IDENTIFICATION OF "JASPER" SOURCES IN PARTS OF THE NORTHEAST AND MID-ATLANTIC REGIONS

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Abstract

A regional sampling survey of "jasper"-bearing formations in parts of the Northeast and Middle Atlantic regions was conducted as part of a study of patterns of chert acquisition among prehistoric groups within the Delaware drainage. Samples were collected from 38 localities representing eight formations within the research area. Six of the formations are primary sources; i.e., *in situ* deposits. The remaining two formations are secondary fluvial deposits. A lithologic method combining both macroscopic and microscopic techniques of analysis indicates that the source of "jaspers" derived from both the primary and secondary deposits can be identified. In addition, the data suggest, very tentatively, that petrographic analysis may be able to distinguish specimens from subareas within the outcrop area of some of the formations, as well as from loci representing different formations.

Introduction

A regional sampling survey of rock units containing fine-grained siliceous materials (e.g., "chert," "flint," and "jasper") within and adjacent to the Delaware River Valley was conducted as part of a study to discern patterns of lithic procurement and exchange among prehistoric Woodland groups once inhabiting the valley area. Ninety-five source locations representing 27 formations were sampled (Lavin 1983; Lavin and Prothero 1981). Several of these formations contain fine-grained siliceous materials of brown, yellow, and red hues (Munsell Code YR, Y, and R). These materials frequently occur within the assemblages of Northeastern and Mid-Atlantic archaeological sites. Archaeologists popularly refer to them as "jaspers."

The appearance of "jasper" artifacts often leads to much speculation about their source and mechanisms of transport, often culminating in the theory of an inter-regional trade relationship with eastern Pennsylvania. This paper is an attempt to clarify the situation by identifying some of the possible sources of "jasper" artifacts within the Northeast and Mid-Atlantic regions, and by distinguishing among them through macroscopic and microscopic analyses of source specimens.

"Jasper" is a term with ambiguous and often conflicting definitions (see Lavin 1983:30-32). It has been defined as a red, brown, or yellow variety of chalcedony whose coloring is due to its iron oxide content (Mason and Berry 1968:41; Sinkankas 1966:437). Confusingly enough, the same authors (Mason and Berry 1968:412; Sinkankas 1966:437) provide virtually identical definitions for the terms "carnelian" and "sard": a red, reddish-brown, or yellowish-brown chalcedony containing iron compounds. In contrast, Huang (1962:289) defines "jasper" as an iron oxide-stained brown or red cryptocrystalline quartz material with no chalcedonic quartz. Other authors define "jasper" as a red, brown, or yellow variety of chert containing iron oxide (Frondel 1962:207, 211; Pettijohn 1975:394; Simpson 1966:213; Sorrell 1973:208).

"Chalcedony" itself is an ambiguous term whose macroscopic definitions fail to distinguish it from other cryptocrystalline siliceous materials. It is usually described as a waxy, translucent or almost transparent siliceous rock ranging in color from pale shades of green, blue, yellow, gray, to nearly colorless (Frondel 1962:198; Sinkankas 1966:436; Sorrell 1973:208). "Chert" and "flint" materials, however, have also been described as "waxy" in lustre (Carozzo 1972:321; Frondel 1962:220). "Cherts" have also been described as subtranslucent (Frondel 1962:220) and light or pale in coloration (Frondel 1962:221; Mason and Berry 1968:431; Meyers 1970:10-12; Tarr 1917:413). The degree of waxiness, translucence, and paleness necessary to define material as "chalcedony" is unclear; assignment appears to be arbitrarily based on each fieldworker's own perception of the degree of these characteristics that constitute a chalcedony. Consequently, the use of "chalcedony" as a descriptive term for "jasper" is superfluous (see Lavin 1983:28-30).

The term "chalcedony" has also been used to describe a mineral component of a chert rock. Chalcedony (the mineral) is defined as microcrystalline silica crystals which seem to consist of "radiating or sheaf-like bundles of fibers" under the light microscope, or a sponge-like surface with cavities for holding water under the electron microscope (Folk and Weaver 1952:500). Folk and Weaver's research indicated that in the field of mineralogy, "chalcedony" seems to be a valid term for micro- or cryptocrystalline fibrous quartz crystals. As such, in this paper the term is used to describe the macroscopic and microscopic veins, veinlets, clots, spherules, etc. only if they have been microscopically identified as being composed of the mineral chalcedony.

The definition of "jasper" as a variety of chert differentiated from other cherts on the basis of color and iron content is also deceptive. For one thing, the red Ordovician cherts in eastern New York have "traditionally been differentiated from jasper" (Hammer 1976:41). Secondly, gray cherts from several formations contain iron compounds; heating will often change the color of these cherts to red (Klein 1973:Tables 1 & 4; Purdy and Brooks 1971:323). Under the former definition, these materials would be classified as "chert" before heating and "jasper" after thermal alteration (Lavin 1983:31).

Lovering (1972:3) differentiates between "jasper" and what he terms "jasperoid." He defines "jasperoid" in terms of its processes of formation. For Lovering, "jasperoid" is "an epigenetic siliceous replacement of a previously lithified host rock. Jasperoid, thus defined, excludes syngenetic or diagenetic forms of silica such as primary chert and novaculite." It may also exclude some "jaspers," such as the "jasper" from the Ironwood Iron-Formation of Michigan and Wisconsin, discussed by Lovering (1972:3). According to Lovering's definition, "jasperoid" includes gray and black fine-grained siliceous rocks (commonly known as "chert" or "flint") as well as red, yellow, and brown "jaspers." Unfortunately, the classification of a lithic artifact as a "jasperoid" would require some form of microscopic or geochemical analysis to determine its form of genesis. These analyses are certainly not normal procedure in archaeological site reporting, nor is it expected to be so in the near future. Financial and curatorial restrictions would make analyses of entire chert assemblages (which the acceptance of Lovering's definition would necessitate) difficult, if not impossible. This being the case, archaeological adoption of Lovering's definition would be impractical. Lovering's study of "jasperoid" formation, however, does have archaeological value as an indicator of probable locations of "jasper"/chert outcrops and their associated prehistoric mining or workshop sites.

Because present geological definitions demonstrate no megascopic or microscopic differences between chert materials archaeologically known as "jasper," we agree with Hammer (1976:44) that the term "jasper" should not be used generically (Lavin 1983:31-32). It should only be used as part of a proper name, such as "Pennsylvania Jasper" for the chert from the Hardyston Formation. All of these materials are chert, and we shall refer to them as such, except when citing other sources. Quite often red, brown, and yellow cherts are identified in the archaeological literature as "Pennsylvania Jasper" for no apparent reason other than their coloring (and, we suspect, the notoriety of the prehistoric quarries in the Lehigh Hills).

Actually, there are at least 23 geologic rock units in the parts of the Northeast and Mid-Atlantic regions of eastern North America comprising the research area of this study that contain red, brown, and yellow cherts. They are the Hardyston Quartzite, Bald Eagle Conglomerate, Little Cattail Creek Chert, Wissahickon Schist, Newark Gabbro, Monkton Quartzite, Normanskill Shale, Beacon Hill Gravel, Pensauken Gravel, Tomstown Dolomite, Conococheague Limestone, and Loudon Conglomerate (Lavin 1983; Lavin and Prothero 1981; Schindler et al. 1982; Stewart 1980). Figure 1 illustrates the geographic distribution of the known brown/yellow chert-bearing outcrops of each formation. We do not mean to imply that these formations represent the only "jasper"-bearing rock units in the Northeastern and Mid-Atlantic United States. In fact, we are aware of "jasper"-bearing outcrops in Rhode Island (Professor Barbara Leudtke, University of Massachusetts Department of Anthropology, personal communication dated June 12, 1983), and from Virginia south to Alabama (Professor William Gardner, Catholic University Department of Anthropology, personal communication dated January 20, 1982) that are unrelated to the formations included in our study. Patricia E. Miller's (1982) geochemical study, which indicated that source identification of "jasper" artifacts can be made with an "acceptable rate of success" (1982:53), involved seven Mid-Atlantic "jasper" source areas representing four rock units - Hardyston, Newark, Flint Run, and Houserville. The latter two rock units are not represented in this study.

Thirty-eight source localities representing eight formations were sampled as part of the regional survey of chert-bearing rock units within and adjacent to the Delaware watershed (Lavin 1983; Lavin and Prothero 1981). Some of the chert samples were donated by local geologists or archaeologists interested in lithic analyses. The majority of samples, however, were collected directly from outcrop areas by the senior author. The locations of chert-bearing outcrops and prehistoric quarry areas were obtained from geologists and archaeologists familiar with local stratigraphy, geological articles, and various geologic maps. Sampling loci were chosen on the basis of quantity; areas with the most numerous and thickest chert concentrations were chosen as loci. Usually, however, there was little choice in the matter, as the cherts were frequently localized in only one area of the site (see Lavin 1983:328).

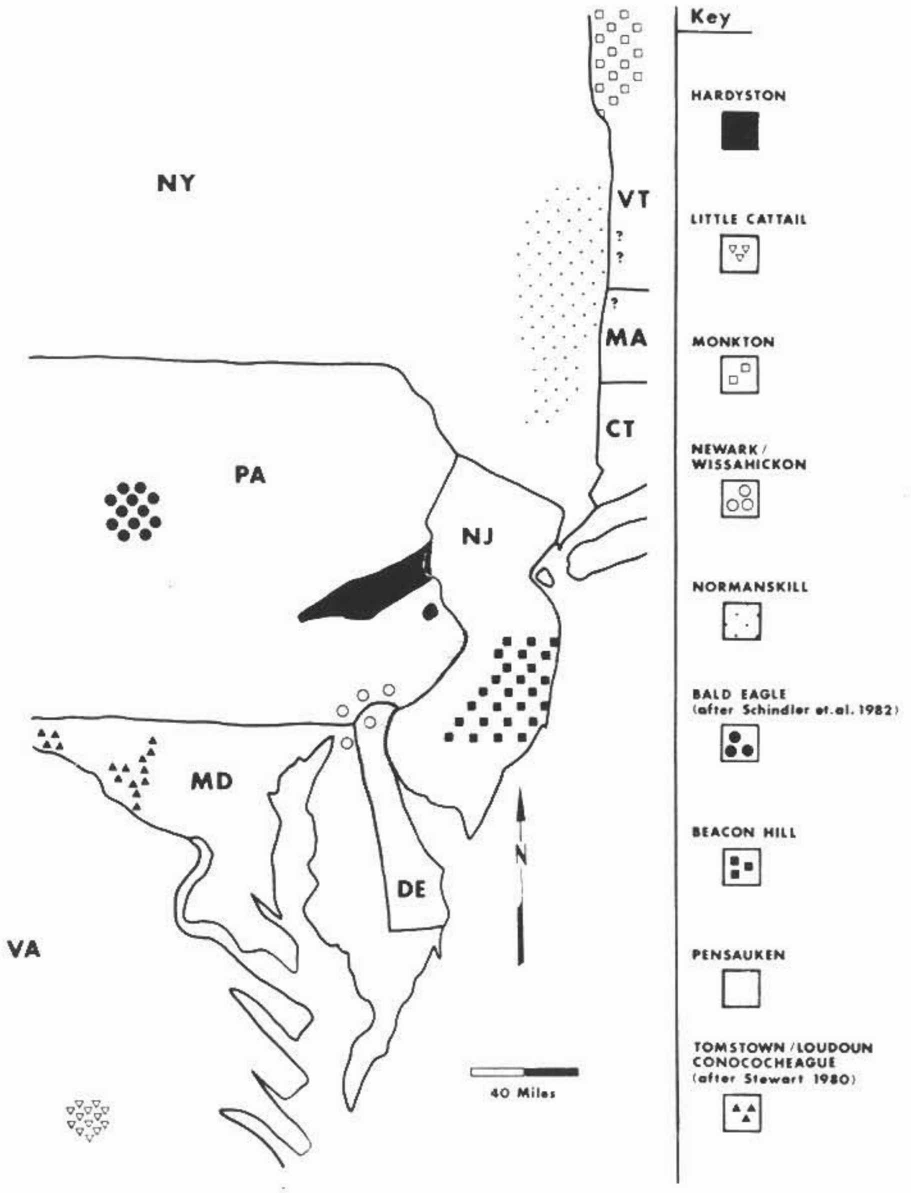

Figure 1. Location of chert types.

When the locus consisted of bedrock cherts, i.e., chert found in its original bedrock location, only *in situ* specimens were sampled in order to obtain the proper stratigraphic data; talus deposits at the base of the bedrock were not sampled. In large outcrops, several loci were sampled. When the locus consisted of residual chert (i.e., *in situ* chert whose bedrock had been destroyed by natural agents), sampling involved only cherts that literally had to be dug out of the ground, as they were most likely in an *in situ* position; loosely lying surface material was not sampled (see Lavin 1983:328-329).

Both macroscopically "typical" and macroscopically "unique" (e.g., those with unusual veining, mottling, coloring, or inclusions) chert lenses / pebbles / cobbles were sampled, in order to gain some insight into the range of inter-outcrop variation wihin each formation, and to test the hypothesis that these variations were much lower than the inter-formational variations through which formations (and therefore chert types) could be differentiated. Because of a number of uncontrollable factors, such as the small size of donated samples, difficulty in acquiring information on the source location of chert-bearing outcrops, and general geological disinterest in cherts, sampling procedures were far from ideal (see Lavin 1983:195-196, 278). Sampling was non-random, and the sample size and number of loci sampled differ widely among the chert types. In addition, because this project is a pilot study on the subject of petrographic identification of chert sources, sample sizes are small. In spite of the inadequacies of the sampling program, however, there is justification for the identification of chert sources on the basis of our present survey data. Firstly, as noted above, attempts were made to microscopically analyze specimens from each chert type that represented the full range of macroscopic variation exhibited by the chert type at the outcrops included in the survey. Secondly, thin-sections of five of the eight chert types included in this study are derived from more than one outcrop area (locus), demonstrating that both intra-outcrop and inter-outcrop variations have little effect on formational identification; even though they were derived from different collecting loci, the cherts still shared common formational characteristics that enabled us to identify them as a single specific chert type. Thirdly, our petrographic data is supported by the analysis of previous investigators (see, for example, McCary 1975; Reudemann and Wilson 1936; Stafford 1971; Wilkins 1967, n.d; and Wray 1948).

For a more complete description of the chert survey, its research design and techniques employed, see Lavin (1983:120-136, 195-197, Appendix A). For a description of each collecting locality sampled, see Lavin (1983:Appendix B).

As indicated above, cherts derived from a specific formation are herein referred to as a chert "type." The geographic distribution and petrography of each chert type is briefly summarized below. Lithic identification consists of both macroscopic (hand-specimen) and microscopic (thin-section) techniques of analysis on specimens ranging in size from 1 1/2- to 2-inch "pebble cherts" (from the secondary fluvial formations) to 5- or 6-inch cobbles or fragments from bedded samples. Macroscopic analysis involved study of specimen color, lustre, opacity, texture, inclusions, and reaction to concentrated hydrochloric acid (12N). Colors are described according to the Munsell Color System (Anonymous 1975). Color identifications were made under a high-intensity fluorescent lamp for the purpose of minimizing perceptual errors. The color sensations represent those of freshly fractured surfaces. One survey (Lavin 1983:121, Tables 2 & 3) and the published literature (see Wray 1948, for example) indicate that the weathered surfaces of cherts are very similar. They normally are white, gray, or brown; sometimes an "iridescent" patina also occurs. In contrast, fresh fractures have a more distinctive color range for each chert type; their use facilitates source identification.

Luedtke's (1979:189-190) definitions of structure, texture, lustre, and opacity were adopted: A "homogeneous" structure demonstrates singular color and texture throughout the specimen. A "shaded" structure demonstrates abrupt or uneven variation. Coarse texture is "grainy"; fine texture is smooth and fine-grained. Medium texture describes cherts whose textural characteristics fall within the bounds of these two polar definitions. The common meanings of "dull," "medium," and "shiny" are used to describe lustre; the common meaning of "opaque," "translucent," and "transparent" are used to describe opacity (see Luedtke 1979).

The only chert type that may be identified solely by macroscopic analysis is Newark chert, due to the presence of metallic gray magnetite, ilmemite, or chromite crystals visible to the naked eye. It is possible, however, that a small flake of Newark chert may not contain a macroscopically visible crystal. Such a situation would require microscopic analysis for proper source identification of the flake.

Microscopic analysis of the specimens involved listing the entire contents of each slide; textural, mineralogical, and chemical attributes were documented. To insure high quality slides, thin-sections were prepared by the Rudolf Von Huene Laboratory of Pasadena California, a professional thin-section laboratory. Petrographic analysis of the slides was performed by the junior author. (For a description of the contents of each individual slide, see Lavin 1983:Appendix C).

Microscopic differences among the chert types studied are strong enough for us to make a dichotomous key of traits for identification of the sample specimens (Figure 2). The cherts are divided into nonfossiliferous and fossiliferous (or normally fossiliferous) chert groupings. Each grouping can then be divided into subgroupings by the presence or absence of textural, chemical, and mineralogical traits.

Description of Chert Types

Hardyston Quartzite (3 localities represented)

The Hardyston Quartzite is a Lower Cambrian formation, outcrops of which often contain oxide-stained chert archaeologically known as "Pennsylvania Jasper." The formation crops out in eastern Lebanon County, central Berks County, southern Lehigh and Northampton Counties, and Bucks County in eastern Pennsylvania, and in northwestern New Jersey from about Riegelsville and Phillipsburg to Owen and North Milford, and into extreme southern Orange County, New York (Gray et al. 1960; Johnson 1950; Offield 1967:42). Drake (1969:79), however, reports that "jasper" is "rarely present" in the Delaware Valley but abundant to the west in Lehigh and Northampton Counties, Pennsylvania. Ludlum (1941:17-18) notes the presence of "jasper" along the Delaware River just below Phillipsburg, New Jersey. Yet James P.

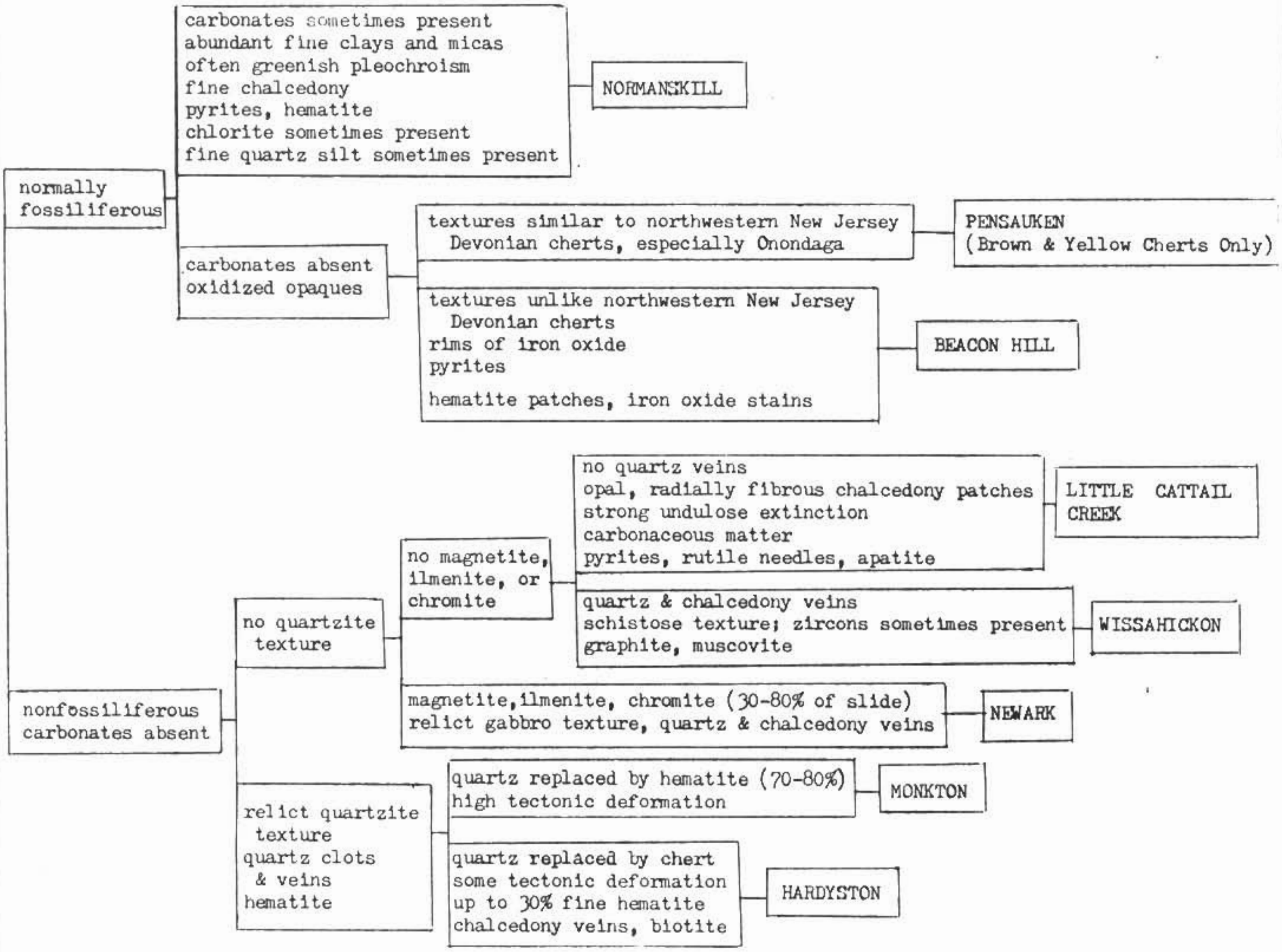

Figure 2. Dichotomous key to chert identification.

Minard, United States Geological Survey geologist who has worked in New Jersey, reports that he has never seen "jasper" in the Hardyston (personal communication dated May 16, 1978). David P. Harper, senior geologist at the New Jersey Bureau of Geology and Topography in Trenton, likewise reports that he has never heard of any "jasper" in the Hardyston of New Jersey, as occurs in Pennsylvania (personal communication dated June 14, 1978). Consequently, except for a localized deposit near Phillipsburg, it appears that chert deposits are restricted to eastern Pennsylvania.

Macroscopic analysis

The chert may be homogeneous, shaded, or mottled in color. Our sample includes homogeneous browns (Munsell Code 7.5 YR 4/4); homogeneous reddish browns (5 YR 4/4; 5 YR 4/5); homogeneous yellowish browns (10 YR 5/6; 10 YR 5/8); shaded yellowish browns (10 YR 4/4-6 and 10 YR 4/3; 10 YR 4/6 and 10 YR 4-5/8; 10 YR 3/4 and 10 YR 4/6; 10 YR 4/3-6; 10 YR 4-5/6 and 10 YR 5/8); various shaded or mottled combinations of yellowish browns and reds, reddish yellow, yellow, brownish yellow, reddish brown, grayish brown, dark browns, and/or black (10 YR 4-5/6, 10 YR 5/8, 10 YR 4/4, and 10 R 4/4; 10 YR 5/4 and 5 YR 6/6; 10 YR 4/6, 10YR 4/4, and 10 YR 7/6; 10 YR 5-6/8, 7.5 YR 2-3/4 and N2; 10 YR 2/4, 10 YR 5/6, 5 YR 3/4 and N1; 10 YR 4/2 and 10 YR 4-5/6); shaded reds (10 R 4-3/4, 10 R 4/6, and 10 R 2.5/1; 10 R 4/2-4 and 10 R 5/4; 10 R 3-5/4); shaded or mottled dark grays and browns (N3 and 10 YR 4/2-3; N3-N4; 5 YR 4/4 and 10 YR 4/2). Hardyston chert often turns red during heating (Klein 1973:Table 4; Section of Archaeology n.d.:1). Black chert has been reported from the quarries at Vera Cruz and Macungie (Witthoft n.d.:4). We discovered a black chert cobble in a residual outcrop near Longswamp, Pennsylvania. Thin-section analysis of the specimen, however, indicated that its source was not the

Hardyston Formation, but one of the adjacent (or overlying) Cambro-Ordovician carbonate units. Evidently, the matrices of both rock units had weathered away, resulting in a residual deposit of chert cobbles derived from both sources. Consequently, the presence of black chert in Hardyston Quartzite is questionable unless the particular outcrop is a bedrock deposit.

Hardyston chert is usually medium or fine-grained in texture. It ranges from dull to shiny in lustre. Samples are usually opaque; a few are translucent along thin edges only. Completely translucent specimens, however, have been reported (Geyer and Lapham 1970:11). There is no reaction to hydrochloric acid (HC1). Veins of chalcedony and quartz are common. Unlike our samples of cherts from the Newark Gabbro, metallic gray euhedral crystals of opaques (i.e., ilmenite, magnetite, and chromite in the Newark material) are not distinguishable in hand specimens or under 10X magnification. As one can see, the macroscopic characteristics are not unique enough to unequivocally identify a specimen as Hardyston Jasper. Microscopic analysis, however, provides a definite set of attributes diagnostic of this chert type.

Microscopic analysis (13 slides representing 3 loci)

The major diagnostic trait of Hardyston chert is its relict fine-grained quartzite texture; the specimens show partial or complete replacement of the original quartzite by microcrystalline quartz and chalcedony. In completely replaced samples, the original quartzite texture is still confirmed by the "ghosts" of quartz grains outlined by opaques; pseudomorphs of microcline and plagioclase are also indicative of an arkosic source rock. Well-developed secondary quartz and chalcedony veins and fine opaques are present. The opaques, which appear to be mainly hematite, are usually abundant, comprising 10-30% of each slide. The following traits are sometimes present: Stylolites of limonite and hematite, and grains of biotite containing hematite (see Lavin and Prothero 1981:6). The degree of quartzite replacement varies among chert specimens within an outcrop as well as among those from discrete outcrops. The degree of inter-outcrop and intra-outcrop variation is not, however, as great as the inter-formational variation between Hardyston and other formations. Hardyston Jasper can easily be distinguished from the other chert types in this study.

Little Cattail Creek Chert (1 locality represented)

The Little Cattail Creek Formation is localized along Little Cattail Creek and the adjacent Ampy and Williamson Farms in Dinwiddie County, Virginia (McCary 1975). The chert is known variously to archaeologists as "Williamson Chert," "Dinwiddie Chert," and "Cattail Creek Chalcedony." The age of the deposit is unknown. Since it was formed on Pre-Cambrian rock, it may be as old as the Pre-Cambrian or Cambrian (Wilkins 1967:35). The Little Cattail Creek unit consists of residual cobbles and boulders of chert from which the original matrix had apparently leached out. So far as we have been able to discern, it has not been associated with any known rock unit. There is the possibility that it belongs to a previously named unit; our analyses indicate, however, that the unit is not one of those studied by us (Lavin 1983; Lavin and Prothero 1981).

Macroscopic analysis

Virtually all of the chert is mottled or shaded. It occurs in many different colors, including browns, yellows, and red; various combinations of yellowish browns (10 YR 6/4, 10 YR 5/4-6, 10 YR 4/4-6); brownish yellow (10 YR 6/6); brown (7.5 YR 4/4-6); very pale brown (10 YR 7/4); reddish browns (5 YR 3/4, 5 YR 2/2, 5 YR 4-5/4); dark grayish browns (10 YR 4-5/1-2); yellowish reds (5 YR 4-5/6); dark reddish gray (5 YR 4/2); and reds (10 R 3/4, 10 R 4/6-8). Sometimes these colors or combinations thereof are mottled with black or very dark gray (N2-N3), or various light grays (N5-N8, 10 YR 6-7/2). Cream and yellow cherts have also been reported in the published literature (McCary 1975:53; Wilkins 1967:35). Brown cherts often turn red with heating (McCary 1975:55).

The chert ranges from dull to shiny in lustre; most of it is dull. It ranges from opaque to translucent, but is mainly translucent, especially along thin edges. Texture is medium to fine-grained. The chert does not react to HC1. Visible quartz and chalcedony veins are virtually absent.

Microscopic analysis (The 6 slides include reds, browns, and other colored specimens as they are indistinguishable microscopically)

The following traits are present: Strong alteration to chalcedony and opalized chalcedony with strong undulose extinction; patches of radiating fibrous chalcedony; carbonaceous matter (ranging from less than 1% to 20% per slide); pyrites. Rutile needles and apatites usually occur. The following traits are sometimes present: Limonite gels; anhedral quartz; chalcedony veins; possible pseudomorphs of sponge spicules; stylolites of iron oxides or chalcedony (Lavin and Prothero 1981:8).

Wissahickon Schist (3 localities represented)

The Wissahickon Formation is thought to be Lower Paleozoic (i.e., Cambro-Ordovician) in age

(Gray et al. 1960; Woodruff and Thompson 1972). It extends from upper Cecil County, Maryland, through New Castle County, Delaware, and southeastern Pennsylvania into the Philadelphia area and as far east as Trenton (Gray et al. 1960; Johnson 1950; Widmer 1964:17-18). Significant amounts of chert have been reported from outcrops in the southern area of distribution (Stafford 1971: Wilkins n.d.; Witthoft and Wilkins n.d.), but chert lenses appear rare to non-existent in the northern outcrops. The chert is known to archaeologists as "Broad Run Chalcedony."

Macroscopic analysis

Our chert samples are shaded. They range from a very pale coloration to the darker browns characteristic of Hardyston and Newark cherts: white, pale yellow, and light brownish gray (2.5 Y 8/2, 2.5 Y 8/4, and 2.5 Y 6/2); yellowish browns, white and very light gray (10 YR 4/4, 10 YR 5/6, 10 YR 8/2, and N8); yellowish red, strong brown, and grayish brown (5 YR 5/6, 7.5 YR 5/6, and 10 YR 5/2). Mottled white, tan, and brown samples, and "nearly colorless translucent gray" samples have also been reported (Stafford 1971:9; Wilkins and Witthoft n.d.:1). The chert has a medium to fine texture, and varies from opaque to translucent. It is dull to medium in lustre. It does not react to HC1.

Microscopic analysis (3 slides from 2 loci)

The distinguishing characteristics of Wissahickon chert is its relict mica schist texture. The schistose texture, an alignment fabric of chalcedony veins and opaques, and graphite and muscovite flakes, and abundant clots and veins of quartz and chalcedony form a diagnostic complex of traits by which the Wissahickon chert may be distinguished from the other chert types in our study. Iron oxides and limonite gels are usually present, sometimes as stylolites. Purple zircons occurred in specimens from Maryland, but not in the specimen from southeastern Pennsylvania. We suggest, quite tentatively, that this inter-outcrop variation may allow us to distinguish the Maryland and Pennsylvania subareas within the general Wissahickon outcrop region (Lavin and Prothero 1981:10).

Newark Gabbro (at least 3 localities represented)

An unnamed body of gabbro crops out in the same geographic areas as and along the flanks of the Wissahickon Formation (Johnson 1950; Widmer 1964:17; Woodruff and Thompson 1972). The gabbro is presumably early Paleozoic in age (Woodruff and Thompson 1972). It intrudes into the Wissahickon Formation, and is therefore younger than the latter (Bascom et al. 1909:44). Chert has been reported only from outcrops in Maryland and Delaware; the brown and yellowish red cherts are commonly referred to as "Newark Jasper," while the black cherts are referred to as "Cecil Black Flint" (Wilkins 1958, 1967). We have extended the term "Newark" to include the entire gabbro unit.

Macroscopic analysis

The Newark chert consists of homogeneous, shaded, and mottled chert, although shaded cherts are the most common. Our samples contained the following colors: Black (N2) with yellowish brown (10 YR 5/4), or brown (7.5 YR 5-6/8) or yellowish red (5 YR 5/6) mottles; yellowish browns (10 YR 4/4, 10 YR 5/6, 10 YR 5/8); dark brown (7.5 YR 4/4); yellowish red and dark yellowish brown (5 YR 5/6, 10 YR 5/6); yellowish red and dark grayish brown (5 YR 5/6, 10 YR 4/2). The brownish cherts often turn red upon heating (Stafford 1971:8; Wilkens 1967:38). The chert is coarse to fine in texture. All are opaque; only one sample is translucent along thin edges. The chert is usually dull in lustre, although a few samples of medium lustre are present. It does not react to HC1. Veins of quartz and secondary chalcedony are very common. The chert contains a great deal of opaques, visible either to the naked eye or under 10X magnification. They are most probably crystals of magnetite, ilmenite, or chromite, as thin-section analysis indicated their presence in every slide (see microscopic analysis below). Nevertheless, we emphasize that the identification cannot be certain unless the rock sample undergoes thin-section analysis. The fact is especially important when attempting to locate the source of an artifact, as hand specimens of Hardyston chert often demonstrate the presence of opaques as well. Under the petrographic microscope, however, these opaques are shown to be hematite (see discussion of the Hardyston Formation). The presence of macroscopically visible metallic gray euhedral crystals, though, have only been found in the Newark specimens.

Microscopic analysis (9 slides representing 3 loci)

Diagnostic traits of Newark chert are a relict gabbro texture and numerous clots and euhedral crystals of the minerals ilmenite, magnetite, and chromite. The original gabbroic texture is represented by chert pseudomorphing of olivine and serpentinized olivine grains, often with a strong alignment of the opaque minerals. Well-developed veins of fibrous chalcedony are very often present. Newark Jasper contains iron oxides, including limonite, in gels and stylolites. Intra-outcrop variation is slight, and mainly due to differential degrees of diagenesis. The Delaware locus has a higher percentage of opaques (80% of each slide) and less chalcedony than the Maryland loci (Lavin and Prothero 1981:8).

Monkton Quartzite (1 locality represented)

The Cambrian Monkton Formation crops out in Vermont; its chert is archaeologically known as "Vermont Jasper."

Macroscopic analysis

Our samples are red (7.5 R 3-4/8). Texture is medium, slightly sandy or "gritty." All of the chert is opaque and dull in lustre. Quartz clots and streaks are sometimes present. Upon contact with HC1, the chert only effervesces on rust-colored patches and spots.

Microscopic analysis (2 slides)

In thin-section, the chert has a uniquely altered fine-grained quartzite texture; the original grains have been virtually all replaced by hematite (70-80% of each slide). The remaining silica is found only in interstices and cracks. Cracks are numerous, indicating a higher degree of tectonism than that found in the Hardyston Formation. Relict bedding planes are present.

Normanskill Shale (19 localities represented)

The Normanskill Formation is centered in New York state along the central and northern Hudson Valley. Outcrops extend into southwestern Vermont and northwestern Massachusetts as well (Fisher et al. 1970). The formation has been assigned to the Lower and/or Middle Ordovician (Prindle and Knopf 1932:280; Ruedemann 1930:27).

The chert occurs in many homogeneous hues of green, blue, olive gray, black, and red, as well as shaded or mottled combinations of these colors (Hammer 1976:52; Ruedemann and Wilson 1936:1542; Wray 1948:33-34). Our survey of Normanskill outcrops failed to locate any red chert lenses. Ruedemann and Wilson's (1936) in-depth study of Normanskill chert indicated, however, that there is no other difference among the various colored cherts except that red cherts contain submicroscopic hematite grains that produce a "clouded" appearance in thin-section. This being the case, the following macroscopic and microscopic descriptions, based mainly upon our analysis of green, blue, gray, and black Normanskill specimens, should prove valid for red specimens as well.

Macroscopic analysis

Hammer (1976:52) reports a Munsell color value of 2.5 R 3/2 for his samples of red Normanskill chert. Our samples of Normanskill cherts have a medium to fine texture. Virtually all are opaque cherts with a dull or medium lustre; a very few (and very rare) specimens have a shiny lustre. Specimens that are translucent along thin edges are extremely rare. Veins and veinlets of quartz and chalcedony are infrequently present. Pyrites are sometimes present. Virtually none of the chert reacts to HC1; a few rare samples effervesced in areas where calcite specks occurred (Richard Charmantz, New York University, Department of Geology, personal communication 1976). Much of the chert is shaley, low-grade material -- what geologists often call "indurated shale." Some samples represent very high quality chert, however, especially those from the Catskill-Coxsackie area.

Microscopic analysis (9 slides representing 4 loci)

Microscopic analysis indicated a very fine-grained chert with abundant fine clays and micas (20-50% of each slide) often showing greenish pleochromism (i.e., greenish coloring under plane light). Fine chalcedony is present. Some slides contain a fine quartz silt. Eight of the nine slides contain abundant pseudomorphs of siliceous microfossils, particularly radiolarians (5-25% of each slide), although sponge spicules and possibly graptolites also occur. Opaques are present, usually pyrites oxidized to hematite. A few slides show minor chlorite alteration. Dolomite rhombs and patches are sometimes present.

Beacon Hill Gravel (1 locality represented)

The Beacon Hill Gravel is an Upper Pliocene formation. It crops out in eastern Burlington and western Ocean and Monmouth Counties, New Jersey (Johnson 1950). It is a secondary source composed of chert, quartz, quartzite, and sandstone pebbles and cobbles redeposited by fluvial action (Minard 1964, 1966).

Macroscopic analysis

Some of our samples are homogeneous, but the majority are shaded, and often banded with two or three thick concentric bands. Representative colors and color combinations include very pale browns (10 YR 7/3-4); yellowish browns (10 YR 4/6-8, 10 YR 6/4, 10 YR 5/6); brownish yellows (10 YR 6/6, 10 YR 6/8); yellows (10 YR 7/6, 10 YR 7-8/8, 2.5 Y 8/4); strong browns (7.5 YR 4/6, 7.5 YR 5/6-8; dark browns (7.5 YR 4/6-8, and light brownish gray (10 YR 7/2). A few samples are a shaded white to yellowish white (N9 and 2.5 Y 8/2). The cherts have a medium to fine texture. They are all dull in lustre and completely opaque with no translucent edges. Many of the samples have a thin shiny patina on their weathered cortex, but their fresh fractures have a dull finish. The whitish samples tend to feel softer than, and are a little chalky in comparison to the brown and yellow samples -- possibly because the former are more weathered, as Howell and Hale (1946) have suggested. All of the samples are water-smoothed and rounded pebbles. The majority are under 1 1/2 inches in length, although a few are 1 1/2- to 2 inches in length. The not uncommon presence of chert cobbles 3 to 4 inches in diameter has been reported, however (James P. Minard, United States Geological Survey, personal communication dated May 16, 1978).

Microscopic analysis (6 slides)

Like Normanskill chert, Beacon Hill chert contains abundant microfossils. Instead of radiolarians and graptolites, however, the chert includes a "hash" of chertified or chalcedonized brachiopods, corals, bryozoans, and spicule-like rods. Opaques are abundant, especially oxidized pyrites and large patches of iron oxides, usually hematite. Post-depositional alteration of these "pebble cherts" are represented by iron oxide "rims" which surround five of the six slides. One slide included a peloid among its fossil contents. None of the slides contain carbonate minerals, such as dolomite or calcite. The specimens exhibit some intra-outcrop variation in texture, typical of a secondary source deposit (Lavin and Prothero 1981:14).

Pensauken Gravel (7 localities represented)

The Pensauken Gravel is a Pleistocene secondary fluvial deposit. It crops out in a belt through central New Jersey and extreme southeastern Pennsylvania, to the Pennsylvania-Delaware border; a few outliers are located southeast of this belt and along the New Jersey coast (Gray et al. 1960; Johnson 1950). The cherts are yellow, whitish with brown outer surfaces, brown, gray, and black. Because it is a secondary fluvial deposit with several parent sources, Pensauken chert as a type exhibits no diagnostic primary attributes. Fortunately, the brown, yellow, and whitish cherts with which this paper is concerned may be distinguished from cherts *in situ* in their parent formations by weathering. Unfortunately, this is not usually true of the gray and black cherts (see Lavin and Prothero 1981:14; Lavin 1983:185).

Macroscopic analysis

Pensauken cherts are sometimes homogeneous in color, but the majority are shaded, often with two or three thick, concentric bands of color. Representative colors are homogeneous very pale browns (10 YR 7/4 or 8/4); homogeneous yellowish browns (10 YR 6/4, 10 YR 5/4, or 10 YR 4/4); sometimes with yellow (10 YR 8/6) edges; homogeneous light brownish grays (10 YR 7/2 or 10 YR 8/2); homogeneous dark brown (7.5 YR 4/4), sometimes with yellowish white (5 Y 8/1) edges; yellowish brown (10 YR 5/4, 10 YR 5/6, or 10 YR 6/4) shaded with one or more of the following colors: dark grayish brown (10 YR 4/2), very pale brown (10 YR 7/4), brownish yellow (10 YR 6/6), yellow (10 YR 8/6), reddish yellow (7.5 YR 6/6, 7.5 YR 7/6), dark olive gray (5 Y 4/1); shaded light brownish gray and dark olive gray (10 YR 6/2 and 5 Y 4/1). Like the Beacon Hill samples, a few pebbles are yellowish white to white (10 YR 8/2, N9). In addition, a shaded yellowish brown sample (10 YR 6/4-6, 7.5 YR 6/6, 10 YR 7/4-6) turned reddish brown (2.5 YR 4/4) after being heated to a maximum temperature of 450 ° C for three hours (Lavin 1983a).

The cherts are medium to fine in texture, opaque, and dull in lustre. Exterior surfaces are water-smoothed and rounded; many specimens have a shiny patina, but their fresh fractures are all dull in lustre. The majority of the specimens are less than 1 1/2 inches long, although a few are 1 1/2 - 2 inches long. Specimens over 2 inches long are virtually non-existent in our survey samples. Salisbury and Knapp (1917:13, 78), however, do mention the presence of cobbles and boulders (i.e., rock fragments ranging from 2 1/2 to over 10 inches in diameter) in their discussions of the Pensauken and Bridgeton Formations. As one can see from this description, hand-specimens of the brown and white Pensauken cherts are virtually identical to those of the Beacon Hill Formation.

Microscopic analysis (12 slides represented 4 loci)

The cherts have been heavily altered by weathering agents. Most or all of the carbonate structures have been leached out and replaced (pseudomorphed) and/or partially obscured by opaques. Opaques are oxidized; slides often exhibit a strong iron oxide stain. All of the samples, however, can be assigned to their primary sources (see Lavin and Prothero 1981:14; Lavin 1983:Appendix C). With the exception of two Helderberg specimens, all are derived from the Onondaga Formation of northwestern New Jersey and eastern New York. It should be noted here that there are no comparable yellowish brown chert lenses within the parent bedrock Onondaga outcrops. The yellow and brown coloring of the Onondaga pebbles within the Pensauken Formation are apparently the result of long-term weathering. The data indicate that yellow or brown chert microscopically resembling Onondaga or Helderberg chert, except for the oxidation of opaques and leaching of carbonates, may be attributed to the Pensauken Formation.

In summary, the brown and yellow cherts from the secondary sources sampled in our survey may be distinguished from the cherts *in situ* in their primary sources by their degree of weathering. The secondary cherts usually have a heavy iron oxide stain. It often forms a "rim" around the pebble; some pebbles consist of several such concentric bands of color. Carbonate minerals (e.g., dolomite, calcite) are virtually always leached out. The voids are usually filled with oxidized opaques. Pensauken brown and yellow cherts may be identified by a combination of these weathering characteristics with the microscopic attributes of northeastern New Jersey or eastern New York Onondaga or Helderberg cherts. Beacon Hill cherts combine these weathering characteristics with a very different microscopic texture, albeit one difficult to convey verbally.

Because they are of similar age, and have undergone similar processes of deposition and/or weathering, these attributes may characterize other Pleistocene deposits not sampled in our survey (such as the Bridgeton Formation, Cape May Formation, Trenton Gravel, and Wisconsin glacial drift), Chert from these formations should be microscopically examined in order to discern if they can be differentiated from cherts in their parent sources, and from the Pensauken and Beacon Hill chert types as well.

For the record, a lithic material known as "Saugus Jasper" crops out in eastern Massachusetts. It is actually a rhyolite, however, and can easily be distinguished from a true chert (i.e., micro- or cryptocrystalline siliceous rock).

Conclusions

In summation, there are quite a few possible sources of "jasper" artifacts besides the Hardyston Quartzite, popularly referred to as "Pennsylvania Jasper" in the archaeological literature. Six of the chert-bearing formations discussed in this article are primary sources, i.e., *in situ* deposits. The remaining two formations (Beacon Hill and Pensauken) are secondary fluvial deposits. A lithologic method combining both macroscopic and microscopic techniques of analysis indicates that the source of cherts derived from the primary deposits can be identified; brown and yellow cherts derived from the secondary deposits may be ascribed to both their primary (original or parent) and secondary (final) sources. In addition, the data from the Newark and Wissahickon slides suggest that petrographic analysis may be able to distinguish specimens from geographic subareas within the outcrop areas of a specific formation, as well as from loci representing different formations. Because of the small sample sizes, these microscopic distinctions are tenuous, and may break down upon further sampling. Moreover, this hypothesis is not supported by all of the "jasper"-bearing formations for which we have more than one sampling locus. In the Hardyston slides, both inter-outcrop and intra-outcrop variation was present, due mainly to the differential degree of quartzite replacement. Inter-outcrop and intra-outcrop variations were also evident in the Normanskill slides. But all of the later specimens derived from the Catskill-Coxsackie subarea. Possibly, the cherts from the Saratoga subarea or eastern Hudson Valley subarea can be microscopically differentiated from these Catskill-Coxsackie cherts. In any case, the overall textures of the Hardyston and Normanskill cherts are quite unique and easily distinguished from the other chert types included in our sampling survey (Lavin 1983; Lavin and Prothero 1981).

The findings are archaeologically important because they indicate that the sources of the raw materials comprising stone artifacts may be identified through geologic analyses. We believe that chert identification will soon become a new analytic tool for archaeologists in this region to increase our understanding of eastern culture history and culture processes. Successful development of the technique should not only allow reconstruction of procurement and trade systems, but also aid in studies of cultural distribution (i.e., geographically isolated clusters of sites manifesting differential procedures for procuring lithic materials may indicate the existence of discrete culture systems).

Our project is, of course, an initial effort. As noted in the introduction, we did not sample all if the "jasper"-bearing rock units in the Northeast and Mid-Atlantic regions, nor did we sample all of the outcrops of the formations discussed in this paper. Yet although the number of slide samples per chert type may be small, the fact that they usually represent several different loci within the outcrop area of the chert type increases the credibility of our petrographic descriptions. It is quite possible that further petrographic analyses may effect changes in our original descriptions. The fact that we are dealing with such bizarre chert sources (especially, the Newark Gabbro, Wissahickon Schist, Normanskill Shale, and the Hardyston Quartzite), however, makes it highly unlikely that there is another formation in the research area that strongly resembles them.

The point to be made here is that the geologic sources of a "jasper" artifact must be identified through a combination of macroscopic and microscopic techniques, not simply by its coloring, lustre, opacity, or macroscopic texture. In any case, the authors welcome further testing of their results in the hope that it will result in increased refinement of the methodology and extension of the data base to include identification of additional chert-bearing formations, and specific outcrop areas or "quarries" within these and the formations discussed in this text.

Acknowledgements

Much of the contents of this paper is derived from the senior author's unpublished doctoral dissertation, presently being microfilmed by University Microfilms International (see Lavin 1983). The reader is referred to it for a fuller presentation of chert sourcing techniques and chert-bearing rock units within the northeast and Mid-Atlantic regions. The project had been funded by the National Science Foundation. Survey of Normanskill outcrops was partially funded by the New York State Museum and Science Service. We would like to thank the following persons and institutions for providing chert samples and/or the locations of chert-bearing outcrops: James Bowman, Lehman College, Department of Geology and Geography; Michael Delacorte, New York University, Department of Anthropology; Alan Geyer, Pennsylvania Geological Survey; Charles Gillette, New York Museum and Science Service; Joel I. Klein, Envirosphere Company; Ben McCary, College of William and Mary, Department of Anthropology; David Parris, New Jersey State Museum Science Center; Ronald Thomas and the Island Field Archaeological Museum and Research Center; Elwood Wilkins, Delaware Archaeological Society. Marina Mozzi, Public Archaeology Survey Team, provided the map enhancement for Figure 1.

Glossary

Note: Definitions marked with an asterisk (*) were excerpted from our Glossary in an earlier article on microscopic analysis of cherts (Lavin and Prothero 1981).

*ALIGNMENT FABRIC (PREFERRED ORIENTATION): Tendency of elements in a rock (crystals, grains, etc.) to be aligned in a parallel or subparallell ("preferred") direction.

*ANHEDRAL: A crystal with no crystal faces.

CHALCEDONY: The portion of chert that has a radiating fibrous habit.

*CLASTIC: Sedimentary particle derived from fragmentation of original material. Shorthand for "sand, silt, and clay," as opposed to "chemical" sedimentary rocks - carbonates and evaporites.

*DIAGENETIC: Refers to textures caused by secondary alteration of rock after deposition, e.g., compaction, cementation, recrystallization, dissolution, replacement, dolomitization.

EPIGENETIC: Formed later than the surrounding rock.

*EUHEDRAL: A crystal completely bounded by crystal faces.

MACROSCOPIC, or MEGASCOPIC ANALYSIS: Analysis of a hand specimen of lithic material for attributes visible to the naked eye.

MICROCRYSTALLINE QUARTZ: The portion of chert that is too fine-grained, even under a microscope, to resolve the individual crystals.

*OPAQUES: Minerals which do not transmit light, e.g., magnetite, hematite, ilmenite, limonite.

PETROGRAPHIC: Microscopic (thin-section, or slide) analysis of the mineralogy, texture, and chemistry of a lithic specimen.

PLANE LIGHT: Light polarized in one direction.

*PSEUDOMORPH: A grain having the apparent form of another grain, due to replacement of the latter by the former.

RELICT QUARTZ GRAINS: Detrital sedimentary quartz sand and silt that has not been replaced by chert, and is, therefore, left over ("relict").

*RELICT TEXTURE: Preservation of original texture during replacement.

*STYLOLITE: A jagged, irregular seam filled with unsoluable residue of opaques, usually due to dissolution.

SYNGENETIC: Formed at the same time as the surrounding rock.

*UNDULOSE (UNDULATORY) EXTINCTION: *Irregular, "wavy" extinction of a crystal when stage* is rotated under crossed nicols, due to distortions of crystal lattice.

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Editor's Note:

This paper was written in 1983, and scheduled to be published in this journal shortly thereafter. Due to unforseen complications, the report is only now making its appearance, and without the inclusion of updated information or references to more recent research.
