V. RESEARCH DESIGN

A. Phase I Survey

1. Stormwater Management Areas

Phase I survey was conducted at the two stormwater management pond sites located north of Glasgow. The general purpose of Phase I survey is to locate and identify cultural resources within a landscape. According to the *Guidelines for Architectural and Archaeological Surveys in Delaware*, Phase I survey "includes a detailed, systematic field inspection, in which the surveyor locates and records all cultural resources in a project area, or conducts archaeological testing in conformance with a valid site predictive model" (Delaware State Historic Preservation Office 1993:9). In the present instance, the types of resources expected could be predicted based on settlement pattern models generated for the region. These models follow work initiated by Custer (1986, 1989), whose temporally based study units, discussed previously, were employed to determine the potential for specific site types.

In summary, the two Phase I survey areas lie in the Mid-Peninsular Drainage Divide Management Unit (Custer 1986). Generally, this Unit exhibits medium potential for the presence of significant prehistoric sites and low development pressure. More specifically, site probability is considered low for large, macro-band base camps, higher for smaller micro-band base camps or procurement or hunting sites.

Generalized settlement pattern models suggest that several physiographic features are consistently associated with site occurrence in similar regions. Areas of high site probability typically combine attributes including distance to a perennial water source (150-250 meters), slopes of 10-15 percent or less, and good soil drainage (Gardner 1978; Thomas 1980; Kavanagh 1981). Secondary attributes may include areas in which floral and faunal habitats overlap, proximity to marshes or wetland areas, and proximity to lithic material of sufficient quality for stone tool manufacture (Thomas et al. 1975; Custer et al. 1983).

Based on these criteria, the survey areas exhibited medium-to-high potential for evidence of prehistoric activity. They were located near the fall line in a region of comparatively high resource diversity, and lay on relatively level, well-drained terraces. The terraces overlooked perennial tributaries of major streams containing secondary lithic resources in the form of stream gravels. Based on specific models developed for the Management Unit, site potential was greatest for the discovery of small procurement stations, which would be associated with larger base camps on nearby, major watercourses. Survey strategies, detailed in the Methodology section below, were designed to locate such small procurement sites through systematic, subsurface testing.

B. Phase II Testing

1. Iron Hill East (7NC-D-108)

General Expectations

The purpose of Phase II investigations is to evaluate site significance in terms of National Register Criteria. According to the *Guidelines for Architectural and Archaeological Surveys in Delaware*, Phase II evaluation "involves systematic testing of potentially eligible sites found in the [Phase I] survey and provides definitive information on both vertical and horizontal boundaries, internal site structure and its integrity, and significant data categories represented at each site" (Delaware State Historic Preservation Office 1993:10).

The Iron Hill East site was located during Phase I survey in an active agricultural field. At the time of the Phase II evaluation, the field was planted in late spring crop. Ground surface visibility was poor, and thus rapid survey by surface inspection was impractical. The testing strategy, detailed in the Methodology section of this report, was thus designed to locate potential activity areas within the site through systematic, subsurface testing. Sampling was designed to test all portions of the right-of-way for indications of quarry-related artifacutal material or other evidence of prehistoric activity.

In addition to site-specific issues of vertical and horizontal boundaries, and resource integrity, it was assumed that testing at the Iron Hill East site could provide data relevant to several general research questions: in particular, issues of chronology, settlement, and technology.

Chronology

The quarrying and use of Newark jasper from the Delaware Chalcedony Complex has occurred throughout the 14,000 year span of known human occupation of the region, from the Paleo-Indian to the Woodland II (Custer et al. 1986a; Vidal 1988). Phase I survey recovered no data to suggest periods of site use. One goal of Phase II evaluation was to determine the potential for undisturbed stratigraphic contexts containing organic material suitable for radiometric dating. The potential for relative dating through morphological and attribute typing of diagnostic lithic or ceramic artifacts was also an important aim of evaluative testing.

Settlement

Phase I survey of the SR 896 corridor provided evidence of prehistoric activity at the Iron Hill East site. Based on its location at the foot of Iron Hill, which is known to contain outcrops of cryptocrystalline lithic raw material use by prehistoric populations, the Iron Hill East site was expected to be a quarry or quarry-related workshop site. Settlement pattern models for the Delaware Chalcedony Complex Management sub-unit indicate a high probability of Paleo-Indian use of the site, based on the assumption that the quarrying of cryptocrystalline lithic material was an important determinant in settlement systems during that period. Another potential site type includes small procurement stations of non-specific chronological affiliation, probably lying adjacent to the tributary stream flowing eastward from Iron Hill.

Technology

Quarry Studies. Other than general issues of chronology and settlement pattern, certain analytical questions concerning lithic technology could potentially be addressed by data from the Iron Hill East site (see Custer 1986, 1994). Comparative data related specifically to quarrying debris are rare in the archaeological literature. Pioneering quarry studies were conducted at the turn of the century by William Henry Holmes, who surveyed quartzite quarries in Washington, D.C. Holmes's studies were innovative in a number of ways. In a series of reports prepared for the Smithsonian Institution, Holmes provided the first North American perspective on prehistoric lithic manufacturing as a process of staged or sequenced reduction, a view which now forms the basis for virtually all analyses of chipped stone lithic technology. In addition, Holmes systematically studied the quarry locales themselves, examining the quarry pits along with the tools associated with them and, to some extent, the workshop debris. Similar, although less systematic quarry surveys, were conducted by Ruth (in Anthony and Roberts 1987:10) and Mercer (1894) in the so-called Reading Prong of eastern Pennsylvania, where jasper and argillite outcrops were quarried by prehistoric populations. Although these investigations were brief and descriptive, Mercer did excavate several of the quarry pits at the Macungie jasper quarry. The works of Holmes, Ruth, and Mercer, conducted in this early period, remain some of the most extensive treatments of quarry sites existing, and among the few which deal directly with the quarry as an important site in and of itself.

More contemporary work has also focused on quarry sites, but typically the perspective has been that of material distribution: i.e., analysis of the movement of lithic raw material across the landscape, generally carried out in support of settlement pattern studies or to delineate exchange networks. Little if any attention is paid to quarrying procedures or to the debris resulting from the quarrying processes, and thus there is no comparative database existing for intersite analysis. In a recent volume dedicated to quarry-site analysis, *Prehistoric Quarries and Lithic Prediction* (Ericson and Purdy 1984), the following declaration heads the introduction to the collected papers:

> A complete analysis of the quarry will allow the researcher to reconstruct the processes of extraction, selection, knapping, and on-site activity of the average knapper, as well as documenting the reduction sequences, changes in technology and rates of production over time. The quarry remains the logical site to begin the study of a stone-tool-using culture. (Ericson 1984:1)

In spite of this statement, the major focus of the studies that follow is on the reduction systems observed at associated workshop sites, or on such matters as access, transportation routes, and the implications of observed distributions for trade and exchange systems. For example, in a paper dealing with quarry production rates, Leudtke (1984) provides estimates that are not based on material evidence from the archaeological record—quarry-related debris or even workshop debitage—but rather are based on calculations of the demand for tools from a given population size (using mostly ethnographic data), the predicted life-span of the tools, and the amount of raw material required to fulfill such a demand. Other analyses from the volume include a refit study that focuses on the regional distribution of chert from a California quarry (Singer 1984), a venture into the socio-political realm of territorial control of quarry sites (Torrence 1984), and an analysis of the economics of resource procurement scheduling (Findlow and Bolognese 1984). In fairness, few of the articles claim to focus on quarries as sites in and of themselves. Yet the pattern is clear, quarry studies are typically used as a means of addressing issues other than quarrying activity.

Regional quarry studies, such as an investigation in New York at the Pleasantdale quarry/workshop site on the Hudson River in Rensselaer County (Brumbach 1985), follow a similar trend. Most of the data presented in the report of the investigation is related to the workshop portion of the site, with little attention paid to debitage, and none to quarry debris specifically. There is a comparison of debitage size based on mean flake weight between the Pleasantdale site and two other sites in the region, neither of which was identified as a quarry-related site (Brumbach 1985:106, Table 12). The purpose of the comparison was to demonstrate a fall-off in flake size in proportion to distance from the presumed quarry locale. Insufficient data were presented to determine the validity of the comparison, although the mean flake weights did appear lower at the sites removed from the quarry.

Stewart (1984; 1987) has reported on rhyolite quarries in the Blue Ridge physiographic province of western Maryland and southeastern Pennsylvania. Subjects of analysis include site typology, chronology, and raw material distribution and the implications for settlement patterning. Some description of quarry pits is provided. In addition, it is observed that few quarry tools were noted in areas where outcrops are exposed. Stewart (1987:50) theorizes that this may be due to the fact that the raw material spalls readily through natural weathering processes, providing little need for an extensive quarrying tool kit. The studies then continue with a focus on quarry workshops and the manufacture of bifaces, distribution patterns, and the sociological mechanisms in terms of trade and exchange implied, and, finally, the implications for regional settlement.

Geasey and Ballweber (1991) reported on the Highland site, a rhyolite quarry in the Blue Ridge of Maryland, and several related lithic processing sites. Again the descriptive analytical emphasis of the investigation is on the quarry-related workshops and the "tools," or bifaces, recovered from them. The presence of debitage is noted, but the material is not described or quantified. Artifact inventories are tabularized for seven sites, but flake debris is not considered—several tables contain the footnote "Debitage was too extensive to collect; therefore it is not included" (Geasey and Ballweber 1991:85). Interpretive discussion focuses on the amount of reduction carried out at the quarry-workshops, and the form of the bifaces transported from the quarry area.

A study of a large hornfels quarry, carried out at the Massachusett Hill Quarry Complex south of suburban Boston (Ritchie and Gould 1985), is another example of the typical quarry analysis, that focuses on external relationships rather than on the quarry site itself. The pits observed at the quarries and the tools present there are briefly described, and inferences are drawn as to the techniques that may have been employed in extracting hornfels and slate, the latter material also being present within the complex. The majority of the analyses concern the regional distribution of hornfels from the quarry based on occurrences of artifacts manufactured from it.

Hatch and Miller (1985) conducted an investigation of Vera Cruz, one of the quarries in Hardyston jasper quarry zone along the Delaware River in Lehigh County, Pennsylvania. They described the quarry pits visible throughout the quarry, and they excavated trenches across several of these pits. The excavations discovered evidence that the entire ridge had been mined with open quarry pits, and that many of the pits had been backfilled and in some cases re-excavated prehistorically. Debitage analyses emphasized the use of heat treatment in biface reduction, considering the quarrying process itself.

Perhaps one of the most extensive and comprehensive treatments of a quarry complex in the Middle Atlantic region is the further study of the Hardyston quarry zone, conducted by Anthony and Roberts (1987). Analyses of a series of quarry sites in the Reading Prong is presented, with emphasis on the types and quantities of tools remaining at the workshop locales. Raw material distribution studies follow, tracing the occurrence of the material throughout the Delaware River Valley and beyond.

At the Bodie Hills quarry in California, Singer and Ericson (1977) provide an example of the analysis of quarry-related debris itself, although there is still little emphasis on the actual process of quarrying. Production rates were calculated directly from workshop debitage using Newcomer's (1971:90-93) estimates of flake production in the manufacture of handaxes. It is estimated that between 960 and 1725 bifaces were produced per year over a span of 5000 years, for a total of 5-8.5 million bifaces (Singer and Ericson 1977:185). Somewhat farther afield geographically, but of similar methodological approach, are estimates of chert tool production at Colha, in Northern Belize, where at least 18,000 large oval bifaces and tranchet bit tools were produced site-wide each year during the Late Preclassic period (a total of at least 4.5 million over the entire 250 period) (Shafer and Hester 1983:529), or obsidian blade production at Copan, Honduras, estimated at up to 600 per year (Mallory 1984).

Analysis of quarrying techniques has been undertaken in Old World contexts. For example, Shepherd's (1980) study of prehistoric quarrying, which he views from an industrial perspective as mining, contains an extensive study of quarry technology as developed during the Neolithic of western Europe. The variety of quarry pits and mining shafts recorded at several sites in Britain and northwestern Europe are catalogued. Quarrying tools and matters such as shaft supports, ventilation, and haulage are also addressed in some detail. Most of the data are derived from flint mines in Great Britain, and the so-called silex[†] mines of northwestern Europe. Chronologically, use of the sites correlates with the Late Archaic in the Middle Atlantic region. And yet, while the more monumental aspects of quarrying are well-documented in the study, there is no analytical attention paid to the debris produced by the quarrying process itself.

In contrast to most of the studies thus far cited, Purdy (1981; 1984), urges the study of quarries as sites. Quarry sites are usually highly eroded, with little vertical separation of temporal components, and are situated in contexts in which the potential for organic preservation is low. Purdy urges the search for new approaches to the problems inherent in such studies, suggesting some which have been applied with varying success at sites in Florida. She notes the use of analysis of patina formation rates; thermoluminescence of heat treated material; and alternative techniques to absolute dating, particularly, relative dating techniques such as the analysis of stratigraphic contexts or of temporally sensitive variations in technology.

Constituent Analysis. Constituent analysis, or materials characterization, of lithic raw materials has provided valuable data for distribution studies of certain raw material types (Bishop and Canouts 1993). The jasper outcrops of the Hardyston formation in the Middle Delaware Valley represent an example of such studies. The outcrops are in fact

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[†] a term that refers to the range of cryptocrystalline lithic material—jasper, chert, chalcedony, flint

some of the best studied lithic raw material deposits known, and the analytical techniques used in their investigation are among the most advanced in use to date. For example, trace element analysis was conducted of material from jasper sources in Pennsylvania as well as Delaware by Blackman (1976), using atomic absorption and flame emission spectroscopy. Neutron activation analysis was conducted of jasper samples from Virginia, central and eastern Pennsylvania, and northern Delaware by researchers from The Pennsylvania State University (Hatch and Miller 1985). A later study (Stevenson et al. 1990) employed X-ray fluorescence to characterize the chemical composition of jasper from three Middle Atlantic quarries, Durham and Vera Cruz in the Hardyston formation, and Iron Hill. The results were then applied to artifact samples from two sites in Chester County, Pennsylvania (Kasowski [36CH161] and Woodward [36CH374]), a preliminary analysis that suggested that lithic raw material from those sites was derived from several primary sources. While constituent analysis was not proposed at the current level of effort, it was assumed that data might be collected that could assist in the development of recommendations should the site be considered sufficiently significant to require mitigation.

Heat Treatment. While results of the Phase I investigation at Iron Hill East did not note the incidence of reddened jasper at the site (Lothrop et al. 1987), literature review suggested the possibility that fire may have been used in some form in the quarrying of japser from the formation. Reddened jasper debitage, presumed to have originated from Iron Hill, has been reported at various quarry-related sites in the region: e.g., the Hitchens site (18CE37) and the Bumpstead site (18CE162), north of Iron Hill (Custer et al. 1986a), and the Brennan site (7NC-F-61A), approximately 8km to the south (Watson and Riley 1994).

While these sites represent secondary lithic reduction, the use of heat treatment at quarry sites is also documented. Holmes (1919:177), for example, mentions the use of fire as a quarrying technique at Flint Ridge, in Licking County, Ohio, as described by Gerald Fowke. Purdy (1981) conducted a literature review that located only two eyewitness accounts of the use of fire in quarrying: one an ethnohistorical account from California, and the other an ethnographic observation from modern-day Australia (Binford and O'Connell 1984). Evidence has been reported of the liberal use of fire in quarrying at Tosawihi, a chert quarry in north central Nevada (Carambelas and Raven 1991). Experimental work at that site suggested that heating served to weld the surrounding tuff allowing it to be removed in large chunks. Heat also helped to initiate cracks in the underlying opalite, which could be used to gain access, e.g., purchase for wedges. Purdy (1981) conducted her own experiments in heat treatment in association with chert encased in limestone, rather than the loose tuff surrounding the cherts at Tosawihi. Her conclusion was that heating was destructive, and could be used to "demolish...unwanted material," but could not be controlled sufficiently to remove tool-quality stone (Purdy 1981:76). A study of the thermal alteration of Bald Eagle jasper, from central Pennsylvania (Schindler et al. 1982), deals extensively with the details of chemical modifications resulting from heating. Analysis of archaeological assemblages in the study focuses on the heat treatment of bifacial cores. That is, the study deals with the use of heat treatment as an aid to biface reduction, rather than as a quarrying technique. An interesting pattern in the incidence of thermally altered flakes is reported, though the implications are not followed out in detail. Heat treatment occurs at considerably lower frequencies for flakes identified as primary thinning flakes than for early or later stage thinning flakes (58 percent compared with 16 and 20 percent, respectively [Schindler et al. 1982: 539, Table 1]). The implication drawn by the researchers was that heat treatment was undertaken only after the initial edging of the biface. At Iron Hill East, it was proposed to examine the frequency and spatial distribution of reddened jasper and limonitic material to determine the extent to which fire may have been used in quarrying and, possibly, how the technique was undertaken.