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Lithic Analysis in the Maya Area

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Ancient Mesoamerican chipped-stone tools made of chert and obsidian, as well as the quarries and outcrops from which raw material was extracted, have long been subjects of archaeological study (e.g., Breton 1902; Holmes 1900; Washington 1921). Culture historians of the early and middle decades of the twentieth century were drawn to Maya stone tools for three principal reasons. First, lithic artifacts are well represented in most archaeological assemblages. Second, they preserve well in nearly all depositional contexts, including the rainforest environments of the Pacific piedmont and the Maya lowlands. Third, archaeological investigations in North America and the Old World had demonstrated that lithic artifacts—like other objects of material culture—are subject to gradual change in technology and morphology. Thus, early Maya scholars hoped to use lithic artifacts as temporal and cultural markers, allowing diachronic comparison within and between sites and regions.

Nevertheless, lithic analysis played only a minor role in Maya archaeology until the mid-1970s. There are many reasons why stone tools were regarded as less important than architecture, ceramics, iconography, and hieroglyphs. Excavation methods practiced until at least the 1960s were—and still are, in many cases—insufficient for recovering small lithic tools and debitage (by-products). Quite simply, we did not know what the full range of lithic assemblages looked like because only bifacial tools and the largest blades were recovered. Incomplete, biased, and otherwise unrepresentative samples, I believe, are still the greatest obstacles to the Maya lithicist. In addition, temporal and spatial variation in the morphological and technological characteristics of stone tools was thought to be quite limited. No less a scholar than Alfred V. Kidder dismissed the culture-historical value of Maya lithic artifacts.[1] Compared to ceramics, architecture, and sculpture, the common Maya prismatic blade and even the less-frequent biface seemed to be remarkably homogeneous and unchanging. Thus, it was believed that stone artifacts were of less value to understanding space-time dynamics than other classes of material culture subject to a greater degree of formal variation. By the 1930s, then, ceramic classification and seriation became important temporal and spatial tools for archaeologists working in the Maya highlands and Southern Lowlands, architectural analysis played a similar preëminent role in the Northern Lowlands, and lithic studies were given far less attention. Notable exceptions are the excellent typological—if not analytical—descriptions presented by Oliver and Edith Ricketson (1937), Kidder (1947), Gordon Willey (1972; Willey et al. 1965), William Coe (1959), Richard B. Woodbury and Aubrey Trik (1953), and Tatiana Proskouriakoff (1962).[2] Another important study of this period is the descriptive catalogue of obsidian and chert eccentrics compiled by the British archaeologist Thomas A. Joyce (1932). It is still a critical resource for Mayanists interested in the symbolic and noneconomic importance of lithic artifacts.

A third reason why Maya stone tools and debitage were seldom studied in detail until the late twentieth century is that the kinds of questions for which lithic analysis is most appropriate—questions related to production, technology, use, and exchange—are fundamentally economic in character. Despite the widely acknowledged importance of ancient trade, the nature of Maya economic systems was rarely subject to systematic study before 1970. The proponents of the early and late empire model and the supporters of the empty ceremonial center paradigm—two views of ancient Maya political and urban organization that dominated our discipline from the 1920s through the 1960s—had little interest in economic questions. To these scholars, economy was truly epiphenomenal and was determined by the politico-religious structures of either highly centralized empires or completely decentralized polities. Moreover, the tenor of debates within the field of economic anthropology was so strident that it may have seemed prudent to some scholars to avoid studies of ancient economy. It is no surprise, therefore, that Maya economy and lithic artifacts were not the subjects of deep and sustained inquiry until after the death of J. Eric S. Thompson and a cease-fire of sorts had emerged in the substantivist-formalist debate.

Characteristics of Lithic Artifacts Relevant to the Study of Ancient Economy

As archaeologists, including Maya scholars, turned to economic questions in the late twentieth century, several important characteristics of chipped-stone tools and debitage became apparent. First, because stone-tool manufacturing is a subtractive process, each artifact carries the marks of human behavior; flake scars, ground platforms, and bulbs of percussion all represent production activities. Second, subtractive by-products reveal important technological information, and replicative experiments can test hypotheses concerning how artifacts were produced (e.g., Ahler 1986; Baumler and Downum 1989; Crabtree 1968; Clark 1982, 1984, 1985; Odell 1989; Patterson 1990; Shott 1994; Towner and Warburton 1990). Third, knapping errors—recorded as scars, poor terminations, and the like—on finished artifacts and debitage provide key information regarding the skill and efficiency of lithic producers. This, in turn, may be related to labor specialization and the organization of production. Fourth, despite the inherent hardness of stone, characteristic wear patterns develop on lithic tools. Through replicative experiments and microscopic (both high- and low-magnification) comparisons of wear patterns, analyses of function, and therefore of material-cultural adaptations, are often possible (e.g., Aoyama 1989, 1993, 1999; Keeley 1977, 1980; Lewenstein 1981, 1987; Semenov 1964; Shea 1992; Tringham et al. 1974). Fifth, social, ideological, and "stylistic" information is sometimes encoded in lithic tools (e.g., Jones 1990; Sackett 1985; Taçon 1991; Weissner 1983, 1985; Whittaker 1987; Young and Bonnichsen 1984). Sixth, lithic materials are often either visually or chemically distinctive, and their ultimate sources can sometimes be determined, allowing trade routes and exchange patterns to be studied (e.g., Dixon et al. 1968; Gramly 1980; Renfrew et al. 1966, 1968; Shafer and Hester 1983, 1985).

Obsidian, or volcanic glass, has several additional properties useful to archaeologists. Unlike cherts, which are commonly encountered in secondary deposits wherever limestone is found, obsidian is relatively scarce. At many sites, the presence of obsidian artifacts necessarily implies interregional or even long-distance exchange (*sensu* Marcus 1983:477–9). Since obsidian outcrops are uncommon, it is usually easy to determine the source of a particular artifact because the compositional "fingerprints" of only a few geological sources need be known, and because obsidian from a particular outcrop or source area is usually homogeneous in composition (cf. Braswell and Glascock 1998; Glascock et al. 1998). In comparison, cherts may be quite heterogeneous (Luedtke 1992), often making source attribution by chemical means a difficult or impossible task. This is particularly true in the Northern Maya Lowlands, where cherts are derived from sedimentary strata deposited on the ocean floor over millions of years. Finally, and related to the compositional homogeneity (particularly the intrinsic water content) of volcanic glass from a particular source area, obsidian hydrates at rates that may ultimately prove to be determinable. For this reason, measurements of hydration-rind thicknesses may provide relative or even absolute chronological data. In practice, however, the determination of hydration rates is often subject to great error (e.g., Braswell 1992, 1997; Ridings 1991). New research confirms that water-glass diffusion should not be modeled in the simple manner that has been used in the Maya region,[3] and that the optical phenomenon measured in the laboratory does not represent a boundary between hydrated and nonhydrated obsidian (Anovitz et al. 1999). Given that the model employed to date is demonstrably flawed and that the observed phenomenon has been misinterpreted, absolute dates generated for the Maya area should not be given much credence. Statistical naiveté and what I consider to be an irrational enthusiasm for the method have led, unfortunately, to unrealistic claims of accuracy and unsupportable revisionist interpretations of chronology (for a discussion of the statistical misinterpretation of large hydration data sets, see Cowgill and Kintigh 1997).

The Lithic Revolution in Maya Studies

Although there are numerous early studies of Maya stone tools worthy of admiration, lithic analysis began to play a prominent role in the study of ancient Maya society only in the 1970s, when Maya archaeologists began to focus in earnest on economic questions. In the mid-1970s a revolution—comparable in several respects to the epigraphic revolution yet distinctly different in outcome—was brought about by several young scholars. Much of the new work was conducted in areas long considered peripheral to the Petén heartland, particularly the southeastern periphery, northern Belize, highland Chiapas, and the Northern Lowlands. The beginnings of this lithic revolution can be dated rather confidently to 1974 through 1976. In the course of these years, several important dissertations were written. These include Payson Sheets's (1974) analysis of the artifacts of Chalchuapa, a followup to earlier work that introduced the notion of the behavioral typology to Maya lithic studies (Sheets 1972, 1975a); Irwin Rovner's (1975; Rovner and Lewenstein 1997) pivotal diachronic study of stone tools from the Northern Maya Lowlands, a pioneering technological and culture-historical analysis; and Jay Johnson's (1976) study of the stone tools of the western Maya periphery.

The year 1976 also saw the first of two Maya lithic conferences. Held in Orange Walk Town, Belize, it had the dual goals of examining the status of lithic research in the Maya region and of introducing archaeologists to the vast chert workshops at Colhá. The papers presented at that conference

(Hester and Hammond 1976), and also those from a second meeting held in San Antonio in 1982 (Hester and Shafer 1991), are valuable not only to the Maya lithicist, but also to the historian of lithic studies. Both conference volumes contain chapters that explicitly discuss the status of Maya lithic studies and describe programs of investigation for later research (Fowler 1991; Sheets 1976; see also Coe 1965, Sheets 1977, and Woodbury 1965 for summary discussions of lithic studies in the Maya lowlands, southeast periphery, and Maya highlands).

In the early 1980s a second generation of lithic scholars began to consider ancient Maya economy. Many of these, such as Patricia McAnany (1986, 1988, 1989, 1991), Suzanne Lewenstein (1981, 1987, 1991), and Beverly Mitchum (1981, 1989, 1991), worked at sites in northern Belize, including Colhá and Cerros. Research at or near Colhá directed by Thomas Hester and Harry Shafer during the 1970s and 1980s not only provided training for several lithicists, but also stands as the lone example of a supply-zone study of lithic production in the Maya lowlands (e.g., Hester 1976; Hester and Shafer 1983, 1991; Hester et al. 1980, 1982, 1991; Potter 1991; Roemer 1991; Shafer 1976, 1991; Shafer and Hester 1979, 1983, 1985; Wilk 1976). In 1979 John Clark wrote his crucially important M.A. thesis, a technological study of the obsidian of La Libertad, Chiapas (published nine years later as Clark 1988a). Since then, Clark has both figuratively and literally towered over lithic studies in Mexico and northern Central America. Another very important dissertation of the late 1970s, Conran Hay's (1978) study of craft production, is the single most important work generated by the Pennsylvania State University Kaminaljuyu Project. It is a great shame that it was never published as a monograph.

In 1981 two Mexican conferences contributed greatly to our understanding of Mesoamerican lithics. The first, held in Pachuca, Hidalgo, and organized by Margarita Gaxiola González and Clark, focused on obsidian studies in Mesoamerica. An important result is the first volume of collected papers devoted to that subject (Clark and Gaxiola 1989). The second, held in concert with the obsidian symposium, was more broadly dedicated to Mesoamerican lithic studies (Soto de Arechavaleta 1990). The two volumes resulting from these conferences are source books of great importance to the student of Mesoamerican lithics.

Five scholars—Frank Asaro, Fred Stross, Fred Nelson, Michael Glascock, and Garman Harbottle—and the large teams employed in their laboratories have conducted critically important chemical studies of obsidian. Although Henry S. Washington (1921) pioneered the chemical sourcing of Maya obsidian in the early twentieth century, these scientists are largely responsible for developing, modifying, and applying X-ray fluorescence, neutron activation analysis, and a host of other techniques used to identify the geological sources of Maya obsidian. Their work in the laboratory has been complemented and made possible by surveys of Maya obsidian outcrops (e.g., Aoyama 1994; Braswell 1996; Braswell and Glascock 1992, 1998; Clark 1981; Cobean et al. 1971; Mejía and Suyuc 2000; Sheets et al. 1990; Sidrys et al. 1976; Williams 1960; Williams et al. 1964).

Many more archaeologists who are not explicitly discussed above made lasting contributions to Maya lithic studies during the 1970s, 1980s, and beyond: Hattula Moholy-Nagy (1975, 1976, 1989, 1990, 1991, 1994, 1997, 1999; Moholy-Nagy et al. 1984; Moholy-Nagy and Nelson 1991), James B. Stoltman (1978), Kazuo Aoyama (1988, 1989, 1993, 1994, 1995, 1996, 1999), Norman Hammond (1972, 1976; Hammond et al. 1984), Brian Hayden (1979, 1987), Heather McKillop (1995, 1996), Rebecca McSwain (1991), Prudence Rice (1984; Rice et al. 1985), and many others come immediately to mind. Mexican and Guatemalan scholars have contributed equally to the understanding of Maya stone tools. These include María Elena Ruiz Aguilar (1981, 1982, 1985, 1986, 1987, 1989, 1996), Carlos Brokmann (2000), Pura Cervera (1996; Andrews et al. 1989), Edgar Carpio Rezzio (1993a, 1993b, 1994, 2000), Rómulo Sánchez (1991), and Héctor Mejía Amaya and Edgar Suyuc Ley (1997, 2000).

Recent Studies of Maya Lithics

The life of a stone artifact can be divided crudely into five stages. These are material procurement and initial production, exchange, secondary production, use, and discard. Exchange, of course, can take place at nearly any point in this sequence, as can additional phases of production and use. This simplified life cycle provides a crude way to organize recent studies of lithic tools and debitage according to different sorts of analytical questions.

Resource-Zone Studies: Material Extraction, Production, and Regional Exchange

To be blunt, there are few adequate studies of raw material procurement and initial production—what may be considered resource-zone studies—for either chert or obsidian in the Maya region. Such studies, of course, are crucial; the only place within a distribution network through which all material of a specific sort flows is its origin. We desperately need to know more about the organization of production in and around both chert- and obsidian-bearing zones.

Colhá remains *the* great example of a resource-zone study of Maya lithics. Craft production and specialization on a large scale at Colhá are particularly well documented. Shafer's (1982) study identified a high degree of craft specialization by quantifying error rates, material-use efficiency, time-input efficiency, standardization, and other factors. His work demonstrates the power of an approach firmly rooted in technological analysis. McAnany's (1986, 1989) groundbreaking research at nearby sites where Colhá chert was consumed provides a dynamic picture of a regional economic system.

Clark (1981), Sheets (1975b), Sidrys et al. (1976), John Graham and Robert Heizer (1968), Michael Coe and Kent Flannery (1964), and Joseph Michels (1975) wrote fascinating short articles on the obsidian sources of the Guatemalan highlands. These reports, for the most part, are derived from single-day visits, but they do contain much useful information. A similar piece by Sheets et al. (1990) provides the only description of two source areas in Honduras, and is relevant more to the study of lower Central American lithics than to the analysis of Maya stone tools.

More recently, small-scale projects have tackled two of the three most important Maya obsidian sources: El Chayal and San Martín Jilotepeque. In 1996 Héctor Mejía and Edgar Suyuc, then students at the Universidad de San Carlos de Guatemala, began a systematic settlement survey and workshop study of the vast and complex El Chayal source region (Mejía and Suyuc 1997, 2000). Their work indicates some level of specialization in the resource zone, but does not support many earlier claims that Kaminaljuyu somehow controlled El Chayal. Although there is significant settlement in the region, it is not dense. Nor are there any signs of garrisons, large state-controlled workshops, or symbols of power and hierarchy. Together, these suggest to Mejía and Suyuc that the source area was not controlled by any large polity. Instead, they posit that access to the *technology* of prismatic blade and bifacial tool production may have been limited.

My own work in San Martín Jilotepeque (SMJ) focused on the relationship between resources, settlement patterns, and economic organization (Braswell 1996, 1998, 2002; Braswell and Glascock 1998). Like Mejía and Suyuc, I concluded that the region was not the center of any large polity, and indeed seemed in many ways to be interstitial, particularly during the Preclassic and Postclassic periods. I could find no evidence of a large Chimaltenango chiefdom, for which some have argued, dating to the Middle and Late Preclassic when SMJ obsidian was widespread throughout the Maya lowlands. Indeed, the region was abandoned during the Late Preclassic, implying that no polity controlled the source at that time. Moreover, there is no evidence for the development of a social hierarchy until the onset of the Classic period. Although I cannot comment on exchange mechanisms near distant consumer nodes such as La Venta and Komchen, finished tools and cores of SMJ obsidian most likely left the region through limited acts of down-the-line dyadic exchange.

In contrast, during the Classic and Postclassic periods there is ample evidence for the development of some level of specialized production of polyhedral cores, prismatic blades, and especially bifacially worked projectile points. Evidence of off-quarry workshops specializing in biface production was found at intermediate-ranked sites located comparatively short distances from exploited quarries. But there is no evidence of the high degree of specialization, skill, and efficiency exhibited by the chert workshops of Colhá. Even the specialized biface workshops of SMJ produced rather crude, error-filled, and highly unstandardized projectile points and handheld bifaces. Most striking, there is no artifactual evidence in SMJ for exchange with communities more distant than about 50 km away. Thus, despite the presence of massive beds of debitage, often more than 1 m deep, there is no reason to suspect that SMJ was ever the center of a large-scale, state- or chiefdom-controlled industry. As an aside, I believe the same to be true for the Ixtepeque source. There currently is no clear evidence that this source region was ever politically, economically, or militarily dominated by a powerful polity such as Copan or Chalchuapa, or that production at the source was standardized, efficient, or otherwise describable in terms that suggest a high level of craft specialization. Still, Maya obsidian source-areas have received considerably less archaeological attention than several of their counterparts in central and west Mexico (e.g., Cruz Antillón 1994; Darras 1999; Healan 1997; Pastrana 1990, 1998). It may be that further study will reveal evidence of more complexly organized forms of production.

Exchange beyond Procurement Zones

Joyce Marcus (1983) has characterized exchange in terms of three levels of scale: intraregional, interregional, and long-distance. With the exception of northern Belize, where McAnany (1986, 1989) brilliantly described the exchange of Colhá chert tools as part of an interdependent regional system, we know nothing at all about the intraregional exchange of chert. For example, I have observed great variety in the cherts, chalcedonies, jaspers, and other similar materials used at Chichén Itzá and in the Puuc region. But I have little idea where these materials came from, except in the negative: They do not seem to come from the chert-bearing zone of northern Belize. Someone needs to go to the vicinity of Xkichmook, in the southern Puuc, where good-quality chert is readily available, and begin a study modeled after Hester's, Shafer's, and McAnany's research. At Copan the vast majority of the chert is local, probably pulled right out of the river and flaked by nonspecialists. The exceptions—material used to make fine bifaces, including the exquisite eccentrics from the Rosalila offerings—come from unknown sources.

Intraregional Obsidian Exchange. We know a bit more about the intraregional exchange of obsidian, particularly in Soconusco and western Honduras (Aoyama 1999, 2001; Clark et al. 1989; Clark and Salcedo

1989), two areas on or beyond the fringes of the Maya area. Aoyama has studied the relationship between politics and exchange in the Copan and La Entrada Valleys. During the fifth through ninth centuries (Acbi through Coner phases), the dynastic center of Copan was a regional hub for the distribution of obsidian from the Ixtepeque, Guatemala, source area. Aoyama's study demonstrates important distinctions between obsidian consumption patterns in elite portions of the city and in non-elite sites in the surrounding Copan pocket. In particular, he concludes that prepared obsidian cores were redistributed rather than subject to market exchange. He notes that redistribution of a utilitarian good may have been important as a means of reinforcing status differences as well as creating and maintaining political power (Aoyama 1999:177). Moreover, although there is ample evidence of part-time lithic production, no data from either Copan or the La Entrada region suggest the existence of full-time specialists engaging in either workshop- or factory-level production. His study, therefore, paints a picture of what might be termed an intermediate economy: one where low-intensity production and traditional ties between individuals and groups have not been replaced by market forces governing production and exchange.

I have studied the intraregional exchange of obsidian in the Northern Maya Lowlands, particularly within the Itzá state and *between* Chichén Itzá and the Puuc region (Braswell and Glascock 2003). My conclusion is that a bounded administered market system focused on Chichén Itzá became part of a more integrated market economy after about A.D. 900. Thus, the intermediate-level economy described by Aoyama for Late Classic Copan was replaced by more complex forms during the Terminal Classic. New levels of economic integration undoubtedly contributed to the vibrant florescence of the Northern Lowlands during the Terminal Classic and Postclassic periods. Still, we desperately need more intraregional research like Aoyama's work in the Copan and La Entrada regions, McAnany's study of northern Belize, and Clark's investigations in Soconusco if we are to develop a diachronic and areawide understanding of the structure of ancient Maya economies.

Interregional Obsidian Exchange. Both interregional and long-distance exchange research has concentrated on the identification of the source of artifacts, usually accomplished through X-ray fluorescence, neutron activation analysis, or other chemical and physical techniques. This aspect of modern Maya lithic studies truly began the decade before the revolution of the 1970s. After initial success with X-ray fluorescence and neutron activation analysis in the 1960s (e.g., Jack and Heizer 1968; Stross et al. 1968; Weaver and Stross 1965), Hammond (1972, 1976) made critical contributions to the subject of interregional obsidian exchange, and Rice (1984; Rice et al. 1985) provided the first diachronic look at shifting obsidian procurement patterns for a single region. More recently, Marie Charlotte Arnauld (1990) has reexamined the movement of obsidian from the Maya highlands to the lowlands. The single most important contribution on interregional and long-distance obsidian exchange, however, is Fred Nelson's (1985) article in *Scanning Electron Microscopy*. In this work, Nelson provides a period-by-period summary of all that was known in the early 1980s about obsidian procurement patterns in the Maya region. Today, we have multiplied the number of sites for which we have obsidian procurement data by at least thirty, and our total sample size is on the order of hundreds of thousands of pieces, most of which come from Copan, Soconusco, and the central Guatemalan highlands (see Braswell 2003). It is high time for large collections from other regions, particularly the central Petén, the western highlands, and the Gulf Coast to be analyzed in a systematic fashion. More to the point, it is time that we begin to discuss what, precisely, procurement data tell us about the structure of ancient economies, and how interregional exchange within the Maya area changed over time. To do this, we need to develop more meaningful ways of quantifying and comparing our data.

Long-distance Obsidian Exchange. Studies of long-distance or transisthmian obsidian exchange have often focused on the trickle of green obsidian from Pachuca, Hidalgo, that reached the Maya region during the Early Classic. In contrast, far less information has been presented regarding long-distance interaction during other periods (Andrews et al. 1989; Braswell 2003; Moholy-Nagy 1999; Nelson 1985; Spence 1996). Moreover, little attention has been given to the trade of Maya-source obsidian beyond the Maya area.

I would like to emphasize three observations. First, far greater quantities of central and west Mexican obsidian entered the Maya region during the ninth through eleventh centuries than during any other period. Second, exotic Mexican obsidian brought to the Maya area before the Terminal Classic period was traded as *finished* artifacts. In contrast, beginning in A.D. 800, most highland Mexican obsidian entered the Maya region in the form of small, refurbished cores from which blades were locally produced. These cores were recycled in much the same fashion as described for Xochicalco by Kenneth Hirth (2002). Third, exotic obsidian in the Maya area that dates to before the Terminal Classic tends to be limited to elite tombs, caches, middens, or other contexts in the epicenters of large sites (Spence 1996). In contrast, there is little or no evidence for status-based access to highland Mexico obsidian after A.D. 800. This tells us something very important about the nature of transisthmian trade before and after this date. Before the Terminal Classic, long-distance obsidian exchange was conducted between elites and for elites. By A.D. 800, obsidian had become a commodity in the

Maya lowlands, and almost certainly was subject to some sort of market exchange. I strongly suspect that the commodification of obsidian and the commercialization of its exchange began earlier on the northwestern side of the Isthmus of Tehuantepec (see Santley 1994), but this is an important subject that needs further study.

Production and Use at Consumption Nodes

Although chert is a resource distributed widely throughout the central and Northern Lowlands, most archaeological projects in the Maya area have been conducted at sites that are more accurately described as concentrations of dwellings and special function structures than as lithic procurement areas. Thus, even though naturally occurring chert can be found at ancient cities such as Calakmul and Copan, they are more usefully thought of as places of secondary production (i.e., production from cores or blanks transported to the site) and consumption than as quarries where initial production activities were the focus of activity.

Secondary Production. Descriptive studies of chipped-stone tool collections from large Maya sites are common; many of the principal studies are cited above. But detailed technological studies of secondary production are largely lacking in the Maya area. There are, in fact, many ways to make a blade from an imported core or to knap a biface from an imported blank, and the details of alternative technological pathways need to be described. Such studies may tell us something about the organization of production at consumer nodes, and also may be relevant to the more basic chores of space-time systematics. A recent symposium on alternative core-blade reduction sequences in Mesoamerica yielded an interesting volume (Hirth and Andrews 2002), but I was disappointed to see that only one Maya lithicist contributed to it. In her chapter, Rissa M. Trachman (2002) discussed provisioning and production constraints at Dos Hombres, northern Belize, and described in detail a newly observed technique of core rejuvenation based on pecking and scoring. The importance of her study is that it broadens our understanding of the complexity of obsidian production technology, and emphasizes the ancient need to carefully curate and reduce imported cores. Clark (1988a, 1997; Clark and Bryant 1997) is among the few other Maya lithicists who pursue the fine details of alternative reduction strategies. It is a subject, no doubt, that will continue to bear fruit.

As discussed above, Aoyama's work at Copan and at other sites in western Honduras has provided us with an important picture of the organization of production and distribution in an important Maya kingdom. What we do not yet fully understand is the physical and social context of secondary production. Signs of lithic production and resharpening—in the form of exhausted polyhedral cores, thinning flakes, and the chunks and shatter resulting from casual percussion industries—can be found in many contexts at nearly all habitation sites. Relatively small concentrations of debitage are routinely recovered from construction fill, slump, middens, floor contexts, and even burials. In most cases, debitage is thoroughly mixed with a wide variety of material remains resulting from the full range of quotidian activities. Does this indicate that nearly all habitation groups were loci of lithic production, if only on a modest household scale? If so, did nearly all households have at least one unspecialized lithic producer or even a part-time specialist? Alternatively, did lithic producers—practicing their craft at whatever level of specialization—routinely travel throughout and between habitation sites not only to exchange, but also to produce lithic tools? Finally, to what degree does the presence of lithic debitage at most habitation groups indicate scavenging of materials from other locations for potential reuse? What seems clear is that at most Maya sites, places of secondary lithic production were not far removed from the house lot.

Use-wear Studies. Functional analyses of Maya stone tools began with Kidder's (1947) monograph on the artifacts of Uaxactun. Nevertheless, Americanist archaeologists did not become fully aware of the promise of use-wear studies until Sergej Aristarchovich Semenov's (1964) book *Prehistoric Technology* became available in English (e.g., Wilk 1978). Early applications of his technique in the Maya region addressed issues such as the manioc grater hypothesis (Lewenstein and Walker 1984; Walker and Wilk 1989), and many studies focused on collections from Belize. The most outstanding and important of these is Suzanne Lewenstein's (1987, 1989, 1991) analysis of the stone tools of Cerros. Several Maya lithicists have used low-powered microscopy techniques for use-wear studies (e.g., Doonan 1996; Dreiss 1988; Menzies 2003; Nance and Kirk 1991; Valdez 1994), but high-powered techniques have also been used (e.g., Aldenderfer et al. 1989), occasionally in conjunction with microscopic analyses of residues (Shafer and Holloway 1979; Sievert 1990, 1992; see also Triadan and Inomata in this volume). Aoyama (1989, 1993, 1995, 1999) is one of the preeminent Maya lithicists using the high-powered technique today, and his work is especially worthy of note. Nonetheless, it is uncommon for lithic analysts in the Maya region to encounter tools and contexts that beg to be analyzed in this way. As others have noted, use-wear analysis is a powerful method waiting for a question.

Discard: Lithic Concentrations as Disposal Sites and Identifying Workshop Loci

Although old tools and debitage were often scavenged from middens and surface contexts for further use or reduction, in most cases disposal, loss, or discard was the final stage in the life of a stone tool. The interpretation of concentrations of lithic materials, including debitage, has been a focus of archaeological and ethnoarchaeological work in the Maya area and throughout Mesoamerica, mirroring the New Archaeology's interest in site formation processes. James Nations (1989) and Clark (1989a) have analyzed the production of stone-tipped arrows by modern Lacandon Maya. An important part of Clark's research is the discard of lithic debris (Clark 1991a, 1991b). His study reveals a variety of disposal patterns, often beginning with the temporary storage of debitage in a gourd kept in the house. Final deposition of debitage is usually in a small, specialized dump 100 to 200 m from the household workshop. Because debitage is sharp, dumps are placed where people are unlikely to tread or engage in milpa farming (e.g., inside an old tree stump, at the base of a rocky slope, and even on the talus of a prehistoric mound). Such patterns of disposal of dangerous material are in accord with Brian Hayden and Aubrey Cannon's (1983) ethnoarchaeological observations and with Robert Santley and Ronald Kneebone's (1993) expectations for ancient disposal patterns.

An important implication is that the archaeological identification of lithic production loci is often indirect. Ancient households, like most of their Lacandon counterparts, were generally swept clean. Because most excavations are conducted in and around structures, rather than in empty terrain between habitation groups, Maya archaeologists have often missed the specialized dumps described by Clark.[4] If we wish to identify places of lithic production and to recover dense concentrations of debitage for study, we will need to excavate interstitial spaces between mound groups (e.g., Healan et al. 1983).

Related to ethnoarchaeological studies of lithic disposal is the question of the identification of lithic workshop spaces (e.g., Clark 1986, 1988b, 1989b; Moholy-Nagy 1990). Although the discussion has occasionally been contentious, it is generally agreed that dense deposits of lithic material do not in themselves indicate the presence of a lithic reduction site. This is particularly true if the stone artifacts are finished tools exhibiting use wear. In most cases, such deposits are either dumps associated with "workshops" where other materials (such as wood) were worked, or are specialized offerings or caches. Examples of the former include some of the obsidian workshops identified at Teotihuacan (Clark 1986), whereas the latter includes the beds of lithic material often found above or below burials in the eastern Petén and western Belize. A few discussions of workshops have, unfortunately, focused on the question of recognizing lithic reduction sites at the expense of identifying a *workshop scale* of production. Questions of production scale, organization, specialization, and intensity—fundamentally economic issues—are of greater interest and importance than the identification of actual workshop spaces. The identification of a workshop industry is not, in fact, dependent on locating and excavating a workshop space.

The Future of Maya Lithic Studies

The lithic revolution of the mid-1970s was markedly different from the epigraphic revolution that began to affect Maya studies during the same decade. Despite a promising beginning, lithic studies have not engendered a new way of thinking about ancient Maya civilization comparable to that afforded by advances in hieroglyph interpretation, even in that area where stone-tool analysis potentially can have its greatest impact: ancient economy. The fundamental reason for this is that we all too often have become enchanted either with our trace-element data or with the minutiae of technological analyses (the latter is far less common). Trace-element data are not particularly important unless we use them to formulate and test models of exchange, which, in turn, can tell us something about the structure of economic systems. Technological details are not especially interesting unless they tell us something about the structure of production, which, again, can tell us something about economy. In particular, we need to move beyond the site as the unit of archaeological analysis, and begin to understand the regional system as the unit of economic integration. As McAnany, Aoyama, and Clark have empirically demonstrated, it is at the regional level of scale that Maya economic structure is most evident. Regional studies of lithics, therefore, should be the focus of our efforts.

Because of its embeddedness in even broader cultural realms, economy is a subject of interest to all Mayanists. The ability to move from the particular to the general has been the strength of the epigraphic revolution; for example, several models of Maya political structure are rooted in hieroglyph interpretation. Maya lithics have much to tell us about the nature of production and exchange, and hence, about the structure of power, about wealth, and even about the nature of political systems. The subject of our volume is the last century of Maya archaeology, but, like most readers, I am much more interested in the next hundred years. I hope that in the coming century we will turn more to these issues, which are relevant not only to our fellow lithicists but also to all Maya archaeologists.

Notes

1. On several occasions, Edwin M. Shook emphasized to me that only exceptional obsidian and chert artifacts (chiefly bifacially worked tools and eccentrics) were routinely recovered during most Carnegie excavations. According to him, A. V. Kidder was particularly dismayed by the apparent lack of regional and temporal variation in the ubiquitous Maya prismatic blade. T. R. Kidder (personal communication, 1995) provided corroborative evidence of Shook's recollection.
2. I have been fortunate to supervise Bárbara Escamilla Ojeda, a *licenciatura* student at the Universidad Autónoma de Yucatán, in her lithic analysis of materials excavated recently by the Proyecto Mayapán, directed by Carlos Peraza Lope. While examining the obsidian collection with Escamilla, my appreciation for Proskouriakoff's (1962) important work at Mayapán deepened. It should be of no surprise that Proskouriakoff brought to lithic

studies the same observational skills, keen intellect, and deductive powers that infuse her better-known research on Maya iconography and architecture.

3. Simple, in this case, is not a pejorative. It means that hydration rates have not been modeled as dependent on concentration. Simple diffusion models (such as those applied until now in the Maya region) are generally more applicable to liquid–liquid diffusion, whereas concentration-dependent diffusion models are more appropriate for liquid–solid diffusion. As liquids diffuse into solids, they often open pathways, increasing the rate of diffusion. Thus, as water concentrations increase in a solid, the diffusion rate may also increase.
4. I have studied materials recovered from a specialized biface dump excavated by the Proyecto Dzibilchaltún, directed by Rubén Maldenado. In this case, thinning flakes were found within, outside, and on top of a small structure. The pattern of deposition suggests that an already abandoned structure was used as a disposal site, analogous to Clark's observation of Lacandon use of an ancient mound.

References

Ahler, S. A. (1986) *The Knife River Flint Quarries: Excavations at Site 32DU508*, Bismarck: State Historical Society of North Dakota.

Aldenderfer, M. S., et al. (1989) "A Microwear Analysis in the Maya Lowlands: The Use of Functional Data in a Complex Society Setting," *Journal of Field Archaeology* 12: 47–60.

Andrews, A. P., et al. (1989) "The Obsidian Trade at Isla Cerritos, Yucatán, Mexico," *Journal of Field Archaeology* 16: 355–63.

Anovitz, L. M., et al. (1999) "The Failure of Obsidian Hydration Dating: Sources, Implications, and New Directions," *Journal of Archaeological Sciences* 26: 735–52.

Aoyama, K. (1988) "Some Socio-economic Observations on Obsidian and Chert Artifacts in the La Venta Valley, Honduras," paper presented at the 53rd Annual Meeting of the Society for American Archaeology, Phoenix, AZ.

———(1989) "Estudio experimental de las huellas de uso sobre material lítico de obsidiana y sílex," *Mesoamérica* 17: 185–214.

———(1993) "Experimental Microwear Analysis on Maya Obsidian Tools: Case Study of the La Entrada Region, Honduras," in *Traces et Fonction: Les gestes retrouvés*, pp. 423–32, Colloque International de Liège, Vol. 50, Liège: Éditions ERAUL.

———(1994) "Socioeconomic Implications of Chipped Stone from the La Entrada Region, Western Honduras," *Journal of Field Archaeology* 21: 133–45.

———(1995) "Microwear Analysis in the Southeast Maya Lowlands: Two Case Studies at Copan, Honduras," *Latin American Antiquity* 6:129–44.

———(1996) *Exchange, Craft Specialization, and Ancient Maya State Formation: A Study of Chipped Stone Artifacts from the Southeast Maya Lowlands*, unpublished PhD Dissertation, Department of Anthropology, University of Pittsburgh.

———(1999) *Ancient Maya State, Urbanism, Exchange, and Craft Specialization: Chipped Stone Evidence of the Copan Valley and the La Entrada Region, Honduras*, Memoirs in Latin American Archaeology, no. 12, Pittsburgh: University of Pittsburgh.

———(2001) "Classic Maya State, Urbanism, and Exchange: Chipped Stone Evidence of the Copan Valley and Its Hinterland," *American Anthropologist* 103: 346–60.

Arnauld, M. C. (1990) "El comercio clásico de obsidiana: Rutas entre tierras altas y tierras bajas en el área maya," *Latin American Antiquity* 1: 347–67.

Baumler, M. F., and Downum, C. E. (1989) "Between Micro and Macro: A Study in the Interpretation of Small-sized Lithic Debitage," in D. S. Amick and R. P. Maudlin (eds.), *Experiments in Lithic Technology*, pp. 101–16, BAR International Series 528, Oxford: British Archaeological Reports.

Braswell, G. E. (1992) "Obsidian-hydration Dating, the Coner Phase, and Revisionist Chronology at Copan, Honduras," *Latin American Antiquity* 3: 130–47.

———(1996) *A Maya Obsidian Source: The Geoarchaeology, Settlement History, and Prehistoric Economy of San Martín Jilotepeque, Guatemala*, unpublished Ph.D. dissertation, Department of Anthropology, Tulane University.

———(1997) "La cronología y la estructura del colapso en Copan, Honduras," in *Los Investigadores de la Cultura Maya 5*, pp. 262–73, Campeche: Universidad Autónoma de Campeche.

———(1998) "La arqueología de San Martín Jilotepeque, Guatemala," *Mesoamérica* 35: 117–54.
———(2002) "Praise the Gods and Pass the Obsidian?: The Organization of Ancient Economy in San Martín Jilotepeque, Guatemala," in M. Masson and D. Freidel (eds.), *Ancient Maya Political Economies*, pp. 285–306, Walnut Creek CA: Altamira Press.
———(2003) "Obsidian Exchange Spheres of Postclassic Mesoamerica," in M. E. Smith and F. Berdan (eds.), *The Postclassic Mesoamerican World*, pp. 131–58, Salt Lake City: University of Utah Press.
Braswell, G. E., and Glascock, M. D. (1992) "A New Obsidian Source in the Highlands of Guatemala," *Ancient Mesoamerica* 3:47–9.
———(1998) "Interpreting Intrasource Variation in the Composition of Obsidian: The Geoarchaeology of San Martín Jilotepeque, Guatemala," *Latin American Antiquity* 9: 353–69.
———(2003) "The Emergence of Market Economies in the Ancient Maya World: Obsidian Exchange in Terminal Classic Yucatán, Mexico," in M. D. Glascock (ed.), *Geochemical Evidence for Long Distance Exchange*, pp. 33–52, Westport: Bergin and Garvey.
Breton, A. (1902) "Some Obsidian Workings in Mexico," *Proceedings of the International Congress of Americanists* 13: 265–68.
Brokmann, C. (2000) *Tipología y análisis de la obsidiana de Yaxchilán, Chiapas*, Colección Científica no. 422, Mexico City: Instituto Nacional de Antropología e Historia.
Carpio Rezzio, E. H. (1993a) "Algunos apuntes acerca de los utensilios de piedra en las sociedades originales de Guatemala," in *Estudios* 1: 57–68, Guatemala City: Instituto de Investigaciones Históricas, Antropológicas y Arqueológicas.
———(1993b) "Obsidian at Balberta," in F. J. Bove, S. Medrano B., B. Lou, and B. Arroyo (eds.), *The Balberta Project: The Terminal Formative—Early Classic Transition on the Pacific Coast of Guatemala*, pp. 83–106, Memoirs in Latin American Archaeology, no. 6, Pittsburgh: University of Pittsburgh.
———(1994) "Obsidiana de La Colonia, Sansare: Utilización de recursos locales," in J. P. Laporte and H. Escobedo (eds.), *VII Simposio de Investigaciones Arqueológicas en Guatemala, 1993*, pp. 147–53, Guatemala City: Museo Nacional de Antropología.
———(2000) "Uso y comercio de la obsidiana, en el área de Tecojate, Escuintla, Guatemala," *Estudios de Cultura Maya* 21: 25–32.
Cervera, M. P. (1996) *Los Artifactos Líticos de Isla Cerritos*, unpublished licenciatura thesis, Facultad de Ciencias Antropológicas, Universidad Autónoma de Yucatán, Mérida, Mexico.
Clark, J. E. (1981) "Guatemalan Obsidian Sources and Quarries: Additional Notes," *Journal of New World Archaeology* 4: 1–15.
———(1982) "Manufacture of Mesoamerican Prismatic Blades: An Alternative Technique," *American Antiquity* 47: 355–76.
———(1984) "Counterflaking and the Manufacture of Mesoamerican Prismatic Blades," *Lithic Technology* 13: 52–61.
———(1985) "Platforms, Bits, Punches and Vises: A Potpourri of Mesoamerican Blade Technology," *Lithic Technology* 14: 1–15.
———(1986) "From Mountains to Molehills: A Critical Review of Teotihuacan's Obsidian Industry," in B. L. Isaac (ed.), *Economic Aspects of Prehispanic Highland Mexico*, pp. 23–74, Research in Economic Anthropology, Supplement no. 2, Greenwich, Connecticut: JAI Press.
———(1988a) *The Lithic Artifacts of La Libertad, Chiapas, Mexico*, Paper no. 52, Provo: New World Archaeological Foundation, Brigham Young University.
———(1988b) "Fifteen Fallacies in Lithic Workshop Interpretation: An Experimental and Ethnoarchaeological Perspective," paper presented at the Pedro Bosch-Gimpera Symposium on Ethnoarchaeology, Mexico City.
———(1989a) "La técnica de talla de los lacandones de Chiapas," in J. E. Clark and M. Gaxiola G. (eds.), *La obsidiana en mesoamérica*, pp. 443–8, Colección Científica no. 176, Mexico City: Instituto Nacional de Antropología e Historia.
———(1989b) "Hacia una definición de talleres," in J. E. Clark and M. Gaxiola G. (eds.), *La obsidiana en mesoamérica*, pp. 213–7, Colección Científica no. 176, Mexico City: Instituto Nacional de Antropología e Historia.
———(1991a) "Flintknapping and Debitage Disposal among the Lacandon Maya of Chiapas, Mexico," in E. Staski and L. D. Sutro (eds.), *The Ethnoarchaeology of Refuse Disposal*, pp. 63–88, Anthropological Research Paper no. 42, Tempe: Arizona State University.
———(1991b) "Modern Lacandon Lithic Technology and Blade Workshops.," in T. R. Hester and

H. J. Shafer (eds.), *Maya Stone Tools: Selected Papers from the Second Maya Lithic Conference*, pp. 251–65, Monographs in World Archaeology, no. 1, Madison: Prehistory Press.

———(1997) "Prismatic Blade Making, Craftsmanship, and Production: An Analysis of Obsidian Refuse from Ojo de Agua, Chiapas, Mexico," *Ancient Mesoamerica* 8: 137–59.

Clark, J. E., and Bryant, D. (1997) "A Technological Typology of Prismatic Blades and Debitage from Ojo de Agua, Chiapas, Mexico," *Ancient Mesoamerica* 8: 111–36.

Clark, J. E., and Gaxiola González, M. (eds.) (1989) *La obsidiana en mesoamérica*, Colección Científica no. 176, Mexico City: Instituto Nacional de Antropología e Historia.

Clark, J. E., and Salcedo Romero, T. (1989) "Ocós Obsidian Distribution in Chiapas, Mexico," in F. J. Bove and L. Heller (eds.), *New Frontiers in the Archaeology of the Pacific Coast of Southern Mesoamerica*, pp. 15–24, Anthropological Research Paper no. 39, Tempe: Arizona State University.

Clark, J. E., et al. (1989) "The Distribution of Obsidian," in B. Voorhies (ed.), *Ancient Trade and Tribute, Economies of the Soconusco Region of Mesoamerica*, pp. 268–84, Salt Lake City: University of Utah Press.

Cobean, R. H., et al. (1971) "Obsidian Trade at San Lorenzo Tenochtitlan, Mexico," *Science* 174: 666–71.

Coe, M. D., and Flannery, K. V. (1964) "The Precolumbian Obsidian Industry of El Chayal, Guatemala," *American Antiquity* 30: 43–9.

Coe, W. R. (1959) *Piedras Negras Archaeology: Artifacts, Caches, and Burials*, Philadelphia: The University Museum, University of Pennsylvania.

———(1965) "Artifacts of the Maya Lowlands" in G. R. Willey (ed.), *Archaeology of Southern Mesoamerica*, Part 2, pp. 594–602, Handbook of Middle American Indians, Vol. 3, Austin: University of Texas Press.

Cowgill, G. L., and Kintigh, K. W. (1997) "How Random Errors in Dates Increase Apparent Lengths of Intervals," paper presented at the 62nd Annual Meeting of the Society for American Archaeology, Nashville, TN.

Crabtree, D. E. (1968) "Mesoamerican Polyhedral Cores and Prismatic Blades," *American Antiquity* 33: 446–78.

Cruz Antillón, R. (1994) *Análisis arqueológico del yacimiento de obsidiana de Sierra de Las Navajas, Hidalgo*, Coleción Científica, Vol. 281, Mexico City: Instituto Nacional de Antropología e Historia.

Darras, V. (1999) *Tecnologías prehispánicas de la obsidiana: Los centros de producción de la región de Zináparo-Prieto, Michoacán*, Cuadernos de Estudios Michoacanos, Vol. 9, Mexico City: Centre d'Études Mexicanes et Centroaméricanes.

Dixon, J. E., Cann, J. R., and Renfrew, C. (1968) "Obsidian and the Origins of Trade," *Scientific American* 218: 38–46.

Doonan, W. (1996) *The Artifacts of Group 10L-2, Copan, Honduras: Variation in Material Culture and Behavior in a Royal Residential Compound*, unpublished Ph.D. dissertation, Department of Anthropology, Tulane University.

Dreiss, M. L. (1988) "Obsidian at Colha, Belize: A Technological Analysis and Distributional Study Based on Trace Element Data," *Papers of the Colha Project*, Vol. 4, San Antonio: Texas Archaeological Research Laboratory, University of Texas.

Fowler, W. R., Jr. (1991) "Lithic Analysis as a Means of Processual Inference in Southern Mesoamerica: A Review of Recent Research," in T. R. Hester and H. J. Shafer (eds.), *Maya Stone Tools: Selected Papers from the Second Maya Lithic Conference*, pp. 1–19, Monographs in World Archaeology, no. 1, Madison: Prehistory Press.

Glascock, M. D., et al. (1998) "A Systematic Approach to Obsidian Source Characterization," in M. S. Shackley (ed.), *Method and Theory in Archaeological Volcanic Glass Studies*, pp. 15–65, New York: Plenum Press.

Graham, J. A., and Heizer, R. F. (1968) "Notes on the Papalhuapa Site, Guatemala," *Contributions of the University of California Archaeological Research Facility* 5: 101–25.

Gramly, R. M. (1980) "Raw Materials Source Areas and Curated Tool Assemblages," *American Antiquity* 45: 823–33.

Hammond, N. (1972) "Obsidian Trade Routes in the Maya Area." *Science* 178: 1092–93.

———(1976) "Maya Obsidian Trade in Southern Belize," in T. R. Hester and N. Hammond (eds.), *Maya Lithic Studies: Papers from the 1976 Belize Field Symposium*, pp. 71–81, Special Report no. 4, San Antonio: Center for Archaeological Research, University of Texas at San Antonio.

Hammond, N., et al. (1984) "Trace Element Analysis of Obsidian Artifacts from a Classic Maya Residential Group at Nohmul, Belize," *American Antiquity* 49: 815–20.

Hay, C. A. (1978) *Kaminaljuyu Obsidian: Lithic Analysis and Economic Organization of a Prehistoric Mayan Chiefdom*, unpublished Ph.D. dissertation, Department of Anthropology, Pennsylvania State University.

Hayden, B. (ed.) (1979) *Lithic Usewear Analysis*, New York: Academic Press.

———(ed.) (1987) *Lithic Studies among the Contemporary Highland Maya*, Tucson: University of Arizona Press.

Hayden, B., and Cannon, A. (1983) "Where the Garbage Goes: Refuse Disposal in the Maya Highlands," *Journal of Anthropological Archaeology* 1: 132–58.

Healan, D. M. (1997) "Pre-Hispanic Quarrying in the Ucareo-Zinapecuaro Obsdian Source Area," *Ancient Mesoamerica* 8: 77–100.

Healan, D. M., et al. (1983) "Excavation and Preliminary Analysis of an Obsidian Workshop in Tula, Hidalgo, Mexico," *Journal of Field Archaeology* 10: 127–45.

Hester, T. R. (1976) "Belize Lithics: Forms and Functions," in T. R. Hester and N. Hammond (eds.), *Maya Lithic Studies: Papers from the 1976 Belize Field Symposium*, pp. 11–19, Special Report no. 4, San Antonio: Center for Archaeological Research, University of Texas at San Antonio.

Hester, T. R., and Hammond, N. (eds.) (1976) *Maya Lithic Studies: Papers from the 1976 Belize Field Symposium*, Special Report no. 4, San Antonio: Center for Archaeological Research, University of Texas at San Antonio.

Hester, T. R., and Shafer, H. J. (1983) "On Obsidian Supply at Colha, Belize," *Current Anthropology* 21: 810–11.

———(1991) "Lithics of the Early Postclassic at Colha, Belize," in T. R. Hester and H. J. Shafer (eds.), *Maya Stone Tools: Selected Papers from the Second Maya Lithic Conference*, pp. 155–61, Monographs in World Archaeology, no. 1, Madison: Prehistory Press.

Hester, T. R., et al. (eds.) (1980) *The Colha Project Second Season, 1980 Interim Report*, San Antonio and Venice: Center for Archaeological Research, University of Texas at San Antonio and Centro Studi Ricerche Ligabue.

———(eds.) (1982) *Archaeology at Colha, Belize: The 1981 Interim Report*, San Antonio and Venice: Center for Archaeological Research, University of Texas at San Antonio and Centro Studi Ricerche Ligabue.

———(1991) "Technological and Comparative Analyses of the Chipped Stone Artifacts from El Pozito, Belize," in T. R. Hester and H. J. Shafer (eds.), *Maya Stone Tools: Selected Papers from the Second Maya Lithic Conference*, pp. 67–83, Monographs in World Archaeology, no. 1, Madison: Prehistory Press.

Hirth, K. (2002) "Provisioning Constraints and the Production of Obsidian Prismatic Blades at Xochicalco, Mexico," in *Pathways to Prismatic Blades: A Study in Mesoamerican Obsidian Core-blade Technology*, pp. 81–90, Monograph 45, Los Angeles: The Cotsen Institute of Archaeology, University of California, Los Angeles.

Hirth, K., and Andrews, B. (eds.) (2002) *Pathways to Prismatic Blades: A Study in Mesoamerican Obsidian Core-blade Technology*, Monograph 45, Los Angeles: The Cotsen Institute of Archaeology, University of California, Los Angeles.

Holmes, W. H. (1900) "The Obsidian Mines of Hidalgo, Mexico," *American Anthropologist* 2: 405–41.

Jack, R. N., and Heizer, R. F. (1968) "'Finger-Printing' of Some Mesoamerican Obsidian Artifacts," *Contributions of the University of California Archaeological Research Facility* 5: 81–100.

Johnson, J. K. (1976) *Chipped Stone Artifacts from the Western Maya Periphery*, unpublished Ph.D. dissertation, Department of Anthropology and Sociology, Southern Illinois University, Carbondale.

Jones, R. (1990) "Hunters of the Dreaming: Some Ideational, Economic and Ecological Parameters of the Australian Aboriginal Productive System," in D. Yen and J. Mummery (eds.), *Pacific Production Systems: Approaches to Economic Prehistory*, pp. 25–52, Canberra: Australian National University.

Joyce, T. A. (1932) "The Eccentric Flints of Central America," *Journal of the Royal Anthropological Institute* 62: xvii–xxvi.

Keeley, L. H. (1977) "The Functions of Paleolithic Flint Tools," *Scientific American* 237: 108–26.

———(1980) *Experimental Determinations of Stone Tool Uses: A Microwear Analysis*, Chicago: University of Chicago Press.

Kidder, A. V. (1947) *The Artifacts of Uaxactun, Guatemala*, Publication 576, Washington, DC: Carnegie Institute of Washington.

Lewenstein, S. M. (1981) "Mesoamerican Obsidian Blades: An Experimental Approach to Function," *Journal of Field Archaeology* 8: 175–88.

———(1987) *Stone Tool Use at Cerros*, Austin: University of Texas Press.

———(1989) "Usos utilitarios de la obsidiana de Cerros, un sitio preclásico en la costa septentrional de Belice," in J. E. Clark and M. Gaxiola G. (eds.), *La obsidiana en mesoamérica*, pp. 177–89, Colección Científica no. 176, Mexico City: Instituto Nacional de Antropología e Historia.

———(1991) "Edge Angles and Tool Function among the Maya: A Meaningful Relationship?" in T. R. Hester and H. J. Shafer (eds.), *Maya Stone Tools: Selected Papers from the Second Maya Lithic Conference*, pp. 207–17, Monographs in World Archaeology, no. 1, Madison: Prehistory Press.

Lewenstein, S. M., and Walker, J. (1984) "The Obsidian Chip/Manioc Grating Hypothesis and the Mesoamerican Preclassic," *Journal of New World Archaeology* 6: 25–38.

Luedtke, B. (1992) *An Archaeologist's Guide to Chert and Flint*, Archaeological Research Tools 7, Los Angeles: The Cotsen Institute of Archaeology, University of California, Los Angeles.

Marcus, J. (1983) "Lowland Maya Archaeology at the Crossroads," *American Antiquity* 48: 454–88.

McAnany, P. A. (1986) *Lithic Technology and Exchange among Wetland Farmers of the Eastern Maya Lowlands*, unpublished Ph.D. dissertation, Department of Anthropology, University of Arizona.

———(1988) "Effects of Lithic Procurement Strategies on Tool Curation and Recycling," *Lithic Technology* 17: 3–11.

———(1989) "Stone-tool Production and Exchange in the Eastern Maya Lowlands: The Consumer Perspective from Pulltrouser Swamp, Belize," *American Antiquity* 54: 332–46.

———(1991) "Structure and Dynamics of Intercommunity Exchange," in T. R. Hester and H. J. Shafer (eds.), *Maya Stone Tools: Selected Papers from the Second Maya Lithic Conference*, pp. 271–93, Monographs in World Archaeology, no. 1, Madison: Prehistory Press.

McKillop, H. I. (1995) "The Role of Northern Ambergris Caye in Maya Obsidian Trade: Evidence from Visual Sourcing and Blade Technology," in T. H. Guderjan and J. F. Garber (eds.), *Maya Maritime Trade, Settlement, and Population on Ambergris Caye, Belize*, pp. 163–74, Lancaster, CA: Maya Research Program and Labyrinthos.

———(1996) "Ancient Maya Trading Ports and the Integration of Long-distance and Regional Economies: Wild Cane Caye in South-coastal Belize," *Ancient Mesoamerica* 7: 49–62.

McSwain, R. (1991) "A Comparative Evaluation of the Produce-consumer Model for Lithic Exchange in Northern Belize, Central America," *Latin American Antiquity* 2: 337–51.

Mejía Amaya, H. E., and Suyuc Ley, E. O. (1997) "Nuevos afloramientos en El Chayal," in J. P. Laporte and H. Escobedo (eds.), *X Simposio de Investigaciones Arqueológicas en Guatemala, 1996*, Vol. 1, pp. 47–59, Guatemala City: Museo Nacional de Antropología.

———(2000) *Ri chay abaj: Proyecto geológico-arqueológico El Chayal*, Utz'ib Serie Reportes, Vol. 1, no. 1, Guatemala City: Asociación Tikal.

Menzies, A. C. J. (2003) *A Technological and Functional Analysis of the Obsidian Assemblage from Minanhá, Cayo Distric, Belize*, unpublished M. A. thesis, Department of Anthropology, Trent University, Peterborough, Ontario.

Michels, J. W. (1975) "El Chayal, Guatemala: A Chronological and Behavioral Reassessment," *American Antiquity* 40: 103–6.

Mitchum, B. A. (1981) "Lithic Artifacts from Cerros, Belize: Production, Consumption and Trade," *Revista mexicana de estudios antropológicos* 27(2): 139–56.

———(1989) "Obsidian as a Non-essential Resource," in J. E. Clark and M. Gaxiola G. (eds.), *La obsidiana en mesoamérica*, pp. 375–8, Colección Científica no. 176, Mexico City: Instituto Nacional de Antropología e Historia.

———(1991) "Lithic Artifacts from Cerros, Belize: Production, Consumption, and Trade," in T. R. Hester and H. J. Shafer (eds.), *Maya Stone Tools: Selected Papers from the Second Maya Lithic Conference*, pp. 45–53, Monographs in World Archaeology, no. 1, Madison: Prehistory Press.

Moholy-Nagy, H. (1975) "Obsidian at Tikal, Guatemala," *Actas del XLI Congreso Internacional de Americanistas*, no. 1, pp. 511–8, Mexico City: Instituto Nacional de Arqueología e Historia.

———(1976) "Spatial Distribution of Flint and Obsidian Artifacts at Tikal, Guatemala," in T. R. Hester and N. Hammond (eds.), *Maya Lithic Studies: Papers from the 1976 Belize Field Symposium*, pp. 91–108, Special Report no. 4, San Antonio: Center for Archaeological Research, University of Texas at San Antonio.

———(1989) "Who Used Obsidian at Tikal?" in J. E. Clark and M. Gaxiola G (eds.), *La obsidiana en mesoamérica*, pp. 379–89, Colección Científica no. 176, Mexico City: Instituto Nacional de Antropología e Historia.

———(1990) "The Misidentification of Mesoamerican Lithic Workshops," *Latin American Antiquity* 1: 268–79.

———(1991) "The Flaked Chert Industry of Tikal, Guatemala," in T. R. Hester and H. J. Shafer (eds.), *Maya Stone Tools: Selected Papers from the Second Maya Lithic Conference*, pp. 189–202, Monographs in World Archaeology, no. 1, Madison: Prehistory Press.

———(1994) *Tikal Material Culture: Artifacts and Social Structure at a Classic Lowland Maya City*, unpublished Ph.D. dissertation, Department of Anthropology, University of Michigan.

———(1997) "Middens, Construction Fill, and Offerings: Evidence for the Organization of Classic Period Craft Production at Tikal, Guatemala," *Journal of Field Archaeology* 24: 293–313.

———(1999) "Mexican Obsidian at Tikal, Guatemala," *Latin American Antiquity* 10: 300–13.

Moholy-Nagy, H., and Nelson, F. W. (1991) "New Data on Sources of Obsidian Artifacts from Tikal, Guatemala," *Ancient Mesoamerica* 1: 71–80.

Moholy-Nagy, H., et al. (1984) "Tikal Obsidian: Sources and Typology," *American Antiquity* 49: 104–17.

Nance, C. R., and Kirk, K. A. (1991) "Obsidian Blades from La Blanca: A Changing Lithic Industry on the South Coast of Guatemala," *Latin American Antiquity* 2: 371–84.

Nations, J. D. (1989) "The Lacandon Bow and Arrow: An Ethnoarchaeological Example of Postclassic Lowland Maya Weapon Manufacture," in J. E. Clark and M. Gaxiola G. (eds.), *La obsidiana en mesoamérica*, pp. 449–57, Colección Científica no. 176, Mexico City: Instituto Nacional de Antropología e Historia.

Nelson, F. W. (1985) "Summary of the Results of Analysis of Obsidian Artifacts from the Maya Lowlands," *Scanning Electron Microscopy* II: 631–49.

Odell, G. H. (1989) "Experiments in Lithic Reduction," in D. S. Amick and R. P. Maudlin (eds.), *Experiments in Lithic Technology*, pp. 163–97, BAR International Series 528, Oxford: British Archaeological Reports.

Pastrana, A. (1990) "Proyecto yacimientos de obsidiana," *Boletín del Consejo de Arqueología*: 190–5.

———(1998) *La explotación azteca de la obsidiana en la Sierra de las Navajas*, Colección Científica no. 383, Mexico City: Instituto Nacional de Antropología e Historia.

Patterson, L. W. (1990) "Characteristics of Bifacial-reduction Flake-size Distribution," *American Antiquity* 55: 550–8.

Potter, D. R. (1991) "A Descriptive Taxonomy of Middle Preclassic Chert Tools at Colha, Belize," in T. R. Hester and H. J. Shafer (eds.), *Maya Stone Tools: Selected Papers from the Second Maya Lithic Conference*, pp. 21–9, Monographs in World Archaeology, no. 1, Madison: Prehistory Press.

Proskouriakoff, T. (1962) "The Artifacts of Mayapán," in H. E. D. Pollock, R. L. Roys, T. Proskouriakoff, and A. L. Smith, (eds.), *Mayapán, Yucatán, Mexico*, pp. 87–169, Publication 619, Washington, DC: Carnegie Institute of Washington.

Renfrew, C., et al. (1966) "Obsidian and Early Cultural Contact in the Near East," *Proceedings of the Prehistoric Society* 32: 30–72.

———(1968) "Further Analysis of Near Eastern Obsidians," *Proceedings of the Prehistoric Society* 34: 319–31.

Rice, P. M. (1984) "Obsidian Procurement in the Central Petén Lakes Region," *Journal of Field Archaeology* 11: 181–94.

Rice, P. M., et al. (1985) "Provenience Analysis of Obsidians from the Central Petén Lakes Region, Guatemala," *American Antiquity* 50: 591–604.

Ricketson, O. G., Jr., and Ricketson, E. B. (1937) *Uaxactun, Guatemala, Group E, 1926–1931*, Publication 477, Washington, DC: Carnegie Institute of Washington.

Ridings, R. (1991) "Obsidian Hydration Dating: The Effects of Mean Exponential Ground Temperature and Depth of Artifact Recovery," *Journal of Field Archaeology* 18: 77–85.

Roemer, E. (1991) "A Late Classic Workshop at Colha, Belize," in T. R. Hester and H. J. Shafer

(eds.), *Maya Stone Tools: Selected Papers from the Second Maya Lithic Conference*, pp. 55–66, Monographs in World Archaeology, no. 1, Madison: Prehistory Press.
Rovner, I. (1975) *Lithic Sequences of the Maya Lowlands*, unpublished Ph.D. dissertation, Department of Anthropology, University of Wisconsin.
Rovner, I., and Lewenstein, S. M. (1997) *Maya Stone Tools of Dzibilchaltún, Yucatán, and Becán and Chicanná, Campeche*, Publication 65, New Orleans: Middle American Research Institute, Tulane University.
Ruíz Aguilar, M. E. (1981) "Estudio preliminar de la lítica de Aquiles Serdán, Chiapas," *Revista Mexicana de Estudios Antropológicos* 27(2): 13–26.
———(1982) "Tecnología lítica," *Anales de Antropología* 19: 151–63.
———(1985) "Observaciones sobre canteras en Petén, Guatemala," *Mesoamérica* 10: 421–49.
———(1986) "Análisis preliminar de la lítica de Mundo Perdido, Tikal," *Mesoamérica* 11: 113–33.
———(1987) "Análisis preliminar de la lítica de Mundo Perdido, Tikal," in *Memorias del Primer Coloquio Internacional de Mayistas*, pp. 331–59, Mexico City: Universidad Autónoma Nacional de Mexico.
———(1989) "Instrumentos líticos procedentes de un basurero, Tikal, Petén," in *Memorias del II° Coloquio Internacional de Mayistas*, pp. 569–601, Mexico City: Universidad Autónoma Nacional de Mexico.
———(1996) "Tecnología prehispánica: Los artefactos de piedra y el manejo de la obsidiana, el pedernal y el jade," in *Piezas maestras mayas: Patrimonio del Museo Nacional de Arqueología y Etnología de Guatemala, Galerías Guatemala III*, pp. 34–43, Guatemala City: Fundación G&T.
Sackett, J. R. (1985) "Style and Ethnicity in the Kalahari: A Reply to Weissner," *American Antiquity* 50: 154–9.
Sánchez, R. (1991) *Las navajas prismáticas de Kaminaljuyu/San Jorge: Un análisis tecnológico funcional*, unpublished *licenciatura* thesis, área de arqueología, Escuela de Historia, Universidad de San Carlos de Guatemala, Guatemala City.
Santley, R. S. (1994) "The Economy of Ancient Matacapan." *Ancient Mesoamerica* 5: 243–66.
Santley, R. S., and Kneebone, R. R. (1993) "Craft Specialization, Refuse Disposal, and the Creation of Spatial Archaeological Records in Prehispanic America," in R. S. Santley and K. G. Hirth (eds.), *Prehispanic Domestic Units in Western Mesoamerica: Studies of the Household, Compound, and Residence*, pp. 37–63, Boca Raton: CRC Press.
Semenov, S. A. (1964) *Prehistoric Technology*, London: Cory, Adams, Mackay.
Shafer, H. J. (1976) "Belize Lithics: 'Orange Peel' Flakes and Adze Manufacture," in T. R. Hester and N. Hammond (eds.), *Maya Lithic Studies: Papers from the 1976 Belize Field Symposium*, pp. 21–34, Special Report no. 4, San Antonio: Center for Archaeological Research, University of Texas at San Antonio.
———(1982) "Maya Lithic Craft Specialization in Northern Belize," in T. R. Hester et al., *Archaeology at Colha, Belize: The 1981 Interim Report*, pp. 31–8, San Antonio and Venice: Center for Archaeological Research, University of Texas at San Antonio and Centro Studi Ricerche Ligabue.
———(1991) "Late Preclassic Formal Stone Tool Production at Colha, Belize," in T. R. Hester and H. J. Shafer (eds.), *Maya Stone Tools: Selected Papers from the Second Maya Lithic Conference*, pp. 31–44, Monographs in World Archaeology, no. 1, Madison: Prehistory Press.
Shafer, H. J., and Hester, T. R. (1979) "Lithic Research at Colha: An Overview," in T. R. Hester (ed.), *The Colha Project, 1979: A Collection of Interim Papers*, pp. 18–27, San Antonio: Center for Archaeological Research, University of Texas at San Antonio.
———(1983) "Ancient Maya Chert Workshops in Northern Belize, Central America," *American Antiquity* 48: 519–43.
———(1985) "A Technological Study of Two Maya Lithic Workshops at Colha, Belize," in M. G. Plew, J. C. Woods, and M. G. Pavesic (eds.), *Stone Tool Analysis: Essays in Honor of Don E. Crabtree*, pp. 277–315, Albuquerque: University of New Mexico Press.
Shafer, H. J., and Holloway, R. G. (1979) "Organic Residue Analysis in Determining Stone Tool Function," in B. Hayden (eds.), *Lithic Usewear Analysis*, pp. 385–99, New York: Academic Press.
Shea, J. J. (1992) "Lithic Microwear Analysis in Archaeology," *Evolutionary Anthropology* 1: 143–50.
Sheets, P. D. (1972) "A Model of Mesoamerican Obsidian Technology Based on Preclassic Workshop Debris in El Salvador," *Ceramica de Cultura Maya* 8: 17–33.

———(1974) *Differential Change among the Precolumbian Artifacts of Chalchuapa, El Salvador,* unpublished Ph.D. dissertation, University of Pennsylvania.

———(1975a) "Behavioral Analysis and the Structure of a Prehistoric Industry," *Current Anthropology* 16: 369–91.

———(1975b) "A Reassessment of the Precolumbian Obsidian Industry of El Chayal, Guatemala," *American Antiquity* 40: 98–103.

———(1976) "Islands of Lithic Knowledge amid Seas of Ignorance in the Maya Area," in T. R. Hester and N. Hammond (eds.), *Maya Lithic Studies: Papers from the 1976 Belize Field Symposium,* pp. 1–9, Special Report no. 4, San Antonio: Center for Archaeological Research, University of Texas at San Antonio.

———(1977) "The Analysis of Chipped Stone Artifacts in Southern Mesoamerica: An Assessment," *Latin American Research Review* 12: 139–58.

Sheets, P. D., et al. (1990) "Obsidian Sources and Elemental Analysis of Artifacts in Southern Mesoamerica and the Northern Intermediate Area," *American Antiquity* 55: 144–58.

Shott, M. J. (1994) "Size and Form in the Analysis of Flake Debris: Review and Recent Approaches," *Journal of Archaeological Method and Theory* 1: 69–110.

Sidrys, R. V., et al. (1976) "Obsidian Sources in the Maya Area," *Journal of New World Archaeology* 1: 1–13.

Sievert, A. K. (1990) "Postclassic Maya Ritual Behavior: Microwear Analysis of Stone Tools from Ceremonial Contexts," in B. Gräslund, H. Knutsson, K. Knutsson, and J. Taffinder (eds.), *The Interpretative Possibilities of Microwear Studies: Proceedings of the International Conference on Use-wear Studies,* pp. 147–57, Uppsala: Societas Archaeologica Upsaliensis and Department of Archaeology, Uppsala Universitet.

———(1992) *Maya Ceremonial Specialization: Lithic Tools from the Sacred Cenote at Chichén Itzá, Yucatán,* Monographs in World Prehistory no. 12, Madison: Prehistory Press.

Soto de Arechavaleta, M. (ed.) (1990) *Nuevos enfoques en el estudio de la lítica,* Mexico City: Universidad Nacional Autónoma de Mexico.

Spence, M. W. (1996) "Commodity or Gift: Teotihuacan Obsidian in the Maya Region," *Latin American Antiquity* 7: 21–39.

Stoltman, J. B. (1978) *Lithic Artifacts from a Complex Society: The Chipped Stone Tools of Becan, Campeche, Mexico,* Occasional Paper 2, New Orleans: Middle American Research Institute, Tulane University.

Stross, F. H., et al. (1968) "Analysis of American Obsidians by X-ray Fluorescence and Neutron Activation Analysis," *Contributions of the University of California Archaeological Research Facility* 5: 59–79.

Taçon, P. S. C. (1991) "The Power of Stone: Symbolic Aspects of Stone Use and Tool Development in Western Arnhem Land, Australia," *Antiquity* 65: 192–207.

Towner, R. H., and Warburton, M. (1990) "Projectile Point Rejuvenation: A Technological Analysis," *Journal of Field Archaeology* 17: 311–21.

Trachman, R. M. (2002) "Early Classic Obsidian Core-blade Production: An Example from the Site of Dos Hombres, Belize," in K. G. Hirth and B. Andrews (ed.), *Pathways to Prismatic Blades: A Study in Mesoamerican Obsidian Core-blade Technology,* pp. 105–19, Monograph 45, Los Angeles: The Cotsen Institute of Archaeology, University of California, Los Angeles.

Tringham, R., et al. (1974) "Experimentation in the Formation of Edge Damage: A New Approach to Lithic Analysis," *Journal of Field Archaeology* 1: 171–96.

Valdez, F. (1994) "Chipped Stone (Obsidian)," in G. R. Willey, R. M. Leventhal, A. A. Demarest, and W. Fash (eds.), *Ceramics and Artifacts from Excavations in the Copan Residential Zone,* pp. 273–90, Papers of the Peabody Museum of Archaeology and Ethnology, Vol. 80, Cambridge, MA: Peabody Museum of Archaeology and Ethnology, Harvard University.

Walker, J., and Wilk, R. (1989) "The Manufacture and Use-wear Characteristics of Ethnographic, Replicated, and Archaeological Maioc [sic] Grater Board Teeth," in J. E. Clark and M. Gaxiola G. (eds.), *La obsidiana en mesoamérica,* pp. 459–63, Colección Científica no. 176, Mexico City: Instituto Nacional de Antropología e Historia.

Washington, H. S. (1921) "Obsidian from Copan and Chichén Itzá," *Journal of the Washington Academy of Sciences* 11: 481–7.

Weaver, J. R., and Stross, F. H. (1965) "Analysis by X-ray Fluorescence of Some American Obsidians," *Contributions of the University of California Archaeological Research Facility* 1: 89–93.

Weissner, P. (1983) "Style and Social Information in Kalahari San Projectile Points," *American Antiquity* 48: 253–76.

———(1985) "Style or Isochrestic Variation? A Reply to Sackett," *American Antiquity* 50: 160–6.

Whittaker, J. C. (1987) "Individual Variation as an Approach to Economic Organization: Projectile Points at Grasshopper Pueblo, Arizona," *Journal of Field Archaeology* 14: 465–80.

Wilk, R. (1976) "Work in Progress at Colha, Belize, 1976," in T. R. Hester and N. Hammond (eds.), *Maya Lithic Studies: Papers from the 1976 Belize Field Symposium*, pp. 35–40, Special Report no. 4, San Antonio: Center for Archaeological Research, University of Texas at San Antonio.

———(1978) "Microscopic Analysis of Chipped Flint and Obsidian," in G. R. Willey (eds.), *Excavations at Seibal*, pp. 139–45, Memoirs of the Peabody Museum of Archaeology and Ethnology, Vol. 14, no. 1, Cambridge, MA: Peabody Museum of Archaeology and Ethnology, Harvard University.

Willey, G. R. (1972) *The Artifacts of Altar de Sacrificios*, Papers of the Peabody Museum of Archaeology and Ethnology, Vol. 64, no. 1, Cambridge, MA: Peabody Museum of Archaeology and Ethnology, Harvard University.

Willey, G. R., et al. (1965) *Prehistoric Maya Settlements in the Belize Valley*, Papers of the Peabody Museum of Archaeology and Ethnology, Vol. 54, Cambridge, MA: Peabody Museum of Archaeology and Ethnology, Harvard University.

Williams, H. (1960) "Volcanic History of the Guatemalan Highlands," in *University of California Publication in Geological Sciences*, Vol. 38, no. 1, pp. 1–86, Berkeley and Los Angeles: University of California Press.

Williams, H., et al. (1964) "Geologic Reconnaissance of Southeastern Guatemala," In *University of California Publication in Geological Sciences*, Vol. 50, no. 1, pp. 1–54, Berkeley and Los Angeles: University of California Press.

Woodbury, R. B. (1965) "Artifacts of the Guatemalan Highlands," in G. R. Willey (ed.), *Archaeology of Southern Mesoamerica*, Part 1, pp. 163–79, Handbook of Middle American Indians, Vol. 2, Austin: University of Texas Press.

Woodbury, R. B., and Trik, A. S. (1953) *The Ruins of Zaculeu, Guatemala*, 2 vols., Richmond, VA: William Byrd Press.

Young, D. E., and Bonnichsen, R. (1984) *Understanding Stone Tools: A Cognitive Approach*, Orono: University of Maine.