GEOARCHAEOLOGY OF THE PLEISTOCENE OCCUPATION OF WESTERN CANADA

ABSTRACT: Recognition of Palaeo-American sites in Pleistocene geological settings is rather problematic for most American archaeologists as no consensus has been reached yet about the timing of the initial Palaeo-American migration from eastern Asia, the level of technology and the associated typological variety of stone tools that the early inhabitants of the continent might have brought with them. One of the principal problems concerns the recognition of artifactual flaked lithics and associated cultural remains deeply buried under or within glacial and glaciogenic deposits in Eastern Beringia and adjacent areas. This fact largely reflects the lack of adequate geomorphological, sedimentological and methodological inquiries, combined with field observations and analytical laboratory expertise (including cultural and natural stone flaking) in the current archaeological studies. Introduction of geoarchaeological research strategies incorporating glacial geology and palaeolithic archaeology, and a more active role of other natural sciences may significantly contribute to elucidation of the earliest New World prehistory, particularly in the formerly glaciated areas of North America. Pioneering investigations in western Alberta at palaeolithic sites sealed by thick (10+ m) surficial deposits formed under or close to the continental ice-sheet or the Cordilleran valley glaciers during the last glacial stage have provided the first definite evidence that early people occupied foothills and the plains east of the Canadian Rocky Mountains prior to the last glacial maximum.

KEY WORDS: Western Canada – Pleistocene glaciations – Quaternary geology – Glaciogenic deposits – Palaeolithic archaeology – Palaeo-American occupation – Lithic industry

INTRODUCTION

The conditions, routes and timing of human colonization of the New World until now remain unresolved problems, despite the fact that there have been many attempts to cope with these issues – on the basis of field data, as well as theoretically by providing various explanatory models. Although a certain progress in the intellectual reasoning on the initial peopling of the Americas and a shift from the traditional "Clovis-first" paradigm has been recently observed due to the acceptance of a 13,000-year-old cultural horizon at the Monte Verde Site in southern Chile (Dillehay 1997), the question of the initial peopling the New World is far from being resolved. Critical assessment of any potential archaeological record older than ca. 12,000 years, i.e. the time horizon which marks the appearance of bifacially shaped stone projectile points, follows three lines of evidence: 1) the cultural character of the record, 2) its primary context, and 3) the chronological assignment. Nevertheless, the need for unequivocal proof of cultural status and original geological context of any claiming Pleistocene-age site or lithic sample is probably the most frequently raised argument of opponents of an earlier pre-Paleoindian occupation of the New World. Currently there is no pre-12,000 year-old site in the Americas whose evidence has been accepted without reservation.

Despite my original professional specialisation in the European Palaeolithic studies, I have become genuinely

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interested in the earliest American prehistory after coming to Canada in 1988. At the beginning, I did not fully realise how controversial the intriguing question of when the first prehistoric populations arrived in North America was. The rest of the continent is for the American scientific community. After my move to Calgary in August 1990, my interest increased significantly after finding several flake and cortical cobbles and retouched flakes eroding from a deep geological context (presumably glacial deposits) about 20–25 m below the present land surface on the western periphery of the city during a casual visit in early October of the same year. The apparent similarity of those specimens with palaeolithic industries I had previously collected in large numbers on high river terraces and other places in southern Moravia, the Czech Republic (e.g. Chlachula 1993), was astonishing, and I could not persuade myself after a close and repeated examination that they were naturally flaked rocks. The realisation that they are, indeed, prehistoric artifacts, was the initial impetus to visit on a regular basis naturally exposed Pleistocene sections along the Bow River on the western periphery of the city of Calgary and to search more systematically for the cultural record and determine its original geological provenance.

As the size of the lithic assemblage expanded, I soon realised — to my surprise — that the collected material included virtually all principal tool types characteristic for the Central European Lower, Middle and in part also the Upper Palaeolithic, that under normal circumstances would not occur together at any of the sites I previously investigated even where identical raw material was used for stone tool production. Uniform textural traits, including degree of abrasion and mineral staining, made me conclude that all quartzite artifacts found associated with each other represent a single and rather specific lithic industry. This conclusion was verified when other “typologically” variable pieces were recovered together within the identical geological context. It was the overall assemblage appearance of the assemblage, including many very rudimentarily modified artifacts, which inspired so much of my personal interest — much more than, e.g., if those finds were perfectly shaped projectile points made on exotic raw materials.

Although the first reactions from most North American archaeologists working on the Western Plains in respect to the Calgary lithic record were overwhelmingly negative or at least taken with much reservation because of the rather unusual geological context producing the alleged artifacts (which would normally be accepted as humanly made if found in a setting on or close to the present surface, as it is the case with most post-glacial prehistoric sites in western Canada), the research continued and gradually developed in a multidisciplinary long-term project. Because of the nature of the record, the methodological and intellectual background for the investigations became inevitably based on combining the Old World Palaeolithic archaeology and North American, specifically western Alberta, Quaternary geology. Particular attention has been paid to geological (stratigraphic and sedimentological), palaeoenvironmental, and climatic modification aspects of investigation. Already in the course of the initial studies, the primary research objectives gradually shifted from archaeological to purely geological ones because of the key issues related to the stone industry provenience, site stratigraphy, Quaternary environments, contextual chronology and human palaeoecology. The geoarchaeological studies were structured to demonstrate, in a logical sequence, the cultural authenticity of the claimed Pleistocene artefacts, as presenting clear evidence of early human presence in this part of North America long before the appearance of the Palaeoindian cultures on the Plains, which are traditionally regarded as the earliest cultural manifestations of the prehistoric peopling of the New World. These pioneering, Pleistocene-oriented geoarchaeological investigations, opening a completely new niche of future archaeological research in the areas formerly affected by glaciations, show the necessity of implementing flexible methodological approaches and research techniques into the current early prehistoric studies in the formerly glaciated parts of western Canada, and North America in general.

PLEISTOCENE GEOARCHAEOLOGY IN ALBERTA: A STUDY CASE — THE BOW VALLEY SITES

At the present time, there are several sites in the province of Alberta that have repeatedly produced clear evidence of an early (pre-last glacial) occupation of this part of western Canada. The sites are distributed in the present and former river valleys east of the Rocky Mountains in a terminal area of 1,500 km from north to south (Figure 1). Geoarchaeologically, the sites show a patterned contextual situation with archaeological finds under last glacial deposits (glacial diamictics) related to the Cordilleran glaciation (Cordilleran 1–3) or the Laurentide glaciation (Laurentide, Illinoian, Edmonton) (Chlachula, Leslie 1998, Chlachula, unpublished data). Except for the open-air sites, there is one potential cave site with early human evidence in the Crownest Pass in the SW Alberta Rocky Mountain Foothills (Eagle Cave). The Calgary sites are, at the present time, the most significant and best studied palaeolithic sites in Alberta.

Geomorphic setting

The sites (114°10’00” W; 51°05’30” N) are located in the Bow River valley on the south-western margin of the Interior Canadian Plains in the western part of the city of Calgary, south-western Alberta. The surrounding topography at an altitude of 1000–1200 m altitude is characterised by a rolling prairie. The locality comprises a series of natural exposures along the NW-SE-oriented north side of the Bow River, with surface altitudes of 1070–1084 m. Two principal places

with actively eroding Quaternary formations, formally referred to as Site 1 (Varsity Estates) and Site 2 (Silver Springs) are located 2.5 km apart (with the latter site being further upstream) (Tables 1A, 3B). A third, most recently studied location (Bowmont), situated further west, is de facto a confluence of the Silver Springs sections which are here much less preserved and exposed only in a recent road cut. The steep northern wall along the river valley is about 35–51 m high, in places deeply dissected by gullies and eroded by slope gravity processes. Beyond the cliff-forming upper margin of the NW-SE oriented "inner valley", forming the top surface of both exposures, a broader and shallower "outer valley" opens, which is bordered by a rolling upland prairie. The relief gradually rises into the foothills area to the front range of the Cordilleran about 100 km west of Calgary (Table 4A).

A variety of glacial, glacial-lacustrine, glacioluvial, alluvial, and colluvial deposits form the local Quaternary geological record overlying the Palaeocene sandstone of the Paskapoo Formation, superimposed over Cretaceous sedimentary rocks. Most of the surficial materials distributed on the present surface are geologically young, being largely derived during the last glacial (Late Wisconsinan) mountain and continental ice advances. The lithology of clastic deposits throughout the study area is fairly uniform. In general, rocks derived by fluvial and glacial processes from the Rocky Mountains region prevail, particularly towards the west, whereas igneous and metamorphic rocks from the Canadian Shield are more widely distributed in the east.

Site stratigraphy

The general stratigraphy at the Bow Valley sites is established from several large scale natural sections at each site. The exposed Quaternary deposits can be traced intermittently for a distance of ca 300 m at the first site, located about 100–200 m north of the present Bow River, and approximately 500 m directly along the river at the second site. The site stratigraphy at the third location is rather limited due to limited thickness of the sediments (0.5–1 m) directly overlying the archaeological horizon as well as the overlap of the uppermost of the lithic industries (ca 50 m). In addition to places with stone industry-bearing deposits, peripheral parts were studied at all locations. Specifically, these include lowermost stratigraphic sequences resting on bedrock at Site 2 (Table 4B), and the
best preserved upper bluff section at Site 1 (Table 1A), which together provided data for establishment of a general chronosтратigraphic framework of the locality. The spatial distribution of individual sedimentary units at the Silver Springs and Varsity Estates Sites, grouped into facies and facies associations, was a priori determined by visual field observation, on the basis of which a sedimentary model and palaeoenvironmental reconstruction were derived.

**Calgary Site 1 (Varsity Estates)**

At the Varsity Estates sections, a complete documentation of the Quaternary record is prevented by lack of exposures. The lower part of the site is largely covered by slope deposits and a tree-shrub vegetation (Table 1A-B). Only locally and partly exposed sections reveal the geological structure of the middle part of the slopes. The upper part of the bluff-forming, gullied slope becomes semi-recessive and is largely covered by grassy vegetation. It is only locally exposed in a deeply incised, 20–25 m high ravine in the western part of the site. Most of the middle and upper section at the site can be stratigraphically documented only from a series of small spatially limited profiles. The general sequence, 25–30 m high, was derived from two larger exposures located about 200 m from each other (VVe and VVe). It was divided according to genetic depositional criteria into 8 stratigraphic units representing 6 different facies, which are grouped into 4 facies sequences, specifying particular sedimentary environments.

**Calgary Site 2 (Silver Springs)**

The Quaternary record at Silver Springs sections comprises up to 35 m of deposits studied in a series of stratigraphically overlapping exposures (1072–1084 m a.s.l. at the upper surface). The upper portion of the original geological profile was eroded during the early postglacial, although it is largely preserved in the western part of the site separated by a deep gully from the eastern portion. The geological sequence above the Tertiary bedrock at the Silver Springs exposure in the eastern part of the site (SSE) is about 23 m thick (Table 4B). The western part of the Silver Springs Site (SW) extends over a distance of about 200 m with up to 34 m thick Quaternary deposits above the bedrock. The Quaternary deposits were described and classified according to genetic criteria into 21 (resp. 19) stratigraphic units represented by 10 facies, which are grouped into 4 facies associations. Stratigraphic correlation between the individual sites as well as sections is based on the facies associations, related to specific depositional settings.

**Calgary Site 3 (Bowmont)**

Quaternary geology of the Bowmont site is consistent with the stratigraphy at the Silver Springs Site (the uppermost part of pre-glacial fluvial gravels), whereas most of the originally overlying overburden (till and lacustrine deposits) were eroded during the early post-glacial.

**Site geoaquacology: methods and approaches**

The three investigated sites, designated as Site 1 (Varsity Estates), Site 2 (Silver Springs) and Site 3 (Bowmont), were consecutively recorded by the author in 1990, 1991 and 1992, respectively (Chluchula 1991, 1992, 1994a, 1994b, 1994c, 1996a, 1996b). Although these locations are referred to as sites, this is meant from a geological point of view and they are not explicitly considered to be archaeological sites sensu stricto, as most of the lithic material is redeposited, thus implying a secondary context. As documented below, only part of the cultural record from...
the first location (Varsity Estates) found in situ can be considered to fulfill the specific requirement of being a largely undisturbed archaeological site.

The initial archaeological and geological investigations primarily focused on the establishment of a chronostratigraphic framework at the particular sites in terms of sedimentary environments, occurrences of the stone industry, and relative chronology of the artifact-bearing deposits. This approach was largely predetermined by the character of the local physiographic and contextual setting. Detailed geological studies have been carried out in places where the sediments are well exposed in several sections, varying horizontally and vertically according to the stability of the slope and the composition of the bluff-forming deposits. Stratigraphic studies and sedimentological interpretation of palaeoenvironmental settings at the Bow Valley locality have provided crucial information on the nature, context, and approximate age of the flaked lithic assemblages. They also provide basic information about the character and configuration of natural forces which act during the formation of these processes of the industry-bearing deposits; and the background to assess the natural potential to mimic cultural flaking patterns in the lithic collections. Specific methodological procedures were applied at individual stages of the field research. Stratigraphic sequences, reconstructed geological processes, and Pleistocene palaeoecology inferred in the study area have been the building blocks of the following archaeological studies. Without describing the geo-contextual background, basic information about the spatial distribution and stratigraphic position of the flake flake cannot be assessed, neither the cultural status of the stone assemblages demonstrated.

For the field documentation of sedimentary structures, several criteria were applied to differentiate between various deposits on a broader spatial scale, specify their origin and palaeocurrent direction, and provide stratigraphic control. Specifically, the particle size analysis describing the shape, size and specific lithological composition of clasts was applied for a lithostratigraphic correlation of deposits and to study the dominant mechanism of sedimentary transport and deposition (Gale, Hoare 1991). Eventually, the data were used to reconstruct palaeoenvironmental conditions during the time of accumulation of these sediments, as well as their subsequent erosion. Both the primary and secondary texture of deposits were investigated and related to the syndepositional and secondary (post-depositional) particle arrangement (fabric and packing), respectively. Recorded characteristics of each particle (in the pebble and cobble group) include form (measured in three orthogonal axes), sphericity, roundness, and surface texture (presence of striation, percussion and chatter marks, degree of weathering, mineral staining and calcium carbonate incrustation).

Directional measurement of current flow in both the clast-supported and fine-grained laminated sedimentary structures (strike and dip) within particular units was used for the palaeocurrent analysis (Selby 1976, Potter, Pettijohn 1977, Gale, Hoare 1991). The recorded orientation of elongate clasts in gravel units and cross-bedding structures in sandy, silty and clayey deposits (i.e. bedding inclined to the principal surface of accumulation) includes the azimuth angle and the angle of inclination in respect to the horizontal plane. The fabric analysis, i.e. the study of orientation of particles in a sediment as referred above, comprised
Quaternary environments

The interpretation of Quaternary deposits is based on context (i.e. sedimentological, mineralogical and petrographic) data and their laboratory analysis. Palaeocurrent data were collected from all gravelly beds in the investigated sites to display a central tendency and degree of dispersion of individual clasts, defining the prevailing flow orientation in respect to the cardinal points (and), as well as to the vertical and horizontal variation of clast orientation angles (i.e. dip and roll, respectively). The palaeo logistical setting at all sites is reconstructed from the geological record and from studies of actual sedimentary (fluvial, colluvial and glacial/fluvial) processes and their facies in various sedimentary environments throughout western Alberta.

Reconstruction of the palaeo logistical environments from the investigated sections is a crucial component for elucidating the nature of flaking of the lithic assemblages. Application of the general concept of sedimentary facies models is prerequisite in order to understand the dynamics and overall configuration of natural forces acting during the deposition of these sediments, and their kinetic potential for simulating cultural flaking patterns. It is also significant to follow the development of the applied methodology. The sedimentary units and reconstructed sedimentary environments provide the principal information about the palaeo ecological area.

Interpretation of the local Quaternary history is based on interpretation of individual sedimentary strata and their relationship through facies models (Harms et al. 1982, Reading 1989, Walker 1986). The concept of a lithofacies (i.e. body of a lithified rock or unconsolidated deposit with specific characteristics defined on the basis of colour, bedding, composition, texture, fossils and sedimentary structures) was used to refer to an individual sedimentary stratigraphic unit. Both quantitative and qualitative parameters were applied to define the nature of each facies. Single facies, occurring together and considered to be environmentally and genetically related, were grouped into facies associations, eventually forming in the stratigraphic column a facies sequence, being a series of individual facies which pass gradually one into another and are bound by gradational, sharp, or erosional surfaces. Internal textural and structural changes within the facies sequence are controlled by shifts of the local sedimentary environment, as manifested in grain size distribution, thickness of individual deposits and variability in mineral composition. These are governed by external environmental factors, including climatic shift, subsidence, change in vegetation cover, etc., all largely influencing the rate of input, transport and deposition of a sediment. Accordingly, a facies model was used as a general summary of specific properties within a sedimentary environment. Its formulation is inferred from the description and classification of any body of sediment in terms of interpretation of processes and environments of deposition (Anderton 1985, Walker 1986, Brodkoziowski, van Loon 1991).

Archaeological record

Palaolithic industry assemblages have been recorded at all localities from the eroded exposures, where flaked quartzite and carbonate cobbles and flakes have been collected on the slope below, as well as identified in several levels within natural sections and subsequently exposed archaeological excavations sites. At Site 1 (Varsity Estates), culturally modified lithics originate as being secondarily redeposited from a Late Pleistocene Bowl Valley till, but also from its gravelly surface from a more intact buried context under 24 m of glaciofluvial sediments of Glacial Lake Calgary (Figures 2–5; Tables 1B, 2A, 3D, 3E, 3F; Site 2 (Silver Springs), identical flaked artifacts are distributed, largely in a secondary position, in the upper part of pre-glacial fluvial gravels (Figure 9; Tables 4B, 5A, 5B), and the basal part of the overlying glacial diamict which is correlated with the till at Site 1; at Site 3 (Bowmont), the lithic artifacts have a similar contextual position as at Site 2, with a stratigraphic provenance on top of the alluvial gravels. Archaeological excavations were conducted at all three sites, exposing 55 m², 6 m² and 4 m², respectively.

Only local classic raw materials derived from the Rocky Mountains area and forming the Quaternary glaciofluvial deposits at the site sections were used for stone tool flaking. The lithic assemblages were separated into two groups: Group A, which includes specimens with demonstrable diagnostic cultural flaking attributes specified in the previous comparative analysis, while Group B are specimens which are likely to have been artifactually modified, but which cannot be indisputably considered as artifactual because of imperfect and simple modification patterns, and/or due to partial reworking. Both groups were qualitatively subdivided into two subgroups in order to provide more detailed qualitative discrimination among individual specimens.

The group of core tools is dominated by various choppers, with rudimentarily modified unifacial type prevailing (Figures 6–7, 10–11), followed by distinctive side scrapers on cobbles produced by an anvil percussion technique (Figures 12–13). Other tool types are much less represented (rocks, picks, unifaces, bifaces, etc.) (Figure 17). The group of flake tools consist largely of morphologically variable side scrapers (Figures 4.2, 8.2, 12.2, 13). Burins and end scrapers, the next most numerous categories, occur much less frequently (Figures 4.1, 14, 15.2–4). Other, sporadically present types include notched and denticulated artifacts, distally pointed tools and retouched (flakes, Tool combinations on individual specimens are relatively common. Utilized flakes (Figures 8.1, 15.6), numerous lithic waste and various cores form the remainder of the collection (Figures 4.8, 10–18).

Geological and occupation history

The sequence of deposits from the investigated sites is interpreted as a succession of alluvial (fluvial) facies in the lower part of the complex, with a transition to glacial and glaciofluvial facies in the middle sections, as a
result of a gradual establishment of full glacial conditions in the former Bow Valley. The reconstructed general sedimentary facies model, based largely on the geological record from Silver Springs, is believed to represent one glacial cycle with ice advance and retreat (Brodzikowski, van Loon 1991:94, fig. 94A). The basal fluvial or proglacial deposits (Facies Association 1) were formed during the advance stage; the glacial deposits (Facies Association 2) during maximum glaciation, while the overland proglacial sands and gravels (Facies Association 3) were deposited during the retreat phase. Disconformity I relates to the time interval elapsed between the accumulation of the uppermost (glaciofluvial) gravels and their burial by the Cordilleran till during the Bow Valley ice advance. Deposition of the glaciolacustrine sediments in the upper part of the exposures (Facies Association 4) occurred later during a subsequent Laurentide glaciation of the NE Calgary area. Disconformity II relates to the temporal hiatus elapsed between the two glacial events. Both disconformities are manifested by the corresponding stratigraphic distribution of two lithic artifact assemblages, implying two episodes of the pre-Paleoindian occupation of the upper Bow River valley, with the earlier at the Silver Springs and Bowmont sites, and later at the Varsity Estates site. As no datable macro-organic material was found at either site, the approximate age of the early American occupation in the Bow Valley is based on the chronostratigraphic correlation of the industry-bearing deposits with the existing Late Quaternary geological framework of the region. The relative age of the source of the lithic clasts recorded within the geological contexts at the Calgary sites is indirectly, but logistically assessed. As stated above, the till incorporating the artifacts is related to a Cordilleran Bow Valley ice advance; the overlying lake sediments to Glacial Lake Calgary formed during the maximum of the subsequent Laurentide glaciation (ca 20 ka). It is assumed that only a relatively short time span separated the two glacial events.

PLEISTOCENE GEOARCHAEOLOGY IN ALBERTA: GEOLOGICAL CONTEXT

Because of the time focus, geoarchaeological contextual investigations are crucial to demonstrate the chronological and cultural authenticity of any particular archaeological record, especially if this is represented only by rudimentarily flaked lithics. Specific characteristics of local depositional environments, associated with occurrences of early lithic assemblages, which are the most likely archaeological inventories to be anticipated, must be addressed in terms of their natural potential for production of pseudoartifacts. The most frequent geological settings in a larger area of Western Canada, which are likely to include buried early cultural record, are river channels and related fluvial deposits, alluvial fan, slopewash and other gravity flow settings, glacial and glaciogenic (glaciofluvial, glaciolacustrine, ice-contact, etc.) depositional environments, lacustrine and glaciolacustrine settings, sea-shore areas and raised beaches (along the Pacific coast), and caves (in the Rocky Mountains).

Fluvial settings
Recognition of roughly modified stone tools in a fluvial setting may be either problematic, particularly if they are found within thick sedimentary units composed of heavy-load clasts (e.g. Tricart, Vogt 1967). On the contrary, flaked artifacts in fine-grained interchannel and overbank deposits should be identifiable without major difficulties even in produced on local raw materials. Evaluation of the possible human character of flaking of a lithic assemblage should take into consideration the following aspects: determination of sedimentary dynamics, including energy level, periodicity and palaeocurrent direction; density of the fluid, and the amount and composition of the saturated matrix; velocity of the current and rate of sedimentation, structural discontinuities and depositional irregularities in sedimentary units; secondary post-depositional disturbances; assessment of the mechanical potential of the present high-energy natural factors in the vicinity of a site and the surrounding area to imitate cultural flaking patterns on local rocks and decorative minerals, identification of natural stone-modification factors in the same geo-context, etc. Understanding of the basic principles of fluvial processes is therefore essential for critical assessment of the source of modification of flaked lithics in a buried context, as well as for interpretation of the existing paleoenvironment and its human inhabitation potential in the vicinity during the time of deposit formation. Patterned spatial distribution of the flaked lithics is one of the most important aspects which may support, although not conclusively establish, the cultural nature of flaking of a lithic assemblage enclosed in a geological context. However, a more or less homogenous distribution of flaked lithics within a deposit does not a priori exclude their artificial origin. The degree of spatial compactness is governed by several factors, including the distance of redeposition, velocity and density of the fluid, character of the local topographic setting, etc., all of which can significantly contribute to a high mixing of the original cultural sample with the derived specimen. Under favourable circumstances, the archaeological material may be horizontally dispersed within a small area on top of the subaerially exposed deposits (e.g. a river bank), and subsequently buried by fine sediments without any major reworking and redeposition (Table 7B). Such occupation surfaces, defined as spatially limited places of association of cultural remains (lithic and other artifacts, patterned cultural material accumulation, etc.) may be expected to occur in low energy fluvial and lacustrine sedimentary settings potentially sealing many early Palaeo-American sites. Distribution of the cultural record at the Calgary sites confirms the fact that artifacts and other cultural remains are likely to be largely dispersed by high energy streams (glaciofluvial, glaciolacustrine, ice-contact, etc.) depositional environments, lacustrine and glaciolacustrine settings, sea-shore areas and raised beaches (along the Pacific coast), and caves (in the Rocky Mountains).

Alluvial fan settings
Alluvial fans deposited near mountain fronts are likely to incorporate early cultural records within thick sequences of sandy-gravelly strata. Alluvial fan and related deposits have proved to be a rich source of Early Paleoindian sites in the Old World (e.g. Isaac 1977, Clark et al. 1984, Bar Yosef 1988, Chalchula 1993). Climate and tectonics are, among other factors, the most important agents affecting alluvial fan formation, especially if acting concomitantly. Periods of intensive denudation usually coincide with accelerated erosion in the source area as a result of disturbance of vegetational cover, change in precipitation patterns, subsidence androgenic activity, or simply as a result of more effective weathering due to increased insulation and/or frost action. Differences in clast composition and varying amounts of fractured rocks in a vertical profile in the deposit have a direct bearing to all aspects of the above considerations. Orbital changes can occur in semi-arid and periglacial zones in North America. The
FIGURE 4. Calgary Site 1 (Varsity Estates). Lithic industry (redeposit in the till): 1 multiple burin, 2 retouched cobble fragment (scraper), 3 cobble core with one flaking platform (quartzite). (All drawings by the author.)

FIGURE 5. Calgary Site 1 (Varsity Estates). Lithic industry (1993 excavation): Cobble core with a cortical flaking platform also used as a hammerstone as evidenced by concentrated percussion marks on the exposed cobble edges. The core was found in situ with other artifacts (Figures 6-9) on the till surface and burial by 24 m of the Glacial Lake Calgary clays.

character and intensity of these phenomena and physical properties of incorporated clastics have a direct bearing on assessment of the potential of an early stone industry distribution in the deposit.

The resulting alluvial fan facies can be highly variable, depending on several variables, including the amount of saturated debris introduced to the site, their lithology, periodicity of deposition, stability of the local bedrock, etc. Accordingly, alluvial fan deposits can occur as chaotically supported paraglomerates formed by mud-flow activity, or orthoglomerates with interbedded fine sandy and gravelly strata periodically laid down by sheet-flows and perennally active braided streams (Reading 1989, Nemec, Steel 1984). Particularly the latter should be a subject of close geoarchaeological studies.

**Glacial and glacigenic settings**

Glacial processes are the most effective high-energy agents in a terrestrial environment responsible for erosion of quantities of surficial materials, their large-scale and long-distance transport, subsequent reworking, and final distribution over large areas. Eroded rock debris of varying form and size are secondarily transported by melt-water or in the form of saturated deposits as gravity (mass)flows, all significantly contributing to progressive modification


FIGURE 11. Calgary Site 2 (Silver Springs). Lithic industry: 1 pointed chopper (siltstone), 2 bifacial core (quartzite).
FIGURE 12. Calgary Site 2 (Silver Springs). Lithic industry: 1 transverse side scraper on a split cobble, 2 lateral side scraper on a cobble fragment (quartzite).

FIGURE 13. Calgary Site 2 (Silver Springs). Lithic industry: 1-3 side scrapers on quartzite flakes.
FIGURE 14. Calgary Site 2 (Silver Springs). Lithic industry: 1–2 dished burins on quartzite cobble fragments.

FIGURE 15. Calgary Site 2 (Silver Springs). Lithic industry: 1 retouched flake, 2 end scraper, 3 lateral side scraper and multiple burins, 4 double lateral side scraper, 5 dished burin, 6 retouched flake (1. silikite, 2-4. quartzite).
FIGURE 16. Calgary Site 3 (Bownmont). Lithic industry: A distally flaked quartzite cobbles from eroding alluvial gravels beneath the till.

FIGURE 17. Calgary Site 3 (Bownmont). Lithic industry: unifacially retouched quartzite cobbles flake (double side-scaper).

FIGURE 18. Calgary Site 3 (Bownmont). Lithic industry: quartzite core with one flaking platform and a series of small negative flake scars.
of the derived clasts. However, the main source of a variety of fractured clasts, particularly close to the mountain areas, is a glacial diamicton (till), i.e. a massive, unstratified, poorly sorted deposit accumulated during an ice advance. Except for simple fracturing, the resulting damage patterns on entrained and transported and differentially abraded rocks carried by a glacier from its source area, or incorporated from former non-glacial deposits into its basal part as subglacial debris, include polishing, faceting and striating.

Other processes of mechanical disintegration and modification of clasts, especially encountered under periglacial conditions, are related to seasonal temperature fluctuations in permafrost regions, thawing of buried ice causing subsequent disturbance of surrounding deposits, frost action and thermal stress, periodic freezing of capillary water in rocks and migration of the fluid in the supporting matrix, movement of unconsolidated surficial materials over partly frozen ground (solifluction), cryostatic pressure (involutions and cryoturbation), glaciofluvial processes of episodic nature active at peaks of thaw seasons, and drastic desiccation of rocks exposed on a barren land by strong periglacial winds during minimal precipitation conditions.

A flaked lithic industry may be difficult to detect in a buried context within a glacial deposit, particularly if generally recognisable cultural attributes are lacking. In such cases, comprehensive contextual as well as actualistic studies are useful to carry out, even if the results obtained are not fully conclusive or are limited to an assessment of a degree of probability (e.g. Schnurrenberger, Bryan 1985). Similarly, a glaciofluvial outwash may be considered as a rather
TABLE 7A. Edmonton, central Alberta. Late Pleistocene sections above the North Saskatchewan River. The stratigraphic sequence includes Glacial Lake Edmonton clays above a Late Wisconsinan continental till and Mid-Wisconsinan "Saskatchewan" sands and gravels above Tertiary shales. Several isolated artifacts affected by strong aeolian abrasion found at the upper contact of the sands with the till indicate harsh environmental conditions in the area prior to the ice advance (Chichakula, unpublished data).

TABLE 7B. Villeneuve, central Alberta. Close view of planar and cross-laminated sandy beds interstratified with fine to medium cobbly gravel beds (direction of flow from left to right). Several isolated artifacts were found at the base of the formation in association with fossil wood (spruce) fragments (Chichakula, unpublished data).

Hillslope settings
In respect to the particular geomorphological position, preservation and recovery of early sites is less likely than in other, more stable landscape settings. In terms of recognition of rudimentarily flaked artifacts, it must be kept in mind that down-slope movement of coarse unconsolidated sediments can also produce fracturing, marginal fracturing, and other casual damage on individual clasts. In cohesive deposits, creep may produce stresses leading to an increased deformation of clasts, eventually resulting in their structural fragmentation. The same can be said about other high-energy slope and gravity phenomena including talus accumulations, rock-falls near steep cliff faces, and slope wash, all causing fracturing of incorporated debris to form a variety of geofacts, especially if fine-grained, matrix-supported deposit is absent. The scale of these processes depends on several factors, the most important of which are the relief gradient, presence and type of vegetation, amount and frequency of rainfall, and tectonic activity. Contextual studies aimed at clarifying the origin of clast fracturing at Palaeo-American sites, where the cultural activity is disputed and other compelling evidence is missing, are of the utmost importance.

Sea-shore settings
The only, though principal area where Pleistocene-age sites are to be expected is along the north-west coast of British Columbia, which may have repeatedly served as another passage to early human immigrants to the New World alternative to the intercontinental route along the eastern slopes of the Rocky Mountains. Both tides and waves produce mass drifts of water due to coastal currents that are the major agent of shoreline sedimentary transport. However, only in exceptional locations are tidal currents capable of eroding coastal rocks (Selby 1985). As in lacustrine environments, wind-induced surface waves are the main source of kinetic energy, but acting here on a much larger scale. Accretion is most rapid at the base of cliffs. As a result, clasts are occasionally occurring in limestone formations, may be an exception. Except for sudden structural disturbances resulting in roof falls, and the presence of cave streams, there are no other natural forces which could contribute to fracturing of stones. Thus, even a very "primitive" lithic industry made on mediocre-quality rocks showing rough "undiagnostic" flaking excavated from undisturbed cave deposits suggests cultural origin (e.g. Belya Roche Belgian, de Lumley 1969). This is particularly true if the raw material does not naturally occur in or near a cave (e.g. perfectly spherical spherelite concretions originating from Cretaceous shales in the Rocky Mountains ca 90 km distant that were found beneath a late Wisconsinan glacial deposit in Eagle Cave, Crownsnest Pass, SW Alberta; A.L. Bryan, unpublished data) (Figure 20).

Cave settings
There are only a few cave sites in the Canadian Rocky Mountains, which may have been shelters to early people during the Pleistocene Period (e.g. Eagle Cave). An early human presence in a cave setting is reported from the Yukon area (Cinq-Mars 1990). In cave setting in general, the possibility of natural production of lithics that would resemble genuine stone tools is relatively limited. This is because the natural intracavernal milieu is a priori excludes the presence of other non-indigenous clastic material, unless these were secondarily derived by gravity slope phenomena, or external stream and glacial action. Chert nodules, occasionally occurring in limestone formations, may be an exception. Except for sudden structural disturbances resulting in roof falls, and the presence of cave streams, there are no other natural forces which could contribute to fracturing of stones. Thus, even a very "primitive" lithic industry made on mediocre-quality rocks showing rough "undiagnostic" flaking excavated from undisturbed cave deposits suggests cultural origin (e.g. Belya Roche Belgian, de Lumley 1969). This is particularly true if the raw material does not naturally occur in or near a cave (e.g. perfectly spherical spherelite concretions originating from Cretaceous shales in the Rocky Mountains ca 90 km distant that were found beneath a late Wisconsinan glacial deposit in Eagle Cave, Crownsnest Pass, SW Alberta; A.L. Bryan, unpublished data) (Figure 20).

Lake basins have been preferred places for human settlement since the earliest prehistoric times. Apart of lakes occupying depressions formed by tectonic, volcanic, landslide or marine processes, which are marginally distributed in western Canada, old glacial and glacioluvial lake settings have a key importance for Palaeo-American investigations. Periglacial agents were especially active in glaciated regions of North America, where glacial debris accumulated by erosion dammed part of a valley, subsequently filled by melt-water. Sedimentation rate in the Pleistocene lacustrine deposits reflects fluctuation of the former lake shoreline and/or the ice margin, and the relative abundance of river-derived clasts. Clastic material as well as possible lithic artifacts, originally distributed along the shore, can be affected to some extent when reworked by wind-generated waves, and, on a larger scale, by landslides or glacial calving. High energy lake drainage currents may also modify deposited materials, although only exceptionally in shallow shoreline waters. On the contrary, in lakes with an interior drainage, fluctuation of the lake level may cause much reworking of the sediments in the proximal shore zone. However, all these actions are more a source of abrasion and rounding of larger clasts than fracturing leading to geofact production. Accordingly, flaked lithics from early Palaeoindian sites in a lacustrine setting should be easily identified and preserved in a relatively fresh condition (e.g. the Varsity Estates Site, Calgary).

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unlikely depositional environment to incorporate early stone artifacts. This, however, should not be a priori discounted, as artifacts, as well as other cultural remains, although largely dispersed by high-energy streams flowing across braided periglacial flood-plains, may be present. Although glacioluvial outwash may be considered as a rather unlikely depositional environment to incorporate an early lithic industry, even this should not be completely discounted. Particularly in Alberta, the occurrence of early cultural records represented by lithic artifacts at the base or partly entrained in glaciogenic deposits is to be expected in view of the regional Quaternary geology. Periglacial non-glacial deposits covered and partly distorted by overlying tills. A clear pattern of site distribution across the province under a mountain or continental till, analogous to the Silver Spring Site, is evident (Figure 1, Tables 6A–B, 7A).
very rarely. Contextual studies of depositional environments constitute a crucial part of any geochronological studies. Further research on the lithic artifact / geofact flakes criteria may significantly contribute not only to resolving questions about the antiquity of man in the Americas, but also to early human dispersal in the Old World.

ANALYTICAL STUDIES

Physical properties of raw material

In addition to the contextual investigations, studies on physical properties of rocks must be included in the methodological framework for critical assessment of a potential pre-Palaeeoindian stone industry distinguished in a geological context, particularly if this represents the only possible cultural manifestation. An adequate knowledge of the physical properties of particular rocks and clastic minerals in their natural depositional environment as a potential source of prehistoric raw material is one of the primary requirements for determining the cultural origin of a lithic assemblage. Structural strength of a lithic raw material should be assessed in terms of its ability to resist deformation by tensile, shear and compressive stresses. Expansivity, plasticity, and plastic behavior, a study of the relative retentive forces of raw materials, a study of the effect of active frictional forces at the contact between bedrock (or the underlying materials) and the transported deposits may provide information about the potential for fragmentation of the clast. Other aspects of the physical structure of raw materials, its static behavior (fracture and deformation, including friction, dilatancy, cracking, grinding, polishing) identified in a local depositional setting is important for understanding the behavior of clasts and potential patterns of use (abrasion, striations, grooves, etc.). The latter are especially useful by reconstructing a geological history of the clast and the character of the most recent depositional processes. Simulation of a rock's behavior, for example, extensively by weathering, etc., should be included in every comprehensive study. Geological context of a lithic collection becomes important in determining if nature would have had the capability of action, such as weathering, etc., which could affect the behavior of raw material, its potential behavior, and the quality of raw material. Distinction of patinated, non-accidental microflaking from accidental "pseudoetch" randomly distributed on morphologically functionless edges should be reliably determined in most cases.

Natural / cultural stone flaking: general aspects

Criteria specifying "diagnostic" flaking patterns of early stone industries, and distinguishing them from natural fractures in a particular geological context, are only exceptionally stated in descriptions of presumably culturally modified lithic assemblages. In both the Old and the New Worlds, only a few attempts have been made to address this issue (e.g. Brea 1955, Dies 1981, Patterson 1983, Schnurrenberger, Bryan 1985). Most of these, however, concern isotropic raw materials, and some of the attributes may not be observable on course-grained rock and minerals. It is preferred (and imperative) in any study to derive a priori specific stone flaking criteria for the particular assemblages, as any unincidental generalisation may be misleading.

Authenticity of the Late Pleistocene palaeolithic stone industries from Alberta is based on quantitative and qualitative comparison with naturally produced geofacts (pseudoskoliths) from the natural environment assemblages, from the area, analogous Holocene-age lithic industries from surface context, and experimentally produced stone tool specimens. The identical raw material in all data sets contributes to the objectivity of the study in terms of a general scheme of the nature and arrangement of flaking patterns, and the specific modification of exposed edges. Surface texture, i.e. the range of features found on the surface of flaked specimens, is considered to be equally informative.

Artifact-diagnostic stone flaking attributes

The palaeolithic stone tool assemblages from Alberta are characterized by specific flaking and edge retouching features, which are not consistently observed in patterned associations with any of the studied naturally-produced comparative assemblages. Because of their dominant occurrence in definite quartzite industries, these particular formal, textural and edge-modification attributes are therefore considered to be diagnostic for the cultural flaking of the tested lithic assemblages if they occur in characteristic, well-defined combinations. However, none of the particular attributes defined as "diagnostic" can be diagnostically considered as a reliable feature if found isolated on flaked lichens. From this point of view, the cultural nature of the recorded lithic specimens is inferred on the basis of their recurrent patterning. In both the flake- and the cobble-core components, the cultural nature of flaking is well-documented if several independent flaking procedures are present.

The artificial nature of the lithic assemblages from the Late Pleistocene sites in Alberta is based on the following general criteria (Chlachula 1994a):

a) regularity of flaking;
b) recurrent and technologically coherent patterns of modification;
c) standardised size range of the resulting forms;
d) presence of a set of associated attributes diagnostic for stone tool production which are absent in assemblages having an identical lithological composition from glacial and fluvial settings, despite the similarity of depositional environments.

The association of the above four criteria on flaked clasts in respect to the particular geological context excludes any possibility of modification of the lithic assemblages by natural forces acting during the accumulation of fluvial and glacial deposits preserved in the studied sections. In view of the characteristic flaking patterns and surface texture on the lithic specimens contextually incorporated on top of fluvial gravels below glacial diamictons, the actual modification must have occurred after deposition of the gravel beds by braided streams and before subsequent disturbance of the more recent sedimentary glaciofluvial or glacial environment. Although there are many tools at the sites which can be easily recognised as artefacts even without any formal comparative lithic analysis, the criteria stated above are specifically designed for the analysis of characteristically reworked specimens, about which questions could arise concerning their cultural authenticity. It is reasonable to suggest that the cultural origin of their flaking is supported because they are directly associated with a lithic industry whose artificial status has been firmly established. In fact, these "less convincing pieces" do not change the implication about the "pre-Palaeeoindian" settlement in the study area. The assumption is maintained that if definite stone tools are present, then it is an archaeological site.

Technology of palaeolithic industries from Alberta

Generally, quartzite artifact assemblages from Alberta pre-glacial sites manifest most of the basic technological traits and corresponding typological forms of stone tool production and lithic inventories that are found in the Old World Early, Middle and Late Palaeolithic. Under the term industry is here meant a particular set of (lich) artifacts spatially and chronologically associated in one technologically and typologically coherent assemblage defined by recurrent tool types produced by a set of specific flaking procedures. The term "Palaeolithic", applied in the description of the stone tool assemblages from Alberta, is primarily used to describe the cultural origin of the recorded lithic specimens is inferred on the basis of their recurrent patterning. In both the flake- and the cobble-core components, the cultural nature of flaking is well-documented if several independent flaking procedures are present.
Discussing the paleo-Mesoamerican cultural and environmental context of the Pleistocene in North America, the author notes the question is not whether or not there was an American Paleolithic, but simply whether it was different from the Old World. Unifacial and bifacial tool-making techniques, which are characteristic of the Old World, were not found in North America until after approximately 12,000 B.P. The lack of these techniques suggests a different cultural history for North America.

The discussion centers around the idea that the Pleistocene in North America was a period of significant cultural change, with the development of new tool-making techniques and the expansion of the human population. The author suggests that the cultural differences observed in North America are due to the unique environmental conditions of the region, which allowed for the development of new cultural practices.

In conclusion, the author suggests that the Pleistocene in North America was a period of significant cultural change, with the development of new tool-making techniques and the expansion of the human population. The cultural differences observed in North America are due to the unique environmental conditions of the region, which allowed for the development of new cultural practices. The author suggests that further research is needed to better understand the cultural history of North America during the Pleistocene.