and Mandel (2012:28 – Figure 9) profiled nine of these during his 2010 geomorphological investigation (stratigraphic Units 1 and 2 had previously been removed as overburden and could not be profiled). The majority of the cultural material was documented from soil stratigraphic Unit 7 down through the top of Unit 9. Three Area B features were identified in association with soil stratigraphic Unit 7 (F94-4, F94-5, and F96-3), four were associated with Unit 8 (85-1, 85-2, 85-3, and 95-2), five were associated with the transition between stratigraphic Units 8 and 9 (94-2, 94-3, 95-3, 96-1, and 96-2), one was associated with the transition between Units 9 and 10 (95-4), one was associated with Unit 10 alone (10-1), two were associated with Unit 11 (96-4 and 10-2), and one is likely associated with Unit 3 (85-4). ALAC's soil stratigraphic units from the block B grid could not be definitively correlated with Wheeler's stratigraphic units from SI Trenches 1 and 2.

Table 13. Cultural Material from Block B Grid by Excavation Unit, Depth Below Surface, and Soil Stratigraphic Unit.

Excavation Unit	Features Present (^{14}C date if dated)	Artifacts Present	Elevation(s) amsl	Soil Stratigraphic Context
93-1	93-1 (8545 ± 65)	—	3,199.20 ft (975.11 m)	Wheeler's "cs" zone
8N 1W	—			
		1 tertiary flake	979.64-977.64 m	Unit 1-7?
8N 2W	96-3		3,207.09 ft (977.52 m)	Unit 7
		2 tertiary flakes	979.64-977.64 m	Unit 1-7?
		1 secondary flake	977.49 m	Unit 7
8N 3W	94-5		3,206.76 ft (977.42 m)	Unit 7
		1 tertiary flake	977.62-977.52 m	Unit 7
		1 secondary flake	977.53 m	Unit 7
8N 4W	—	—	—	—
8N 5W	96-4		3,205.12 ft (976.92 m)	Unit 11 (near top)
		1 tertiary flake	977.62-977.52 m	Unknown
		1 tertiary flake	977.52-977.42 m	Unknown
		1 tertiary flake	977.32-977.22 m	Unknown
8N 6W	96-2		3,206.00 ft (977.19 m)	Unit 8/9 transition
		3 tertiary flakes	977.42-977.32 m	Unit 8 (top)
9N 1W	—			
		1 tertiary flake	977.09-977.04 m	Unit 10
9N 2W	95-3 (7862 ± 88)		3,206.50 ft (977.34 m)	Unit 8/9 transition
		Fluted point base	977.34-977.29 m	Unit 9 (top)
		2 tertiary flakes	977.59-977.54 m	Unit 7 (base)
		3 tertiary flakes	977.54-977.49 m	Unit 7/8 transition
9N 3W	94-4 (9150 ± 230)	—	3,207.12 ft (977.53 m)	Unit 7 (base)
	96-1		3,206.27 ft (977.27 m)	Unit 8/9 transition
9N 4W	94-4 (9150 ± 230)		3,207.12 ft (977.53 m)	Unit 7 (base)
		Mano	3,207.12 ft (977.53 m)	Unit 7 (base)
		2 tertiary flakes	977.32-977.22 m	Unknown
9N 5W	—	—	—	—
9N 6W	94-2	—	3,206.36 ft (977.30 m)	Unit 8/9 transition
	94-3		3,206.33 ft (977.29 m)	Unit 8/9 transition
	10-1 (9150 ± 25)		3,205.48 ft (977.03 m)	Unit 10
	10-2		3,205.15 ft (976.93 m)	Unit 11
10N 1W	—	—	—	—
10N 2W	95-2 (8993 ± 87)	—	3,206.50 ft (977.34 m)	Unit 8
	95-4		3,206.00 ft (977.19 m)	Unit 9/10 transition
10N 3W	—	2 tertiary flakes	977.49-977.44 m	Unit 7

A test unit was also excavated "just west of SI Trench 1" at Area B in 1987 by ARC (Haug 1987:3). However, ARC's archives contain no notes, collection, or more precise provenience data from this investigation, so the findings, which include a radiocarbon-dated feature, cannot be evaluated within the context of other findings from the site.

Despite ALAC's efforts at Area B, the recovered cultural material was extremely limited. Only 45 artifacts were discovered in the locality, 21 (or 47 percent) of which, including the only three Angostura specimens, were discovered on the surface. The only diagnostic specimen recovered from a buried context at Area B was the bifluted projectile point base believed to be of Clovis or

Folsom manufacture. However, the specimen was recovered from the same soil stratigraphic unit (the 8/9 transition) as hearth Features 95-2 and 95-3, which were AMS dated to 8993 ± 87 and 7862 ± 88 RCYBP, respectively. Concerns over the reliability of the suite of radiocarbon dates obtained from Area B were addressed earlier (see Buhta et al. 2012:12-16). Wheeler (1995:447) was unable to reconcile the 1,665-year time-gap between his Area A date (9380 ± 500) and the two dates he obtained from what was believed to be the Angostura occupation surface at Area B (7715 ± 740 and 7073 ± 300). Several of ALAC's dates from Area B contradict what one would expect to see when considering stratigraphy and superposition. In some instances, earlier dates were collected from positions stratigraphically above younger dates, while in other instances, samples collected from two different features at the same depth and encased in the same soil stratigraphic unit yielded dates that varied from one another by more than 1,000 years.

Area C Findings

Area C is the smallest of the site's three localities and was investigated only by Wheeler. Reservoir wave-action destroyed Area C prior to ALAC's work at the site. Prior to his investigations there, Wheeler (1995:395) described the locality as "...extensively eroded and sparsely grassed." Investigations in Area C resulted in the documentation of a sparse surface scatter of lithic tools and debitage, including a drill reworked from an Angostura point, and the excavation of 14 5-ft-x-5-ft (ca. 1.5-m-x-1.5-m) units (see Buhta et al. 2012:46 – Figure 24). Ultimately, investigations in Area C resulted in the documentation of 1 hearth feature, 42 lithic tools, 3 lithic cores, and 185 lithic flakes (Tables 14 and 15), the majority of which were of the light red-to-purple-colored fine-grained quartzite that the majority of the Angostura points from the site were produced from.

Table 14. Summary of Artifacts Documented at Area C, Site 39FA65.

Artifact Type	Artifact Count	Artifact Provenience*	Notes	Reference
Lithic core	3	Surface	2 are of fine-grained quartzite of the type used to produce the majority of Angostura points from the site	Wheeler 1995:398
Lithic flake	185	Surface and Units O, N2, S2, E2, N4, S4, E4, and N6	119 are of fine-grained quartzite of the type used to produce the majority of Angostura points from the site	Wheeler 1995:398-399
Lithic tool	42	Surface and Units W2 and N6	Includes 4 projectile points/point fragments (2 unidentifiable and 2 Archaic period); 14 knives; 1 drill reworked from an Angostura point; 9 scrapers; 2 utilized flakes; 4 choppers; 4 hammerstones; 2 palettes; 1 metate; and 1 mano	Wheeler 1995:399-404

*** See Buhta et al. 2012: Appendix K for complete catalog specifics**

Table 15. Summary of Cultural Features Documented at Area C, Site 39FA65.

Feature No.	Feature Type/ Description	Feature Provenience	Radiocarbon Date(s) Obtained?	Reference
1	Unprepared hearth	S½ of Unit N6; 0.1 ft (0.03 m) below surface	No, but charcoal lot from F1 is curated under catalog no. 267 at SI MSC	Wheeler 1995:398

Geoarcheological and Site Formation Processes

Based on geoarcheological investigations at Areas A and B of the Ray Long site in 2010, Mandel (2012:31) offered the following conclusions regarding site formation processes:

> At the Ray Long site, archeological materials, including the Angostura component, are sealed in alluvial fan deposits. Area A is on the upper midsection of the fan, and Area B is on a distal segment. Based on the results of the 2010 investigation, the Angostura component identified by Wheeler (1995) in Area A rests on coarse-grained channel deposits (high-energy depositional environment) overlain by fine-grained alluvium (low-energy depositional environment). The absence of a soil in the channel fill indicates that it was not exposed at the surface for a long period, i.e., burial was rapid. Also, the alluvium that encased the Angostura component has been only slightly modified by development. Soil 2, which is immediately above the Angostura level, has a weakly expressed ABk-BCk profile. Hence, it is unlikely that soil-mixing processes, such as bioturbation, have greatly affected the Angostura cultural deposits in this portion of the site.
>
> In Area B of the site, fan sedimentation appears to have been rapid for most, if not all, of the period of record. However, unlike Area A, no channel deposits were observed in the block excavation. Instead, this portion of the fan mostly consists of stratified fine-grained alluvium that was deposited by low-energy sheet flows; thin lenses of fine gravel only occur in four sedimentary units. Sedimentation on the fan was not interrupted by soil development until the fan stabilized sometime after ca. 7000 RCYBP. Hence, the Angostura people occupied an unstable, aggrading geomorphic surface, and their material remains were rapidly buried. Although some biogenic features, such as krotovina and worm burrows, were observed in the walls of the excavation block, the cultural deposits have been spared the effects of soil development [Mandel 2012:31].

The challenge at Ray Long is in correlating the Angostura occupational surface at Area A of the site with an equivalent surface at Area B. We know that there was an Angostura presence at Area B because diagnostic Angostura artifacts were documented on the surface and in a slump block adjacent to SI Trenches 1 and 2. Unfortunately, the specimens eroding from the wall adjacent to Trenches 1 and 2 were not in situ, and those discovered on the surface further to the east (upslope on the fan) were redeposited from even further upslope via sheetwash. Also problematic is the fact that one cannot simply trace the same soil stratigraphic units across the site from Area A to Area B. Unfortunately, due to geomorphological processes characteristic of the formation of alluvial fans, the soil stratigraphic units observed in Area A do *not* extend to Area B of the site.

Because diagnostic artifacts cannot be used to link the two site areas (no diagnostics were found in situ in Area B) and because the soil stratigraphic units cannot be traced from Area A to Area B, we are left to rely on radiocarbon dates for determining which ancient surface in Area B is coeval with the Angostura occupation level at Area A. Eighteen radiocarbon dates were obtained from Area B; however, the dates appear to have raised more questions than they have answered about this part of the site. Although soil stratigraphic Unit 10 has many lithologic similarities with the Angostura occupation surface at Area A and also correlates closely with the timeframe based on three AMS dates (9100 ± 65, 9140 ± 80, and 9150 ± 25 RCYBP), dates that are coeval with the Area A Angostura occupation were also obtained from soil stratigraphic Units 7, 8, and 9 in Area B (see Tables 12 and 13, above). So, while soil stratigraphic Unit 10 seems to present the most consistent evidence for being the ancient surface that best correlates with the Angostura occupation of Area A, it is impossible to be certain given the present suite of available dates from the site.

Paleoenvironmental Considerations

In addition to completing a geomorphological analysis, Mandel (2012:26-31) conducted a study of stable carbon isotopes from Areas A and B at Ray Long. His conclusions are reiterated here:

> Stable carbon isotopes analysis of organic carbon in soils and sediments in the Trench I profile at Area A and the north wall profile at Area B indicate that a cool-season C_3-dominated vegetation community existed at the site during the period of Angostura occupation. However, in the Trench I profile, a distinct shift towards heavier $\delta^{13}C$ values above the boundary between Soils 1 and 2 (71 cmbs) indicates that sometime after ca. 9000 RCYBP a mixed C_3/C_4 vegetation community replaced the C_3-dominated vegetation community. This vegetation change probably was in response to climatic warming and drying during the early Holocene, a pattern recorded elsewhere in the region (see Mandel 2008; Murphy and Mandel 2012) [Mandel 2012:31].

Earlier palynological (Fredlund 1988; Scott and Lewis 1986) and charcoal and seed studies (Scott Cummings 1988) were also conducted at Ray Long (see Buhta et al. 2012: Appendix J and Hannus 1986). However, since these analyses were confined to small sections of Area B and no complete soil columns were examined, it is difficult to draw definitive conclusions from these studies. In general terms, the pollen and phytolith studies tend to corroborate Mandel's findings of a cooler, more temperate paleoenvironment during the Angostura occupation of the site, followed shortly thereafter by a marked warming trend. Scott Cummings (1988:3) notes that evidence suggestive of a transitional climate abounds from Montana, Idaho, and elsewhere during the 7000-9000 RCYBP timeframe. However, these earlier interpretations must be viewed with a certain degree of caution as they are based solely on the analysis of incomplete stratigraphic samples confined to Area B; a locality for which dating problems are known to exist. At best, these findings can be accepted tentatively in that they corroborate the more recent and reliable stable isotope study.

Site Interpretations

Wheeler (1995:448) believed that Area C was unrelated to Areas A and B at Ray Long because of the presence of two Archaic-period projectile points and because of the soils and the general disposition of the artifacts documented there. Artifact deposits in Area C were described as being "superficial," and Wheeler interpreted the deposits as being confined to a different soil stratigraphic unit than the material from the other two areas. However, a number of indicators may suggest otherwise. Principal among these is the presence of the purple-colored, fine-grained quartzite drill in Area C that was reworked from an Angostura point. Additionally, the lone hearth feature documented at Area C is of the same ephemeral, unprepared nature as the hearths in Areas A and B that Wheeler attributes to the Angostura occupation. Unfortunately, because Area C has since been destroyed, investigators may never know for sure. A possible means of clarifying this dilemma would be to obtain a radiocarbon date from the charcoal fill of Feature 1, which is presently curated at the SI's MSC in Suitland, Maryland.

Wheeler also posited a definitive cultural correlation between Areas A and B. He based this conclusion on a series of traits observable from the archeological record that he found to be characteristic of both Areas A and B while being absent from Area C and all other sites from the Angostura Reservoir area and the region beyond. The traits cited by Wheeler include:

> ...unprepared, small and medium-size, circular, subcircular or oval, lightly fired hearths; unprepared, medium-size, subcircular or oval, heavily fired hearths; narrow lanceolate, diagonally

ripple flaked dart-points with narrow and slightly concave or straight base and ground lateral edges, of Angostura type; knives (curiously few in number; of indeterminate size and shape in Component B; large narrow lanceolate with straight base and small ovate with straight base in Component C [Component C is equivalent to Area A]); drill points (?); and medium-size and small flake-scrapers; utilized flakes; medium-size trapezoidal core-biface scrapers (cf. "Clear Fork gouges," etc.); small ovate (?) core-biface choppers; small subtriangular core-uniface scrapers; small hand-hammers (oval in Component B; flat, subtriangular in Component C); small unifacial palettes; small and minute, tissue paper-thin, waste flakes; and very fragmentary, unidentifiable animal bones [Wheeler 1995:446-447].

The features and artifacts described above by Wheeler *are* consistent across both Areas A and B at Ray Long. However, aside from the actual Angostura projectile points, Wheeler's other identified "traits" are *not* specific only to Areas A and B of the Ray Long site. In fact, some of the traits he notes *are* also present at Area C. The two most obvious are the drill reworked from the Angostura point and the ephemeral hearth feature found there. Other artifacts identified by Wheeler, such as the scrapers, bifacial choppers, hammerstones, and thin waste flakes, are ubiquitous in North America's prehistoric archeological record. The very limited and fragmentary nature of faunal material at the site may relate to the fact that the soils at Ray Long are highly acidic, which would greatly accelerate the rate of decay of bone and other organic materials (Wheeler 1995:397); this causes difficulty in interpreting such things as diet, game procurement, and potential subsistence strategies.

Ephemeral, shallow unprepared hearths have been documented at other sites in North America (see for example Arnn 2012:63), as well as at sites on the other side of the world (see Alperson-Afil et al. 2007). Arnn (2912:63) notes the fairly common occurrence of unlined hearths on the Plains and hints that the decision of a particular hunter-gatherer group to line their hearths with rocks oftentimes was simply dictated by resource availability; one cannot line a hearth with rocks if no rocks are to be had. The Ray Long site was positioned on what, at the time, was a constantly aggrading alluvial fan, and there was likely an abundance of small pebbles and gravels nearby but not fist-sized or larger cobbles; evidence from repeated excavations at the site supports this hypothesis.

Based on the discussion above, Wheeler's presumption that the ephemeral hearths identified at Ray Long were somehow indicative of the Angostura occupation at the site is flawed.[1] The presence of two different stemmed Archaic projectile points at Area C of Ray Long clearly suggests a post-Angostura occupation at the site. It could also reasonably be assumed that Archaic-period groups camping on the fan also had limited access to rocks for hearth lining and would have used unlined hearths similar to those documented from the Angostura occupation.

The knowledge that there was an Angostura presence at all three Ray Long site localities, and that there was a subsequent Archaic occupation in at least Area C, may be useful information. What seems to be a more pertinent question, though, is: how many of the hearths from Areas B and C are actually Angostura? Or, from where *stratigraphically* in Area B does the Angostura component derive?

[1] This is not an indictment of Wheeler's methodology or interpretations. At the time, Wheeler was attempting, with no baseline for comparison, to interpret sites that did not fit into any known typologies. Obviously, today there is a much larger body of comparative data as well as far greater access to that data.

Unfortunately, due to the absence of in situ diagnostic artifacts and the issues associated with radiocarbon dates from Area B (see page 48, above and Buhta et al. 2012:12-16), it is difficult to draw firm conclusions about the Angostura occupation of Ray Long based on the evidence from Area B. These questions also cannot be answered for Area C because the locality is destroyed and the charcoal sample taken from the lone feature identified there has not been dated (although it still could be). Area A, with in situ, buried diagnostic projectile point fragments, still provides the most secure, conclusive evidence of the Angostura occupation at Ray Long.

Wheeler's ultimate interpretation of the Ray Long site and the inhabitants he identified as "Angostura" was as follows:

> The settlement features, artifacts and refuse materials [at Ray Long] imply seasonal hunting camps of extended family or small band units which at first lived chiefly, if not exclusively, by hunting big game with dart-thrower and darts (Component C),[2] and later subsisted both by hunting with dart-thrower and darts and by collecting and processing wild plant products (Component B), perhaps because of a dwindling supply of large game [Wheeler 1995:449-450].

These conclusions are based on the absence of long-term habitation evidence in the archeological record (such as cache pits, middens, or post molds) at the site and the presence of several Angostura projectile points, lithic tool manufacture refuse and knapping stations, some mano, metate, and chopper tools, and clumps of charred vegetal matter. ALAC concurs with Wheeler's basic premise that Ray Long represents a series of small, temporary camps occupied by small, mobile prehistoric groups; archeological and geomorphological evidence supports this hypothesis. However, on other points, ALAC's interpretation varies from Wheeler's.

Clearly the assemblage of projectile points from the site implies a subsistence technology that is associated with big game hunting, be it deer, bison, pronghorn, sheep or other such mammals. ALAC would argue that what the archeological evidence at Ray Long does *not* demonstrate, however, is Wheeler's suggestion of the "exclusive" reliance upon big game, specifically bison, during the earlier years of site occupation. The acidic soils at Ray Long have degenerated organic matter at the site to such an extent that virtually no bone or other organic materials have survived to be documented. This makes it impossible to reach conclusions about subsistence other than that big game hunting was practiced. As to what extent big game hunting supplemented, or was supplemented by, gathering, foraging, fishing, or small game hunting, simply cannot be said.

The presence of other tools at the site, such as manos and metates, does suggest that inhabitants of Ray Long also processed plant material, and pollen residue tests from an in situ mano recovered from Area B indicate evidence of both grass and Umbelliferae (carrot/parsley family) use at the site (Hannus et al. 2012:46-49). The mano was recovered in situ from soil stratigraphic Unit 7 adjacent to a hearth feature (94-4) dated to 9150 ± 230 RCYBP (Hannus et al. 2012:42; see Tables 12 and 13, above). However, as previously noted, some of the dates are problematic and no diagnostic artifacts were identified at this locality. What can be definitively inferred is that a prehistoric group processed plant material at Area B at some point in the past and that group may or may not represent the Angostura occupation.

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[2] Wheeler's Component C is analogous with his Area A, whereas his Component A refers to material recovered from Area C (see Wheeler 1995:396).

Stable carbon isotope evidence does suggest that a cooler, more temperate climate existed during the dated Angostura occupation of the site, and that the climate grew substantially warmer and drier shortly after this time (see page 49, above). This evidence suggests that bison herds would have remained prevalent on the surrounding Plains; however, it does not necessarily imply that the Angostura occupants of Ray Long practiced a subsistence economy that revolved around seasonal bison hunts. Because so many questions exist about the lifeways of the Angostura inhabitants of the Ray Long site, and because so little evidence from the site can adequately address these questions, researchers are forced to search for answers elsewhere on the landscape. This topic will be addressed in greater detail below.

THE ANGOSTURA CULTURAL/TECHNOCOMPLEX

Defining Angostura

Clarification of the cultural/technocomplex that Wheeler (1995:415-416) originally described as "Angostura" was a primary objective of continued research at the Ray Long site. As noted in the previous discussions by Bradley and Kay, several factors have contributed to confusion and misidentifications in the literature. Among these is the fact that Wheeler's work went unpublished for nearly 50 years and the only illustration identifying the point type (Wormington 1957) was actually either a preform or knife, thereby further adulterating the data. The situation was made even more complicated by the lack of recovery of any complete specimens from the type-site and the fact that many of the fragmented specimens exhibited evidence of substantial reworking (see Kay, this report, pages 18-36).

In an attempt to rectify these issues, Wheeler's (1995) manuscripts were published and Bruce Bradley reconstructed a complete Angostura specimen through an extensive analysis of the broken tip and base fragments that were collected from Ray Long. The "Angostura Type" conceptualized by Wheeler is a parallel, oblique flaked, lanceolate projectile point with heavy edge grinding on the lateral margins (from mid-point on the blade) and the base. The Angostura specimens at Ray Long are produced, predominantly, from fine-grained quartzite, which yielded a level of durability and strength not available in other lithic materials. Bradley's description of the Angostura point is as follows:

> The Ray Long Angostura points are long lanceolate forms that evenly curve to a sharp tip and taper to a straight to slightly concave base from about the middle of their length. Flake scar patterns are consistently serial, parallel oblique running from upper left to lower right. Flake scars may run past the midline toward the center of the point but tend to meet near the midline near the base. Flake removal sequence is mostly from base to tip on the left side (with point viewed tip up) and tip to base on the right. There is little to no margin retouch except on one example where steep noninvasive pressure flaking produced a slight bibevel near the tip. Only one specimen retains part of a percussion flake scar. Although most pieces are evenly lenticular in cross section, there is a tendency toward slightly plano-convex cross sections as well. Projectile point margins from the greatest width to the base are ground smooth [Bradley, this report, page 15].

In comparison, based on an extensive examination of Late Paleoindian projectile points from the southern Rocky Mountains, Bonnie Pitblado defines Angostura specimens as:

> ...lanceolate bifaces with flaking patterns that range from, most typically, parallel-oblique to collateral to irregular and very rarely, horizontal, with some specimens showing different patterns on opposite faces. The basal sides of the points converge toward the base, which is usually slightly concave in outline. As with virtually all Paleoindian spear points, the basal edges of finished

> Angostura points are ground. In longitudinal cross-section, Angostura points are usually symmetrical but are not uncommonly "D-shaped," "twisted," or otherwise asymmetrical [Pitblado 2007:315-316].

Of particular note is the variance between Bradley's (this report, page 15) *always* parallel obliquely flaked definition and Pitblado's (2007:315) description of specimens that are *typically* parallel obliquely flaked but may also exhibit parallel collateral, irregular, and even sometimes horizontal flaking patterns. Bradley (this report, page 17) also calls attention to this variance, suggesting that the serial parallel oblique pressure flaking observed within the assemblage of Angostura specimens from Ray Long was the product of conscious decision-making on the part of Angostura flintknappers at the site. He notes, based on the experimental replication of these points using multiple types of toolstone, that the particular parallel oblique approach "represents a technological solution to pressure flaking quartzite and other strong but brittle materials..." that "...produces straight, razor sharp edge results that require no further preparation and, on brittle materials, is more resistant to damage than it would be on chert or flint" (Bradley this report, page 17). He concludes that this manufacture technique is optimal for use on toolstone types like the fine-grained quartzite from which the majority of the Angostura specimens at Ray Long were produced.

Bradley, however, examined only a finite number of specimens from the type-site, and Wheeler (1995:415) himself noted that "A few specimens also show horizontal ripple flake scars." It is not unreasonable to expect some minor degree of variation among the types of toolstone utilized and the flake patterning on specimens when considering a larger sample-size from a broader geographic context, particularly considering that the type-site yielded no complete specimens. For example, Pitblado's (2003:127) definition is based on the examination of 65 projectile point specimens from Colorado and Utah. Within this sample, the majority of specimens exhibited parallel oblique flaking although, as previously noted, this trait was not exclusive.

Radiocarbon evidence from Area A at Ray Long has provided a sound date range of 9110-8830 RCYBP within which the Angostura occupation of the site can be viewed (Buhta et al. 2012:11). This, however, is only one site, and the dates may represent but a portion of the timeframe that the complex collectively was present on the landscape. Archeological evidence from Ray Long is largely inadequate for addressing broader topics such as subsistence and settlement strategies, geographic and temporal distribution, population diffusion, and land use patterns. In order to truly begin to understand Angostura, evidence from Ray Long must be compared with other Angostura and Late Paleoindian sites, both regionally and beyond. Such a comparison should afford a clearer picture of emerging patterns of this complex and may allow several of the above-listed topics to be addressed.

Ray Long and the Broader Pattern of Angostura Site Distribution

The initial step in attempting to understand the Ray Long site within the larger context of North American Late Paleoindian archeology is to identify other sites on the landscape with documented Angostura components. On the surface, this would not appear to be a difficult exercise. However, decades of confusion over the precise definition of the Angostura cultural/technocomplex, have greatly complicated the process. It is comparatively easy to locate those sites in the archeological record that were originally identified as containing an "Angostura" component; determining whether that "Angostura" designation is a correct reflection of our current understanding of the Angostura projectile point type, is decidedly more complex.

Perpetuating the confusion is that Angostura specimens share certain traits (medium to long lanceolate bifaces with ground basal edges and frequently parallel oblique flaking) with other Paleoindian points that, if only cursorily examined, may lead to erroneous or cross-classifications. Pitblado (2007:311-337) has thoroughly addressed the differences and similarities between Angostura and Jimmy Allen and has demonstrated that they do, indeed, appear to represent separate complexes. Both Wheeler (1995:417) and Bradley (1982:194-195, this report, page 2) have noted the similarities between Angostura and Agate Basin specimens, but have also pointed out that the differences are clearly representative of two separate complexes.

Careful analysis of Angostura projectile points by field experts has resulted in the conclusion that they are, indeed, technologically different from other Paleoindian weaponry in the archeological record, though oftentimes the defining characteristics are subtle. In order to conclusively classify a given specimen as Angostura (or, for that matter, as *not* Angostura), a researcher must first understand what it is that technologically distinguishes Angostura from other complexes, and then actually be able to examine the specimen *in-person*. The following discussion details the general geographic breadth of reported or designated Angostura site components beyond Ray Long; Figure 31 illustrates this distribution.[3] An attempt is also made to determine which of these designations can be confirmed as Angostura based on the present definition of the technocomplex.

After completion of the RBS investigations at Ray Long, Wheeler (1995:416-417) identified several projectile points from other localities that exhibited characteristics similar to the Angostura specimens from Ray Long. Among the specimens noted, which include both broken and complete pieces, are 21 from find spots in Morrill, Sioux, and Dawes counties, Nebraska (see Appendix M), one medial fragment of a possible Angostura point from Mule Creek Rockshelter (site 48CK204) in the Keyhole Reservoir area of Wyoming (Wheeler 1996:104), a fragment from near Kotzebue, Alaska, one from the surface of site 48FR49 at Boysen Reservoir in Wyoming (Wheeler 1997:232, 250-251), a reported base found during a survey for the Alzada Reservoir in northeastern Wyoming, nine "Oblique Yumas" reported from Lewis Ranch near Glendive in east-central Montana (Mulloy and Lewis 1943:298-299), one specimen from Yuma County, Colorado (Figgins 1935:Plate IV), one small specimen from Blackwater Locality 1 in east-central New Mexico (Sellards 1952:72, 74), one resharpened specimen from a site on the Snake River near Glenns Ferry in southwestern Idaho (Kehoe 1955:13-15), and another from the Johnsons Park Reservoir site in western Idaho (Caywood 1948:251) (see Figure 31). Also reported are two specimens from near Regina in south-central Saskatchewan (Howard 1939:278) and a fragmentary piece from the Great Bear River site in Canada's Northwest Territories (MacNeish 1956:64).

[3] Data for Figure 31 were compiled from the following sources: Colorado and Utah data provided by Bonnie Pitblado; South Dakota data obtained from site files housed at the Archaeological Research Center, Rapid City, South Dakota; Nebraska data obtained from Wheeler (1995) and Bamforth (2007); Oregon and Idaho data obtained from Pitblado (2003, 2010); Montana data obtained from Pitblado (2003) and Kay (this report); Wyoming data obtained from Pitblado (2003), Frison and Walker (2007), Husted and Edgar (2002), Larson et al. (2009), and WYSHPO site files.

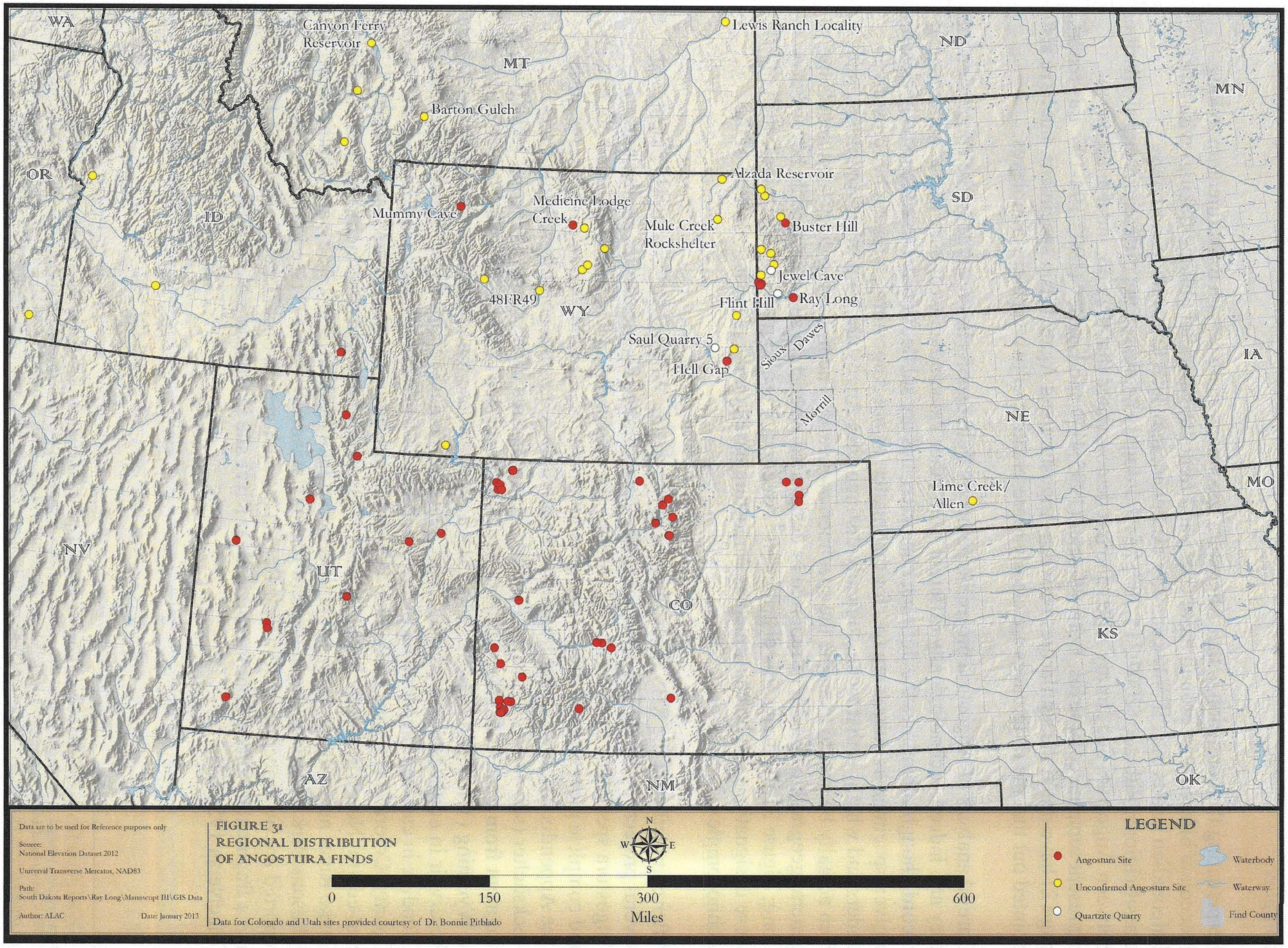


FIGURE 31
REGIONAL DISTRIBUTION OF ANGOSTURA FINDS

Wheeler's report is unclear as to whether he actually examined all of the specimens personally, although it is believed that the majority were either reported to him or were viewed via photographs in reports or publications (a method typically regarded as inadequate for definitive classification purposes). Therefore, classification of the above-listed specimens as Angostura is necessarily tentative. Herbert Alexander (1963:513), who cites many of the same above-listed authors (including MacNeish 1952; Mulloy 1959; Sellards et al. 1947; and Wormington 1957), demonstrates the confusion and divergent opinions that pervaded the archeological community relative to the classification of Angostura and Plainview projectile points at the time. The pitfalls inherent in relying too heavily upon early Angostura classifications without further verification are illustrated by Bruce Bradley, who was able to personally reexamine 16 of the 19 specimens from Sioux and Dawes counties, Nebraska. He concluded that only four specimens exhibit traits conclusively characteristic of Angostura. Three other specimens were classified as Agate Basin based on this reexamination, while the remaining pieces were either too fragmentary to classify or were not accessible for examination (see Appendix M).

Husted and Edgar (2002:96-97) provide commentary on several of the specimens noted above by Wheeler. They feel that the piece from Johnsons Park Reservoir does not match the morphology of Angostura, and note that the fragment from Kotzebue, Alaska is a distal tip that cannot be positively identified. They agree that the pieces from the Lewis ranch near Glendive, Montana and the specimen from near Glenns Ferry, Idaho appear to be Angostura but not the piece from the Blackwater No. 1 locality. They also note the presence of several Angostura specimens, discovered after Wheeler's time, at the Pine Spring site in southwestern Wyoming (Sharrock 1966). During their reassessment, Husted and Edgar (2002:96) make a critically important comment concerning the identification of specimens as Angostura by archeologists during and shortly after Wheeler's time. In essence, the reader is reminded that parallel oblique flaking was used as a major component in the identification process without the foreknowledge that numerous different types of parallel obliquely flaked lanceolate points existed on the landscape. It is another cautionary reminder of the problems inherent in relying solely on the literature when attempting to understand site distribution for a given cultural group.

Since Wheeler's time, a multitude of additional archeological sites have been classified as Angostura based on the presence of any parallel obliquely flaked lanceolate projectile points. The classification of another Archaic-period projectile point form from the southern Plains as Angostura further complicated matters. This projectile point, which is distinct from true Angostura, is present at numerous sites throughout Texas, and researchers have only recently begun referring to it as "Texas Angostura" (see Holliday 2000:227; Thoms 1993; Thoms and Mandel 2007; Turner and Hester 1993).

In South Dakota, 11 additional sites with designated Angostura components are listed in the archeological record. Interestingly, these sites are located in Butte (n=2), Custer (n=3), Fall River (n=2), Lawrence (n=1), Meade (n=1), and Pennington (n=2) counties – all within the immediate vicinity of the Black Hills (see Figure 31). Four of these sites, 39CU3572, 39FA273, 39FA1896, and 39MD145 (Buster Hill), have confirmed Angostura components; however, none are from reliably dated contexts. Buster Hill (39MD145) is located on the northeastern edge of the Black Hills about 115 km north-northwest of Ray Long (Hannus et al. 1997), while the other three sites (39CU3572, 39FA273, and 39FA1896) are on the southwestern edge of the Black Hills about 54 km northwest of Ray Long (Kruse et al. 2008). The seven additional sites, which include 39BU69 and 39BU107 (Keller and Keller 1984), 39CU1199 (Miller 1992), 39CU1658 (Buechler 1999), 39LA3 (Gant 1961; Tratebas 1977), 39PN128 (Sheveland et al. 1998), and 39PN219 (Flemmer and Sheveland 1993; Hamilton 1977, 1980; Noisat 1988; Padilla and Schlosser 2011), reportedly yielded Angostura projectile points; ALAC was unable to physically examine these specimens and cannot confirm the validity of the Angostura designation. However, as the designations for sites 39BU107 and 39CU1199 are based solely on the presence of projectile point distal tip and mid-sections, they should be viewed as tenuous at this time.

In 1999, Bonnie Pitblado (1999, 2003) completed a Ph.D. dissertation that focused on the Late Paleoindian occupation of the southern Rocky Mountains. She examined 589 Late Paleoindian projectile points from sites across Colorado and Utah. Sixty-five of the examined points were classified as Angostura specimens; their distribution is illustrated in Figure 31, above (some of the depicted sites contained more than one specimen).

Pitblado's study identified several other sites from beyond Colorado and Utah with either reported Angostura or other Late Paleoindian components that she lumped together with Angostura for the purpose of regional comparisons (Pitblado 2003:114, 116). Among those complexes initially amalgamated with Angostura for regional comparison were Alder (Davis et al. 1989), Hardinger (Davis et al. 1988), and Lusk (Greene 1967). In a 2007 article, Pitblado (2007:317) clarifies that, although projectile points from the Lusk, Alder, and Hardinger complexes are "apparently" similar to Angostura, "...none has yet been sufficiently described and illustrated in the literature that I could make a determination of whether one or more of them could be appropriately applied to my southern Rocky Mountain material." She (Pitblado, personal communication 2013) has since had the opportunity to examine several Lusk specimens and believes that they do, indeed, fit the criteria assigned to Angostura. The connection between Angostura and Alder and Hardinger is less conclusive; however, Kay (this report, page 35) examined Alder complex specimens from Montana and found them to be "indistinguishable" from Angostura.

Pitblado (2003:115-116) identified 19 published radiocarbon dates from 18 sites associated with Angostura and the other three "lumped" complexes (Alder, Hardinger, and Lusk). The age range of the 19 dates is 9700-7550 RCYBP; the median age is 8790 RCYBP (Pitblado 2003:116). The dates from Area A of Ray Long fall within the earlier portion of this range; however, it bears noting that several of the published dates have fairly large standard deviations and/or were processed several decades ago (Wheeler's dates from Ray Long are included). Also, those dates solely associated with Alder, Hardinger, or Lusk components may ultimately prove to have little or no relationship to Angostura.

As part of her research, Pitblado hoped to discern whether projectile point variation and geographic distribution could help identify subsistence and land use patterns among different Late Paleoindian cultural groups in the southern Rockies project area. Findings of the study led to her classification of Angostura projectile points as the "hallmark" southern Rocky Mountain Late Paleoindian type, dominating the regional assemblage but scarcely found in the Plains or Great Basin regions (Pitblado 2003:233). The pattern of geographic distribution revealed by the study shows that, while Angostura specimens were most prevalent in the parklands and lower foothills, they were present in all elevations of the Rockies, from the foothills to the high montane and alpine zones. This suggests that Angostura groups exploited all Rocky Mountain environments (Pitblado 2003:233). Additional findings suggest that Late Paleoindian projectile points in the Southern Rockies are predominantly produced from quartzites quarried locally and transported short distances (Pitblado 2003:233). Technologically, these specimens, particularly the Angostura ones, are often produced on flakes, exhibit parallel oblique flaking and excellent craftsmanship, are long and thick, have heavy basal and haft element grinding, exhibit a high degree of breakage, and are commonly reworked into other tools (Pitblado 2003:234).

Extending the pattern of distribution and morphological traits of the projectile point to land use and subsistence tendencies, Pitblado (2007:326) hypothesized that Angostura groups spent the entire year exploiting the resources of the southern Rocky Mountains, necessarily occupying the lower elevation zones during the winter months and then moving in smaller groups into the higher elevations during the warmer months of the year. This, then, implies that Angostura groups maintained a generalized hunter-gatherer economy quite different from that seen among other Late Paleoindian bison hunting groups on the Plains (such as Eden and Cody). A distinct parallel is present between this hypothesized land-use strategy and Frison's earlier "Foothill/Mountain" concept (see Kornfeld et al. 2010:95-97), although Pitblado (2007:327-328) points out that, while Frison's concept encompasses Angostura, it includes a broader array of Late Paleoindian complexes as well.

Brunswig (2007) also conducted a localized study of Late Paleoindian land-use patterns in the Rockies, but his (Brunswig 2007:285) study is geographically restricted to northern Colorado and is based on the examination of site files data. He found the highest percentage of Angostura sites (with which he combined the "essentially identical" Lusk type) to be in high-altitude localities (54 percent) followed by sagebrush steppe zones (37.5 percent). This data contradicts the findings of Pitblado; however, two important factors should be noted: 1) the study area included a smaller geographic locality with much higher average elevations, thereby creating a bias towards the presence of higher elevation sites in the study; and 2) the study was based on an examination of state site files, not actual artifacts, thereby calling into question whether these pieces can be labeled "Angostura" with certainty. The combination of these two factors speaks to the limited value of Brunswig's study as it pertains to the broader, current understanding of Angostura.

Pitblado's (1999, 2003, 2007) definition of Angostura conforms extremely well to the definition established by Wheeler (1995) and subsequently presented by Bradley (this report), and her research, like that of Wheeler and Bradley, is based on the physical examination of projectile points rather than site files and old reports. Therefore, her data and hypotheses represent viable and intriguing "test subjects" with which to compare the findings from Ray Long.

Pitblado's (2003:238-246) data suggest that projectile points most closely affiliated with the Plains and southern Rockies are more indicative of a "collector" land use strategy that favored weapon reliability over maintainability. Projectile point characteristics affiliated with this strategy include large size, excellent craftsmanship, a focus on the haft, a lack of reworking, a high degree of breakage, and a reliance on tough lithic raw materials (Pitblado 2003:245). All of these characteristics fit the Angostura projectile point assemblage from Ray Long except one: the lack of reworking. Ray Long Angostura specimens exhibit evidence of extensive reworking (see Kay, this report) and the reasons for this inconsistency with Pitblado's findings are currently unclear.

Also noteworthy is the toolstone used in projectile point manufacture and its source location. Pitblado (2003:233) found that the majority of Rocky Mountain Angostura points were produced from locally quarried (less than 70 km (43.5 mi) from the particular site) quartzite. Nearly all of the Angostura specimens from Ray Long were produced from a fine-grained orthoquartzite that, at least superficially, shares many characteristics with toolstone found at prehistoric quarry sites in the southern Black Hills. Although the source of toolstone for the Ray Long Angostura points has not been definitively ascertained, an X-ray fluorescence (XRF) study was recently conducted on two Angostura points from Ray Long to clarify this issue (Boen et al. 2013; see Appendix N).

The XRF study compared the two points from Ray Long to seven known prehistoric quartzite quarries in the Black Hills and Hartville Uplifts of South Dakota and Wyoming. The XRF signatures of the two Ray Long points correlate strongly with the signatures obtained from three of the seven quarries tested: Saul Quarry #5 in eastern Wyoming, and Flint Hill (39FA49) and Jewel Cave (39CU484) in the southern Hills. A combination of microscopic analysis and evidence from the XRF signatures led Boen et al. (2013:37-38) to conclude that Saul Quarry #5 is the most likely point of origin for the two Ray Long specimens. However, it is cautioned that the similarities between the XRF signatures of these samples are such that it may prove impossible to definitively source quartzite toolstone beyond a regional level without a much larger sample size.

The most intriguing part of these results is how they compare to Pitblado's (2003:233) findings of Angostura groups in the Rockies predominantly utilizing locally quarried quartzites for projectile point production (see above). Both Flint Hill and Jewel Cave are located fairly near Ray Long (approximately 24 km (15 mi) west-northwest and 54 km (33 mi) northwest of the site, respectively; see Figure 31, above) and well within the "local" range of quarried toolstone identified by Pitblado. Saul Quarry #5, however, is located some 145 km (90 mi) southwest of Ray Long and beyond Pitblado's local zone. If the Ray Long specimens did, indeed, originate from the Saul Quarry #5 site, then the pattern of toolstone acquisition identified for the Angostura occupants of Ray Long is atypical of that observed among the majority of southern Rocky Mountain Angostura sites.

Pitblado's (2007:323) data indicate that 67 percent of the Angostura specimens in her study sample were recovered from the southern Rockies whereas only 5 percent came from the Plains. Another inspection of the confirmed and reported Angostura site distribution data beyond Pitblado's Colorado/Utah study area (see Figure 31) reveals that this trend persists, particularly if one views the Black Hills as an extension – albeit an isolated one – of the Rockies (and geologically and environmentally they ostensibly are [see Froiland 1978:11]). It should, however, be pointed out that Figure 31 is incomplete; only South Dakota, Colorado, and Utah are wholly represented in terms of Angostura site distribution, whereas data from the adjoining states are merely a representative sample of some of the more significant sites with Angostura or potential Angostura affiliations identified from the literature. If every reported Angostura site in all of the depicted states and beyond was identified, the pattern of distribution may very well appear different.

Utilizing existing data and incorporating Pitblado's hypotheses, the Black Hills could be viewed as a microcosm of the Rockies. Assuming this is true, and taking into account only those confirmed South Dakota Angostura sites, then the geographic position of Ray Long in the Black Hills foothills would likely imply a revisited, colder-season camp or habitation. This would also be true for sites 39CU3572, 39FA273, and 39FA1896, although the absence of intact site deposits and faunal assemblages associated with the Angostura points at these localities makes such a distinction impossible to verify. Interpretation of seasonal occupation is more difficult for the Buster Hill site (39MD145), which is located in a stream valley canyon within a more mountainous portion of the Black Hills (Hannus et al. 1997). Though not in the foothills, Buster Hill is only a few miles up the canyon from this setting and the site assemblage is more reflective of a smaller, temporary hunting or transient camp than that of a larger basecamp. It would fit more closely with a warm-season resource exploitation model, although, again, the site integrity was such that this could not be ascertained with any degree of certainty. If the Southern Rockies hypothesis holds for the Black Hills, researchers could expect to see larger percentages of Angostura sites in the foothills and meadows although, a lesser presence should still be detectable in the other environmental/elevational zones across the landscape. The more Angostura sites that are identified, the more the hypothesis can be tested.

Of particular interest in examining the regional distribution of Angostura sites are the anomalous localities; i.e., the areas that seem to contradict Pitblado's interpretations of Angostura as an intermontane manifestation. On Figure 31, localities such as the Lewis Ranch in eastern Montana (Mulloy and Lewis 1943:298-299), the Lime Creek and Allen sites (Davis 1962:47 and Figures 20C, 28; see also Davis 1953, 1954; Davis and Schultz 1952) in southwestern Nebraska, the surface finds from Sioux, Dawes, and Morrill counties in western Nebraska (see Appendix M), and the cluster of sites identified by Pitblado in extreme northeastern Colorado, are particularly curious. The specimens from northeastern Colorado were all examined by Pitblado. As previously mentioned, Bruce Bradley reexamined the Sioux and Dawes County specimens and determined that four of them are, indeed, Angostura. Although he did not examine the pieces from the Lime Creek and Allen sites personally, Bradley (personal communication 2013) did examine their photograph, line drawing, and metric data and concluded that they appear to fit well within the range of Angostura. These sites could collectively raise a host of new questions concerning land-use patterns and subsistence strategies of Angostura groups. This topic will be further discussed below.

What the Future Holds

Management of the Ray Long Site

The Ray Long site (39FA65) is a regionally significant historic property that is eligible for listing on the National Register of Historic Places. It is the type site for the Paleoindian-period Angostura complex as well as one of the first Paleoindian sites excavated on the northern Plains. The site has been under the management of Reclamation since the late 1940s when land was acquired for the construction of Angostura dam and subsequent filling of the reservoir. As a cultural resource, the data generated during excavation and the results shared following analysis help determine its value and whether it has the potential to contribute further to our knowledge of prehistory on the northern Plains. In this case, it is clear that the Ray Long site has further potential to yield additional information of use to interpreting the past. Therefore, Reclamation's management from this point forward would focus on preservation and protection of the intact segments of the site.

The site's shoreline was successfully stabilized in 2000 and this has greatly assisted in the preservation of remaining site deposits for the foreseeable future. Continued preservation and protection efforts would include ongoing monitoring of this stabilized shoreline, as well as impacts from visitors. The site is easily accessible and at this time, the Area Archaeologist for Reclamation checks this site at least three or four times a year. The frequency of these visits allows for the identification of problems with erosion, vandalism, or looting. A more formal visit would be conducted at least once every five years to collect GIS data on the shoreline, examine the cutbank for exposed artifacts or features, and complete a monitoring form for the site file.

In addition to visits by the Area Archaeologist, Reclamation would alert its law enforcement officer for the reservoir and the state park manager and staff to the sensitive nature of this location. These individuals would be asked to check the site on their regular rounds, particularly during the tourist and hunting seasons or flooding episodes. The Area Archaeologist would be contacted if problems are identified during these checks and follow-up with a site visit and appropriate action.

In an effort to share the knowledge compiled in these volumes, Reclamation should consider creating an exhibit for the park's visitor center. It is often difficult to bring the results of years of research to the public. An exhibit would enhance the visitor's experience to the area and provide information on its distant past.

Unanswered Questions and Avenues for Further Exploration

In Manuscript II (Buhta et al. 2012:48-49), the topic of acquiring additional radiocarbon dates from the Ray Long site was discussed as an avenue for further research. Despite the fact that 24 dates have been obtained from the site, only four were secured from features in an intact, buried cultural zone that was directly associated with Angostura projectile point specimens. These dates, all from Area A of the site, produced a time span of 9110-8830 RCYBP for the Angostura occupation of Ray Long (Buhta et al. 2012:11-12). The other 20 dates, all of which were obtained from Area B, are not associated with a clearly distinguishable Angostura component; Area C of the site was not dated.

However, because Wheeler collected multiple carbon samples from the site and curated them at the SI's MSC, it remains possible to obtain additional radiocarbon dates for all three areas at Ray Long. Table 16 lists a select number of curated samples that would be good candidates for future dating. See the discussion in Manuscript II (Buhta et al. 2012:48-49) for more specifics.

Table 16. Smithsonian Institution Curated Carbon Samples from Site 39FA65.

Sample Catalog Number	Site Provenience	Sample Description
127	Area A, Units B3L3 and B3L4, Feature 2	Charcoal lot from Feature 2 fill – large unprepared heavily fired hearth in close proximity to an Angostura projectile point
381	Area A, upper soil stratigraphic unit	Charcoal lot from upper soil stratigraphic unit – gray-brown, coarse to fine granular clay with scattered soft shale, angular fragments of limonite and gypsum crystals
204	Area B, SI Trench 1, Unit N7 E4, charcoal lens	Lot from charcoal lens previously dated by Wheeler to 7715 ± 740 RCYBP
507	Area B, SI Trench 1, Unit N6 E3, Feature 11	Charcoal lot from Feature 11 fill – large amorphous burn area associated with a mano

Table 16 (continued).

Sample Catalog Number	Site Provenience	Sample Description
510	Area B, upper soil stratigraphic unit, granular clay	Bulk SOM sample from the upper soil stratigraphic unit – light yellow-brown granular clay with scattered chips of soft shale, fragments of limonite, crystals of gypsum, and charcoal flecks
511	Area B, lower soil stratigraphic unit of clay shale	Bulk SOM sample from the lower soil stratigraphic unit – light gray-brown massive weathered clay shale with many fragments of limonite, gypsum crystals, and charcoal flecks
559	Area B, upper soil stratigraphic unit, granular clay	Bulk SOM sample from the upper soil stratigraphic unit – light yellow-brown granular clay with scattered chips of soft shale, fragments of limonite, crystals of gypsum, and charcoal flecks
560	Area B, lower soil stratigraphic unit of clay shale	Bulk SOM sample from the lower soil stratigraphic unit – light gray-brown massive weathered clay shale with many fragments of limonite, gypsum crystals, and charcoal flecks
561	Area B, SI Trench 2, occupation level (974.70-975.25 m amsl)	Charcoal lot from general occupation zone in SI Trench 2 – light gray-brown massive weathered clay shale with many fragments of limonite, gypsum crystals, and charcoal flecks
562	Area B, SI Trench 2, occupation level (974.70-975.25 m amsl)	Charcoal lot from general occupation zone in SI Trench 2 – light gray-brown massive weathered clay shale with many fragments of limonite, gypsum crystals, and charcoal flecks
267	Area C, Unit N6, Feature 1	Charcoal lot from Feature 1 fill – shallow unprepared hearth

An issue that remains unresolved is the whereabouts of the 12 Angostura projectile point fragments missing from the SI's MSC (see Buhta et al. 2012:34-39, Table 11 and Figures 13-20). Although casts of two of these specimens were produced and a set of photographs was subsequently discovered in the possession of Wheeler's daughter, the actual artifacts remain missing. Relocation of these specimens would allow for a detailed analysis of each piece, which would then permit a comparison between these and other identified Angostura specimens from Ray Long and elsewhere.

The identification and comparison of additional projectile point specimens is of paramount importance to attaining a better understanding of the Angostura complex more broadly. Researchers must continue attempts to identify additional Angostura specimens from other sites in the Plains, Rocky Mountains, and Great Basin for analysis, and comparisons should be made among those specimens that have already been identified. Pitblado (1999, 2003, 2007) has done a commendable job of this for the southern Rockies, and her research could be used as a baseline for future investigations. However, the specimens from her study have not been compared with those from the Ray Long site or other Angostura specimens from the Black Hills and elsewhere in North America. The collation of these data would afford researchers a more viable sample with which to test existing hypotheses concerning land use and subsistence strategies employed by Angostura people. As part of this initiative, those reported or unconfirmed Angostura specimens identified in Figure 31 should be examined in light of our present understanding of the Angostura technocomplex to determine whether they are, indeed, Angostura.

Additional data are also available for comparative studies. Radiocarbon dates have been obtained from Ray Long (Buhta et al. 2012:1-16) and Pitblado (1999:197-202, 2010:130) has identified dates and date ranges from other Angostura sites in the Rockies. However, the temporal and geographic distribution of known, dated Angostura sites has not been investigated in sufficient detail to address questions of possible diffusion of groups across the landscape over time. For instance, as we continue to gain a better understanding of dated Angostura sites on the landscape, we may find ourselves better equipped to answer such questions as: Where do Angostura groups seem to have come from?; Where else on the landscape are we seeing Angostura and how do the dates at these sites compare with those from other localities?; Does the distribution of these dates seem to suggest a time-transgressive diffusion from one particular area into another?; and, Does the Angostura complex seem to be autonomous, or are its roots intimated in earlier complexes?

Pitblado (2007:332) suggests that Angostura groups practiced a "Foothills-Mountain," or "collector" subsistence strategy and remained largely confined to the Rockies on a year-round basis. However, evidence of Angostura groups *is* present hundreds of kilometers east of the Rockies in the Black Hills and potentially on the Plains of Nebraska and eastern Montana, indicating a possible exception to the perceived rule. Further investigation of these sites may help clarify why certain Angostura groups were utilizing the Plains while the majority kept to the mountains. Perhaps climate played a role and this topic could be explored through an examination of paleoenvironmental data associated with a number of these sites.

A final pressing issue relates to the identification, or misidentification, of Angostura specimens in state databases and the casual, overuse of the term "Angostura" in the archeological literature (see Thoms 1993). As Pitblado (2007:317) notes, after Wheeler's time, Angostura has frequently been used as a general "wastebasket" typological label for any parallel obliquely flaked lanceolate point that could not be more precisely classified. Because of this, state files and databases likely abound with "Angostura" sites that may very well not be Angostura at all. Complicating matters is the classification of another lanceolate projectile point found on the Southern Plains as "Angostura." This point, now generally termed "Texas Angostura," is lanceolate and exhibits parallel oblique flaking but is otherwise distinct from that originally identified by Wheeler (Holliday 2000:227; Turner and Hester 1993). One could only truly obtain meaningful data related to the temporal and spatial distribution of Angostura sites by first searching the state site files and databases and then reexamining the actual point specimens classified as Angostura to determine how many actually fit the definition of the point as it is now understood. Reliance solely upon the site files to test hypotheses about site distribution and land use patterns could easily lead to erroneous conclusions.

REFERENCES CITED

Ahler, S. A., and P. R. Geib

2000 Why Flute? Folsom Point Design and Adaptation. *Journal of Archaeological Science* 27:799-820.

Alexander, H. L., Jr.

1963 The Levi Site: A Paleo-Indian Campsite in Central Texas. *American Antiquity* 28(4):510-528.

Alperson-Afil, N., D. Richter, and N. Goren-Inbar

2007 Phantom Hearths and the Use of Fire at Gesher Benot Ya`aqov, Israel. *PaleoAnthropology* 2007:1-15.

Arnn, J. W., III

2012 Defining Hunter-Gatherer Sociocultural Identity and Interaction at a Regional Scale: The Toyah/Tejas Social Field. In *The Toyah Phase of Central Texas: Late Prehistoric Economic and Social Processes*, edited by N. A. Kenmotsu and D. K. Boyd, pp. 44-75. Texas A&M University Press, College Station.

Bamforth, D. B.

1991a Flintknapping Skill, Communal Hunting, and Paleoindian Projectile Point Typology. *Plains Anthropologist* 36(137):309-322.

1991b Population Dispersion and Paleoindian Technology at the Allen Site. In *Raw Material Economies Among Prehistoric Hunter-Gatherers,* edited by A. Montet-White and S. R. Holen, pp. 357-374. Publications in Anthropology 19. University of Kansas, Lawrence.

Bamforth, D. B. (editor)

2007 *The Allen Site: A Paleoindian Camp in Southwestern Nebraska.* University of New Mexico Press, Albuquerque.

Benedict, J. B.

1981 *The Fourth of July Valley.* Research Report No. 2. Center for Mountain Archeology, Ward, Colorado.

1985 *Arapaho Pass.* Research Report No. 3. Center for Mountain Archeology, Ward, Colorado.

1990 *Archeology of the Coney Creek Valley.* Research Report No. 5. Center for Mountain Archeology, Ward, Colorado.

1996 *The Game Drives of Rocky Mountain National Park.* Research Report No. 7. Center for Mountain Archeology, Ward, Colorado.

Bleed, P.
1986 The Optimal Design of Hunting Weapons: Maintainability or Reliability. *American Antiquity* 51:737-747.

2001 Trees or Chains, Links or Branches: Conceptual Alternatives for Consideration of Stone Tool Production and Other Sequential Activities. *Journal of Archaeological Method and Theory* 8(1):101-127.

Boen, R. M., J. Bush, and H. Sieverding
2013 *Sourcing Quartzite Projectile Points from 39FA65, the Ray Long Site, Fall River County, South Dakota.* Cultural Resource Project No. 2013.003q. Prepared by U.S. Department of the Interior, Bureau of Reclamation-Dakotas Area Office, Kadrmas, Lee & Jackson, Incorporated, and Kiksapa Consulting, LLC. Submitted to U.S. Department of the Interior, Bureau of Reclamation-Dakotas Area Office, Rapid City, South Dakota.

Bradley, B. A.
1982 Flaked Stone Technology and Typology. In *The Agate Basin Site: A Record of the Paleoindian Occupation of the Northwestern High Plains*, edited by G. C. Frison and D. J. Stanford, pp.181-208. Academic Press, Inc., New York.

Brunswig, R. H.
2007 Paleoindian Cultural Landscapes and Archaeology of North-Central Colorado's Southern Rockies. In *Frontiers in Colorado Paleoindian Archaeology*, edited by R. H. Brunswig and B. L. Pitblado, pp. 261-310. University Press of Colorado, Boulder.

Buechler, J. V.
1999 *An Intensive (Class III) Cultural Resources Inventory Survey of the Dacotah Cement Land Exchange Proposal in Southwestern Custer County, South Dakota, Volumes I and II.* Project No. 99-9. Dakota Research Services, Rapid City, South Dakota. Submitted to Dacotah Cement, Rapid City, South Dakota.

Buhta, A. A., R. D. Mandel, and L. A. Hannus
2012 *The Archeology, History, and Geomorphology of the Ray Long Site (39FA65), Angostura Reservoir, Fall River County, South Dakota: Manuscript II.* Archeological Contract Series No. 254. Archeology Laboratory, Augustana College, Sioux Falls, South Dakota. Submitted to U.S. Department of the Interior, Bureau of Reclamation, Rapid City Field Office, Rapid City, South Dakota.

Caywood, L. R.
1948 Yuma Point from Western Idaho. *American Antiquity* 13(3):251.

Cotterell, B., and J. Kamminga
1990 *Mechanics of Pre-industrial Technology.* Cambridge University Press, Cambridge.

Davis, E. M.
1953 Recent Information from Two Paleo-Indian Sites on Medicine Creek, Nebraska. *American Antiquity* 18:380-386.

1954 The Culture History of the Central Great Plains Prior to the Introduction of Pottery. Unpublished Ph.D. dissertation, Department of Anthropology, Harvard University.

1962 *Archeology of the Lime Creek Site in Southwestern Nebraska.* Special Publication No. 3. University of Nebraska State Museum, Lincoln.

Davis, E. M., and C. B. Schultz
1952 The Archaeological and Paleontological Salvage Program at the Medicine Creek Reservoir, Frontier County, Nebraska. *Science* 115:288-290.

Davis, L. B.
1993 Paleo-Indian Archaeology in the High Plains and Rocky Mountains of Montana. In *From Kostenki to Clovis: Upper Paleolithic - Paleo-Indian Adaptations*, edited by O. Soffer and N. D. Praslov, pp. 263-277. Plenum Press, New York.

Davis, L. B., S. A. Aaberg, W. P. Eckerle, J. W. Fisher, Jr., and S. T. Greiser
1989 Montane Paleoindian Occupation of the Barton Gulch Site, Ruby Valley, Southwestern Montana. *Current Research in the Pleistocene* 6:7-9.

Davis, L. B., S. A. Aaberg, and S. T. Greiser
1988 Paleoindians in Transmontane Southwestern Montana: The Barton Gulch Occupation, Ruby River Drainage. *Current Research in the Pleistocene* 5:9-11.

Davis, L. B., M. Kay, and S. T. Greiser
1998 Barton Gulch Paleoindian Alder Complex Functional Analysis. *Current Research in the Pleistocene* 15:73-74.

Field, J. E.
1965 Fracture of Solids. *Annual Report of the Smithsonian Institution for 1964:*431-438.

Figgins, J. D.
1935 *Folsom and Yuma Artifacts, Part II.* Proceedings of the Colorado Museum of Natural History 14(2).

Flemmer, D., and G. J. Sheveland
1993 *A Level III Heritage Resource Inventory of the Thompson Timber Sale, Black Hills National Forest in Pennington County, South Dakota.* Project No. E-10-93. Black Hills National Forest, Custer, South Dakota.

Fredlund, G. G.
1988 *Palynological Analysis of Four Archaeological Samples from the Ray Long Site (39FA65), Southwestern South Dakota.* Department of Geography, University of Kansas, Lawrence. Submitted to South Dakota State Historical Society, Archaeological Research Center, Rapid City, South Dakota.

Frison, G. C.
1991 *Prehistoric Hunters of the High Plains.* 2nd ed. Academic Press, New York.

1992 The Foothills-Mountains and the Open Plains: The Dichotomy in Paleoindian Subsistence Strategies Between Two Ecosystems. In *Ice Age Hunters of the Rockies,* edited by D. J. Stanford and J. S. Day, pp. 323-342. Denver Museum of Natural History and University Press of Colorado, Niwot.

Frison, G. C., and D. J. Stanford
1982 *The Agate Basin Site. A Record of the Paleoindian Occupation of the Northwestern High Plains.* Academic Press, New York.

Frison, G. C., and D. N. Walker (editors)
2007 *Medicine Lodge Creek: Holocene Archaeology of the Eastern Big Horn Basin, Wyoming, vol. I.* Clovis Press, Colorado Springs.

Froiland, S. G.
1978 *Natural History of the Black Hills.* The Center for Western Studies, Augustana College, Sioux Falls.

Gant, R. D.
1961 An Early Man Site in the Black Hills. *Museum News* 22(10):1-2, 7-8. On file, W. H. Over Dakota Museum, University of South Dakota, Vermillion.

Greene, A. M.
1967 The Betty Greene Site: A Late Paleo-Indian Site in Eastern Wyoming. Unpublished Master's thesis, Department of Anthropology, University of Pennsylvania, Philadelphia.

Hamilton, E.
1977 *Redbird Draw Timber Sale.* Project No. E-12-77. Black Hills National Forest, Elk Mountain District, Custer, South Dakota.

1980 *Briggs Spring Improvement.* Project No. E-12-80. Black Hills National Forest, Elk Mountain District, Custer, South Dakota.

Hannus, L. A.
1986 *Report on 1985 Test Excavations at the Ray Long Site (39FA65) Angostura Reservoir, Fall River County, South Dakota.* Archeological Contract Series No. 27. Archeology Laboratory, Augustana College, Sioux Falls, South Dakota. Submitted to State Archaeological Research Center, Ft. Meade, South Dakota, Contract No. 86C-016.

Hannus, L. A., R. P. Winham, and J. Albanese
1993 *Final Report: 1992 Archeological/Geomorphological Investigations at the Ray Long Site (39FA65), Angostura Reservoir, South Dakota.* Archeological Contract Series No. 86. Archeology Laboratory, Augustana College, Sioux Falls, South Dakota. Submitted to U.S. Department of the Interior, Bureau of Reclamation, Missouri-Souris Projects Office, Ecology Division, Bismarck, North Dakota.

Hannus, L. A., R. P. Winham, and A. A. Buhta
2012 *The Archeology, History, and Geomorphology of the Ray Long Site (39FA65), Angostura Reservoir, Fall River County, South Dakota: Manuscript I.* Archeological Contract Series No. 254. Archeology Laboratory, Augustana College, Sioux Falls, South Dakota. Submitted to U.S. Department of the Interior, Bureau of Reclamation, Rapid City Field Office, Rapid City, South Dakota.

Hannus, L. A., R. P. Winham, T. V. Gillen, E. J. Lueck, J. Strait, and K. Lippincott
1997 *Archeological Mitigation of the Buster Hill Site (39MD145), A Multi-component Archeological Site in the Black Hills, South Dakota.* Archeological Contract Series No. 114. Archeology Laboratory, Augustana College, Sioux Falls, South Dakota. Submitted to State Archaeological Research Center, Rapid City, South Dakota, Contract No. 93C-415.

Haug, J. K.
1987 The 1987 Angostura Project. *Newsletter of the South Dakota Archeological Society* 17(3-4):2-3.

Haug, J. K., and R. A. Alex
1985 Proposed Survey and Testing of Bureau of Reclamation Lands Adjacent to the Angostura Reservoir. Draft of 12 July 1985. On file, Archeology Laboratory, Augustana College, Sioux Falls, South Dakota.

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

Holder, P., and J. Wike
1949 The Frontier Culture Complex, A Preliminary Report on a Prehistoric Hunter's Camp in Southwestern Nebraska. *American Antiquity* 14:260-266.

Holliday, V. T.
2000 The Evolution of Paleoindian Geochronology and Typology on the Great Plains. *Geoarchaeology: An International Journal* 15(3):227-290.

Holmes, W. H.
1894 Natural History of Flaked Stone Implements. *Memoirs of the International Congress of Anthropology*:120-139. Chicago.

Howard, E. B.
1939 Folsom and Yuma Points from Saskatchewan. *American Antiquity* 4(3):277-279.

Hughes, J. T.
1949 Investigations in Western South Dakota and Northeastern Wyoming. *American Antiquity* 14:266-277.

Husted, W. M., and R. Edgar
2002 *The Archeology of Mummy Cave, Wyoming: An Introduction to Shoshonean Prehistory*. Special Report No. 4. U.S. Department of the Interior, National Park Service, Midwest Archeological Center, Lincoln, Nebraska.

Johnson, J. K.
1993 North American Biface Production Trajectory Modeling in Historic Perspective. *Plains Anthropologist* 38(143):151-162.

Kay, M.
1984 Late Caddo Subtractive Technology in the Red River Basin. In *Cedar Grove: An Interdisciplinary Investigation of a Late Caddo Farmstead in the Red River Valley,* edited by N. L. Trubowitz, pp. 174-206. Research Series No. 23. Arkansas Archeological Survey, Fayetteville.

1996 Microwear Analysis of Some Clovis and Experimental Chipped Stone Tools. In *Stone Tools: Theoretical Insights into Human Behavior,* edited by G. H. Odell, pp. 315-344. Plenum Press, New York.

1997a Buster Hill Site (39MD145) Microwear Analysis. In *Archeological Mitigation of the Buster Hill Site (39MD145), A Multi-component Archeological Site in the Black Hills, South Dakota,* by L. A. Hannus, R. P. Winham, T. V. Gillen, E. J. Lueck, J. Strait, and K. Lippincott, pp. 20.1-20.12. Archeological Contract Series No. 114. Archeology Laboratory, Augustana College, Sioux Falls, South Dakota. Submitted to State Archaeological Research Center, Rapid City, South Dakota, Contract No. 93C-415.

1997b Imprints of Ancient Tool Use at Monte Verde. In *The Archaeological Context and Interpretation,* edited by T. D. Dillehay, pp. 649-660. Monte Verde: A Late Pleistocene Settlement in Chile, vol. II, T. D. Dillehay, general editor. Smithsonian Institution Press, Washington, D.C.

Kehoe, T. F.
1955 Some Chipped Stone Artifacts from Southwestern Idaho. *Plains Anthropologist* 3:13-18.

Keller, S., and R. Keller
1984 *Belle Fourche River Project, Volume 1: Western Butte County, South Dakota.* Contract Investigations Series No. 144-I. South Dakota State Historical Society, Archaeological Research Center, Rapid City, South Dakota.

Kornfeld, M., G. C. Frison, and M. L. Larson

2010 *Prehistoric Hunter-Gatherers of the High Plains and Rockies*. 3rd ed. Left Coast Press, Inc., Walnut Creek.

Krieger, A. D.

1944 The Typological Concept. *American Antiquity* 9(3):271-288.

Kruse, J. M., T. V. Gillen, J. R. Bozell, L. Palmer, and A. A. Buhta

2008 *A Level III Cultural Resources Evaluation of Powertech (USA) Incorporated's Proposed Dewey-Burdock Uranium Project Locality within the Southern Black Hills, Custer and Fall River Counties, South Dakota*. Archeological Contract Series No. 216. Archeology Laboratory, Augustana College, Sioux Falls, South Dakota. Submitted to Powertech (USA) Incorporated, Centennial, Colorado.

Larson, M. L., M. Kornfeld, and G. C. Frison (editors)

2009 *Hell Gap: A Stratified Paleoindian Campsite at the Edge of the Rockies*. The University of Utah Press, Salt Lake City.

MacNeish, R. S.

1952 A Possible Early Site in the Thunder Bay District, Ontario. *Annual Report of the National Museum of Canada, for the Fiscal Year 1950-1951*, Bulletin No. 126:28-47. Department of Mines and Resources, Ottawa.

1956 Two Archaeological Sites of Great Bear Lake, Northwest Territories, Canada. *Annual Report of the National Museum of Canada for the Fiscal Year 1953-1954.* Bulletin 136:54-84. Department of Mines and Resources, Ottawa.

McCracken, H., W. R. Wedel, R. Edgar, J. H. Moss, H. E. Wright, Jr., W. M. Husted, and W. Mulloy

1978 *The Mummy Cave Project in Northwestern Wyoming.* The Buffalo Bill Historical Center, Cody, Wyoming.

Mandel, R. D.

2008 Buried Paleoindian-age Landscapes in Stream Valleys of the Central Plains, USA. *Geomorphology* 101:342-361.

2012 Geoarcheology and Paleoenvironmental Context of the Ray Long Site. In *The Archeology, History, and Geomorphology of the Ray Long Site (39FA65), Angostura Reservoir, Fall River County, South Dakota: Manuscript II*, by A. A. Buhta, R. D. Mandel, and L. A. Hannus, pp. 17-31. Archeological Contract Series No. 254. Archeology Laboratory, Augustana College, Sioux Falls, South Dakota. Submitted to U.S. Department of the Interior, Bureau of Reclamation, Rapid City Field Office, Rapid City, South Dakota.

Miller, P. V.

1992 *A Level III Cultural Resource Inventory of Buckhorn and Wabash Timber Sales on the Custer Ranger District, Black Hills National Forest, Custer County, South Dakota*. Project No. C-23-92. Frontier Cultural Services, Custer, South Dakota.

Mulloy, W.
1959 The James Allen Site, Near Laramie, Wyoming. *American Antiquity* 25(1):112-116.

Mulloy, W., and O. Lewis
1943 Some Early Types of Points from the Lower Yellowstone Country. *American Antiquity* 6(3):298-299.

Murphy, L. R., and R. D. Mandel
2012 Paleoenvironmental Context: The Stable Carbon Isotope and Phytolith Record. In *Agate Basin Archaeology at Beacon Island, North Dakota,* edited by M. D. Mitchell, pp. 191-199. Research Contribution No. 86. Paleocultural Research Group Monograph Series, Arvada, Colorado.

Noisat, B.
1988 *National Register of Historic Places Evaluation of Sites 48WE76, 39CU25, 39CU26, 39CU242, 39CU243, 39CU249, 39CU649, 39CU720, 39PN94, 39PN96, 39PN99, 39PN100, 39PN150, 39PN174, 39PN186, 39PN218, 39PN219, 39PN223, 39PN239, 39PN422, 39PN423, 39PN426, 39PN436, 39PN444, 39PN449, 39PN451, Black Hills National Forest, Elk Mountain Ranger District, Custer and Pennington Counties, South Dakota.* Niwot Archeological Consultants, Niwot, Colorado.

Padilla, M., and A. Schlosser
2011 *A Level III Cultural Resource Inventory of the Briggs Spring Analysis Project in the Black Hills National Forest, Hell Canyon Ranger District, Custer and Pennington Counties, South Dakota.* Black Hills National Forest, Hell Canyon District, Custer, South Dakota.

Perino, G.
1985 *Selected Preforms, Points, and Knives of the North American Indians,* vol. 1. Points and Barbs Press, Idabel, Oklahoma.

Pettipas, L.
1970 Early Man in Manitoba. In *Ten Thousand Years: Archeology in Manitoba*, edited by W. M. Hlady, pp. 5-28. Manitoba Archaeological Society, Winnipeg.

Pitblado, B. L.
1998 Peak to Peak in Paleoindian Time: Occupation of Southwest Colorado. *Plains Anthropologist* 43(166):333-348.

1999 Late Paleoindian Occupation of the Southern Rocky Mountains: Projectile Points and Land Use in the High Country. Unpublished Ph.D. dissertation, Department of Anthropology, University of Arizona, Tucson.

Pitblado, B. L. (continued)
2003 *Late Paleoindian Occupation of the Southern Rocky Mountains: Early Holocene Projectile Points and Land Use in the High Country*. University Press of Colorado, Boulder.

2007 Angostura, Jimmy Allen, Foothills-Mountain: Clarifying Terminology for Late Paleoindian Southern Rocky Mountain Spear Points. In *Frontiers in Colorado Paleoindian Archaeology*, edited by R. H. Brunswig and B. L. Pitblado, pp. 311-327. University Press of Colorado, Boulder.

2010 Preliminary Subsurface Exploration at the Fox Site, Southeastern Idaho. *Current Research in the Pleistocene* 27:129-131.

Prewitt, E. R.
1981 Cultural Chronology in Central Texas. *Bulletin of the Texas Archeological Society* 52:65-89.

Reimer, P. J., M. G. L. Baillie, E. Bard, A. Bayliss, J. W. Beck, P. G. Blackwell, C. Bronk Ramsey, C. E. Buck, G. S. Burr, R. L. Edwards, M. Friedrich, P. M. Grootes, T. P. Guilderson, I. Hajdas, T. J. Heaton, A. G. Hogg, K. A. Hughen, K. F. Kaiser, B. Kromer, F. G. McCormac, S. W. Manning, R. W. Reimer, D. A. Richards, J. R. Southon, S. Talamo, C. S. M. Turney, J. van der Plicht, and C. E. Weyhenmeyer
2009 INTCAL09 and MARINE09 Radiocarbon Age Calibration Curves, 0-50,000 Years CAL BP. *Radiocarbon* 51(4):1111-1150.

Root, M. J., J. D. Williams, M. Kay, and L. K. Shifrin
1999 Folsom Ultrathin Biface and Radial Break Tools in the Knife River Flint Quarry Area. In *Folsom Lithic Technology: Explorations in Structure and Variation,* edited by D. S. Amick, pp. 144-168. Archaeological Series 12. International Monographs in Prehistory, Ann Arbor.

Scott, L. J., and R. O. Lewis
1986 Pollen and Phytolith Analysis at the Ray Long Site (39FA65) South Dakota: A Feasibility Study. In *Report on 1985 Test Excavations at the Ray Long Site (39FA65) Angostura Reservoir, Fall River County, South Dakota,* by L. Adrien Hannus, pp. 31-41. Archeological Contract Series No. 27. Archeology Laboratory, Augustana College, Sioux Falls, South Dakota. Submitted to State Archaeological Research Center, Ft. Meade, South Dakota, Contract No. 86C-016.

Scott Cummings, L.
1988 *Charcoal and Seed Analysis at the Ray Long Site, South Dakota.* PaleoResearch Laboratories, Denver, Colorado. Submitted to Office of the State Archaeologist, South Dakota State Historical Society, Archaeological Research Center, Rapid City, South Dakota.

Sellards, E. H.
1952 *Early Man in America.* University of Texas Press, Austin.

Sellards, E. H., G. L. Evans, and G. E. Meade
1947 Fossil Bison and Associated Artifacts from Plainview, Texas, with Description of Artifacts by Alex D. Krieger. *Bulletin of the Geological Society of America* 58:927-954. New York.

Semenov, S. A.
1964 *Prehistoric Technology.* Cory, Adams and MacKay, London.

Sharrock, F. W.
1966 *Prehistoric Occupation Patterns in Southwest Wyoming and Cultural Relationships with the Great Basin and Plains Culture Areas.* Anthropological Papers No. 77. Department of Anthropology, University of Utah, Salt Lake City.

Sheveland, G. J., C. Wood, and J. Garcia
1998 *Testing, Evaluation, Mitigation, and Monitoring of Seven Sites (39PN128, 39PN319, 39PN464, 39PN1395, 39PN1444, 39PN1445 and 39PN1485) Pactola/Harney Ranger District, Black Hills National Forest, Pennington County, South Dakota.* Project No. PH-34-98/PH-20-97. Pactola/Harney District, Black Hills National Forest, Custer, South Dakota.

Sollberger, J. B., and T. R. Hester
1972 The Strohacker Site: A Review of Pre-Archaic Manifestations in Texas. *Plains Anthropologist* 17(58):327-344.

Suhm, D. A., and E. B. Jelks
1962 *Handbook of Texas Archeology: Type Descriptions.* Special Publications No. 1. Texas Archeological Society, Texas Memorial Museum Bulletin No. 4. Austin.

Thoms, A. V.
1993 Knocking Sense from Old Rocks: Typologies and the Narrow Perspective of the Angostura Point Type. *Lithic Technology* 18(1 & 2):16-27.

Thoms, A. V., and R. D. Mandel (editors)
2007 *Archaeological and Paleoecological Investigations at the Richard Beene Site South-Central Texas – Volume I: Paleoecological Studies, Cultural Contexts, and Excavation Strategies.* Reports of Investigations 8. Center for Ecological Archaeology, Texas A&M University, College Station.

Tratebas, A. M.
1977 Excavations at the Boulder Canyon Site (39LA3). *Newsletter of the South Dakota Archaeological Society* 7(4):4-5.

Turner, E. S., and T. R. Hester
1993 *A Field Guide to Stone Artifacts of Texas Indians.* 2nd ed. Texas Monthly Fieldguide Series. Gulf Publishing, Houston.

Wheeler, R. P.
1954 Selected Projectile Point Types of the United States: II. *Bulletin of the Oklahoma Anthropological Society* 2:1-6.

1995 *Archeological Investigations in Three Reservoir Areas in South Dakota and Wyoming: Part I, Angostura Reservoir.* Reprints in Anthropology No. 46. J & L Reprint Company, Lincoln.

1996 *Archeological Investigations in Three Reservoir Areas in South Dakota and Wyoming: Part II – Keyhole Reservoir.* Reprints in Anthropology No. 47. J & L Reprint Company, Lincoln.

1997 *Archeological Investigations in Three Reservoir Areas in South Dakota and Wyoming: Part III – Boysen Reservoir.* Reprints in Anthropology No. 49. J & L Reprint Company, Lincoln.

Wormington, H. M.
1949 *Ancient Man in North America.* 3rd ed. Popular Series No. 4, Denver Museum of Natural History, Denver.

1957 *Ancient Man in North America.* 4th ed. Popular Series No. 4. Denver Museum of Natural History, Denver.

APPENDIX M

1) PROJECTILE POINT SPECIMENS FROM SIOUX AND DAWES COUNTIES, NEBRASKA

2) MICROWEAR ANALYSIS OF UNIFACIAL AND GROUNDSTONE ARTIFACTS AND THEIR DEBITAGE AND A BIFLUTED PROJECTILE POINT FROM THE RAY LONG SITE (39FA65)

1) SPECIMENS FROM SIOUX AND DAWES COUNTIES, NEBRASKA

The majority of the Sioux and Dawes County, Nebraska specimens (Figures M1-M6), classified by Wheeler (1995) as Angostura, were briefly examined by Bruce Bradley and Marvin Kay. The specimens shown in Figure M1 were classified by Bradley as Agate Basin; those in Figure M2 as Angostura; those in Figure M3 as unknown; and those in Figure M4 as too fragmentary to identify. The items in Figures M5 and M6 were not available for examination at the time. Table M1 summarizes the comments made by Bradley on each specimen.

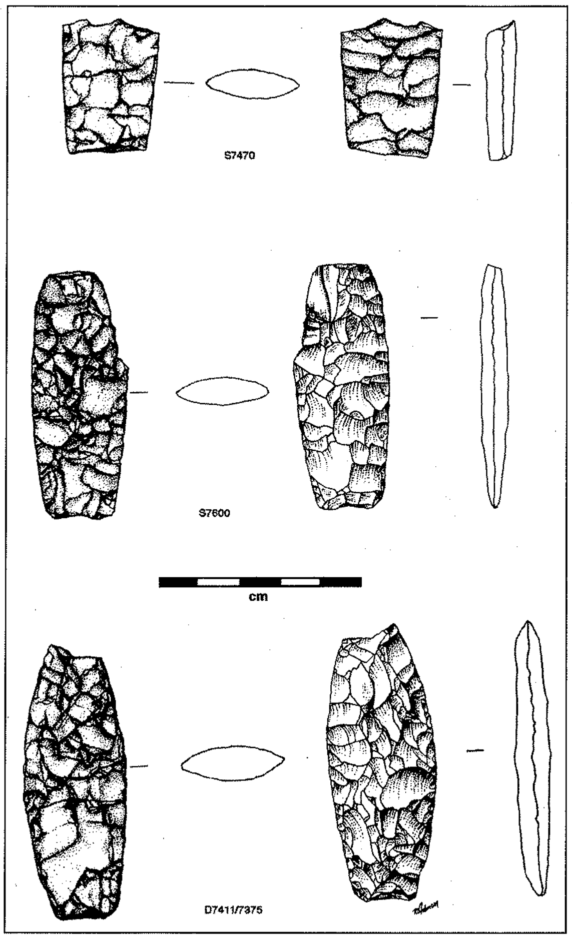


Figure M1. Group 1, Agate Basin.

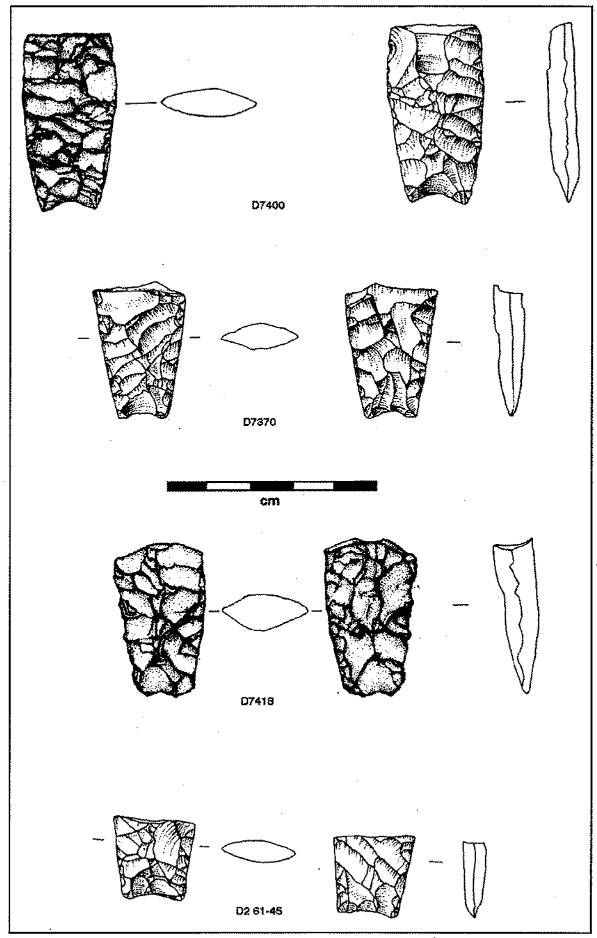


Figure M2. Group 2, Angostura.

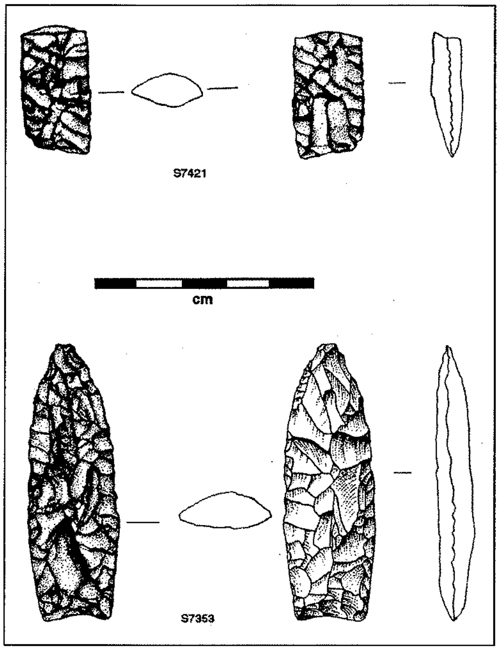


Figure M3. Group 3, Unknown.

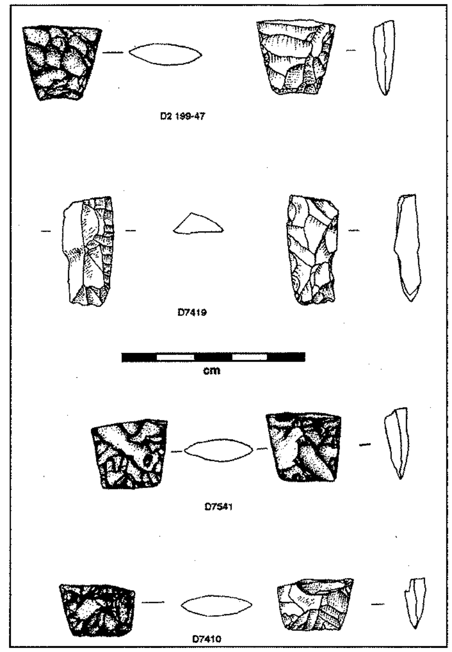


Figure M4. Group 4, Not Identifiable.

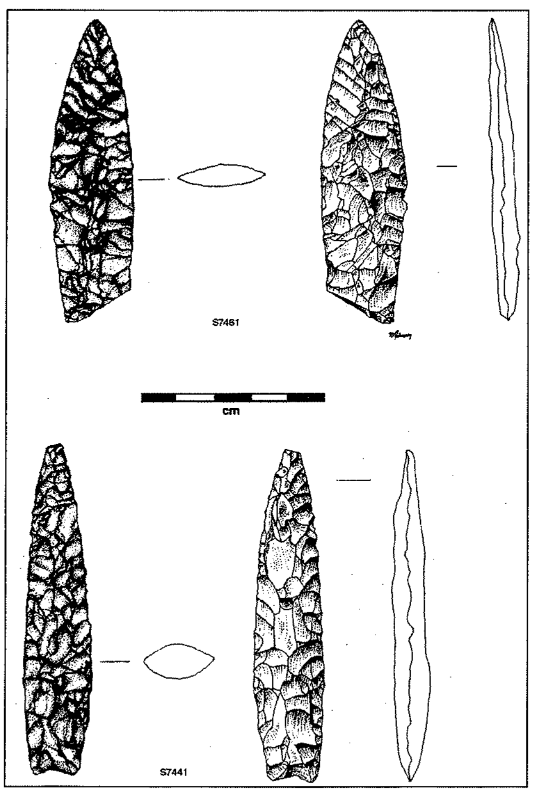


Figure M5. Group 5, Not Examined.

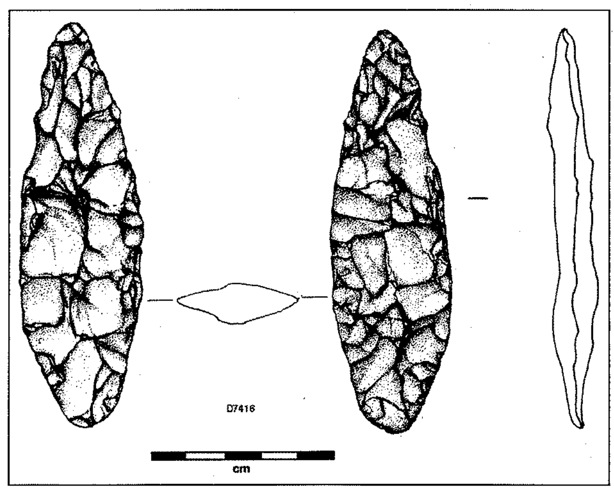


Figure M6. Group 6, Not Examined.

Table M1. Comments on the Sioux and Dawes County Specimens Identified by Wheeler as Angostura.

Specimen	Bruce Bradley's Comments	Marvin Kay's Specimen No.
	Agate Basin	
S7470	Basal midsection, impact break, Spanish Diggings quartzite	Kay's specimen 16
S7600	Incomplete base, impact break, Spanish Diggings quartzite	Kay's specimen 17
D7411/7375	Unfinished, manufacture break?, tip missing	Kay's specimen 13; TRSS
	Angostura	
D7400	Basal 2/3, impact break, gray quartz	Kay's specimen 22; Quartzite
D7370	Basal 1/2, break unknown, quartzite	Kay's specimen 21
D7418	Base? Fragment, break unknown, quartzite, badly beat up	Kay's specimen 14
D2 61-45	Base fragment, impact break, quartzite	Kay's specimen 20
	Unknown	
S7421	Base fragment, possibly reworked Cody?, white quartzite? Spanish Diggings?	Kay's specimen 18 Unground base
S7353	Complete, possibly reworked, quartzite	Kay's specimen 19
	Fragmentary	
D2 199-47	Base, quartzite, bend break	Kay's specimen 23
D7419	Split base, red quartzite, impact break?	Kay's specimen 12
D7541	Base, banded quartzite, impact break	Kay's specimen 15
D7410	Base, quartzite, impact break	Kay's specimen 24
S7461	Not examined	Kay's specimen 10; Quartzite Unground base
S7441	Not examined	Kay's specimen 8; Quartzite
D7416	Not examined	Kay's specimen 11; Quartzite

2) MICROWEAR ANALYSIS OF UNIFACIAL AND GROUNDSTONE ARTIFACTS AND THEIR DEBITAGE AND A BIFLUTED PROJECTILE POINT FROM THE RAY LONG SITE (39FA65)

Marvin Kay

UNIFACIAL AND GROUNDSTONE ARTIFACTS

The sample of reduction flakes from Ray Long includes six relatively large specimens, which conceivably could have been used as tools. Nine others, while smaller and less likely to have been tools, were also subjected to the microwear analysis, as were nine small sandstone fragments (see Table 2, Groups 1 and 2, page 20). Of the 15 flakes, only one of quartzite (Specimen 5-Figure M7-d) has indisputable evidence of use. Its broken, distal edge appears to have been employed as a hand-held borer used in a rotary fashion. This tool would have been either an ad hoc or expedient tool, or one that was deliberately prepared by radial fracture.

Two sandstone fragments also display use-wear. The larger is from an intentionally ground slab. Its use-wear consists of parallel striae obliquely oriented to what may have been an edge of the tool (Specimen 44-Figure M8). The fragment is too small to determine the kind of grinding tool. The other fragment does not conjoin but may be from the same artifact.

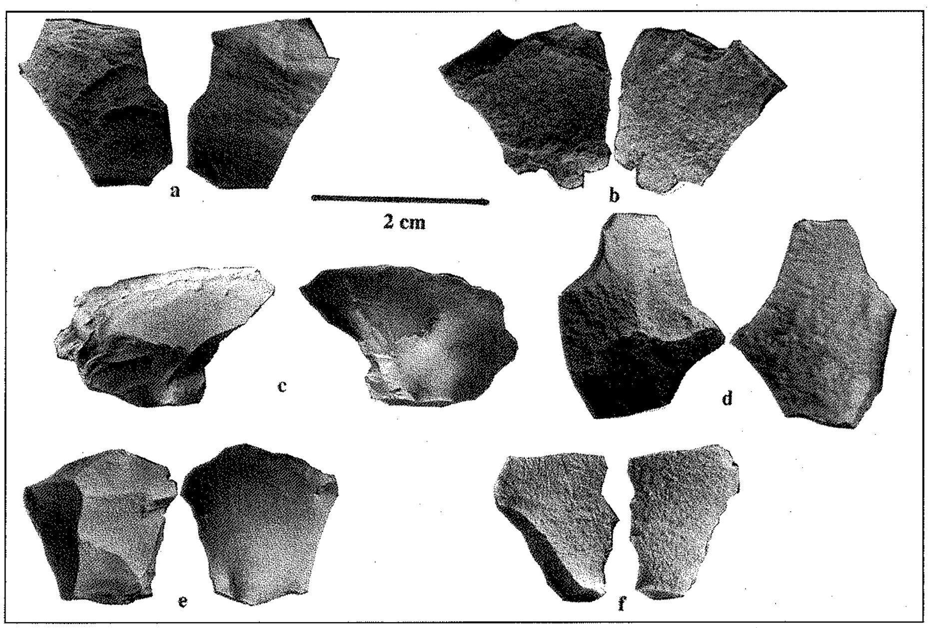


Figure M7. Large flakes from the Ray Long site (note that Specimen No. 5 [d] is the only tool): a) Specimen No. 2; b) Specimen No. 41; c) Specimen No. 35; d) Specimen No. 5; e) Specimen No. 37; f) Specimen No. 45.

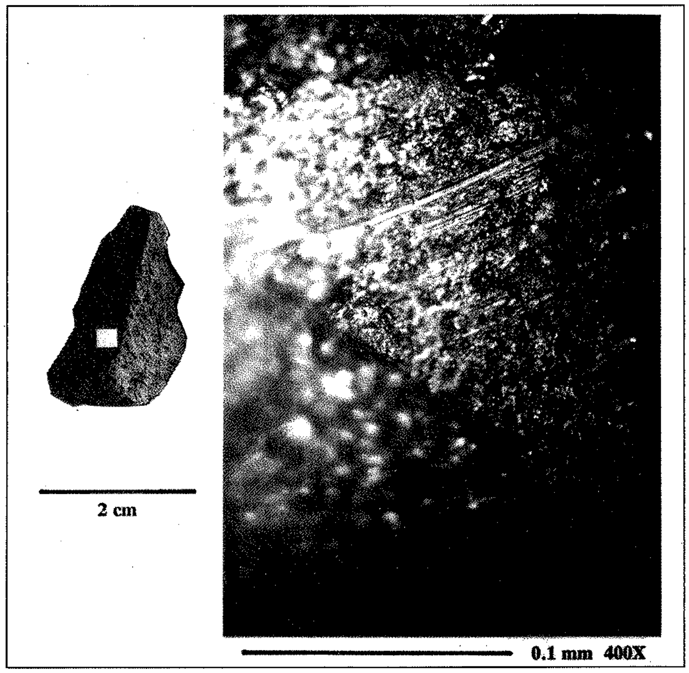


Figure M8. Oriented photomicrograph of abrasive use-wear on ground sandstone fragment (Specimen No. 44). The solid square is the approximate area of the enlargement.

Bifluted Projectile Point Base

One bifluted projectile point base, excavated at the Ray Long site in 1995, comes from stratigraphically sealed deposits below the Angostura component and figures only indirectly in the Angostura analysis. Sharing attributes of both Clovis and Folsom points, this artifact (Figures M9-M11) is too incomplete to make a foolproof distinction. It is of silicified sediment.

The bifluted point base from Ray Long was compared to a Clovis point base of comparable size and optically similar material from the Lange-Ferguson site (39SH33), located east of Ray Long in the White River Badlands, Shannon County, South Dakota. The latter has definitive haft wear traces and what appear to be secondary impact-related striations, in addition to lateral edge grinding. The bifluted lanceolate base from Ray Long presented no analytical problems but has no use-wear other than lateral edge grinding. Edge grinding of this kind relates not to use but to manufacture or optional maintenance. Either it better facilitates flaking (by deliberately flattening and roughening the striking platform), or dulls the edge for prehension or hafting; haft preparation if not actual evidence of being attached to a foreshaft is the more likely in this case. Additional provenience and descriptive information concerning the bifluted projectile point base from the Ray Long site is available in Buhta et al. (2012:60-61).

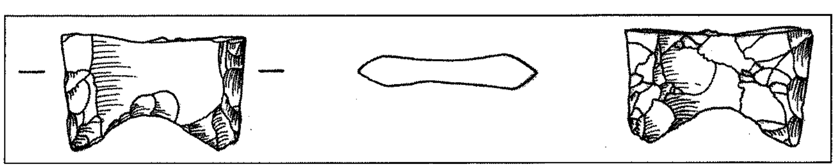


Figure M9. Scale line drawing of bi-fluted projectile point base recovered from soil balk of Level I, Unit 9N 2W, Area B.

Figure M10. Close-up of obverse (left) and reverse (right) faces of bifluted projectile point base recovered from Level I, Unit 9N 2W, Area B.

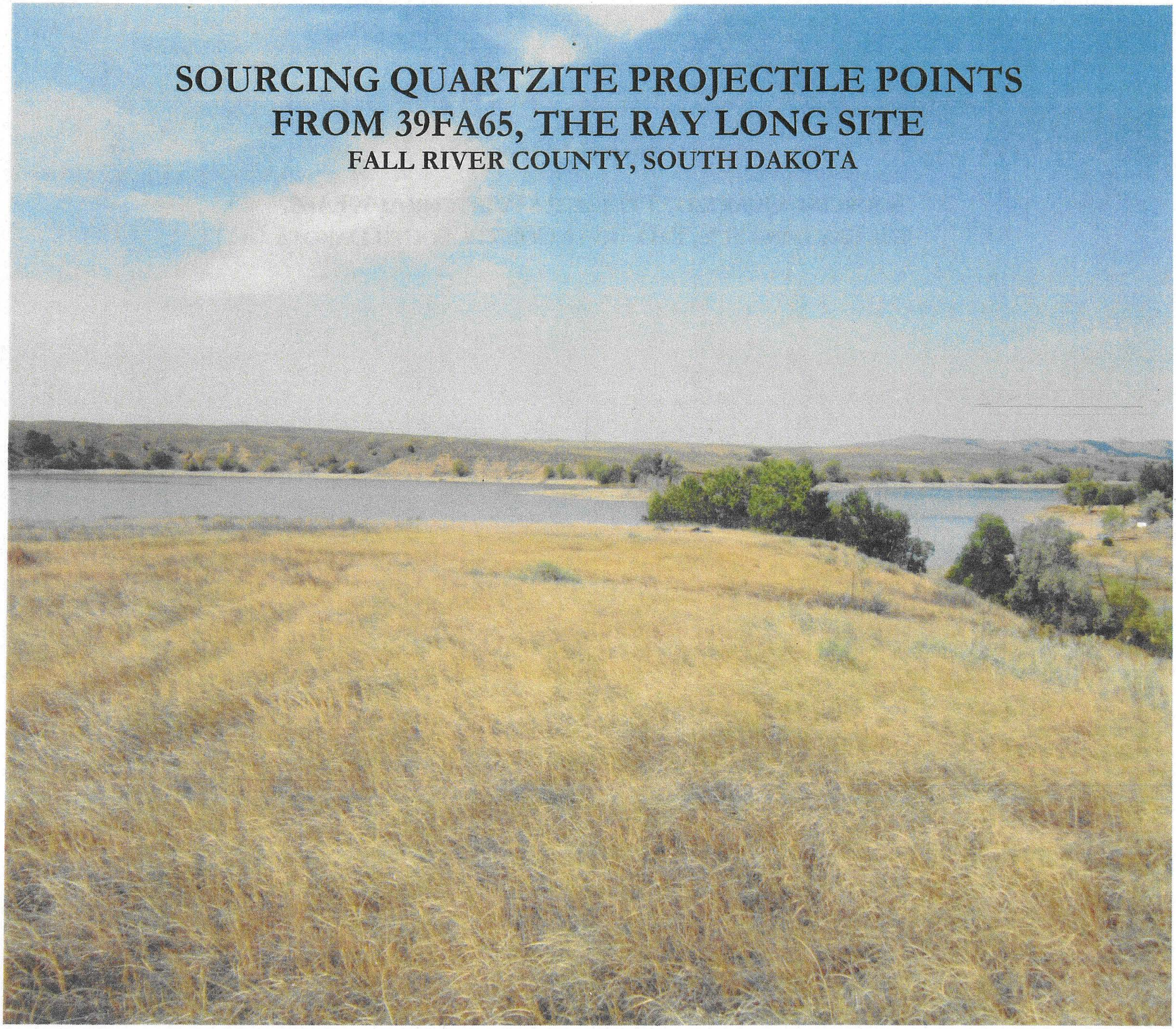
Figure M11. Fluted projectile point obverse, reverse, and cross-section view with oblique lighting to highlight some flake scars (image courtesy of Peter Bostrom – not to scale).

APPENDIX N

SOURCING QUARTZITE PROJECTILE POINTS FROM 39FA65, THE RAY LONG SITE, FALL RIVER COUNTY, SOUTH DAKOTA

SOURCING QUARTZITE PROJECTILE POINTS FROM 39FA65, THE RAY LONG SITE

FALL RIVER COUNTY, SOUTH DAKOTA



Renee M. Boen
Jessica Bush
Heidi Sieverding

2013

SOURCING QUARTZITE PROJECTILE POINTS FROM 39FA65, THE RAY LONG SITE

FALL RIVER COUNTY, SOUTH DAKOTA

Renee M. Boen
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November 2013

Cultural Resource Project No. 2013.003q

Renee M Boen

Renee M. Boen, Principal Investigator

Sponsored by the
Bureau of Reclamation
Dakotas Area Office
Rapid City Field Office

Dedicated to a great archaeologist and friend,
Ned Hanenberger;
his love of knowledge has been an inspiration.

ABSTRACT

The purpose of this research was to determine if the tool stone used for two quartzite Angostura projectile points from the Ray Long site (39FA65), Fall River County, South Dakota, could be linked to a specific quarry or geologic formation. The Ray Long site is the type-site for the Paleoindian period Angostura complex which has a regional distribution of Utah, Colorado, southeastern Idaho, Wyoming, southwestern South Dakota, and western Nebraska. The seven quarries selected for the study are located in the Black Hills Uplift in South Dakota and the Hartville Uplift in Wyoming. The study applied macroscopic and microscopic examination to lithologically describe and XRF testing to define initial XRF signatures for the quarries and the two projectile points. Results suggest that the tool stone material used to produce the projectile points likely originated in the Spanish Diggings quarry complex in the Cloverly Formation of the Hartville Uplift.

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ACKNOWLEDGEMENTS

Anyone who has contributed to the tool stone comparative collection at the South Dakota State Archaeological Research Center has contributed to this paper; we thank you!. Without the foundation of samples built over the past 40 years, or nearly 100 years if W.H. Over is included, the current research would not have been possible. With respect to the x-ray fluorescence study presented here, Renee Boen, Bureau of Reclamation, collected several of the samples, ran them in 2011, and prepared the tool stone sections of the paper. In 2013, Jessica Bush, Kadrmas, Lee & Jackson, Inc. (KLJ), conducted the qualitative analysis of the samples, prepared the sections describing this process, and prepared the XRF graphs and screen shots. Heidi Sieverding, Kiksapa, Inc. prepared the geology sections, wrote the geologic descriptions of the samples and projectile points, and constructed the maps. Sieverding and Boen completed the edits to the entire draft. We had many good discussions concerning what the results meant and where future studies should focus. It could be described as an accidental collaboration between the three of us that turned out better than we could have anticipated! For a start at building XRF signatures and geologic descriptions of quarry tool stone on the Northern Plains, we hope that this provides inspiration to others. Thanks to everyone who has contributed along the way.

Renee M. Boen
Jessica Bush
Heidi Sieverding
November 27, 2013

INTRODUCTION

A number of prehistoric quartzite quarries have been recorded and researched by archaeologists in the Black Hills and Hartville Uplifts of South Dakota and Wyoming (Ahler 1975; Cassells 1980; Church 1990; Craig 1983; Lee 1925; Tratebas, et. al. 1978). The previous research documents types of quarrying methods, geologic formations exploited, workshops and occupation areas, distribution of materials at archaeological sites, and tool stone descriptions. The purpose of this research was to determine if the tool stone used for two quartzite Angostura projectile points from the Ray Long site (39FA65), Fall River County, South Dakota, could be linked to a specific quarry or geologic formation (Figure 1). The Ray Long site is the type-site for the Paleoindian period Angostura complex which has a regional distribution of Utah, Colorado, southeastern Idaho, Wyoming, southwestern South Dakota, and western Nebraska (Pitblado 2003). Pitblado noted that tool stone used by Angostura complex groups were often from local sources found within approximately 70 kilometers (113 miles) of the site.

Determining the source of tool stone material recovered from an archaeological site can be used to predict the mobility of cultural groups, comprehend a group's interaction within a region, and lead to a better understanding of the group's land use. Identifying quarries used by a group can also help determine if the tool stone was acquired by direct collection or indirectly through trade. In this study seven previously recorded prehistoric quarries in four geological formations in the Black Hills Uplift in South Dakota and the Hartville Uplift in Wyoming were sampled, researched, examined macroscopically and microscopically, and subjected to x-ray fluorescence testing (XRF). As a tool, XRF determines the presence or absence of trace elements in samples within the middle range of the periodic table. The XRF test results from a group of samples collected from the same quarry were averaged to create an XRF signature for that source. The testing was non-destructive, therefore, both projectile points from the Ray Long site were also tested and results were compared to the quarry XRF signatures.

Two questions were posed for this study. First, do the quartzite quarries each have a unique XRF signature compared to other quartzite quarries, whether they are from the same geologic formation or not? Second, can the two quartzite projectile points from the Ray Long site be matched to a specific quarry or more generally, to a geologic formation included in the study? If so, is the tool stone used for both points from the same quarry or formation?

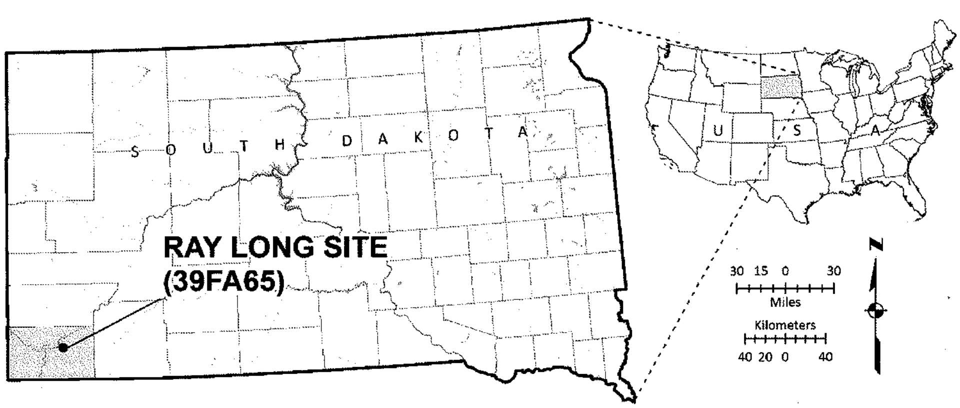


Figure 1. Location of the Ray Long site.

BACKGROUND

In the 1970s the South Dakota State Historical Society-Archaeological Research Center (Center) collected and traded for tool stone materials from around the Northern Plains to create a comparative collection. In addition, samples were extracted from the early twentieth century collections established by W.H. Over, a curator and later director of the Dakota Museum (now the W.H. Over Museum) in Vermillion, South Dakota. Over and H.E. Lee, a collector and friend of Over's who lived in the Black Hills, had samples from such well known quarries as Flint Hill, Battle Mountain, and Cowboy Hill in the Black Hills Uplift and the Spanish Diggings quarry complex in the Hartville Uplift. Over time, contributions to the comparative collection were also made by Dr. Stan Ahler, Dr. Robert Alex, Tim Church, Michael Fosha, Thomas Haberman, Dr. Steve Holen, Benjamin Rhodd, Dr. Alice Tratebas, Robert Vallejo, Wade Haakenson, Dan Wendt, and Roger Williams, among others. Many of these individuals published their research on specific sources or have contributed quarry information and identification in archaeological literature. Although the collection started informally with no funding source or formal management, the majority of the samples contain the necessary provenience and geologic information to be useful. What the collection lacked was a standardized nomenclature and description of the samples.

To increase its value and distribute examples to other agencies, the larger collection was sampled and four comparative kits were created by Renee Boen and Roger Williams at the Center. The kits are now housed at the Center (for a quick reference), Augustana College in Sioux Falls, South Dakota, the Natural Resources Conservation Service in Huron, South Dakota, and the Nebraska National Forest in Chadron, Nebraska. The kit samples were selected to represent variations in color, texture, patina, cortext, and changes caused by heat-treatment, if available. Each tool stone type was assigned a number that corresponds to its source area on a regional map that accompanies the kit (Figure 2). Unfortunately, descriptions of the tool stone samples were in draft form only at the time of the publication.

However, the first step, standardizing the nomenclature, was initiated and used to label the kit's samples. It favors the geologic formation of a source and the popular names most frequently found in the archaeological literature. This allows for continuity and comparisons. Researchers need to be able to exchange information and know that they are talking about the same source material. The numbers assigned below are only necessary to reference the map and kit samples; they have no other significance. Please bear in mind that these are sample points, however the potential source area for many of these lithic sources are typically broader than the point represented. The point location is meant as a general locality. For instance, 4c and 6e both occur within the Minnelusa Formation which 'rings' the Black Hills Uplift; these chert and quartzite lithic types could conceivable be found anywhere where this geologic formation and appropriate conditions are present.

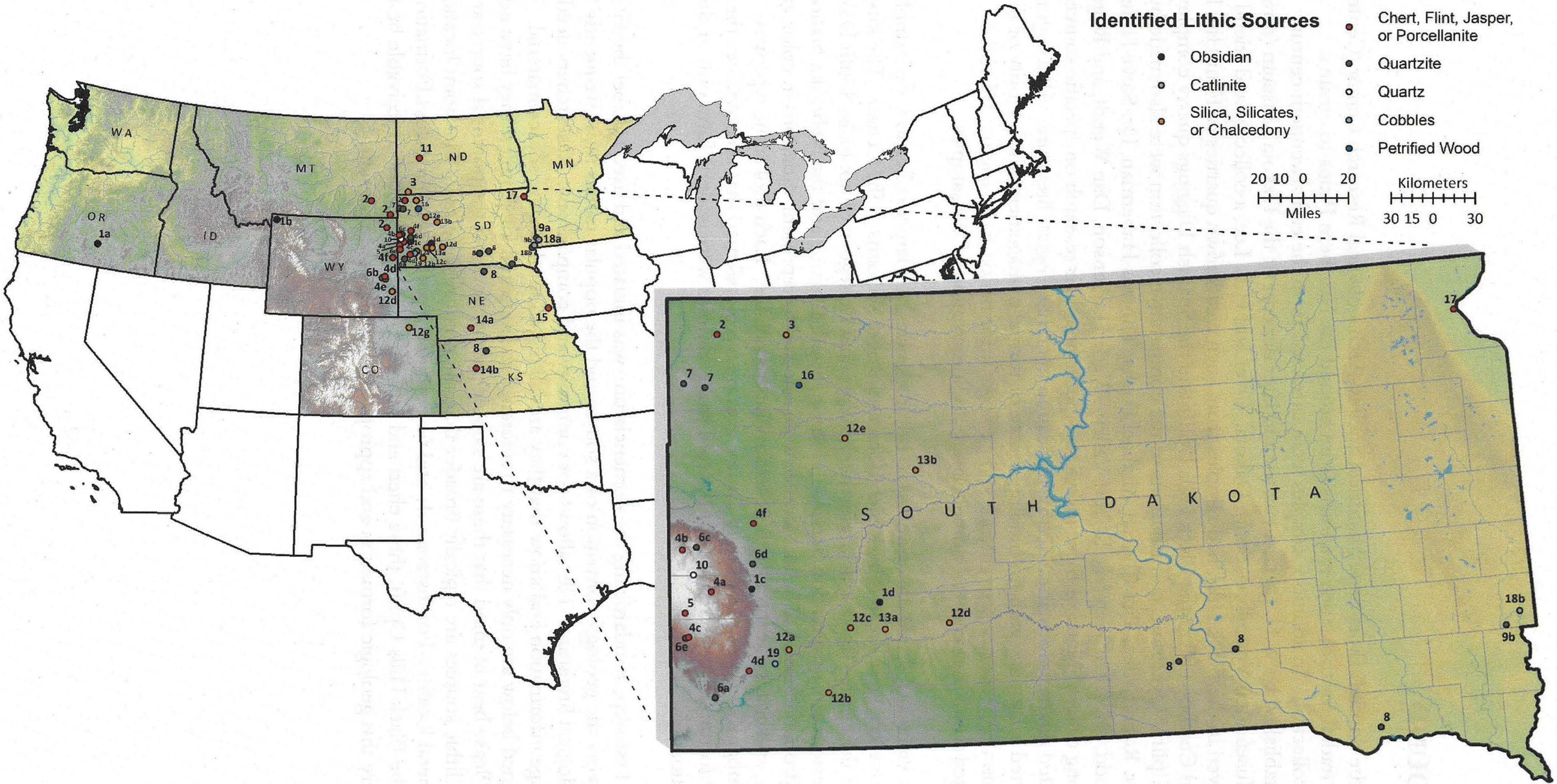


Figure 2. Regional map showing tool stone quarries and procurement sites.

The following list represents the nomenclature (in bold) used for the tool stone followed by the source samples:

1. **Obsidian**
   a. Lake County, Oregon
   b. Obsidian Cliff, Wyoming
   c. Tomahawk Country Club, Lawrence County, South Dakota
   d. 39PN76, Pennington County, South Dakota
2. **Porcellanite and non-volcanic natural glass, Montana, Wyoming, & South Dakota**
3. **Tongue River silica, North & South Dakota**
4. **Black Hills (BHU) and Hartville Uplifts (HU) cherts & chalcedonies**
   a. (Precambrian) Ferruginous chert (BHU), South Dakota
   b. (Mississippian) Paha Sapa chert (BHU), South Dakota
   c. (Pennsylvanian) Minnelusa chert (BHU), South Dakota
   d. (Jurassic) Morrison chert (BHU), South Dakota
   e. Guernsey chert (HU), Wyoming
   f. Alluvial deposits of pebbles, cobbles and boulders (BHU), Wyoming
5. **Spearfish chert, South Dakota**
6. **Black Hills (BHU) and Hartville Uplifts (HU) quartzites**
   a. (Inyan Kara) Fall River & Lakota quartzites (BHU), South Dakota
   b. Cloverly Formation (same as Inyan Kara Group in SD) quartzites (HU), Wyoming
   c. Deadwood quartzites (BHU), South Dakota
   d. Morrison quartzites (BHU & HU), South Dakota & Wyoming
   e. Minnelusa quartzites (BHU), South Dakota
7. **Short Pines quartzite, South Dakota**
8. **Bijou Hills quartzite, South Dakota, Nebraska, & Kansas**
9. **Sioux quartzite**
   a. Pipestone, Minnesota
   b. Minnehaha County, South Dakota
10. **Precambrian quartz, South Dakota**
11. **Knife River flint, North Dakota**
12. **White River Group silicates**
    a. French Creek, South Dakota
    b. West Horse Creek, South Dakota
    c. Scenic, South Dakota
    d. 39JK174, South Dakota
    e. Fox Ridge, South Dakota
    f. Table Mountain, Wyoming
    g. Flattop Butte, Colorado
13. **Plate chalcedony**
    a. Badlands, South Dakota
    b. Ziebach County, South Dakota
14. **Jaspers**
    a. Republican River, Nebraska
    b. Smoky Hill River, Kansas
15. **Nehawka flint, Nebraska**

16. **Petrified wood, western South Dakota**
17. **Swan River chert-39RO10, Roberts County, South Dakota**
18. **Catlinite and red pipestone**
    a. Pipestone, Minnesota
    b. Minnehaha County, South Dakota
19. **Grassland cobbles, southwestern South Dakota**

In 2011 samples from many of these sources were subjected to XRF testing. The XRF process identifies the trace elements in a sample and measures their abundance. The goal of averaging the data from multiple samples collected from a single tool stone source is to establish a characteristic XRF signature against which unknown samples from an archaeological context can be compared. To increase reliability of the data, tool stone samples should be systematically collected from a variety of locations within a prehistoric quarry. The researcher must also be well acquainted with the geology of the source area to ensure accurate identification of the geologic formation. Only outcrops that were exploited prehistorically need to be included in trace element studies. Outcrops not exploited prehistorically would have little relevance in studies of the distribution or exchange of tool stone (Foradas 2003:90). Samples would not need to be collected throughout a geologic formation; rather, the focus should be on prehistoric quarries. That being said, state site records are one of the main sources of initial information when studying a particular site type. These records, particularly the earliest ones, may contain incomplete and inaccurate data or even data that has not been field checked. Further discussion on this topic is presented in the Quarry Samples section.

It is recommended that prepared samples are approximately the same thickness. The XRF readings may be taken from several locations on the same sample. It is expected that the accuracy of the XRF signature would increase in direct proportion to the number and variety of samples that are analyzed. Therefore, the quarry XRF signature should be refined as additional samples are collected, analyzed, and added to the data set.

Some stone materials are better candidates for XRF analysis than others. For example, obsidian is a good candidate for XRF analysis because it typically has a homogenous composition. Discrete obsidian sources represent a single episode of magma deposition and different underlying geology resulting in a unique chemical XRF signature (Speakman 2009:3; Kunselman and Husted 1996:27). As one of the highest quality tool stones available to prehistoric groups, it was traded over great distances from the various sources. It has been found hundreds of miles from its source in cultural settings; providing a hint at the trade routes used by early groups. Sources in Russia and Alaska have also been tested in migration studies related to the Bering land bridge. For these reasons identifying the XRF signatures for obsidian sources has received a great deal of attention from archaeologists.

Cherts and chalcedonies, on the other hand, may be less than ideal candidates for XRF analysis because they typically have a heterogeneous chemical composition. Other means for identifying cherts and chalcedonies might be more reliable, for example, identifying fossils present, banding, mineralogy (Foradas 2003), cortext, and the use of long or short-wave ultraviolet light. Neutron activation analysis has also had some success for sourcing cherts and chalcedonies in the upper Midwest by the University of Michigan Museum of Anthropology Neutron Activation Analysis Project (Luedtke 1978). This study also showed that artifacts from a buried environment may exhibit some degree of change in their chemical properties. Even though there may be limitations to the data, many samples of cherts and chalcedonies from known sources on the Northern Plains were run in 2011 using XRF. However, only a few of the chalcedonies have been fully processed and none of the results have been analyzed. Before completely discounting the XRF process for heterogeneous samples the results from the 2011 runs should be examined.

PREHISTORIC QUARRIES

For the purposes of this study the term quarry is defined as a primary source for extracting stone by Native American's for the purpose of creating tools or weapons used to support their lifestyle. Archaeologists have applied tool stone studies of quarries to predict the mobility of cultural groups, comprehend a group's interaction within a region, and study their land use. The data can be used to build models to explain the use of a source, particularly if a source had greater or lesser use during a particular time period (Kunselman and Husted 1996). If archaeologists identify patterns of acquisition and distribution of tool stone within and among groups co-existing on the landscape, they can begin to understand interaction within a region. Tool stone is acquired by a group either directly or indirectly (Hofman 1990; Luedtke 1976). Direct acquisition is defined as the collection of tool stone from a primary or secondary source where there is no restriction to access. It may be as a result of a planned trip to the source for the specific purpose of replenishing tool stone for immediate or later use, part of travel to acquire other nearby seasonal resources, or during migration. Indirect acquisition is defined as trading with others for tool stone from a source where access is restricted and typically originates outside the group's normal range of travel, sometimes by hundreds of miles. This definition of indirect acquisition suggests that even locally available materials in terms of distance to the source may have had restricted access if it was controlled by another group. Trade with that other nearby group would be necessary to acquire that material. In the archaeological record these short-range trade activities may be interpreted as direct acquisition. Local tool stone versus non-local or exotic tool stone is typically defined by archaeologists as distance from the cultural site where the material was recovered, a definition that is fluid.

Both direct and indirect acquisitions involve applying economic decisions to weigh the benefit of the investment of time, energy, and possibly trade goods for that tool stone. Tool stone was a significant resource for prehistoric groups and would have ranked high as a need. Procuring tool stone should be considered an activity that requires considerable cost. Thus it should also be considered that stone may be cached for future use at local campsites away from the source (Hayden 1989: 34).

For the archaeologist, the prehistoric quarries represent a static resource used by prehistoric groups that is still located in the same place on the landscape as it was during its original use. For this reason, the resource lends itself to many avenues of research (e.g. Craig 1983, Reher 1991). For example, did tool stone preferences change through time or vary with tool type; was the range of use higher for better quality stone than poorer quality stone, and which materials were valued by groups for trade outside the local area? Large prehistoric quarries may include valuable evidence of methods of stone extraction, waste materials indicative of knapping methods, or habitation areas nearby that may help date the quarry's period of use.

In the case of large outcrops of high quality tool stone in the Black Hills and the Hartville Uplifts, access routes could be predicted based on the topography. One would expect to find small campsites along these ingress/egress routes and waste materials or discards in the camps. The large quarry sites themselves, such as Flint Hill in South Dakota and Spanish Diggings in Wyoming, both have associated campsites (tipi rings in these two cases), workshop areas littered with debitage, numerous quarry pits, and exploited outcrop exposures. These site types provide insight into the quarrying methods used to extract that stone. However, depending on the amount of soil deposition and stratigraphic distinctions at these sites, delineating specific time periods of use could be difficult. Multi-component sites that can span thousands of years in the Black Hills are often compressed into a few centimeters of the slowly developing soil. Another avenue of research would be to compare the XRF signature of samples collected directly from outcrops (fresh) to samples of quarry blanks, preforms, tools, and debitage from the surface in the adjacent campsite and workshop to determine if surface exposure has altered the chemical make-up in a recognizable manner.

METHOD OF STUDY

The scope of this project is to determine the source of quartzite used to create two Angostura projectile points from the Ray Long site. To this end, XRF data were collected from both projectile points and samples from each of seven previously recorded quarries in four geologic formations of the Black Hills and Hartville Uplifts in South Dakota and Wyoming (Table 1 and Figure 3). The data were processed and XRF signatures for each quarry and artifact were defined. The quarry samples and projectile points (catalog numbers 12-0046-48 and 12-0046-50) were examined macroscopically, Munsell colors were identified, and observations were recorded. In addition, they were examined using a binocular microscope and described using standard geologic terminology. The XRF signatures for the projectile points were then compared to the quarry XRF signatures and geologic descriptions were reviewed against results. To simplify the reference to the projectile points in this study, catalog numbers 12-0046-48 and 12-0046-50 will be referred to as P48 and P50, respectively.

In 1975 Dr. Stan Ahler collected raw material samples from two Platte County, Wyoming quarries referred to as Saul Quarry #1 and Saul Quarry #5 (Ahler 1975). In about 1985 Tim Church collected raw material from four South Dakota quarries at Battle Mountain in Fall River County, Cowboy Hill in Pennington County, Meadow Creek in Meade County, and Jewel Cave in Custer County (Church 1990). In 2011 Boen collected raw material from three South Dakota quarries at Flint Hill and Battle Mountain in Fall River County, and Cowboy Hill in Pennington County. All of these collections were sampled and used in this study. The two Angostura projectile points that are the focus of the study were collected by Dr. L. Adrien Hannus, Augustana College from the surface of the Ray Long site in 1985. Four readings were taken on P48 and two on P50.

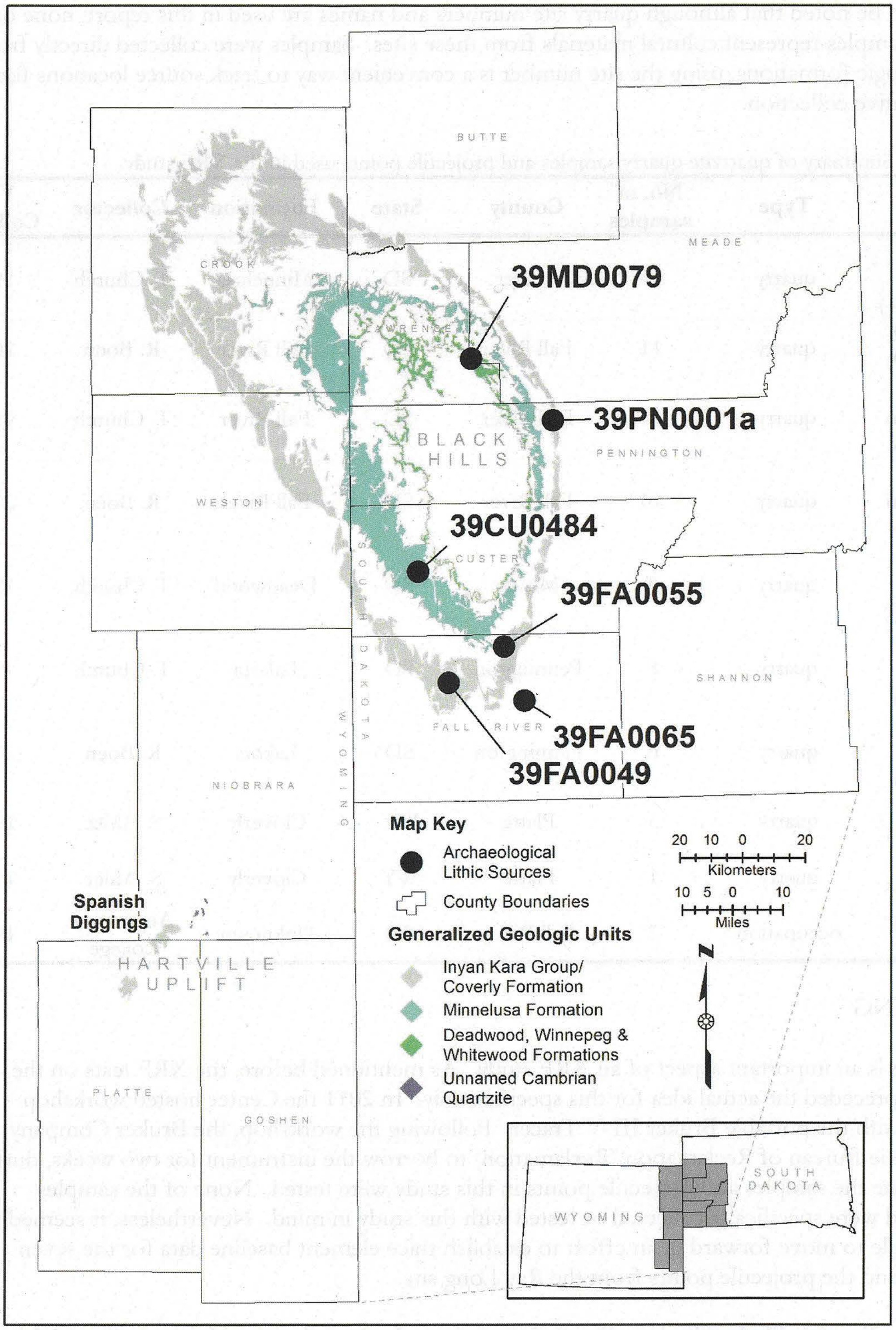


Figure 3. Location of the Ray Long site (39FA65) and the quarries included in this study.

It should be noted that although quarry site numbers and names are used in this report, none of the quarry samples represent cultural materials from these sites. Samples were collected directly from the geologic formations; using the site number is a convenient way to track source locations for the comparative collection.

Table 1. Summary of quartzite quarry samples and projectile points used in the XRF study.

Site	Type	No. of samples	County	State	Formation	Collector	Year Collected
Jewell Cave (39CU484)	quarry	6	Custer	SD	Minnelusa	T. Church	1985
Flint Hill (39FA49)	quarry	11	Fall River	SD	Fall River	R. Boen	2011
Battle Mountain (39FA55)	quarry	4	Fall River	SD	Fall River	T. Church	1985
Battle Mountain (39FA55)	quarry	10	Fall River	SD	Fall River	R. Boen	2011
Meadow Creek (39MD79)	quarry	3	Meade	SD	Deadwood	T. Church	1985
Cowboy Hill (39PN1)	quarry	8	Pennington	SD	Lakota	T. Church	1985
Cowboy Hill (39PN1)	quarry	6	Pennington	SD	Lakota	R. Boen	2011
Saul Quarry #1	quarry	3	Platte	WY	Cloverly	S. Ahler	1975
Saul Quarry #5	quarry	1	Platte	WY	Cloverly	S. Ahler	1975
Ray Long (39FA65)	occupation	2	Fall River	SD	Unknown	Augustana College	1985

SAMPLING

Sampling is an important aspect of an XRF study. As mentioned before, the XRF tests on the samples preceded the actual idea for this specific study. In 2011 the Center hosted workshop training with the portable Bruker III-V Tracer. Following the workshop, the Bruker Company allowed the Bureau of Reclamation (Reclamation) to borrow the instrument for two weeks, during which time the samples and projectile points in this study were tested. None of the samples processed were specifically collected or tested with this study in mind. Nevertheless, it seemed worthwhile to move forward in an effort to establish trace element baseline data for the seven quarries and the projectile points from the Ray Long site.

Future studies should plan the sampling technique in such a way that samples are collected from various locations within an outcrop in close proximity to the quarry to ensure that a representative sample has been created. Approximately 10-30 samples should be collected from homogeneous sources such as the quartzites. In this study only three sources exceeded a sample of 10; Cowboy Hill (14 samples), Flint Hill (11 samples) and Battle Mountain (14 samples). The other four quarries had six or fewer samples; Meadow Creek (3 samples), Saul Quarry #5 (3 samples), Saul Quarry #1 (1 sample), and Jewel Cave (6 samples).

ELEMENT IDENTIFICATION

The XRF data was processed by Jessica Bush in 2013. Before the analysis using Spectra could be started, the data had to be converted to text (.txt) files using S1PXRF. This was accomplished by completing a 'Group Conversion' of the data and executing the .pdz files. The Full-Width Half-Maximum (FWHM) used for the conversion was 150 electron volts (eV). All data were compressed from 2048 channel spectrum to 1024 channels. The 'Replace duration with livetime' box was then checked as a last step. This allows all the spectra to be normalized to the same live time.

Once the data was converted to a .txt file, it was opened as a new project in Spectra. Each spectrum was opened individually and the elements present identified. Once a spectrum was open, the periodic table of elements was opened and 'Auto Ident' selected. This allowed the program to automatically identify elements present in each spectrum. Because this feature does not always identify every element that is present, it was then necessary to go through each spectrum and make sure that any missed elements were identified. In order to identify elements, the peaks that show up on the spectra, based on kilo electron volt (keV) values, are matched with the K and L series lines for each element.

QUALITATIVE RESULTS

Once the elements for each spectrum were identified, a methods file was created so that the qualitative number for each sample could be calculated. For this data set, five cycles were selected and the energy range analyzed was 0.8 keV to 30 keV. Spectra then evaluated the results and all the numbers were exported as a spreadsheet table in Excel.

CORRELATION

The final analysis run on the data was to complete a correlation analysis for each spectrum. This allows Spectra to take each sample and compare how similar it is with the other samples within the same project. As the entire project data is already in the program, this requires the user to go into the analyze drop-down menu and select 'Match…'. The 'Start energy' was set at 0.8 keV and the 'End energy' at 30 keV. 'Min. correlation' was set to 20 percent, so that all spectra in the data set would be compared and 'Number of hits' was set to 100.

GEOLOGY

BLACK HILLS UPLIFT

Spanning approximately 100 miles north to south and 80 miles east to west, the Black Hills are located in southwestern South Dakota, northeastern Wyoming, and extreme southeastern Montana. This feature is part of the Laramide Uplift that occurred about 48 million years ago in the early

Tertiary or possibly late Cretaceous time (United States Geological Survey 2013:1). It represents the easternmost outlier of the Rocky Mountain system and is likely structurally related to the isolated mountain ranges in central Montana and Wyoming (Gries 1996: 217; Schwartz 1928:57). The uplift may have occurred as a result of the floor of the Pacific Ocean and the North American continent colliding. The uplift followed millions of years of rising and falling sea levels in the region that included periods of land exposure and erosion. Materials that settled out of the sea during these episodes, such as sands, silt, and calcium, provided the parent material for the layers of rock exposed on the surface today.

Encompassing all periods except the Silurian, the Black Hills are made up of at least 30 formations although some are only minimally represented. Erosional forces from 48 million to 37 million years ago exposed all of the Cretaceous and older formations to the PreCambrian complex (1.7-2.5 billion years old) (Schwartz 1928: 57). The oldest metamorphic and igneous rocks of the PreCambrian complex comprise the highest point, Harney Peak, at 7,242 feet above mean sea level, in the central core. These same rocks are represented in the area surrounding Harney Peak, referred to as the Needles. Moving out from the central core the main formations encircling the central core are the Pahasapa (Madison) limestone and the Minnelusa, the Opeche-Spearfish, the Lakota-Skull Creek, and the Newcastle-Niobrara Formations. The stratigraphic column of the Black Hills formations is shown in Figure 4. Post-depositional actions and fluid movements within a formation such as contact metamorphism are spatially variable; which can result in variations in the elements that make up the composition of the formation.

Four of the 30 formations that comprise the Black Hills are included in this study. From oldest to youngest, these are the Deadwood, Minnelusa, Lakota, and Fall River Formations. All of these formations contain quartzites that were used as tool stone by prehistoric inhabitants in the region. A quartzite is metamorphosed sandstone that is welded so firmly together that when stressed it breaks across the grains instead of around them as in loosely bonded sandstone. Mineral composition of quartzite is dominated by quartz, which makes up from 60 to 95 percent of the rock. They are among the hardest and most resistant of common rock types due to the high quartz content and strong bonding. Quartz is perhaps the most durable mineral present at the earth's surface and is harder than steel. Quartzite presents colors the same as sandstone; that is, browns, yellows, grays, reds, and whites (Heinrich 1956:206, Pough 1955:24 & 316). Although it would be useful if color, determined by compounds, not trace elements, in the stone, could be used as an identifying characteristic of all stone. However, in most cases, it is not because there is typically no direct correlation between trace elements and color.

ERATHEM	SYSTEM	ABBREVIATION FOR STRATIGRAPHIC INTERVAL	GEOLOGIC UNIT	THICKNESS IN FEET	DESCRIPTION
CENOZOIC	QUATERNARY & TERTIARY (?)	QTac	UNDIFFERENTIATED ALLUVIUM, TERRACES AND COLLUVIUM	0-50	Sand, gravel, boulders, and clay.
		Tw	WHITE RIVER GROUP	0-300	Light colored clays with sandstone channel fillings and local limestone lenses.
	TERTIARY	Tui	INTRUSIVE IGNEOUS ROCKS	--	Includes rhyolite, latite, trachyte, and phonolite.
MESOZOIC	CRETACEOUS	Kps	PIERRE SHALE	1,200-2,700	Principal horizon of limestone lenses giving teepee buttes. Dark-gray shale containing scattered concretions. Widely scattered limestone masses, giving small teepee buttes. Black fissile shale with concretions.
			NIOBRARA FORMATION	[1]80-300	Impure chalk and calcareous shale.
			CARLILE SHALE	[1]350-750	Light-gray shale with numerous large concretions and sandy layers. Dark-gray shale.
			GRANEROS GROUP: GREENHORN FORMATION	225-380	Impure slabby limestone. Weathers buff. Dark-gray calcareous shale, with thin Orman Lake limestone at base.
			GRANEROS GROUP: BELLE FOURCHE SHALE	150-850	Gray shale with scattered limestone concretions. Clay spur bentonite at base.
			GRANEROS GROUP: MOWRY SHALE	125-230	Light-gray siliceous shale. Fish scales and thin layers of bentonite.
			GRANEROS GROUP: MUDDY SANDSTONE / NEWCASTLE SANDSTONE	0-150	Brown to light-yellow and white sandstone.
			GRANEROS GROUP: SKULL CREEK SHALE	150-270	Dark-gray to black siliceous shale.
		Kik	INYAN KARA GROUP: FALL RIVER FORMATION	10-200	Massive to thin-bedded, brown to reddish-brown sandstone.
			INYAN KARA GROUP: LAKOTA FORMATION	35-700	Yellow, brown, and reddish-brown massive to thinly bedded sandstone, pebble conglomerate, siltstone, and claystone. Local fine-grained limestone and coal.
	JURASSIC	Ju	MORRISON FORMATION	0-220	Green to maroon shale. Thin sandstone.
			UNKPAPA SS	0-225	Massive fine-grained sandstone.
			SUNDANCE FORMATION	250-450	Greenish-gray shale, thin limestone lenses. Glauconitic sandstone; red sandstone near middle.
			GYPSUM SPRING FORMATION	0-45	Red siltstone, gypsum, and limestone.
	TRIASSIC	TRPs	SPEARFISH FORMATION	375-800	Red silty shale, soft red sandstone and siltstone with gypsum and thin limestone layers. Gypsum locally near the base.
PALEOZOIC	PERMIAN	Pmk	MINNEKAHTA LIMESTONE	[1]25-65	Thin to medium-bedded, fine grained, purplish-gray laminated limestone.
		Po	OPECHE SHALE	[1]25-150	Red shale and sandstone.
	PERMIAN / PENNSYLVANIAN	PℙPm	MINNELUSA FORMATION	[1]375-1,175	Yellow to red cross-bedded sandstone, limestone, and anhydrite locally at top. Interbedded sandstone, limestone, dolomite, shale, and anhydrite. Red shale with interbedded limestone and sandstone at base.
	MISSISSIPPIAN	MDme	MADISON (PAHASAPA) LIMESTONE	[1]<200-1,000	Massive light-colored limestone. Dolomite in part. Cavernous in upper part.
	DEVONIAN		ENGLEWOOD FORMATION	30-60	Pink to buff limestone. Shale locally at base.
	ORDOVICIAN	Ou	WHITEWOOD (RED RIVER) FORMATION	[1]0-235	Buff dolomite and limestone.
			WINNIPEG FORMATION	[1]0-150	Green shale with siltstone.
	CAMBRIAN	OCd	DEADWOOD FORMATION	[1]0-500	Massive to thin-bedded brown to light-gray sandstone. Greenish glauconitic shale, flaggy dolomite, and flat-pebble limestone conglomerate. Sandstone, with conglomerate locally at the base.
PRECAMBRIAN		pCu	UNDIFFERENTIATED IGNEOUS AND METAMORPHIC ROCKS		Schist, slate, quartzite, and arkosic grit. Intruded by diorite, metamorphosed to amphibolite, and by granite and pegmatite.

[1] Modified based on drill-hole data

Modified from information furnished by the Department of Geology and Geological Engineering,

Figure 4. The Black Hills Uplift stratigraphic column. (Modified from Carter, Driscoll & Sawyer, 2003)

DEADWOOD FORMATION

The Deadwood Formation was created during the Upper Cambrian/ Lower Ordovician period (485-445 million years ago). The type section of the Cambrian age Deadwood Formation is located along Highway 14A near the town of Deadwood. The Deadwood Formation is the oldest sedimentary formation present in the Black Hills. It is composed of glauconitic sandstones, shale, limestone, and a basal flat-pebble conglomerate. The Deadwood Formation is variable in thickness and can range from not being present to 500 feet thick. The depositional environment of the Deadwood Formation is unique; this formation was deposited during an atmospheric change and the grains and clasts have a different weathering pattern than what is seen in younger formations. Grains, if not strongly metamorphosed, are well rounded and deposits of frac sand are present in the formation. At least two distinct types of quartzite are found in this formation. One is a coarse-grained quartzite ranging from dark red to orange. A conchoidal fracture creates a somewhat rough surface and breakage patterns, with respect to knapping, are not as predictable as the Inyan Kara Group quartzites from the Fall River and Lakota Formations. A very different type of material, fine-grained yellowish gray/brown siliceous quartz sandstone with fossil Scolithus burrows, caps the Deadwood Formation. Although this material has a smooth conchoidal fracture, the numerous burrow cavities present flaws throughout that would make the material inconsistent for stone tool manufacturing. Only the coarse-grained dark red to orange quartzite was used in this study.

MINNELUSA FORMATION

The Minnelusa Formation was created during the Pennsylvanian (318.1-299.0 million years ago)-Permian (299.0-251.0 million years ago) period. The formation can be significantly variable in thickness, ranging from just less than 400 feet to over 1000 feet in thickness. The formation consists mainly of red and yellow sandstone, limestone and anhydrite in the upper third, a layer of interbedded sandstone, limestone, dolomite, shale, and anhyrdate in the middle third, and a lower third with red shale with interbedded limestone and sandstone at the base (Gries 1996:331). The Minnelusa Formation was deposited in aeolian, interdune, and sabkah environments. In Wyoming the Minnelusa Formation correlates with the Tensleep and Amsden Formations and to the Williston Basin in North Dakota it correlates with the Amsden and Tyler Formations. The basal sandstone member of the Minnelusa is called the Belle Sand, it is typically a loosely cemented, fine-grained white aeolian sandstone. The middle members of the Minnelusa are known as the Leos. These are typically four Leos, they are massive cross-bedded red to yellow sandstones beds. The upper sandstones of the Minnelusa are called the Converse or Tensleep sands, two sandstone beds are typically present. The Converse sands are more loosely consolidated and often have a 'popcorn' weathering texture. The Minnelusa formation and its' equivalents in both Wyoming and North Dakota are an oil trapping units and have been extensively explored for oil and gas deposits. The samples used in the study are fine to medium-grained, producing a fairly smooth conchoidal fracture, and range in color from pinks to browns to reds. Color banding can be present in this material.

FALL RIVER FORMATION

The Fall River Formation is the upper member of the Inyan Kara Group, deposited during the Albian period of the Lower Cretaceous. The formation is composed of interbedded sandstone, siltstone, and shale and was deposited in a marginal-marine sedimentary environment (Dahlstrom and Fox 2003:S1). The formation ranges in thickness from 135 to 180 feet in the Black Hills area.

The Fall River Formation contains abrupt facies changes which make unit subdivision and correlation difficult. Sandstone stringers range from thin to massive. Worm burrows and tracks and ripple marks are abundant on bedding surfaces in the informal, thinly bedded sandstone lower unit (Post 1967:474). The informal middle unit is more massively bedded from a distance but upon close inspection there are scour-and-fill, cross-stratification, and slumping structures. The informal upper unit is silty, thinly bedded, slabby and contains ripple marks near the top of the sandstone bed (Post 1967:476). A regional transgressive disconformity separates the Fall River Formation from the underlying Lakota formation (Dahlstrom and Fox 2003:S1, S2) and forms part of the Cretaceous hogback ridge on the outer ring of the Black Hills.

LAKOTA FORMATION

The Lakota Formation is the lower member of the Inyan Kara Group, deposited during the Lower Cretaceous (121-135 million years ago) period, specifically the Neocomian series. The Lakota Formation has three subdivisions: the Fuson, Minnewaste Limestone, and Chilson Members and contains a wide variety of rock types including conglomerates, sandstones, shale, coal, and limestone (Dahlstrom and Fox 2003:S1, S2). The formation typically ranges in thickness from 100 to 550 feet in the Black Hills area. Fluvially-deposited sandstone units form the prominent ridges of the hogback. The Lakota Formation has a predominantly sedimentary source (Dahlstrom and Fox 2003:S1), meaning the grains composing the rock had been previously deposited in other sandstone units. Four formal fluvial units have been identified, two in the Chilson Member and two in the Fuson Member. These units are predominantly differentiated by architectural elements which are often macroscopic in nature; it is often difficult to discern from small samples how or where they fit in the fluvial architecture. Within the Lakota Formation, as with most all sandstones in the Black Hills, there are localized areas of contact metamorphism due to Tertiary intrusions. There are also regional areas of differential cementation due to high-temperature fluid flow and mineralization. Because of variable nature of the fluvial sediments present, fluid flow is anisotropic and resulting cementation is often 'patchy'. The color, texture, and composition of the sandstone are often regionally variable and the formation is generally classified based on facies and depositional texture. The Lakota Formation correlates to the Cloverly Formation in the Hartville Uplift in eastern Wyoming (Hahn and Jessen, 2010).

INYAN KARA GROUP

The Fall River and Lakota Formations were initially grouped together into the Inyan Kara Group by W. Rubey in 1930 because the formations we so difficult to differentiate (Post 1967:457). Once out of geologic context, the formations are even more difficult to differentiate. Fall River sandstones generally have more tabular bedding and more ripple marks in comparison to the Lakota. (Post 1967:473) Both members of the Inyan Kara Group contain 'anomalous radioactivity' on the southern, western, and northern flanks of the Black Hills. Economic-level deposits of uranium and related minerals such as vanadium have been mined from the sandstones of the Inyan Kara. However, uranium mineralization is generally concentrated in carbonate-cemented sandstone with sporadic pyrite (Robinson and Gott, 1958:12) so it is unlikely that quartzite samples from the Inyan Kara will have anything other than trace uranium or vanadium mineralization.

Several well-known prehistoric tool stone quarries have been recorded in these two formations including site Flint Hill, Battle Mountain, and Cowboy Hill in South Dakota and Saul Quarry #1, Saul Quarry #5, and Dorsey quarries (also broadly known as the Spanish Diggings complex) in eastern Wyoming. All of these quartzites are typically well sorted; well to moderately well rounded, fine to medium-grained with varying amounts of cement. They most often present a smooth conchoidal fracture; most likely at least one of the reasons they were popular choices for tool stone. The color range is wide including grays, browns, yellows, and reds. Colors may be solid or banded. Although distinctions between the materials extracted from the Wyoming and South Dakota quarries have been noted (cf. Witzel and Hartley 1976), unknown source samples can be difficult to sort by quarry-type with any more than a relative degree of certainty. To do an effective sort one needs a wide variety of comparison samples from all the sources that may or may not result in accurate determinations.

HARTVILLE UPLIFT

The Hartville Uplift is located in southeastern Wyoming. It is a Laramide anticlinal dome with a PreCambrian core, however unlike the Black Hills; there is direct evidence of a pre-Laramide orogeny. There is extensive evidence of three, possibly four Proterozoic deformation events, a Trans-Hudson related uplift (~1.82 Ga), and an unnamed deformation/uplift (~2.1 Ga) (Sims et al, 1996:2). The core of the uplift is composed of Late Archean-aged granite called the Rawhide Butte Granite, Archean gneisses and the PreCambrian-aged Whalen Group. A set of PreCambrian granite and diorite intrusions bisect the Whalen Group. It is a complex structural area with many structures overprinting other structures, but the net result is a slightly rotated north-south trending uplifted mountainous region with a large central thrust fault called the Hartville fault. The Hartville Uplift is approximately 40 miles long and 24 miles wide with elevations ranging from 4700 to 6100 feet (Reher 1991:255). Outward from the PreCambrian core of igneous and metamorphic rocks there are outcroppings of Cambrian or Devonian aged quartzites, the Devonian or Mississippian aged Guernsey Formation followed by the Carboniferous (Mississippian/Pennsylvanian) Hartville Formation. This is overlain by the more familiar units of the Opeche Shale, Minnekahta Limestone, then the equivalent of the Black Hills' Spearfish Formation (a Triassic gypsum and red-shale sequence), followed by the Chugwater Formation. The Chugwater Formation is also the local equivalent of the Black Hills' Spearfish Formation. This is overlain by a basal Jurassic sandstone sequence, then the Sundance Formation, the Morrison Formation and then the Cloverly Formation. The Cloverly Formation is the equivalent of the Inyan Kara Group. This is overlain by Tertiary claystone and sandstone (Denson and Botinelly, 1949). Many of the geologic formations present in the Hartville Uplift have geologic equivalents in the Black Hills and similar depositional environments. The Hartville Uplift is well known for their copper and hematitic/magnetic iron deposits. Mineral production began somewhere around 1880 and has continued sporadically through the present day (Sims et al, 1996:21).

CLOVERLY FORMATION

This formation is the local equivalent of the Inyan Kara Group, specifically the Fall River Formation. The Cloverly Formation is Early Cretaceous (Neocomian to Albian) in age (Finn 2010:6) and can be up to 80 feet thick (Reher 1991:257). It is a fluvially deposited sandstone unit with interbedded conglomerates, siltstones, and shales. The Cloverly Formation was deposited in a floodplain and playa environment. The basal unit is the Pryor Conglomerate which contains abundant black chert. The Pryor Conglomerate is overlain by the Little Sheep Member which is predominantly a bentonite-rich mudstone. The upper member is a clean channel-filled sandstone deposit which intersects variegated mudstones called the Himes (Moberly 1960:1137). This is overlain by the Greybull Member, a fine to medium gray sandstone depending on geographic location (Finn 2010:6). Above the Cloverly in the southern Bighorn Basin, sandstone and siltstones beds have a distinctive 'rust' color which is why they are called the Rusty Bed Member; these units are sometime included in the Cloverly and sometimes considered to be part of the Thermopolis Formation depending on geographic location. The Rusty Bed Member is believed to correlate with the Fall River Formation. Vertebrate fossils have been found in the Himes Member of the Cloverly Formation in Wyoming. The Cloverly Formation is known to produce both mottled cherts and very fine-grained quartzites in a wide variety of hues (Reher 1991:257). The Spanish Diggings is comprised of large number of quarries in the Hartville Uplift, numbers range from around ten to upwards of more than 60 quarries as listed by Reher. The Hartville Uplift contains many different potential tool sources; however there are two quartzite-bearing formations which stand out for quality: the Cloverly Formation and an unnamed Precambrian or Devonian aged quartzite. When cross-referenced, historical maps, scientific references and archaeological resources are often conflicting as to the locations of many of the quarries, perhaps because they are so numerous. However, there is a general agreement that the majority of these quarries are located in outcroppings of the Cloverly Formation. Saul Quarries #1, also known as the Barbour quarry, and #5 are located in the Cloverly Formation.

QUARRY SAMPLES

The study included samples from seven previously recorded archaeological sites identified as quarries in the Black Hills and Hartville Uplifts of South Dakota and Wyoming (see Table 1). Macroscopic comparisons concluded that only the Meadow Creek samples could be distinguished from the other quarries with any degree of reliability due to its coarse texture as compared to the fine to medium-grained texture of the other quarry samples. Although slight macroscopic differences were noted between Flint Hill and Spanish Diggings quartzites by Witzel and Hartley (1976:15), Flint Hill having fewer but relatively larger reflective surfaces and a rougher conchoidal fracture surface than Spanish Diggings samples, these distinctions are difficult to ascertain when the sample base is expanded to include more quarries. The collection location of the Spanish Diggings quarry samples used by Witzel and Hartley (1976:14) in their study correspond to the location of Saul Quarry #5 (Ahler 1975) in this study. The only other macroscopic distinction noted between the quarry samples was that some but not all of the Cowboy Hill samples exhibited banding. Color was of little value when attempting to link a sample to a source.

Microscopic differences between the quarry samples are subtle with a few distinguishing characteristics noted for each. The details are presented below using standard geologic terminology. Once again, the Meadow Creek samples were the most recognizable due to their consistently larger grain sizes (¼ to ½ mm), although some of the grains in the Saul Quarry samples reached ½ mm. Rose quartz grains were only identified in the Cowboy Hill samples; none of the other quarries had this distinct grain color. However, the rose quartz was only present in two of the samples. Samples from both Saul Quarry #1 and #5 were notable for the high percentage of lithic fragments present in each of the sample (25%); greater than in any other quarry samples examined. Thus, microscopic differences between quarries are present. These can provide a foundation for differentiating materials recovered from an archaeological context. Other test results, such as the XRF data, have the potential to offer another means of identifying unique markers or properties to distinguish between quarries. The results of the macroscopic and microscopic examination of the samples are presented below.

MEADOW CREEK QUARRY (39MD79)

Site Description. The non-cultural samples collected from the Meadow Creek quarry in Meade County, South Dakota are from the Deadwood Formation (Figure 5). The site was recorded in 1977 during the Kelly timber sale project for the Black Hills National Forest (Tratebas, et. al. 1978) as a *possible* quarry. What may be cores and debitage or possibly naturally spalled quartzite material from an outcrop is scattered on a steep slope from the edge of the ridge top down to a rocky knoll at the bottom of a narrow drainage. Large blocks of Deadwood Formation quartzite outcrop near the top of the ridge. The surrounding area consists of steep-sided, narrow gulches and small, narrow ridge tops in a rugged portion of the northern Black Hills. The site should be re-visited to determine if the outcrop represents an actual quarry or is a natural outcrop that was not utilized by prehistoric groups. Regardless of this question and the author's argument that only actual quarries need to be tested using XRF, it was decided to include the samples in the study as, at the very least, good examples of the Deadwood quartzite. If this is not a quarry, it would not be given consideration in future studies.

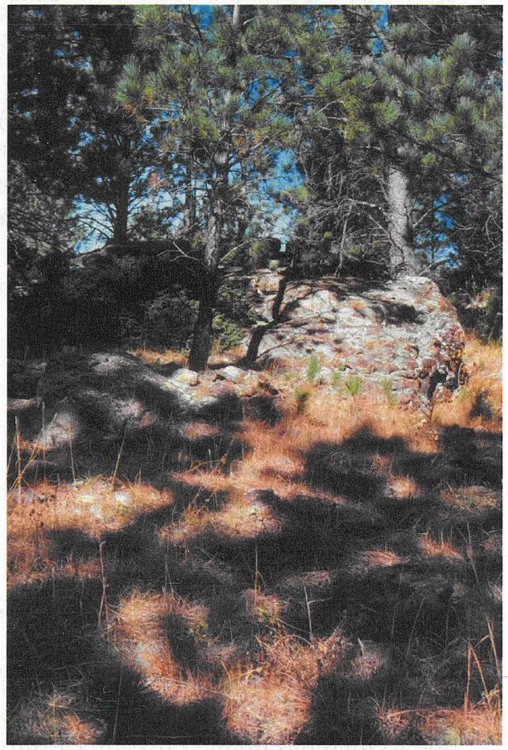


Figure 5. The quartzite outcrop at the possible quarry, Meadow Creek, in Meade County, South Dakota. Photo courtesy of the Black Hills National Forest.

Sample Description. Meadow Creek quarry samples are a medium monocrystalline quartzite with hematitic and glauconitic inclusions. They exhibit angular, well sorted grains of ¼ to ½ mm in diameter and are composed of clear, smoky, and purple-toned single-grained quartz crystals with veining of up to ½ mm of hematite and ¼ mm pockets of glauconite. The rock is highly metamorphosed and individual grains have been fully recrystallized. It is also well bonded and silicified with the exception of the glauconite and hematite. The rock is well compacted and composed of approximately 10% smoky quartz, 20% clear quartz, 50% purple quartz, 15% hematite, and 5% glauconite. Overall color of the rock is influenced by the grains. Breakage patterns are somewhat unpredictable. Conchoidal fracturing presents as a somewhat rough surface.

JEWEL CAVE QUARRY (39CU484)

Site Description. The non-cultural samples collected from the Jewel Cave quarry in Custer County, South Dakota are from the Minnelusa Formation (Figure 6). The site was recorded in 1980 during the Hawkright timber sale for the Black Hills National Forest (Cassells 1980). The site consists of nodules, flakes, and cores of red quartzite on a ridge top and slope. A concentration of flakes was observed on the ridge top. The site is situated in a small valley surrounded by steep slopes and small ridge tops in a rugged portion of the southwestern Black Hills.

Sample Description. Jewel Cave quarry samples are a very fine-crystalline quartzite. They exhibit angular, spherical, well sorted, ⅛ mm diameter quartz crystals with minor lithic fragments. Matrix color is variable and includes blackish-dusky reds to light red. Some spots of black mineral staining are present in the matrix. The rock is very well compacted and composed of over 95% clear quartz crystals and less than 5% black lithic fragments. Some bedding is present in the rock samples; however grain size and sorting appear to be uninfluenced by the bedding pattern. Edge solution had taken place; therefore, the edges of the grains were not visible. Overall color of the rock is influenced by the matrix. Conchoidal fracturing presents as a fairly smooth surface.

Figure 6. The Jewel Cave quarry in Custer County, South Dakota. Photo courtesy of the Black Hills National Forest.

FLINT HILL QUARRY (39FA49)

Site Description. The non-cultural samples collected at the Flint Hill quarry in Fall River County, South Dakota are from the Fall River Formation (Figure 7). The site includes numerous quarry pits and tailings, exposed outcrops quarried on the slopes, stone circles, and workshop areas on a high broad ridge surrounded by steep slopes and canyons in the southern Black Hills. In the 1920s, W. H. Over, curator and later director of the Dakota Museum in Vermillion, South Dakota (now the W.H. Over Museum), and H.E. Lee, self-taught archaeologists in the Black Hills, both visited the site on a number of occasions. These early twentieth century collections are curated at the South Dakota Archaeological Research Center (Center). Another early collection was made by area rancher, Neal Conboy. Conboy's collection was examined by archaeologists from the Smithsonian Institution during the River Basin Survey Project at nearby Angostura Reservoir (Hughes 1949). It was reported that Conboy's collections included a wide variety of projectile

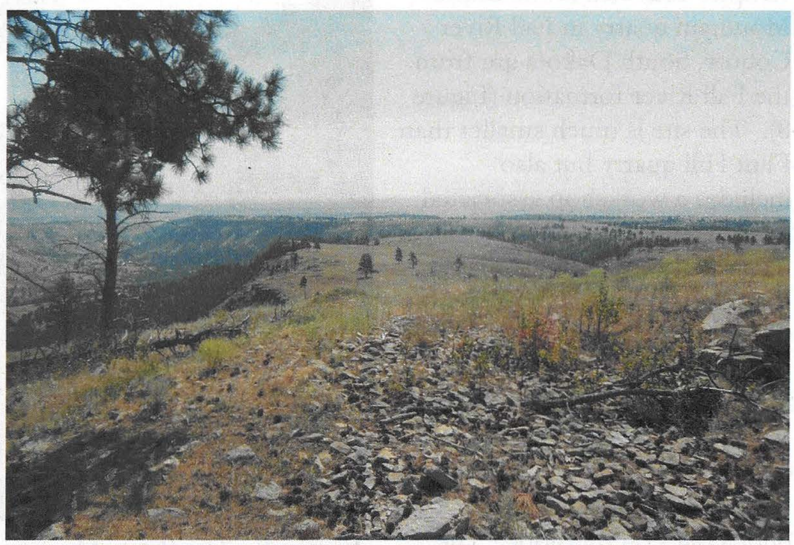


Figure 7. The Flint Hill quarry in Fall River County, South Dakota.

points resembling other types known from the surrounding area. A Late Archaic point was identified in one of their photographs of this collection. No projectile points have been found in the Flint Hill collections stored at the Center. Although direct evidence is lacking this site may have been mined for its high quality quartzites by prehistoric groups for thousands of years.

Several archaeologists have visited Flint Hill since those early years. One of those investigators, Dr. Stan Ahler, made an extensive collection from the site (Ahler 1975; Ahler 1977). Ahler dispersed his collections from the quarry to the Center, the Illinois State Museum-Springfield, the National Park Service-Midwest Archeological Center in Lincoln, Nebraska, and the University of North Dakota-Grand Forks. A recent investigation for a transmission line project resulted in the most intense mapping and recording ever done at the Flint Hill quarry (Shaver and Smith 2013). However, during this project no projectile points were observed on the surface and no artifacts were collected.

Sample Description. Flint Hill quarry samples are a fine-crystalline quartzite. They exhibit angular to sub-rounded, spherical, well sorted grains of ⅛ to ¼ mm diameter composed of variable colored silica matrix. The rock is highly silicified and well bonded with variable colored cement. The rock is well compacted and composed of approximately 95% semi-transparent to clear quartz crystals and 5% dark lithic fragments which can be larger in diameter, up to ½ mm, with minor inclusions of hematite. Overall color of the rock is influenced by the matrix. Conchoidal fracturing presents as a smooth surface with breakage occurring across the grains.

BATTLE MOUNTAIN QUARRY (39FA55)

Site Description. The non-cultural samples collected at the Battle Mountain quarry in Fall River County, South Dakota are from the Fall River formation (Figure 8). The site is much smaller than Flint Hill quarry but also includes a workshop associated with two massive outcrops of quartzite bearing sandstone on the highest point of the ridge. Quarrying occurred laterally into the bedrock exposures while quarrying debris litters the slope below the quartzite blocks. Cores, waste material, and tool fragments are present in the debris piles on the slope. The site is situated on a ridge top in the Hogback Ridge with steep slopes on all sides near the Red Valley in the southern Black Hills.

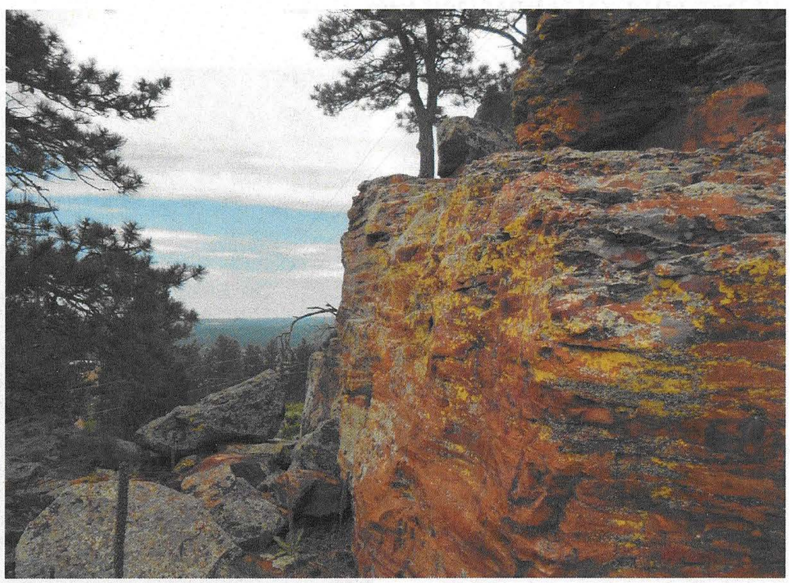


Figure 8. The Battle Mountain quarry in Fall River County, South Dakota.

Sample Description. Battle Mountain quarry samples are fine-grained quartzite. They exhibit sub-rounded to sub-angular, spherical, well sorted, ⅛ to ¼ mm diameter quartz and lithic fragments. The silica matrix is variable-colored with occasional powdery iron inclusions. Minimal evidence of compression is present; grain edges are rounded and well silicified. The rock is poorly compacted and composed of approximately 65% clear quartz grains, 25% tan quartz grains and 10% dark lithic fragments. Angularity, sorting, and grain size distribution appears to be influenced by bedding patterns in the parent rock. Overall color of the rock is influenced by the matrix. Conchoidal fracturing presents as a smooth surface with breakage occurring across the grains.

COWBOY HILL QUARRY (39PN1)

Site Description. The non-cultural samples collected at the Cowboy Hill quarry in Pennington County, South Dakota are from the Lakota formation (Figure 9). H.E. Lee, a self-taught archaeologist from the Black Hills, reported the location of the quarry in a May 12, 1925 letter to his friend, W. H. Over (Lee 1925). Over was the curator and later director of the Dakota Museum (now the W.H. Over Museum) in Vermillion, South Dakota. There is no indication in the site records that Over ever visited this site. Lee describes quarry pits on the brow of the highest point on Cowboy Hill, which he refers to as Cowboy Range, as similar to but smaller than those at the Flint Hill quarry. He noted that quartzite outcrops on the slope just below the ridge top and that quarry shafts would not have to be very deep to reach the material. Lee also mentions stone circles on top of the highest hill in the range that covered an area of 20 acres, although he believed most of the stones had been washed down the hill or possibly buried.

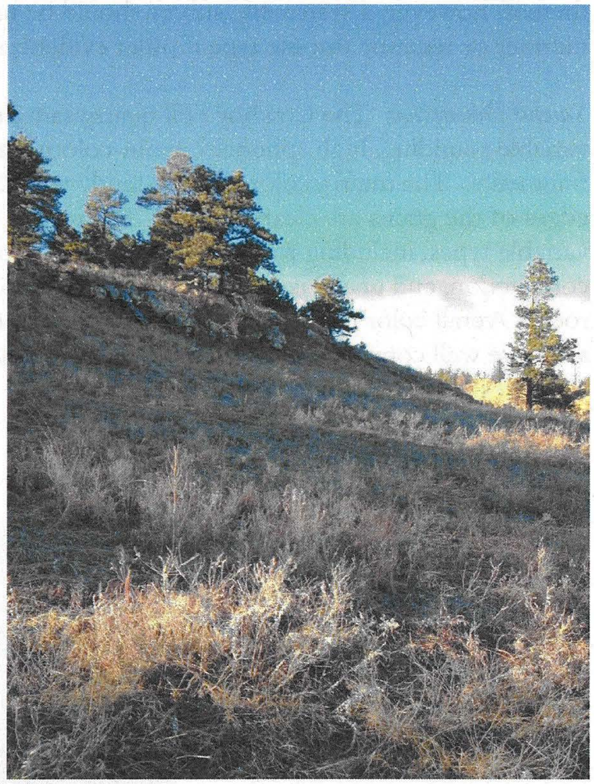


Figure 9. The quartzite outcrop on Cowboy Hill in Fall River County, South Dakota.

The Cowboy Hill area was visited by both Ahler (1975) and Church (1990), who did not find the evidence of stone circles or quarrying activities described by Lee. However, there were no formal updates to the site records following those visits. The authors have conducted non-systematic surveys of the Cowboy Hill area on several occasions to search for evidence of stone circles and quarrying activities. One location at the north end of the range seemed to fit with Lee's description of the highest hill in the range, where he says the tipi rings were located. Numerous naturally eroding rocks are present on this particular ridge top that fall within the range of sizes used for weighting down the edge of a tipi cover. Nevertheless, no evidence of stone circles was found on the ridge. It is possible that Lee mistakenly identified the numerous rocks on this ridge as the remnants of stone circles.

On the next ridge to the south of this high point, readily available quartzite outcrops and slump blocks are situated on the slope. No evidence of quarry pits on the brow of this or other nearby ridges has ever been found by the authors. A few quartzite flakes and spent cores have been observed in and around the area of this ridge, typically exposed on one of the numerous hiking trails. However, the description by Lee seems to be out of proportion to the actual resource. Although quartzite may have been acquired in this area by prehistoric inhabitants, the evidence is slim (the few flakes on the trails) and no direct evidence of actual quarrying has been found. This again presented a conflict as to whether the materials from Cowboy Hill should be used in the study as representative of a quarry. It was decided that the materials should be included in the study as examples of Lakota Formation quartzite; however, they would not likely be given consideration in future studies of this nature. The authors will update the state site files as to these findings, or lack thereof, however, a systematic survey should be undertaken before deciding whether to close the site number or redefine the site type if other evidence of cultural use is present.

Sample Description. The Cowboy Hill quarry samples are a fine-grained quartzite. They exhibit variable rounding, high sphericity, grain-colored, and ⅛ to ¼ mm diameter quartz grains and lithic fragments. The matrix color is consistently white. Minimal evidence of compaction is present; the edges of the grains are clearly visible. The rock is composed of approximately 90% quartz grains of variable types, including rose quartz, and 10% variable-colored lithic fragments. Angularity, sorting, compaction, and grain size distribution appears to be influenced by bedding patterns in the parent rock. Overall color of the rock is influenced by the grains. The rock compaction is variable, some areas are well compacted and others are not. Conchoidal fracturing presents as a smooth surface with breakage occurring across the grains.

SAUL QUARRY #1 AND SAUL QUARRY #5

Site Description. The non-cultural quarry samples from Saul Quarry #1 and #5 are located approximately one-half mile apart in Platte County, Wyoming in the Cloverly Formation (Figure 10) and are part of the Spanish Diggings quarry complex. Saul Quarry #1 (Saul 1969) is also known as the Barbour quarry (Reher 1991:264 and 266). Saul Quarry #1 (Saul 1969) consists of approximately 200 quarry pits, rubble piles, and stone circles located south of the quarry area. Flaking debris is scattered between the quarry and the stone circles. The quartzite material at this location was buff, grey, light purple, and lavender (Ahler 1975:5).

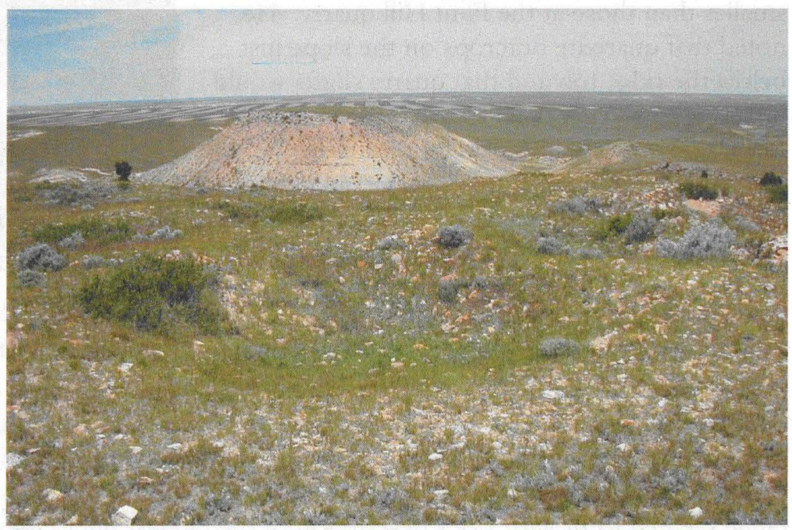


Figure 10. Saul Quarry #1 in Platte County, Wyoming. Photo courtesy of the Wyoming State Historic Preservation Office.

Saul Quarry #5 (Saul 1969) is located southwest of Saul Quarry #1. There are many quarry features in this area and without a field check, it is not possible to link this location to other named quarries described in the extensive literature on the Spanish Diggings complex. It seems best not to speculate. The legal location used in Ahler's (1975:26) manuscript corresponds to the samples used in this study. This quarry consists of a single pit on a dome-shaped hill top and two stone cirlces. It contained mainly a yellow quartzite and a large amount of flaking debris (Ahler 1975:5).

Sample Description. The Saul Quarry #1 and Saul Quarry #5 samples from Platte County, Wyoming were examined separately but described together because of their strong similarity. The Saul quarry materials are a fine-grained to medium crystalline quartzite. They exhibit well sorted, spherical, and sub-rounded quartz grains and lithic fragments. Composition is variable, but typically is approximately >75% quartz of assorted coloration and <25% lithic fragments. Material can be variable in grain size and recrystallization; however, it is typically consistent within a given lithic sample. Grain size ranges from ⅛ to ½ mm with the reddish/purple, more recrystallized material dominating the larger grain sizes. The larger grain sizes do not break across the grain boundaries and whereas the smaller, more fine-grained material which is less recrystallized breaks cleanly across grain boundaries and produces a more smooth conchoidal fracture. Several patinas were present, but of note, a malachite green, caliche-like weathering by-product was present on one of the lithic samples. Clast size, color, compaction, and composition are highly variable between lithic samples as is matrix color.

QUARRY STONE COLORS

The Munsell Rock Color chart (1984) was used to identify the range of quarry stone colors among the sampled rock (Table 2), although other colors may be present in the parent formations or the quarries themselves. The color range is presented below; however it must be kept in mind that color is the least reliable method for distinguishing the source of quarry samples.

Table 2. Range of colors in the quarry samples using the Munsell Rock Color chart.

Munsell Code	Munsell Color	39MD79 Deadwood Formation	39CU484 Minnelusa Formation	39FA49 Fall River Formation	39FA55 Fall River Formation	39PN1 Lakota Formation	Saul #1 Cloverly Formation	Saul #5 Cloverly Formation
N 9	White				X			
N 8	Very light gray				X			
N 7	Light gray			X	X			X
N 6	Medium light gray				X			
N 5	Medium gray							
N 4	Medium dark gray				X			X
N 3	Dark gray			X	X			
5 P 4/2	Grayish purple			X		X	X	
5 P 6/2	Pale purple					X		
5 RP 2/2	Very dusky red purple					X		
5 RP 4/2	Grayish red purple					X	X	
5 RP 6/2	Pale red purple					X	X	
5 YR 2/2	Dusky brown	X						

Table 2. continued

Munsell Code	Munsell Color	39MD79 Deadwood Formation	39CU484 Minnelusa Formation	39FA49 Fall River Formation	39FA55 Fall River Formation	39PN1 Lakota Formation	Saul #1 Cloverly Formation	Saul #5 Cloverly Formation
5 YR 3/2	Grayish brown	X			X			X
5 YR 3/4	Moderate brown				X			X
5 YR 4/1	Brownish gray			X			X	
5 YR 5/2	Grayish orange pink	X		X		X	X	X
5 YR 4/4	Moderate brown			X	X			
5 YR 5/6	Light brown							X
5 YR 6/1	Light olive gray			X	X	X		
5 YR 7/2	Grayish orange pink						X	
10 YR 2/2	Dusky yellowish brown	X		X				
10 YR 4/2	Dark yellowish brown	X		X	X		X	
10YR 5/4	Moderate yellowish brown		X		X			X
10 YR 6/2	Pale yellowish brown			X		X	X	
10 YR 8/2	Very pale orange							X
5 R 2/2	Blackish red	X	X	X		X		
5 R 2/6	Very dark red				X			
5 R 3/4	Dusky red		X		X	X		
5 R 4/2	Grayish red	X	X	X	X	X		
5 R 5/4	Moderate red		X		X			
5 R 6/2	Pale red		X	X		X		
5 R 7/4	Moderate pink		X					
5 R 8/2	Grayish pink							
10 R 2/2	Very dusky red	X	X		X			
10 R 3/4	Dark reddish brown		X		X			
10 R 4/2	Grayish red		X			X		
10 R 4/6	Moderate reddish brown		X					
10 R 5/4	Pale reddish brown		X					

Table 2. continued

Munsell Code	Munsell Color	39MD79 Deadwood Formation	39CU484 Minnelusa Formation	39FA49 Fall River Formation	39FA55 Fall River Formation	39PN1 Lakota Formation	Saul #1 Cloverly Formation	Saul #5 Cloverly Formation
10 R 6/2	Pale red				X		X	
5 Y 5/2	Light olive gray			X				X
5 Y 6/1	Light olive gray				X			
5 Y 7/2	Yellowish gray			X		X		
5 Y 8/1	Yellowish gray					X		

RAY LONG SITE (39FA65)

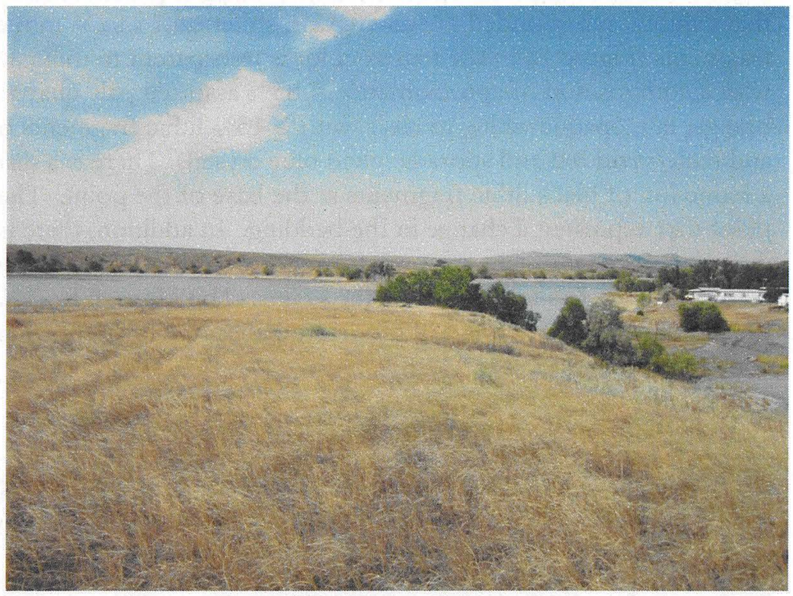


Figure 11. The Ray Long site in Fall River County, South Dakota.

The Ray Long site is a multi-component prehistoric occupation site that dates to the Paleoindian and Middle Plains Archaic periods and possibly before and after those time periods. Based on the recovery of obliquely-flaked lanceolate points during the 1940s and 1950s, it is the type-site for Angostura projectile points and the Angostura complex. The site is situated on the right bank of the now inundated Horsehead Creek in southwestern South Dakota just outside the Black Hills (Figure 11). Horsehead Creek originally flowed northwest from the site to its confluence with the much larger Cheyenne River. The location provides access to a wide variety of natural resources associated with the plains, the foothills of the Black Hills, and the Black Hills Uplift.

Among those resources are an abundance of tool stone outcrops and secondary deposits within a few miles of the site. Compared to the surrounding plains, a wide variety of primary sources of quartzites and cherts are available within the Black Hills Uplift (see Figure 2). Although many of these stone types have eroded out onto the foothills and plains surrounding the Black Hills, secondary sources would not have provided the same quality, quantity, or size of material available at the outcrop. Discontiguous sources of cherts and chalcedonies in remnants of the White River Group in South Dakota, Wyoming, and Nebraska would also have been available to groups living at the Ray Long site.

Beginning with the Smithsonian Institution's River Basin Survey in 1948 and intermittently through 2010, archaeological excavations have been conducted at this well preserved site (cf Wheeler 1995;

Buhta et. al. 2012; Fredlund 1988; Hannus 1986; Hannus et. al. 1993; Hannus et. al. 2012; Haug 1987; Scott and Lewis 1986; Scott 1988;). After construction of Angostura Dam in the 1950s Horsehead Creek was flooded and a portion of the site (Area C) was inundated. Water also submerged approximately 30.5 meters (100 feet) of the western edge of the site (Area B). Today, the site lies adjacent to the Angostura Reservoir on land managed by the Bureau of Reclamation (Reclamation). Reclamation funded several investigations at the Ray Long site by Augustana College over the past 25 years. During their 1985 field investigations two quartzite Angostura projectile point fragments, catalog #s 12-0046-48 (P48) and 12-0046-50 (P50), were recovered from the surface in a deflated area just east of Area B. Soil AMS dating of this area suggests a time frame of ca. 8250 B.C. for P48 and P50. In 2011 the projectile points were subjected to XRF testing and the data was processed in 2013. The descriptions below are based on the macroscopic and microscopic examination completed in 2013.

Projectile Point Catalog #12-0046-48 (P48). Projectile point P48 is made from a fine-grained quartzite that exhibits sub-rounded to sub-angular, spherical, ⅛ to ¼ mm diameter quartz grains and lithic fragments (Figure 12). The matrix color is transparent to milky white. It has a normal compaction, with a composition of approximately < 85% assorted pale quartz grains ranging from yellow, light orange, tan, opaque white, to clear, with > 15% lithic fragments of assorted colors including black and dark/vivid red and sporadic vivid blue crystals. There is a distinct color change in the grains and a reduction of black lithic fragments at the base of the point. The color change near the base of the point may represent a change in the bedding. In addition, there is a distinct malachite green surface deposit/patina or caliche of some form on several locations towards the tip of the point. Overall color of the rock is influenced by the grains. The Munsell Rock Color is 5 YR 5/2 pale brown on the upper portion and 5 R 5/4 moderate red on the lower portion. This material produces a smooth conchoidal fracture.

Figure 12 . Angostura projectile point catalog #12-0046-48 (P48) from the Ray Long site.

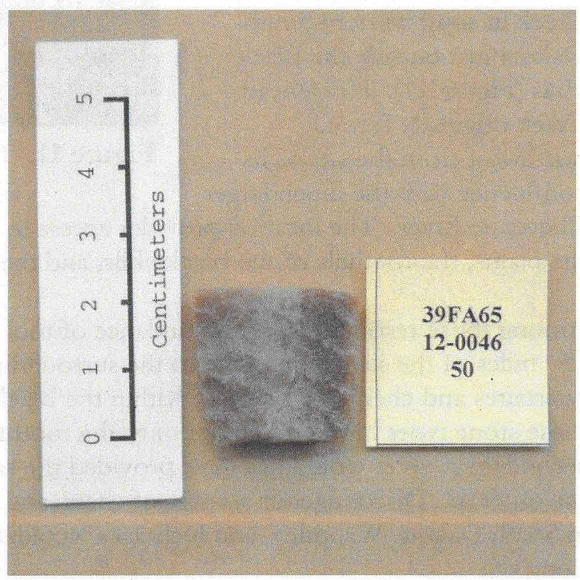


Figure 13. Angostura projectile point catalog #12-0046-50 (P50) from the Ray Long site.

Projectile Point Catalog #12-0046-50 (P50). Projectile point P50 is made of a fine-grained quartzite that exhibits well rounded to sub-rounded, well sorted, well cemented, ⅛ to ¼ mm diameter quartz grains and lithic fragments (Figure 13). This material is poorly compacted but well cemented with a clear silica matrix. This rock is composed of approximately 75% transparent, well rounded quartz with >20% sub-rounded lithic fragments and <5% metallic fragments, possibly pyrrhotite or chalcopyrite. The metallic glints and sheen associated with these small inclusions are visible to the naked eye. The color and variability of the lithic fragments dominate the color and texture of this rock. The majority of the rock is composed of clear transparent quartz with black mineralization within them but fragments also include red textured fragments and brown, black, tan, pink, red, and mixed earth tone clasts. Overall color of the rock is influenced by the grain color not by the matrix. Bedding is visible and is parallel to the projectile and does not influence the texture or durability of the material. The Munsell Rock Color for this artifact is 5 YR 4/1 brownish gray. This material produces a smooth conchoidal fracture across grain boundaries.

RESULTS

In order to facilitate the analysis the sample names were shortened so that specific spectra were easier to identify and compare. Table 3 shows the original XRF sample names, the analysis names, and the shortened names used for reference in this report.

Table 3. XRF sample and analysis names and the corresponding reference names used in the report.

Sample Name	Analysis Name	Reference Name
39CU484.1	39CU484.1@230813_132422	39CU484.1
39CU484.2	39CU484.2@230813_132422	39CU484.2
39CU484.3	39CU484.3@230813_132422	39CU484.3
39CU484.4	39CU484.4@230813_132422	39CU484.4
39CU484.5	39CU484.5@230813_132422	39CU484.5
39CU484.6	39CU484.6@230813_132422	39CU484.6
FlintHillFACoBrown.1	FlintHillFACoBrown.1@130913_130549	39FA49.1
FlintHillFACoBrown.2	FlintHillFACoBrown.2@130913_130549	39FA49.2
FlintHillFACoGrey.3	FlintHillFACoGrey.3@130913_130549	39FA49.3
FlintHillFACoGrey.4	FlintHillFACoGrey.4@130913_130549	39FA49.4
FlintHillFACoGrey.5	FlintHillFACoGrey.5@130913_130549	39FA49.5
FlintHillFACoDKGrey.6	FlintHillFACoDKGrey.6@130913_130549	39FA49.6
FlintHillFACoDKGrey.7	FlintHillFACoDKGrey.7@130913_130549	39FA49.7
FlintHillFACoDkGrey.8	FlintHillFACoDkGrey.8@130913_130549	39FA49.8
FlintHillFACoDkGrey.9	FlintHillFACoDkGrey.9@130913_130549	39FA49.9
FlintHillFACoLtPurple.1	FlintHillFACoLtPurple.1@130913_130549	39FA49.10
FlintHillFACo	FlintHillPnCo@130913_130549	39FA49.11
BattleMntFACo	BattleMntFACo@170913_122223	39FA55.1
BattleMntFACoGrey.2	BattleMntFACoGrey.2@170913_122223	39FA55.2
BattleMntFACoGrey.3	BattleMntFACoGrey.3@170913_122223	39FA55.3
BattleMntFACoGrey.4	BattleMntFACoGrey.4@170913_122223	39FA55.4
BattleMntFACoBrown.5	BattleMntFACoBrown.5@170913_122223	39FA55.5
BattleMntFACoBrown.6	BattleMntFACoBrown.6@170913_122223	39FA55.6
BattleMntFACoRed.7	BattleMntFACoRed.7@170913_122223	39FA55.7
BattleMntFACoRed.8	BattleMntFACoRed.8@170913_122223	39FA55.8

Table 3. continued

Sample Name	Analysis Name	Reference Name
BattleMntFACoRed.9	BattleMntFACoRed.9@170913_122223	39FA55.9
BattleMntFACoRed.10	BattleMntFACo@170913_122223	39FA55.10
BattleMntFACoLargeBrown.11	BattleMntFACo@170913_122223	39FA55.11
39FA55.1	39FA55.1@230813_132422	39FA55.12
39FA55.2	39FA55.2@230813_132422	39FA55.13
39FA55.3	39FA55.3@230813_132422	39FA55.14
39FA55.4	39FA55.4@230813_132422	39FA55.15
39PN1.1	39PN1.1@170913_121053	39PN1.1
39PN1.2	39PN1.2@170913_121053	39PN1.2
39PN1.3	39PN1.3@170913_121053	39PN1.3
39PN1.4	39PN1.4@170913_121053	39PN1.4
39PN1.5	39PN1.5@170913_121053	39PN1.5
39PN1.6	39PN1.6@170913_121053	39PN1.6
39PN1.7	39PN1.7@170913_121053	39PN1.7
39PN1.8	39PN1.8@170913_121053	39PN1.8
MHillPnCo.2	MHillPnCo.2@170913_130549	39PN1.9
MHillPnCo.5	MHillPnCo.5@170913_130549	39PN1.10
MHillPnCo	MHillPnCo@170913_130549	39PN1.11
MHillPnCoBanded.4	MHillPnCo.4@170913_130549	39PN1.12
MHillPnCoMottled.6	MHillPnCo.5@170913_130549	39PN1.13
MHillPnCoOrange.3	MHillPnCo.3@170913_130549	39PN1.14
39MD79.1	39MD79.1@170913_145454	39MD79.1
39MD79.2	39MD79.2@170913_145454	39MD79.2
39MD79.3	39MD79.3@170913_145454	39MD79.3
SaulQuarry1	SaulQuarry1@031113_112837	SaulQuarry1
SaulQuarry5.1	SaulQuarry5.1@031113_112837	SaulQuarry5.1
SaulQuarry5.2	SaulQuarry5.2@031113_112837	SaulQuarry5.2
SaulQuarry5.3	SaulQuarry5.3@031113_112837	SaulQuarry5.3
39FA65.851a.2	39FA65.851a.2@170913_152334	39FA65.48a
39FA65.851a.3	39FA65.851a.3@170913_152334	39FA65.48b
39FA65.851a.4	39FA65.851a.4@170913_152334	39FA65.48c
39FA65.851a	39FA65.851a@170913_152334	39FA65.48d
39FA65.853c.1	39FA65.853c.1@170913_152334	39FA65.50a
39FA65.853c.2	39FA65.853c.2@170913_152334	39FA65.50b

The elemental identification of the data provided by Reclamation showed that 11 different elements were present in the samples (Table 4). The graphic result for each sample can be found in Appendix A.

Table 4. Elements identified by XRF as present in each sample.

Sample	Zirconium	Nickel	Copper	Iron	Zinc	Strontium	Titanium	Arsenic	Yttrium	Manganese	Calcium
39CU484.1	X	X	X	X							
39CU484.2	X	X	X	X							
39CU484.3	X	X	X	X	X						
39CU484.4	X	X	X	X	X						

Table 4. continued

Sample	Zirconium	Nickel	Copper	Iron	Zinc	Strontium	Titanium	Arsenic	Yttrium	Manganese	Calcium
39CU484.5	X	X	X	X							
39CU484.6		X	X	X	X	X					
39FA49.1	X	X	X	X	X			X			
39FA49.2	X	X	X	X							
39FA49.3	X	X	X	X	X						
39FA49.4	X	X	X	X	X	X					
39FA49.5	X	X	X	X	X						
39FA49.6	X	X	X	X	X						
39FA49.7	X	X	X	X	X						
39FA49.8	X	X	X	X	X						
39FA49.9	X	X	X	X	X						
39FA49.10	X	X	X	X	X						
39FA49.11	X	X	X	X	X						
39FA55.1	X			X	X						
39FA55.2	X	X	X	X	X	X					
39FA55.3	X	X	X	X	X	X					
39FA55.4	X	X	X	X	X						
39FA55.5	X	X	X	X	X	X					
39FA55.6	X	X	X	X	X						
39FA55.7	X	X	X	X	X						
39FA55.8	X	X	X	X	X						
39FA55.9	X	X	X	X	X	X	X		X		
39FA55.10	X	X	X	X	X						
39FA55.11	X	X	X	X	X	X					
39FA55.12	X	X	X	X	X		X	X			
39FA55.13	X	X	X	X							
39FA55.14	X	X	X	X	X						
39FA55.15	X	X		X	X						
39PN1.1	X	X	X	X	X						
39PN1.2	X	X	X	X	X						
39PN1.3	X	X	X	X	X	X					
39PN1.4	X	X	X	X	X	X					
39PN1.5	X	X	X	X	X						
39PN1.6	X	X	X	X	X					X	
39PN1.7	X	X	X	X	X						
39PN1.8	X	X	X	X	X						
39PN1.9	X	X	X	X	X	X		X			

Table 4. continued

Sample	Zirconium	Nickel	Copper	Iron	Zinc	Strontium	Titanium	Arsenic	Yttrium	Manganese	Calcium
39PN1.10	X	X	X	X	X						
39PN1.11	X	X	X	X	X						
39PN1.12	X	X	X	X	X						
39PN1.13	X	X	X	X	X						
39PN1.14	X	X	X	X	X	X					
39MD79.1	X	X	X	X	X						
39MD79.2	X	X	X	X	X					X	
39MD79.3	X	X	X	X	X						X
SaulQuarry1	X	X	X	X		X	X	X			
SaulQuarry5.1	X	X	X	X	X	X	X	X			
SaulQuarry5.2	X	X	X	X	X	X	X	X			
SaulQuarry5.3	X	X	X	X	X	X	X	X			
39FA65.1a	X	X	X	X	X						
39FA65.1b	X	X	X	X	X						
39FA65.1c	X	X	X	X	X						
39FA65.1d	X	X	X	X	X						
39FA65.2a	X	X	X	X	X	X					
39FA65.2b	X	X	X	X		X					

QUALITATIVE DATA

Based on the elements identified using Spectra, the qualitative data for each sample was generated. As this is qualitative, not quantitative data, the numbers listed in Table 5 represent the intensity (concentration of the element) of each peak in the sample, or the net area of the peak. *These numbers do not reflect the amount of the element present in each sample.*

Table 5. The concentration of the elements present in each sample.

Sample	As K12	Ca K12	Cu K12	Fe K12	Mn K12	Ni K12	Sr K12	Ti K12	Y K12	Zn K12	Zr K12
39CU484.1			259	1043		363					849
39CU484.2			249	855		308					800
39CU484.3			288	914		313				224	5076
39CU484.4			247	1056		307				245	558
39CU484.5			213	370		308					1011
39CU484.6			281	711		366	319			244	
39FA49.1	374		372	4135		385				277	1007
39FA49.2			313	2071		370					670

Table 5. continued

Sample	As K12	Ca K12	Cu K12	Fe K12	Mn K12	Ni K12	Sr K12	Ti K12	Y K12	Zn K12	Zr K12
39FA49.3			269	159		308				227	770
39FA49.4			310	239		395	343			240	1096
39FA49.5			278	161		371				265	803
39FA49.6			286	335		323				222	640
39FA49.7			327	324		361				306	483
39FA49.8			342	450		312				307	739
39FA49.9			231	407		376				216	510
39FA49.10			247	506		320				197	1729
39FA49.11			28	105		51				53	240
39FA55.1				6390						54	547
39FA55.2			350	437		351	106			282	2800
39FA55.3			314	281		366	89			329	3895
39FA55.4			280	398		400	182			288	1749
39FA55.5			489	7236		343	199			358	1000
39FA55.6			280	7138		385				287	2492
39FA55.7			197	1834		341				222	1067
39FA55.8			254	10501		354				203	689
39FA55.9			327	4884		300	145	137	204	267	4551
39FA55.10			259	14432		308				265	1924
39FA55.11			280	6423		345	130			217	1070
39FA55.12	221		295	15435		311		293		288	801
39FA55.13			300	1920		313					656
39FA55.14			271	1483		325				202	808
39FA55.15				2276		377				219	8140
39PN1.1			254	399		318				224	741
39PN1.2			252	235		376				287	864
39PN1.3			258	3374		326	148			216	2030
39PN1.4			220	771		341	150			263	559
39PN1.5			302	2729		374				229	752
39PN1.6			238	328	292	375				243	606
39PN1.7			305	705		376				263	538
39PN1.8			265	217		363				215	795
39PN1.9	261		242	6303		308	174			277	2791
39PN1.10			301	2316		350					3548
39PN1.11			44	240		55					296
39PN1.12			317	1108		367					599
39PN1.13			247	5656		323					1822
39PN1.14			331	3161		333	284				786
39MD79.1			286	6552		282					212

Table 5. continued

Sample	As K12	Ca K12	Cu K12	Fe K12	Mn K12	Ni K12	Sr K12	Ti K12	Y K12	Zn K12	Zr K12
39MD79.2			293	11887	124	272				271	402
39MD79.3		1071	283	16848		266				234	286
SaulQuarry1	60		229	467		307	155	172			240
SaulQuarry5.1	89		297	218		340	217	167		30	260
SaulQuarry5.2	101		464	397		331	43	91		74	398
SaulQuarry5.3	82		391	337		343	36	88		14	502
39FA65.48a			311	582		363				224	634
39FA65.48b			280	666		349				248	861
39FA65.48c			279	364		375				258	614
39FA65.48d			281	219		364				234	824
39FA65.50a			269	540		397				229	2844
39FA65.50b			319	696		337					3813

CORRELATION DATA

The final analysis of the lithic material samples was to compare the results from the two quartzite projectile points, P48 and P50, from the Ray Long site to each known quarry sample and determine a correlation percentage. The percentage reflects how likely it is that each projectile point is related to the samples tested from the known quarry sources.

Figure 14 shows the XRF signatures of P48 and P40. Figure 15 shows the XRF signatures of P48 and P50 compared to the XRF signatures of the quarries, Meadow Creek (39MD79), Jewel Cave (39CU484), Flint Hill (39FA49), Battle Mountain (39FA55), Cowboy Hill (39PN1), Saul Quarry #1 and Saul Quarry #5.

Figure 14. Graph comparing the XRF signatures for the Ray Long projectile points, P48 and P50.

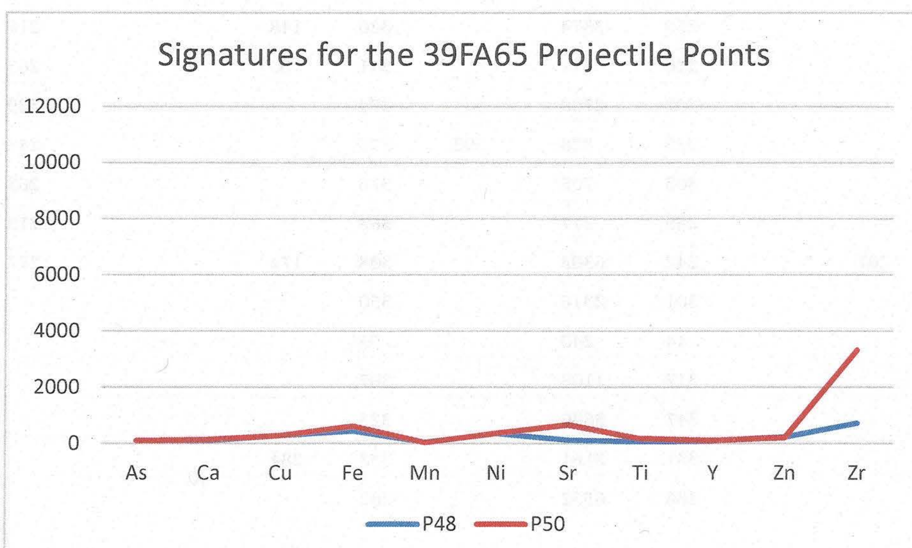


Figure 15. Graph comparing the XRF signatures for the Ray Long projectile points, P48 (39FA65.851a) and P50 (39FA65.853c) and the quarries (39CU484 lies directly behind 39FA49).

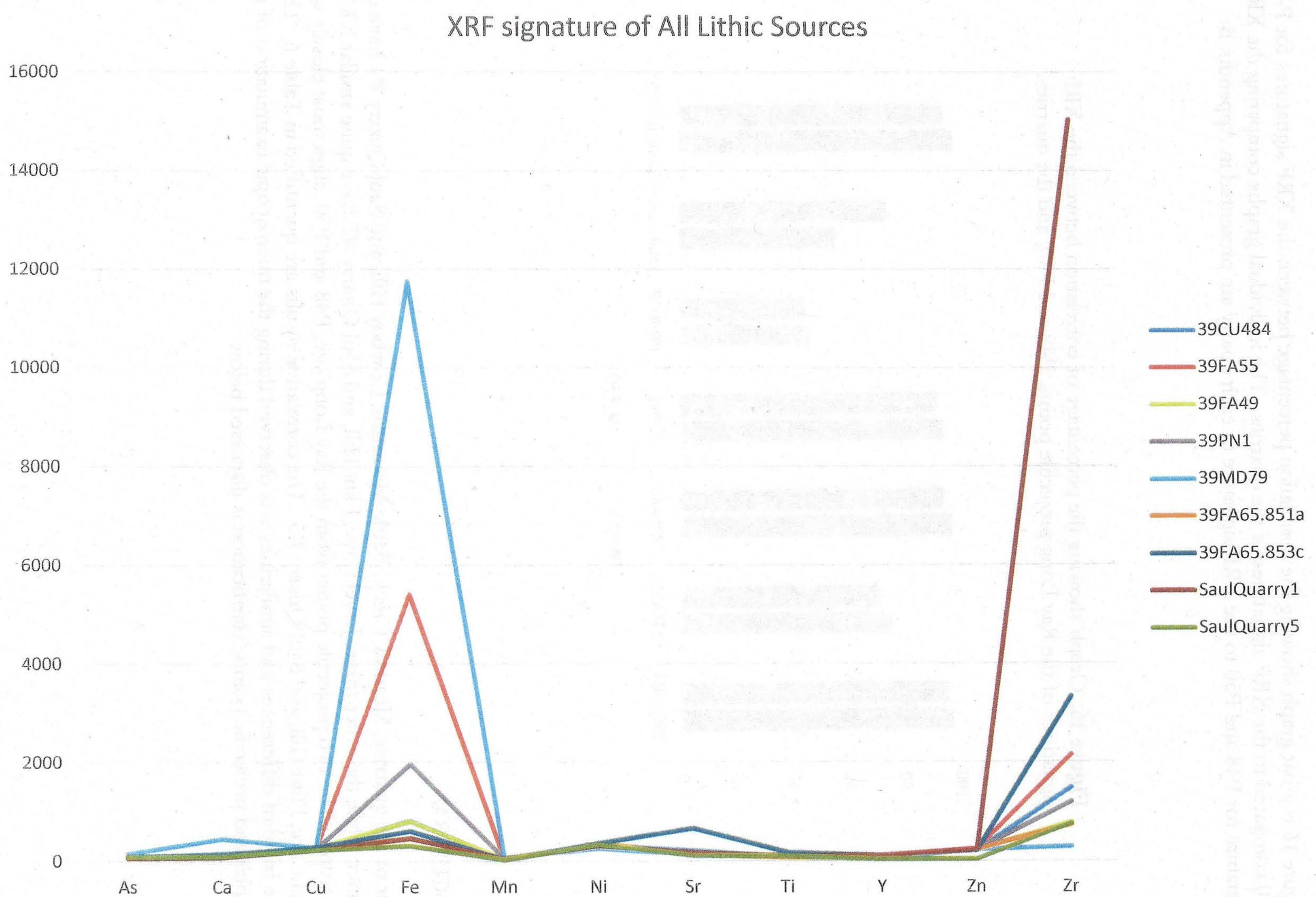
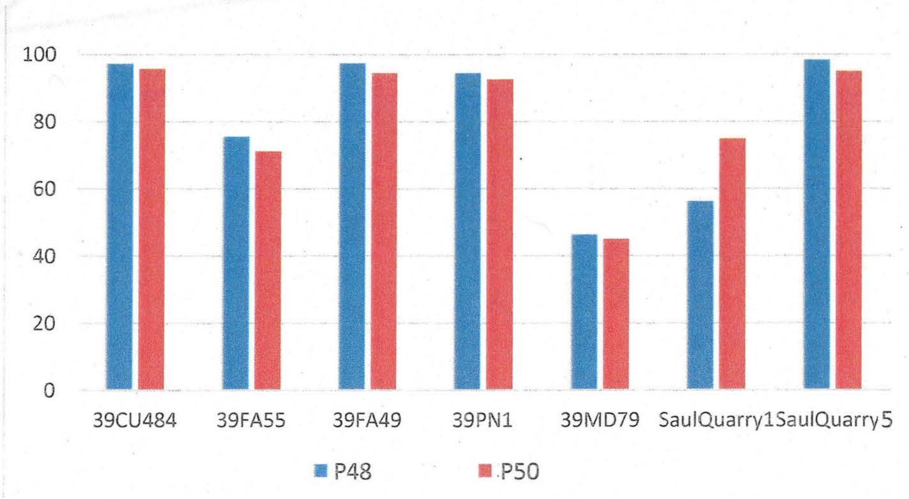


Figure 16 is a bar graph showing the correlation percentage between the XRF signatures for P48 and P50 compared to the XRF signatures of the quarries. The individual graphs comparing the XRF signature for P48 and P50 to the XRF signature of each quarry are presented in Appendix B.

Figure 16. Graph showing the percentage of correlation between the XRF signatures of the Ray Long projectile points, P48 and P50, and the quarries.



DISCUSSION

Four of the quarries, Meadow Creek, Battle Mountain, Cowboy Hill, and Saul Quarry #1 have quite distinct, while the other three, Jewel Cave, Flint Hill, and Saul Quarry #5 have quite similar XRF signatures. The two projectile points from the Ray Long site, P48 and P50, align most closely with Jewel Cave, Flint Hill, and Saul Quarry #5. The correlative results are quantified in Table 6. This same trend of differences and similarities was observed during the microscopic examination of the samples and projectile points; clarification is discussed below.

Table 6. Percentage points or strength of correlation between the XRF signature of the Ray Long projectile points, P48 and P50, and the quarries.

FORMATION: QUARRY	P48 CORRELATION (%)	P50 CORRELATION (%)
Deadwood: Meadow Creek (39MD79)	46.3	44.97
Minnelusa: Jewel Cave (39CU484)	97.07	95.69
Lakota: Cowboy Hill (39PN1)	94.26	92.49
Fall River: Flint Hill (39FA49)	97.28	94.36
Fall River: Battle Mountain (39FA55)	75.44	71.1
Cloverly: Saul Quarry #1	56.2	74.86
Cloverly: Saul Quarry #5	98.23	94.95

The Meadow Creek quarry is situated in the Deadwood Formation of the northern Black Hills approximately 112 kilometers (70 miles) north of the Ray Long site. Its XRF signature is the most distinct among the seven quarries. It had a strong iron reading and also a reading for calcium in one sample and manganese in another sample. None of the other samples in the study had a positive response for calcium. One sample from Cowboy Hill had a response to manganese. Macroscopically and microscopically it is also the most distinct material compared to the other quarries. Microscopically, this medium monocrystalline quartzite has a unique composition: smoky quartz (10%), clear quartz (20%), purple quartz (50%), hematite (15%), and glauconite (5%). None of the other samples contained purple quartz crystals or glauconite. None of the other samples contained purple quartz crystals or glauconite. The deep red color is a response to the purple quartz and hematite; its strong iron response in the XRF results is due to the presence of iron oxides such as hematite. The color range includes browns, grayish orange pink, yellowish browns, and dark reds. Ray Long site projectile points P48 and P50 have a weak correlation to the Meadow Creek quarry; P48 at 46.3% and P50 at 44.97%.

The Battle Mountain quarry is situated in the Fall River Formation of the southwestern Black Hills approximately 13 kilometers (8 miles) miles north and west of the Ray Long site. This fine-grained quartzite has the next most distinct XRF signature among the seven quarries. The element titanium is present in two of the Battle Mountain samples, unlike any other Black Hills quarries sampled. Titanium was present in the Saul Quarry #1 and all the Saul Quarry #5 samples. One Battle Mountain sample had a response to arsenic and another to yttrium. Yttrium does not show up in any of the other samples in the study. Other quarries that showed a response to arsenic include Flint Hill (1/11 samples), Cowboy Hill (3/14 samples) and Saul Quarry #1 (1/1 sample) and Saul Quarry #5 (3/3 samples). Sample colors include white, grays, browns, yellowish browns, reds, and tans, although it is known for its massive deep red quartzite outcrops. The deep red color is influenced by the matrix in the stone, not the quartz grains, which are predominantly, clear (65%) and tan (25%). Color cannot be used as a definitive macroscopic identification for this quarry. Ray Long site projectile points P48 and P50 have a weak correlation to the Battle Mountain quarry; P48 at 75.44% and P50 at 71.1%.

Saul Quarry #1 is situated in the Cloverly Formation in eastern Wyoming approximately 145 kilometers (90 miles) southwest of the Ray Long site. Although quite similar macroscopically and microscopically to Saul Quarry #5, their XRF signatures were quite different. At this time it is unknown whether this represents a sampling bias or not, considering that only one sample was tested from Saul Quarry #1 and three from Saul Quarry #5. Trace elements strontium, titanium, and arsenic are all present in the single sample from Saul Quarry #1. Colors include purples, browns, yellowish browns, and reds, based on the examination of other tool stone material collected by Ahler (Ahler 1975) at this location but not tested using XRF. Ray Long site projectile points P48 and P50 have a weak correlation to Saul Quarry #1; P48 at 56.2% and P50 at 74.86%.

The Cowboy Hill quarry is situated in the Lakota Formation in the northern Black Hills approximately 95 kilometers (60 miles) north of the Ray Long site. This fine-grained quartzite has the third most distinct XRF signature among the seven quarries. The XRF testing identified arsenic in one sample and manganese in another. Microscopically, a distinct quality of this fine-grained material is that some, but not all, of the samples contain rose quartz grains. The rose quartz is responsible for the orange pink color of some of these samples. Rose quartz was not present in any of the other samples examined for this study. Other colors include purples, browns, yellowish browns, reds, and grays. Ray Long site projectile points P48 and P50 have fairly strong correlations to the Cowboy Hill quarry; P48 at 94.26% and P50 at 92.49%.

The Jewel Cave quarry is situated in the Minnelusa Formation in the southwestern Black Hills approximately 55 kilometers (34 miles) northwest of the Ray Long site. Microscopically, this fine-crystalline quartzite contains some black mineral staining that is not present in any of the other samples examined for this study. It also has less than 5% lithic fragments present. Colors lend towards the browns, yellowish browns, reds, and pinks which are influenced by the matrix, not the quartz grains. Ray Long site projectile point P48 has a strong correlation, 97.07%, and P50 has its strongest correlation among all the quarries, 95.69%, to the Jewel Cave quarry.

The Flint Hill quarry is situated in the Fall River Formation of the southern Black Hills approximately 24 kilometers (15 miles) northwest of the Ray Long site. Microscopically, this fine-crystalline quartzite contains about 5% lithic fragments and some iron oxide (hematitic) inclusions not present in the samples from Jewel Cave quarry. Colors, which are influenced by the matrix, are also more variable than the Jewel Cave samples, including grays, purples, browns, yellowish browns, pinks, reds, and yellows. Ray Long site projectile points P48 and P50 both have a strong correlation to the Flint Hill quarry; P48 at 97.28% and P50 at 94.36%.

Saul Quarry #5 is situated in the Cloverly Formation of eastern Wyoming approximately 145 kilometers (90 miles) southwest of the Ray Long site. Although quite similar macroscopically and microscopically to Saul Quarry #1, their XRF signatures were quite different. At this time it is unknown whether this represents a sampling bias or not, considering that only one sample was tested from Saul Quarry #1 and three from Saul Quarry #5. Trace elements strontium, titanium, and arsenic are present in all three samples from Saul Quarry #5. Colors include grays, browns, yellowish browns, and pale orange. A striking feature of these samples was the high percentage of lithic fragments (25%). In addition, a malachite green caliche-like weathering by-product was present on one of the lithic samples. A small representation of this same type of weathering by-product was present on P48. Ray Long site projectile point P48 has its strongest correlation, 98.23%, and P50 has its second strongest correlation, 94.95%, to Saul Quarry #5.

CONCLUSIONS

The purpose of this research was to determine if the tool stone used for two quartzite Angostura projectile points from the Ray Long site in Fall River County, South Dakota, could be linked to a specific quarry or geologic formation. The study applied macroscopic and microscopic examinations and XRF technology to the projectile points and samples from seven previously recorded prehistoric quarries in South Dakota and Wyoming. A detailed physical description and an XRF signature, based on an average of the XRF test results, were established for the projectile points and each quarry. The results were used to address two questions defined in the introduction, which follow.

QUARRY TEST RESULTS

First, do the quartzite quarries each have a unique XRF signature and physical description compared to the other quartzite quarries, whether from the same geologic formation or not? The answer to this is 'yes', although some of the distinctions are slight. With regards to the XRF results, the elements iron, strontium, titanium and arsenic represent the greatest variation in readings between all the samples, iron being the greatest. Four quarries had distinctly different XRF signatures, Meadow Creek (Deadwood Formation), Battle Mountain (Fall River Formation), Cowboy Hill (Lakota Formation), and Saul Quarry #1 (Cloverly Formation). Although Battle Mountain and Saul Quarry #1 are from correlative geologic groups, Inyan Kara, their XRF signatures are not a close match.

Microscopically, these four quarries also present distinct differences with respect to gain size; Meadow Creek (medium-grained), Battle Mountain and Cowboy Hill (fine-grained), and Saul Quarry #1 (fine to medium-grained). It should be noted that all of Ahler's Saul Quarry #1 XRF samples were examined microscopically even though only one was tested using XRF. Meadow Creek samples are well compacted and contain hematitic and glauconititc inclusions, which the other three do not have. Cowboy Hill has minimal compaction and Battle Mountain is poorly compacted. Color in Meadow Creek and Cowboy Hill samples were influenced by the grain color while Battle Mountain and Saul Quarry #1 samples were influenced by the matrix color. Lithic fragments were present in the Battle Mountain, Cowboy Hill, and Saul Quarry #1 samples, but not Meadow Creek.

Two quarries, Jewel Cave (Minnelusa Formation) and Flint Hill (Fall River Formation) have similar XRF signatures even though they represent different geologic time periods. Yet the two Fall River Formation quarries, Flint Hill and Battle Mountain, are distinctly different. Microscopically, quarry samples from Jewel Cave and Flint Hill were, again, similar but not the same. Differences include the minor inclusions of hematite or iron oxide in Flint Hill that are not present in Jewel Cave and some bedding present in Jewel Cave that is not present in Flint Hill. Otherwise, their physical descriptions are quite similar. They also share the color range of browns, yellowish browns, reds, and pinks while Flint Hill also includes grays, purples, and yellows.

The XRF signature of Saul Quarry #5 in the Cloverly Formation, with the exception of the presence of titanium and arsenic in all its samples, was similar to the Jewell Cave and Flint Hill quarries as well. Only one sample from Flint Hill and none from Jewel Cave contained arsenic. Microscopically, Saul Quarry #5 contained a higher percentage of lithic fragments (25%) than either Jewel Cave (5%) or Flint Hill (5%). Grain sizes in the Saul Quarry #5 samples also had a greater variation ($^1/_8$ to $^1/_2$ mm) than either Flint Hill ($^1/_8$ to $^1/_4$ mm) or Jewel Cave ($^1/_8$ mm). Angular, sub-rounded, and spherical grains were present in the Flint Hill and Jewel Cave samples but only spherical and sub-rounded grains were present in the Saul Quarry #5 samples. Black mineral staining was only present in the Jewel Cave samples.

The inter-formational differences and similarities discovered demonstrate the complexities of sedimentary depositional environments. They may be the result of facies correlations versus time correlations, reworking of older sedimentary units, similar source material, and/or they may represent subtle differences or shifts in sediment sources internally within the formations.

Thus, the results are mixed. In the region surrounding the Black Hills and Hartville Uplifts on the Northern Plains, relying only on macroscopic properties of an artifact to define the tool stone source would not likely produce reliable, testable results. If microscopic analysis is added to this examination and evaluation, the results would likely improve dramatically, however, to what degree is unknown. Taking analysis to yet another level, using XRF, would likely, again, improve results and be testable.

Given that samples were not collected specifically for this study and that the number of samples varied between quarries, it is clear that future testing should focus on collecting additional samples from a variety of locations within a quarry to refine the XRF signatures of the quarries. If XRF is not available, then researchers should consider a "Black Hills quartzite" type that crosses formation boundaries and encompasses a large geographic area in the Black Hills Uplift. This level of identification would likely be more useful in regional mobility studies as opposed to localized mobility within the Black Hills. The Cloverly quartzites in the Hartville Uplift are already commonly referred to as the "Spanish Diggings quartzites;" a term that is well known and is appropriate for the tool stone from that area. Future XRF tests should be undertaken with Spanish Diggings samples to determine if there are other distinct differences within the quarry complex as suggested by the limited sampling done for this study. It is recommended that future studies on quarry tool stone do not include Cowboy Hill samples. No large or even small scale quarrying activities have been discovered in this locality following Lee's 1925 visit. Although state site records will be updated by the authors based on current visits, a systematic survey to formally document and verify whether any other cultural resources are present should be completed. The Meadow Creek quarry should be revisited to determine if this is a prehistoric quarry or natural erosion of a quartzite outcrop. If natural, it too should be eliminated from future studies. However, the results from Meadow Creek samples supports the likelihood that quarries from the Deadwood Formation would hold their own as a specific type and represent at least one material that, if found in Black Hills area archaeological sites may be distinguishable on macroscopic and microscopic traits alone.

PROJECTILE POINT TEST RESULTS

Second, can two quartzite projectile points from the Ray Long site, located in the southwestern foothills of the Black Hills, be matched to a specific quarry or geologic formation included in the study? If so, are they from the same tool stone source? The answer to this is yes, with certain qualifiers. Based on macroscopic and microscopic examinations and XRF test results, there is no clear match between P48 and P50 to the Meadow Creek, Battle Mountain, Saul Quarry #1, or Cowboy Hill quarries. These quarries can likely be dismissed as possible sources for the quartzites used to produce P48 and P50. On the other hand P48 and P50 had strong XRF matches to Jewel Cave (P48 97.97%, P50 95.59%), Flint Hill (P48 97.28%, P50 94.36%) and Saul Quarry #5 (P48 98.23%, P50 94.95%). Microscopically, the most distinctive characteristics of these two projectile points was the strong presence of lithic fragments (P48 >15%, P50 >20%), lack of angular grains, and their colors are influenced by the grains, not the matrix. These characteristics more closely fit the description of Saul Quarry #5 than either Flint Hill or Jewel Cave samples, regardless of the slightly stronger XRF affiliation (by 0.74%) of P50 to Jewel Cave quarry. The microscopic comparison of P50 to Saul Quarry #5 is stronger in this case.

Taking a more comprehensive view geographically, Saul Quarry #5 is situated within a large expanse of quarrying activities within the Cloverly Formation; a geologically complex formation. The limited number of samples used in this study, only three from Saul Quarry #5, suggests that more XRF testing needs to be done to determine if specific quarries within the Cloverly have distinct XRF signatures. At this time it would be prudent to limit conclusions by suggesting that there is a high probability that the quartzite source for both P48 and P50 lies in the Spanish Diggings quarry complex in the Cloverly Formation of the Hartville Uplift in eastern Wyoming.

If these results are accepted, researchers may postulate whether this tool stone material was obtained by direct or indirect acquisition. If direct acquisition, was it collected by a group during migration out of the southern Rocky Mountains, or was it collected by a group of flint knappers that made a special trip (seasonally?) to the quarry to obtain the high quality stone for the hunt? Also, would a tool stone source 90 kilometers (145 miles) distant from the Ray Long site be considered a local or non-local source? If indirect acquisition, who were they trading with, related groups of the Angostura complex or another group? Did they trade other goods as well? These are all important areas of research that should be explored.

There is also the question of how do other quartzite quarries in the region measure up to these, such as Parker Peak quarry (39FA762) only a few miles west of Flint Hill in the Fall River Formation. Will its XRF signature be similar to Flint Hill or as different as that for Battle Mountain in the same formation? What other types of testing, such as mass spectrometry or petrographic thin sections, may be needed to create a useful composite picture of a quarry? Another consideration for future studies includes looking outside the Black Hills to create XRF signatures for quartzite quarries in other major source areas, such as the Big Horn Mountains in Wyoming to address regional mobility questions. Whether these other quarries will have XRF signatures distinct from the correlative formations in the Black Hills is unknown, but would be important to determine.

Finally, the defining characteristics of the material from tool stone quarries need to be gathered from various levels of examination and testing to create a strong composite picture of the quarry stone. Microscopic examination and geologic definitions of known quarries should be a goal that is attainable if approached on a project-by-project basis and without large investments of time and funding. On the other hand, special studies, such as XRF testing, petrographic thin sections, mass spectrometry, and other geochemical testing, would require a larger investment but would update and strengthen the initial research presented in this study. Until such studies are done, it is recommended that postulating the tool stone source for quartzite artifacts from the Black Hills region should be more broad than specific.

REFERENCES

Ahler, Stanley A.
1975 *Report to the Midwest Archeological Center on a Field Trip in Western South Dakota and North Dakota for the Purpose of Locating and Sampling Prehistoric Lithic Source Materials.* On File at the South Dakota Archaeological Research Center, Rapid City, South Dakota.

Ahler, Stanley A.
1977 Lithic Resource Utilization Patterns in the Middle Missouri Subarea. *Plains Anthropologist* Memoir 13:132-150.

Buhta, A. A., R.D. Mandel, and L.A. Hannus
2012 *The Archeology, History, and Geomorphology of the Ray Long Site (39FA65), Angostura Reservoir, Fall River County, South Dakota: Manuscript II.* Archeological Contract Series No. 254. Prepared by the Archeology Laboratory, Augustana College, Sioux Falls, South Dakota. Prepared for the Bureau of Reclamation, Dakotas Area Office, Rapid City, South Dakota.

Carter, Janet M, Daniel G. Driscoll, and J. Foster Sawyer
2003 *Ground-Water Resources in the Black Hills Area, South Dakota.* Water-Resources Investigations Report 03-4049. U.S. Department of the Interior, U.S. Geological Survey prepared in cooperation with Bureau of Reclamation, South Dakota Department of Environment and Natural Resources, and West Dakota Water Development District: Rapid City, South Dakota.

Cassells, E. Steve
1980 *Cultural Resource Investigations of the Hawkwright Timber Sale, Black Hills National Forest, Custer County, South Dakota.* Project No. C-11-80. Prepared by Plano Archaeological Consultants, Longmont, Colorado. Prepared for the Black Hills National Forest.

Church, Tim
1990 *Prehistoric Lithic Resources of the Black Hills, South Dakota: Progress Report-1989-1990.* University of Montana, Department of Anthropology.

Craig, Carolyn
1983 *Lithic Source Analysis and Interpretation in Northeastern Wyoming and Southeastern Montana.* University of Wyoming, Department of Anthropology, Thesis: Laramie

Dahlstrom, David J. and James E. Fox
1995 *Fluvial Architecture of the Lower Cretaceous Lakota Formation, Southwestern Flank of the Black Hills Uplift, South Dakota.* U.S. Geological Survey Bulletin 1917: Evolution of Sedimentary Basins – Powder River Basin, U.S. Geological Survey: Denver, Colorado.

Denson, N.M. and Theodore Botinelly
1949 *Geology of the Hartville Uplift, Eastern Wyoming.* Oil and Gas Investigations. United States Department of the Interior, Geological Survey, Denver, Colorado.

Finn, Thomas M.
2010 Subsurface Stratigraphic Cross Sections Showing Correlation of Cretaceous and Lower Tertiary Rocks in the Bighorn Basin, Wyoming and Montana. Chapter 6 of *Petroleum Systems and Geologic Assessments of Oil and Gas in the Bighorn Basin Province, Wyoming and Montana.* USGS Digital Data Series DDS-69-V. U.S. Geological Survey Bighorn Basin Province Assessment Team, Reston, Virginia.

Foradas, James G.
2003 Chemical Sourcing of Hopewell Bladelets. In P.N. Kardulias and R.W. Yerkes (Eds.), *Written in Stone: The Multiple Dimensions of Lithic Analysis.* Lexington Books: Lantham, Maryland.

Fredlund, G.G.
1988 *Palynological Analysis of Four Archaeological Samples from the Ray Long Site (39FA65), Southwestern South Dakota.* Prepared by the Department of Geography, University of Kansas, Lawrence. Prepared for the South Dakota State Historical Society, Archaeological Research Center, Rapid City, South Dakota.

Gries, John Paul
1996 *Roadside Geology of South Dakota.* Mountain Press Publishing Company: Missoula, Montana.

Hahn, William and Chris Jessen
2006 *Green River Basin Water Plan Technical Memoranda: Available Ground Water Determination.* Wyoming State Water Plan. Wyoming Development Office, Cheyenne, Wyoming.

Hannus, L.A.
1986 *Report on 1985 Test Excavations at the Ray Long Site (39FA65), Angostura Reservoir, Fall River County, South Dakota: Manuscript III.* Archeological Contract Series No. 27. Prepared by the Archeology Laboratory, Augustana College, Sioux Falls, South Dakota. Prepared for the South Dakota State Historical Society, Archaeological Research Center, Rapid City, South Dakota.

Hannus, L.A., R.P. Winham, and J. Albanese
1993 *Final Report: 1992 Archeological/Geomorphological Investigations at the Ray Long Site (39FA65), Angostura Reservoir, Fall River County, South Dakota: Manuscript II.* Archeological Contract Series No. 86. Prepared by the Archeology Laboratory, Augustana College, Sioux Falls, South Dakota. Prepared for the Bureau of Reclamation, Dakotas Area Office, Rapid City, South Dakota.

Hannus, L.A., R.P. Winham, and A.A. Buhta
2012 *The Archeology, History, and Geomorphology of the Ray Long Site (39FA65), Angostura Reservoir, Fall River County, South Dakota: Manuscript I.* Archeological Contract Series No. 254. Prepared by the Archeology Laboratory, Augustana College, Sioux Falls, South Dakota. Prepared for the Bureau of Reclamation, Dakotas Area Office, Rapid City, South Dakota.

Haug, J.K.
1987 The 1987 Angostura Project. *Newsletter of the South Dakota Archeological Society 17(3-4):2-3.*

Hayden, Brian
1989 From Chopper to Celt: The Evolution of Resharpening Techniques. In Robin Torrence, (Ed.), *Time, energy, and stone tools*. Cambridge Press: Cambridge.

Heinrich, E. William
1956 *Microscopic Petrography*. McGraw-Hill Book Company, Inc.: New York.

Hofman, Jack L.
1990 Paleoindian Mobility and Utilization of Niobrara or Smoky Hill Jasper on the Southern Plains. *Kansas Anthropologist* 11(2): 1-13.

Hughes, Jack T.
1949 Investigations in Western South Dakota and Northeastern Wyoming. *American Antiquity* 14(4). Archaeological Researches in the Missouri Basin by the Smithsonian River Basin Surveys and Cooperating Agencies.

Kunselman, Raymond and Wilfred M. Husted
1996 Prehistoric Obsidian Utilization in the Beartooth Mountains of Montana and Wyoming. *The Wyoming Archaeologist* 40(1):27-34.

Lee, H.E.
1925 *Correspondence from H.E. Lee, Rapid City, South Dakota, to W.H. Over, Curator, Dakota Museum, May 12, 1925, re: Cowboy Hill Quarry and Medicine Crow's Village Site.* On File at the South Dakota Archaeological Research Center, Rapid City, South Dakota.

Luedtke, Barbara E.
1978 Chert Sources and Trace-Element Analysis. *American Antiquity* 43(3):413-423.

Moberly, Ralph Jr.
1960 Morrison, Cloverly, and Sykes Mountain Formations, Northern Bighorn Basin, Wyoming and Montana. *Geological Society of American Bulletin* 71(8):1137-1176.

Pitblado, B.L.
2003 Late Paleoindian Occupation of the Soutnern Rock Mountains: Early Holocene Projectile Points and Land Use in the High Country. University Press of Colorado, Boulder.

Post, Edwin V.
1967 *Geology of the Cascade Springs Quadrangle Fall River County South Dakota.* Geology and Uranium Deposits of the Southern Black Hills. Geological Survey Bulletin 1063-L. U.S. Department of the Interior, Geological Survey, prepared on behalf of the U.S. Atomic Energy Commission, Denver, Colorado.

Pough, Frederick H.
1957 *A Field Guide to Rocks and Minerals, 2nd edition.* Riverside Press: Cambridge.

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.* Ed.: Anta Montet-White and Steven Holen. University of Kansas, Publications in Anthropology 19:251-284.

Robinson, G.S. and G.B. Gott
1958 *Uranium Deposits of the Black Hills South Dakota and Wyoming.* Trace Elements Investigations Report 723. U.S. Department of the Interior, Geological Survey on behalf of the U.S. Atomic Energy Commission, Denver, Colorado.

Rock-Color Chart Committee
1984 *Rock-Color Chart.* Geological Society of America: Boulder, Colorado.

Saul, John M.
1969 Study of the Spanish Diggins, aboriginal flint quarries of southeastern Wyoming. *National Geographic Society Research Reports 1964 Projects,* pp. 183-199. Washington, D.C.

Schwartz, G.M.
1928 The Black Hills Mineral Region. *American Mineralogist* 13:56-63.

Scott, L.J. and R.O. Lewis
1986 Pollen and Phytolith Analysis at the Ray Long Site (39FA65) South Dakota: A Feasibility Study. In: *Report on 1985 Test Excavations at the Ray Long Site (39FA65) Angostura Reservoir, Fall River County, South Dakota,* by L. Adrien Hannus, pp. 31-41. Archeological Contract Series No. 27. Prepared by the Archeology Laboratory, Augustana College, Sioux Falls, South Dakota. Prepared for the South Dakota Archaeological Research Center, Rapid City, South Dakota.

Scott Cummings, L.
1988 *Charcoal and Seed Analysis at the Ray Long Site, South Dakota.* PaleoResearch Laboratories, Denver, Colorado. Prepared for the South Dakota Archaeological Research Center, Rapid City, South Dakota.

Shaver, Douglas and Kathryn Smith
2013 *Mitigation of Potential Adverse Effects to National Register of Historic Places Listed Archeological Site 39FA0049 for the Black Hills Power Hot Springs to Edgemont 69 KV Transmission Line Rebuild.* Project #SD3913002. Prepared by Quality Services, Inc. Prepared for Black Hills Power, Rapid City, SD.

Sims, Paul K., Warren C. Day, George L. Snyder, and Anna B. Wilson.
1996 *Precambrian Tectonics and Metallogeny of the Hartville Uplift, Wyoming.* Edited by Open-File Report 96-4, Field Trip No. 26, Colorado Geological Survey, Denver, Colorado.

Speakman, Jeff
2009 Following the Obsidian Trail. *Mammoth Trumpet* 24(2):3-6.

Saul, John M.
1969 Study of the Spanish Diggins, aboriginal flint quarries of southeastern Wyoming. *National Geographic Society Research Reports 1964 Projects*: 183-199. Washington, D.C.

Tratebas, Alice M., Renee M. Boen, and Rowena Dalla
1978 *Archaeological Surveys in the Black Hills National Forest, South Dakota 1977-1978.* Contract Investigation Series No. 5. Prepared by the South Dakota Archaeological Research Center, Rapid City, South Dakota. Prepared for the Black Hills National Forest.

United States Geological Survey
2013 Geology of Devils Tower National Monument, Wyoming. *Geological Survey Bulletin* 1021-1.

Wheeler, R.P.
1995 *Archeological Investigations in Three Reservoir Areas in South Dakota and Wyoming: Part I, Angostura Reservoir.* Reprints in Anthropology No. 46. J & L Reprint Company, Lincoln, Nebraska.

Witzel, Frank and John Hartley
1976 Two Possible Source Areas for the Quartzite Artifacts of the Hudson Meng Site – A Comparative Study. *Transactions of the Nebraska Academy of Sciences* 3 (1974-1976), October 1976:12-19.

APPENDIX A
XRF SIGNATURE GRAPHS AND SCREEN SHOTS

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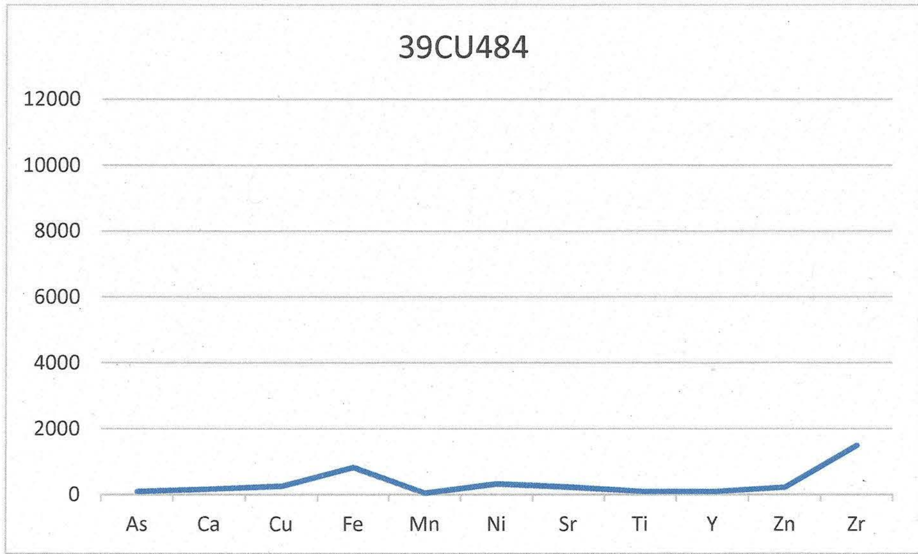

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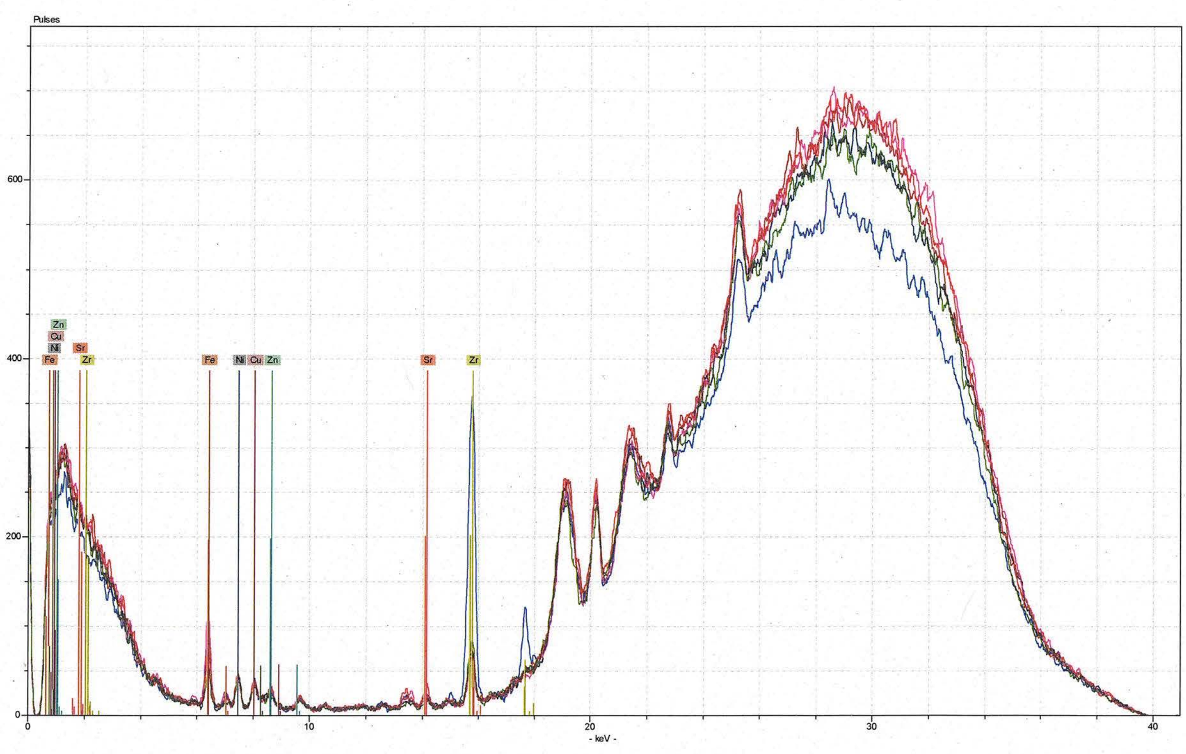

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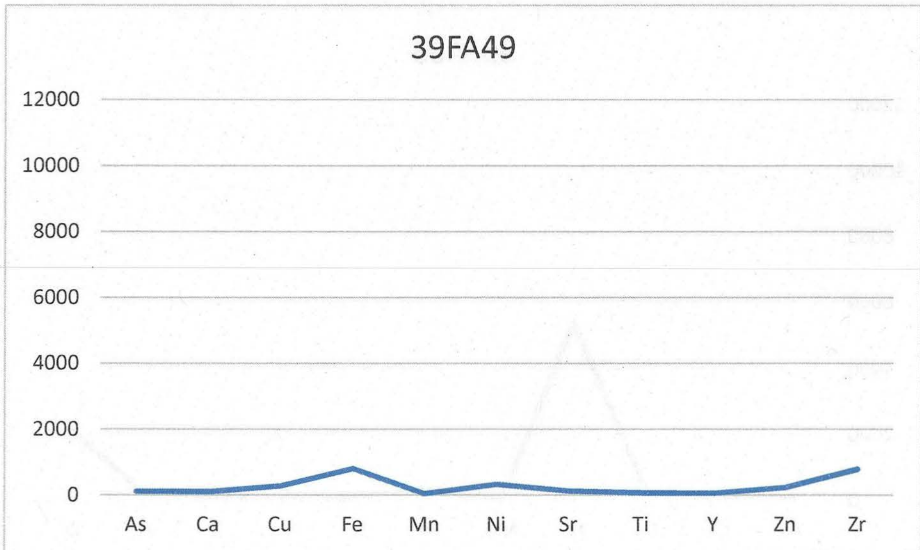

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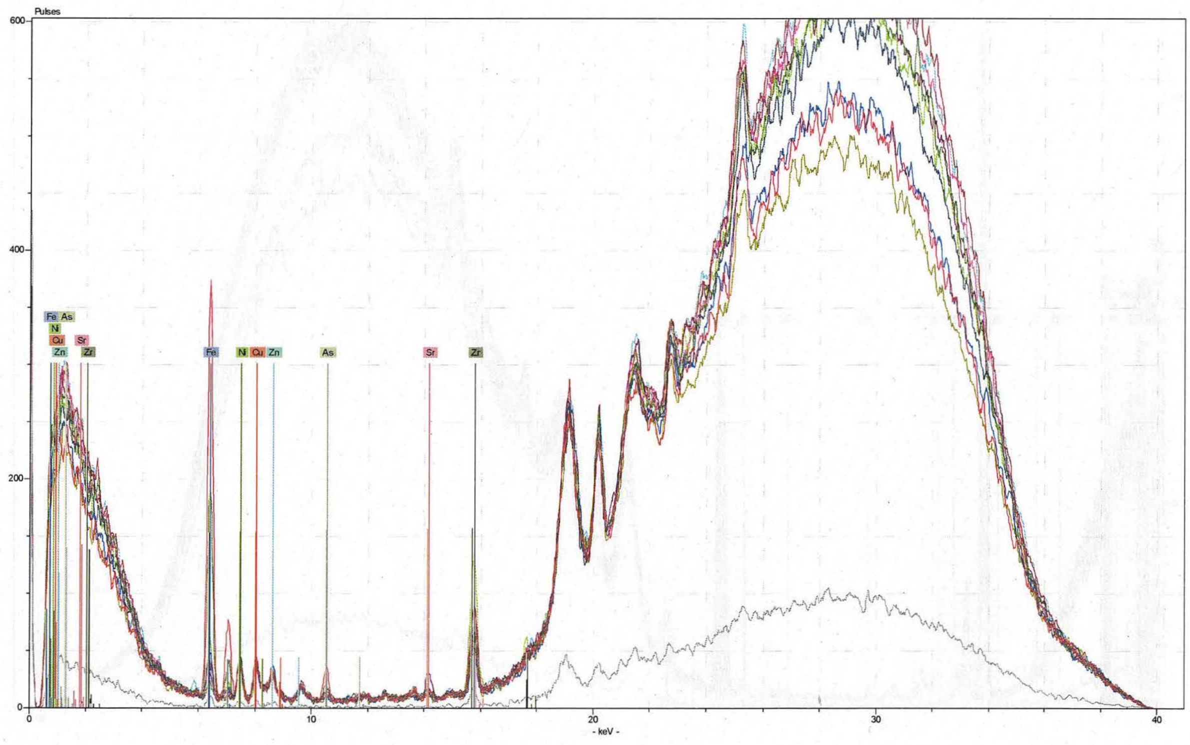

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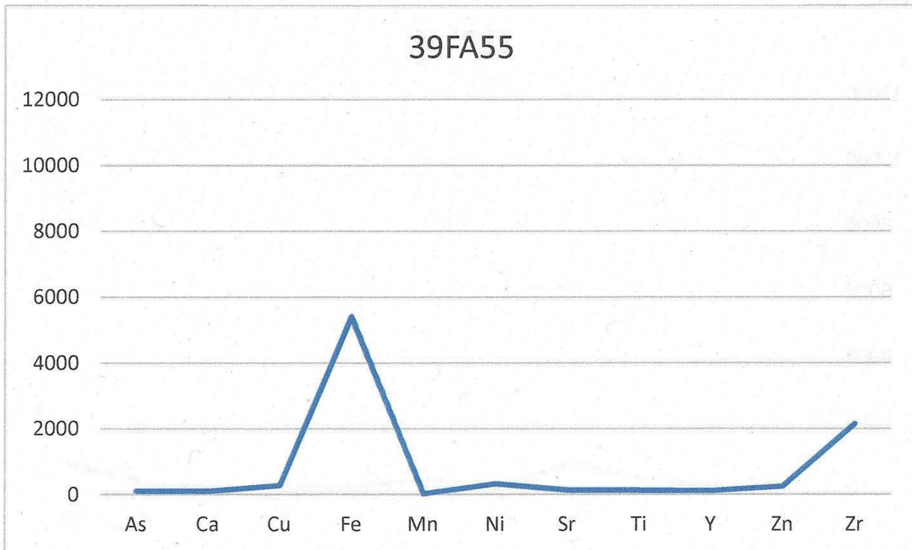

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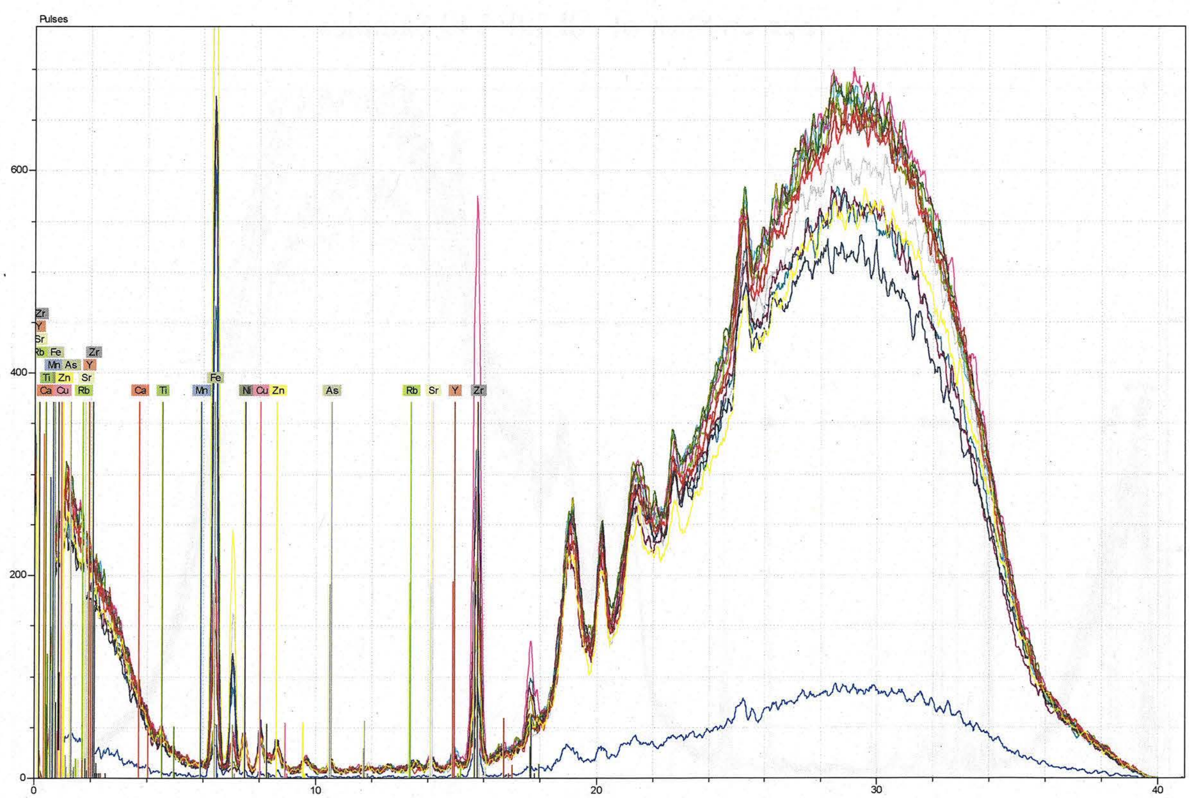

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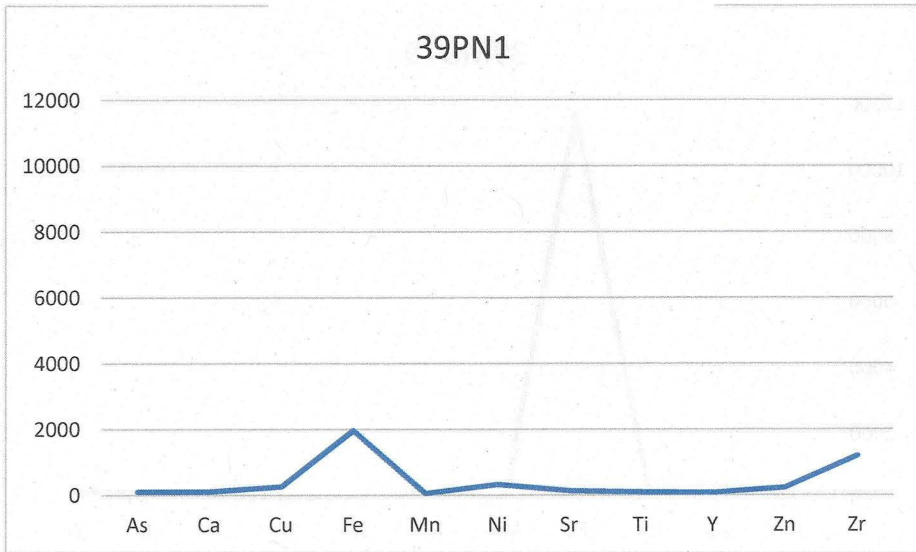

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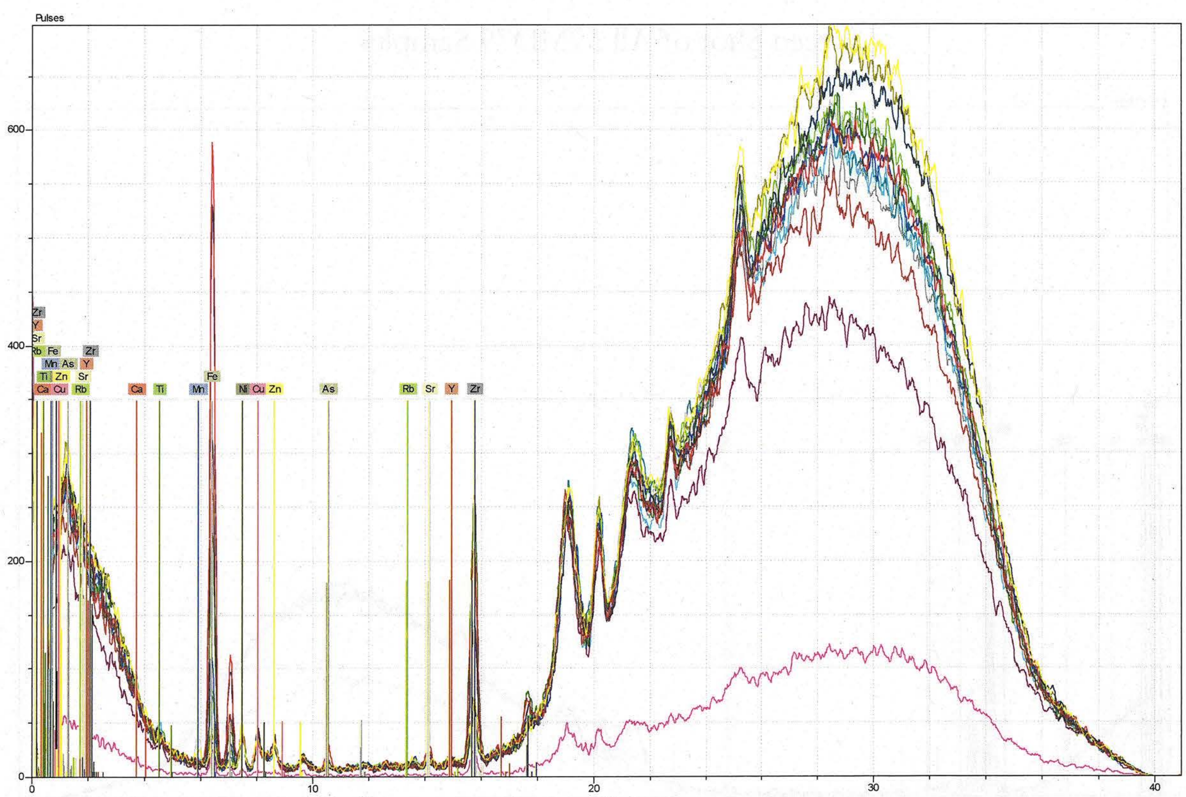

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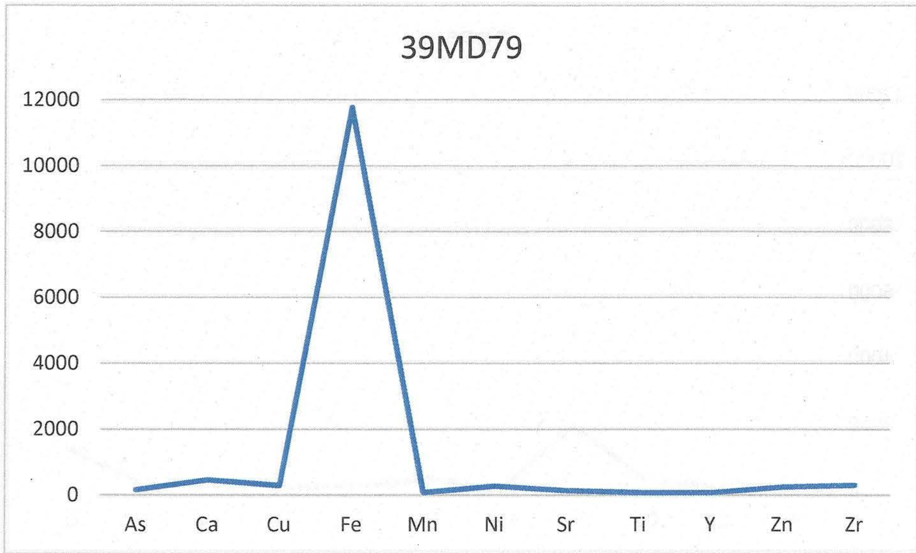

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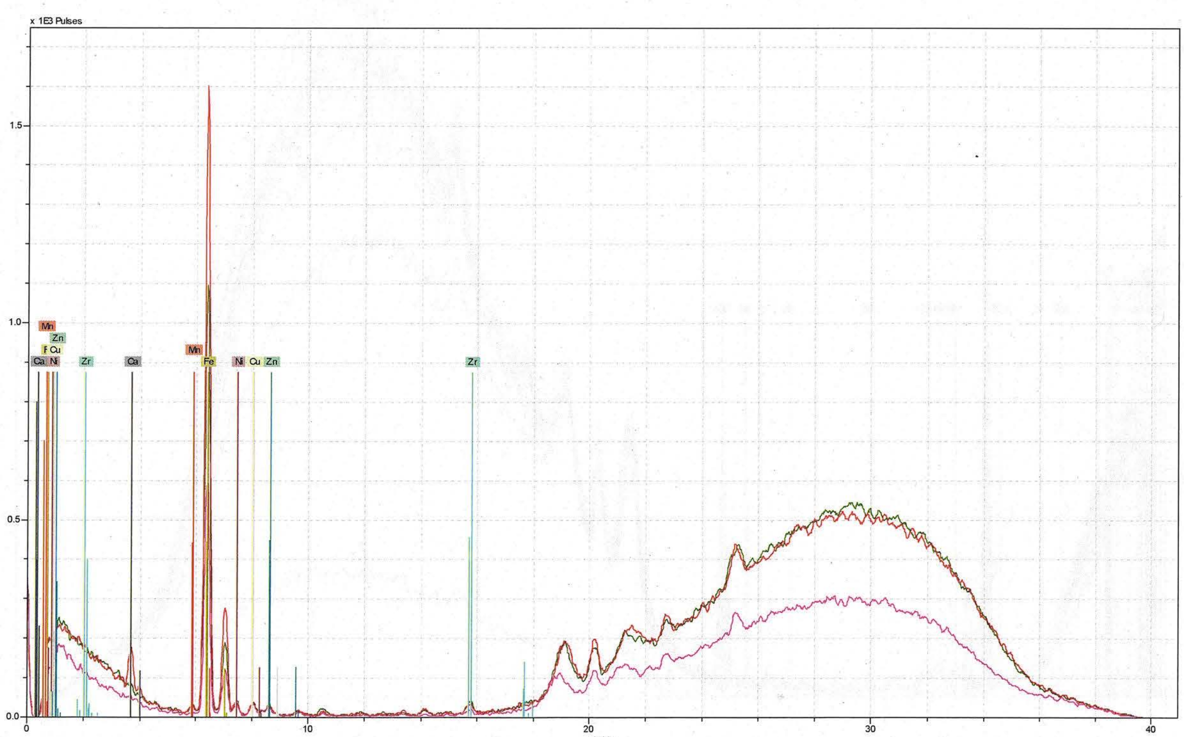

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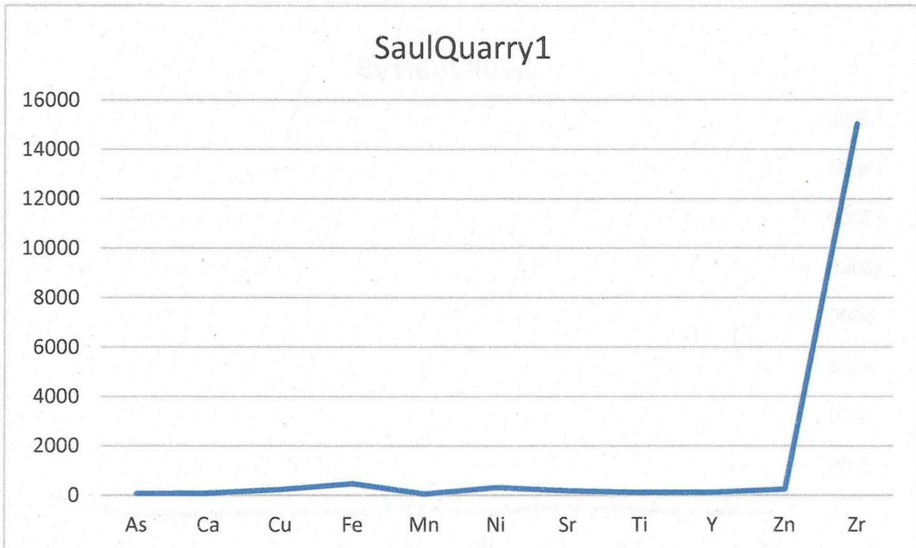
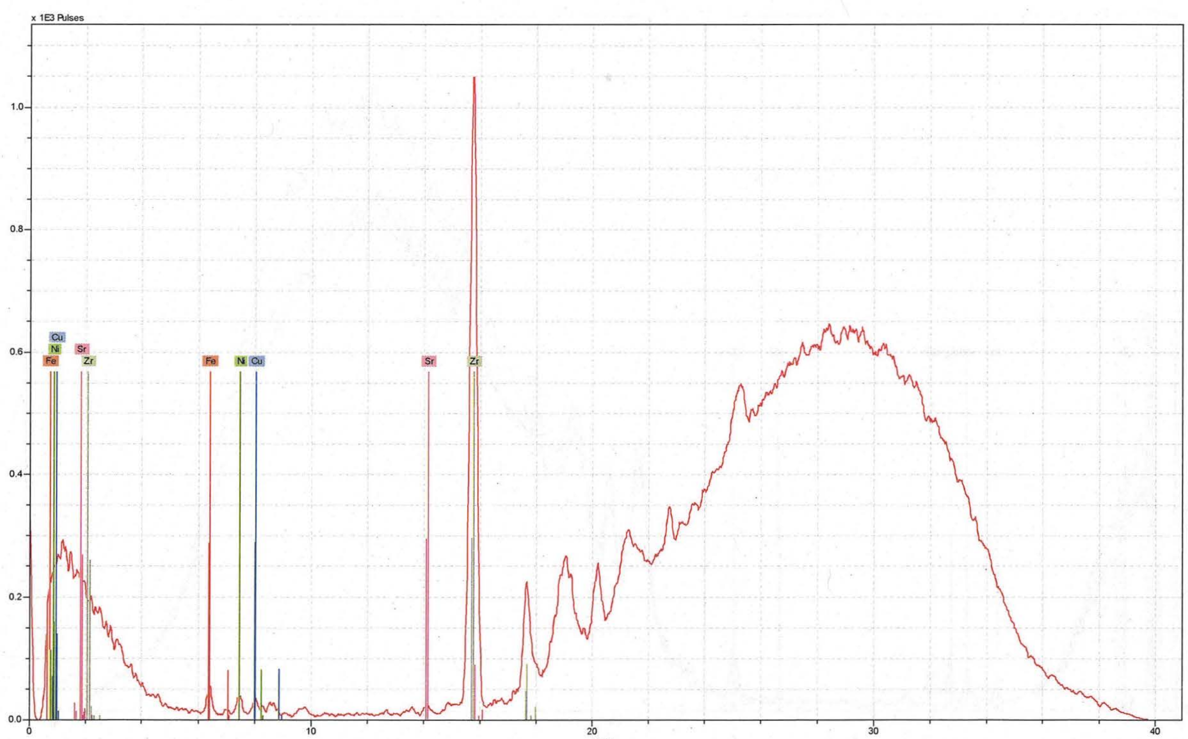


Screen Shot for the Saul Quarry #1 Sample



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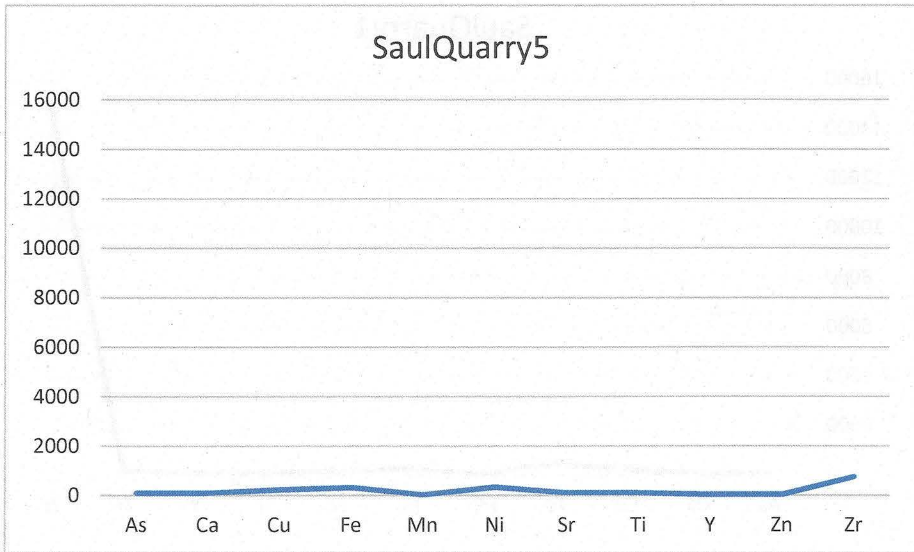

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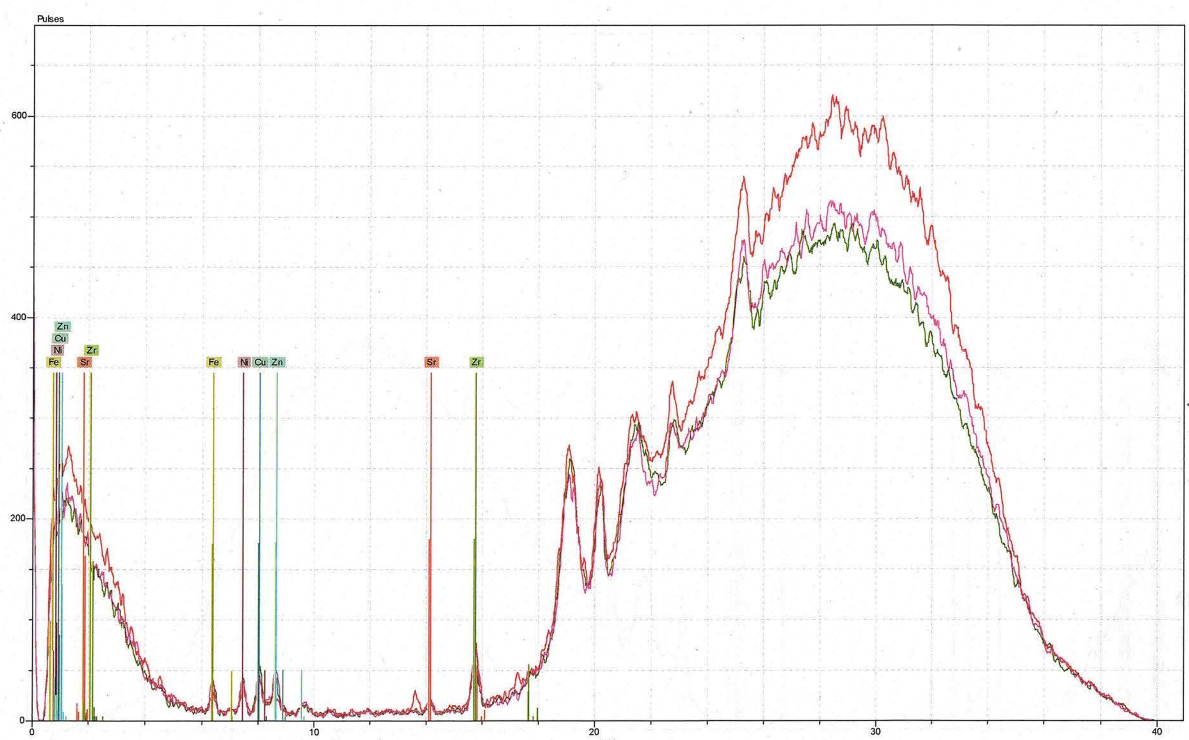
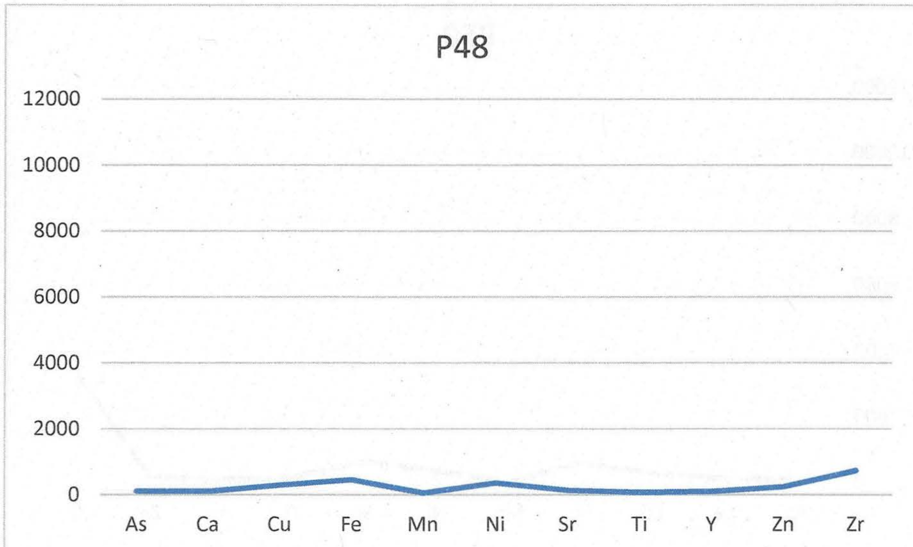
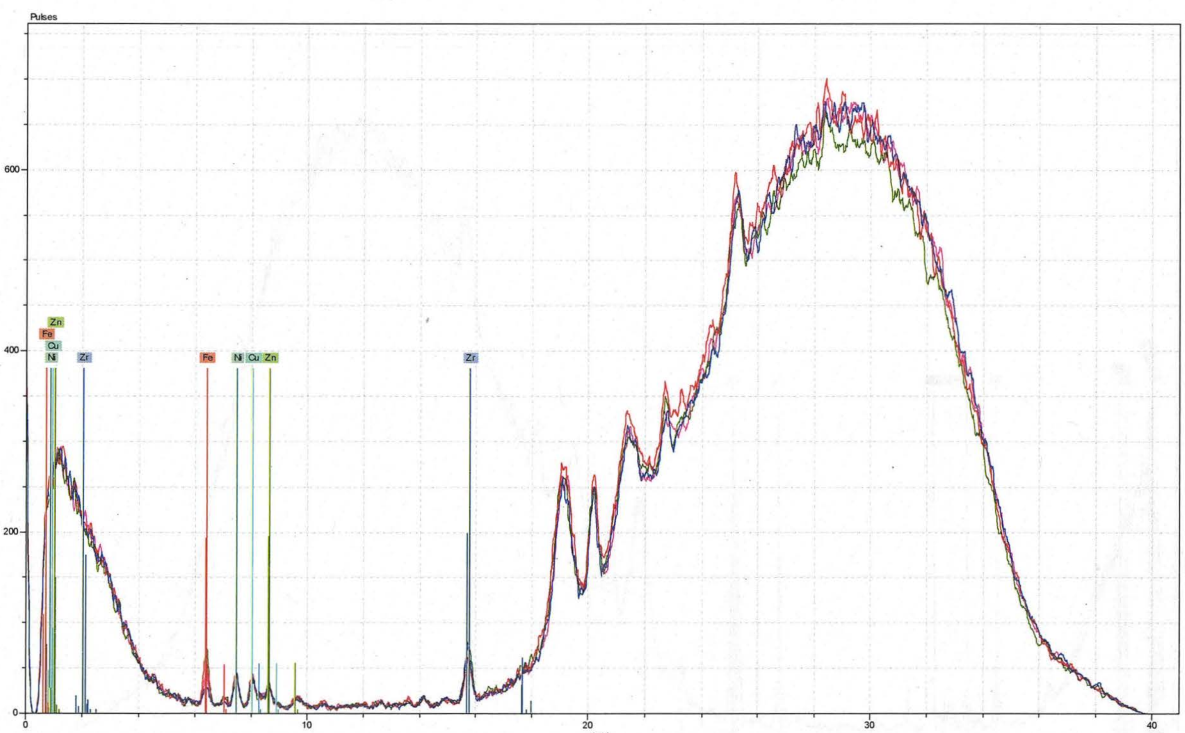


XRF signature for Ray Long Site Projectile Point P48



Screen Shot of All XRF Runs for Ray Long Site Projectile Point P48



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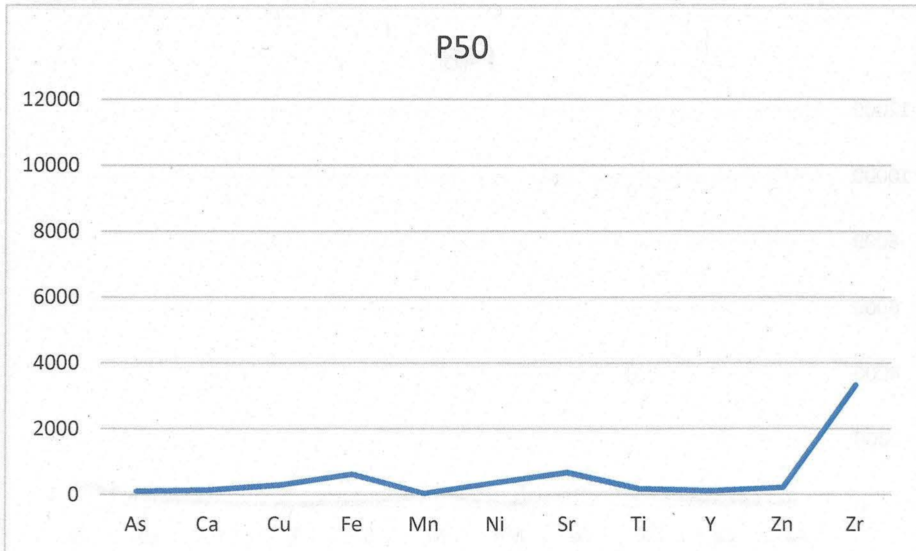

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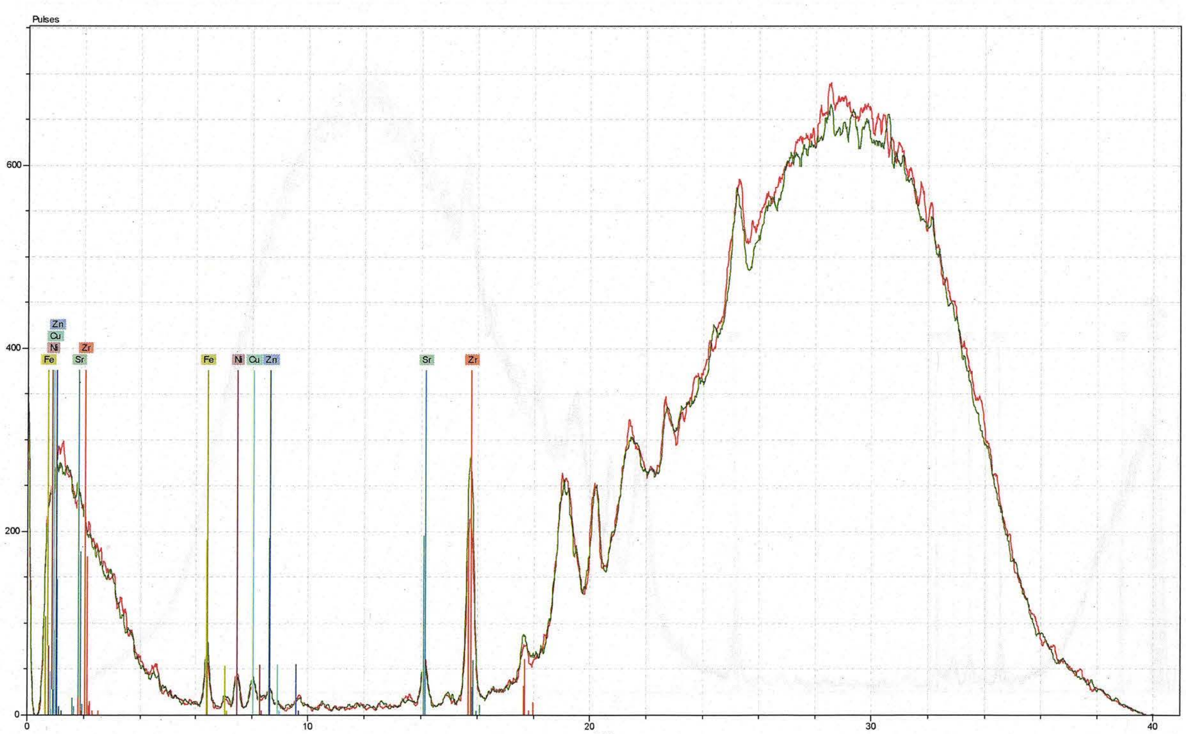
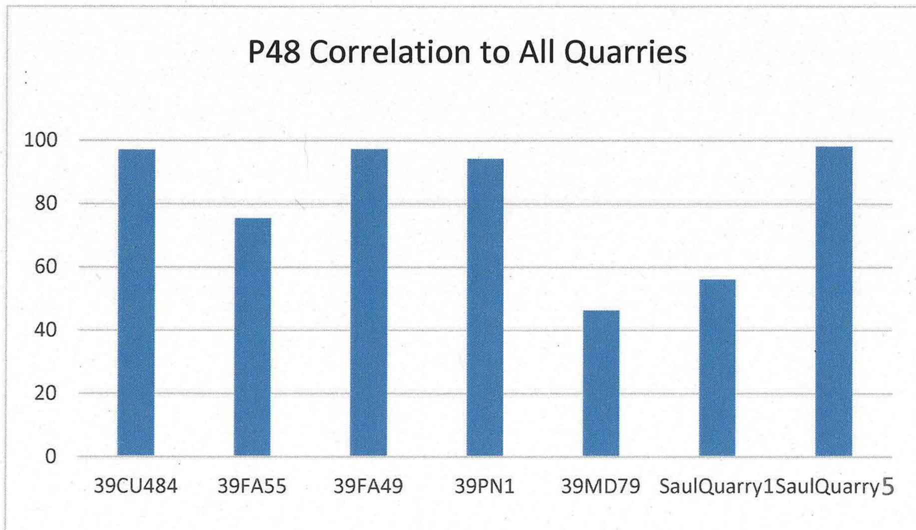
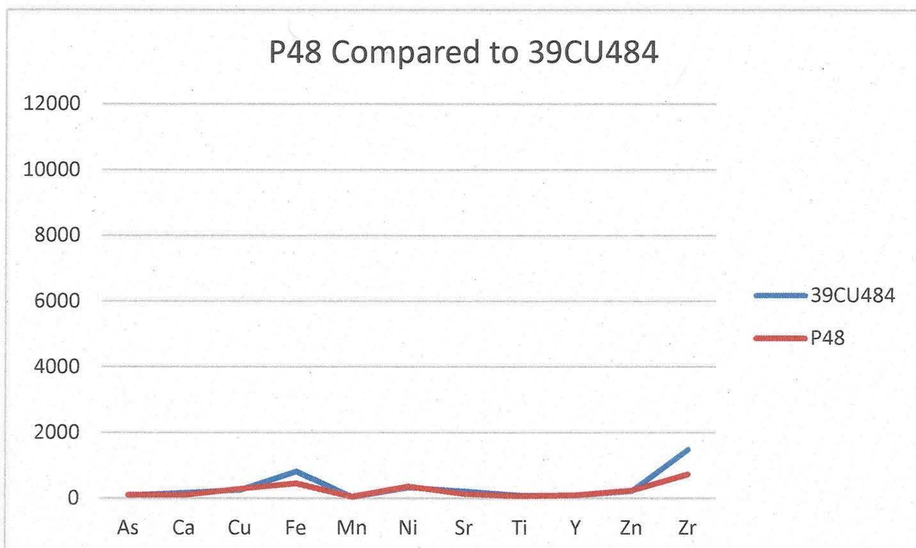
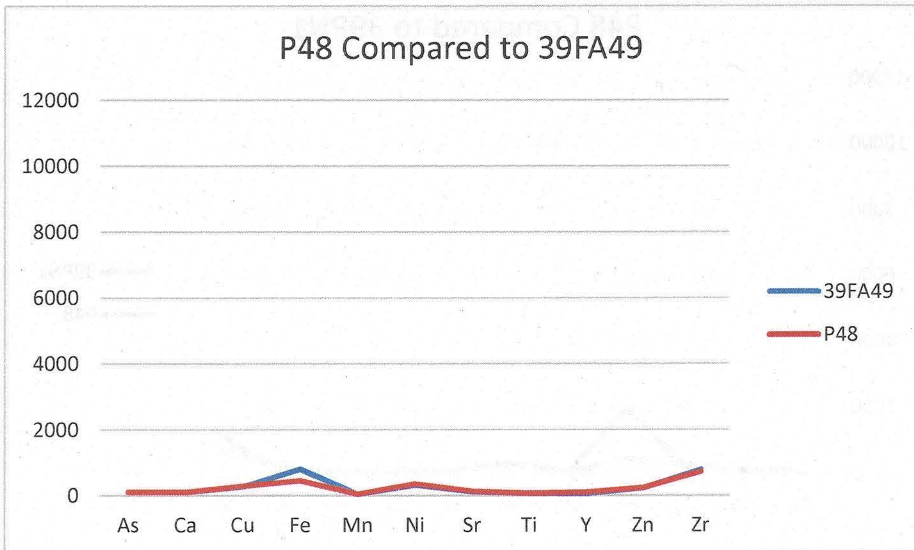


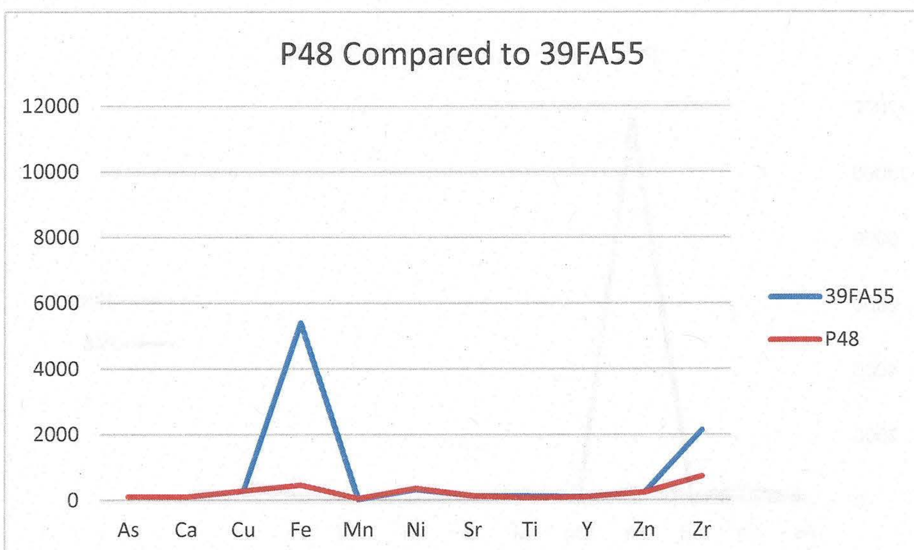
APPENDIX B
CORRELATION GRAPHS AND
PROJECTILE POINT COMPARISONS TO QUARRIES

DATA CAPTURED FOR RAY LONG SITE PROJECTILE POINT P48






P48 Compared to 39FA49
12000
10000
8000
6000
4000
2000
0
As
Ca
Cu
Fe
Mn
Ni
Sr
Ti
Y
Zn
Zr
39FA49
P48


P48 Compared to 39FA55
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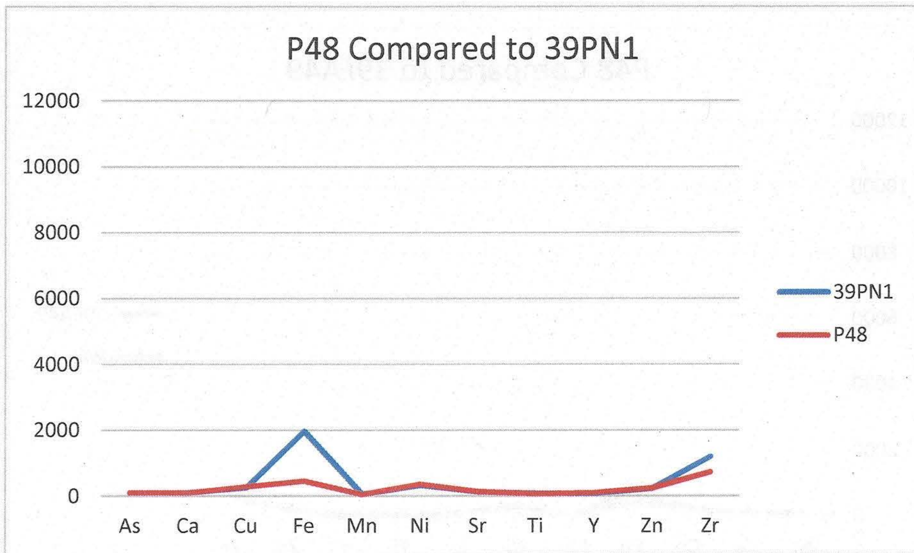
10000
8000
6000
4000
2000
0
As
Ca
Cu
Fe
Mn
Ni
Sr
Ti
Y
Zn
Zr
39FA55
P48


P48 Compared to 39PN1
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As
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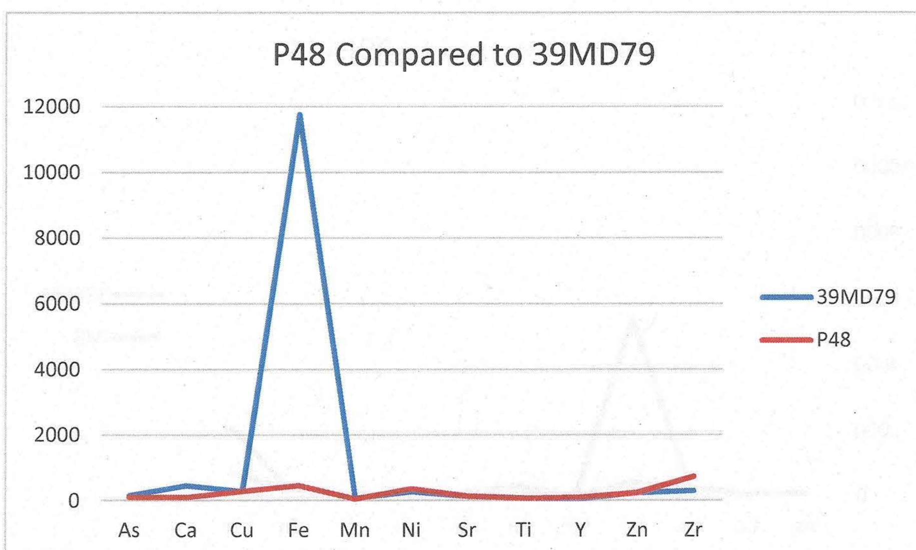
Mn
Ni
Sr
Ti
Y
Zn
Zr
39PN1
P48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6000
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2000
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As
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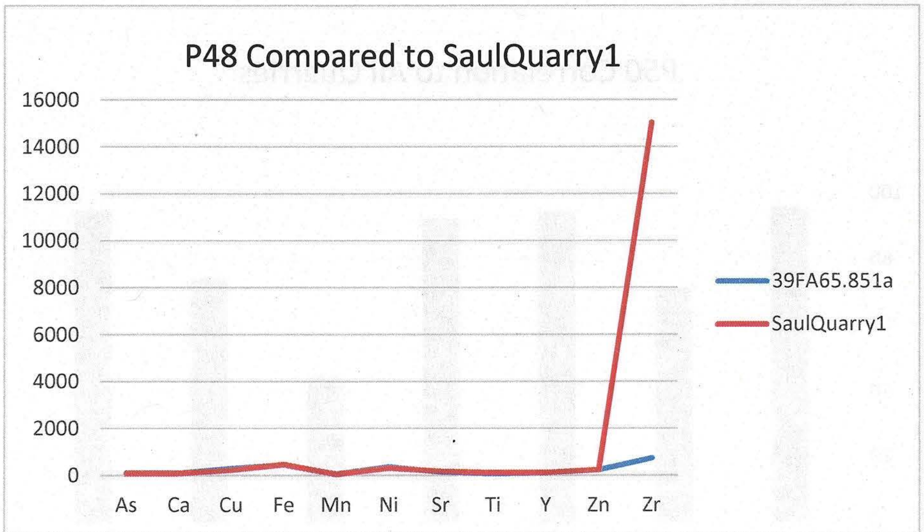
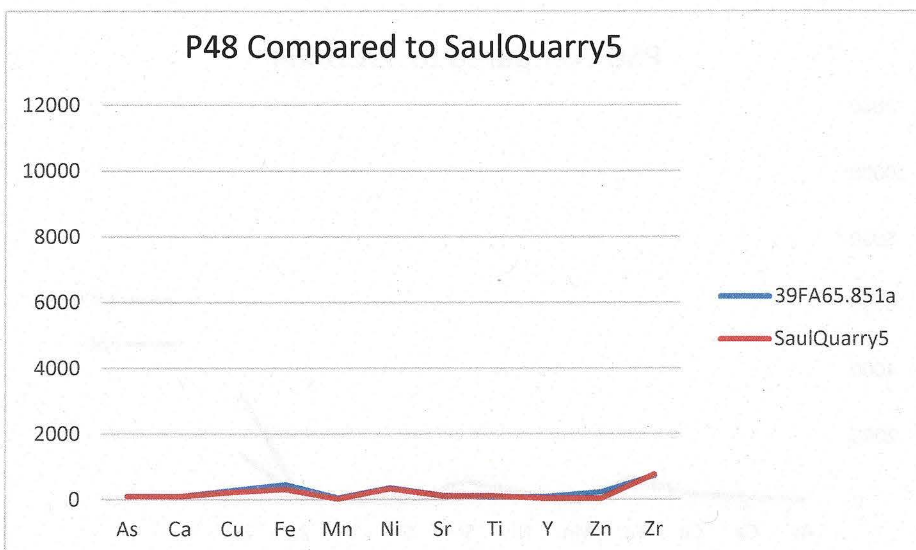
Cu
Fe
Mn
Ni
Sr
Ti
Y
Zn
Zr
39MD79
P48


P48 Compared to SaulQuarry1
16000
14000
12000
10000
8000
6000
4000
2000
0
As
Ca
Cu
Fe
Mn
Ni
Sr
Ti
Y
Zn
Zr
39FA65.851a
SaulQuarry1


P48 Compared to SaulQuarry5
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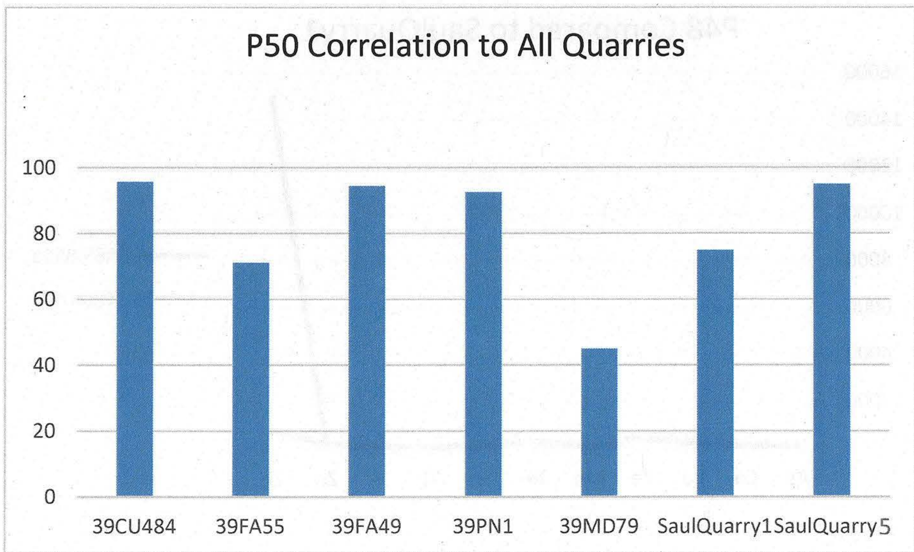
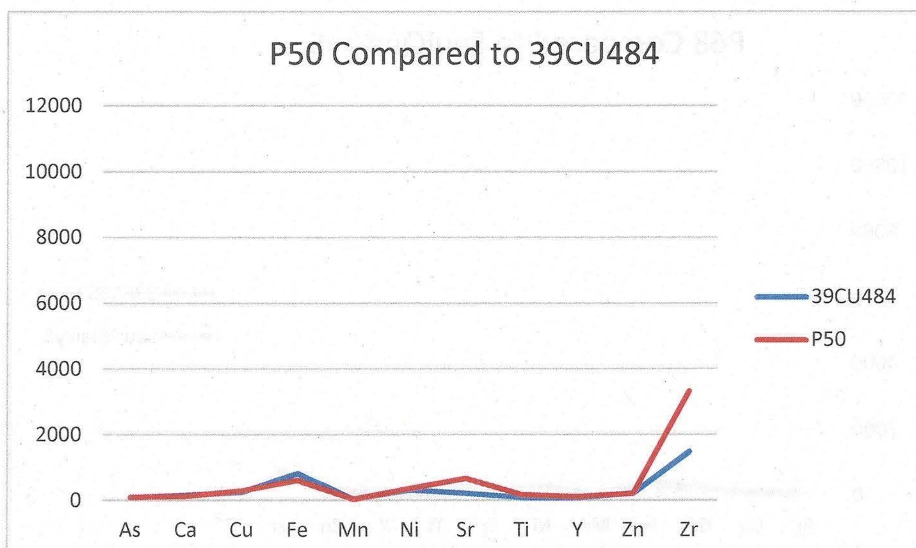
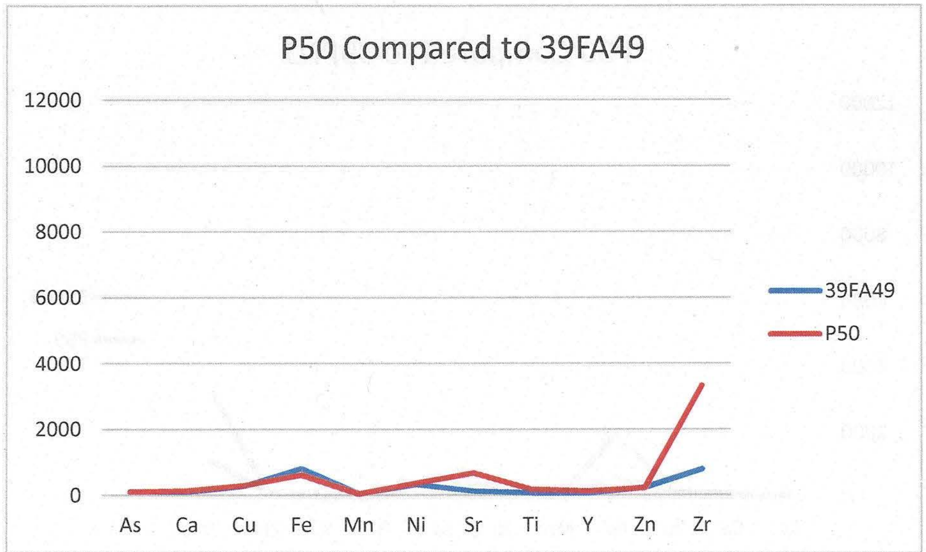
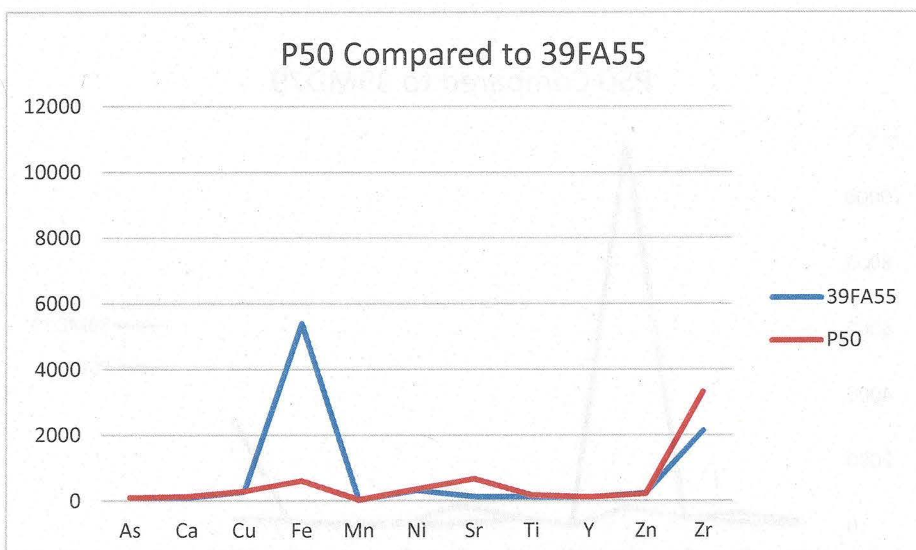
10000
8000
6000
4000
2000
0
As
Ca
Cu
Fe
Mn
Ni
Sr
Ti
Y
Zn
Zr
39FA65.851a
SaulQuarry5

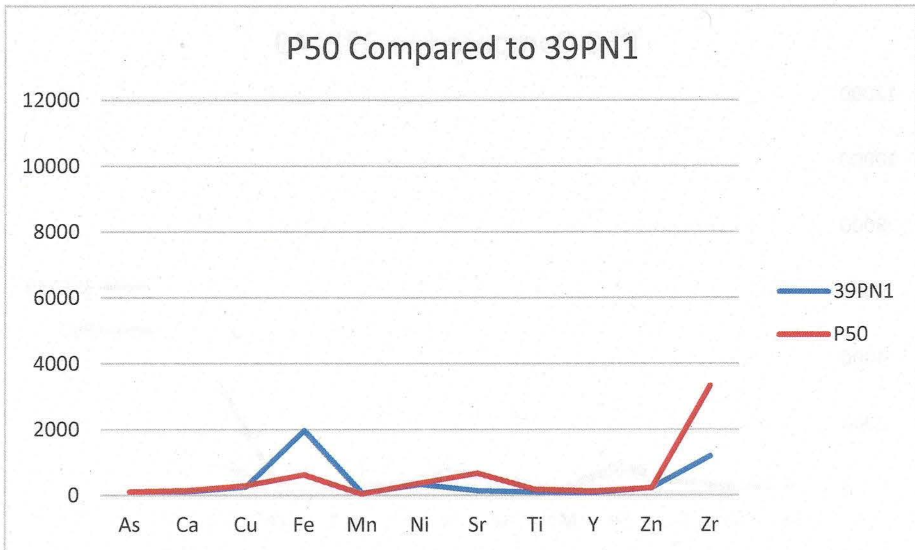
DATA CAPTURED FOR RAY LONG SITE PROJECTILE POINT P50

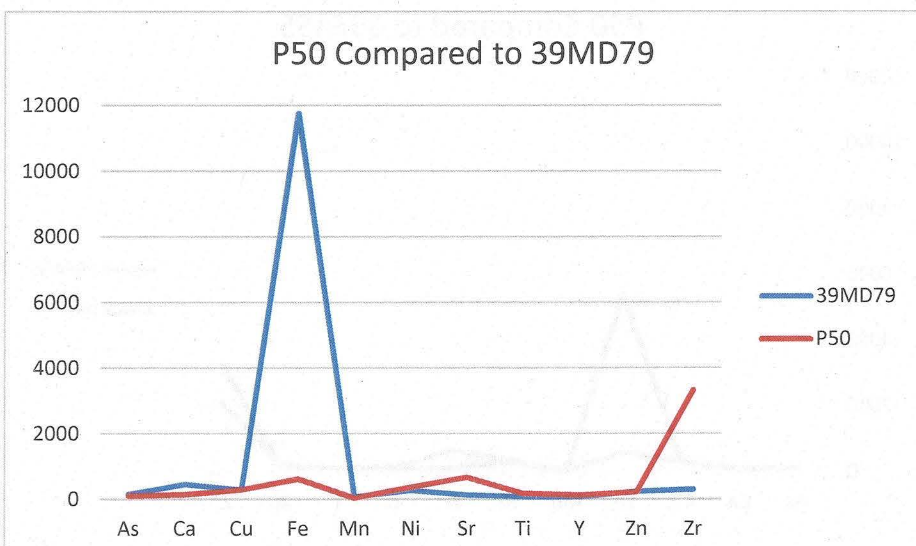


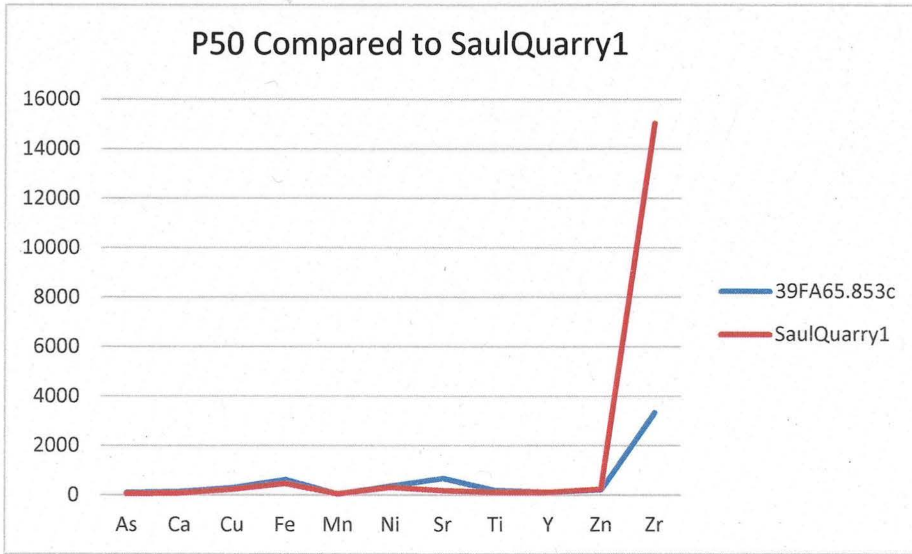


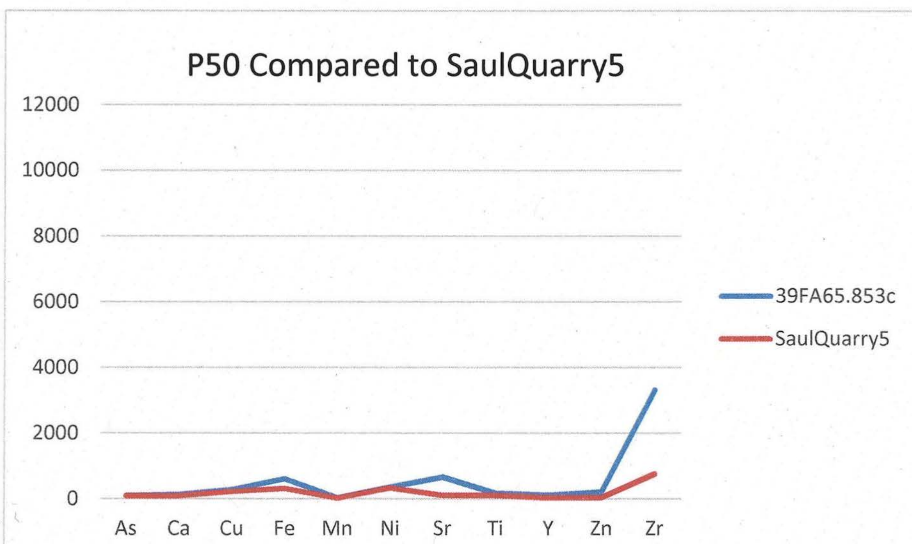

P50 Compared to 39FA49
12000
10000
8000
6000
4000
2000
0
As
Ca
Cu
Fe
Mn
Ni
Sr
Ti
Y
Zn
Zr
39FA49
P50


P50 Compared to 39FA55
12000
10000
8000
6000
4000
2000
0
As
Ca
Cu
Fe
Mn
Ni
Sr
Ti
Y
Zn
Zr
39FA55
P50


P50 Compared to 39PN1
12000
10000
8000
6000
4000
2000
0
As
Ca
Cu
Fe
Mn
Ni
Sr
Ti
Y
Zn
Zr
39PN1
P50


P50 Compared to 39MD79
12000
10000
8000
6000
4000
2000
0
As
Ca
Cu
Fe
Mn
Ni
Sr
Ti
Y
Zn
Zr
39MD79
P50


P50 Compared to SaulQuarry1
16000
14000
12000
10000
8000
6000
4000
2000
0
As
Ca
Cu
Fe
Mn
Ni
Sr
Ti
Y
Zn
Zr
39FA65.853c
SaulQuarry1


P50 Compared to SaulQuarry5
12000
10000
8000
6000
4000
2000
0
As
Ca
Cu
Fe
Mn
Ni
Sr
Ti
Y
Zn
Zr
39FA65.853c
SaulQuarry5