Expanding the Geochemical Database for Virginia Jasper Sources

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Abstract

Instrumental neutron activation analysis (INAA) has been performed on 101 samples of jasper from Virginia. The study includes geological samples from five geological localities and artifacts from six different archaeological sites. Geological samples available for this study came from Brook Run (15), Flint Run (20), Bonifant (16), Rockbridge (20), and Virginia Beach (20). Ten artifacts were obtained from multiple sites located on Fort Pickett and from Maycock's Point (44PG40). The source data were examined to identify elemental differences that could be used to differentiate between individual sources. The artifact data were then projected against the source groups to determine the most probable sources. Assignments of the artifacts to geological sources were successfully made for 80% of the archaeological samples.

Introduction

Throughout prehistory in the Eastern United States the extraction and distribution of resources varied in response to population consumption levels, political agendas, and to changes in the ecological structure of the resource base. The trade and exchange of resources is one strategy that responds to the need for commodities and esoteric items that help keep communities intact. In a much-reference paper, Stewart (1989) recognizes two broad forms of exchange. The first is characterized as a *broad-based* exchange network where exchange between people or communities occurs in a down-the-line manner through an interconnected web of relationships. The second form is referred to as *focused* network exchange and categorizes communities that acquire objects from broad-based networks outside of their territory or home range and hoard the objects for their own use or consumption. Focused exchange can play a significant role in more complex chiefdom societies where exotics are used to legitimize social position and political office (Helms 1979; Earle 1997). However, it is also found in less complex organizations such as the Hopewell core area where the gift giving of exotic items was used to bind together dispersed and segmented tribal societies after long periods of

separation (Yerkes 2002). Through the study of jasper distributions we hope to gain additional insights into the various forms of the prehistoric exchange process.

The focus of this paper is to develop a statistical solution for source provenience investigations of jasper artifacts recovered from archaeological sites in the southern part of the middle Atlantic region. Once this baseline information has been established it will be possible to address the forms and temporal variation in prehistoric exchange within Virginia. Here, we present new results on the chemical analysis of five Virginia sources by instrumental neutron activation analysis (INAA) and show how the unique composition of geological sources in different regions can be used to establish characteristic chemical signatures.

Previous Research

The chemical characterization of jasper sources has continued for more than a quarter century and has become increasingly broad in scope and sophisticated in the treatment of analytical data. This has been paralleled by the discovery of new jasper deposits that brings the total documented number to 27 sources that extend from Nova Scotia to Virginia (Table 1; Figure 1). Most of the jasper deposits can be characterized as point sources that consist of discreet surface exposures made accessible by geological uplift and surface erosion. In two instances, the closely spaced deposits have been grouped into the regional source areas of the Reading Prong (Anthony and Roberts 1988; Hatch 1994) and the Iron Hill/Chestnut Hill complexes (Cunningham 2005). A second source type consists of terrain sources characterized by secondarily deposited water-worn nodules in river sediments. The deposits in the vicinity of Virginia Beach along the shores of the Chesapeake Bay is one such example.

In the earliest provenance investigation of eastern U.S. jaspers, Blackman (1974) contrasted the chemistry of the Reading Prong sources with that of Iron Hill as determined by atomic absorption and flame emission spectrophotometry. He found that the two regions were easily differentiated as a result of the non-overlapping concentration ranges of Na, K, Cr, Ni, Co, Fe, and Rb. This initial effort was followed by the pioneering work of Miller (1982) who conducted INAA analysis of seven jasper sources that included the newly recognized Houserville jasper quarry in Central Pennsylvania. Discriminant analysis of the data set indicated that all jasper bearing regions could be successful partitioned. However, within the Reading Prong misclassifications were present between the Lyons, Macungie and Vera Cruz quarries. A follow-up study to this research indicated that twenty archaeological unknowns from the Kinport Site (Miller 1987) could be confidently assigned to the Houserville, Vera Cruz, Flint Run and Iron Hill sources. Also during this period, Luedtke (1987) contrasted the chemistry of the Lime Rock, RI, and Reading Prong jaspers and was able to successfully partition the two source areas using a simple bivariate plot of cobalt versus lanthanum. The assignment of archaeological unknowns from sites in Massachusettes using the same approach prompted her to hypothesize that many artifacts originated from the Reading Prong and made their way to New England during the late Middle Woodland Period.

A few years later, an additional project involved the analysis of 20 jasper locations (n=266) from the Reading Prong region, the Houserville/Branch Road source area, Iron Hill, and Flint Run using X-ray fluorescence (XRF) analysis (Stevenson et al. 1992). The results were complementary to the work of Miller (1982) in that the regional source areas could be statistically discriminated, but that individual sources within the Reading Prong did not have discreet chemical signatures. This led to a significant number of misclassifications in the discriminant analysis that was improved upon by grouping the quarries in the Reading Prong into four subgroups based upon spatial proximity.

A subsequent study by King and Hatch (1997) use a portion of the XRF data set of Stevenson et al. (1992) representing 12 quarries (n=158) in the middle Atlantic region. They also processed an additional 80 archaeological samples derived from sites located from southern Virginia to Maine. The intent of study was to document the geographic range of Pennsylvania jaspers and to evaluate the initial observations of Luedtke (1987) that Pennsylvania jaspers were represented in New England archaeological assemblages. The researchers were able to improve upon the discriminant solution of Stevenson et al. (1992) by transforming the raw data so that is more closely met the assumption of normality required by the statistical procedure. The observed versus predicted classifications could distinguish each of the regional source groupings within Pennsylvania and Delaware. However, a significant number of misclassifications (10 of 29) were made between the Flint Run source and the Reading Prong source areas.

The 80 archaeological specimens were assigned to three of the source groups: Reading Prong (n=20), Houserville/Branch Road (n=7) and Flint Run (n=54). No artifacts were assigned to Iron Hill. In their consideration of the results King and Hatch (1997) explain the absence of Iron Hill assignments from the small number of source samples that did not represent the full source chemical variability and thus hindered the ability of the algorithm to make a classification. The assignment of a large number of artifacts to the Flint Run source was also problematic and was interpreted to be a result of undocumented sources within the archaeological assemblage.

The conclusions of King and Hatch (1997) appear to be correct. Since their work was published five new jasper sources have been discovered within Virginia (Table 1). All of them are located to the south of Flint Run and are found in the Coastal Plain, Piedmont or foothills of the Blue Ridge (Figure 1). Only one of the quarries has been systematically investigated. Extensive excavations at the Brook Run site (44CU122) revealed high-quality jasper that was heavily exploited during the Early Archaic period (10000-8500 BP). INAA analysis of a sample of the artifacts (n=15) was also completed under the same study (Monaghan et al. 2004). The remaining four sources have not been systematically investigated or chemically characterized until now. Intriguing is the possibility that if the Virginia sources account for a sizable proportion of the Flint Run source assignments of King and Hatch (1997), it suggests that Virginia was a core area for the distribution of jasper into the northern middle Atlantic region.

For this paper, we conduct INAA on geologic samples obtained from four jasper quarries (Bonifant, Flint Run, Rockbridge, Virginia Beach) and incorporate the previously reported data from Brook Run (Monaghan 2004) to develop a regional data set for Virginia sources. Also included in this analysis are ten archaeological unknowns from southern Virginia sites that will be used to evaluate the potential for source group assignments. Based upon the distributional analysis of jaspers by Hatch and Maxham (1995) in Pennsylvania, it is likely that the vast majority, 80%, of artifacts within a region are discarded less than 160 km from the source. Therefore, if our discriminant solution is successful, we can expect that eight of our eleven unknowns will be assigned to a geological source within Virginia.

Geological and Archaeological Contexts

Geological

The jasper deposits used in this analysis here have the following geological contexts (USGS 1993):

Bonifant: Located near Macon, Virginia, in the eastern Piedmont, this is a point source associated with a formation of porphyoblastic garnet-biotite gneiss.

Brook Run: This point source is found in the subsided intrusive volcanic and metamorphic rocks of the Triassic Culpeper Basin. Multiple north-south trending faults are contained within the basin and the quarry is associated with one of these faults where siltstone and sandstone deposits interface (Monaghan 2004).

Flint Run: A point source in the northern Shenandoah Valley located at a zone of contact between the Beekmantown carbonates and Blue Ridge formations.

Rockbridge: Located in Arnold's Valley within the Blueridge Mountains, this point source is found within the Chilhower Group of the Blue Ridge Anticlinorium; a formation of conglomerate, quartzite, and metasiltstone-phyllite.

Virginia Beach: This terrain source, located near the entrance to the Chesapeake Bay, is associated with the Tabb formation; a pebbly sand that grades up to muddy, fine grained sand and sandy silt.

A sixth source known as Beasley Bay has been reported (Lowrey 2003) but no samples were available for analysis. This is a terrain source of small pebbles contained within the Kent Island Formation on the eastern shore of Chesapeake Bay. This is a medium to coarse-grained sand and sandy gravel with well-sorted finely grained sand.

Archaeological

Ten jasper samples were obtained from six archaeological sites within two distinct regions. Four artifacts were from Maycock's Point (44PG40) and six jasper samples were collected from the Fort Pickett Maneuver Training Center (MTC) (Table 2). These specimens were collected from five sites and one survey location within Nottoway and Dinwiddie Counties. The provenience information for each of these samples is described below.

Maycock's Point (44PG40)

Four jasper flakes (DHR-431 to DHR-434) were selected from the shell midden deposits at Maycock's Point (44PG40), a Middle Woodland site located along the shore of the James River in Prince George County, eastern Virginia (Figure 1). Previous research at this site by C.G. Holland (Holland n.d.), The College of William and Mary (Barka and McCary 1977; Opperman 1980), and Anthony Opperman (Opperman 1992), have documented the presence of an extensive shell midden that is up to 90 cm deep. This prehistoric occupation dates to between AD 245+/-90 and AD 875+/-90. Excavations have revealed nine distinct strata of shell, burned shell, and soil that contain high densities of cultural material and perishable faunal and botanical remains. The earlier analyses of the Maycock's ceramic assemblage indicate that Middle Woodland Mockley Ware predominates and that only very small percentages of Early Woodland and Late Woodland materials are present. The jasper artifacts came from Units A3, Level B1 (10-15 cm bgs) and A4, Level G1 (45-50 cm bgs).

44DW305

Two jasper artifacts were recovered from site 44DW305 (DHR-333, DHR-335). The site is a Late Archaic and Early-Middle Woodland procurement site located on a small knoll at an elevation of 77 m (250 feet) AMSL, 70 m (230 feet) northeast of a small, unnamed intermittent creek. No jasper artifacts were recovered during the Phase I survey of site 44DW305, and only two were collected during Phase II evaluation. Both artifacts came from Test Unit 4, with the first specimen (specimen #402.4) provenienced to the upper Ap-horizon at 11-13.5 cm below datum while the second (specimen #410.2) was recovered from the lower Ap-horizon at 22-30 cm below datum. These samples were in association with quartz-tempered pottery of cordmarked surface treatment and flakes made of rhyolite, diabase, and quartz. Both of the jasper specimens were tertiary reduction flakes.

44DW308

The jasper specimen from site 44DW308 (DHR-330) was collected from Shovel Test CE23. The site is located on a slight northeast-facing ridge at an elevation of 97 m (315 feet) AMSL, and 46 m (150 feet) east of an unnamed intermittent creek. The single jasper artifact was recovered from the Ap-horizon and was the only artifact recovered from within Shovel Test CE23. Other shovel tests excavated within this site yielded quartzite, quartz, and crystal quartz flakes. Like the specimens described above, the

jasper artifact from site 44DW308 is a tertiary reduction flake. As no diagnostic artifacts were recovered from this site, the temporal affiliation is not known.

44NT62

Site 44NT62 was identified from visible artifacts on the ground surface as a result of plowing. The site is located on the crest of a small northeast-southwest-trending ridge nose at an elevation of 131 m (435 feet) AMSL and overlooks a small, unnamed tributary of Tommeheton Creek located at a distance of 450 m to the southeast. All artifacts were surface collected and included, in addition to a jasper endscraper (DHR-331), a metavolcanic Morrow Mountain projectile point, two unidentified quartz bifaces, and several pieces of quartz debitage. The presence of the Morrow Mountain point type suggests a Middle to Late Archaic period occupation at site 44NT62.

44NT78

One jasper artifact (DHR-334) was collected during a Phase II evaluation of 44NT78 conducted in the summer of 2004. This Transitional-Late Archaic-Early Woodland site is located on a knoll at an elevation of 74 m (235 feet) AMSL overlooking a small, unnamed intermittent creek 24 m (80 feet) to the south. The age assignment is based on the presence of both steatite vessels and sand/grit tempered, predominantly fabric impressed (73% of identified sherds) ceramics. The jasper specimen was a tertiary reduction flake, recovered from the B-horizon in Test Unit 8, at a depth of 10-20 cm below datum. Also recovered from the same stratum, level, and quadrant of this unit was a chert projectile point provisionally identified as Merom (800 B.C. to A.D. 1), flakes of diabase, quartz, quartzite, rhyolite, and three steatite bowl fragments.

Site 2004.2

Site 2004.2 is located on a broad ridge top at an elevation of 105 m (333 feet). Small drainages descend from the landform and feed Birchin Creek. Archaeological debris occurs within a 200 x 300 m area and consists of a continuous low-to-moderate density distribution of artifacts within the plowzone. Diagnostics from the site reveal occupations during the Early and Late Archaic. An Early Archaic Palmer point with a missing base was recovered through shovel testing. The point was manufactured from light-brown jasper.

Analytical Methods

The source samples and artifacts were washed in de-ionized water to remove all possible dirt and other loose materials from the surface. Samples for INAA were prepared by placing the source specimens between two tool steel plates and crushing them with a Carver Press to obtain a number of small 50-100 mg fragments. The fragments were examined under a magnifier to eliminate any with metallic streaks or crush fractures that could possibly contain contamination. Several grams of clean fragments were obtained from each sample and stored temporarily in plastic bags.

Two separate analytical samples were prepared from each source and artifact specimen. The first sample used for short irradiations was made by placing about 200 mg of fragments into clean high-density polyethylene vials. A second sample used for long irradiation and weighing about 800 mg was placed in clean high-purity quartz vials. Individual sample weights were recorded to the nearest 0.01 mg using an analytical balance. Both irradiation vials were sealed prior to irradiation. Standards made from the National Institute of Standards and Technology (NIST) certified standard reference materials SRM-1633a (Coal Fly Ash), SRM-278 (Obsidian Rock), and SRM-688 (Basalt Rock) were similarly prepared.

Irradiation and Gamma-ray Spectroscopy

Instrumental neutron activation analysis (INAA) of archaeological materials at MURR, which consists of two irradiations and a total of three measurements of emitted gamma rays, constitutes a superset of the procedures employed at most other INAA laboratories. As discussed in detail in Glascock (1992), a short irradiation is carried out through the pneumatic-tube irradiation system. Samples and standards in polyethylene vials are sequentially irradiated, in pairs, for five seconds by a thermal neutron flux of 8 x 10^{13} n cm^{-2} s^{-1}. Following irradiation, the samples undergo decay for 25 minutes so that radioactivity from the short-lived radioisotope ^{28}Al (half-life = 2.24 min) is reduced to an acceptable level for sample handling. The sample vials are mounted in sample holders at a distance of 10 cm from the face of separate high-purity germanium (HPGe) detectors. The sample holders are designed to continuously rotate the samples during a 12-min counting period in order to compensate for slight differences between individual sample shapes. The short-count, gamma-ray spectra are stored and subsequently analyzed in batches to determine the concentrations of elements in the unknown archaeological samples relative to the known concentrations in the standard reference materials. The short-lived elements measured are aluminum (Al), calcium (Ca), dysprosium (Dy), potassium (K), manganese (Mn), sodium (Na), titanium (Ti), and vanadium (V). A few of the elements are below detection in some of the samples.

The long irradiation samples and standards in high-purity quartz vials are wrapped in bundles of approximately 32 unknowns and six standards each. Two sample bundles are placed inside an aluminum can and irradiated for 70 hours by a thermal neutron flux of 5 x 10^{13} n cm^{-2} s^{-1}. Following irradiation, the sample bundles are unwrapped and the quartz vials are washed in aqua regia to remove possible surface contamination. Two separate gamma measurements are performed on the individual samples from each bundle using a pair of HPGe detectors coupled to automatic sample changers with rotating sample holders. The first measurement for 2,000 seconds (i.e., the "middle count") is usually made about one week after the end of irradiation after allowing ^{24}Na (half-life = 15 hr) to decay to a safe handling level. The middle count yields data for the determination of several medium half-life elements, including arsenic (As), barium (Ba), lanthanum (La), lutetium (Lu), neodymium (Nd), samarium (Sm), uranium (U), and ytterbium (Yb). After an additional three- or four-weeks of decay, a final measurement on each sample for three hours (i.e., the "long count") is carried out.

The latter measurement yields the data for several long-lived elements, including cerium (Ce), cobalt (Co), chromium (Cr), cesium (Cs), europium (Eu), iron (Fe), hafnium (Hf), nickel (Ni), rubidium (Rb), antimony (Sb), scandium (Sc), strontium (Sr), tantalum (Ta), terbium (Tb), thorium (Th), and zinc (Zn). Additional details about gamma-ray spectroscopy, neutron activation analysis, and standardization can be found in Glascock (1998).

The element concentration data from the three measurements were tabulated in parts per million using the EXCEL spreadsheet program. Descriptive data for the archaeological samples were appended to the concentration spreadsheet and the data were stored in a dBASE/FOXPRO database file useful for organizing, sorting, and extracting sample information.

Interpreting the Compositional Data

Interpretation of compositional data obtained from the analysis of archaeological materials is discussed in detail elsewhere (e.g., Baxter and Buck 2000; Bieber et al. 1976; Bishop and Neff 1989; Glascock 1998; Harbottle 1976; Neff 2000) and is only summarized here. The main goal of data analysis is to identify distinct homogeneous groups within the analytical database. Based on the provenance postulate of Weigand et al. (1977), different chemical groups may be assumed to represent geographically restricted sources. For lithic materials such as obsidian, basalt, and cryptocrystalline silicates (e.g., chert, flint, and jasper), raw material samples are frequently collected from known outcrops or secondary deposits and the compositional data obtained is used to define the source localities or boundaries. In contrast, the locations of ceramic raw materials are often inferred by comparing unknown specimens (i.e., ceramic artifacts) to knowns (i.e., clay samples) or by indirect methods such as the "criterion of abundance" (Bishop et al. 1992) or by arguments based on geological and sedimentological characteristics (e.g., Steponaitis et al. 1996). The ubiquity of ceramic raw materials usually makes it impossible to sample all potential "sources" intensively enough to create groups of knowns to which unknowns can be compared. Lithic sources tend to be more localized and compositionally homogeneous in the case of obsidian or compositionally heterogeneous as is the case for most cryptocrystalline silicates (e.g., chert, flint, and jasper).

Compositional groups are viewed as "centers of mass" in the compositional hyperspace described by the measured elemental data. Groups are characterized by the locations of their centroids and the unique relationships between the elements (i.e., correlations). Decisions about whether to assign a specimen to a particular compositional group are based on the overall probability that the measured concentrations for the specimen could have been obtained from that group.

Potential compositional groups can be hypothesized initially by using non-compositional information (e.g., archaeological context, visual attributes, etc.) or by application of one or more different pattern recognition techniques to the multivariate chemical data. Some of the pattern recognition techniques that have been used to

investigate archaeological data sets are cluster analysis (CA), principal components analysis (PCA), and canonical discriminant analysis (CDA). Each of the techniques has it own advantages and disadvantages for data interpretation that may depend upon the types and quantity of data available.

Whether a source group can be discriminated easily from other groups can be evaluated visually in two dimensions or statistically in multiple dimensions. A metric known as the Mahalanobis distance (or generalized distance) makes it possible to describe the separation between groups or between individual samples and groups on multiple dimensions. The Mahalanobis distance of a specimen from a group centroid (Bieber et al. 1976, Bishop and Neff 1989) is defined by the equation:

$$D^2_{y,X} = [y - \overline{X}]^t I_x [y - \overline{X}]$$

where y is the 1 x m array of logged elemental concentrations for the specimen of interest, X is the n x m data matrix of logged concentrations for the group to which the point is being compared with $\overline{X}$ being it 1 x m centroid, and I_x is the inverse of the m x m variance-covariance matrix of group X. Because Mahalanobis distance takes into account variances and covariances in the multivariate group it is analogous to expressing distance from a univariate mean in standard deviation units. Like standard deviation units, Mahalanobis distances can be converted into probabilities of group membership for individual specimens. For relatively small sample sizes, it is appropriate to base probabilities on Hotelling's T^2, which is the multivariate extension of the univariate Student's t.

When group sizes are small, Mahalanobis distance-based probabilities can fluctuate dramatically depending upon whether or not each specimen is assumed to be a member of the group to which it is being compared. Harbottle (1976) calls this phenomenon "stretchability" in reference to the tendency of an included specimen to stretch the group in the direction of its own location in elemental concentration space. This problem can be circumvented by cross-validation, that is, by removing each specimen from its presumed group before calculating its own probability of membership (Baxter 1994; Leese and Main 1994). This is a conservative approach to group evaluation that sometimes excludes "true" group members.

Results and Discussion

The INAA results were tabulated using the EXCEL spreadsheet program and combined with the descriptive data to create a database for sorting and extraction of subsets. In this study we determined that canonical discriminant analysis (CDA) was our best option for establishing differences between the known geological sources. Due to the large number of missing values for many of the elements, only 16 elements could be used satisfactorily: As, Ba, La, Sm, Yb, Ce, Co, Cr, Eu, Fe, Sb, Sc, Th, Zn, Mn, and Na (Appendix I). Data for the specimens from the six sources were log-transformed prior to

performing the CDA in order to reduce the possible "weighting effect" that occurs when high concentration elements such as Fe are compared to low concentration elements such as the REEs. A plot based on discriminant analysis of the geological specimens is shown in Figure 2 (CD function #1 versus CD function #2). The plot displays a reasonable degree of differentiation between the sources. The ellipses are calculated at the 90% confidence level for each source.

The discriminant functions determined from the source data were applied to the jaspers from Fort Pickett (44DW305, 44DW308, 44NT33, 44NT62, 44NT78) and Maycock's Point (44PG40) so that artifacts could be compared to the geological source groups. Figures 2 shows the artifacts projected against the source ellipses.

Mahalanobis distance based probabilities for membership of artifact specimens in the five geological source groups were calculated as shown in Table 3 using the cross-validation procedure discussed above. Using the information presented in Figure 2 and Table 3, it appears that we can be reasonably confident in stating that four of the six artifacts from Fort Pickett originated from the Bonifant source that is approximately 50 kilometers distant. These are samples: DHR-330, DHR-331, DHR-333, and DHR-336. Sample DHR-335 fell just outside of the 90% confidence ellipse for the Bonifant source while artifact DHR-334 has the highest probability of belonging to the Rockbridge group. All of the artifacts (DHR-431 to DHR-434) from Maycock's Point are linked to the Virginia Beach source (90 km distant) although DHR-433 has a lower probability that could place it within the Rockbridge source. These classifications resulted in the assignment of 80% (8 of 10) of the unknowns to a geological source and left 2 (20%) samples without a provenience assignment. This result is comparable to the results of Hatch and Maxham (1995) who observed that up to 80% of jasper samples in Pennsylvania were discarded within 160 km of the geological source.

Conclusions

Our study suggests that the major sources of jasper in Virginia can be differentiated from one another on the basis of INAA data and canonical discriminant analysis. Most artifacts from Fort Pickett, Virginia appear to be from the Bonifant source, and artifacts from Maycock's Point are most probably from Virginia Beach.

Acknowledgements

Table 1: Documented Jasper Sources in Delaware, Maryland, Pennsylvania and Virginia

Source Name	State/Province	Site Number	Source Type
Heath Farm	Delaware	18CE8	Point
Iron Hill Cut	Delaware	18CE65	Point
Iron Hill School	Delaware	7NC-D-34	Point
Cooch Complex	Delaware	7NC-D-108	Point
Choptank River	Maryland	--	Terrain
Point of Rocks	Maryland	--	Point
Cape May	New Jersey	--	Terrain
Stokes Co.	North Carolina	--	Point
Bay of Fundy	Nova Scotia	--	Point
Branch Road	Pennsylvania	36CE258	Point
Durham	Pennsylvania	36BU26	Point
Houserville	Pennsylvania	36CE238	Point
King's	Pennsylvania	36LH2	Point
Longswamp	Pennsylvania	36BK479	Point
Lyons	Pennsylvania	36BK15	Point
Macungie	Pennsylvania	36LH11	Point
Mast Farm	Pennsylvania	36LH37	Point
Urffer's Farm	Pennsylvania	36LH57	Point
Vera Cruz	Pennsylvania	36LH12	Point
Lime Rock	Rhode Island	--	Point
Monkton	Vermont	--	Point
Arnolds Valley	Virginia	44RB323	Point
Beasley Bay	Virginia	44AC136	Terrain
Bonifant	Virginia	44PO132	Point
Brook Run	Virginia	44CU122	Point
Flint Run	Virginia	44WR12	Point
Virginia Beach	Virginia	44VB5	Terrain

Table 2: Archaeological Jasper Artifacts Analyzed by INAA

Lab Number	Site Number	Provenience	Material	Cultural Context
DHR-330	44DW308	ST. CE23	Flake	Unknown
DHR-331	44NT62	Surface	Endscraper	Middle-Late Archaic
DHR-333	44DW305	402.4NE, S1, L.2	Flake	Late Archaic- Middle Woodland
DHR-334	44NT78	805.3, NE, Quad, L.2	Flake	Transitional-Middle Woodland
DHR-335	44DW305	410.2, SW Quad	Flake	Late Archaic-Middle Woodland
DHR-336	2004.2	Bag 15, 455N 500W	Palmer Point	Early Archaic
DHR-431	44PG40	Unit A3, L. B1	Flake	Middle Woodland
DHR-432	44PG40	Unit A3, L. B1	Flake	Middle Woodland
DHR-433	44PG40	Unit A3, L. B1	Flake	Middle Woodland
DHR-434	44PG40	Unit A4, L. G1	Flake	Middle Woodland

Table 3: Mahalanobis Distance Probabilities

ID No.	Bonifant	Brook Run	Flint Run	Rockbridge	Virginia Beach	Group
DHR-330	36.550	0.000	0.000	0.000	0.003	1
DHR-331	0.498	0.000	0.000	0.001	0.000	1
DHR-333	2.981	0.000	0.000	0.000	0.000	1
DHR-334	0.000	0.000	0.000	1.929	0.087	4
DHR-335	3.732	0.000	0.000	0.000	0.000	1
DHR-336	0.177	0.000	0.000	0.000	0.001	1
DHR-431	0.000	0.011	0.001	0.014	79.668	5
DHR-432	0.000	0.024	0.000	0.037	4.913	5
DHR-433	0.000	0.000	0.000	0.004	0.011	5
DHR-434	0.000	0.290	0.000	0.019	11.843	5

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Figure 1: Distribution of jasper sources (red) and locations of archaeological unknowns (yellow) in the middle Atlantic region
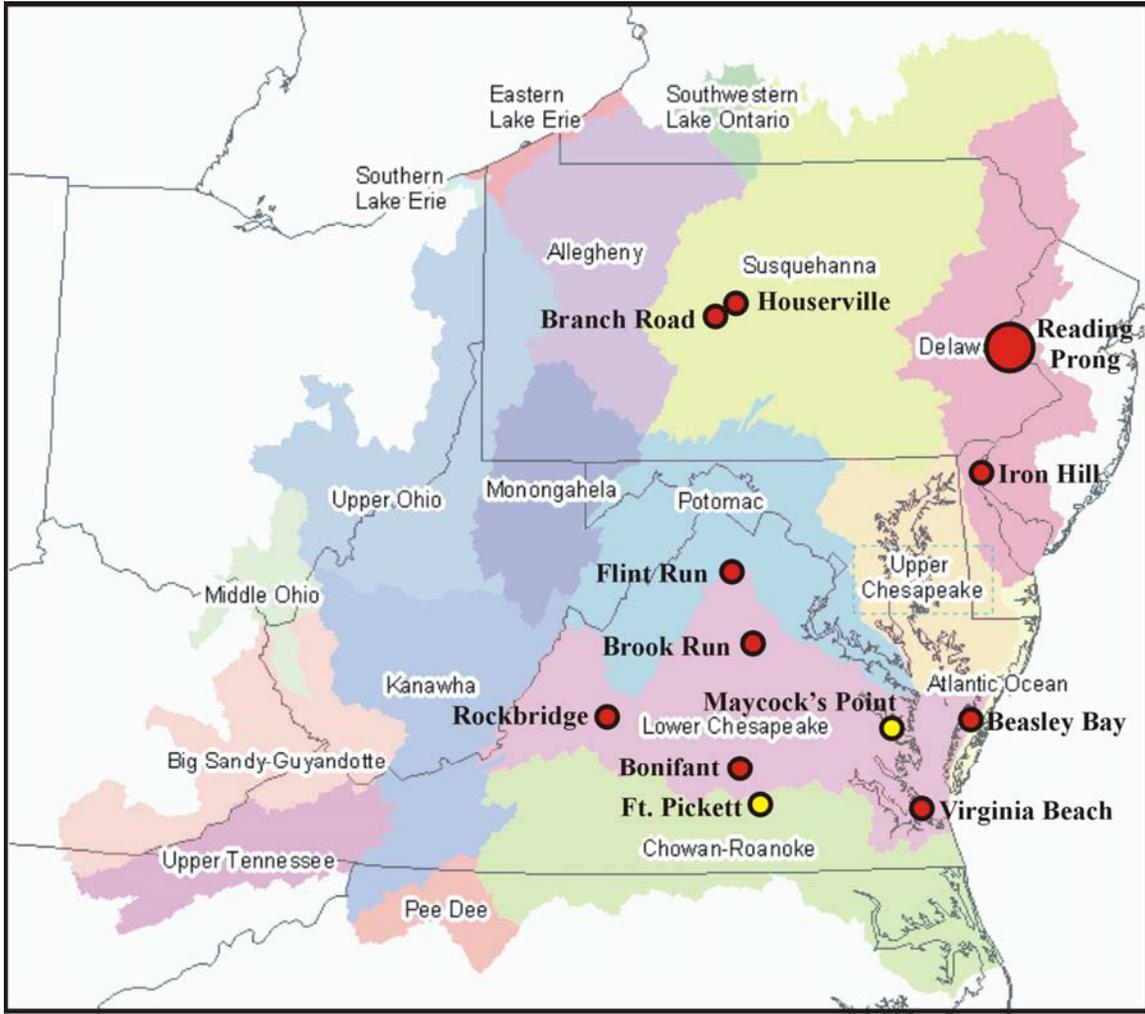
Figure 2: Plot of canonical discriminant functions 1 and 2 for Virginia jasper sources
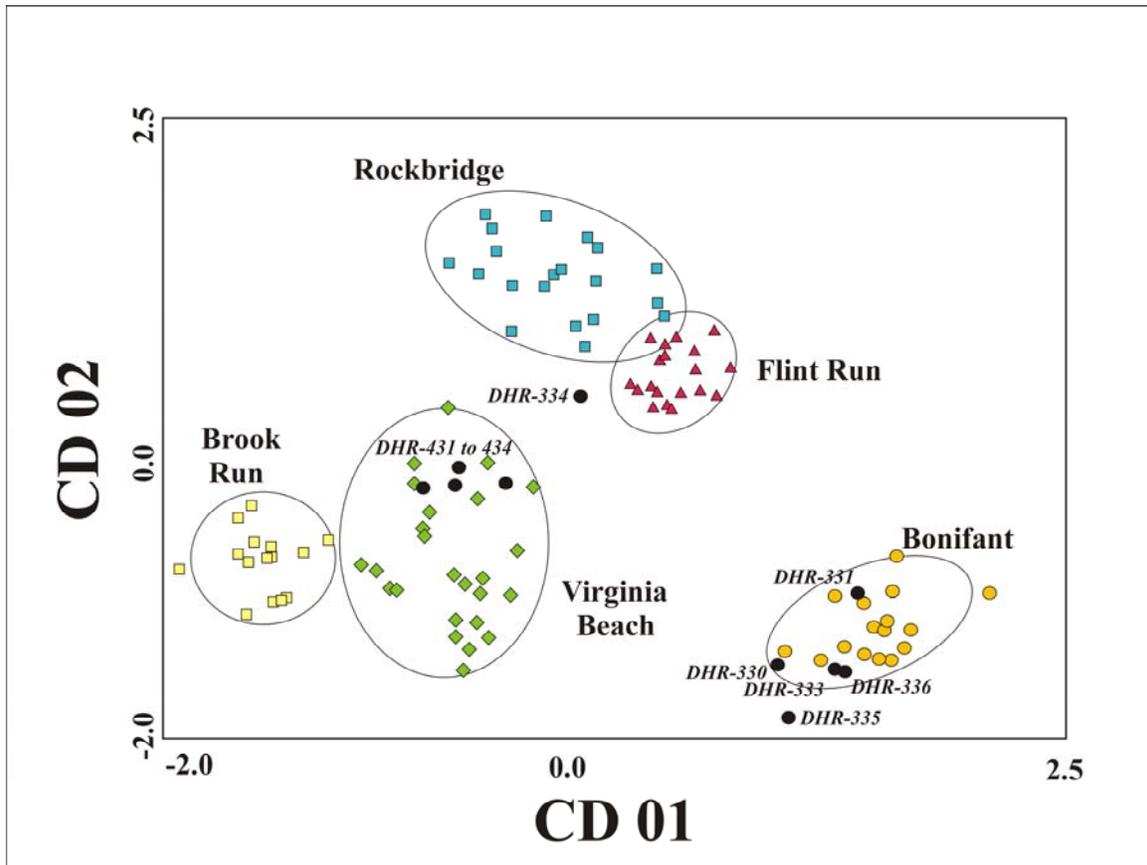
Appendix I: Elemental Data for Virginia Jasper Sources

Lab No.	Source/Site Name	As	Ba	La	Sm	Yb	Ce	Co	Cr	Eu	Fe	Sb	Sc	Th	Zn	Mn	Na
CHR001	Brook Run	25.29	23.1	1.395	0.468	0.455	2.086	0.834	0.295	0.142	21004	0.1	0.6	0.000	8.75	377.4	234.0
CHR002	Brook Run	33.81	0.0	0.644	0.546	0.741	1.466	0.620	1.422	0.197	18284	0.1	0.6	0.026	8.27	140.3	237.8
CHR003	Brook Run	24.21	20.7	0.722	0.261	0.297	0.793	0.571	0.303	0.082	20425	0.2	0.6	0.000	7.14	232.0	150.4
CHR004	Brook Run	34.56	31.7	1.267	0.668	0.632	2.436	0.745	0.686	0.212	17514	0.1	0.4	0.000	5.80	410.6	192.5
CHR005	Brook Run	19.53	11.7	0.645	0.449	0.535	1.763	0.652	0.819	0.140	15403	0.1	0.3	0.034	6.13	101.4	187.1
CHR006	Brook Run	15.27	29.8	2.171	0.610	0.589	2.532	2.444	1.966	0.178	24548	0.4	0.8	0.043	9.48	318.1	259.4
CHR007	Brook Run	20.04	12.5	0.433	0.146	0.133	0.847	0.457	0.193	0.041	14441	0.1	0.5	0.000	5.22	136.7	191.7
CHR008	Brook Run	20.78	0.0	0.434	0.143	0.147	0.891	0.580	0.565	0.041	15999	0.1	0.7	0.048	6.98	126.8	198.4
CHR009	Brook Run	31.01	0.0	1.397	0.519	0.397	1.966	0.681	0.777	0.157	24505	0.1	0.4	0.019	11.17	66.1	198.5
CHR010	Brook Run	15.59	14.5	1.403	0.533	0.730	2.161	2.379	1.629	0.185	24337	0.3	1.1	0.196	10.81	324.2	257.6
CHR011	Brook Run	19.70	38.1	0.785	0.428	0.416	1.636	0.788	0.477	0.129	21795	0.3	0.5	0.000	7.19	256.7	231.8
CHR012	Brook Run	20.73	0.0	0.248	0.165	0.211	0.435	0.462	0.359	0.049	15558	0.0	0.6	0.000	7.96	72.6	183.6
CHR013	Brook Run	8.81	20.7	0.443	0.424	0.616	0.798	1.346	0.908	0.145	18830	0.2	0.7	0.000	5.64	613.6	278.9
CHR014	Brook Run	19.30	22.8	0.448	0.244	0.137	0.502	0.436	0.301	0.057	15855	0.1	0.2	0.000	5.33	269.0	191.8
CHR015	Brook Run	12.20	6.9	0.476	0.459	0.639	1.001	0.872	0.871	0.153	17245	0.3	0.4	0.000	4.69	491.3	240.0
DHR246	Bonifant #4	0.00	19.1	2.860	0.495	0.129	1.112	0.620	0.933	0.095	8638	0.0	0.1	0.047	2.30	19.7	105.3
DHR247	Bonifant #4	0.00	0.0	0.992	0.220	0.227	0.000	9.344	1.386	0.047	59400	0.0	0.1	0.049	28.31	81.5	130.3
DHR248	Bonifant #4	0.00	0.0	1.331	0.465	0.254	0.000	1.843	0.000	0.086	15534	0.0	0.1	0.000	4.39	35.9	99.1
DHR249	Bonifant #4	0.00	0.0	1.751	0.395	0.221	0.972	4.714	0.378	0.087	29595	0.0	0.1	0.000	13.02	32.2	98.4
DHR250	Bonifant #4	0.00	0.0	0.630	0.136	0.107	0.555	1.817	0.667	0.027	9974	0.0	0.1	0.019	5.66	54.4	140.2
DHR251	Bonifant #4	0.00	33.3	0.732	0.151	0.102	0.605	2.030	0.807	0.030	15348	0.0	0.1	0.041	6.85	15.9	90.7
DHR252	Bonifant #4	0.00	14.3	0.649	0.164	0.102	0.000	4.505	0.338	0.033	27326	0.0	0.1	0.000	11.56	16.2	102.1
DHR253	Bonifant #4	0.00	0.0	0.806	0.192	0.096	1.154	1.813	0.923	0.032	12486	0.0	0.1	0.070	3.41	6.6	117.3
DHR254	Bonifant #4	0.46	0.0	0.829	0.180	0.128	1.197	1.761	0.668	0.034	11337	0.0	0.1	0.040	4.94	20.6	105.6
DHR255	Bonifant #4	0.12	39.7	0.623	0.158	0.080	0.700	1.606	0.812	0.024	10071	0.0	0.1	0.027	7.20	67.9	142.1
DHR256	Bonifant #4	0.33	8.1	0.761	0.144	0.089	0.847	1.466	0.422	0.027	9703	0.0	0.0	0.046	5.48	21.7	86.9
DHR257	Bonifant #4	0.11	29.9	0.297	0.090	0.078	0.480	1.452	0.804	0.014	10751	0.0	0.0	0.015	5.30	19.4	103.6
DHR258	Bonifant #4	0.00	11.1	1.122	0.335	0.171	1.300	2.672	0.685	0.063	19903	0.0	0.0	0.023	8.84	27.3	107.1
DHR259	Bonifant #4	0.00	8.8	1.127	0.326	0.133	1.031	1.437	1.167	0.072	12592	0.0	0.1	0.068	4.85	20.9	86.1
DHR260	Bonifant #4	0.13	39.2	0.866	0.172	0.119	1.043	2.418	0.836	0.035	13724	0.0	0.1	0.062	8.79	128.2	120.6

DHR261	Bonifant #4	0.29	82.7	1.020	0.208	0.182	0.846	3.251	0.991	0.042	21173	0.0	0.1	0.026	11.95	25.2	106.7
DHR262	Flint Run	0.95	4.6	0.230	0.055	0.037	0.360	0.638	3.907	0.012	10576	0.0	0.2	0.025	19.17	135.9	73.4
DHR263	Flint Run	0.77	0.0	0.197	0.035	0.026	0.208	0.486	0.149	0.008	8838	0.0	0.1	0.000	16.00	104.7	72.5
DHR264	Flint Run	0.27	0.0	0.086	0.029	0.010	0.134	0.234	0.921	0.005	10977	0.1	0.0	0.005	3.23	15.4	114.0
DHR265	Flint Run	0.28	3.3	0.121	0.034	0.016	0.234	0.312	1.439	0.006	15175	0.1	0.0	0.000	4.62	19.8	94.5
DHR266	Flint Run	0.33	0.0	0.119	0.033	0.000	0.180	0.279	1.115	0.006	15894	0.1	0.0	0.000	4.94	17.7	94.3
DHR267	Flint Run	0.44	3.9	1.725	0.273	0.095	1.840	0.275	0.910	0.065	1754	0.0	0.1	0.054	5.81	12.2	79.9
DHR268	Flint Run	0.56	5.4	1.314	0.201	0.080	1.714	0.543	1.125	0.057	7196	0.0	0.1	0.056	16.84	10.8	82.8
DHR269	Flint Run	0.57	6.9	2.451	0.295	0.075	3.005	0.511	1.439	0.071	2994	0.0	0.1	0.089	9.53	19.9	112.5
DHR270	Flint Run	0.27	16.4	1.207	0.501	0.125	2.443	0.679	0.595	0.117	6665	0.0	0.3	0.073	7.58	28.6	86.3
DHR271	Flint Run	0.55	5.3	0.213	0.092	0.109	0.548	0.936	0.535	0.021	10566	0.0	0.3	0.024	20.88	48.0	93.1
DHR272	Flint Run	1.06	107.2	11.479	5.243	0.900	22.376	2.234	3.376	1.171	15914	0.0	0.6	0.335	34.27	93.8	93.1
DHR273	Flint Run	0.27	15.3	0.266	0.263	0.154	0.820	0.767	0.365	0.065	6745	0.0	0.2	0.043	8.51	22.7	64.8
DHR274	Flint Run	0.76	6.6	0.197	0.106	0.428	0.440	2.755	0.524	0.028	19633	0.0	0.3	0.017	27.29	97.3	81.4
DHR275	Flint Run	1.03	5.5	0.116	0.064	0.362	0.391	4.269	0.624	0.018	27778	0.1	0.3	0.000	35.49	175.5	61.1
DHR276	Flint Run	0.53	8.2	0.081	0.048	0.297	0.179	2.034	0.371	0.015	13829	0.1	0.3	0.000	19.24	145.1	74.9
DHR277	Flint Run	1.56	13.8	0.157	0.084	0.276	0.449	6.589	1.218	0.024	37489	0.1	0.4	0.017	54.70	156.6	69.5
DHR278	Flint Run	1.22	878.9	38.054	28.398	1.904	98.370	7.181	9.134	7.229	28211	0.0	1.2	0.823	43.29	197.5	155.7
DHR279	Flint Run	1.65	1456.6	60.504	45.097	3.369	166.850	5.245	14.461	12.549	31767	0.0	1.8	1.237	59.42	112.9	163.9
DHR280	Flint Run	1.26	404.9	15.674	11.985	0.837	38.013	3.172	4.434	2.858	20434	0.0	0.8	0.444	28.61	161.8	95.2
DHR281	Flint Run	2.83	704.5	27.895	19.620	1.126	66.653	9.153	8.364	4.795	62638	0.1	1.8	0.268	65.01	192.9	132.1
DHR339	Rockbridge	3.63	30.0	0.651	0.172	0.071	0.920	1.003	1.223	0.025	27077	0.2	0.2	0.109	17.59	62.5	90.3
DHR340	Rockbridge	4.45	17.5	1.829	0.359	0.205	2.575	0.595	2.472	0.066	19307	0.2	0.4	0.223	41.08	36.7	93.9
DHR341	Rockbridge	17.23	4210.2	2.745	0.752	0.261	12.809	10.772	0.560	0.123	30591	0.3	0.8	0.014	38.67	24096.5	0.0
DHR342	Rockbridge	12.61	7.3	1.190	0.355	0.202	2.000	0.714	1.489	0.068	37116	0.2	0.2	0.133	25.43	396.0	83.4
DHR343	Rockbridge	13.90	445.2	0.389	0.086	0.034	0.501	1.348	0.587	0.009	16094	0.0	0.0	0.013	10.40	5854.6	22.0
DHR344	Rockbridge	1.72	11.3	0.582	0.235	0.112	1.174	1.144	1.245	0.028	32152	0.3	0.2	0.000	26.25	77.5	107.5
DHR345	Rockbridge	3.51	13.5	0.434	0.212	0.101	0.652	1.107	1.335	0.025	39144	0.3	0.1	0.013	33.30	40.3	96.1
DHR346	Rockbridge	0.89	8.7	1.027	0.154	0.044	0.786	0.335	0.692	0.022	7637	0.1	0.1	0.045	9.84	23.6	83.7
DHR347	Rockbridge	10.59	10.1	1.225	0.395	0.254	2.125	1.634	3.777	0.076	44227	0.4	0.4	0.479	24.45	106.9	97.1
DHR348	Rockbridge	1.24	15.5	1.106	0.277	0.164	2.008	0.226	0.481	0.043	4234	0.1	0.1	0.053	10.02	45.0	94.9

DHR349	Rockbridge	0.84	16.3	2.314	0.817	0.344	2.847	0.263	0.353	0.143	2744	0.6	0.2	0.036	7.18	36.9	99.5
DHR350	Rockbridge	10.35	256.6	68.498	11.584	1.470	133.842	0.703	7.280	2.510	49009	0.4	1.4	0.706	26.23	458.9	151.6
DHR351	Rockbridge	9.90	106.9	94.481	8.615	0.569	76.036	0.876	2.337	1.612	27756	0.2	0.7	0.069	43.37	249.6	234.7
DHR352	Rockbridge	2.57	75.4	2.545	0.449	0.124	2.629	0.439	4.814	0.081	13704	0.1	0.3	0.122	34.99	44.4	89.5
DHR353	Rockbridge	29.25	36.7	1.274	0.381	0.098	2.121	0.874	1.456	0.042	28100	0.4	0.1	0.066	23.57	2464.8	113.2
DHR354	Rockbridge	4.79	32.1	0.758	0.162	0.091	1.411	0.392	1.359	0.033	15805	0.2	0.3	0.141	49.57	13.4	83.4
DHR355	Rockbridge	9.64	30.0	3.889	0.494	0.140	7.020	0.632	3.290	0.092	27450	0.2	0.2	0.071	23.28	359.1	100.1
DHR356	Rockbridge	6.64	15.3	0.816	0.332	0.186	1.401	1.875	1.226	0.064	51290	0.2	0.1	0.027	27.63	643.7	76.5
DHR357	Rockbridge	11.03	43.5	4.049	0.894	0.256	6.830	2.808	13.123	0.156	68365	0.6	1.0	0.278	61.18	544.1	102.8
DHR358	Rockbridge	16.09	41.7	0.320	0.091	0.037	0.539	0.678	1.029	0.013	31687	0.2	0.1	0.035	16.68	1858.9	95.4
DHR411	Virginia Beach	0.44	6.9	7.979	2.936	0.867	11.067	0.237	2.567	0.808	1415	0.0	0.2	0.120	2.87	6.3	332.5
DHR412	Virginia Beach	3.10	20.7	0.256	0.208	0.074	1.186	0.349	0.214	0.017	5319	0.1	0.1	0.051	9.42	28.8	145.6
DHR413	Virginia Beach	4.93	279.9	0.584	0.150	0.060	1.099	2.732	1.369	0.031	13384	0.3	0.4	0.025	7.86	141.6	181.1
DHR414	Virginia Beach	2.21	206.7	3.753	0.917	0.279	8.693	1.942	3.320	0.218	10237	0.0	0.4	0.317	10.62	45.3	581.6
DHR415	Virginia Beach	3.30	104.9	5.157	1.975	0.527	8.671	1.473	4.085	0.486	5598	0.1	0.3	0.138	3.22	22.2	322.5
DHR416	Virginia Beach	6.26	72.0	1.567	0.550	0.283	3.833	5.335	1.428	0.135	18446	0.2	0.9	0.131	6.80	108.8	309.1
DHR417	Virginia Beach	4.25	189.3	22.645	3.080	0.603	40.500	0.681	8.608	0.656	7790	0.1	2.4	1.283	9.12	10.3	448.1
DHR418	Virginia Beach	8.80	362.2	3.252	0.418	0.146	4.897	1.465	6.848	0.100	10739	0.1	0.7	0.342	4.47	61.6	364.9
DHR419	Virginia Beach	20.49	176.9	8.712	1.461	0.677	12.911	8.295	31.548	0.320	29668	0.3	3.3	0.952	21.13	122.0	522.9
DHR420	Virginia Beach	4.97	835.4	1.778	0.226	0.114	2.342	1.498	13.696	0.045	6101	0.0	0.8	0.361	12.92	21.6	292.9
DHR421	Virginia Beach	0.57	20.9	0.307	0.122	0.064	0.629	0.364	0.432	0.029	2768	0.0	0.5	0.083	1.99	13.1	265.3
DHR422	Virginia Beach	1.27	790.2	1.073	0.162	0.116	1.800	0.654	1.178	0.034	3490	0.1	0.6	0.309	1.58	20.8	151.9
DHR423	Virginia Beach	11.43	366.8	14.925	3.550	1.130	34.009	11.672	4.532	0.876	19041	0.2	2.2	0.411	14.79	306.1	100.3
DHR424	Virginia Beach	1.25	90.1	0.915	0.211	0.063	1.521	0.466	1.596	0.048	2659	0.0	0.3	0.138	3.58	25.5	154.7
DHR425	Virginia Beach	3.80	2091.2	15.698	1.951	0.477	20.557	4.230	5.553	0.441	5134	0.1	1.2	0.835	4.69	29.4	232.7
DHR426	Virginia Beach	3.48	68.7	3.246	0.472	0.128	6.005	8.652	2.617	0.097	3800	0.0	0.2	0.249	4.04	17.9	154.3
DHR427	Virginia Beach	0.54	106.2	0.280	0.039	0.019	0.486	0.275	0.350	0.009	550	0.0	0.1	0.037	2.38	13.0	207.0
DHR428	Virginia Beach	0.50	219.2	0.503	0.078	0.047	0.682	0.111	2.078	0.015	566	0.1	0.3	0.151	1.49	1.0	185.9
DHR429	Virginia Beach	0.66	17.4	4.166	0.662	0.258	8.285	0.468	1.368	0.161	3026	0.1	0.8	0.041	6.31	7.7	211.6
DHR430	Virginia Beach	9.97	42.2	2.480	0.907	0.353	5.049	5.872	7.761	0.212	23920	0.2	2.5	0.291	11.10	239.3	218.8
DHR431	Maycock's Point	0.00	723.0	2.843	0.774	0.326	8.097	1.245	2.880	0.152	5811	0.3	1.3	0.327	8.68	36.7	198.8

DHR432	Maycock's Point	2.12	34.9	0.787	0.167	0.423	1.699	0.979	1.893	0.028	6077	0.2	0.2	0.163	12.88	63.8	293.3
DHR433	Maycock's Point	18.69	85.5	3.234	0.839	2.060	6.686	1.009	0.950	0.090	21856	0.3	0.2	0.113	12.30	439.4	253.7
DHR434	Maycock's Point	11.13	53.9	0.643	0.280	0.119	2.325	0.809	0.481	0.036	14407	0.1	0.1	0.125	7.07	334.7	201.3
DHR330	44DW308	0.39	0.0	0.336	0.092	0.084	0.565	1.007	0.891	0.015	16049	0.0	0.1	0.029	4.58	17.7	166.3
DHR331	44NT62	0.26	8.3	0.373	0.174	0.060	0.776	0.667	0.511	0.011	13997	0.0	0.0	0.027	3.35	20.7	182.4
DHR333	44DW305	0.00	0.0	0.727	0.162	0.000	1.010	4.498	0.505	0.018	22494	0.0	0.1	0.000	15.01	95.4	180.1
DHR334	44NT78	0.50	0.0	7.693	0.511	0.118	4.768	0.173	0.748	0.100	1201	0.2	0.0	0.042	0.97	24.0	106.5
DHR335	44DW305	0.85	49.7	2.660	0.554	0.159	2.888	5.018	1.056	0.079	24397	0.0	0.1	0.038	5.04	171.4	205.2
DHR336	2004.2	0.00	54.3	0.378	0.116	0.062	0.660	2.408	0.527	0.010	8734	0.0	0.5	0.027	3.92	642.1	144.8