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Stratigraphic, Sedimentological and Faunal Evidence for the Occurrence of Pre-Sangamonian Artefacts in Northern Yukon

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ABSTRACT. The stratigraphic position of artefacts of undoubted Pleistocene age found in the Old Crow Basin has long been in question. We report on geological, palaeontological and archaeological excavations and studies there which show that artefacts made by humans occur in deposits of Glacial Lake Old Crow laid down before Sangamonian time, probably during a phase of the Illinoian (≡Riss) glaciation. The geological events surrounding and following the deposition of Glacial Lake Old Crow were complicated by a changing lake level, localized soft-sediment flowage, pingo formation and dissolution, and by the colluvial transport of vertebrate fossils and artefacts. Following deepwater stages of the Lake, an environment not greatly different from that of the present is suggested by the excavated vertebrate fauna and by permafrost features, although warming during the succeeding Sangamon can be considered likely. Sangamonian and later phenomena in the Old Crow Basin are referred to briefly; they show that humans persisted in the area for some time.

RÉSUMÉ. Depuis un certain temps, une incertitude règnait tant au contexte stratigraphique de témoins façonnés datant du Pléistocène, dans le bassin de la rivière Old Crow au Yukon. Nous présentons des données géologiques, paléontologiques et archéologiques qui démontrent que des objets de fabrication humaine se trouvent dans des dépots du lac glaciaire Old Crow, qui dateraient d'avant l'interstade de Sangamon, probablement pendant une phase de la glaciation d'Illinois (Riss). Les évènements géologiques pendant et suivant la déposition des sédiments du lac glaciaire Old Crow furent compliqués par des changements du niveau lacustre, le mouvement restreint de dépots, la formation et dissolution de pingos et le transport colluvial de fossiles vertébreés et témoins façonnés. A en juger, de la faune vertébreé, des indices de pergélisol et des témoins façonnées, l'environnement après les phases profondes du lac aurait été très semblable à celui d'aujourd'hui. De plus, pendant la période suivante du Sangamon, un réchauffement semble probable. Des phénomènes du Sangamon et post-Sangamon sont brièvement traités. Ceux-ci démontrent la persistance de l'homme dans cette région pendant une durée de temps considérable.

Traduit par les auteurs.

Реферат. Стратиграфическое положение остатков материальной культуры древнего человека, найденных в котловине Олд Кроу и несомненно относящихся к плейстоденовой эпохе, долгое время находилось под вопросом. Мы сообщаем о геологических, палеонтологических и археологических раскопках и исследованиях, которые показывают, что остатки материальной культуры древнего человека встречаются в отложениях ледникового озера Олд Кроу, сложившихся до сангамонской стадии, по всей вероятности во время стадии иллинойского /рисс/ оледенения. Геологические явления, сопровождающие и следующие за отложением ледникового озера Олд Кроу, были осложнены изменяющимся уровнем озера, локализованной текучестью мягких осадков, образованием и растворением холмов почвенного льда, а также коллювииальным транспортом позвоночных ископаемых и остатков материальной культуры древнего человека. Позвоночная фауна, найденная во время раскопок, и признаки вечной мерзлоты указывают на то, что вслед за глубоководными стадиями озера, там возникла среда, не намного отличная от теперешней, хотя и потепление во время последующей сангамонской стадин представляется весьма возможным. Мы также вкратце упоминаем сангамонские и более поздние явления в котловине Олд Кроу; они показывают, что древние люди жили некоторое время в этом районе.

INTRODUCTION

Scope

We report in this paper the preliminary results of geological and palaeontological studies pertaining to archaeological specimens of human workmanship excavated at exposures of Pleistocene age along the lower middle course of the Old Crow River. Our present study area comprises about 15 linear km of gallery forest and taiga, cutbank and point bar (Figs. 1 and 2). However, our interpretation is based also on observations as far up the Old Crow River as the Alaska boundary; along Johnson, Black Fox, Schaeffer, Potato, Surprise and Timber creeks; and in parts of the Porcupine River valley and surrounding uplands. These extensive field studies and very large collections of fossils and artefacts will be described in other publications.

The study area shown in Figures 1 and 2 has become well-known as a source of vast quantities of Pleistocene vertebrate fossils and as one of several places in the Old Crow Basin where such fossils are commonly associated with human artefacts (e.g. Irving, 1968; Irving and Harington, 1973; Bonnichsen, 1979). Recently, it has become almost as well known for its outstanding exposures of litho- and biostratigraphy in bluffs under active erosion. Our present concern is with the stratigraphic position of sediments excavated with the purpose of recovering artefacts under controlled conditions, at bluffs named Locality 12, 15 and 300. In particular, we discuss the characteristics of our Unit 1b (Fig. 3), which corresponds to part of the deposit of a major glacial lake first described in the literature by Hughes (1969a), which we will call Glacial Lake Old Crow. Hughes has suggested (pers. comm., 1980) that a stratigraphically higher deposit of glacial lake clay be referred to Glacial Lake Kutchin. In this paper, we refer to these and other sediments only as necessary to interpret the events surrounding and immediately following the deposition of the clays of Glacial Lake Old Crow. We discuss here the ages of these deposits as indicated by geomorphic, glaciological, palaeontological, radiocarbon, and fission track (tephra) evidence, especially as the evidence bears on the ages of artefacts found in the same sediments. The artefacts are described only in order to establish their authenticity; detailed interpretation of their significance will be attempted elsewhere.

Prior Work

Work directly pertinent to our present interests began in 1960 with the Geological Survey of Canada's Operation Porcupine (Norris, 1975, 1976; Hughes, 1969a, 1972). This set the stratigraphic framework which we continue to use. Although the unglaciated northern Yukon had long

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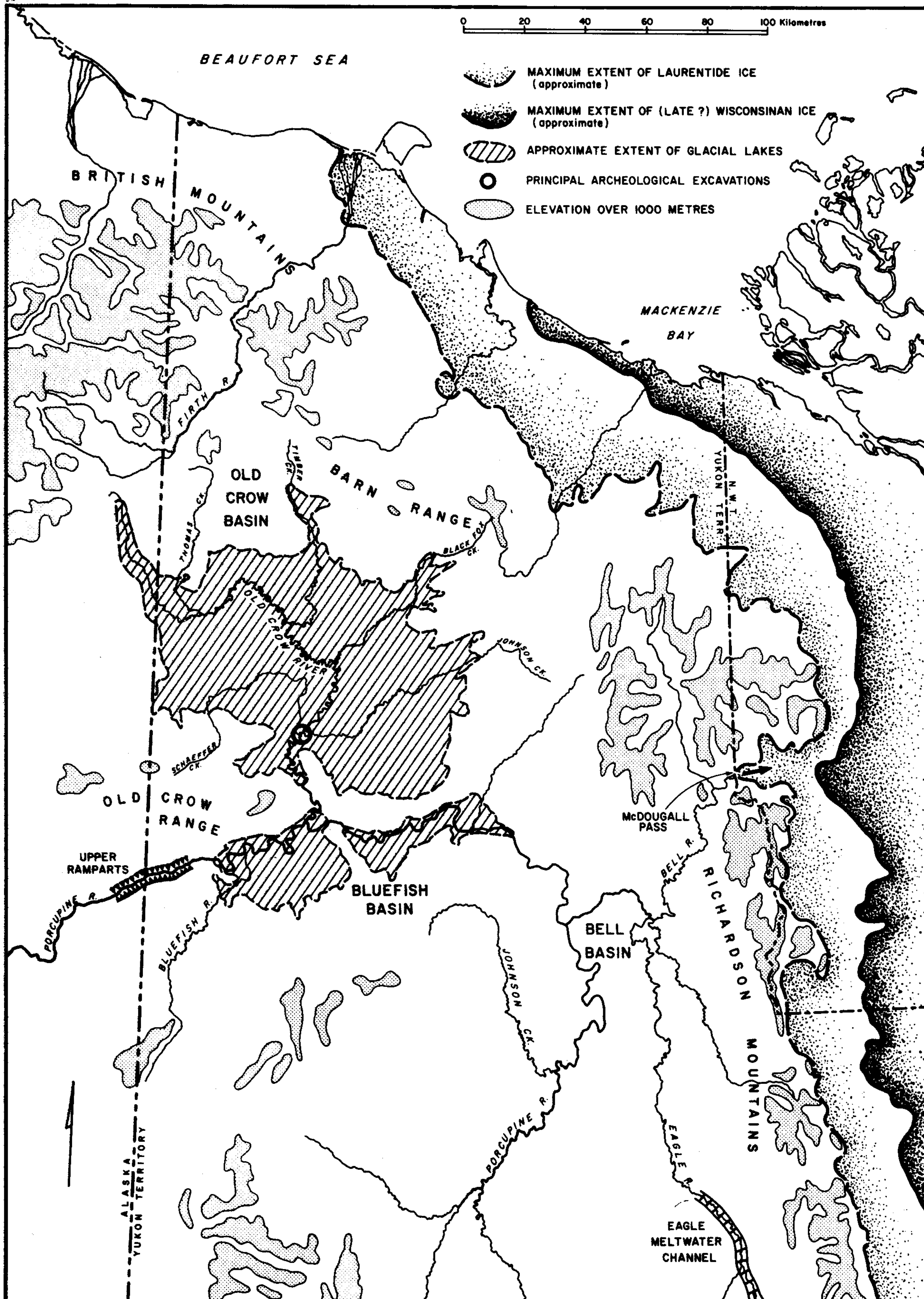


FIG. 1. Locality sketch of northern Yukon, showing Old Crow Basin and other physiographic features referred to in the text; ice limits based on GSC Glacial Map of Canada, and extent of glacial lakes (Old Crow and Bluefish Basins) based largely on data of Hughes (1972). The study area is delineated by the circle, and the indentations in the margin of the (hachured) lake area to the south and west refer respectively to the Mt. Schaeffer and King Edward promontories (granitic bedrock).

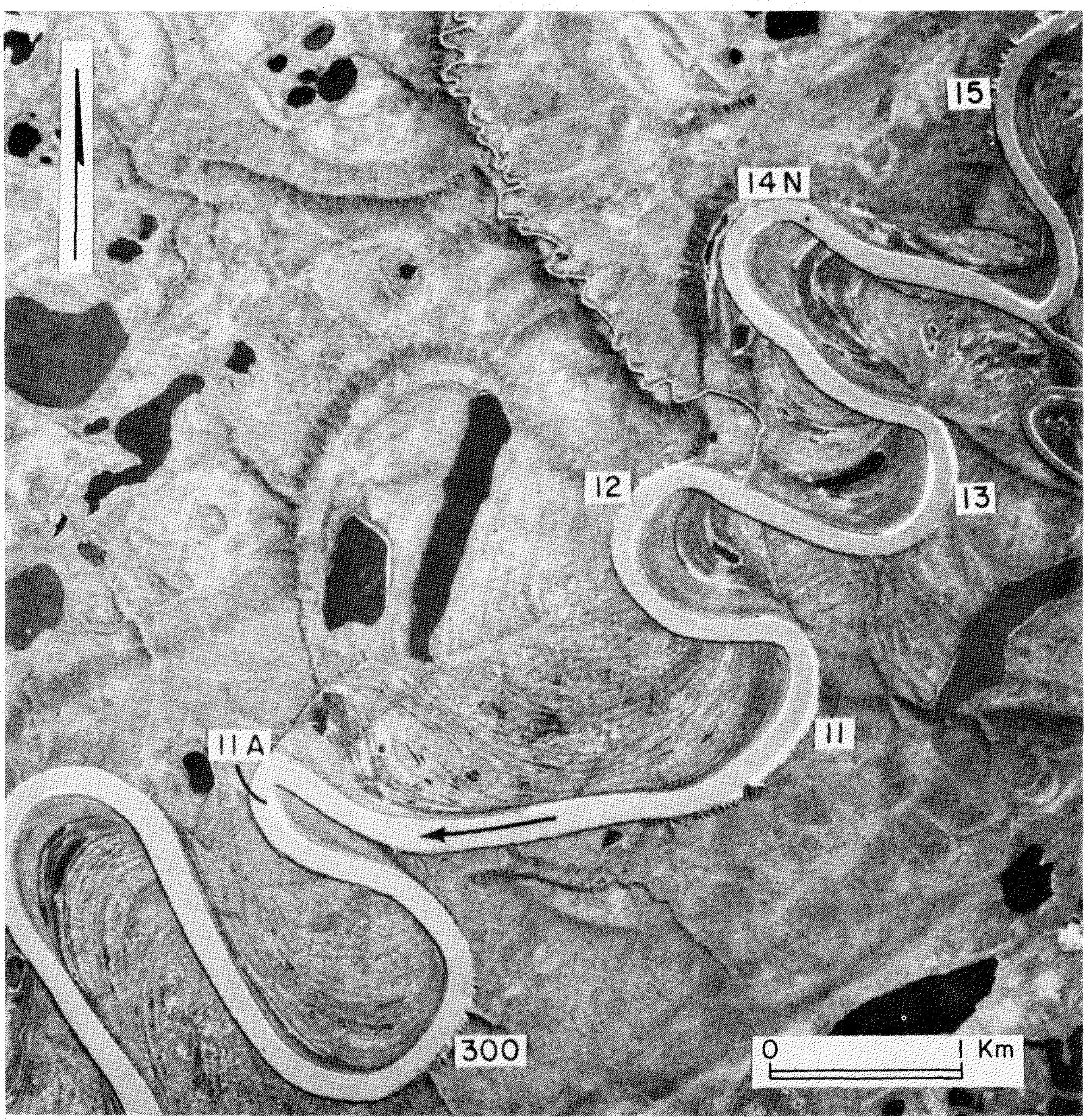


FIG. 2. Air photograph showing site locations within the study area. Schaeffer Creek is shown joining Old Crow River between OCR 12 and 13. The photograph shows various physiographic features (not marked) such as bluffs, point bars, scroll and swale patterns, river terraces and shallow lakes.

attracted archaeologists interested in the subject of Early Man (e.g. Bliss and Osborne, Leachman, MacNeish, Lowther, Wilmsen) and vertebrate fossils (Murie, Geist and others much earlier), it remained for C. R. Harington, in 1966, to show that the wet tundra of the Old Crow Basin was something other than an obstruction to archaeology. His collecting trip with guide Peter Lord that year on the Old Crow River led to Lord's recognition of an artefact among the Pleistocene fossils at OCR 14N. This led to the detection of other artefacts in that collection which seemed to merit archaeological attention. One of us (W.I.) had been excavating a late prehistoric site on the Porcupine River at the time, and was taken with John Joe Kay by Harington and Lord to revisit OCR 14N. The collections from OCR 14N subsequently were shown to have come from recent point bar deposits (T. D. Hamilton, pers. comm., 1967), but there could be no doubt about the Pleistocene origin of now-extinct vertebrate fossils; one specimen was a veritable implement and it appeared certain that others had been modified by Man, who therefore had to be considered a part of the Pleistocene fauna of the Old Crow Basin (Irving and Harington, 1973). All of the site designations except for OCR 11A and those in the 300s have been conferred by Harington.

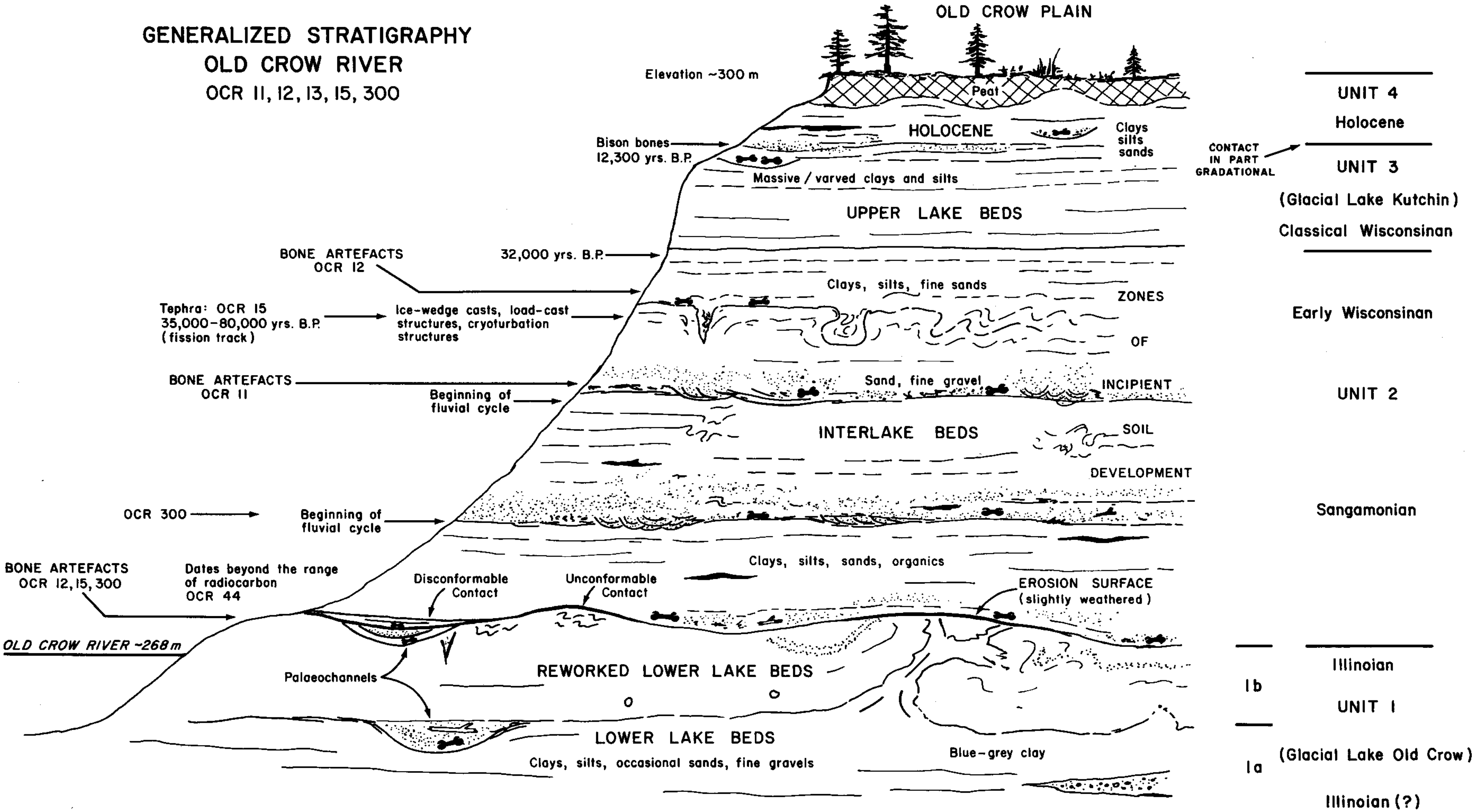


FIG. 3. Schematic lithostratigraphy of the Pleistocene and Holocene deposits exposed along the banks of the Old Crow River in the study area. Observations, except where otherwise specified, are those made by NYRP personnel; correlation with those of others is yet to be made. Tephra observed and collected by Morlan, Matthews, Schweger *et al.*, and dated by Briggs and Westgate (1978). Radiocarbon dates are from Harington (1977), cited in Morlan (1979). Subdivision of Unit 2 awaits further study, and fluvial cycles are schematic (partial or even absent in some sections). Units 1 to 3 are designated in terms of informal field nomenclature (Lower, Reworked, Inter- and Upper Lake). Cut-and-fill terraces of late Wisconsinan/Holocene age are not shown in the diagram. Stratigraphic data were obtained by cutting steps and trenches in river embankments, and by jet drilling in the subsurface. Section is not to scale.

In 1967 Harington and Irving both took parties to the Old Crow River, each pursuing his special interests and with the dual objectives of confirming the association of artefacts with Pleistocene fauna, and of finding one or both of these in an informative stratigraphic context. Irving was accompanied that summer by Lazarus Charlie, Jacques Cinq-Mars, R. E. Morlan and Abraham Peter, and visited by T. D. Hamilton.

In late June of that year Irving's party collected fossils at OCR 12, 15, and 42 (also called King Edward Bluff) which probably were eroded from relatively old deposits at these sites, unrelated to those of the modern floodplain. However, our knowledge of both the bone technology we sought and the sedimentary history of the basin was then so rudimentary that we placed little faith in either; Irving's field notes record that small "archaeologically undiagnostic" fragments of bone were found at OCR 12 and 15 in places where artefacts were excavated *in situ* in 1977 and 1978.

Harington has returned to the Old Crow River sites nearly every year since that time, with results that appear in his many publications (e.g. 1978).

In 1970 Irving's party included Lazarus Charlie, John Holland and David Stothers, later joined by T. D. Hamilton and Thomas Ager. Excavations at OCR 12 exposed some bones and one cobble on what appeared to be an erosional surface developed at the top of the beds that we now think were deposited by Glacial Lake Old Crow and later deformed. None of the specimens or observations gave clear evidence at that time of human activity, although the cobble's presence in between the beds of clay and fine sand was a striking anomaly. The then presumed erosional surface at this locale cannot be easily restudied because it has since been buried under landslide material; its peculiar shape may have resulted in part from deformation. The 1967 and 1970 observations of bones apparently *in situ* at OCR 12 and 15 had little significance at the time because a) they were few and scattered, b) they did not appear to clearly indicate human activity, and c) we could not perceive a sequence of sedimentary events that made sense to us. In 1970 at these two localities we did observe, but did not correctly interpret, bone fragments found in the precise location depicted in Figure 6 (OCR 12) and near that shown in Figure 9 (OCR 15).

In 1972 R. Bonnichsen perceived in specimens recovered by Irving from OCR 14N definitive evidence of a tool manufacturing system based on the percussion fracture of bone. The system includes subsystems for butchering, for the fragmentation of large bones, and for the use of bone fragments as tools and as cores to produce flakes which can serve for cutting and scraping. This perception provided a rationale for the many hundreds of fragments of mammoth and horse bone broken while fresh, which could not be convincingly related to the extraction of marrow. The new rationale provided considerable impetus to research on early human activity in the Yukon, in addition to being of widespread interest (Bonnichsen, 1979); it also served to stimulate further interest in the stratigraphic succession of the basin.

Beginning in 1975, the level of scientific activity in the Old Crow Basin rose significantly and continued through 1979. Most of the work reported here involved a rather extended community of Quaternary specialists, their students and supporting personnel, amounting sometimes to as many as 40 people focussing attention on a 15-km stretch of the Old Crow River. The majority were members of the Northern Yukon Research Programme or the Yukon Refugium Project, coordinated, respectively, by W. N. Irving and R. E. Morlan.

While Irving, J. C. Ritchie and J. A. Westgate observed and recorded at OCR 12 in 1976, it was not until 12 July of the following year that bones diagnosed as having been fractured by humans were recovered by Beebe, and Fred Frost of Old Crow Village, from a distinct depositional layer some 12 m below the top of the bluff exposure (i.e. several metres below the clays of the classical Wisconsinan lake and about 20 m above river level). Excavations here were temporarily suspended when bone fragments began to emerge in test excavations stratigraphically far below the 12 m level at OCR 12, in deposits previously investigated by Lazarus Charlie in 1970. Soon thereafter Masakazu Yoshizaki recognized signs of human activity, in the form of fractured bones and utilized cobbles, in a deeply buried deposit surface at OCR 300. In the meantime Yukon Refugium Project members working at OCR 15, 12 and other sites recovered bone artefacts from surfaces near the 12-m horizon, which they now designate Disconformity A (Morlan, 1980).

In 1978, Jopling began work in the Old Crow Basin, and an extensive survey of the regional stratigraphy was begun. The stratigraphic and sedimentological studies on which we report here were made as part of a comprehensive study of sedimentation in the Old Crow Basin. In that year, archaeological findings at OCR 12 and 300 were confirmed and extended. In addition, a small collection of vertebrate fossils including some artefacts, first recognized by Peter Josie on June 26, was excavated from just below an erosion surface at OCR 15 (the erosion surface delimits Units 1b and 2). Soon thereafter, Tom Andrews with Willie Thomas and Josie recovered quantities of fossil bone and artefacts from Unit 2 alluvium exposed at OCR 11. Most of these observations were reconfirmed in 1979 by Irving, Beebe and Andrews, except at OCR 15 and 300 where conditions that year were not favourable for work.

RÉSUMÉ OF THE PHYSIOGRAPHY OF THE OLD CROW - PORCUPINE REGION

The Old Crow Basin has an area of approximately 8300 km^2 and it is located about 160 km north of the Arctic

Circle. Lawrence (1973) has described it as an intermontane basin with approximately 600 - 1500 m of Mesozoic and Tertiary clastics overlying as much as 3000 m of Upper Devonian to Permo-Carboniferous sediments. The latter overlie the severely deformed Neruokpuk Formation of Proterozoic to early Palaeozoic age. The youngest sediments of the basin, represented by the Quaternary, attain a thickness of at least 40 or 50 m, but few subsurface data are available (in the adjacent Bluefish Basin, the exposed Quaternary sediments attain a thickness of about 58 m; Hughes, 1972).

The basin is surrounded by mountain ranges (Fig. 1) comprising tectonically disturbed strata that belong to both the Eastern (i.e. Richardson Mountains) and the Interior (i.e. British Mountains and Old Crow Range) systems of the Cordillera. Because of the tectonic complexity, the area has been designated on the Geological Map of Canada as the *Northern Yukon Fold Belt* (Douglas *et al.*, 1976; Norris, 1975, 1976, Open File Reports). Tertiary earth movements of uplift and downwarping are reputedly responsible for the basin structure of the Old Crow area.

The folded strata surrounding the basin are now expressed topographically as linear ridges, low mountains and broad valleys. In places old erosion surfaces dating back to the early Tertiary or late Cretaceous have bevelled the geologic structures to form flat-topped upland ridges and terraces (Bostock, 1976:22-23); some of these surfaces are probably of cryoplanation origin (for further discussion see Reger and Péwé, 1976). In describing the physiographic elements of the northern Yukon, Bostock (1976:23) states that the Old Crow Plain, representing the general level of the basin floor, is the northernmost part of the Porcupine Plateau. The elevation of the Old Crow Plain is almost 300 m. The plateau, together with other parts of the northwestern Yukon, remained essentially unglaciated during the Pleistocene.

However, the Pleistocene sequence of the Old Crow Basin does include two geographically widespread units deposited under glaciolacustrine conditions at the time when glacial meltwaters were diverted into the basin. The lower unit comprises sediments laid down in Glacial Lake Old Crow, which we now believe to be of Illinoian age, whereas the upper unit corresponds to the sediments laid down in Glacial Lake Kutchin of classical Wisconsinan age. These glaciolacustrine units have not been named formally; we use the names here for convenience to designate beds occurring within the Old Crow Basin, which may well correlate with similar beds in other nearby basins. Well-developed fossil beaches that most likely correspond with the second (Wisconsinan) ponding are now found around the margins of the basin at elevations of approximately 300-350 m and perhaps higher.

The physiographic evidence cited by Bostock (1976) and Hughes (1969a, 1972) suggests that the drainage system in the Old Crow Basin was disrupted at least twice when the Laurentide ice sheet impinged on the eastern flank of the Richardson Mountains. Bostock has suggested that the ice may have extended through McDougall Pass, a gap in the Richardson Mountains (Fig. 1) formerly occupied by an easterly or northeasterly flowing stream (ancestor Porcupine) that, together with its tributary system, drained the Old Crow-Porcupine area during the late Tertiary, and probably throughout most of the Pleistocene as well. Blockage of McDougall Pass by ice sealed off the easterly drainage, causing ponding in the Old Crow and Bluefish Basins, and elsewhere in what is now the Porcupine drainage. Further to the south the drainage waters of the ancestor Peel River were diverted into the Bell Basin via the Eagle meltwater channel (Morlan, 1979: Fig. 1). All three basins were interconnected by overflow channels and discharged their waters, augmented by glacial meltwaters, over an outlet at the site of the Ramparts canyon on the Alaskan segment of the present Porcupine River, and possibly through other outlets not yet identified. Following the wastage of the ice sheet, easterly drainage was resumed through McDougall Pass, ushering in an episode of fluvial and shallow lacustrine sedimentation during the Sangamon. Fluviolacustrine conditions prevailed through the Sangamon and the Wisconsin until a readvance of Laurentide ice again established a glacial lake (Kutchin) in the Old Crow Basin at the time of the maximum late Wisconsinan glaciation, about 18 000 BP. By the time the ice sheet had wasted, however, downcutting at the Ramparts canyon had lowered the outlet to such an extent that McDougall Pass was abandoned. In a reversal of drainage directions, waters from the Old Crow River were then diverted into the westerly-flowing Porcupine. It is possible that further research in the Old Crow-Porcupine region may modify this interpretation of the ponding mechanism. Few data, for example, are available on the Quaternary tectonics of the region, including those related to the isostatic effects of the Laurentide ice sheets. Finally, the Holocene witnessed the accumulation of fluvial and shallow lacustrine sediments which, in the middle to lower tract of the Old Crow River, commonly attain a thickness of about five metres.

The Old Crow River and its tributaries are now entrenched below the level of Old Crow Plain, thus exposing the Quaternary succession down to the level of the earlier Glacial Lake Old Crow deposits. The main episode of downcutting probably began about 12 000 to 13 000 BP, in early postglacial time. Weirich (1978) in a comprehensive literature review which includes the Old Crow Basin, has attempted to correlate the various Quaternary lake deposits throughout the Yukon and the District of Mackenzie, N.W.T.

The remainder of the paper is concerned specifically with the litho- and bio-stratigraphy, sedimentology, and geological events that characterized the history of Glacial Lake Old Crow. It also endeavours to place in perspective the events that culminated in Man's occupancy of the basin.

RÉSUMÉ OF THE QUATERNARY STRATIGRAPHY

In the absence of formal stratigraphic designations, the sedimentary succession exposed along the middle course of the Old Crow River will be referenced to the provisional lithologic units described by Hughes (1969a, 1972) for the Porcupine River. Hughes published two almost identical sections from the south bank of the Porcupine that serve as interim "type" sections for the Quaternary of the Bluefish and Old Crow basins. The 1972 section is reproduced here in Table 1 and compared with the stratigraphic nomenclature used in our investigations at OCR 15, 13, 12, 11, 300 and 42 (King Edward Bluff), progressing downstream along the course of the Old Crow River (see Fig. 2 for localities).

For the purposes of our field research we have subdivided the stratigraphic sequence into four prime units listed in Table 1 and illustrated schematically in Figure 3. Each unit is a separate entity with sufficient lithologic character to warrant the designation of *member* status in accordance with the rules of stratigraphic terminology (see Code of Stratigraphic Nomenclature, American Commission on Stratigraphic Nomenclature, 1961). Glaciolacustrine Units 1 and 3 are distinctive on the basis of their widespread geographic distribution and characteristic lithology. Locally, however, both units have gradational contacts with adjoining unit(s). Unit 2 in the study area commonly bears the imprint of one or more cycles, or partial cycles, of fluvial aggradation, each with a fining-upward sequence (albeit irregular in some instances). Unit 2 also bears the imprint of climatic fluctuations, as evidenced by the sporadic occurrence of ice-wedge casts and cryoturbation/thermokarst features in the middle to upper part of the section. Penecontemporaneous deformation related to the soft-sediment flowage of incompetent beds of silt and clay is also a characteristic feature of Unit 2. We have not been able to correlate the occurrences of ice-wedge and thermokarst features from one locality to another with any regularity.

The differentiation of Unit 1 into Subunits 1a and 1b, and the relationship between Units 1 and 2, are topics that are discussed in detail in the following pages. In our overall interpretation of the history of Glacial Lake Old Crow, we invoke a) a relatively deepwater glaciolacustrine phase corresponding to the deposition of Unit 1a, and b) a shallower glaciolacustrine phase that is transitional into a deltaic and fluvial phase, corresponding to the deposition of Unit 1b. We believe that Units 1a and 1b are genetically related in the sense that a) there is a measure of lithological and sedimentological continuity between them; and b) there is no field evidence of a major disconformity between them except possibly at OCR 11. Further field research may modify our interpretation of the interrelationship.

SEDIMENTARY HISTORY OF GLACIAL LAKE OLD CROW

The maximum observed thickness of outcropping sediments of Unit 1 is approximately nine metres, located in an overhanging streamcut exposure close to the junction of Little Flat and Johnson creeks. The section is composed primarily of dark blue-grey clay (Unit 1a) that grades upwards, near the top of the section, into a silty and sandy facies (Unit 1b) characterized by tabular units of cross-bedding, one of which has an estimated thickness of 0.2 m and a northwesterly palaeocurrent direction. The clay extends below the river level of Johnson Creek to an undetermined depth. Our limited subsurface data from other locations, which were obtained by jet drilling through the permafrost, suggest that Unit 1a has a thickness (~13 m) comparable to that of the equivalent unit exposed along the bluffs of the Porcupine River in the Bluefish Basin (Hughes' Unit 3, Table 1). Tentatively, we correlate Unit 1b (~6 m) with Hughes' Unit 4. In citing a communication by Delorme, Hughes (1969a) noted that the characteristic absence of the fossils in the clay (Unit 1a) was indicative of deposition in cold, turbid waters of glacial origin. Isolated pebbles, and even boulders, imbedded in the clay are suggestive of rafting. Locally, leaves and sticks are abundant, indicating vegetation coming from within the drainage area surrounding the lake; this may have been growing while the lake was present, or may have dated to an earlier time.

A generalized section based on a) the accessible part of the unit exposed above the low stage of river level on the Old Crow River, and b) our limited subsurface data, is shown in Figure 4. The coarse clastics associated with fines in the lower to middle part of the section constitute only a small part of the deposit volumetrically, and they may owe their origin to density underflows.

The influx of silt and fine sand towards the top of the section suggests that during the closing stages of deposition the lake level was subsiding, and that the coarser clastics from the margins of the basin were being reworked and shifted basinwards by fluvial, wave, and perhaps aeolian processes. The rare occurrence of palaeochannels towards the upper part of Unit 1, an excellent example of which can be seen at OCR 11, poses an intriguing problem of interpretation. No simple answer is forthcoming, but we will attempt to explore several plausible hypotheses, the most obvious of which is an episode of subaerial erosion toward the closing stages of glaciolacustrine sedimentation.

Palaeochannel at OCR 11: Sedimentological and Palaeontological Significance

A well-defined palaeochannel that is exposed near river level (elevation ~268 m) about halfway along the bluff is sketched in Figure 5. The coarse, poorly sorted channel fill is incised into blue-grey clay and is composed of coarse sand to granule-size material with numerous intercala-

TABLE 1. Generalized stratigraphy, nomenclature and tentative correlations: Porcupine-Old Crow Region

Generalized Porcupine-Old Crow Stratigraphy* based on Hughes (1969a) Unit	Description	Thickness ft	m	Inferred Environment of Deposition (after Hughes)	Informal Field Nomenclature Used in this Paper (OCB)	Informal Stratigraphic Units Used in this Paper (OCB)
9	Silt, probably eolian	1.5	0.4	Fluvial, shallow lacustrine with widespread peat deposition	Undifferentiated Holocene	Unit 4
8	Peat, wood, mostly unhumified	3.0	0.9			
7	Silt, grey-brown, with twig and wood lenses, thin peaty layers; probably fluvial	17.5	5.3			
6	Clay, silty, dark grey (moist), pale grey (dry) sediments slumping and flowing, poorly exposed; glaciolacustrine	10.5	3.2	Glaciolacustrine	Upper Lake beds	Unit 3 (corresponding to Glacial Lake Kutchin)
5	Silt and very fine-grained sand, dark grey to grey-brown (moist), yellow-brown (dry); gravel lens 1 ft thick in middle of unit; lacustrine and fluvial	37.0	11.3	'Normal' lacustrine, deltaic and fluvial	Interlake beds	Unit 2
4	Silt, grey-brown (moist), yellow-brown (dry); lenses of gravel and of twigs and wood; bedding in upper 3 to 4 feet highly convoluted by cryoturbation	20.5	6.2		Reworked Lower Lake beds	Unit 1b (corresponding to Glacial Lake Old Crow)
3	Silt, dark grey-brown (moist), medium brown-grey (dry); massive; markedly jointed with oxidized joint surfaces; glaciolacustrine; overlies Unit 2 disconformably	41.5	12.7	Glaciolacustrine	Lower Lake beds	Unit 1a
2	Silt, sand, fine gravel bedded, grey-brown to yellow-brown; twig and wood layers abundant in lower 25 feet; upper 4 feet highly convoluted by cryoturbation, with convolutions truncated at contact with Unit 3; overlies Unit 1 disconformably	40.0	12.2	Fluvial, deltaic and probably lacustrine; in part subaerial evidence of cryoturbation	Hughes' Units 1 and 2 rarely outcrop in Old Crow Basin	
1	Sand, coarse, and fine gravel, with a few thin silt layers, grey, in part oxidized to dull red-brown; very compact cf. Units 2, 4 and 5; abundant logs (spruce) with diameter to 20 inches	12.0	3.7			
	TOTAL	183.5	55.8			

*See Fig. 3 for schematic representation of stratigraphy used in this paper

Note: the correlation of Unit 1b with Hughes' Unit 4 is tentative and needs further clarification

tions of clay, silt and fine sand; detrital wood has accumulated on the downstream margins of the palaeochannel to produce a levee-like embankment.

Vertebrate fossils obtained from the fill included a ribbed enamel fragment from an incisor of *Castoroides ohioensis* (giant beaver), a dentary fragment with teeth of *Ochotona* cf. *whartoni* (giant pika), a fragmented operculum of a fish (*Catastomus* sp., sucker) and a few other small bone fragments, some of which appear to be derived from ungulates. *Castoroides ohioensis*, which was well established in southern North America by Illinoian time, is present in other deposits of Unit 1b and in Unit 2, suggesting that it probably reached Beringia in the latest Illinoian/earliest Sangamonian or, perhaps, during an Illinoian interstadial. A giant pika, *Ochotona whartoni*, is known in Alaska during early to ?middle Pleistocene time. Fossils excavated from Units 1b and 2 suggest that this, or a related species, may have survived until Sangamonian or early Wisconsinan time in the Old Crow Basin. None of the bones excavated or screened from the channel fill show evidence of having been worked by Man.

Because of the overburden of landslide material, we were unable to ascertain the precise stratigraphic relationship between the palaeochannel and the enclosing sediment at OCR 11. Another occurrence of relatively coarse detritus at the upstream end of the bluff posed the same problem; here, however, we even had difficulty in identifying the channel boundary. In both areas, however, the juxtaposition of fine and relatively coarse clastics testifies to rapid changes in the environmental conditions of deposition.

The origin of the palaeochannel at mid-bluff can be considered in terms of both subaerial (fluvial) and subaqueous (density underflow) processes. For the first hypothesis, we could readily postulate the rapid draining of the lake via McDougall Pass, either during an interstadial or at the close of the Illinoian glaciation, concomitant with a marked lowering of water level and the establish-

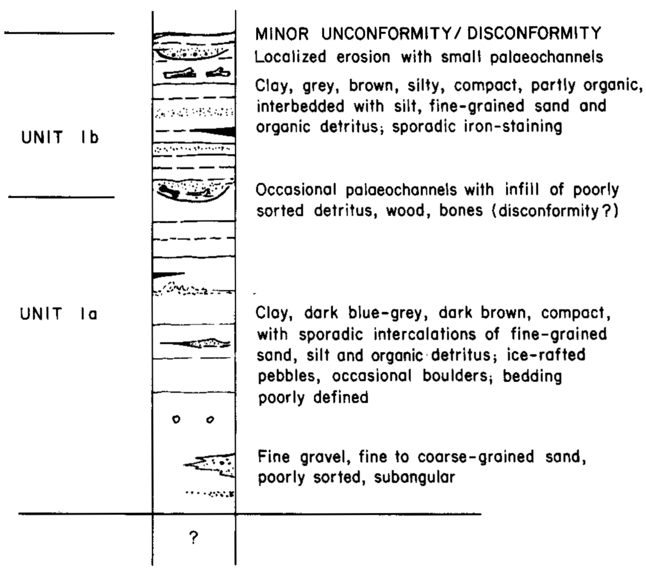


FIG. 4. Generalized stratigraphic section showing the characteristic lithology of Units 1a and 1b, with intertonguing fine and coarse clastics in 1a, the coarsening-upward trend, and the cut-and-fill channels. Data from lower part of section based on jet drilling; the colour recorded for sediments is that corresponding to wet state (exposed permafrost face). The thickness of Unit 1 is estimated at ± 19 m.

ment of a fluvial drainage system. Under these conditions the fill could well have been derived by reworking of the coarse facies around the margins of the glacial lake.

The coarse detrital nature of the channel fill at OCR 11 is a unique occurrence among the few palaeochannels that we have observed associated with Unit 1. At OCR 12 the palaeochannel is infilled with fine clastics and organic debris of colluvial origin, and at OCR 305 in the upper tract of the river, a palaeochannel cut into Unit 1 is filled primarily with organic detritus (60%), including logs and stumps, with subsidiary clay, silt and sand, and secondarily with pebbles, boulders and vertebrate fossils (*Mammuthus* sp., *Equus* sp.); the fossils probably were rafted along on vegetal mats. The occurrence at OCR 11 represents a relatively dynamic depositional environment when compared with the occurrences at OCR 12 and 305; it is also, in our opinion, in a stratigraphically lower context than the palaeochannel at OCR 12. At OCR 305 the channel, which has a cross-sectional width of 30 m, appears to be incised approximately 3-4 m into the fine clastics of Unit 1. The coarser clastics diagnostic of Unit 1b in our study area are missing, presumably because of a lateral facies change, so that the channel fill is overlain directly by the sediments of Unit 2.

There is insufficient evidence to unequivocally document the inception of a cycle of fluvial erosion at the close of Unit 1a deposition. We attribute the dominantly fine clastics of the Reworked Lower Lake (Unit 1b) to lacustrine and deltaic rather than fluvial processes, because in a number of sections that we have examined along the Old Crow River there is a general coarsening-upward sequence characterized by a systematic transition from the dark blue-grey clays of Unit 1a to interbedded blue-grey clays, silts and sands of Unit 1b (fluvial cycles are normally characterized by fining-upward sequences). Stratigraphically, the position of the palaeochannel at OCR 11 probably marks the base of the general coarsening-upward sequence for the unit as a whole.

The presence of a fish in the channel-fill fauna suggests that the channel fill dates to a period when a varied aquatic fauna was established in the basin, following the virtually sterile phase of the glacial maximum. Alternatively, the specimen might be regarded as having been redeposited from an earlier formation. Because of the presence of *Casteroides ohioensis* (which probably immigrated into the basin not earlier than the Illinoian), the channel entrenchment may have been a post-depositional event with respect to Glacial Lake Old Crow; that is, the channel may have cut through five metres or more of Unit 1b. Because of landslide debris, however, the field relationships are not clear.

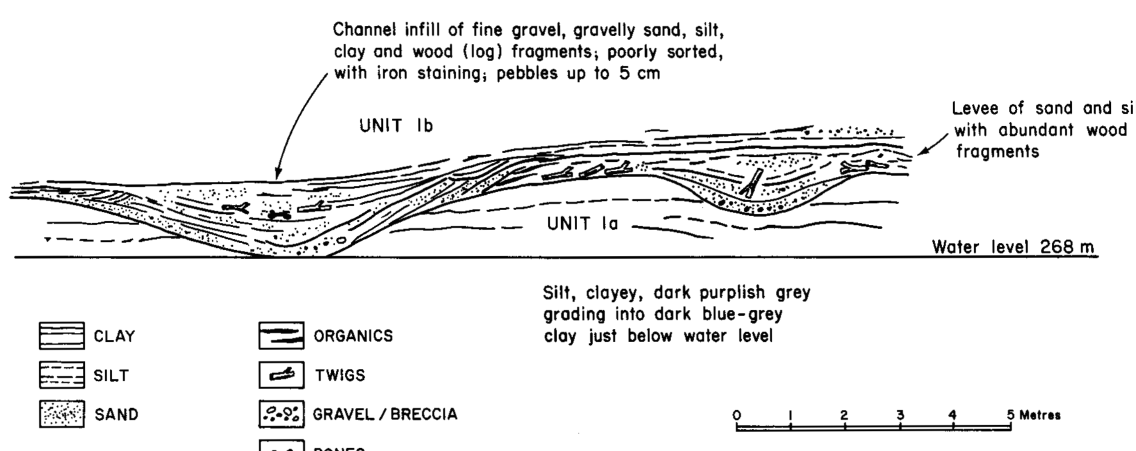


FIG. 5. Sketch of the palaeochannel, mid-bluff area OCR 11. The infill is fine gravel (massive), sand, silt, clay, detrital wood and fossils; there is some semblance to a fining-upward sequence, together with a trace of cross-bedding. The section exposed along the bluff is probably an oblique cross-section of the channel; palaeoflow direction not yet established. The faunal assemblage is not inconsistent with a late Illinoian age for the channel. The elevation of 268 m asl refers to the approximate water level of Old Crow River in mid-summer.

In summary, our interpretation of the sequence of events, based on a subaerial hypothesis, would involve either: a) the excavation of the channel during a low (albeit temporary?) stand of the lake, followed by a partial restoration of lake level; or b) post-depositional downcutting after the Reworked Lower Lake sediments had been laid down.

Several alternative explanations merit consideration, namely a subaqueous origin for the palaeochannel infill related to the operation of either: a) a massive grain flow; b) a more or less continuous density underflow; or c) a major turbidity flow (Blatt *et al.*, 1972) at the close of Lower Lake times.

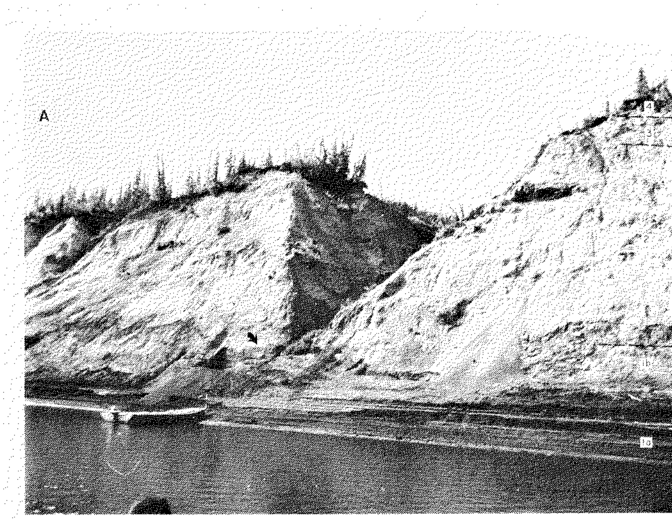
The first hypothesis is attractive because a small but rapid drawdown of lake level could easily trigger the mass flow of granular detritus down the basin slope (such deposits are transitional to turbidite deposits). The second explanation is also feasible because the palaeochannel may have functioned as a subaqueous drainage depression carrying the finer clastics towards the deeper parts of the basin in which case the accumulation of gravel, wood and vertebrate fossils may represent a lag deposit on the channel floor. Some of the coarser detritus, shifted around by wave and current action, or otherwise distributed by subaqueous slumping, may have been shifted into, and trapped within, the subaqueous channel. The rather widespread presence of logs and other vegetal detritus at the stratigraphic level of the palaeochannel does not disprove this hypothesis.

As for the turbidity flow hypothesis, no graded beds of turbidite origin have been recognized as yet in the exposed deposits of Glacial Lake Old Crow. Such beds could be expected to originate as a sequel to a major slump or slide of unconsolidated material down the slope of the basin. However, the few subsurface data that we have obtained by jet drilling in the permafrost below elevation 268 m are not incompatible with such a mode of origin. The drilling-log data can be summarized as follows:

a) At OCR 12, at the upstream end of the bluff, dark grey/blue-grey silty clays extend from elevations 269 to ~259 m;

b) At OCR 11N, near the upstream end of the bluff, dark grey/blue-grey silty clays with stringers of fine sand extend from elevations 269 to ~256 m;

c) At OCR 11, near the downstream end of the bluff, dark grey/blue-grey silty clays, with several layers of fine grey sand, extend from elevations 268 to ~264 m; fine to coarse sand, fine (4 mm) gravel, with layers of dark grey/blue-grey silty clay, extend from elevations 264 to ~258 m; interlayered fine to coarse sand, fine to medium gravel (subangular pebbles up to 6 mm), and dark grey/blue-grey silty clay extend from elevations 258 to ~256 m;



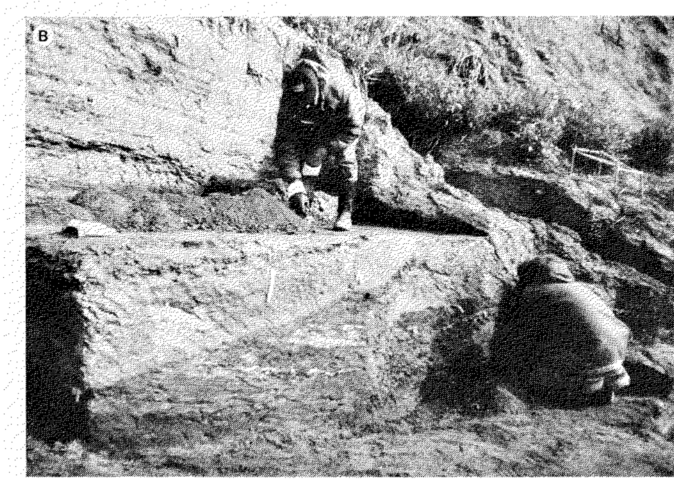


FIG. 6. A. General view of archaeological site at OCR 12, showing excavations (arrow) and stratigraphic units. B. Detail of archaeological excavation at OCR 12, showing ice wedge, channel section, and overlying colluvial deposits; bone layers are labelled and detailed in Fig. 7. The position of a flake artefact of proboscidean bone is shown at the bottom of the channel (lower left).

d) At a site halfway between OCR 11 and 11A, dark grey/blue-grey silty clays occur with fine to coarse sand that grades into fine, subangular gravel; and

e) In a large scour hole at the sharp river bend near OCR 11A, grab samples of plastic blue-grey clay were obtained at an elevation of ~252 m.

The subsurface data thus attest to an intertonguing of fine and coarse clastics, both ostensibly deposited under relatively deep-water conditions. Noting that the deep-water deposits of Glacial Lake Old Crow outcrop at an elevation of approximately 270 m in our study area, and that well-defined fossil beaches outcrop around the margins of Old Crow Basin at elevations of up to 350 m, it is reasonable to infer a water depth of up to 80 m. However, this estimate could be in error because we presently cannot differentiate the beaches, spits and bars of Glacial Lake Old Crow from those of Glacial Lake Kutchin.

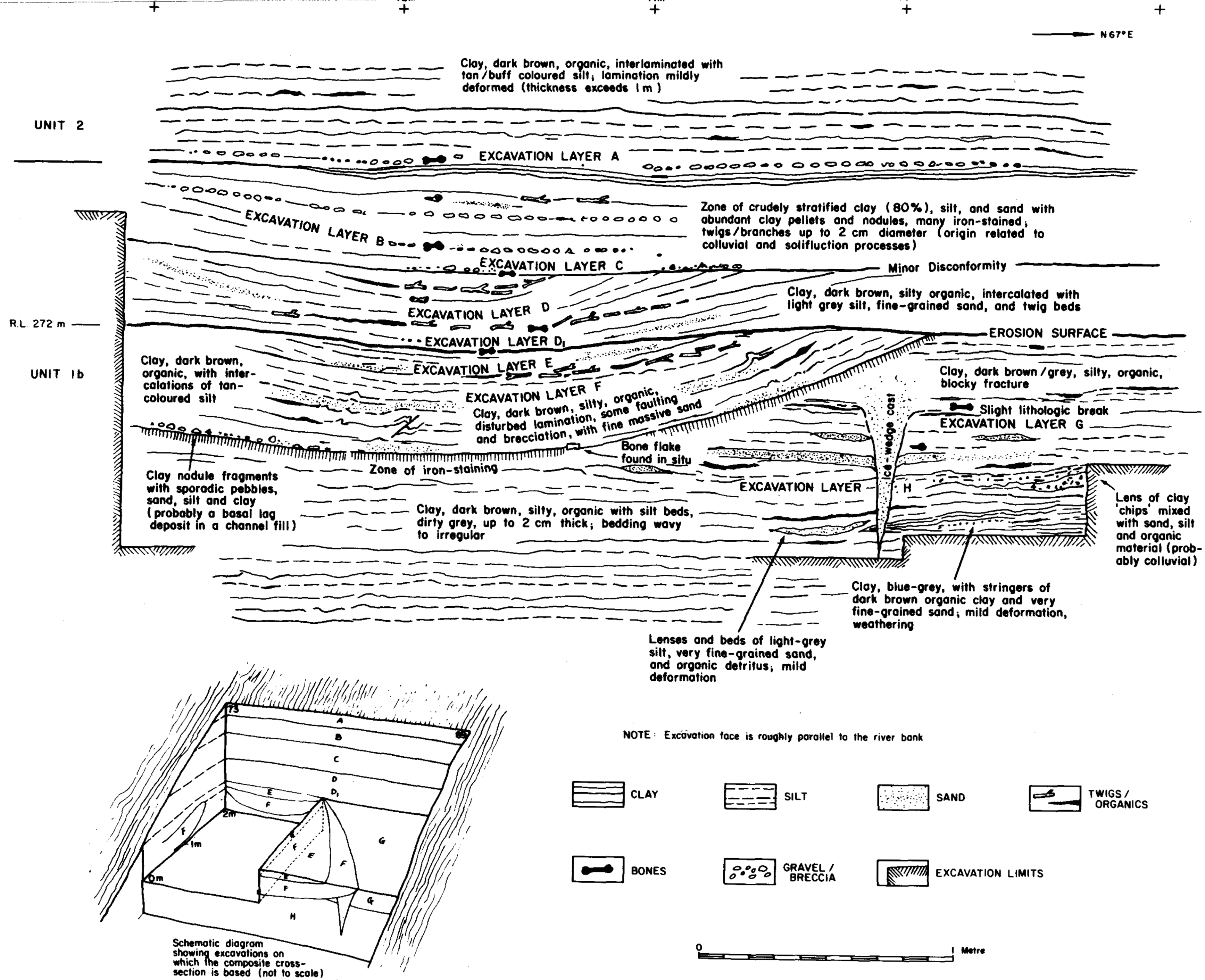


FIG. 7. Composite cross section through excavation at OCR 12, based primarily on 1978 notes. Layers A through D are thin beds of colluvium containing archaeological bone, separated by thicker layers of archaeologically sterile silty sands. Layer E may overlie the weakly expressed erosion surface that truncates Layer G. Layer F is notable for its lack of larger clasts, except for a bone flake found near the lower contact. Bones of terrestrial vertebrates occur sporadically in Layer H and below.

Given this evidence, and considering the proximity of the high promontories situated less than seven km to the south (Mt. Schaeffer) and 10 km to the west (King Edward), connoting a relatively steep basin slope, we certainly cannot discount the hypothesis of a turbidity-current origin for the emplacement of these sands and gravels (Fig. 1 for location). From our studies along the middle reach of the Old Crow River, in the central and more distal part of the basin, we have already observed that the sands that are characteristic of Unit 1b in the study area tend to die out because of a lateral facies change. On the other hand, the Mt. Schaeffer and King Edward promontories, with their beaches, bars and spits, must have represented ideal source areas for coarse clastics found in the study area.

We also concede that some of the subsurface sands and gravels may have been injected into the overlying fine clastics because of soft-sediment deformation.

Because of the inherent complexities, a final determination concerning the origin of the OCR 11 palaeochannel must be held in abeyance, but we have attempted to place in perspective its crucial sedimentological significance in the overall interpretation of basin history.

Inferred Permafrost Conditions During Closing Stages of Sedimentation

The lower palaeochannel stage of lake sedimentation represented a turning point in the history of the lake. Thereafter the lake appears to have been shallow and the sedimentation more varied, as shown by the influx of coarser clastics and the increasing percentage of vegetal detritus. The common occurrence of clay-lump nodules and breccia in the upper part of the section suggests that exposed portions of the lake floor on the margin of the basin were comminuted by frost processes (cf. the formation and dissolution of ground ice) and then eroded by solifluction and fluvial action. Some of the reworked detritus was shifted toward, and deposited in, the deeper part of the basin (i.e. study area). The breccia is intercalated with sands and silts presumably derived in part from the reworking of the sandy margins of the basin.

The presence of an ice-wedge cast in the top part of Unit 1b at OCR 12 indicates a frigid climate (Figs. 6, 7) during the closing stages of sedimentation. The scenario is that of a shrinking glacial lake fringed by strandlines and frozen mud flats that were subjected to a suite of cold-climate denudational processes, leading to resedimentation within the deeper part of the basin as the water level receded. Eventually, parts of the lake floor were transformed into a subaerial landscape.

Non-Diastrophic Deformation in the Glaciolacustrine Sediments

Locally, the lake sediments have been intensely deformed by soft-sediment flowage that occurred during, and probably after, the closing stages of sedimentation. In such locales the lake sediments are overlain unconformably by the horizontally bedded fluviolacustrine sediments (basal part of Unit 2) of Sangamonian age. Elsewhere, however, the lake sediments are relatively undisturbed, having a conformable to disconformable contact with the overlying beds, as at OCR 42 and at a number of bluffs along the middle reaches of the Old Crow River. For these locales it appears either that sedimentation was continuous or that there was a break in sedimentation without structural disturbance. Some disconformable contacts are characterized by a weak palaeosol and by distinctive iron-staining and mottling.

Our interpretation of the geological events that shaped the deformational history of Unit 1 invokes permafrost penetration coupled with soft-sediment flowage. Thus we postulate that permafrost conditions gradually permeated the barren mud flats of the partially drained lake floor, leading to a frozen crust on the exposed areas. We can speculate that at this stage the former lake floor was covered by innumerable shallow lakes with interconnected drainage and that internal deformation was taking place within the sediments, as illustrated by the development of a beach terracette around a small island squeezed up by soft-sediment flowage in the underlying blue-grey clay at OCR 13 (Fig. 8).

Elsewhere, as at OCR 15, clastic dikes, sills and irregular bodies of blue-grey clay, silt and sand were squeezed into the overlying cover of frozen sediment causing a considerable amount of deformation and dislocation in the host material (Fig. 9). Some of the dikes are truncated by the erosion surface. The regularity of some of the intrusive bodies suggests flowage of semi-liquid material into and along bedding fissures and cracks associated with a frozen but fractured crust (even now some of the dark blue-grey clay has a slightly plastic consistency). Some of the cracks and fissures may have formed as a result of desiccation. Part of the deformation may also have occurred superficially at a slightly later stage because of cryoturbation and mass-wasting processes operating on the subaerial parts of the old lake floor. Moreover, any subsequent thawing (especially differential thawing) of the frozen material, as for example during the Sangamon, could well have led to thermokarst processes and further flowage. Differential loading by sediments of Unit 2 also could have accentuated the deformation, especially near channel embankments.

Flowage in the blue-grey clay bed has caused local doming of the Reworked Lower Lake sediments at OCR 12, 13 and 300, and probably at OCR 15, as shown in Figures 8 to 11 inclusive. At OCR 12, the dips of the beds recorded in a trench dug on the bank of the river at the downstream end of the bluff (Fig. 11) at elevation ~269 m were up to 70°, and further up the same stratigraphic section the beds were dipping in a general westerly direction at an angle of approximately 40°. We believe that

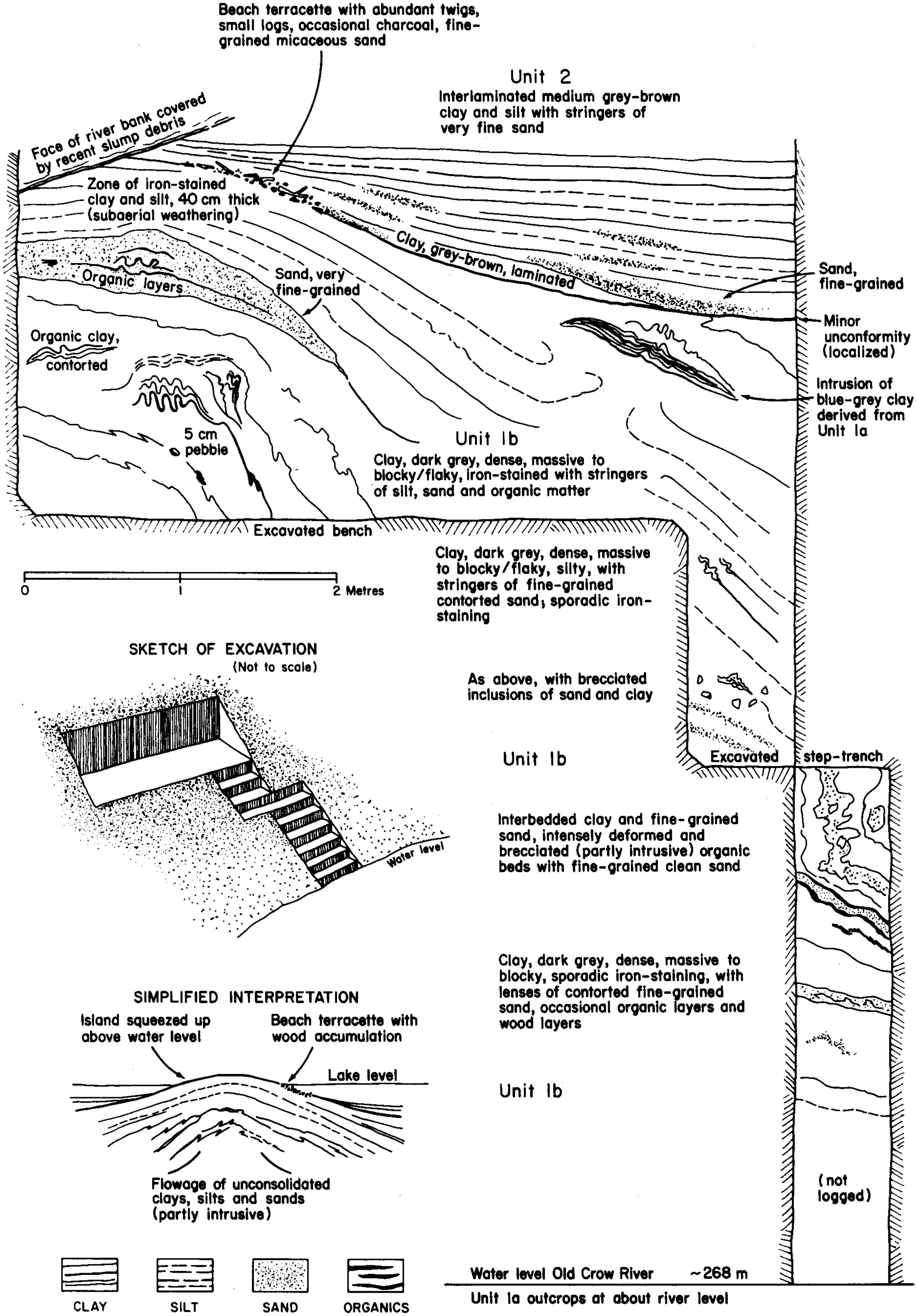


FIG. 8. Vertical section of a gentle anticlinal or domal bulge in Unit Ib formed by soft-sediment deformation near the upstream end of OCR 13. Here the overlying unit is draped over the bulge and shows a slightly unconformable relationship with Unit Ib. In one other section on the same bluff the relationship was a disconformable to conformable one, with little apparent break in sedimentation. One interpretation of the depositional environment is diagrammed in the bottom LH corner. The orientation of the section is approximately N 30°W.

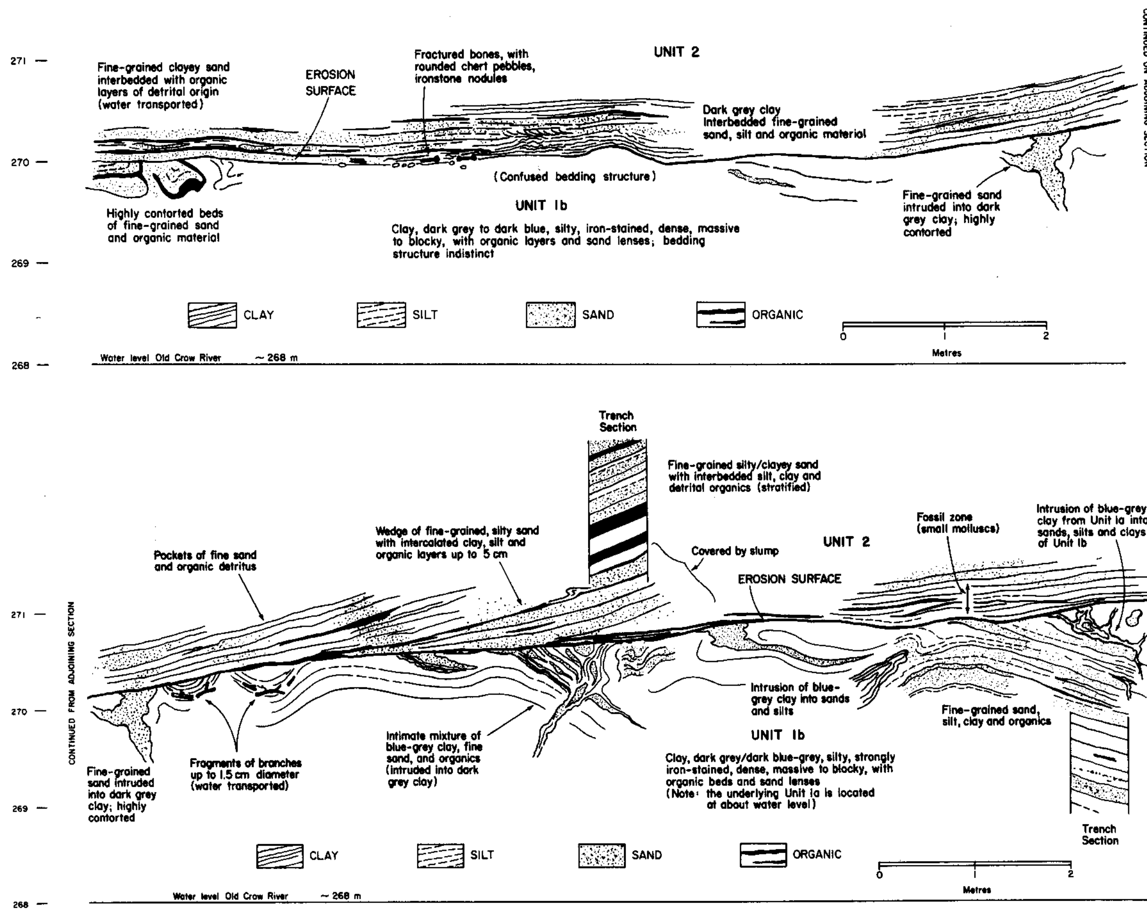


FIG. 9. Vertical section of the unconformable contact zone between Units 1b and 2 at OCR 15, showing intense soft-sediment deformation. In places the dark blue-grey clay of Unit 1a has been injected into Unit 1b as dikes, sills and irregular masses; silt and sand have been similarly affected. This intimate mixing of materials is not supportive of the idea of an appreciable hiatus between Units 1a and 1b. Fossils and artefactual material were found only in low area on the LH side of the joint section. Orientation of the sections is approximately N-S.

gentle doming associated with soft-sediment flowage and intraformational deformation helped to create some gentle relief on the drained lake floor.

The explanation for the soft-sediment deformation in the lake sediments is only speculative, but could be related to: a) cryostatic pressure induced by frost penetration from the surface downwards; b) disruption of a permafrost crust by artesian water; c) injection folding related to differential loading; d) intraformational deformation of a weak bed (i.e. blue-grey clay) triggered by the draining of the lake, by slight regional tilting and differential compaction, or by Quaternary earthquake shocks; or e) most likely, by a combination of causes or mechanisms.

The composite evidence for OCR 12, with its gently domed erosion surface, internal deformation, colluvial mantle, ice wedge and channel cross-section, indicates that a pingo origin is the most rational explanation for this particular occurrence (Figs. 6, 7, 11). Whether the pingo conformed to the closed-system, Mackenzie type described by Mackay (1963), or to the open-system, Greenland type of other authors — or, indeed, to an intermediate type — is a matter for speculation at this stage. Subsurface data indicate that in our study area sands and gravels are associated with blue-grey clays at an elevation of ± 260 m; thus an open-system explanation based on artesian pressure may be in order, assuming some measure of physical continuity between these sands and gravels and the coarse clastics of the marginal beach facies. It can be noted that Hughes (1969b) has described open-system pingos from the central Yukon.

Finally, reference must be made to the fact that we have virtually no information on the substrate beneath the Lower Lake beds in our study area. In Hughes' Porcupine River section fairly coarse clastics underlie the glaciolacustrine clays (Table 1). The same may hold in our area, in which case the conditions would favour the formation of the open-system type of pingo. The trace of the strata of Units 2 and 3 outcropping along the face of the bluff at OCR 12 gives the distinct impression of being gently arched or domed, a phenomenon that can perhaps be explained by differential compaction of the superincumbent sediments over the rim of a collapsed pingo at this site (Fig. 11).

Closing Stages of Lake Sedimentation

The limited sedimentary evidence from exposures along the Old Crow River and the general physiographic setting

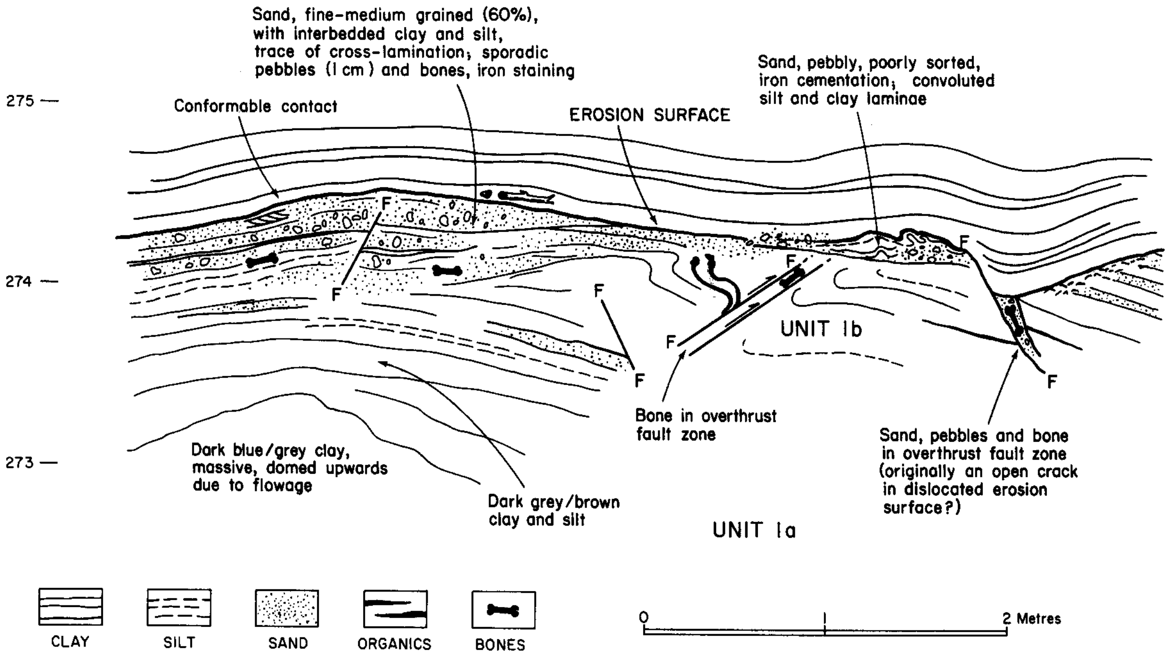


FIG. 10. Vertical section of the contact zone between Units 1b and 2 at OCR 300. The 'dirty', poorly sorted, gravelly sand represents a fossiliferous lag deposit of fluvial origin, left behind on an erosion surface of inferred Illinoian Age. After deposition, the beds were evidently further deformed by doming and faulting, probably while denudation was still taking place in a permafrost environment. Solifluction deposits (not shown) occur to the right of the section on the flank of the rise. The contact between Units 1b and 2 is locally disconformable to unconformable; section is oriented about N 30°E.

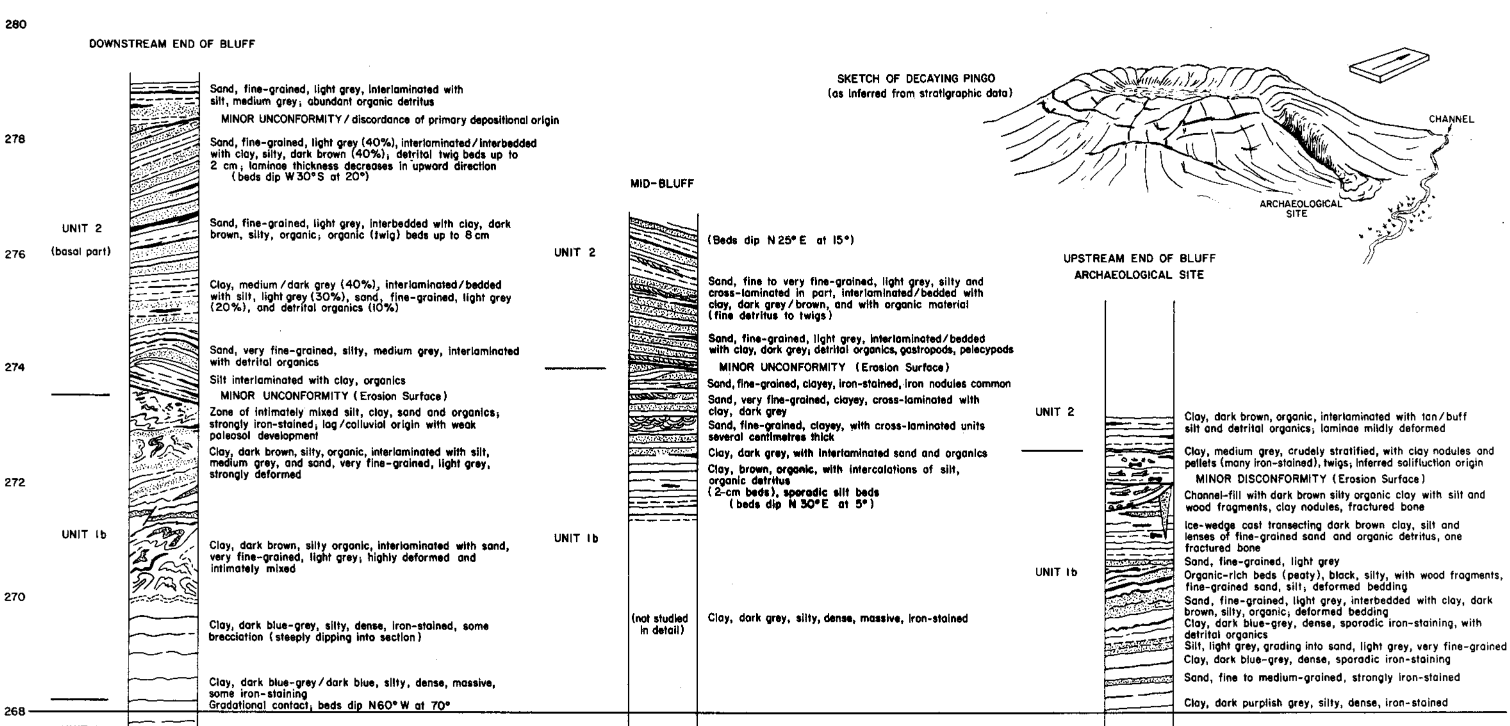


FIG. 11. Stratigraphic section following the bluff at OCR 12, showing the arched contact between Units 1b and 2. It is believed that the contact represents a cross-sectional profile of a pingo developed in late Illinoian time. The deformed beds are interpreted as part of the collapsed internal structure of the pingo, and the colluvial deposits at the archaeological site represent the products of pingo denudation. The eroded surface of the pingo (*viz.* unconformity surface) at the downstream end of the bluff slopes about 20° in a general SW direction, and the original crest may possibly have been located somewhere in the centre of the existing river. Early Man may have used the pingo as a lookout. The length of the section is about 150 m and its orientation is 45-60° east of true north.

of the area suggest that the lake floor was transformed into a flat subaerial landscape with shallow lakes, sporadic pingos and an evolving drainage system. In some localities the upper beds of the glacial lake were first deformed and then truncated by subaerial erosion, concomitant with the development of an iron-stained weathering profile. There is also some evidence of weak soil development, as at the downstream end of the bluff at OCR 12 (Fig. 11). In the archaeological excavations in Unit 1b at OCR 12 (Figs. 6 and 7), a drainage channel cross-section is shown truncating an ice-wedge cast. The channel appears to have been infilled with fine detritus of fluvial to colluvial origin, and it is buried under an assortment of beds of colluvial and fluvial overbank origin. The clay-lump breccias, nodules and pelletoid beds of poorly sorted colluvium are sometimes ferruginized and mixed with plant detritus and strongly suggest a solifluction origin, the material having been derived from the eroding flank of the pingo.

While the pingo was being eroded, sedimentation continued elsewhere (as in surrounding marshy areas) with the deposition of fine clastics, organic detritus, silt and sand, and the transition to the overlying Sangamonian beds appears to have been both orderly and structurally conformable. The deposits of Unit 1b are almost invariably more compact than those of the overlying beds, this being one of the field criteria used in delimiting the contact. The contact is sometimes distinguished by a poorly developed palaeosol with minimal weathering, indicating subaerial exposure but probably with little erosion of the horizontal strata. In other places, however, there is a conformable contact with a significant amount of iron-staining, with or without traces of palaeosol development. The contact is therefore strongly marked in some localities by either a disconformable or uncomformable relationship, but elsewhere it appears to be gradational with no clear break in sedimentation. The incoming of small fragile unidentified pelecypods, for example at OCR 15, is sometimes the first tangible evidence of the changing environmental conditions at the close of the glaciolacustrine stage. Finally, the upper beds of the Reworked Lower Lake deposit were locally dissected by fluvial erosion, as shown by the preservation of palaeochannels at OCR 12, 300 and 305.

Summary of Depositional and Post-Depositional Events

Our interpretation of the sequence of events is as follows:

a) Glaciolacustrine sedimentation during the Lower Lake stage, resulting in accumulation of fine clastics in a deepwater lake; intercalation of relatively coarse clastics may be related to density underflows; b) Possible draw-down of water level at the close of the Lower Lake stage, leading to subaerial (?) erosion and the deposition of fine gravel at OCR 11; alternative explanations are possible; c) Partial restoration of water level, accompanied by the continuation of glaciolacustrine sedimentation; a coarsening-upward sequence of sediments reflecting shallowing of the lake and reworking of the margins; as the lake drained towards the close of the Illinoian ice age, there was a transition to fluvial, deltaic and shallow lacustrine deposition; d) Localized soft-sediment deformation in closing stages of sedimentation, creating some relief on the partly emergent lake floor; e) Invasion of the area by permafrost, accompanied by the development of ice wedges and localized pingo formation, during the late Illinoian; inferred occupation of the flanks of the pingo by humans, who left behind tool fragments and camp debris; f) Erosion of the gentle relief on the emergent parts of the lake floor (upper Unit 1b) resulting in local accumulation of colluvial material, cryoturbation, and chemical weathering (as revealed by iron-staining); g) Local transport of bone artefacts and late Illinoian fauna in the colluvium attesting to Early Man's occupancy of the basin before or at that time; and h) Amelioration of climate, corresponding probably to the deposition of the lower beds of Unit 2 during the Sangamon. Bone artefacts persist in these beds.

AGE OF UNIT 1b

Although the available chronological evidence is fragmentary and incomplete, it is of several different kinds and we believe that it is internally consistent.

Palaeontological and Chronometric Evidence

Seven excavated Pleistocene faunal assemblages of interest with respect to the age of Unit 1b are presented in Table 2. Of these, faunas 2, 6 and 7 contain screened microfaunal remains. Analyses of the ichthyan and avian specimens are not yet completed, but the large majority of mammalian specimens have been identified. The faunal collections will be described later in more detail (Beebe, in prep.)

Unit 1b, represented by faunas 1 to 4, dates to a period no earlier than Illinoian as indicated by the presence of immigrants from non-glaciated southern North America and from Eurasia which probably reached Beringia no earlier than in Illinoian time. The southern immigrants include *Castoroides ohioensis* (giant beaver) and *Ondatra zibethicus* (muskrat). *Castoroides ohioensis* became widespread south of Laurentide ice in Illinoian time. The earliest record of *Ondatra zibethicus*, from the late Illinoian of Kansas (Kurten and Anderson, 1980), may be broadly contemporaneous with a record from Alaska that is of late Illinoian or possibly Sangamonian age (Péwé and Hopkins, 1967). Neither *Castoroides ohioensis* nor *Ondatra zibethicus* was capable of reaching Beringia during Illinoian time until Laurentide ice retreated towards the close of the Illinoian glaciation or, perhaps, during an interglacial. As both species are aquatic, they may have reached Beringia relatively soon after the onset of deglaciation by moving along a series of lakes or ponds beside the retreating

TABLE 2. Pleistocene faunal assemblages excavated from Old Crow Basin, Yukon Territory

	Faunal Assemblages*						
	Latest Illinoian				?Sangamon		Early Wisconsin
Taxa	1	2	3	4	5	6	7
Class Osteichthyes		X			X	X	X
Coregonus sp. (whitefish)						X	
Stenodus leucichthys (inconnu)						cf.	
Thymallus arcticus (Arctic grayling)						X	
Catastomus sp. (sucker)	X	X				X	
Catastomus catastomus (longnose sucker)		X					
Lota lota (burbot)						X	
Class Aves		X				X	X
Anatidae (ducks and geese)		X				X	
Chen sp. (goose)					cf.		
Tetraonidae (grouse and ptarmigan)		cf.		X	X	X	
Charadriiformes (shorebirds)						cf.	
Passeriformes (perching birds)						X	
Class Mammalia	X	X	X	X	X	X	
***Ochotona* cf. *whartoni* (giant pika)	X	X				X	
O. princeps (pika)		X				X	
Lepus americanus (varying hare)		X		X		X	X
#*L. arcticus* (Arctic hare)		X			X	X	
Castor canadensis (beaver)		X				X	
***Castoroides ohioensis* (giant beaver)	X	X	X		X	X	
Spermophilus sp. (ground squirrel)		X		X		X	
S. parryii (Arctic ground squirrel)		X		cf.	X	X	
Microtinae, genus *incertae sedis* (vole)		X					
Clethrionomys rutilus (red-backed vole)						X	
Lemmus sibiricus (brown lemming)		X				X	X
Phenacomys intermedius (heather vole)						X	X
Dicrostonyx sp. (lemming)		X				X	X
#*Dicrostonyx (Misothermus)* sp. (lemming)		X				X	
D. torquatus (varying lemming)							X
Ondatra zibethicus (muskrat)		X				X	cf.
Microtus sp. (vole)		X				X	X
M. miurus (singing vole)		X				X	X
M. pennsylvanicus (meadow vole)							X
M. oeconomus (tundra vole)		X				X	
M. xanthognathus (chestnut-cheeked vole)		X				cf.	X
Carnivora (large carnivore)		X					
Canis sp. (canid)		?				X	
C. lupus (wolf)		cf.				X	
Alopex lagopus (Arctic fox)		cf.		X		cf.	
Martes pennanti (fisher)						X	
Gulo gulo (wolverine)						X	
***Mammuthus* sp. (mammoth)		X	X	X	X	X	X
#*Equus* sp. (horse)		X	X	X	X	X	X
***E. (Plesippus) verae* (large horse)						cf.	
#*Cervus elaphus* (wapiti)		?					
Rangifer tarandus (caribou)		X				X	X
#*Bison* sp. (bison)						X	X
#Ovibovini (musk ox)					X		
***Soergelia* sp. (musk ox)			X				

*Faunal assemblages 1 to 4 were recovered from Unit 1b at OCR 11, 12, 15 and 300, respectively; assemblages 5 and 6 from fluvial deposits at mid-bluff levels of Unit 2 at OCR 300 and 11, respectively; and assemblage 7 from a minor disconformity in the upper part of Unit 2 at OCR 12.

**Taxa extinct.

#Taxa extirpated in Yukon Territory or recently re-introduced.

glaciers. Palaearctic taxa which reached North America across the Illinoian Beringian land bridge (Harington, 1977; Repenning, 1980) include the lemming *Dicrostonyx* and *Alopex lagopus* (arctic fox).

Also included in the faunas of Unit 1b is *Ochotona* cf. *whartoni* (giant pika). *Ochotona whartoni* was the first described from deposits of ?Nebraskan age in Alaska (Guthrie and Matthews, 1971) and may have survived to Illinoian time (Péwé, 1975; Harington, 1977). The recovery of specimens from Unit 2 of OCR 12, if these are not reworked, suggests that the species survived in Old Crow Basin at least until Sangamonian time.

Contrary to other evidence, one specimen recovered from Unit 1b at OCR 15 suggests a pre-Illinoian age. It must be noted here that the specimen, a horn core fragment of *Soergelia* sp. (musk ox), unlike the other fossils, was not recovered in controlled excavation. *Soergelia* sp. has been proposed as an index fossil for correlating beds of Kansan age in North America with those of Mindel or Elster age in Eurasia (Harington, 1977). The occurrence of *Soergelia* in Unit 1b may suggest a late surviving refugial population. Alternatively, the specimen may have been recycled. Noting that the Reworked Lower Lake beds of OCR 15 (Fig. 9) have been strongly deformed by hydroplastic injection, it is possible it may have been brought up from below.

The presence of fish remains in the faunas of Unit 1b suggests that a varied aquatic biota had been reestablished in the basin subsequent to the draining of the organically near-sterile Glacial Lake Old Crow. The recovery of an anatid (duck or goose) from OCR 12 suggests that bird migration into the region may have been reestablished by this period, assuming of course that it had ceased during full glaciation.

The faunas of Unit 1b are indicative of a landscape of sedge-grass-herb, mesic or xeric tundra on higher sites, and wet tundra in a lowland probably occupied by numerous shallow lakes and streams with wooded riparian habitat. This palaeoenvironment is consistent with the floral succession that might be expected on a recently drained lake floor. The pingo eminence that we have inferred in our environmental reconstruction was most likely part of this Illinoian landscape. We tentatively assume that neither pingos nor ice wedges formed during the Sangamonian interglacial; however, we have no direct evidence for this except the apparent absence of periglacial features from the lower portion of Unit 2.

Although *in situ* fossils of suggested Illinoian age have been reported from Canada — a few specimens of horse and caribou in Old Crow Basin by Harington (1977) and a small fauna from a cave deposit in southern Ontario by Churcher and Dods (1979) — no extensive fauna suggestive of Illinoian age has previously been recorded from Canada.

Unit 2 is represented by faunas 5, 6 and 7 which were derived from alluvial and fluvial deposits at mid-bluff levels. Collections at OCR 300 were made approximately 15 m above modern base river level in alluvial deposits. Faunal assemblages at OCR 11 were recovered from a number of sites between 8 and 17 m above base river level.

Collections at OCR 12 were made from a former floodplain surface at an elevation of 20 m above base river level. This minor disconformity surface is characterised by evidence of cryoturbation and, at some areas along the bluff, by the presence of small pelecypods. Morlan (1980) refers to an erosion surface preserved at a similar height at OCR 15 as Disconformity A; the surface is attributed to an early Wisconsinan age based on an associated fission track tephra date of 35 000 to 80 000 BP (Briggs and Westgate, 1978) and a radiocarbon date of > 51 000 BP for an autochthonous peat sample obtained from a level thought to represent Disconformity A. Four finite dates (GSC-1191, GSC-2756, GSC-2507, GSC-2574) ranging from 31 000 to 41 000 BP and representing mid-Wisconsinan time have been obtained at various exposures from levels above that represented by Disconformity A at OCR 15 (Morlan, 1980).

A similar floodplain surface is preserved at OCR 11 at an elevation of 18 m above base river level. It is not now known how the floodplains at OCR 11, 12 and 15 correlate. The tephra marker bed preserved at OCR 15 apparently is not represented at OCR 11 and 12, which suggests that these minor disconformities are of different ages. The similar stratigraphic positions and associated indications of cold climate (cryoturbation), however, suggest that all three probably correlate with the early Wisconsinan glaciation.

Faunas 5 and 6, recovered from stratigraphic contexts below the level of the early Wisconsinan disconformity, may represent Sangamonian and/or early Wisconsinan time. Fauna 6, a composite fauna obtained from a number of sites at OCR 11, may include both components. Further field study of these deposits is required.

The presence of migratory birds in these faunas might favour a Sangamonian rather than an early Wisconsinan age, but as the species involved have not yet been identified and Pacific coastal migrations cannot be ruled out, the evidence for this is tenuous. However, additional evidence supporting a Sangamonian age for these faunas is provided by the recovery of *Martes pennanti* (fisher) at the 10 m level of Unit 2 at OCR 11, which suggests that the enclosing in-channel sediments were deposited during the presence of boreal coniferous forest, the fisher's strict habitat. Such habitat requirements would have been best met in Sangamonian time. This is the earliest known occurrence of *M. pennanti*. Previously, fossils have been recovered from late Wisconsinan deposits in the eastern U.S. and from deposits lacking a precise stratigraphic context in Old Crow Basin (Harington, 1977). Presently, the northern range of the fisher extends only into southernmost Yukon Territory. Anderson (1970) suggested that the species may have entered North America from Asia in late Illinoian or early Wisconsinan time. The recovery of *M. pennanti* from Unit 2 at OCR 11 suggests an Illinoian migration.

Faunas 5 and 6 have elements with non-aquatic habitat requirements ranging from tundra to boreal forest. A taiga is thus suggested, but taphonomic mixing of fossils cannot be ruled out.

Harington (1977, 1978) has reported a probable Sangamonian fauna from OCR 44 in the basin, including, significantly *Spilogale* sp. (spotted skunk) which is recorded far north of its present range. Palaeoenvironmental indicators support a Sangamonian age, and radiocarbon dates on mammoth and horse of >39 900 BP (I-4228 and I-4223) and on wood of >44 000 BP (GSC-1593), >54 000 BP (GSC-2066) and >39 000 BP (GSC-3572) are not in disagreement. This fauna apparently correlates with a stratigraphic position above Unit 1b, at the base of our Unit 2.

Palynological evidence obtained from a number of exposures in Old Crow Basin (Lichti-Federovich, 1973) indicates a sedge-grass-herb tundra or dwarf birch-herb tundra environment after draining of Glacial Lake Old Crow, followed by spruce forest-tundra habitat and a subsequent return to sedge-grass-herb tundra prior to formation of Glacial Lake Kutchin.

Fauna 7, derived from the minor disconformity at the 20 m level in Unit 2 of OCR 12 and attributed to an early Wisconsinan age, suggests an environment of sedge-grass-herb tundra with wet lowlands and riparian willow/alder habitat. Comparison of this fauna with the other faunas reveals a major difference in representation of the genus *Dicrostonyx*, which is considered to be of chronological significance.

Three species of *Dicrostonyx* are recorded from the Quaternary of North America. *Dicrostonyx hudsonius*, currently restricted to the Ungava peninsula of eastern Canada, once had a much broader distribution as shown by its recovery from late Pleistocene deposits in Alaska (Repenning, 1978) and late Wisconsinan deposits in Pennsylvania (Guilday, 1963). *Dicrostonyx torquatus*, presently found in the arctic regions of North America, has been recovered from the late Pleistocene of Alaska (Repenning *et al.*, 1964; Guthrie, 1968) and Yukon Territory (Harington, 1977) and the late Wisconsin of Wyoming (Guilday, 1968). An extinct species, *Dicrostonyx henseli*, tentatively has been described from deposits of suggested early Illinoian age in Alaska (Guthrie and Matthews, 1971) and from deposits containing reworked fossils of Pleistocene age in Old Crow Basin, Yukon (Harington, 1977).

The most primitive of these three species, on the basis of molar complexity, is *D. hudsonius:* M^1 and M^2 each lack a posterolingual vestigial angle and have posterior surfaces which are usually convex with reduction in enamel thickness, and M_3 lacks the anterior labial and lingual vestigial angles. *Dicrostonyx henseli*, first described from the Late Pleistocene of Europe, has increased complexity with the addition of a vestigial labial angle to M_3, but a molar pattern otherwise similar to *D. hudsonius* (Hinton, 1926). Both species are included within the subgenus *Misothermus* (Guilday, 1973; Guthrie and Matthews, 1971). *Dicrostonyx torquatus*, of the subgenus *Dicrostonyx* has the most complex molar pattern: a posterolingual angle is usually vestigially developed on M^1 and M^2, and the posterior surfaces of these teeth are usually concave in outline with no reduction of enamel thickness: M_3 is usually developed with both anterior labial and lingual vestigal angles. All characters distinguishing these species are variable.

Dicrostonyx specimens recovered from Old Crow Basin include representatives of all three of the foregoing species. Harington (1977) reported the recovery of *D. torquatus* and *D.* cf. *henseli*; the latter, however, was recovered out of stratigraphic context. In our excavated faunas, dentaries retaining M_3, maxillary fragments retaining M^1 or M^2, and isolated specimens of M^1, M^2 or M_3, i.e. those specimens of diagnostic value, fall into two categories, one representing *D. torquatus* and the other *Dicrostonyx (Misothermus)*, which appear to be stratigraphically isolated from each other. In fauna 7, from the minor disconformity near the top of Unit 2 of OCR 12, six of 15 specimens are represented by taxonomically distinctive molars; five of these are typical of *D. torquatus* and the sixth, an ?LM_3 fragment, is more typical of *D. henseli*, but within the range of variation of *D. torquatus*. Fauna 6, from Unit 2 of OCR 11, contains 39 *Dicrostonyx* specimens of which 20 are diagnostic. Of these 20 specimens, seven are characteristic of *D. henseli*, six of *D. hudsonius* and seven of either of these two species, being identified only as *Dicrostonyx (Misothermus)*. Fauna 2, from Unit 1b at OCR 12, contains 14 specimens referred to *Dicrostonyx* including one *D. henseli*, two *D. hudsonius* and two unidentified *Dicrostonyx (Misothermus)*. Three specimens, dentaries with M_1 and M_2, are of such primitive appearance that they appear best referred to *Predicrostonyx* as described by Guthrie and Matthews (1971) from the ?Nebraskan of Cape Deceit, Alaska, but are included for the present within *Dicrostonyx (Misothermus)* as possible examples of extreme individual variation.

Our data thus suggest that the earliest *Dicrostonyx* in Old Crow Basin were of the *Misothermus* line which was replaced by *D. torquatus* in early Wisconsinan time. The co-occurrence of two species of the subgenus *Misothermus* suggests that the two "species" might represent the extremes of variation within one population. The modern *D. hudsonius* has previously been considered a relict of an earlier and more widespread holarctic *Dicrostonyx (Misothermus)* population (Guilday, 1963; Guthrie and Matthews, 1971; Rausch, 1978; Repenning, 1978).

In contrast to our observations, Harington (1977) reports *D. torquatus* in deposits of Sangamonian age from Old Crow Basin. This raises the question of whether Harington's record represents a further example of individual variation in a *Dicrostonyx (Misothermus)* population or whether two populations, *Dicrostonyx (Misothermus)* and *Dicrostonyx (Dicrostonyx)*, co-existed in eastern Beringia during late Pleistocene time. Harington's record plus the presence of *Predicrostonyx*-like specimens in Unit 1b suggest that *Dicrostonyx* has been an extremely variable genus throughout its Beringian record.

In summary, the faunas of Old Crow Basin suggest that Unit 1b is of latest Illinoian age and that Unit 2 dates from Sangamonian to mid-Wisconsinan time. The minor disconformity surfaces preserved at a number of localities, at levels of approximately 18 - 20 m above base river level, are of probable early Wisconsinan age. The mid-bluff level fluvial deposits may be of Sangamonian and/or early Wisconsinan age. If these deposits prove to be early Wisconsinan, it would appear that they contain reworked elements of an earlier Sangamonian fauna.

Considering the overall evidence, we could surmise that Lower Lake (Unit 1a) deposition corresponded to an Illinoian glaciation, dating back at least 120 000 years. On the other hand, given the limited data, it could also be argued that the Lower Lake (Unit 1a) beds correspond to an even earlier glaciation. Indeed, other researchers are currently entertaining very different ideas from ours in connection with the antiquity of the Lower Lake. Thus Bombin (1980), in citing a personal communication from C. Schweger, has suggested a palaeomagnetic age corresponding to the Matuyama reversed epoch for the Lower Lake beds. This would imply an absolute age in excess of half a million years, far greater than the figure we are advancing in this paper. Such a date would imply a long period of non-deposition (a stillstand) in the history of alluviation of the basin, or otherwise a protracted episode of erosion and soil formation about which we presently have little information. The possibility of another explanation of the palaeomagnetic observations should be kept in mind.

Evidence Based on Weathering Data

Using weathering information, we can now make some qualitative observations on age. Both the Lower Lake and Reworked Lower Lake beds are quite distinctive in terms of lithology and mode of weathering. Compact to dense semi-lithified clays and silts of a dark blue-grey, medium brown or dark brown colour characterize the Lower Lake, and clays, silts, sands and organics characterize the Reworked Lower Lake beds. Present-day outcrops of the Reworked Lower Lake beds along the banks of the Old Crow River weather by fracturing into small block- and flake-like fragments, accompanied by the deposition of iron (and probably manganese) oxides in cracks and joints, and by the iron-oxide impregnation of clays, silts and sands. Nodules of iron oxide are also common. This has been alluded to by Hughes (1972).

It would appear that the ongoing processes of chemical weathering and mechanical fragmentation are partly controlled by the primary texture and structure of the material. Thus, fresh clay and silt from the Reworked Lower Lake commonly displays a shadowy, brecciated appearance due to the inclusion of clay lumps, pellets and irregular fragments composed of essentially the same material. Much of this material appears to have been transported to the site of deposition by current action, but some at the top of Unit 1b may be the product of *in-situ* fragmentation related to the growth and decay of ground ice. Regardless of the origin, the brecciation has almost certainly expedited the rate of weathering and it may help to explain the mottled pattern of yellow-brown to purplish staining. Fluctuations of groundwater level may also have induced mottling and promoted cementation.

It is difficult to differentiate the modern cycle of weathering from the much earlier, post-depositional phase of late Illinoian weathering. In those places where we have pared back the river bank material to the permafrost face, we have noted that the depth of iron-staining and ferruginous cementation may extend for several metres below the late Illinoian erosion surface. This suggests an early post-depositional cycle of weathering, probably with complications introduced by subsequent diagenetic changes in the sediments themselves. Soil profile development was weak, presumably because of truncation in an actively eroding (solifluction) environment. Nevertheless, the weathering data corroborate the idea of an appreciable interval of subaerial exposure for parts of our study area, and this in itself is meaningful. This is consistent with the apparent absence of cryogenic deformation in the lower parts of Unit 2.

There is a distinct possibility that several cycles of fluvial downcutting and aggradation (cut-and-fill) exhumed parts of the Lower Lake and Reworked Lower Lake deposits during the late Wisconsin. This would complicate the weathering processes. We have tentative evidence, for example, that the 7-m terrace at OCR 11A was deposited on an eroded 'basement' of tenacious Lower Lake material. The compact and relatively resistant lithology of this material may have created a local base level that arrested down-cutting. The Upper Pleistocene fauna preserved in this terrace is accompanied by a few elements of Lower to Middle Pleistocene age. Our ongoing study of the terrace morphology and chronology (e.g. Beebe, 1980; Harvey, 1980a, 1980b) may help to elucidate the weathering sequence. As of now it is difficult to differentiate the several cycles of weathering that may have affected the Lower Lake/Reworked Lower Lake sediments.

In summary, further field and laboratory researches are required to substantiate the age of Unit 1a, but palaeontological evidence points to an Illinoian age for Unit 1b.

Moreover, we concede that our chronological framework for the complex sequence of events during the closing stages of lake deposition may eventually need revision. There could well be some important gaps in our fragmentary field data. However, taking account of all of the evidence now available, we have a measure of confidence in stating that Man occupied the basin during the Illinoian, perhaps during an interstadial, or during the retreat of the Laurentide ice sheet. Based on the ^{230}Thorium/^{234} Uranium datings of speleothems cited in Ford (1976) for glacial and interglacial events in the Nahanni Park, Mackenzie District, N.W.T., the absolute chronologic age for the late Illinoian would be about 150 000 years, (i.e., the Sangamon was cited at 145 000 ± 6000 BP). This particular estimate of age for the late Illinoian should be fairly reliable because of the high concentration of Uranium coprecipitated with calcite in the speleothems (D. C. Ford, pers. comm., 1980).

ARCHAEOLOGICAL EXCAVATIONS IN UNIT 1B

We shall describe excavations and some of the artefacts recovered from Unit 1b at OCR 12 (Figs. 2, 6, 11) and refer briefly to specimens from comparable and slightly higher strata at OCR 11, 15 and 300. More detailed descriptions of these and other sites and collections will be given elsewhere.

Background

Locality OCR 12 is one of perhaps a dozen active or recently active erosion cuts in our study area which expose some 30 m of fine-grained sediments. It was designated a collecting locality by Harington in 1966. In 1967 it was examined by Irving's party, with ambiguous results. In 1970 Irving made extensive excavations along the central section of the bluff, which revealed dipping and even folded beds of peat in the vicinity of what we now call the top of Unit 1b. At that time, an anomalous cobble was found in one of the peat beds, and small bone fragments were recovered from a zone near the major gully (Fig. 6). The 1970 observations were repeated by Irving's party in 1976. By 1977, all but a small portion of the previously exposed sections of Unit 1b where excavation had begun had been covered by great volumes of slumped material; all of the controlled excavations reported on here were done in 1977-79, at the single small exposure just downstream from the major gully (Fig. 6A). The few specimens from other parts of Unit 1b appear to be of little archaeological interest and do not modify our inferences about chronology.

Excavations at OCR 12: 1977-79

Although extensive testing continued, grid-controlled excavations were carried on primarily at the small exposure mentioned above (Figs. 6, 11). Horizontal control is related to a "base line" which follows stakes set at approximately 25-m intervals along the curving edge of the river; the zero point is a large stake where the upstream end of the bluff is intersected by the cut-bank edge of the modern floodplain some 5 m above low water level. Vertical datum is a large stake set near the excavation at 274.8 m asl. Controlled excavations were conducted between BL 69 and 73 m, between 273 and 271 m asl. Figure 7 is a composite profile based largely on 1978 notes. Most of the matrix was trowelled and passed through ⅛-inch mesh screens; portions of layers F and H were removed with shovels.

The majority of the 440 catalogued fossils, including bone artefacts, and several hundred unidentifiable and uncatalogued fragments, comes from thin layers of colluvium interbedded with sediments of overbank or other shallow-water deposition in which indicators of wave and current action are scarcely discernible; these are Layers A - E (Fig. 6B), which overlie the small, filled channel. Each of these layer designations refers to a thin depositional unit containing a mixture of plant and animal remains, small to large clay-silt and peat clasts with traces of oxidation due to soil-forming processes, and occasional artefacts. The deposits testify to a gentle slope near a steeper one, which we suggest was the pingo. Farther up the section and beyond the controlled excavation there are finely laminated, but dipping, beds of fine sand and silt, one to two metres in thickness. We think that these record an ephemeral, shallow lake or slough on a slowly aggrading landscape; the dip may be due to later deformation.

We infer a campsite on the flanks of a collapsed or collapsing pingo. The campsite overlooked a small stream, for at the bottom of the channel fill, Layer F, we recovered a single flake artefact of proboscidean bone (Fig. 6B). At some time during or after its occupation, the campsite became subject to erosion by mass movement and rillwash, which resulted in transport of some of its residue to the excavation site. Because of the physical processes involved, we assume that this transport entailed lateral displacement of only a very few metres. This is consistent with the high frequency of bone fragments and the clear lack of sorting according to size or density among the organic specimens recovered during excavation. Following and perhaps during the colluviation which produced the layering, a small lake encroached over the excavation site.

The sedimentary context of the few other fossils and artefacts excavated from this part of Unit 1b does not imply an important difference in their ages from those we have discussed. They underlie Layer E, which is a deposit of woody peat containing few fossils; Layer E itself rests upon a minor, in-channel erosion surface. Below it lie the channel fill, Layer F, which contained a single bone flake, and the complex deposits designated G and H, which include an ice-wedge cast and a small number of vertebrate fossils.

The formation and dissolution of an ice wedge occurred at some time prior to the channel cutting and filling recorded by Layer F. Whether the melting of the ice wedge was due to local causes only, or whether it was caused by a warming trend responsible also for the weathering of Unit 1b, which we think occurred in late Illinoian/early Sangamonian time, are matters for speculation. Layer H appears virtually sterile.

Artefacts from Unit 1b, OCR 12: Rationale

Research on Pleistocene bone artefacts from the Old Crow region has progressed through several stages each of observation, analysis, experiment and conjecture since 1966. It has revealed aspects of an industry (or a manufacturing complex) and of useful and apparently non-utilitarian artefacts, unexpected in the Western Hemisphere. Our consideration of the specimens excavated at OCR 12 is guided by our collective experience with many thousands of Pleistocene vertebrate fossils from recent alluvial deposits in the Old Crow Basin. We are confident that experience is of great help in the appraisal of bone artefacts, but surely none of us has seen the full range of bone artefacts produced prior to classical Wisconsinan time, the period best represented in our collections according to existing radiocarbon dates (Morlan, 1980). Also, we are not yet able to subdivide this industry chronologically.

The industry and artefacts now under discussion are represented by specimens of bone, ivory, tooth and antler. Implements of chipped stone and grinding tools are indicated unequivocally by cut marks and ground facets of human workmanship, but the quantity of hammer stones, chipped stone implements and debitage is remarkably small and no grinding stones have yet been recognized. No examples of flaked or ground stone have been excavated at OCR 12.

The artefacts from Unit 1b at OCR 12 come mainly from excavation Layers A through D, which appear to record periodic lateral displacements of anthropogenic soil. They have been identified among 223 vertebrate fossils for which excavated provenience is known; several hundred unidentifiable fragments also were excavated. An additional 217 specimens were recovered by sifting the excavated matrix with screens of ⅛″ mesh. For present purposes we may divide the collection into four classes: 1) specimens of purely palaeontological significance; 2) fragments and whole bones that one might expect to find among camp refuse; 3) bone fragments that show clear indication of percussion fracture by Man (artefacts, *sensu lato*); and 4) those that show evidence of other intentional or use-related modification that can be attributed only to Man.

All of the screened specimens and all but 21 of the excavated specimens are accommodated by classes 1 or 2. All of the excavated long bones of large vertebrates occur as fragments. Of the 21 specimens in classes 3 and 4, 17 show curvilinear fracture, in some cases in patterns that suggest tool manufacture. However, we will limit our description to four specimens that fit in class 4, including a scraper edge rejuvenation flake, a polished fragment of proboscidean tusk, a fragment of bird or small mammal bone shaped by grinding, and a fragment of proboscidean bone with curvilinear fracture surfaces and locally worn edges.

Although it is true that carnivores can cause curvilinear fractures on, for example, bovid bones, which in some cases would be difficult or impossible to distinguish from fractures caused by humans (Haynes, 1980), certain man-induced fractures on bovid bones and certain patterns of attrition on bone are diagnostic of human activity (Irving, laboratory and field notes; Bonnichsen, 1979). More significantly, no serious objection has been raised to the rationale presented by Irving and Harington (1973): curvilinear or spiral fracture occurs only in relatively fresh bone; fresh cortical bone of mammoth, 2-4 cm thick, cannot, as far as is known, be fractured by carnivores; no other natural agency in the Old Crow Basin can be invoked to cause curvilinear fractures in fresh proboscidean bones; therefore Man is indicated by such fractures. Systematic observations show that bone exposed to the elements will develop a tendency to fracture along the split-line system within a few months or years (Tappen and Peske, 1970; Miller, 1975; Haynes, 1980). Other observations suggest that this tendency may begin to develop in a very short time especially under freezing conditions (L. Pavlish and P. Sheppard, lab notes; Irving, field notes). Some additional data may be helpful, although this is not intended to be a thorough review of the subject. Experiments by Stanford and Bonnichsen (unpublished) have shown: a) that features observed on the Old Crow proboscidean fossils can be reproduced by skilled artisans working with recently dead elephant bone; and b) that the initial fracture of an elephant humerus requires the extremely forceful application of at least a 20-lb boulder (R. Bonnichsen and D. Stanford, pers. comm., 1978).

It is true that fractures which appear at first glance to be curvilinear may develop in aged or fossilized bone. However, close examination of recently broken fossils from Old Crow Basin shows that these are distinguished by fracture surfaces with a granular texture, and often by a surface relief that is distinguished by series of right-angled steps.

Thus, it is possible to distinguish some fractures made on proboscidean cortical bone while it was fresh, and this recognition is evidence for human activity because of the extremely remote likelihood of some other agency having caused the fracture. It is, however, important to note that not all fractures in fresh bone can be identified as such with the criteria now available.

The study of percussion fracture of ivory or tusk has not progressed as far as that of bone; it will be discussed in connection with the single specimen of that material on which we report here. The same general principles are thought to apply.

The problem of identifying retouch flakes or flaking as having been caused only by human activity is much the same whether the material is stone or bone. Minor, albeit significant differences include: a) features of conchoidal fracture, although they may occur in bone, are usually much less distinct than they would be in stone broken under similar circumstances and they may be expressed somewhat differently; b) the internal structure of bone is basically cellular and specifically linear, and this may cause fractures to follow courses through bone that they would not follow through a piece of virtually amorphous flint or quartzite of similar shape and size. Thus, for example, as in the case of larger scales of modification, curvilinear fracture does not always result from a blow to fresh bone: the fracture may approximate a rectilinear pattern, and in this respect resemble fractures that are characteristic also of dried or fossilized bone. This observation narrows the application of this criterion.

The subject of bone retouch flaking has been dealt with only briefly in literature; therefore all statements about it must be interpreted in terms of the current, primitive, state of the archaeological art. Nevertheless, we shall address it because it occurs occasionally in our general collections, and an example appears in our excavated collection. The question is how to specify reasons for judging that flakes detached from bones have been removed by humans, rather than by carnivores or by some agent of mechanical weathering such as alluvial transport. A bone core and flake industry has been defined by Bonnichsen (1979); we add to this edge modification, including both edge preparation and edge sharpening or rejuvenation by the detachment of flakes.

The problem we confront now is superficially similar to the problem that Barnes (1939) and earlier students addressed when they disputed the human origin of "eoliths" — fractured flints found in the Plio-Pleistocene Crag formations in southeastern England. However, our task is easier than theirs: because of its durability flint will survive for a long time as nodules or fragments in a high-energy environment capable of detaching series of flakes, whereas bones will not. The processes of weathering so weaken the bone material that it quickly falls apart under stresses that in a stronger material, such as flint, would produce a series of flake scars over a long period of time. It is therefore virtually impossible to imagine the accidental removal of a series of flakes from a bone fragment by forces such as wave or current action, which would almost certainly soon destroy the bone fragment itself. This is borne out by consideration of the distribution of vertebrate fossils along the Old Crow River: they occur in tens of thousands among the fine sediments above the "Canyon", where we have measured the river gradient as approximately 1:20 000; from below the canyon, where the gradient is much steeper and boulders abound, not a single Pleistocene fossil has been found to our knowledge. According to our interpretation of the sedimentary record, the dynamics of fluvial transportation and deposition in the Old Crow Basin did not vary significantly over the relevant time interval; that is, the "wear and tear" on bones in the modern river is probably comparable with what it was in late Illinoian and Sangamonian rivers.

It seems reasonable to infer that most flakes removed from the edges of the Old Crow River fossil bone fragments probably were not removed by river action. The brief period of high-energy river flow that occurs annually at breakup may seem to flaw the reasoning. However, all the flaking we have observed appears to have occurred at one time, before mineralization took place; using the same criterion, on most specimens there is nowhere any indication of other attrition by natural forces capable of causing curvilinear fracture, as opposed to splitting.

In the near absence of stones of cobble size or larger along those parts of the Old Crow River where vertebrate fossils and artefacts are most numerous, it is virtually impossible to imagine that gravitationally induced impacts (i.e., falling rocks) on bones caused series of flake removals. In fact, we are not aware of an example of flake removal from a fresh bone in which there is any indication that the event was caused by physical accidents such as moving stones or ice blocks. However, "non-accidental" modification can be caused by animals and by humans, and some way to distinguish between the two kinds of modification is needed.

Our (B.F.B. and W.N.I.) studies (in progress) of carnivore modification have focussed mainly on archaeological or palaeontological specimens. In general, they show a high incidence of gnawing marks in some Old Crow collections but not in others, and the co-occurrence of carnivore tooth marks and curvilinear fracture. At present there are no simple objective criteria that can be used to determine, in the absence of tooth marks, that a given specimen with curvilinear fracture was in fact modified by a carnivore. Neither can we specify single criteria that will alone identify all curvilinear fractures not caused by carnivores, or all such fractures caused by Man; at least two criteria are needed.

Although it is necessary to evaluate each specimen as unique, it is possible to describe some conclusions that make this task simpler. We already have stated our assumption that the largest Beringian carnivore, probably *Arctodus*, a cursorial bear, could not have broken large proboscidean bones when they were fresh. But it is also important to state that we know of no evidence that carnivores can simulate the secondary characteristics of percussion fracture: detachment of flakes from the surface of a marrow cavity incidental to heavy percussion, and detachment from an angular edge of flakes with a greater width than length or with length more than a few centimetres.

Perhaps of greatest significance in discriminating between man-induced fractures and all others is the question: can the specimen be interpreted as the result of a sequence of events in a system of fabrication, curation, or use, or one involving all three, and not as the result of any other possible sequence of events? If the answer is yes, and the observations are accurate, there should be no room for uncertainty about the diagnosis.

Artefacts from Unit 1b, OCR 12: Description

All of the long bones of large vertebrates excavated at OCR 12 in Unit 1b are fragmentary, and although the pieces vary considerably in size, their mean diameter and weight appear small by comparison with most other Old Crow River collections. These observations mean only that the specimens can be placed in class 2 as plausible components of a midden. No similar concentration of fragmented bone has been noted elsewhere at OCR 12, so we may be reasonably confident that we are dealing with a special occurrence rather than a random selection from the prehistoric landscape.

Twenty of the 223 excavated specimens show curvilinear fracture, which suggests modification by Man using percussion; in only one case is carnivore gnawing indicated. Three of these also show either use wear or deliberate modification by grinding, and a fourth specimen is modified only by grinding. Descriptions of these four follow.

Specimen OCR 12-78 A137 (Fig. 12) is from Layer B. It is a small, linear fragment approximately 5 mm thick, detached from the broken edge of a long bone of an animal the size of a caribou. This specimen, like the other three, has been examined under a binocular microscope at up to 80X power.

On the exterior surface of the bone fragment, numerous very fine sub-parallel striations occur (Fig. 12). They pass through some of the other marks on the surface, but have been obliterated near one edge (X) by light abrasion or polish, which is not evident in the same degree on other edges. None of the sub-parallel striations terminate at the edge opposite the polished one. Additional features on the exterior surface include three small pits at end A, one of which is adjacent to a small depression resembling a flake scar on the adjacent fracture surface. There is an indentation with crumbling in the surface near end B, which may have resulted from a sharp blow. It is accompanied by a shallow groove, which extends in the direction of a small notch in the polished edge, probably also produced by a blow. Almost at right angles to the striations is a straight, shallow groove made by a narrow, chisel-like, slightly irregular cutting edge. At end A, a minor fracture surface that adjoins edge X subtends three radiating incipient fractures, indicating a probable point of percussion.

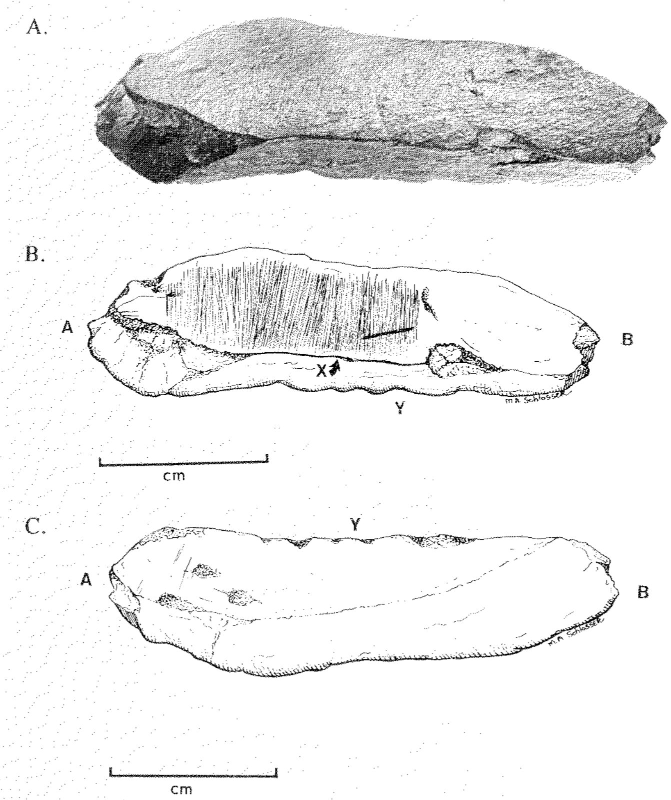


FIG. 12. A. Scraper edge rejuvenation flake. The two lower edges show damage due to use. Striations, also use-related, appear on the cortical surface. Length 32 mm. (OCR 12-78 A137, Layer B.) B. External surface. C. Internal surface.

On the interior, or marrow cavity, surface of the fragment, a few remarkably short straight scratches appear. Near end A, opposite the pits on the exterior surface, are three somewhat larger pits.

The edge formed by the interior surface and fractured surface, edge Y, is nicked in several places; no nicks occur on any other edges, which, in general, have undergone no change except for very slight rounding since they were formed. We think that the nicks in edge Y result from its use as a tool, but we do not suggest a specific function.

Such a large number of observations on so small a fragment will support more than one interpretation; we present those that seem most worthy of consideration.

The light striations on the exterior surface, because of their fairly consistent orientation and limited occurrence in relation to the most rounded edge, appear to result from human use of the original bone as a scraper. The nicks on edge Y, which is less rounded, also may indicate use as a tool. The large nick and the nearby indentation in the exterior surface both may have resulted from a blow or blows which detached the fragment from the parent bone. The minor fracture surface near end A, and the inferred point of percussion, may be associated with an earlier attempt to remove portions of the edge, possibly indicating a scraper edge rejuvenation flake. This interpretation may be complicated by the small pits opposed on the

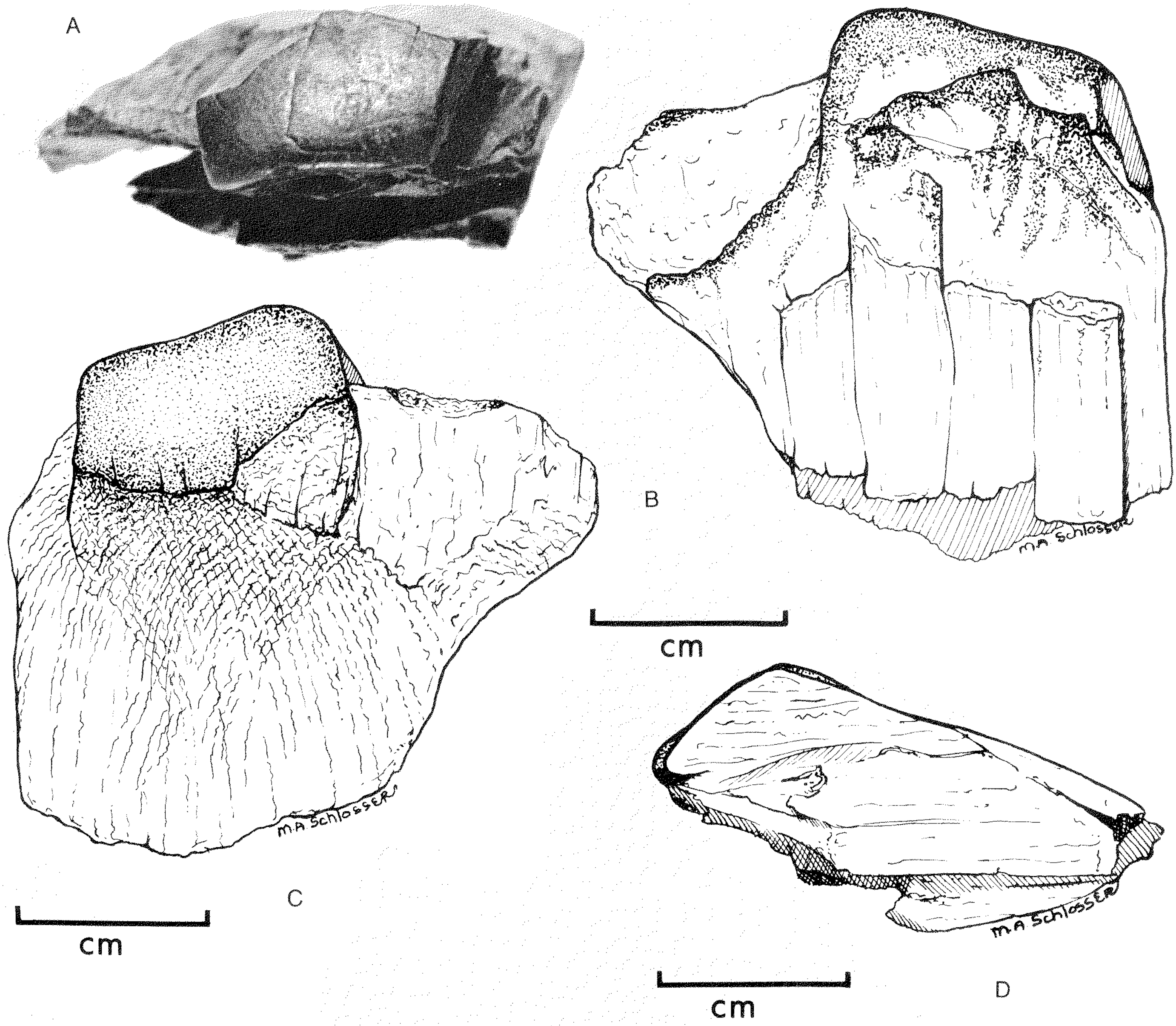


FIG. 13. A. Tusk fragment, showing one of two adjacent highly polished surfaces. Width 31 mm. (OCR 12-78 A310, Layer C.) B. Concave aspect. C. Convex aspect. D. Lateral aspect. Polished zones are stippled.

exterior and interior surfaces, one of which appears associated with the removal of a very small flake. This complex of features might have been caused by a medium-sized carnivore, leading to consideration of other possible effects of carnivore activity, including detachment of the fragment itself, which might be an alternative to the first interpretation. In either case the status of the fragment as an indicator of human activity is not compromised.

A small, battered fragment of proboscidean tusk from Layer C, OCR 12-78A 310 (Fig. 13) bears two highly polished facets which intersect to form a rounded edge with an angle of about 60°. Each of the facets cuts across the natural linear orientation of the tusk, and at least one must therefore have been *post mortem*; indeed, it appears certain that both were made after the death of the animal, because the polishing extends over the edges of the several percussion fracture surfaces and thus post-dates them. It would appear that the fragment was very nearly its present size and shape when polished. No known sedimentary process can have produced two such polished surfaces on a piece that everywhere else is angular. Therefore, only a human, with hands warm enough for careful, forceful manipulation, would seem to have been able to effect the highly localized pair of polished facets.

While we cannot suggest a use for this polished fragment, we have assigned it to the group of 50 or so fossil specimens in our collections from the Old Crow Basin which also exhibit polished facets. Some of this larger group may have been modified some time after the process of mineralization had begun (D. Brown, pers. comm., 1978), but this does not appear to be true of the specimen under discussion.

A fragment of a bird or small mammal long bone, with a flat ground or polished facet which truncates the shaft at an angle of about 60°, was found in Layer D (OCR 12-78 A244; Fig. 14). A glossy, polished area and a few light striations occur on the shaft adjacent to the facet. Only a portion of the original bone has been recovered; it is not clear whether the grinding was done before or after the bone was broken.

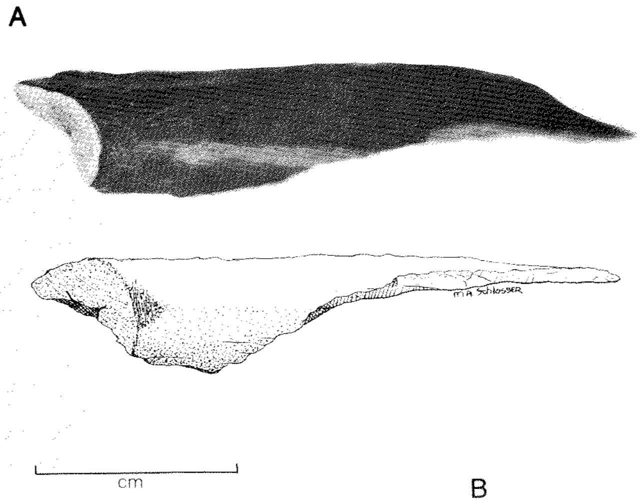


FIG. 14. A. Fragment of bird or small mammal bone, with flat polished facet diagonal to the shaft and faint striations on the adjacent cortical surface. Length 29 mm. (OCR 12-78 A244, Layer D.) B. Stippling indicates areas of polish or grinding.

(It appears unlikely that these two specimens were ground for what we would identify as a practical or useful purpose. Whether they resulted from ritual or from displacement activity can only be speculated upon.)

In the same layer, a large, flat fragment of proboscidean cortical bone (OCR 12-78 A140; Fig. 15) has three main curvilinear fracture surfaces which bear hacklemarks such as frequently occur on fractures caused by percussion. A possible fourth surface is virtually indistinguishable from an adjoining one. All the fracture surfaces and much of the cortical surface are covered by light root etching, except for portions near ends A and B which may have been removed by subsequent fracture; the cause(s) of the subsequent fractures have not been ascertained. The interior surface of the fragment of bone is the plane at which cortical and spongy bone meet; nearly all the spongy bone has been removed. The cortical bone is a nearly uniform 2.3 cm thick throughout its length and width.

Other modifications that have been noted are "polish" and a single cut by a very sharp implement; the sides of the cut are glossy, which suggests that it was made recently, probably by a trowel. The polish, detectable visually and by palpation, is localized along short portions of edge and adjacent fracture surfaces near ends A and B of the specimen. The edges of the rest of the specimen are only slightly rounded, in contrast with the pronounced rounding that resulted from the polishing. The removal of two

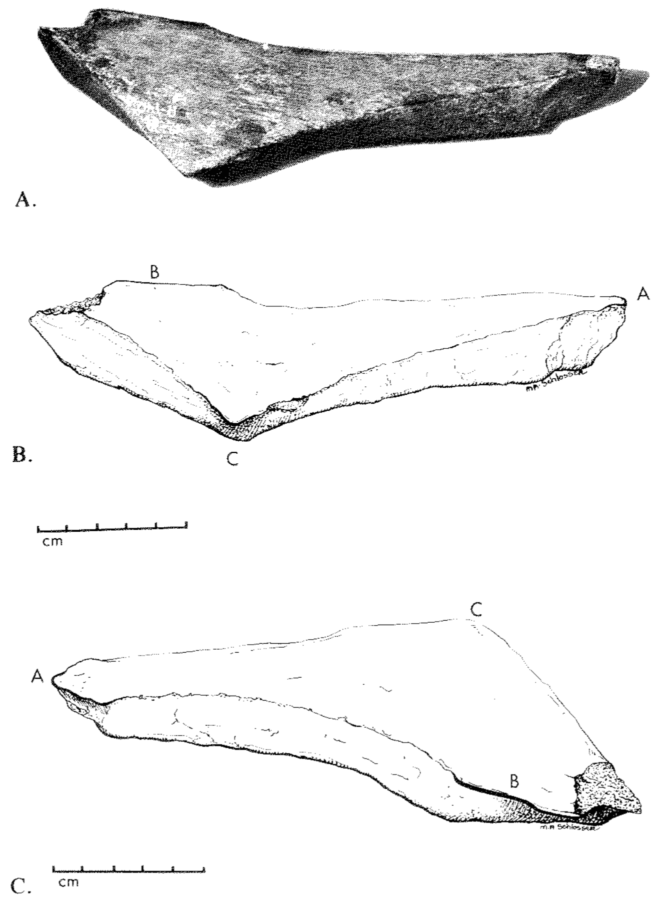


FIG. 15. A. Fragment of proboscidean bone showing curvilinear fractures and, at the left extremity, an impact mark, all due to percussion. At the right end, about 2 cm of the top edge and the edge formed by two fracture surfaces are rounded; the other edges are sharp. (OCR 12-78 A140, Layer D.) B. and C. Dark lines and hachures show use wear at A and B.

small flakes from end A and one from end B appears to have carried away portions of edge that had become rounded, but no later use wear has been detected so edge rejuvenation may not be indicated.

Our interpretation is that the (three or four) long curvilinear fractures were caused by several blows of a hammer. The spongy bone may have been removed deliberately or inadvertently. The acute angles at either end of the specimen were then employed, perhaps in butchering or skinning animals, but also possibly for scraping or gouging wood or bark. This resulted in the rounding of the utilized edges, and the light polish faintly visible on adjacent surfaces. The three small flakes or fragments "subsequently" removed may have been driven off by the imprudent application of force while the implement was being used; they do not appear to have been caused by attempts to sharpen the tool, but this possibility cannot be ruled out. The implement lay for some time in a root zone after it was discarded. It also was exposed to a mineralizing, unfrozen environment; the timing of these events has not been established. Probably after root etching and mineralization had been completed, the specimen was incorporated in a permafrost matrix.

All four of the specimens have been mineralized and are brown or dark purple-brown in colour. No laboratory examination of the chemical or physical properties introduced by mineralization has yet been made. It probably is significant, in the light of studies on other bone from Old Crow (e.g. Badone, 1980) that in terms of colour, texture, and "freshness" all are well within the range of variation of vertebrate fossils from the Old Crow Basin.

Our observations on these four objects lead us to the conclusion that they are artefacts and thus evidence for human (hominid) activity.

The four artefacts we have described, although each is unique, are not remarkable in the larger context of archaeological specimens recognized among the very large collections of vertebrate fossils from the Old Crow Basin. It is their generally small size which renders them unusual, and we suggest that this is due to their having been excavated from an anthropogenic soil rather than from alluvium or from an undifferentiated former ground surface. They demonstrate, without question in our minds, that humans were present and active in various ways at the time when Unit 1b was being deposited and reworked.

Also of interest is the occurrence of a small flake of proboscidean bone, OCR 12-78 A474, recovered from the bottom of Layer F, the channel fill (Fig. 11). This fragment resembles both those produced experimentally by Bonnichsen and a number of examples found at sites along the Old Crow River.

In addition to these specimens, fragments (± 1 cm in diameter) of wood charcoal found in Layer B may be tentatively attributed to human activity, although they do not constitute definitive proof.

Sixty-four vertebrate fossils, including seven in our class 2, were excavated at or near the contact between Unit 1b and Unit 2, near the bottom of the exposure at OCR 15 (Fig. 9). At OCR 300, 85 specimens of fossil bone were excavated from the upper layers of Unit 1b; of these, six are provisionally placed in class 2; there also is a split cobble with heavy wear along one edge from this level. We mention these specimens to show that the findings at OCR 12 can be extended to other sites in the area. Further examination may lead to the transfer of some specimens from class 2 to class 3.

Our study of artefacts among the fossils recovered from Unit 2 is still incomplete, but it allows us to say that bone implements and debitage occur in significant quantities in sedimentary deposits which we attribute to Sangamonian and early Wisconsinan time.

DISCUSSIONS AND CONCLUSIONS

We believe that the evidence indicates human presence in the Old Crow Basin before the beginning of the long sequence of alluviation represented by Unit 2. Faunal evidence suggests that the basal part of this unit was deposited no later than during Sangamonian time. We think that humans arrived there during the later stages of deposition of Unit 1b, a period locally represented by colluvium, fluvial deposits, or by a disconformity as at parts of OCR 12 and 15.

All the sedimentary and diagenetic information known to us is accommodated by some variant of a simple model in which Glacial Lake Old Crow was drained, the margins of the basin reworked, and the floor invaded and deformed by permafrost before a somewhat warmer interval which we interpret as the Sangamon. None of our observations indicates the rate at which these events occurred or the time intervals that they represent. Moreover, the palaeomagnetic observations mentioned earlier probably are subject to several different interpretations, at least one of which is consistent with the model we have given.

However, evidence not now apparent could require a revision of this simple model. For example, the sporadic occurrence along the modern Old Crow River of vertebrate fossils of early and middle Pleistocene age suggests that somewhere in the basin there are older Quaternary deposits which are still undiscovered. None of these older fossils shows evidence of human workmanship.

The chronometric age of Unit 1b is probably beyond the limit of the most advanced radiocarbon measuring apparatus now known (Pavlish and Banning, 1980); we must therefore rely for dating on the suggested correlation of Unit 1 with Ford's (1976) Clausen glaciation, i.e. with the Illinoian continental glaciation in North America. This is consistent with the vertebrate fauna contained in our Unit 1b.

While the full significance of these findings may not be immediately apparent, they provide a basis for discussion and conjecture. We offer a tentative reconstruction of the circumstances and events of human activity shown by excavation at OCR 12.

Shortly after the drainage of Glacial Lake Old Crow, the still marshy Old Crow Basin was colonized by tundra vegetation and subsequently invaded by a diverse fauna consisting of established northern species and new immigrants from Asia and southern North America. Permafrost began entering the previously unfrozen lake bed, resulting in characteristic deformation including pingo formation, the origin of which may have been related to artesian pressure in underlying aquifers. We infer that one pingo was located less than 100 m from the site of our archaeological excavations. We may wonder about biogenic as well as cryogenic deformation of the labile crust of the lake floor; in groups of five or ten, large mammoths may have been locally significant disturbers of soil and ground cover.

The new relief brought about by this deformation both accelerated the local development of drainage channels and brought about the removal of incipient soils by colluviation. Some of the vertebrate fossils and bone artefacts incorporated in the alluvial and colluvial deposits are inferred to have come from a human campsite, placed near a pingo for both the shelter and the commanding outlook it provided. We may conjecture that the campsite was on the side of the pingo for reasons of drainage, and that the colluviation occurred, at least in part, as a result of a thin vegetative cover having been worn away by foot traffic. The recurrence of bone artefacts and small fragments of bone in Layers A-D suggests, but does not prove, that the pingo campsite was used several times. At some uncertain time weathering processes, especially oxidation, locally modified the clays of Glacial Lake Old Crow to depths of a few metres; this was followed by the deposition of Unit 2, the sediments of which commonly appear to display a gradational contact with Unit 1b.

It is evident from other research within the study area that humans were present intermittently or continuously through much of the period represented by Unit 2 (Sangamon to mid-Wisconsin). Thousands of bones modified by humans during these periods have been found, from which we conclude that our excavated artefacts are not the result of unique or trivial occurrences.

The apparent scarcity of stone implements in Old Crow River deposits, and their complete absence from collections that we report on here, deserve comment. The ratio of stone to bone in Old Crow collections, although significant, may not be significantly different from the incidence of stone implements (excluding projectile points) in "buffalo jumps" that have been excavated with care (e.g. Forbis, 1962; Keyhoe, 1967; Frison, 1974). If most of our collections are ultimately derived from kill sites — and there seems to be no simple alternative to this assumption — then the low incidence of stone implements, although noteworthy, needs no special local or regional explanation.

But the collection excavated at OCR 12 does not fit the known pattern of artefacts and bones recovered from kill sites: the bone fragments are small, and two of the four artefacts discussed here probably are non-utilitarian. We conclude that the collection from OCR 12 must therefore be compared with collections from look-out and camp sites. Unfortunately, in most of the Boreal Forest and Subarctic bone preservation at excavated and surface sites is extremely poor. However, it appears that the incidence of stone tools is often low in relation to tools of organic materials, where the latter are preserved in late prehistoric Eskimo and Indian archaeological sites (e.g. Morlan, 1973; Mathiassen, 1927). It is not possible to calculate ratios from the data available; however, experience suggests that the proportion of stone to bone is likely to range from 1:100 to 1:10 000 in late prehistoric sites with good organic preservation. If this is even approximately true, it is reasonable to hypothesize a Pleistocene campsite at OCR 12, where the ratio of stone to bone is somewhat less than 1:400.

This is not to say that the scarcity of stone debitage and implements, and indeed of implements made of any material, is insignificant. This scarcity of hardware has in the past drawn archaeological attention to the difficulty of basing culture-historical or processual studies of late prehistoric cultures on objects in large parts of the Boreal Forest, because stones were little used and other materials are not preserved. In our present case, we think that having found these materials in the northernmost Subarctic, dating from a very ancient time, is highly significant in terms of the development, or evolution, of Man's ability to cope with low temperatures and other characteristics of high latitudes. It underscores the fact that we cannot assume a simple relationship between the complexity of preserved material culture and the capability of ancient human life support systems to cope with challenging environments. This may become of interest to evolutionary theorists, some of whom think of the stone-rich Upper Palaeolithic of Europe as the best — if not the first — adapted subarctic culture stage in the world. It now appears demonstrable that the early (perhaps the first) men in the north carried with them a minimal amount of durable impedimenta.

It is interesting that these early human inhabitants predate the extinction in Europe and western Asia of most or all populations of *Homo sapiens neandertalensis*. Indeed, if Unit 1 is of Illinoian ≡ Riss age, these artefacts probably are older than Mousterian cultures and Neandertal Man. Elsewhere, Irving (1978a, b) has commented on a plausible relationship of these early cultures to the Early Palaeolithic of the Far East, a relationship anticipated by Chard (e.g. 1963) and more recently by Rouse (1980), although terminologies differ. Bryan (1978) has published an unusual human calotte from Brazil which beckons renewed attention in this connection.

In a recent announcement Chia *et al.* (1979) describe a large collection of vertebrate fossils and stone artefacts found near Hsuchiayao in Yangkao County, Shansi, China. They attribute the entire collection to an age comparable with that of the Riss (Illinoian) glaciation. The associated human skeletal remains are said to be intermediate between *Homo erectus* and *Homo neandertalensis (sic)*. Elsewhere Medvedev (1979) appears to have documented the northward progress of *Homo* sp. as far as the Aldan Plateau in Siberia, 200 000 or more years ago. We must now, therefore, entertain seriously the possibility that a variant of *Homo erectus* reached the Western Hemisphere, as recently suggested by Yoshizaki (pers. comm., 1981). If true, this must profoundly affect both studies of the origin of *Homo sapiens* and studies of New World populations.

One conclusion emerges clearly from research in the Old Crow Basin, and this may be the most important one. The bearers of this seemingly nondescript and certainly generalized, or primitive, material culture had potent technical and organizational capabilities at a very early time; the compelling evidence is that without these capabilities human societies cannot survive in high latitudes. By resorting to a mode of deduction that includes judicious use of "impossibilism" as a legitimate and cogent principle, we are led to contemplate the importance of "software" in the history of mankind's relationship with the natural environment. Inductive study of the "hardware" cannot, by itself, tell us much about this at present. In another view of the same phenomenon, our finds suggest that the task of pre-Clovis prehistorians in the Western Hemisphere should be more like the study of adaptation in the sense of Bennett (1976), than like the study of culture in the sense(s) of Kroeber and Kluckhohn (1952). With much more evidence and study we surely will be able to characterize the cultures of these very early times in interesting and useful ways. For now, perhaps it is enough to realize that they once existed here.

We suggest that our evidence requires a new, careful and thorough approach to the problem of when humans first effectively occupied the Western Hemisphere, and who they were in terms of cultural, evolutionary (or adaptive) and biological status. The new approach must be based on the recognition of clues that prove human existence, rather than exclusively on evidence of artefacts that can be classified in the categories to which we are accustomed, for our findings show that such artefacts may be extremely rare and also perishable in non-permafrost regions. The rigid definitions of "culture" and the habits of analysis and thought that have served archaeologists reasonably well in the study of Clovis and later cultures will continue to be useful as we turn up more "implements" of early Wisconsinan and older age. But a total reliance on these modes of study no longer can be justified.

Our present findings, although startling, are based on conventional research methods. Others (e.g. Breuil, 1939; Armenta Camacho, 1978; Frison, 1974; Keyhoe, 1967) have recognized percussion-worked bones as human artefacts. The four excavated specimens in our class 4, three of which have been modified by percussion, also exhibit various kinds of polish and abrasion which can be attributed only to Man. Their occurence with plausible midden debris broadens the base for their interpretation. The beds from which they come were laid down before the Sangamonian interglacial; all the evidence of which we are aware is consistent on this point.

The ascripton of evidence for humans in North America to periods before the Wisconsinan glaciation has been attempted before, but for a variety of reasons it has not succeeded in gaining acquiescence from a significant number of prehistorians. We think that our evidence for Man in Beringia in Illinoian time is compelling because we are unable to interpret it to reach any other conclusion, however tentative. It remains to be seen, of course, whether our observations and the conclusions we draw from them can be repeated by others. We predict that they can.

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