AN INVESTIGATION OF CONTRACTING STEM PROJECTILE POINTS IN WEST-CENTRAL COLORADO

Neil Hauser
Coal Creek Research Inc.
nhauser.ccr@gmail.com

ABSTRACT

The purpose of this study is to compare contracting stem projectile points found in west-central Colorado with contracting stem points from the Great Basin by using a cluster analysis approach. Two hundred fifty-two contracting stem projectile points from west-central Colorado are compared with 54 points from three sites in Nevada. The 54 points are from Gypsum Cave, Gatecliff Shelter, and O'Malley Shelter. The study found that the points from Nevada are best represented by four shapes, while those from west-central Colorado are best represented by eight shapes. The points from Nevada did cluster with some west-central Colorado point shapes, but many points from west-central Colorado are not similar to the Nevada points.

INTRODUCTION

Contracting stem projectile points that occur in west-central Colorado are typically grouped into the Gypsum cluster as defined by Justice (2002). This is also true of points from Gypsum Cave, O'Malley Shelter, Gatecliff Shelter, and many other sites in the Great Basin. Casual visual examination of points from sites in the Great Basin and those found in west-central Colorado appear to indicate both similarities and differences in morphology. Notable visual differences are also seen among the Great Basin contracting stem points found in Gypsum Cave, O'Malley Shelter, and Gatecliff Shelter. For example, Fowler et al. (1973) identified three variants of contracting stem points within the O'Malley Shelter assemblage alone, Series A, Series B, and "small points."

This analysis investigates the morphology of points from west-central Colorado and the three sites named above in Nevada to inform the extent to which the morphologies of contracting stem points in the Great Basin are present in west-central Colorado.

APPROACH

Contracting stem points from Nevada, specifically those defined as the Gypsum cluster by Justice (2002), were compared to contracting stem points from west-central Colorado. Twenty parameters, both measurements and proportions (ratios), were calculated for each point. K-means clustering (Geron 2019) was used to group similar points assuming different numbers of clusters. With the K-means clustering algorithm, it is necessary to specify the number of expected clusters or groups. For this paper, "group" was used as the number of clusters to be created by the K-means clustering algorithm for a given run. Analysis of K-means clustering results was then used to assess the best morphological description of the contracting stem point assemblages.

Images of 54 contracting stem points from sites in Nevada and 252 contracting stem points from west-central Colorado (CCR 2021) were used in this analysis. The points from Nevada included four specimens from Gypsum Cave (Eugene Hattori, personal communication 2021), 17 from Gatecliff Shelter (David Hurst Thomas, personal communication 2020), and 33 from O'Malley Shelter (Fowler et al. 1973).

Measurements were taken from the images on the most complete vertical half of each of the 306 projectile points. Using tpsDig232, a free software tool developed by Stony Brook University for morphometric analysis (Rohlf 2004), 18 landmark (LM) locations on each point were recorded. Two additional landmark locations, 3 cm apart on the embedded scale, were taken to allow any scale corrections of the images (Table 1; Figure 1). Using the coordinates of those landmarks, 20 different measurements and ratios based on modified parameters from Thomas (1981), Berry (2020), and Gunn and Prewitt (1975) were calculated for each of the 306 points (Table 2; Figure 2).

Table 1. Landmark Definitions

Landmark (LM) No.	Defined location
1	On left blade edge of point close to the top
2	On left blade edge below LM 1 at significant change in slope of edge
3	On left blade edge below LM2 at next significant change in slope of edge
4	On left blade edge below LM3 near shoulder, used with LM3 to define blade slope
5	On left side of tang or on the end of tang if tang or shoulder comes to a point
6	On right side of tang or shoulder or on LM5 if tang or shoulder comes to a point
7	On distal edge of notch toward body, used with LM6 to define distal edge angle
8	Back of the notch or intersection of distal and proximal edges
9	On proximal edge closest to LM8, used with LM10 to define proximal edge angle
10	On first change of slope below LM9, used to define proximal edge angle
11	Co-located with LM10, width at first change in slope below LM9
12	Location of last change of slope that defines bottom of the base
13	Location of left side of basal notch or basal concavity
14	Location of highest (deepest) part of basal notch or concavity
15	Location of lowest point on base
16	Location of center point of bottom of the base
17	Back of notch or intersection of distal and proximal edges on right side
18	At the point tip (or co-located with LM17 if tip was missing)
19	Location on scale in image at 1 cm
20	Location on scale in image at 4 cm

Table 2. Measurements and Ratios (Properties) Used

1	Shoulder Width
2	Neck Width
3	Notch Direction
4	Notch Depth
5	Total Angle
6	Distal Edge Angle
7	Proximal Edge Angle
8	Base Width
9	Maximum Base Extent
10	Base Depth
11	Base Concavity
12	Shoulder Extent from Maximum Extent of Base
13	Angle of Edge with Centerline

14	Neck Width/Shoulder Width
15	Base Width/Shoulder Width
16	Depth of Base/Base Width
17	Maximum Base Extent /Shoulder Width
18	Depth of Base/Shoulder Width
19	Neck Width/ Base Width
20	Shoulder Extent/Maximum Base Extent

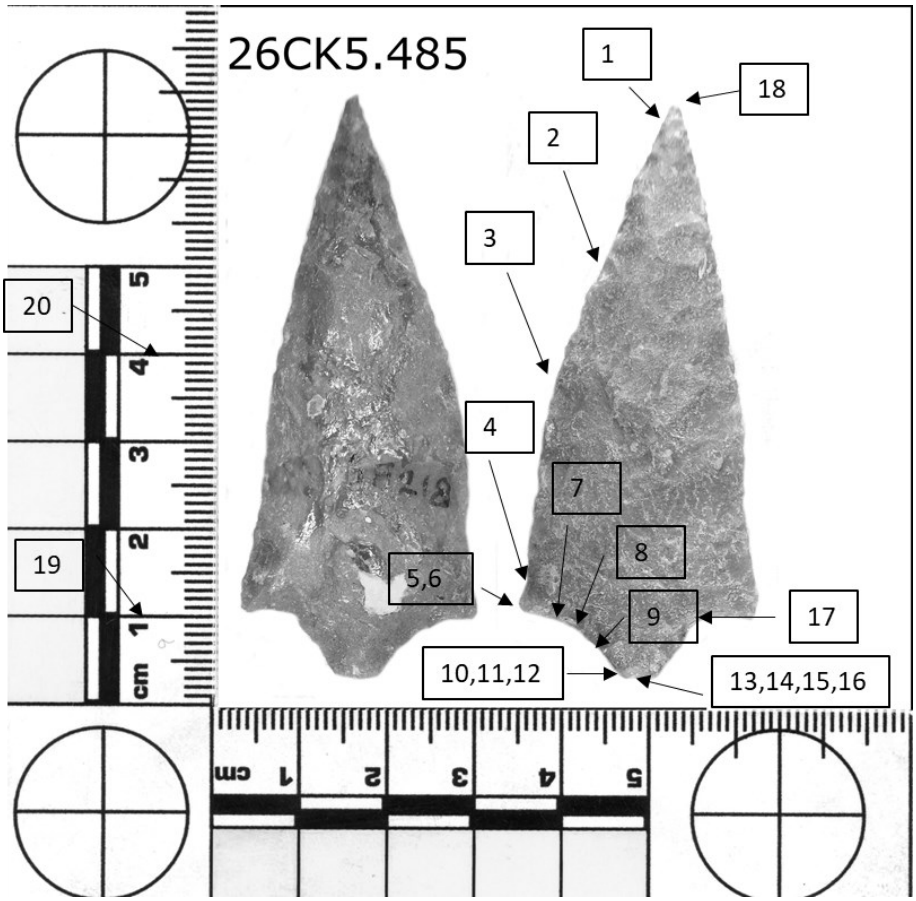

Figure 1. Example of Landmark Placements on Gypsum Cave Contracting Stem Point

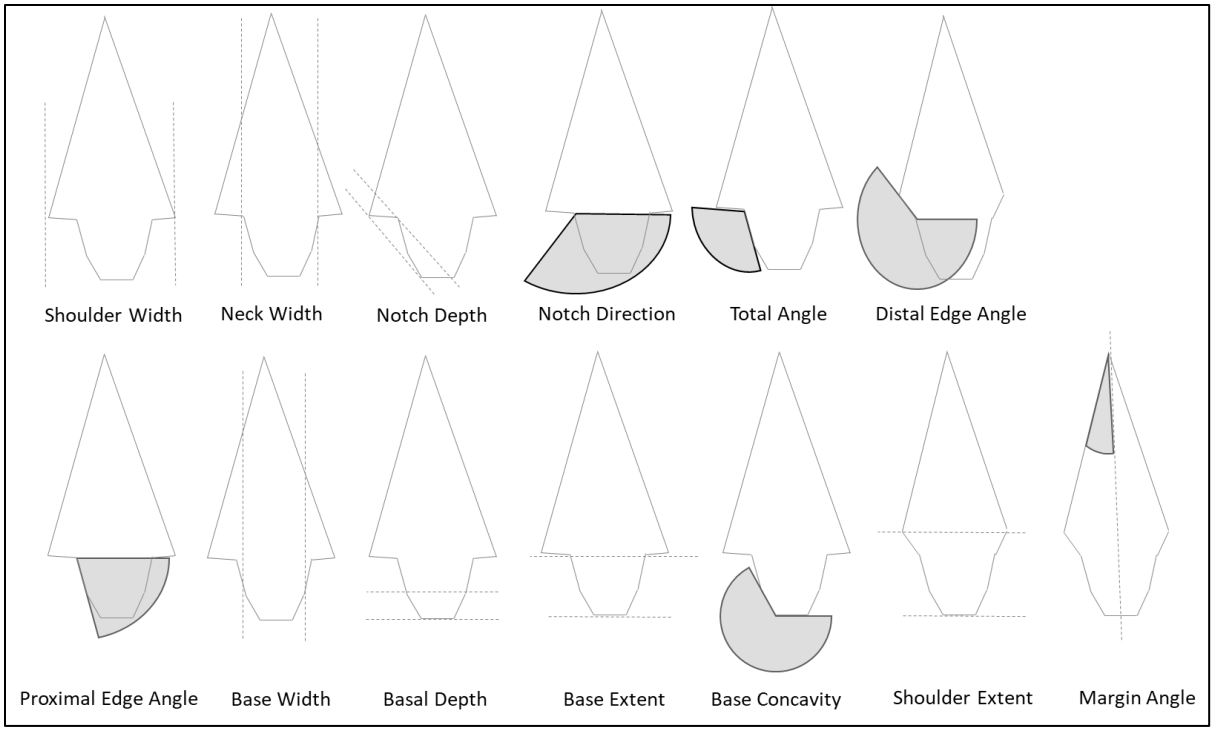

Figure 2. Definition of Projectile Point Properties

THE NEVADA POINTS

The Nevada contracting stem points were examined first. As described above, these points were derived from Gypsum Cave, Gatecliff Shelter, and O'Malley Shelter, with Gypsum Cave points organized into three groups (Series A, Series B, and "small points"). In this approach, the K-means process was repeated five times with a different number of expected groups specified: two groups, three groups, four groups, five groups, and finally six groups. For each of the five K-means runs a representative, synthetic projectile point line drawing was created using the values of the parameters at the centroid of each cluster, i.e., the average value of each of the parameters using all the points in each cluster (Figures 3A through 3F). Dimensions of all synthetic points are in millimeters.

Nevada Contracting Stem Point K-means Algorithm Runs

Deciding how many clusters best describe the variation in the assemblage is subjective. Tables 3A through 3F show how the points in the assemblage, by site and categories, are distributed among the clusters as the number of clusters increases. The synthetic image for the single group can be considered the generic contracting stem point, based on the points used in this analysis. The small contracting stem points are separated from the others first in the two-group run (Figure 3B). Straight versus convex base and slope of the shoulders are the next largest differences resulting from the three-group run (Figure 3C). Next, the width of the neck (Figure 3D) distinguishes the Gypsum Cave points and five of the O'Malley Shelter Series A points from the remaining larger-sized contracting stem points. Finally, the five-group run distinguishes more subtle differences in the shape of the shoulders. However, in the five-group run it could be argued that clusters 2 and 5 would be hard to separate in the real world using visual observation. This indicates that the slope and extent of the shoulders has more importance in objective K-means clustering than it does in

subjective clustering. The same assessment can be made in the six-group run for clusters 3 and 4 and possibly clusters 2 and 5. Therefore, the six clusters could be reduced to four clusters by combining clusters 2 and 5 into one cluster and clusters 3 and 4 into another. The resulting synthetic points from the four clusters (Figure 4) are nearly indistinguishable from those in Figure 3D. Therefore, as a result of this inspection process, the data set from Nevada is best described using only four clusters.

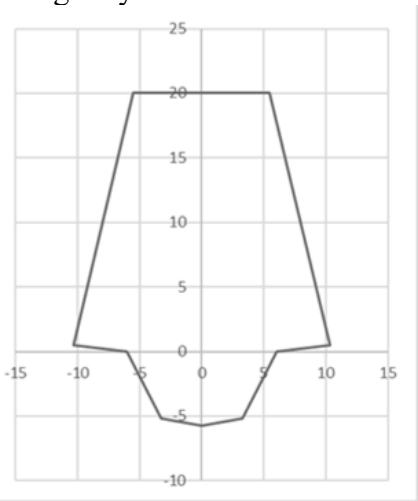

Figure 3a. Nevada Points, 1 Cluster

Table 3a. Nevada Assemblage Distribution with 1 Cluster

Cluster	1	2	3	4	5	6
Gypsum Cave	4					
OMS Series A	19					
OMS Series B	5					
OMS small point	9					
Gatecliff Shelter	17					

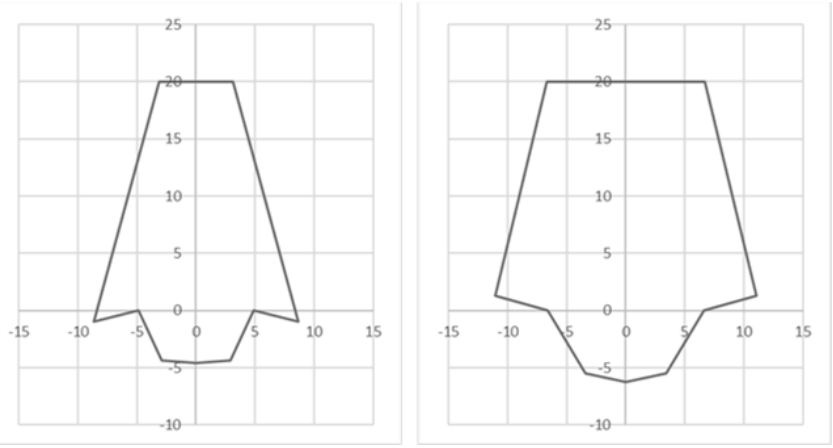

Figure 3b. Nevada Points, 2 Clusters

Table 3b. Nevada Assemblage Distribution with 2 Clusters

Cluster	1	2	3	4	5	6
Gypsum Cave	0	4				
OMS Series A	1	18				
OMS Series B	1	4				
OMS small point	8	1				
Gatecliff Shelter	8	9				

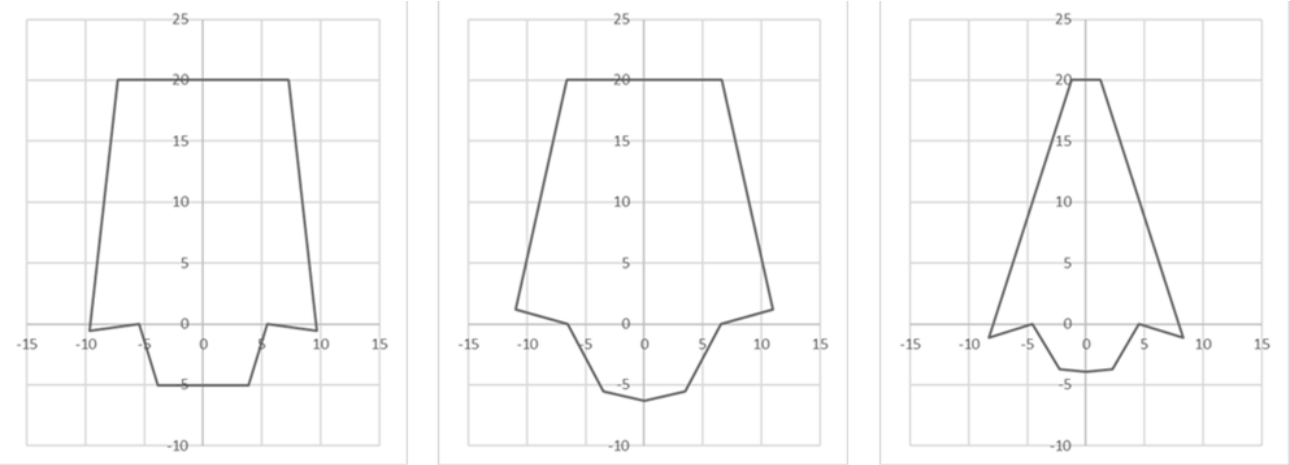

Figure 3c. Nevada Points, 3 Clusters

Table 3c. Nevada Assemblage Distribution with 3 Clusters

Cluster	1	2	3	4	5	6
Gypsum Cave	0	4	0			
OMS Series A	1	17	1			
OMS Series B	1	4	0			
OMS small point	1	1	7			
Gatecliff Shelter	1	12	4			

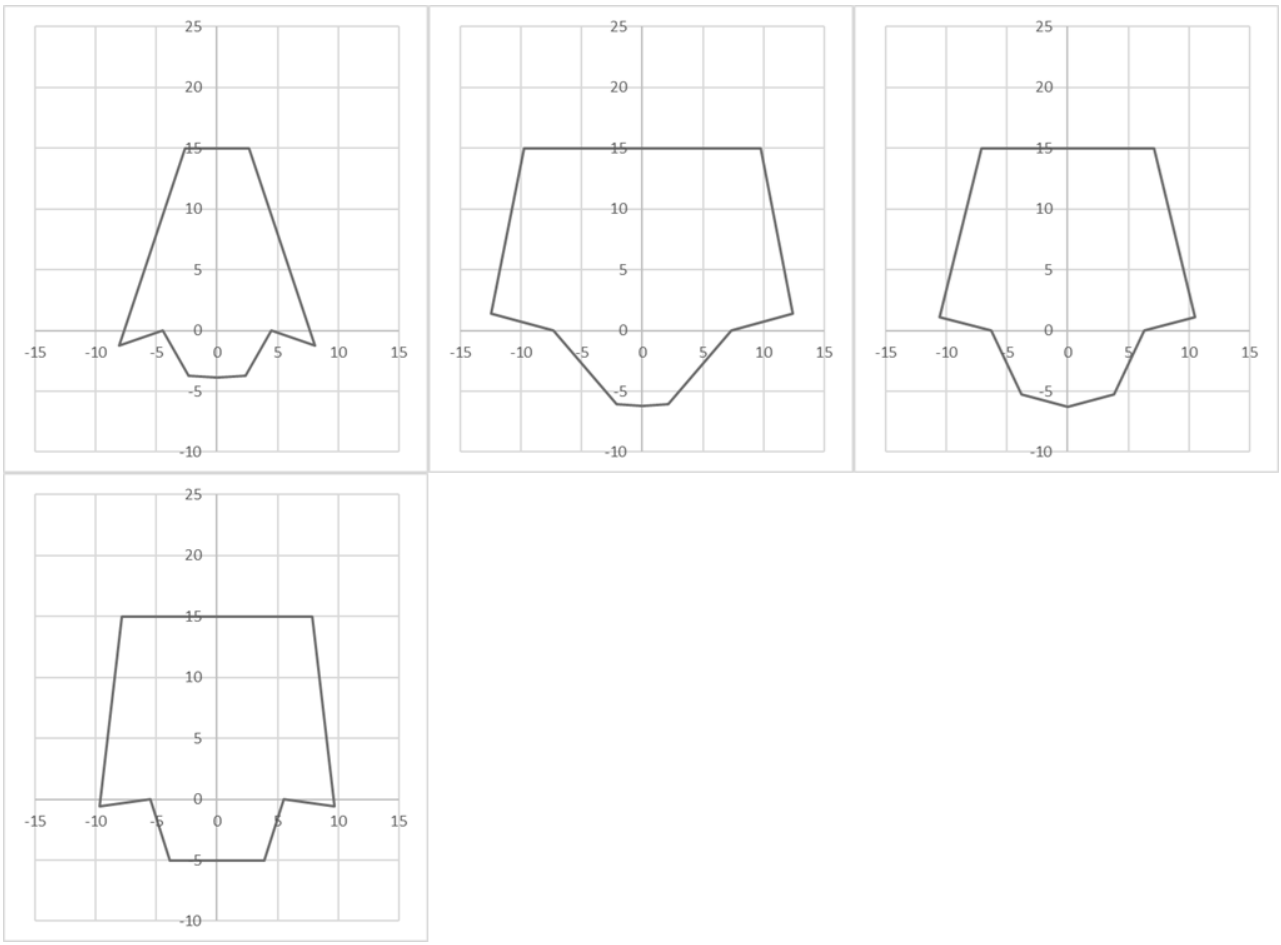

Figure 3d. Nevada Points, 4 Clusters

Table 3d. Nevada Assemblage Distribution with 4 Clusters

Cluster	1	2	3	4	5	6
Gypsum Cave	0	4	0	0		
OMS Series A	0	5	13	1		
OMS Series B	0	0	4	1		
OMS small point	7	0	1	1		
Gatecliff Shelter	4	0	12	1		

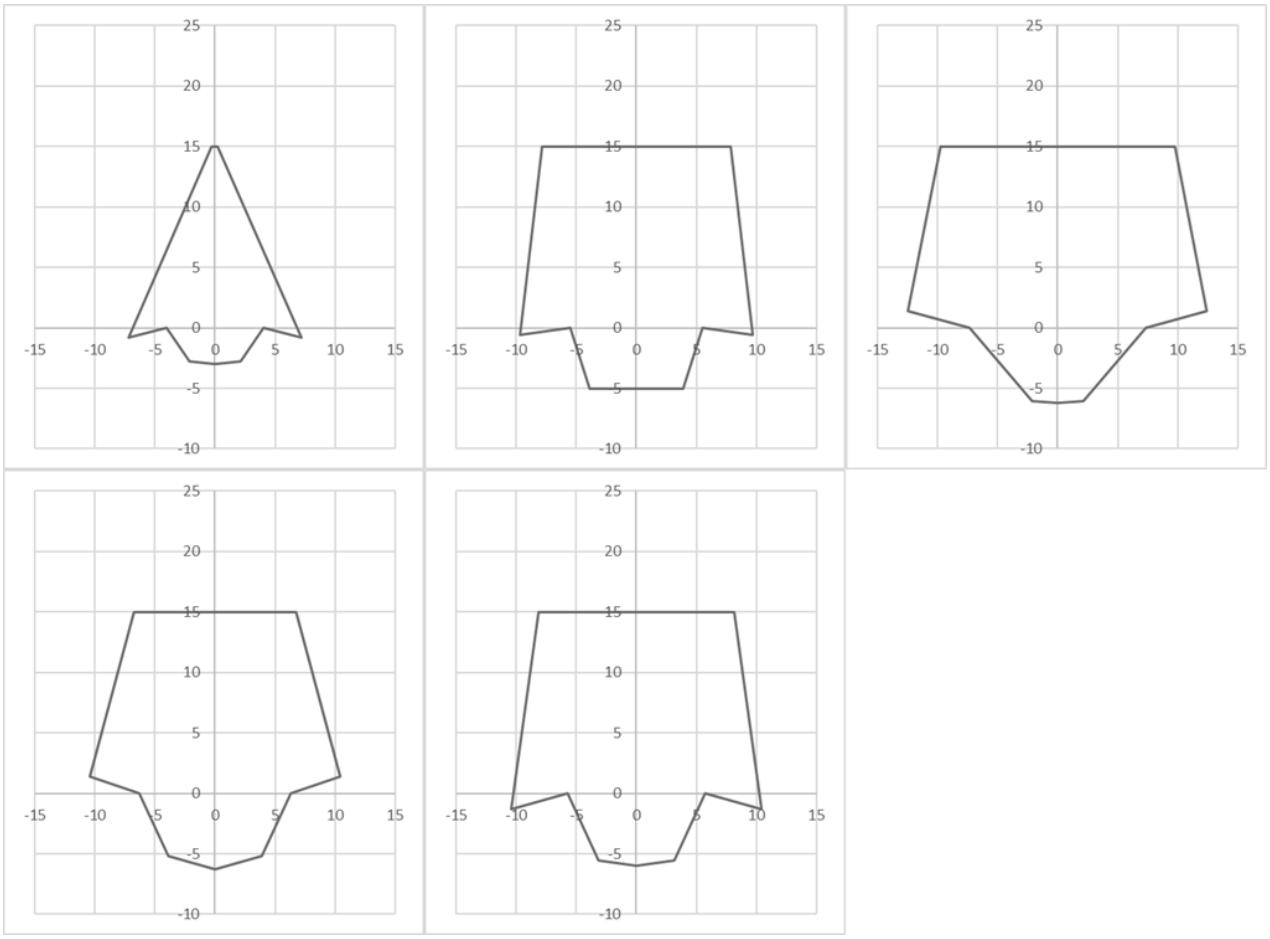

Figure 3e. Nevada Points, 5 Clusters

Tabe 3e. Nevada Assemblage Distribution with 5 Clusters

Cluster	1	2	3	4	5	6
Gypsum Cave	0	0	4	0	0	
OMS Series A	0	1	5	13	0	
OMS Series B	0	1	0	4	0	
OMS small point	7	1	0	1	0	
Gatecliff Shelter	0	1	0	8	8	

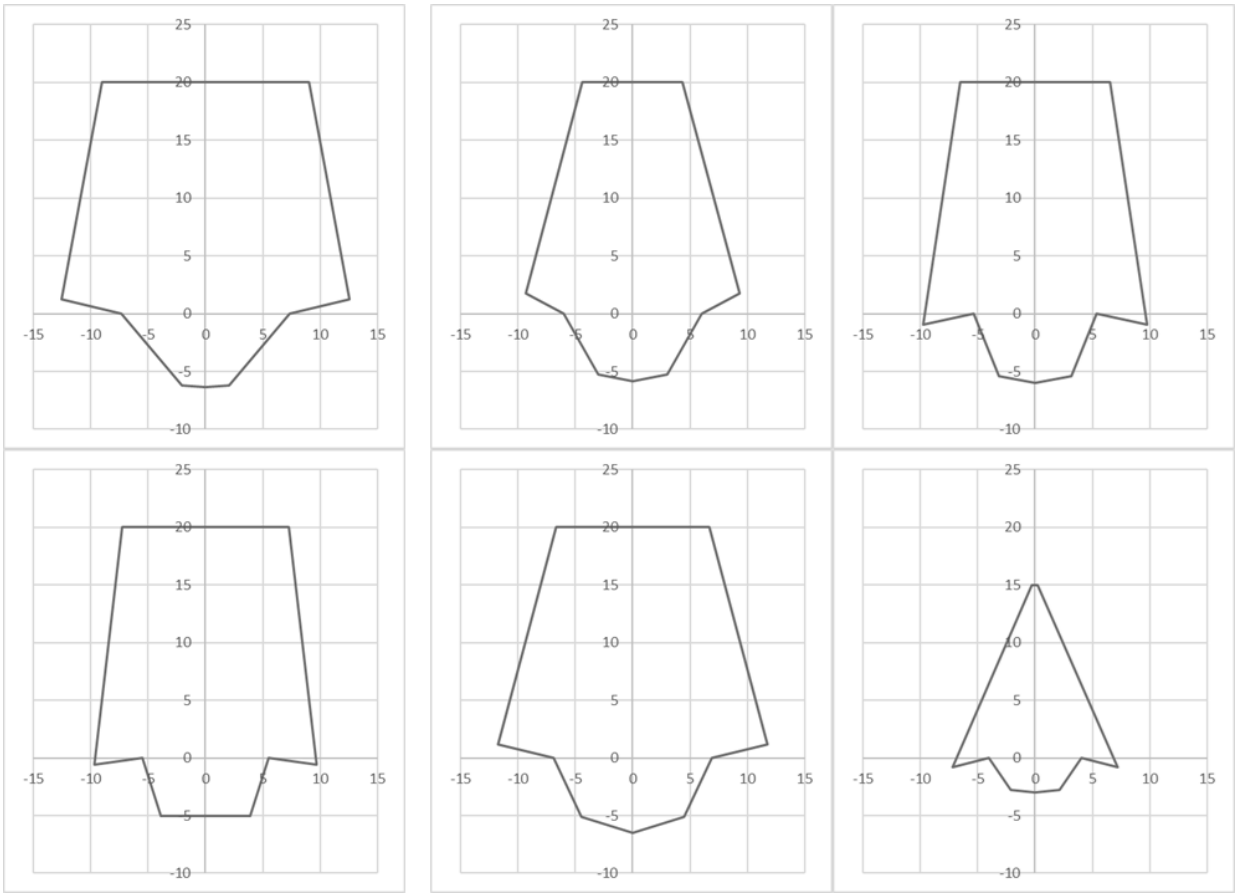

Figure 3f. Nevada Points, 6 Clusters

Table 3f. Nevada Assemblage Distribution with 6 Clusters

Cluster	1	2	3	4	5	6
Gypsum Cave	4	0	0	0	0	0
OMS Series A	4	6	0	1	8	0
OMS Series B	0	2	0	1	2	0
OMS small point	0	1	0	1	0	7
Gatecliff Shelter	0	2	9	1	6	0

Nevada Contracting Stem Point K-means Algorithm Runs

Deciding how many clusters best describe the variation in the assemblage is subjective. Tables 3A through 3F show how the points in the assemblage, by site and categories, are distributed among the clusters as the number of clusters increases. The synthetic image for the single group can be considered the generic contracting stem point, based on the points used in this analysis. The small contracting stem points are separated from the others first in the two-group run (Figure 3B). Straight versus convex base and slope of the shoulders are the next largest differences resulting from the three-group run (Figure 3C). Next, the width of the neck (Figure 3D) distinguishes the Gypsum Cave points and five of the O'Malley Shelter Series A points from the remaining larger-sized contracting stem points. Finally, the five-group run distinguishes more subtle differences in the shape of the shoulders. However, in the five-group run it could be argued that clusters 2 and 5

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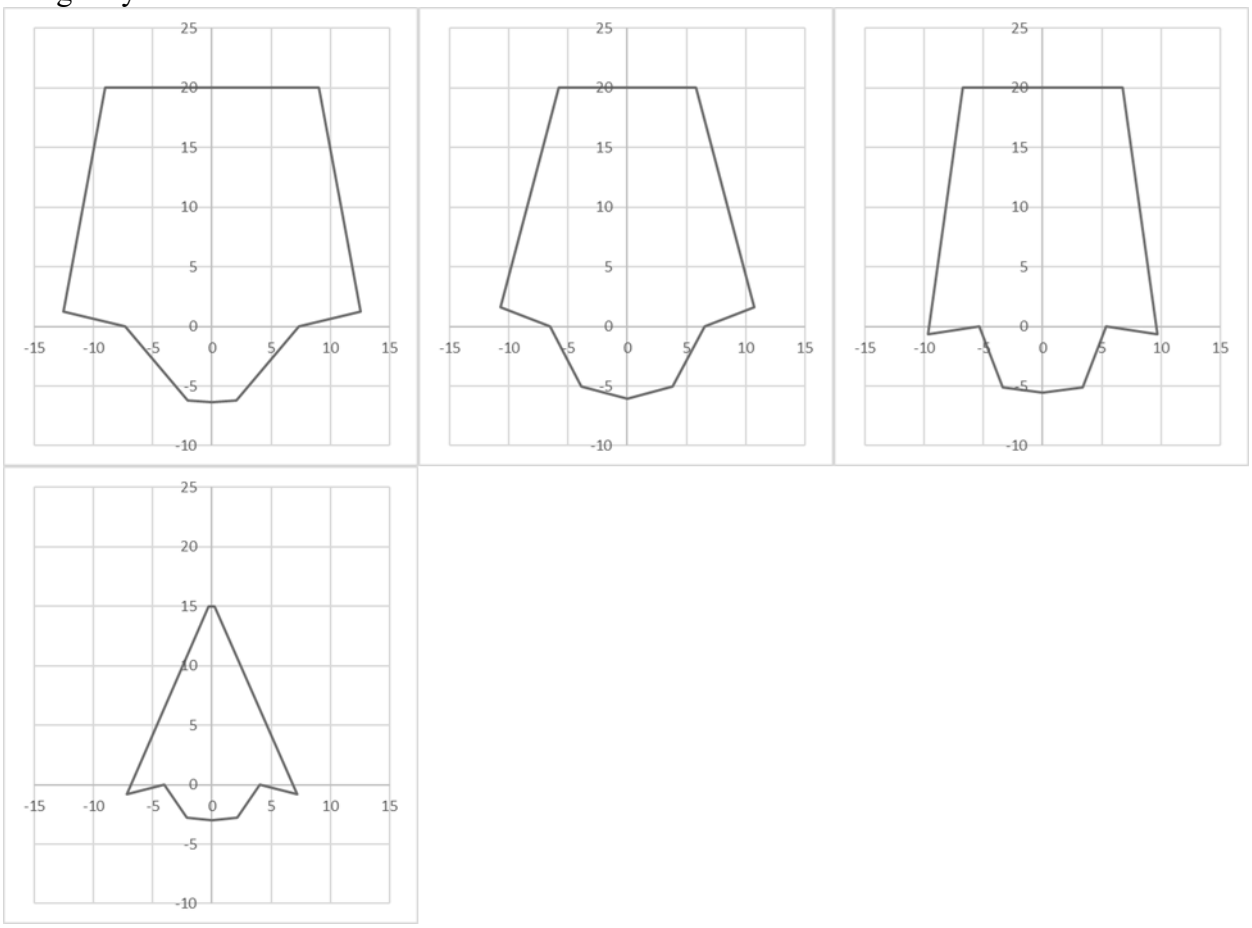

Figure 4. Synthetic Point Diagrams Assessed to Best Represent the Nevada Assemblages

Comparison with Traditional K-means Inflection Point

The result of the six-group run was compared to that obtained using the traditional "elbow curve" method (Kodinariya and Makwana 2013) for K-means, which is the inflection point in the curve of explained variance versus number of groups (Figure 5). The inflection point method predicts six groups. However, while the inflection point in the K-means variance curve predicts that six is the optimum number of groups, after examining the synthetic points and the distribution of the Nevada points into clusters, four clusters seems to be the best characterization of the points based on the six-group run where clusters 2 and 5 and clusters 3 and 4 are combined.

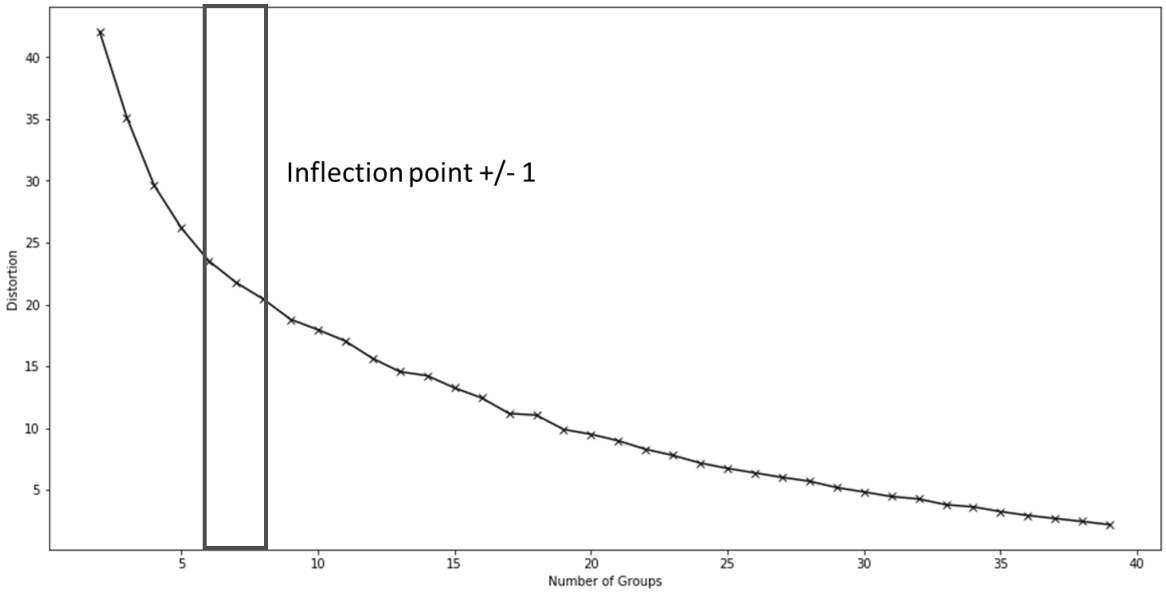

Figure 5. K-means Elbow Curve for Nevada Assemblage

WEST-CENTRAL COLORADO AND NEVADA POINTS COMBINED

The synthetic line drawing method of determining the best number of clusters was then applied to all of the contracting stem points in the Nevada and west-central Colorado assemblages. Instead of starting with a one-group run, since we know that the Nevada points alone accounted for four clusters, four was used as the initial number of groups and incremented one at a time until two or more clusters, based on the synthetic point line drawings, were similar. Synthetic line drawings were done for K-means clustering results with four to nine clusters (Figures 6A through 6F), and the distribution of points for each case is given in Tables 4A through 4F.

Starting with four clusters (Figure 6A), the Nevada points are largely separated from most of the points from west-central Colorado in cluster 3, indicating that Nevada points more closely resemble each other than they do most of the points from west-central Colorado. Until the eight-group run (Figure 6E; Table 4E) the differences in the Nevada points are not completely discernible. With that number of groups, four clusters of west-central Colorado points are again distinguishable. However, again clusters 3 and 6 and clusters 4 and 8 may be hard to distinguish visually in the real world. The only difference in each pair of clusters is that one cluster has approximately a 30% larger shoulder width than the other cluster. The inflection point in the K-means variance curve (Figure 7) predicts that eight clusters is the optimum number.

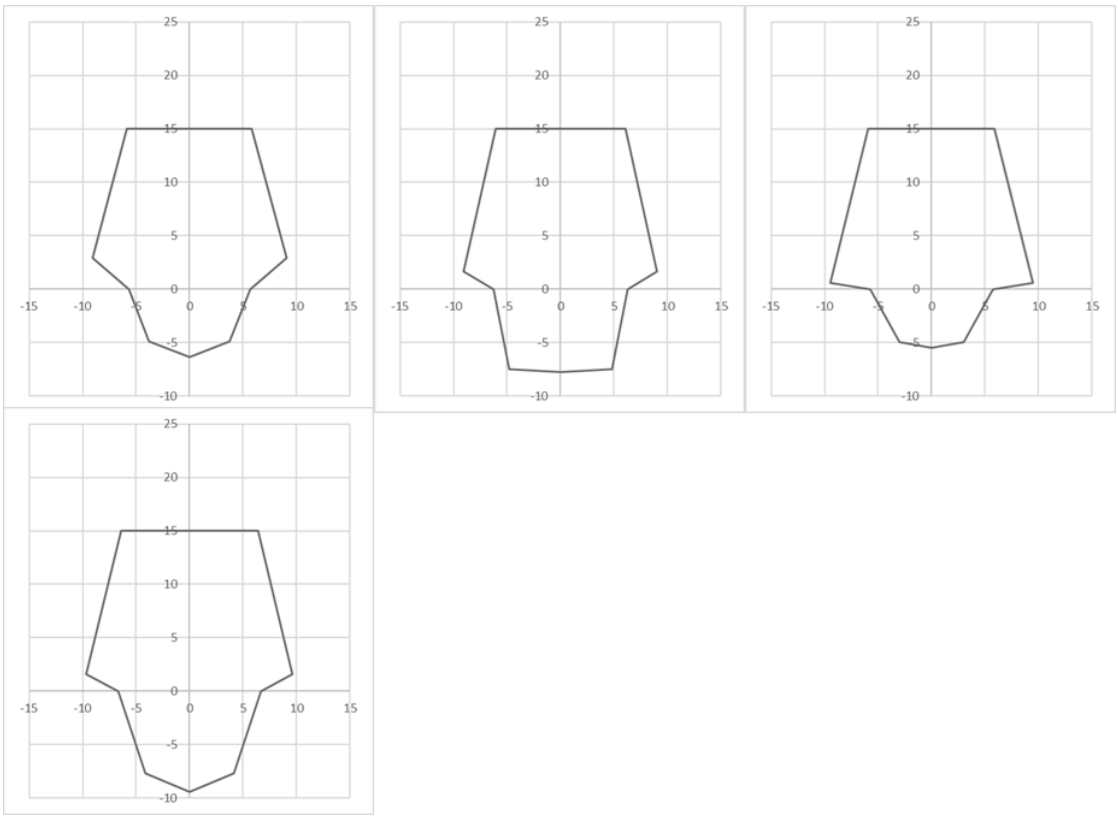

Figure 6a. All Study Points, 4 Clusters

Table 4a. Distribution of total assemblage using 4 Clusters

Cluster	1	2	3	4	5	6	7	8
Gypsum Cave	0	0	4	0				
OMS Series A	3	1	14	1				
OMS Series B	1	0	4	0				
OMS small point	1	0	8	0				
Gatecliff Shelter	1	1	14	1				
West-central Colorado	52	50	33	117				

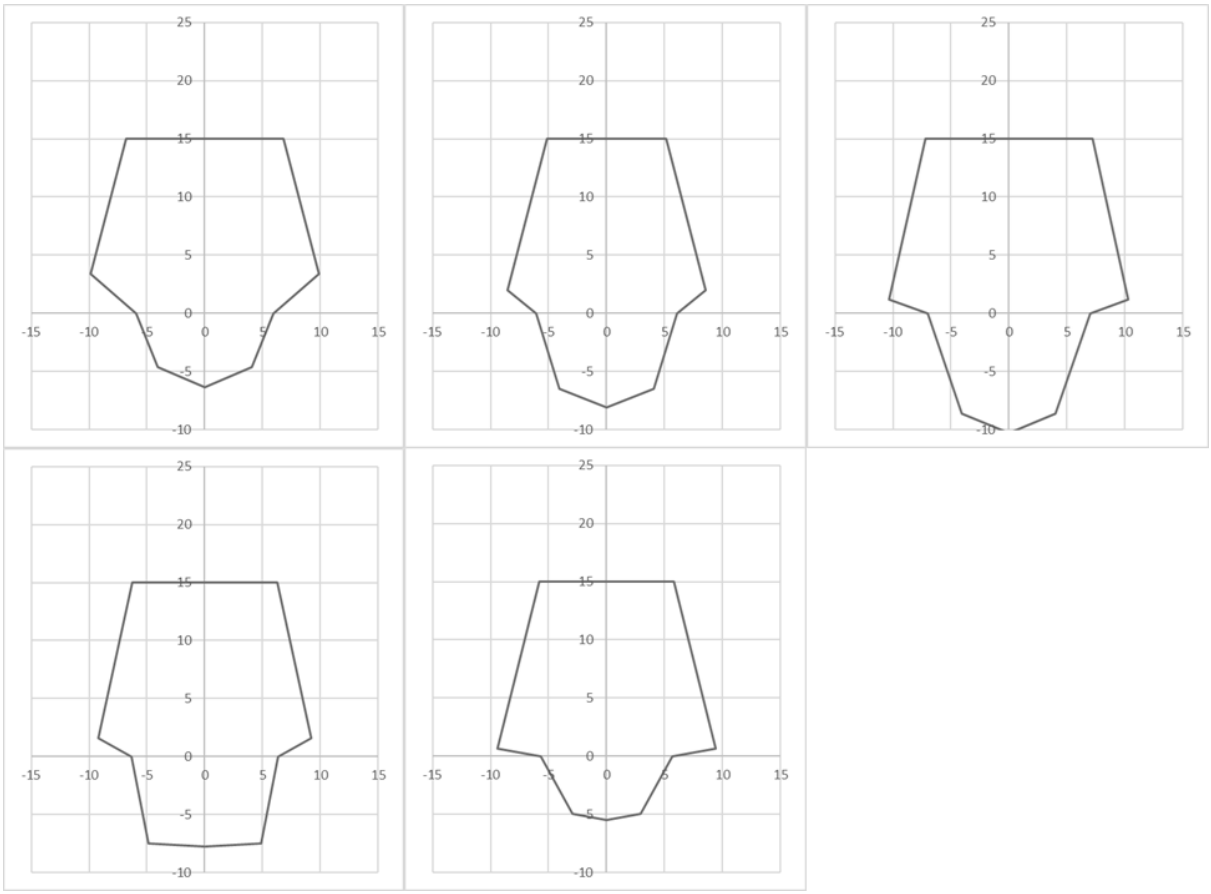

Figure 6b. All Study Points, 5 Clusters

Table 4b. Distribution of Total Assemblage using 5 Clusters

Cluster	1	2	3	4	5	6	7	8	9
Gypsum Cave	0	0	0	0	4				
OMS Series A	2	1	0	1	19				
OMS Series B	1	0	0	0	5				
OMS small point	0	0	0	0	9				
Gatecliff Shelter	1	0	1	1	17				
West-central Colorado	32	77	61	46	36				

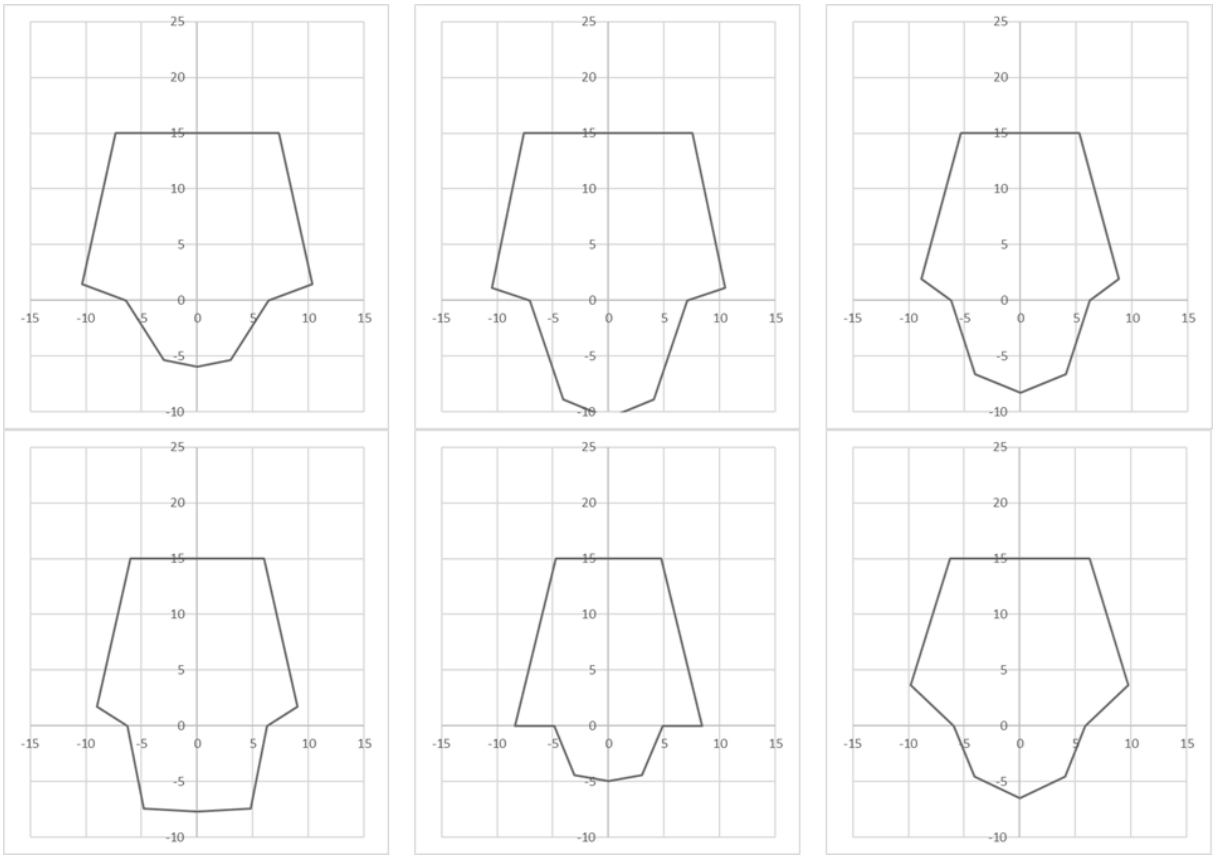

Figure 6c. All Study Points, 6 Clusters

Table 4c. Distribution of Total Assemblage using 6 Clusters

Cluster	1	2	3	4	5	6	7	8	9
Gypsum Cave	4	0	0	0	0	0			
OMS Series A	14	0	1	1	1	2			
OMS Series B	2	0	0	0	2	1			
OMS small point	0	0	0	0	9	0			
Gatecliff Shelter	2	1	0	1	12	1			
West-central Colorado	24	49	82	51	19	27			

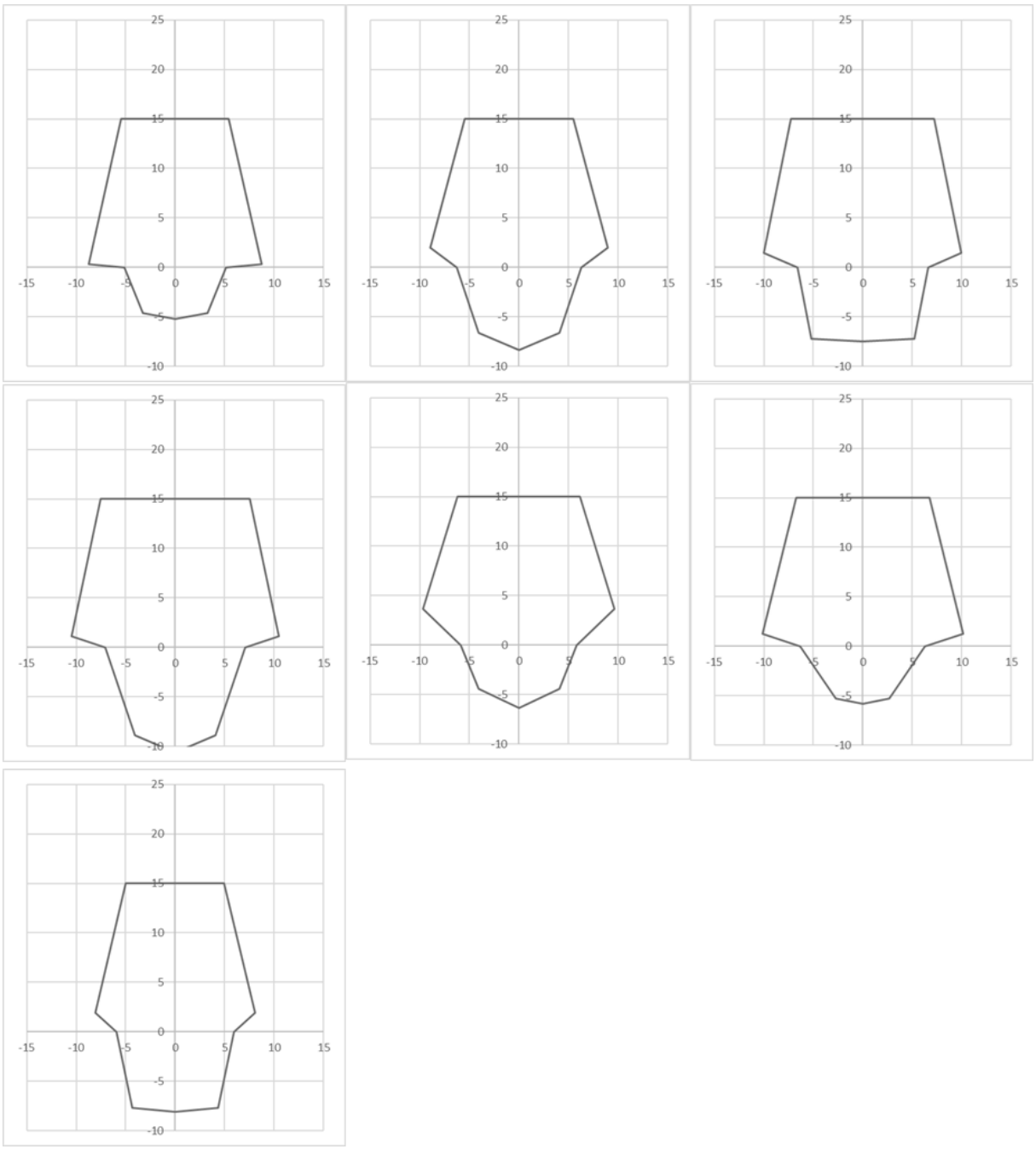

Figure 6d. All Study Points, 7 Clusters

Table 4d. Distribution of Total Assemblage using 7 Clusters

Cluster	1	2	3	4	5	6	7	8	9
Gypsum Cave	0	0	0	0	0	4	0		
OMS Series A	3	1	1	0	2	12	0		
OMS Series B	2	0	0	0	1	2	0		
OMS small point	7	0	0	0	0	2	0		
Gatecliff Shelter	12	0	1	1	1	2	0		
West-central Colorado	26	81	24	48	26	17	30		

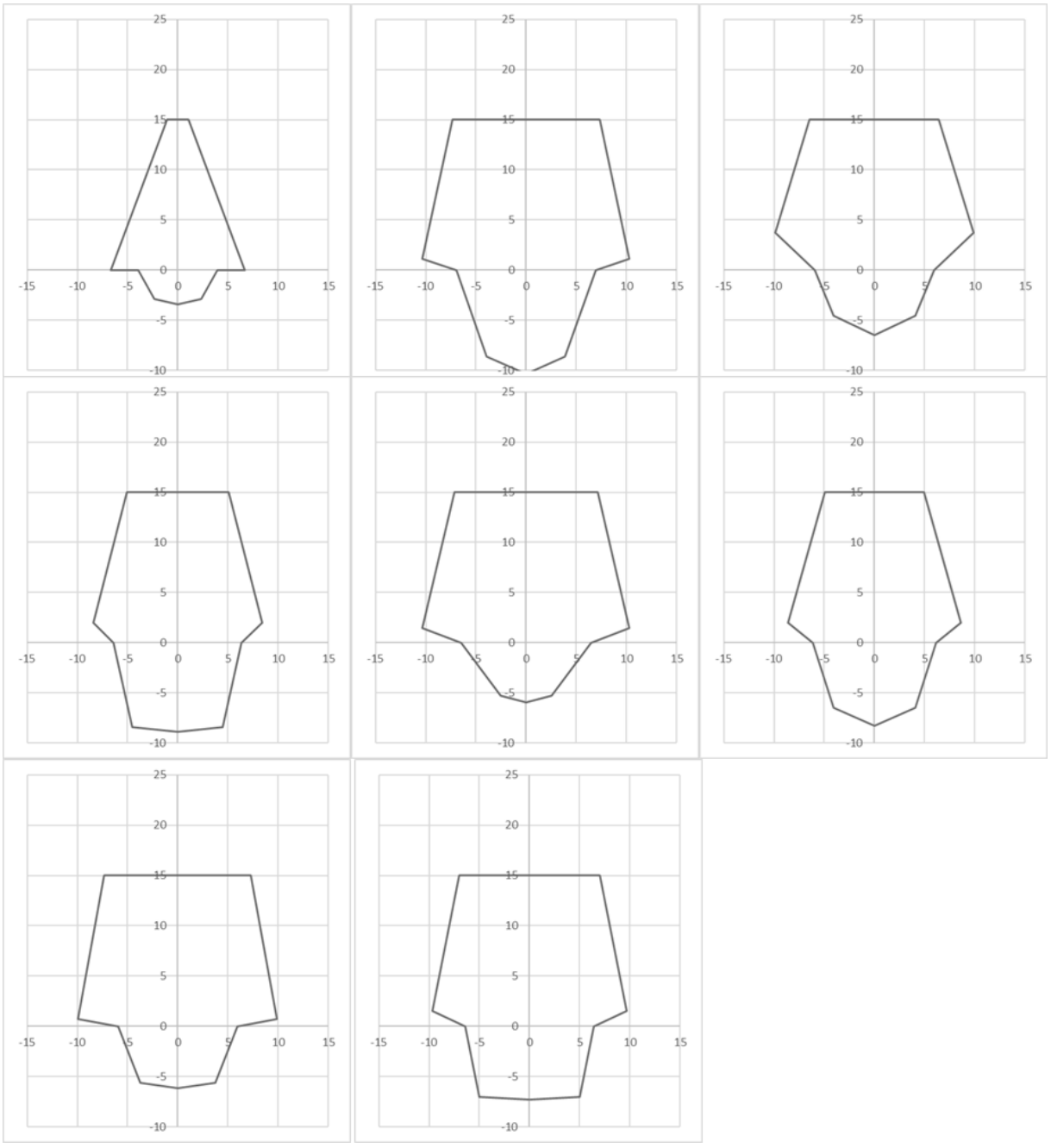

Figure 6e. All Study Points, 8 Clusters

Table 4e. Distribution of Total Assemblage using 8 Clusters

Cluster	1	2	3	4	5	6	7	8	9
Gypsum Cave	0	0	0	0	4	0	0	0	
OMS Series A	0	0	2	0	10	1	5	1	
OMS Series B	0	0	1	0	0	0	4	0	
OMS small point	9	0	0	0	0	0	0	0	
Gatecliff Shelter	0	1	1	0	1	0	13	1	

West-central Colorado	8	53	26	26	14	68	28	29	

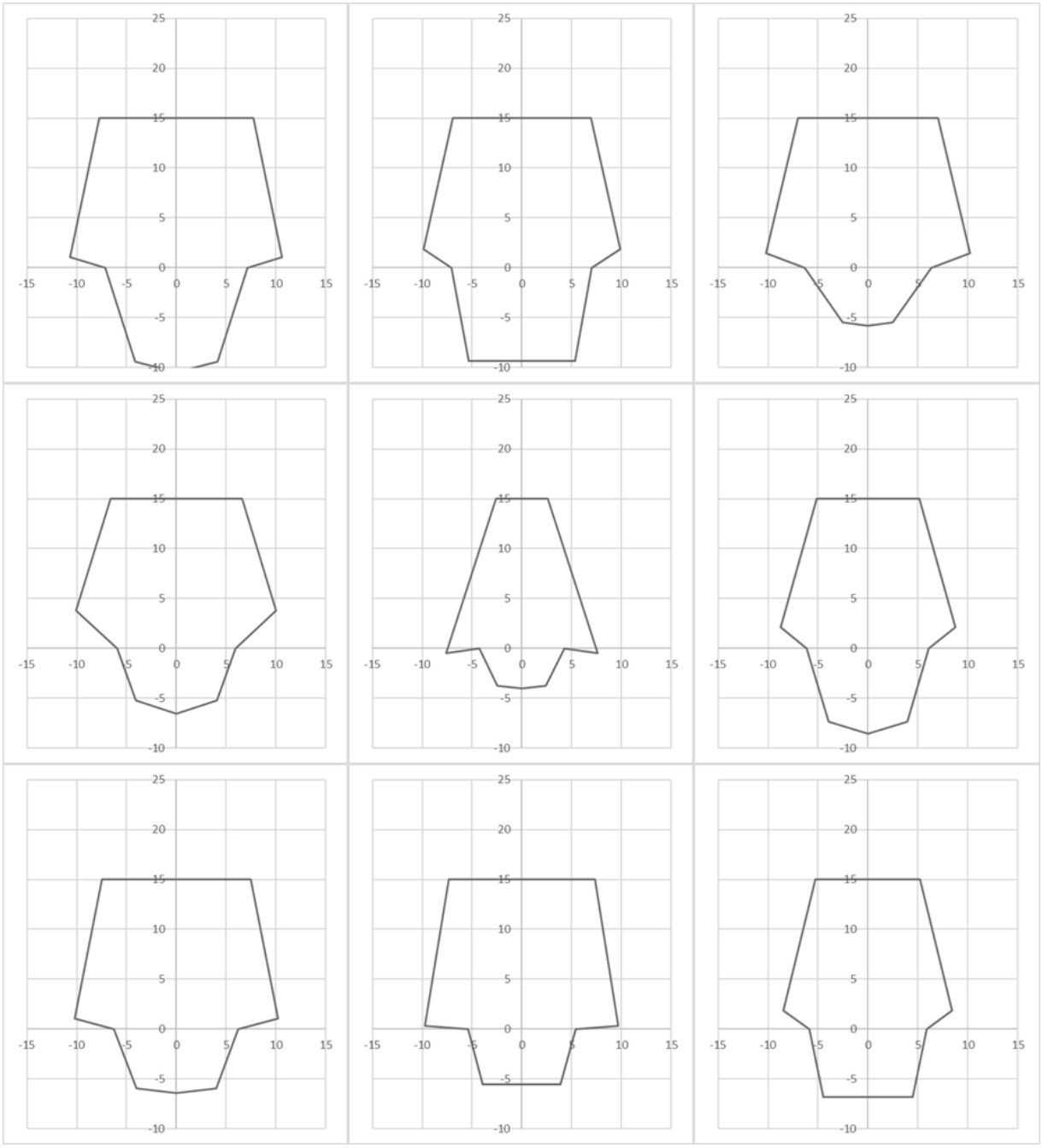

Figure 6f. All Study Points, 9 Clusters

Table 4f. Distribution of Total Assemblage using 9 Clusters

Cluster	1	2	3	4	5	6	7	8	9
Gypsum Cave	0	0	4	0	0	0	0	0	0
OMS Series A	0	0	10	2	0	0	6	1	0
OMS Series B	0	0	0	1	0	0	3	1	0

OMS small point	0	0	0	0	8	0	0	1	0
Gatecliff Shelter	1	0	1	1	4	0	9	1	0
West-central Colorado	49	20	16	25	8	71	28	8	27

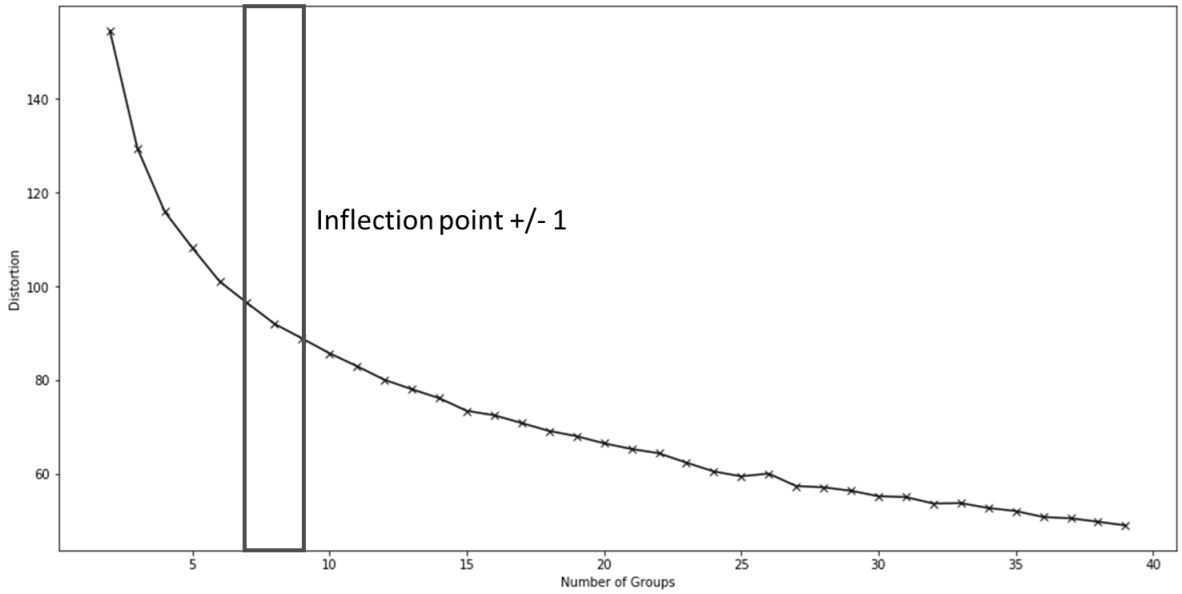

Figure 7: K-means Elbow Curve for All Projectile Points Used in this Study

To explore further how similar the Nevada points are to those from west-central Colorado, the Euclidean distance between the point and the centroid in the 20-dimensional space defined by the 20 parameters was used as a measure of how similar a point is to the average (centroid) for the cluster. If points from Nevada are spread throughout a cluster, those points can be considered very similar to the west-central Colorado points. However, if they are much farther from the centroid than most of the points in the cluster they are more likely to be separated from that cluster in subjective visual grouping. Table 5 gives the average distance from the centroid for the whole cluster for all Nevada points and for all west-central Colorado points in each of the eight clusters in Figure 6E, divided (scaled) by the average distance. The closer the value is to 1, the closer the point is to the average for the cluster. In cluster 8, where there are only two Nevada points, both are well beyond the average distance from the centroid for that cluster. In cluster 5, the points from O'Malley Shelter and Gatecliff Shelter are closer to the average than those from Gypsum Cave, which are well beyond the average. In cluster 3, the single point from Gatecliff Shelter is closer to the centroid than those from O'Malley Shelter, which are very near the average. Table 5. Measure of the Average Distance from the Centeroid of Each Cluster

	West-central Colorado	Nevada	Gypsum Cave	OMS Series A&B	OMS small point	Gatecliff Shelter
Cluster 1	0.90	1.02	none	none	1.02	none
Cluster 2	1.00	1.05	none	none	none	1.05
Cluster 3	1.01	.95	None	0.98	none	0.84
Cluster 4	1.00	none	none	none	none	none

Cluster 5	0.98	1.02	1.24	0.92	none	1.04
Cluster 6	1.00	1.07	none	1.07	none	none
Cluster 7	0.94	1.08	None	1.04	None	1.10
Cluster 8	0.98	1.27	None	1.31	none	1.24

DISCUSSION

The cluster analysis of the points from Nevada seems to indicate that Gypsum Cave points and some of the points from O'Malley Shelter are morphologically different from the points from Gatecliff Shelter and another group of points from O'Malley Shelter. These results may be partially due to the small number of points representing Gypsum Cave, or it could indicate two morphological variants represented by Gypsum Cave and Gatecliff Shelter, both of which occur at O'Malley Shelter. It is tempting to hypothesize the existence of two different groups of people, each having a different variant of contracting stem point and each having used O'Malley Shelter. Certainly, analysis of points from more sites around and between the three used in this analysis might further inform this hypothesis.

When the Nevada and Colorado points are combined, it is immediately clear from the cluster analysis that those from Nevada are more like each other than they are like the points from west-central Colorado. Separating the points into more clusters appears to maintain the distinction between Gypsum Cave and Gatecliff Shelter as well as indicating that roughly half of the larger contracting stem points from O'Malley Shelter are associated with each of the other two clusters. All of the small contracting stem points from O'Malley Shelter are distinguishable from the rest of the contracting stem points from Nevada and are grouped with only 3% of the points from west-central Colorado.

CONCLUSIONS

This analysis clearly shows that the majority of contracting stem points found in west-central Colorado are morphologically different from those at Gypsum Cave, O'Malley Shelter, and Gatecliff Shelter in Nevada. The analysis also indicates that only approximately 20% of the points from west-central Colorado are contained in the clusters which include the majority of contracting stem points from Nevada.

As with any analysis, new questions arise. These questions are (1) Are the stemmed points on the western slope of west-central Colorado indigenous to that area, and if not, from where were they introduced? (2) Did the west-central Colorado contracting stem points spread to other areas? (3) Were the few points that are similar to the various contracting stem points in Nevada traded, curated, replicated, or transported into the west-central Colorado area? (4) Are there at least two variants of the larger contracting stem points in Nevada? (5) If there are variants, what are their temporal and spatial distributions? These questions can be informed by lithic materials and sources as well as analysis of projectile points similar to that presented here, as well as adding associated chronological information from many more sites throughout the Great Basin and western Colorado. Such an analysis could extend into at least the western parts of the Great Plains.

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