A Technical Study of the Rosebud Winter Count

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Plains Indian drawings and historical records produced in the nineteenth and early twentieth centuries made progressively greater use of nontraditional drawing materials such as commercial colored pencils, crayons, ink and watercolors. Similarly, cloth and paper begin to supplant traditional hide supports during this period. These non-traditional materials rarely have been studied in this context, yet their dates of manufacture and subsequent availability through traders and missionaries, or distribution by the Bureau of Indian Affairs, has the potential to inform about the creation date of a drawing or historical record. An analysis of the materials and methods used to produce the Rosebud winter count, a Lakota pictographic calendar, is described. Results indicate that the 136 motifs on the Rosebud winter count were produced, likely in sequence, by two different hands, followed by general outlining and finally, motif numbering. The materials used in the winter count were for the most part unavailable before the nineteenth century. Colored pencil containing the pigment Prussian blue was found to form an integral part of the winter count, thus allowing the date of manufacture to be placed most likely after 1883.

Keywords: Winter count, Lakota, Rosebud, drawing materials

Artists' materials utilized by Indians of the American Plains changed radically with the introduction of trading posts throughout the central and western United States in the 1800s. Traditional materials included mineral-based colors on hide supports (Ewers 1939:3; Moffat et al. 1997). In the nineteenth century non-traditional supports, such as cloth and paper, and non-traditional media, such as commercial pigments, pencil, colored pencil, watercolors and ink began to be used to produce drawings and historical records. While it is difficult to determine exactly when these materials may have been introduced to a particular area, for those materials with known inception dates it may at least be possible to provide a *terminus post quem*.

Unfortunately, traders and ethnographers who recorded colorants used for paints by Plains' tribes in the early nineteenth century either were not specific or not accurate in their accounts (see for example, the journals of Henry and Thompson recounting travels among the Piegan from 1799–1814 [Coues 1897:731] and of Harmon [1903:226, 328–329] in 1818 near Athabasca Lake in Saskatchewan). One documented introduction of non-traditional materials occurred in 1833–1834, when artist Carl Bodmer gave members of the Mandan tribe watercolors and paper so they could create pictures for him and for Prince Maximilian (Ewers 1957:5). Towards the end of the century, in notes accompanying Dakota Sioux pen and ink drawings collected in 1891,

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Ritzenthaler (1961:3, 7) describes a pallet of clays and earths as traditional colors, but affirms that the drawings in question were done with colored inks and crayons "...in variance with the old paintings". Although historical accounts are invaluable, they may contain misleading or contradictory information, and conclusions regarding the authorship or dating of works benefit from technical analysis to confirm the use of specific materials.

In the present study, a Lakota winter count, a pictographic calendar, was examined in order to identify the materials and techniques used in its creation, from which the dates of different campaigns of media application may be inferred. The ability to add dating information and to distinguish between different hands is particularly important for winter counts, since these documents are known to have proliferated in the 1870s (Mallery 1893), were traditionally held by a tribal historian for annual updating (Howard 1960), and are documented as having been copied by non-Indian agents for use in scholarly studies (Mallery 1886). As Burke (2007:3) points out, winter counts produced between the 1870s and 1930s are not necessarily annually updated records, and include numerous copies made by Indians and non-Indians from original calendars. Despite their ambiguous histories, winter counts are important representations of history originally recorded by tribal members.

Previous scholarship on winter counts or related ledger-style drawings generally have not included detailed descriptions of the materials used, although a few authors have traced pigments in traders' inventories in the Plains during the seventeenth through nineteenth centuries, and have, for example, shown the high value placed on the trade pigment vermilion (Hanson 1971, 1981; Phillips 1995). Mallery (1886:52) notes trade pigments in use by 1880, including vermilion, red lead, lead chromate, Prussian blue, chrome green, ivory black, lamp black, zinc oxide white, and Chinese white (another form of zinc oxide). Petersen (1971:25) notes that Indians imprisoned in Fort Marion, Florida in 1875 were given sketch books, pencils, and colored pencils of unspecified colors "through gift, trade, or capture." An exceptional description of materials is included in the publication of an Oglala Sioux record produced between 1890 and 1913 (Blish 1967:73–77). In another study, detailed analysis of 258 paint samples from 95 northern Plains objects with known collection dates found mineral-based earth colors on objects attributed to before 1850, and trade pigments on objects attributed to between 1850 and 1930 (Moffat et al. 1997).

ROSEBUD WINTER COUNT COLLECTION HISTORY

Pictorial and support materials on most winter counts have generally not been analyzed scientifically; rather authors have relied on visual identification of familiar commercial materials (Howard 1979; Thornton 2007:62–63). The current study is designed to provide detailed information about materials and methods used in the production of the Rosebud (or Anderson) winter count, a pictographic calendar in the collection of the National Anthropological Archive in Washington, D.C. (2001.10) (Figure 1). As described below, the 136 pictographs were applied to muslin using graphite and colored pencil, along with multiple colored media which were applied wet. Since the authorship and date of the Rosebud winter count, as well as its relationship to other winter counts, is currently approximate (Thornton 2002, 2007), data concerning its materials and media will provide information that may be used for comparative purposes and assist in clarifying chronology.

The Rosebud winter count was discovered in 1998 by Professor Timothy Tackett, who found it stored in a trunk that belonged to his great-aunt Myrtle Miller Anderson (Thornton 2002). Myrtle Miller Anderson's husband was John Anderson, a photographer who lived and worked among the Lakota at the Rosebud reservation on and off from 1883–1922, during which time he collected and was compensated with Lakota cultural items (Hamilton 1971). Despite Professor Tackett's longstanding interest in the Lakota items collected by his relatives, he was unfamiliar with the winter count until its discovery in 1998 (Timothy Tackett, personal communication 2007). In 2000, the Rosebud winter count was given without supporting documentation to the National Anthropological Archives, Smithsonian Institution, where it is now part of the permanent collection along with

Figure 1. Rosebud winter count (2001.10) National Anthropological Archives, Smithsonian Institution. Dimensions are 88.3 cm x 175.2 cm (34¾ x 69 in).

10 other Lakota counts (Burke 2000). Thornton (2007:59–62) has described the collection history of this count in detail.

The Lakota or Teton Sioux resided on reservations west of the Missouri River during the period from 1870 to 1930, the time in which it is believed most winter counts were produced (Burke 2007:3). The primary evidence linking Anderson's winter count to the Rosebud reservation is provided by the pictographic similarities evident on works photographed by Anderson at Rosebud (Thornton 2007:59, 65–69). As discussed below, the Rosebud winter count is attributed to the Brulé band of the Lakota Sioux based on similarities to motifs on other counts of known Brulé origin (Thornton 2007:63–67).

WINTER COUNT MATERIALS AND METHODS

Winter counts are believed to have been drawn first on native tanned skins, and then on fabric; later counts have been produced on paper and have included only text and no pictographs. Some winter counts have written inscriptions near each motif indicating the year and providing descriptive text (Praus 1962). Because of a Plains tradition of burying important documents with the deceased keeper, no original winter counts on skin are preserved. The Lone Dog winter count, which is known from a copy produced on cloth in 1877, was recreated for Mallery on a buffalo hide to suggest how it might have looked in an earlier form (Mallery 1877).

Each motif on a winter count represents a noteworthy or unusual natural, political, or social event in the life of the community (Risch 2000). Selecting an event to be depicted for the year was the responsibility of important members of the tribal community, one of whom was chosen to be the keeper of the calendar. Winter counts typically contain motifs important to the band, so that the motif chosen to represent a year by one band might not be significant to, or may be interpreted differently from, a neighboring band. Traditionally, the keeper of the count added pictographs, interpreted the count to the community, and assured its safekeeping. The addition of pictographs to a winter count could have occurred annually, or a group of images might have been added all at once. When the guardianship of a winter count changed, some motifs may have been copied and new ones added. As previously noted, entire winter counts were also copied. An account of the materials and methods used in the production of a winter count therefore may assist in clarifying whether or not pictographs are contemporaneous.

ROSEBUD WINTER COUNT, PREVIOUS SCHOLARSHIP

The 136 images on the Rosebud winter count represent the years 1752–1753 to 1886–1887 (Thornton 2007:63). An analysis of the iconography of the Rosebud winter count by Plains historian Michael Cowdrey (1999) suggests it most closely follows the counts of Battiste Goode and his son, High Hawk, of the Brulé band of the Lakota for both the early years of 1752–1834 and the years 1835–1871. The years represented as 1871–1872 in particular are noted by Cowdrey as reflecting the work of High Hawk, who was known to reside at the Rosebud Reservation and was a contemporary of Anderson. Cowdrey's (1999) analysis suggests that there are multiple hands represented on the Rosebud winter count, distinguished by both style and media changes; he assigns motifs 1–122 to one keeper working in 1871, and subsequent motifs from 1871 to 1889 (*sic* actually 1887) to possible different hands. This observation suggests the count was copied from an earlier version and maintained by the same keeper until 1871, with subsequent motifs added by later keeper(s).

Thornton (2007:62) has examined the numbering applied to the Rosebud winter count, noting that the motif labeled as number one was originally labeled as twenty-three, leading to changes in successive numbering. It is also noteworthy that the person applying the numbers may have used multiple numbers to annotate a single event, for example in cases where more than one figure constitutes a pictograph (Thornton 2007:62). The current study uses the revised numbering system to designate pictographs in the materials discussion.

EXAMINATION METHODOLOGY

A variety of analytical techniques were used to examine the nature of the textile and colorants in the Rosebud winter count. A strong emphasis was placed on non-invasive testing, that is, the recovery of information without removing material from the winter count. A complete visual examination was carried out with the aid of a stereomicroscope and an ultraviolet light source (Sirchie Fingerprint Labs S/N 34826), which often can produce characteristic fluorescence from materials that can aid in distinguishing organic media.

Elemental composition of the colorants was measured by non-invasive X-ray fluorescence (XRF) spectroscopy, using a portable Innov-X Systems Alpha Series XT-440 XRF spectrometer[1]. The elemental composition of common pigments is well known, and therefore, based on the elements detected by XRF, the nature of the pigment often may be inferred. However, many pigments are composed of elements which are not detectable by the XRF spectrometer used in this study[2] or may not have a unique elemental signature. In these cases, XRF analysis alone is insufficient to conclusively determine which specimens are present, and additional analysis using a molecularly specific technique is required. Therefore, following the initial visual and XRF study, samples of each of the suspected colorants were removed for study by Raman microscopy.

Samples of pigmented fiber, each approximately 30 microns in length, were removed from motifs 17, 106, 131, 133, and 136 and analyzed using a Renishaw InVia Raman micro-spectrometer[3]. In Raman spectroscopy, identification is made by comparing the resulting spectrum to one from a known sample of the material or from a spectral library. If the compound cannot be identified by comparison to a reference source, certain characteristics of the molecular structure can be deduced from the position of the individual bands within the Raman spectrum.

RESULTS

The results of the individual analyses are summarized in Table 1 and discussed below. As previously noted, each motif on the Rosebud winter count is numbered, and each sample or test area is referred to by motif number and color.

Textile Support

The Rosebud winter count is on a fine plain weave fabric (with single fibers at right angles to each other) measuring 88.3 cm x 175.2 cm (34¾ x 69 in). Polarized light microscopy confirmed the fiber is cotton (Figure 2). There are two selvages: the warp fibers run in the short (vertical) direction producing selvages at the top and bottom edges, while the weft fibers run in the long (horizontal) direction. The fibers are all single-ply, i.e. consist of a single thread element, and have a Z-twist. There is minor variation in the fiber thickness: the weft fibers measure between 0.3 and 0.5 mm, and the warp fibers measure between 0.3 and 0.5 mm. The textile is not seamed. The selvages at the top and bottom edges of the textile are woven with paired rather than single wefts. Seventeen pairs of wefts constitute the selvage, which measures 6.4 mm (1/4 in) near motif number 103. At the bottom selvage, 6.4–8.4 mm (1/4–1/3 in) of the selvage is consistently and uniformly folded under, possibly as prepared at manufacture. The width of the fabric from selvage to selvage is very uniform at 88.3 cm (34¾ in) where folded. The length of the Rosebud winter count, which is cut at each end, is also quite uniform. The fabric is tightly woven, consistent with being produced on a power loom; the weave count is also uniform and measures 72 wefts per inch and 80 warps per inch, as counted with a linen pick between motifs number 125 and 126 and motifs 106 and 107. This is considered a fine weave, according to the American Cotton Handbook of 1941 (Merrill et al. 1941:497).

The fabric was not in pristine condition when the drawings were applied, as is evident from staining and deposits that lie underneath the first layers of pictographic application. This is illustrated, for example, by drips of a red colorant underneath motif number 116 and above motif number 69. Further damage also occurred after pictographs were drawn, as evidenced by broad areas of yellow to orange color staining which appear to relate to migration of the colorants. This is supported by XRF spectroscopic results, which indicate that many of the stains contain the same elements found in the adjacent colorants. In addition, the visible fluorescence of some stains under an ultraviolet light source is similar to the nearby colorant.

Other staining or damage may have occurred

Table 1: Summary of Analytical Results Obtained for the Pigments/Inks Identified on the Rosebud Winter Count..

Motif	Colors examined/ sampled	Vermilion	Chrome Yellow	Ultra-marine	Prussian Blue	Additional findings/ comments
1	Red	X				
2	Red	X				
62	Red	X				Zinc white plus other unidentified components also possibly present
90	Red	X				
121	Red	X				
133	Red (red and yellow particles)	R	R			
134	Red	X				Zinc white also possibly present
136	Red	X, R				
3	Yellow		X			Bright orange
25	Yellow		X			fluorescence
45	Yellow		X			under UV
49	Yellow		X			
70	Yellow		X			
131	Yellow		X, R			
17	Blue (with small particles of red)	R		R		XRF did not detect elements associated with
106	Blue				R	other blue pigments

Note: The letter indicates the method by which the result was obtained: X = XRF, R = Raman microscopy. Not every color on each motif was examined.

while the Rosebud winter count was in use or in storage. There is a transferred impression of a grosgrain ribbon along one end (Figure 3), indicating a close association with a ribbon element in storage, but the pattern does not correspond to the trunk in which it was found. The winter count shows no insect damage despite the presence of well adhered case webbings (Figure 4 case webbing) produced by a case making moth (*Tinea pellionella*) that incorporated bright red feather fragments and red frass in the case, suggesting that the Rosebud winter count was stored with a feathered artifact (Figure 5). The lack of insect damage on the Rosebud winter count is not surprising, since cotton is not part of the diet of case making moths.

Figure 2. Cotton fiber from motif 17 at approximately 100X magnification. Photo by Liz Werden.

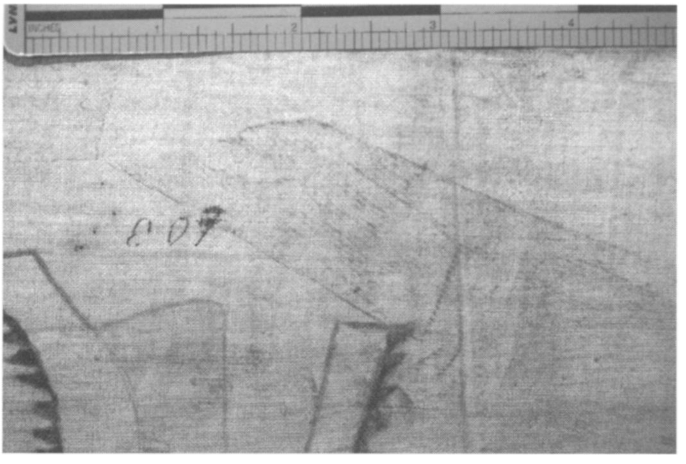

Figure 3. Transferred impression of grosgrain ribbon. Photo by Melvin Wachowiak.

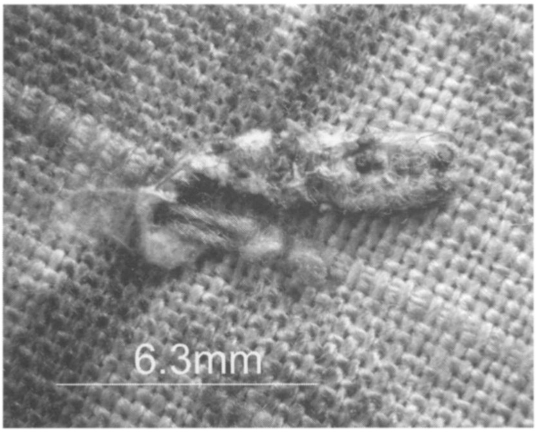

Figure 4. Case making moth case. Photo by Melvin Wachowiak.

Pictographs

Preliminary outlines of motifs on the Rosebud winter count were drawn with grey pencil and colored using a limited palette consisting of reds, yellows, blues, and black. The motifs were subsequently reinforced with black pencil, a brown ink or paint, and finally, a black ink was used to enumerate the motifs. These materials and the results of their analysis will be described in the order of their application on the winter count.

Grey pencil was the first medium applied (Figure 6, motif 117). It is non-penetrating and sits on the highpoints of the textile weave. Its hydrophobic behavior and fastness in water and organic solvents suggests that it contains a minimal amount of wax and no soluble dyes. Therefore, the pencil probably contains simple graphite[4] and is not, for example, a specialty pencil such as a type patented in 1877 which includes blue and purple water-soluble dyes (Dube 1998; US Patent Office 1877a).

Red, yellow, and blue colors were clearly applied after the pencil outlines were completed. While reds and yellows are used throughout the winter count, blues are more restricted, occurring in only 29 of the 136 motifs, with none occurring before motif 16. Visual examination of the colorants indicates the presence of two different reds, two different blues and one yellow.

Of the two red colorants apparent on the Rosebud winter count, one is orange-red in appearance, does not show evidence of fading, has been applied fairly dry, and is found throughout motifs 1–130. The second red, found primarily in motifs 131–136, is a paler orange-red in appearance, and is distinguished by its application as a wash, which has penetrated through the textile. This penetrating pale orange-red color is not restricted to motifs 131–136, but also appears on motifs 116 and 117, where its application preceded

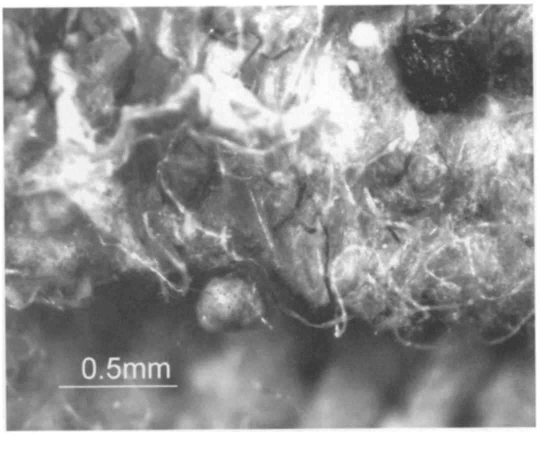

Figure 5. Detail of feather fragments in moth case. Photo by Melvin Wachowiak.

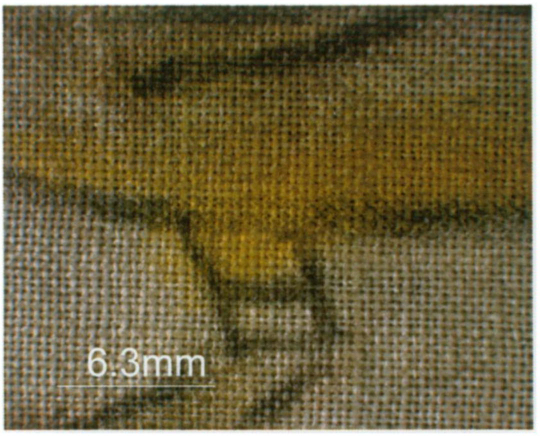

Figure 6. Motif 117. Pencil used below and on top of yellow colorant. Photo by Melvin Wachowiak.

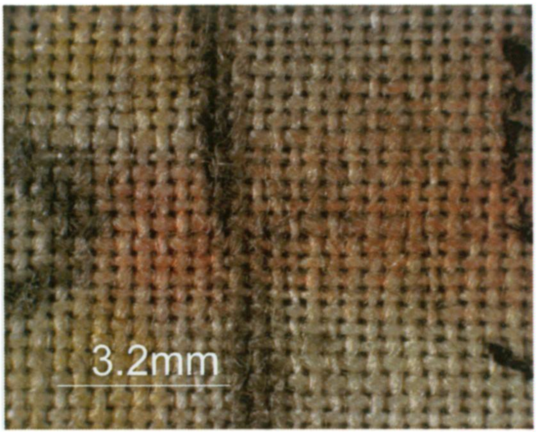

Figure 7. Motif 117. Red stain on muslin below applied colors. Photo by Melvin Wachowiak.

Figure 8. Motif 85. Solvent solubility test using acetone on the medium for the red colorant. Photo by Ellen Pearlstein.

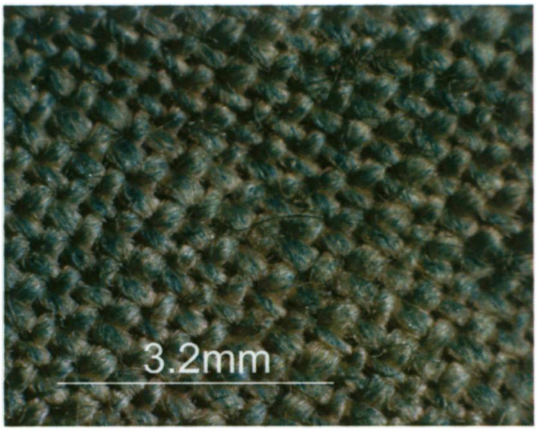

Figure 9. Motif 75. Prussian blue colorant on the high points of the textile. Photo by Melvin Wachowiak.

the yellow and blue colorants (Figure 7 [facing page]). This pale orange-red wash also shows signs of fading on its surface (compared to lower layers of the pigment visible under magnification), suggesting the presence of a fugitive organic dye.

All of the red areas tested in this study were identified as mercuric sulfide, available as the commercial pigment vermilion[5]. However, based on visual appearance, an organic red colorant, such as carmine or alizarin, is also likely present in those motifs in which the paler orange-red wash was observed. Unfortunately, the detection of these organic colorants necessitates the removal of unacceptably large amounts of material for analysis, so, for the moment, they will remain unidentified. The red colors throughout the Rosebud winter count are readily soluble in acetone, which suggests they were applied in a medium other than watercolor (Figure 8 [facing page], motif 85).

The yellow used throughout the Rosebud winter count is best described as a "school bus yellow." It is a non-penetrating color that nonetheless fully wets the support surface. The yellow fluoresces, or glows visibly purple, when viewed under a long wave ultraviolet source. XRF spectroscopic analysis of the yellow in motifs 3, 25, 45, 49, 70 and 131 revealed the presence of the elements lead and chromium, suggesting the colorant is likely chrome yellow (lead (II) chromate), a synthetic pigment first produced in the early nineteenth century[6]. The yellow in motifs 131–136 has a different visual appearance than in the earlier motifs, and only trace amounts of lead were detectable by XRF spectroscopy, which at first seemed to suggest the possibility of two different yellow colorants being used. However, Raman microscopy confirmed the presence of lead chromate in a sample from motif 131, indicating that it is merely a difference in application consistency that differentiates the yellows in motifs 1–130 from motifs 131–136.

Two shades of blue are found on the Rosebud winter count, a turquoise color and a deep purple-blue. Both blues are non-penetrating and have generally been applied with visible strokes, where the color remains only on the high points of the textile weave (Figure 9 [facing page], motif 75). The turquoise blue may have been applied dry and then manipulated to create washes. The turquoise and deep purple-blue were identified by Raman microscopy as the pigments Prussian blue and ultramarine, respectively[7]. Both blue colors have application marks that correspond with dry, rather than wet, deposition. Furthermore, the quality of the lines and their insolubility in organic solvents suggest that the medium for the Prussian blue and ultramarine was colored pencil rather than crayon (Ellis and Yeh 1998).

A second black pencil, which appears to have been applied last in the sequence of colors, is also observed. This pencil produced strokes that are broader and blacker than that used for preliminary outlines (Figure 10). Furthermore, it appears to have been applied dry and was subsequently wet to produce a motif color rather than an outline, for example in the flag in motif 102. Such water soluble pencil media, produced with aniline and clay in a gelatinous binder, were patented as replacements for watercolors in 1878 (US Patent Office 1878).

Brown ink or paint was used both as a motif color and to reinforce most of the motifs after the colors were applied. The same brown material appears to have been used throughout the winter count, as evidenced by its consistent color, purplish red ultraviolet fluorescence, penetration through the textile, and uniform solubility in organic solvents. This material also appears to have been applied to form the scrolled outlines between the rows of motifs. In its use to reinforce the motif outlines, the application of the brown is not loyal to the pencil drawing, and shows a great deal of variety, including both smooth and abrupt marks. In its use as an outline, it appears to have been brush-applied, based on the observation of color concentration at the ends of the strokes (see for example motif 75). Unfortunately, identification of the brown material was complicated by interference from nearby colorants and trace elements identified in the textile matrix; further analysis is required to identify the nature of this brown material.

Finally, the motifs in the Rosebud winter count were numbered, and as previously described, renumbered with corrections applied as strike

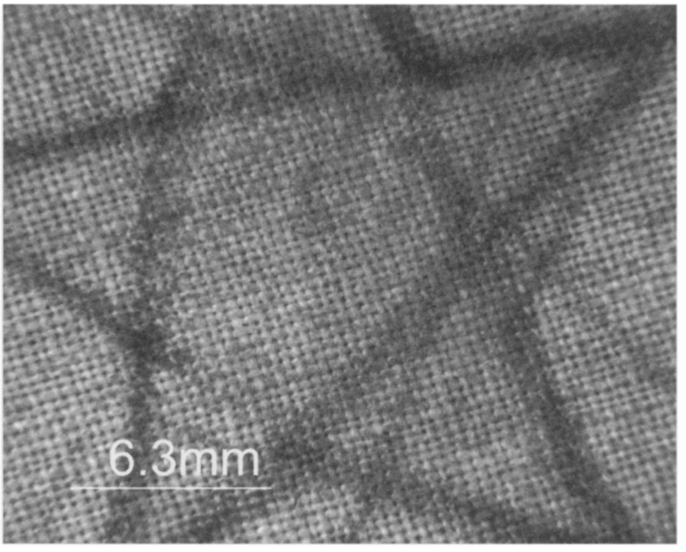

Figure 10. Motif 72. Thin and thick pencil used below and above red colorant. Photo by Melvin Wachowiak.

outs. The black material used to strike out the earlier numbers is distinct in that it penetrates the textile, while the earlier black application does not. The original numbers were applied using a viscous and glossy black material, which does not dissolve in any of the organic solvents tested. This material is not fluorescent when observed under an ultraviolet light source. The numbers and corrections appear to be the final application, i.e. are over the brown outlines and the colors. Both blacks are presumed to be carbon-based inks based on visual appearance and lack of detection of heavy elements by XRF spectroscopy[8].

DISCUSSION

Of the colorants identified on the Rosebud winter count, chrome yellow has the most recent date of introduction, only becoming commercially available in the early nineteenth century (Fitzhugh 1997), therefore establishing that, despite the presence of motifs beginning in 1752, no parts of the count were produced before the early nineteenth century. The two blue colors have application marks that correspond with dry rather than wet deposition. Furthermore, the quality of the lines and their insolubility in organic solvents suggest that the medium for the Prussian blue and ultramarine was colored pencil rather than crayon (Ellis and Yeh 1998).

Archival evidence suggests that blue colored pencils were introduced later than other colors. Petroski (1990:102–103) notes only black and red pencils among the American and English tools in an 1827 catalog of the Boston stationer Andrew J. Allen. The Staedtler pencil company archives include correspondence from 1834 in which J. S. Staedtler announces the new manufacture in Germany of red colored pencils, the first color aside from black to be produced (Staedtler 2007).

Perhaps documenting one of the earliest uses of Prussian blue in a pencil medium is a U.S. Patent awarded in 1877 for an improvement in "paint pencils," which lists Prussian blue, tallow, and "resin" as the major ingredients for indelible blue pencils (U. S. Patent 1877b). Henry Berol, a descendant of the founder of Eagle Pencils, notes 1877 as the first year that company marketed indelible magenta pencils (Petroski 1990:302). Records at A.W. Faber, a prominent drawing media company with origins in the eighteenth century, include inventories dating to 1881 and 1883 with lists of Schieferfarben, Blei-Schiefer-Farben, or Bleistift-Fabrik, each of which corresponds to colored pencils (Faber-Castell 2007). The blue colors listed as available in pencils include ultramarine, indigo, cerulean, and Miloriblau (Prussian blue) as well as mixtures of blue pigments (Kremer Pigment 2007). Prussian blue is listed in 1883 as a "Neue Farbstifte zum Zeichnen für Künstler" (new color drawing pencil for artists), suggesting its recent introduction (Hilsenbeck and Luther, personal communication 2007). A. W. Faber's archives on American materials include a New York catalog from 1897 which is the first American Faber catalog to list a colored pencil based on Prussian blue (Faber-Castell WK 01-0604 2007:26; Luther, personal communication 2007).

Most American and European pencil companies operating in the nineteenth century have not maintained careful archives, so that information gleaned from the previous few manufacturers and distributors is especially valued. As late as 1892, Prussian or Berlin blue was noted as requiring significant admixtures of acid to render it soluble, a manufacturing limitation when compared with water soluble aniline dyes (Lehner and Brannt 1892:136–139).

Colored pencils based on Prussian blue thus appear to be a later development than black or red pencils, and were possibly not available to a winter count keeper or copyist on the Plains until the very end of the nineteenth century. That a full palette of colored pencils was likely unavailable mid-century is supported by the account of the artist Rudolph Friederich Kurz, who recorded his travels on the Mississippi and Missouri rivers during the years 1846–1852. Kurz complains about the difficulties caused by needing to complete sketches using watercolors instead of oils, because he needed easily packed, quick drying materials to supply color (Hewitt 1937:135).

Results of the technical study outlined above support Cowdrey's (1999) suggestion that there were different hands at work on the Rosebud winter count. Motifs 131–136 (corresponding to the years 1883–1887) appear stylistically different than the earlier motifs, and furthermore were apparently created using a different red colorant mixture and possibly in a different medium than the earlier motifs. It therefore seems likely that these motifs were produced subsequent to the application of motifs 1–130, which show sufficient consistency in materials and application methods to have been rendered, or copied from an earlier count, by one individual. No distinction in materials or methods was found to support different hands responsible for motifs numbered 123–130, as suggested by Cowdrey (1999).

The brown material used throughout the winter count to outline motifs, to fill in select motifs, and to produce the scrolled line between motifs, appears to be a uniform medium applied after all the motifs were rendered. There are many instances where the application of this color can be seen to overlap earlier pencil and colors. It is possible that the outlining and scrolled line were applied by the same hand that applied motifs 131–136, or by a third hand. The application of the motif numbers is a different material, and overlaps the brown outlines, suggesting yet another hand involved in the manufacture of the winter count.

Materials that were not useful for specific dating or distinguishing hands include the graphite pencil and the textile support. By the early nineteenth century, graphite, a naturally occurring carbon mineral, was used widely in the manufacture of pencils for distribution throughout the U.S. (Pinney 1988:10).

Muslin textiles similarly are not easily assigned a source or date. Although results of the textile support examination and analysis suggest that the Rosebud winter count was produced on cotton that was not modified following its removal from the roll, textile industry sources, including historic sample books (Nichols and Broomhead 1927), indicate that details such as width, weave count and selvage construction are insufficient in themselves to source or date the textile. By 1754, cotton muslin was available in a yard width from firms in Boston (Montgomery 1984:304). Traders' inventories document distribution of British and American muslin to southeastern North American tribes beginning in 1798–1799 (Waselkov 1998:Table 1). From 1850 to 1930, bleached and unbleached cotton muslin was available from both the United States and Britain in an astounding variety of widths and weights. Nonetheless, the stains which predate the pictographs found on the Rosebud winter count suggest that muslin was reused and not taken for granted. While cotton muslin represents a non-traditional support material, Howard's 1979 report on 56 winter counts includes 14 on "muslin" measuring 87.6–91.4 cm (34½– 36 in) indicating that a similar support was available and used throughout the Plains. Further study and comparison between muslins may provide more information about common sources.

CONCLUSIONS

The analysis of colorants on winter counts or ledger drawings is inherently challenging because they generally are very thinly applied, which makes them subject to interferences from the cloth or paper support and also severely limits opportunities for sampling. Nevertheless, this study has employed a number of non-invasive analytical techniques (stereomicroscopy, ultraviolet fluorescence, and XRF spectroscopy) along with techniques requiring the removal of only microscopically sized samples (Raman microscopy, polarized light microscopy) to generate a wealth of information about the identity of the colorants used in the creation of the Rosebud winter count. From this information we have been able to propose a possible sequence and approximate date of the various application campaigns. The identification of the wet and dry binding media would be of enormous value in distinguishing between different applications where the same colorant is used. However, current technology requires the removal of amounts of material which would be disfiguring to the winter count; therefore no samples for media analysis were removed at this time.

The study of Lakota winter counts has been enhanced by recent historical and comparative scholarship (Greene and Thornton 2007). However, many questions remain about materials and methods of manufacture. Material examination of the Rosebud winter count conducted in this study has identified several colorants, including chrome yellow and Prussian blue applied as colored pencil, supporting a manufacture date late in the nineteenth century. In addition, manufacture of the Rosebud winter count can be related to at least two different sets of materials and styles, and therefore to at least two different hands, although it is possible that the hands are contemporary with each other. All of the brown outlines appear to be contemporaneous, with the same color being used to divide the motifs and to fill in select motifs. The black numbers used for each motif appear to have been applied after all of the motifs.

Results of this technical examination highlight the benefits of applying materials analysis to scholarship on winter counts. In particular, the chronological introduction of colored pencils is shown here to be a potentially important indicator for the dating of winter counts, as well as related ledger drawings and other drawings that incorporate this media.

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NOTES

1. The Innov-X Systems Alpha Series XT-440 handheld energy dispersive X-ray Fluorescence (XRF) spectrometer has a silver anode, Si PiN diode detector, 1.4 cm diameter instrument window and a spectral resolution of < 200 eV. Pre-set beam

conditions were 35 kV and 13 μA with an aluminum filter for elements with atomic numbers greater than iron, and 15 kV and 12 μA with an aluminum filter for elements between iron and potassium. The instrument was operated in the handheld mode, so exposures were limited to 30 seconds. Reported elemental composition is primarily based on the qualitative, raw spectra.

2. The XRF spectrometer used in this study is an air-path instrument, and as such cannot detect elements with atomic numbers less than potassium, which includes many elements commonly found in pigments, such as carbon, aluminum, silicon, sulfur, and chlorine.

3. Raman microscopy is a non-destructive technique that provides information about the molecular structure of the species under investigation. Because the Raman spectrometer is coupled to a microscope, Raman spectra can be obtained on particles even a few micrometers across, including individual pigment grains. The samples in this study, provided on glass slides, were analyzed in situ, with no further preparation to the samples. The samples were analyzed using a Renishaw InVia Raman micro-spectrometer (equipped with 514 nm Ar ion and 633nm He-Ne excitation lasers; spectral acquisition time 10 to 60 sec over the spectral range 100-3200 cm^{-1}, spectra calibrated to the 520.5 cm^{-1} line of a silicon wafer.

4. XRF analysis did not detect any heavy elements in the grey and black areas which could account for their coloration, suggesting that these areas are colored with a carbon-based material. However, it should be noted the XRF spectrometer used in this study cannot detect carbon, and therefore the presence of carbon materials is presumed, pending confirmation.

5. XRF analysis identified the presence of the element mercury (Hg) in a number of areas (see Table 1), suggesting the presence of the pigment vermilion (mercuric sulfide, HgS). Raman spectroscopic analysis confirmed the presence of vermilion in the samples indicated. XRF analysis also detected the element zinc (Zn) in motifs 62 and 134, suggesting the possible addition of a white pigment based on zinc oxide.

6. Barium (Ba) was also detected in these areas, suggesting the chrome yellow is possibly mixed with a barium sulfate (baryta) extender.

7. Prussian blue is an iron-based pigment which has extremely high tinting power, and therefore may be present at levels below the detection limits of the XRF spectrometer used in this study. Similarly, ultramarine is a sodium, silicon, aluminum sulfur compound; none of these elements can be detected using the XRF spectrometer used in this study. However, both of these colorants can easily be detected using Raman spectroscopy.

8. As discussed above, the XRF spectrometer used in this study cannot detect carbon, so the presence of carbon-based materials is presumed based on the lack of evidence of other materials, as well as visual appearance.