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LATE WISCONSINAN LAURENTIDE GLACIAL LIMITS OF NORTHWESTERN CANADA: THE TUTSIETA LAKE AND KELLY LAKE PHASES

O.L. Hughes

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Critical Reader

J-S. Vincent

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LATE WISCONSINAN LAURENTIDE GLACIAL LIMITS OF NORTHWESTERN CANADA: THE TUTSIETA LAKE AND KELLY LAKE PHASES

Abstract

Extensive segments of well preserved moraine and other ice-marginal features have been recognized within the all-time limit of the northwestern part of the Laurentide ice sheet. Many of the segments can be linked to define the margin of the ice sheet at the culmination of a Late Wisconsinan advance, here called the Tutsieta Lake Phase. Others can be linked to define the limit of a later advance, here called the Kelly Lake Phase. Still other moraine segments cannot be referred readily to either phase.

Radiocarbon dating indicates that the advance of the Laurentide ice sheet to its all-time limit during Hungry Creek Glaciation culminated about 30 000 years ago, and dates for causally related inundation of Old Crow and Bluefish basins support that timing. Interpretations placed on "old" dates on marine shells from the Mackenzie Delta area, however, are incompatible with a Late Wisconsinan age for the maximum Laurentide advance, posing a major chronological problem.

Radiocarbon dates indicate an age of about 13 000 years or somewhat older for culmination of the Tutsieta Lake Phase, and some time before 10 600 years ago for the Kelly Lake Phase.

The correlation suggested here implies that during the Late Wisconsinan Tutsieta Lake Phase, westerly moving ice in Amundsen Gulf impinged against the northwest flank of Brock Upland to a level of 455 m and extended westward beyond Parry Peninsula. In contrast, other workers have suggested that during the Late Wisconsinan, an ice lobe in Amundsen Gulf barely reached the eastern margin of the study area. This difference in interpretation indicates a need for field checking of the photo-interpretive correlations offered herein.

Résumé

De vastes segments bien conservés de moraine et d'autres éléments proglaciaires ont été identifiés à l'intérieur de la limite absolue de la partie nord-ouest de l'inlandsis des Laurentides. Un grand nombre de ces segments peuvent être rattachés les uns aux autres de façon à définir la marge de l'inlandsis à l'apogée d'une avancée de la fin du Wisconsinien, ici appelée phase de Tutsieta Lake. D'autres segments peuvent être rattachés de sorte à définir la limite d'une avancée plus récente, soit la phase de Kelly Lake. D'autres segments encore ne peuvent pas être rattachés à l'une ou l'autre de ces phases.

La datation au carbone radioactif indique que l'avancée de l'inlandsis des Laurentides jusqu'à sa limite absolue au cours de la glaciation de Hungry Creek a atteint son apogée il y a environ 30 000 ans; les dates établies pour l'inondation connexe des bassins de Old Crow et de Bluefish confirment cette chronologie. Cependant, l'interprétation des âges «anciens» obtenus par datation des coquillages marins provenant de la région du delta du Mackenzie est incompatible avec l'âge donné pour l'avancée maximale de l'inlandsis des Laurentides, soit le Wisconsinien supérieur, phénomène qui présente donc un important problème de chronologie.

La datation au carbone radioactif indique que l'apogée de la phase de Tutsieta Lake a eu lieu il y a au moins 13 000 ans et que celui de la phase de Kelly Lake a eu lieu il y a moins de 10 600 ans.

La corrélation proposée dans la présente étude semble indiquer qu'au cours de la phase de Tutsieta Lake du Wisconsinien supérieur, la glace qui se déplaçait vers l'ouest dans le golfe Amundsen a remonté le flanc nord-ouest de la haute-terre de Brock jusqu'à une élévation de 455 m et s'est étendue vers l'ouest au delà de la péninsule de Parry. Par opposition, certains chercheurs ont suggéré qu'au cours du Wisconsinien supérieur, un lobe glaciaire dans le golfe Amundsen aurait à peine atteint la marge est de la région étudiée. Cette différence d'interprétation indique qu'il faut vérifier sur le terrain les corrélations établies par photo interprétation proposées dans cette étude.

INTRODUCTION

The recognition and delineation of the westward and northwestward limits of successive advances of ice sheets from the Canadian Shield (hereafter called Laurentide ice sheet[1] without implication as to age) was begun by Bostock (1948). On the basis of interpretation of trimetrogon airphotos, Bostock delineated the "western limit of last glaciation" along the east flank of Richardson Mountains and northwestward to near Herschel Island. The limit was shown extending westward across and beyond Bonnet Plume Basin, with a narrow tongue projecting westward through McDougall Pass (Fig. 1). The limit has been refined but not greatly changed by subsequent reconnaissance studies (Hughes, 1972; Rampton, 1982) and extended eastward and southeastward around the arc of Mackenzie Mountains to Keele River, where an ice tongue projected westward up the valley (Fig. 1, maximum all-time extent of Laurentide ice sheet).

Bostock referred to the glacial limit as that of the "last Laurentide glaciation" but offered no opinion as to its age. Subsequent mapping showed that the limit marks the all-time

[1] Banks and Victoria islands lie within the northwestern sector of the Laurentide ice sheet, but beyond the scope of this paper.

maximum extent of the Laurentide ice sheet[1]. The associated glaciation was named the Hungry Creek Glaciation in Bonnet Plume Basin and adjacent areas (Hughes et al., 1981, p. 341) and Buckland Glaciation in northern Yukon (Rampton, 1982, p. 19).

A radiocarbon date on wood from beneath Hungry Creek Till in Bonnet Plume Basin indicates that Hungry Creek Glaciation culminated after 36 900 ± 300 BP (GSC-2422, Fig. 1); limiting dates for inundation of Old Crow and Bluefish basins due to drainage diversion and reversal associated with the glaciation suggest culmination as recently as 30 000 years ago (Hughes et al., 1981, p. 359). On the other hand, Rampton (1982) considered Buckland Glaciation to be of Early Wisconsinan age. An ice sheet situated at the Buckland limit must have covered the entire Mackenzie Delta region, yet marine shells from Garry Island and near Kendall Island, both on the periphery of Mackenzie Delta, have yielded "infinite" radiocarbon dates (>35 000 BP, GSC-562; >35 000 BP, GSC-690; Hughes et al., 1981; Fig. 1). The dates seem to preclude expansion of Laurentide ice to the Buckland limit in Late Wisconsinan time as suggested by correlation with Hungry Creek Glaciation. Although the limit of Hungry Creek Glaciation appears to be traceable into the limit of Buckland Glaciation, two separate glacial events may be involved. Alternatively, the date from beneath Hungry Creek Till may be in error, or the marine shells from the periphery of Mackenzie Delta may be redeposited from older marine sediments.

Rampton has indicated a tentative "Early Wisconsin (?)" glacial limit on Tuktoyaktuk Peninsula and to the east of Mason River (1981b, c; A of Fig. 1) and along the west side of Franklin Bay (1981a; B of Fig. 1). An "approximate limit of Late Wisconsin glaciation" shown by Klassen (1971; C of Fig. 1) around the upland between Liverpool Bay and Franklin Bay is essentially a continuation of the limit shown by Rampton.

Whereas the limits of Hungry Creek and Buckland glaciations as mapped define all-time limits of Laurentide glaciation in their respective regions, glacial deposits are found outside the limits depicted by Rampton and Klassen. Along a creek tributary to Horton River, peat dated at >41 000 BP (GSC-1100, Lowdon et al., 1971, p. 306; Fig. 1) is overlain by one till and underlain by two others (Klassen and Yorath, 1975, p. 1). Peat from a similar section nearby yielded a date of >38 100 BP (GSC-576, Lowdon et al., 1971, p. 307; Fig. 1). Thus the limits shown by Rampton and Klassen do not mark the all-time limit of Laurentide glaciation, but rather the limits of a restricted glaciation following earlier more extensive ones. This relationship suggests that the limits are those of a glaciation younger than Hungry Creek and Buckland glaciations, but further data are needed before an age assignment is possible.

Acknowledgments

Among numerous colleagues who collaborated with the author in mapping and stratigraphic studies that formed the original basis for this report, V.N. Rampton, D.A. Hodgson, J.J. Veillette, J. Pilon, S.C. Zoltai, W.W. Pettapiece, P. Hanley, S.C. Chatwin, K.W. Savigny, J.V. Matthews, Jr., R.E. Morlan, N.W. Rutter, and S.C. Schweger deserve special mention.

A workshop on Quaternary Geology of the Beaufort Sea Coastal Area, held in Calgary in April 1984, provided opportunity for a brief presentation of the main elements of the report, and this version has benefited from discussion of regional chronological problems at that workshop.

LEGEND

(This legend is common to figures 2 to 14)

Glaciofluvial fan; mainly sand and gravel .... Gf
Glaciofluvial plain; mainly sand and gravel .... Gp
Glaciofluvial plain with thermokarst ponds and depressions; sand and gravel overlie silt and clay .... Gpk
Generalized direction of ice movement ....
Drumlin or glacial fluting ....
Ice margin; spur on ice side ....
Meltwater channel ....

Figure 2

Tutsieta Lake Moraine, north of Tutsieta Lake (106 O). Moraine segment shown is designated as the type locality for the Tutsieta Lake Phase. Glacial meltwater discharged to Iroquois River and thence via Carnwath and Anderson rivers to Liverpool Bay. Ice-marginal features that delimit a former ice tongue in the deeply entrenched channel are inset on the channel walls, indicating that the channel was incised prior to the Tutsieta Lake Phase. NAPL A21585 190-192.

[1] The "all-time maximum extent" or "all-time limit" of the Laurentide ice sheet is used herein without implication as to age; conflicting evidence as to the age of various parts of the all-time limit is discussed later.

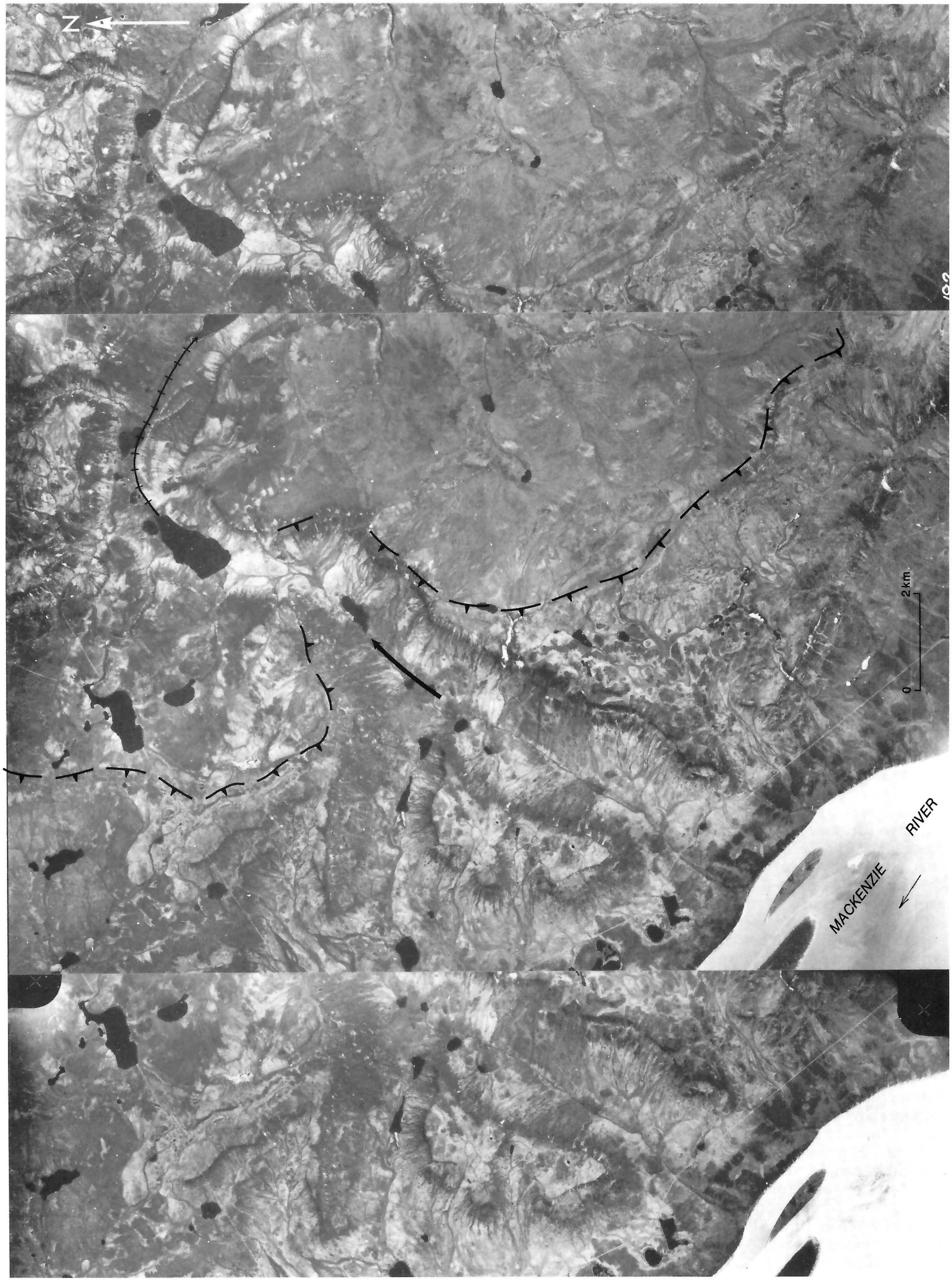

Figure 2

E.A. Fuller and A.L. Holland assisted in the preparation of figures.

I am indebted to J-S. Vincent for careful and thoughtful criticism of an early version of this report. The present version embodies several of his suggestions.

LATE WISCONSINAN ICE-MARGINAL FEATURES

Within the "older" limits of glaciation discussed above, there are numerous and in some cases extensive segments of well preserved moraines and associated ice-marginal features that mark the limits of significant later advances or stillstands. These ice-marginal features have been recognized and delineated over a period of nearly three decades, beginning with a reconnaissance terrain study by Mackay (1958) and continuing with reconnaissance mapping by Klassen (1969), Fulton (1970), Fulton and Klassen (1970), Rampton (1970, 1972a, b, 1980, 1982), Hughes (1972), Hughes et al. (1972), Pilon (1974), and Hanley et al. (1975). No attempt has been made until now, however, to correlate the ice-marginal segments regionally (a summary description of the physiography and geology of northern Yukon Territory and Mackenzie Delta by Hughes et al. (1983), drew freely on this report, which was then in preparation). For areas not yet mapped (NTS 96N, O; 97A, B; 107A) and locally in the previously mapped areas, available data have been supplemented by airphoto interpretation by the author.

In the interpretation presented here, many of the segments of moraine and other ice-marginal features are linked into two systems that are thought to mark the limits of two Late Wisconsinan readvances of the Laurentide ice sheet, here named the Tutsieta Lake Phase and Kelly Lake Phase (Fig. 1). Other segments of moraine are shown as "uncorrelated" either because they are clearly not associated with either of the named phases or because evidence for assigning them to one or the other of the named phases is equivocal.

TUTSIETA LAKE MORAINE AND CORRELATIVE ICE-MARGINAL FEATURES

Tutsieta Lake Moraine is a strikingly sharp, single or multiple moraine ridge, or locally the sharp outer limit of a belt of hummocky moraine, that is continuously traceable from the south end of Tutsieta Lake northward for more than 50 km (Fig. 1, 2)[1]. The moraine defines part of the eastern margin of the lobe of the Laurentide ice sheet in Mackenzie valley at the culmination of the Tutsieta Lake Phase. Tutsieta Lake Moraine is selected as the type locality for the Tutsieta Lake Phase because of the remarkable clarity and continuity of the moraine as seen on airphotos and the relatively easy accessibility, either on foot from Mackenzie River or from nearby lakes using float plane.

From Tutsieta Lake, a broad belt of hummocky moraine can be traced across Canot Lake map area (106 P). The distinct outer margin of the belt, locally defined by a sharp narrow ridge (push moraine?), passes north of Yeltea, Manuel, and Canot lakes and an unnamed lake east of Canot Lake (Pilon, 1974; Fig. 3). The hummocky moraine contrasts markedly with terrain to the north, much of which consists of drumlinoid topography developed on shale and sandstone of Devonian and Cretaceous age (Cook and Aitken, 1975) with a thin veneer of till. From the eastern margin of Canot Lake map area, the limit can be traced, with some discontinuity, to the southeast corner of Crossley Lake map area (107 A). From there, it can be traced continuously in an arc passing northeast of Andrew River (Fig. 4) to near the confluence of Carnwath and Anderson rivers, and thence northeasterly some 180 km, passing south of Sadene and Bekere lakes (Fig. 5) to a point north of the west end of Binamé Lake (Fig. 6, 7).

Beginning about 12 km southwest of where the limit crosses Horton River, and continuing east to an unnamed large lake northwest of Binamé Lake, the limit is bordered to the north by a large outwash complex. The outwash complex occupies a reentrant between the glacial limit just described, and the sharp southern limit of hummocky moraine that bounds the outwash to the north. On the south side of the reentrant, outwash fans are directed northward into the outwash complex (Fig. 6, 7), whereas on the north side, outwash fans are directed southward into the outwash complex (Fig. 7). Glacier ice that bounded the south side of the reentrant flowed into the area by way of the headwaters region of Anderson River to the southwest. The ice that bounded the north side of the reentrant must have formed the south margin of an ice lobe lying in Amundsen Gulf. The manner in which glaciofluvial fans are directed into the outwash complex from opposing ice fronts provides evidence that is critical to the correlation of former limits of a lobe lying in Amundsen Gulf with limits of ice that flowed from the south and southeast.

Meltwater that deposited the outwash complex described above drained westward via the present lower reaches of Horton River. The course of lower Horton River is remarkable in that it occupies a rather narrow valley that is deeply incised into the broad crest of a northward trending upland. It seems likely that the valley was incised during an earlier, more extensive glaciation by meltwater that was confined between a lobe of ice in Amundsen Gulf and a lobe that lay against the west flank of the upland.

Klassen (1969, p. 4) concluded from a widespread mantle of bedrock debris and paucity of erratics that tablelands of Brock Upland, the highest part of Horton Plain (Bostock, 1969), were largely ice free during the last (Late Wisconsinan) glaciation in the northern part of the upland. Klassen (1971) also mapped a prominent moraine at lower elevation on the northwest flank of the upland, northwest of Brock River. That moraine, and a glacial limit traceable for 85 km on the west side of the upland (Fig. 8) are assigned to the Tutsieta Lake Phase. The former marks the southern margin of ice that occupied Amundsen Gulf during the Tutsieta Lake Phase and the latter marks the northeastern margin of ice that moved northwesterly along Hornaday River. That ice merged with ice in Amundsen Gulf, but the position where ice from the respective sources merged is not clear. A distinct glacial limit between Hornaday and Horton rivers (Fig. 9) marks the western limit of the ice stream in Hornaday valley. To the west of Horton River, several distinct moraine segments, when joined together, appear to mark the eastern margin of ice that moved northerly in the broad area now drained by upper Anderson River (Fig. 10).

Moraines and ice-marginal features that mark the southwestern margin of ice that moved along Hornaday River valley become less and less distinct as the former margin is traced southward towards Horton Lake. Consideration of surface elevations suggests that the ice margin should have swung southwestward somewhere north of Horton Lake to join the eastern margin of the ice that moved northwesterly in the headwaters of Anderson River.

From the northern end of Tutsieta Lake Moraine as initially defined, moraine segments and other ice-marginal features can be traced northward then westward, with some interruptions, to the east side of Travaillant Lake (Fig. 11). To the north and west of Travaillant Lake, discontinuous ice-marginal features suggest that the limit of the Tutsieta Lake Phase is the same limit as one mapped by Rampton (1980) that includes a prominent moraine on the east and north sides of Sitidgi Lake, here referred to as Sitidgi Lake Moraine. Sitidgi Lake Moraine delimits in part a sublobe of an ice lobe in Mackenzie Valley; the latter extended to or beyond the outer margin of the present day Mackenzie Delta.

[1] See p. 8-19 for Figs. 3-14.

In the vicinity of Tutsieta Lake, the crest of Tutsieta Lake Moraine attains elevations between 380 and 395 m (determined from topographic maps with 50 ft contour interval). Prominent moraines and other ice-marginal features that occur at elevations up to 400 m around the southern periphery of Grandview Hills (Fig. 12) are judged to be correlative with the Tutsieta Lake Moraine.

The position of the western margin of an ice lobe in Mackenzie Valley during the Tutsieta Lake Phase is uncertain except along the western margin of Mackenzie Delta north of 68°N, where a limit mapped by Rampton (1982, Fig. 18) as the "limit of Late Wisconsin glaciation" is a probable correlative. The "limit of Wisconsinan Laurentide ice" as mapped by Hughes (1972) to the east of the confluence of Peel and Snake rivers (D of Fig. 1) is also a possible correlative of the Tutsieta Lake Phase. However, most of the moraine segments and other ice-marginal features that extend northward along the Peel Plateau to about 68°N (E of Fig. 1), which were also mapped as "limit of Wisconsinan Laurentide ice", appear to be too high to mark ice-marginal positions correlative with the Tutsieta Lake Phase. Consideration of elevations along the eastern margin of the lobe suggests that the western margin may have been adjacent to the high scarp that lies immediately west of Peel River, although no convincing ice-marginal features occur on the steep gullied face of the scarp.

Although the region is one of generally low relief, ice movement patterns during Tutsieta Lake Phase, as defined by moraines, drumlinoid features, and glacial meltwater channels, were complex. A major ice flow moved northwesterly and northerly, forming a major lobe in Mackenzie River valley. Northwesterly moving ice formed a lobe in the headwaters area of Anderson River and extended a sublobe northeastward towards Darnley Bay. Ice of a major lobe in Amundsen Gulf moved southwesterly along the northwestern margin of Brock Upland, westerly across Parry Peninsula, and impinged against the scarp that forms the southwestern margin of Franklin Bay. The manner in which glaciofluvial fans are directed from both north and south into an outwash complex in a reentrant west of Binamé Lake (described previously) constitutes the principal evidence that ice of the Anderson River, Hornaday River, and Amundsen Gulf lobes occupied the area south of Darnley Bay simultaneously, and that the lobes merged at the maximum of the Tutsieta Lake Phase. A complex array of morainic and glaciofluvial deposits south of Darnley Bay suggests that there may have been considerable shifting of the zone where ice of the respective lobes merged.

The glacial limits east and west of upper Horton River indicate that during the Tutsieta Lake Phase an extensive area, essentially the drainage basin of upper Horton River, remained ice free. Although the ice-free area was clearly glaciated, glacial features within the area appear subdued compared with those of the Tutsieta Lake Phase.

If moraines around the ice-free area were indeed truly contemporaneous, then meltwater that discharged from the surrounding ice margins into Horton River must, of necessity, have escaped across ice lying northwest of the ice-free area. A possible course begins at a sharp bend of Horton River south of Fallaize Lake, and extends northwards to Fallaize Lake along a sinuous channel (now occupied by the underfit Whalemen River), thence via Binamé Lake to the reentrant, described above, that leads westward to lower Horton River.

The extent of retreat of the Laurentide ice sheet prior to the Tutsieta Lake Phase has not been determined. It is reasonable to assume that if the moraines and ice-marginal features that mark the limit of the phase were introduced by a stillstand of the ice front or a minor readvance of a few kilometres, there should be little or no discordance of the ice flow patterns within the Tutsieta Lake limit and those beyond the limit. In some areas, however, there is marked discordance between the respective flow patterns, implying a major readvance to the limit of the Tutsieta Lake Phase.

Marked discordance in ice flow patterns is evident around the ice-free area of upper Horton River (Fig. 1). Whereas ice had earlier moved northwesterly across the area, during the Tutsieta Lake Phase the ice divided around the ice-free area and locally along the west side of that area ice flowed northeasterly to form minor sublobes. Discordance of flow patterns on a comparable scale is evident in the headwaters area of Iroquois, Carnwath, and Andrew rivers. Earlier ice flow, as defined by drumlinoid patterns, had swept northward across a regional divide (Fig. 1). During the Tutsieta Lake Phase, ice was confined to the south side of the regional divide, except that on the north side of the divide a sublobe of ice extended west-southwest towards Andrew River. West-southwesterly flow of ice in the sublobe is inferred from the shape of the sublobe, from the slope of bounding moraines, and from the gradient of an outwash plain bordering the southwest margin of the sublobe.

The degree of difference between the respective ice flow patterns suggests that the Laurentide ice sheet may have retreated in the order of 100 km or more within the limit of the Tutsieta Lake Phase before readvancing to that limit.

KELLY LAKE PHASE

The moraine that lies along the eastern margin of an upland east of Kelly Lake (Fig. 1, 13) is here called Kelly Lake Moraine, and the glacial advance during which it and correlative moraines were formed is called the Kelly Lake Phase.

From Kelly Lake, a system of moraines and other ice-marginal features is traceable northward across Hare Indian River, then northeastward where it passes around the east side of an upland between Lac des Bois and Lac Belot, around the north end of that upland, and thence around the periphery of the Lac Belot depression, where it outlines a sublobe of ice that pressed southward into the depression. Several moraine segments and other ice-marginal features occur to the west and north of Colville Lake (F of Fig. 1) but the relationship of these to the Kelly Lake Phase is uncertain.

Kelly Lake Moraine is a single, sharp ridge (Fig. 13), as are some other segments of the moraine system. Locally, as in the south end of the Lac Belot depression, the moraines are massive. Some segments of the moraine system as mapped are actually the sharp outer margin of a broad belt of hummocky moraine, with or without a distinct moraine ridge at that margin (Fig. 14). The crest of Kelly Lake moraine attains elevations of 490 m, and the elevation of the moraine system declines northward to about 210 m near Hare Indian River, rising above 400 m against the upland beween Lac Belot and Lac des Bois, and declining again to below 300 m at the south end of Lac Belot.

As in the case of Tutsieta Lake Phase, the magnitude of glacial advance in the Kelly Lake Phase has not been determined. The pattern of ice flow during Kelly Lake Phase is locally discordant with an earlier pattern recorded by drumlins in areas outside the limit of that phase. The discordance is most marked along the east side of Lac Belot where moraines constructed by southward moving ice truncate a drumlinoid pattern produced by an earlier northwesterly ice movement.

UNCORRELATED ICE-MARGINAL FEATURES

There are numerous segments of moraine and other ice-marginal features within the all-time limit of Laurentide glaciation that cannot readily be related to either the

Tutsieta Lake Phase or the Kelly Lake Phase. As noted previously, moraines and other ice-marginal features that extend northward along Peel Plateau west of Peel River to about 68°N appear to be too high to be related to the Tutsieta Lake Phase. These features are possible correlatives of an earlier more extensive Sabine Phase (Rampton, 1982, Fig. 18, p. 21; G of Fig. 1) of the Buckland Glaciation.

A belt of hummocky moraine with a sharp northern limit lies immediately south of Rengleng River in Arctic Red River map area (106N) and extends westward to Peel River north of Fort McPherson (H of Fig. 1). The moraine marks a readvance or at least a significant stillstand of the margin of an ice lobe in Mackenzie Valley after culmination of the Tutsieta Lake Phase and prior to the Kelly Lake Phase.

A prominent moraine system can be traced southward for 70 km beginning west of Horton Lake (I of Fig. 1). From its topographic position, the moraine is younger than the Tutsieta Lake Phase and is possibly but not demonstrably correlative with the Kelly Lake Phase. An ice-marginal position marked by moraines and ice-marginal channels on the north side of Smith Arm, Great Bear Lake (J of Fig. 1), is also possibly correlative with the Kelly Lake Phase.

Another moraine system on Parry Peninsula, first mapped by Mackay (1958, Fig. 8) and called Parry Peninsula Moraine by Klassen (1975, Fig. 2, 4, p. 3) marks a readvance or stillstand of an ice lobe in Amundsen Gulf subsequent to culmination of the Tutsieta Lake Phase. It too is a possible correlative of the Kelly Lake Phase.

CHRONOLOGY

As discussed previously, evidence from Bonnet Plume Basin indicates that the advance of the Laurentide ice sheet to its all-time limit during Hungry Creek Glaciation culminated sometime after 36 900 BP. Radiocarbon dating of the correlative inundation of Old Crow and Bluefish basins to the west of Richardson Mountains indicates that the glaciation culminated as late as 30 000 years ago (Hughes et al., 1981, p. 359). The limit of the Tutsieta Lake Phase lies considerably within the all-time limit, so that when allowance is made for retreat from the all-time limit, and subsequent readvance to the limit of the Tutsieta Lake Phase, an age considerably less than 30 000 BP is to be expected for culmination of the latter event. This assumption, however, is placed in question by radiocarbon dates on marine shells (discussed previously), which would place the advance to the all-time limit in Early Wisconsinan time.

Pieces of waterworn wood from gravel of an outwash train that originates at Tutsieta Lake Moraine have been radiocarbon dated at >42 000 BP (GSC-2765; Fig. 1). If an age of about 30 000 years is accepted for culmination of Hungry Creek Glaciation, with the ice margin at the all-time glacial limit, then the date is clearly too old, in which case the wood is probably reworked from widespread subtill organic beds of the area that have yielded "greater-than" dates.

Organic deposits collected by V.N. Rampton from outwash associated with Sitidgi Lake Moraine, considered here to be correlative with the Tutsieta Lake Moraine, have yielded radiocarbon dates (Fig. 1) of 34 500 ± 690 BP (GSC-1682), 14 100 ± 170 BP (GSC-1784), 12 900 ± 150 BP (GSC-1784-2) and 13 000 ± 130 BP (GSC-1995; all in Blake, 1984). GSC-1682 contained 95% wood fragments, mostly rounded, that were judged to be reworked hence the sample does not date the containing sediments (unpublished GSC Bryological Report No. 151 by M. Kuc). The remaining samples consisted of grasses (unpublished GSC Bryological Report No. 202, 202 Supplement, and 264 by M. Kuc). Of these, GSC-1784-2 and -1995 received the most careful treatment to avoid possible contamination by older organic material and are regarded as the most reliable dates for the containing sediments. Accordingly, an age of 13 000 years is adopted for Sitidgi Lake Moraine and correlative ice-marginal features of the Tutsieta Lake Phase. A date of 13 100 ± 150 BP (GSC-3387; Blake, 1983, p. 24; Ritchie et al., 1983; Fig. 1) from Twin Tamarack Lake, a locality within the limit of Tutsieta Lake Phase southeast of Inuvik implies a somewhat older date for culmination of the phase. The Laurentide ice sheet had retreated from the limit of the Tutsieta Lake Phase to leave the vicinity of Fort Good Hope ice free by 11 530 ± 170 BP (I-3734; Mackay and Matthews, 1973; Fig. 1).

Peat from a bog in a depression impounded by Kelly Lake Moraine yielded a date of 9600 ± 80 BP (GSC-2379, Fig. 1). The date is minimum for the Kelly Lake Phase. However, the Great Bear River area, with a general surface elevation some 300 m below the elevation of the nearby Kelly Lake Moraine, could not have become ice free until the Laurentide ice sheet had undergone considerable retreat from the moraine. The date of 10 600 ± 260 BP (GSC-2328, Lowdon and Blake, 1979, p. 34; Savigny, in press; Fig. 1), which is minimum for ice retreat from Great Bear River area is therefore also minimum for retreat from Kelly Lake Moraine and the end of the Kelly Lake Phase.

DISCUSSION

Late Wisconsinan history of the mainland area as proposed here differs significantly from that proposed by Vincent (1983, p. 83-85) for Banks Island, some 110 km to the north across Amundsen Gulf. Whereas two significant readvances culminating at or before 13 000 years ago and before 10 600 years ago are suggested for the mainland, Banks Island experienced only one Late Wisconsinan advance, during the Russell Stade of Amundsen Glaciation, not more than 10 600 years ago. Moreover, only the northeastern extremity of Banks Island was affected, by ice emanating from Viscount Melville Sound and Victoria Island. From consideration of the regional pattern of Late Wisconsinan glaciation on Banks Island and adjacent Victoria Island, Vincent (1983, Fig. 69) would place the limit of ice in Amundsen Gulf against the mainland coast during the Late Wisconsinan at about 122°W, that is, not farther west than the eastern border shown in Figure 1. Yet, the moraines and glacial features of the coastal area, which herein are attributed to the Tutsieta Lake Phase, and hence to the Late Wisconsinan, have a fresh appearance that supports that age assignment.

The interpretation offered herein and previous work which it incorporates relied heavily on airphoto interpretation of glacial landforms with minimal supporting stratigraphic observations, whereas the work of Vincent (1983) in Banks Island involved extensive field checking and careful stratigraphic studies supported by many radiocarbon and amino acid age determinations. Clearly, the apparent contradictions in age assignment cannot be resolved until a comparable data base is developed on the mainland, particularly in the area where ice of a lobe in Amundsen Gulf merged with ice moving northwesterly along Hornaday River and ice emanating from the upper reaches of Anderson River.

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Figure 3. Limit of Tutsieta Lake Phase, east of Canot Lake (106 P). NAPL A21585 241-243.

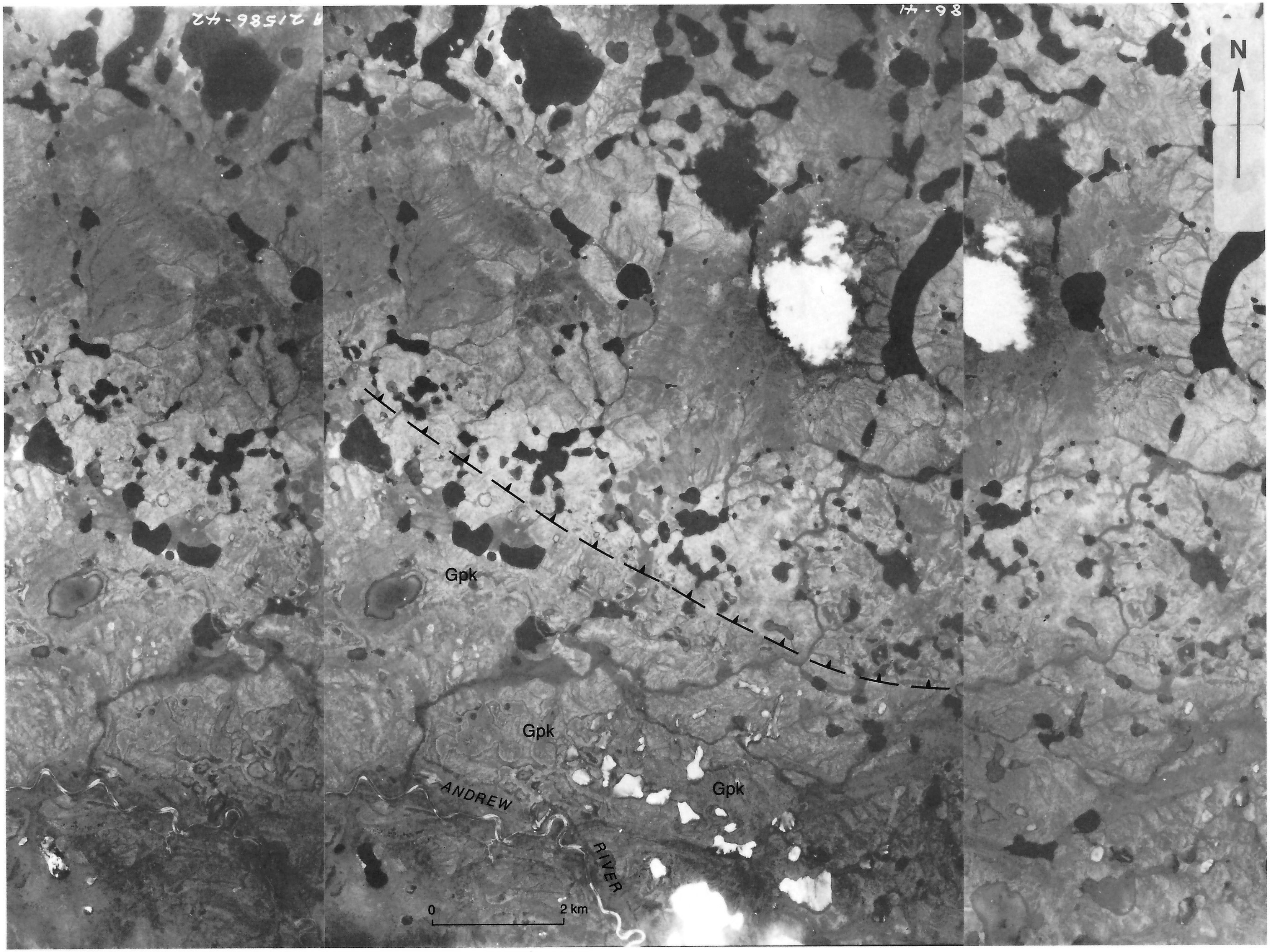

Figure 4. Limit of Tutsieta Lake Phase, northeast of Andrew River, central Anderson Plain (107 A). Contrast between morainic topography to the northeast of the limit and glaciofluvial plain to the southwest is reduced by thermokarst topography developed in the latter. NAPL A21586 40-42.

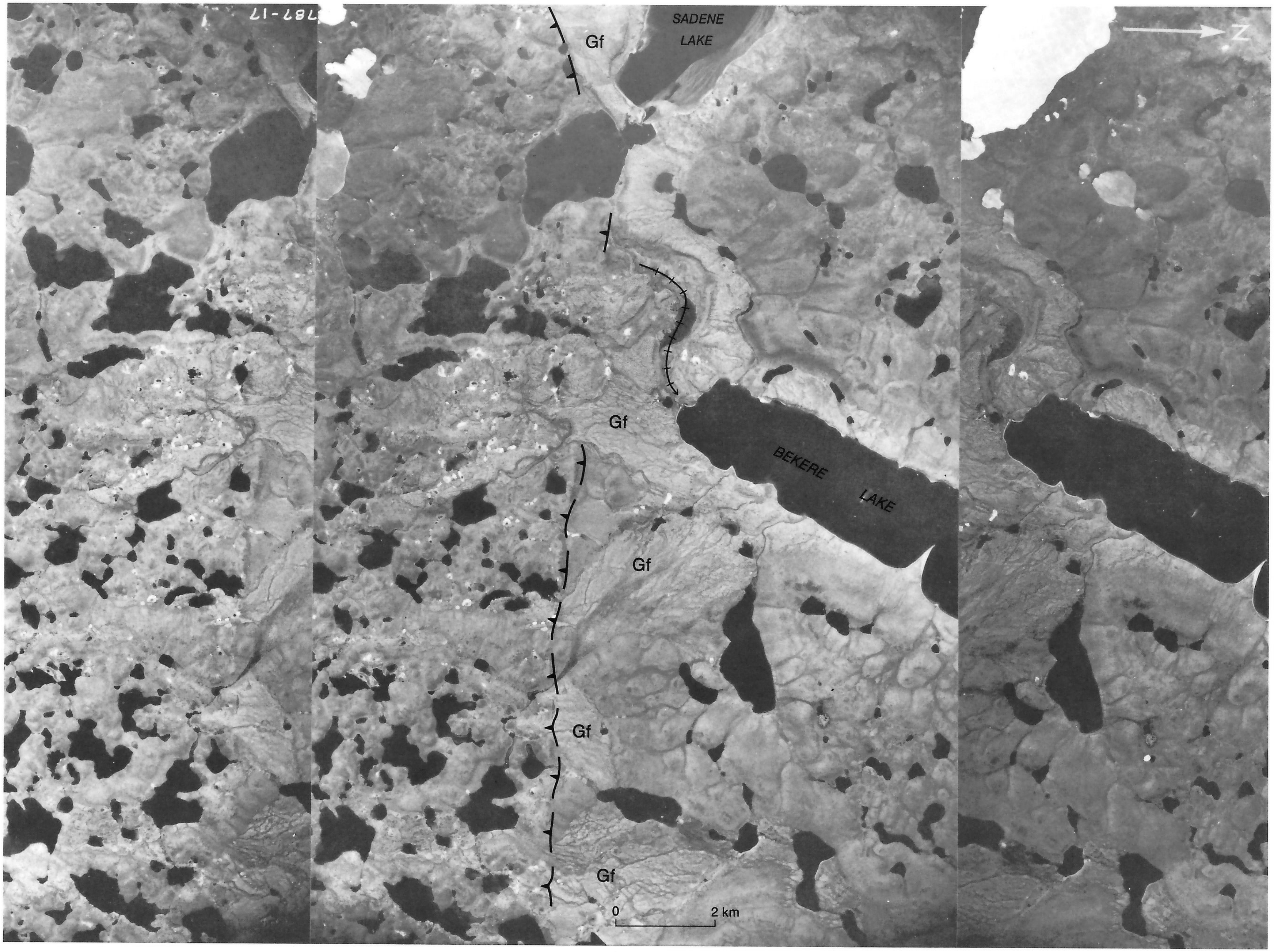

Figure 5. Limit of Tutsieta Lake Phase, south of Bekere Lake, northeastern Anderson Plain (97 B). Glacial meltwater drained northward via Bekere Lake to lower Horton River. NAPL A13787 15-17.

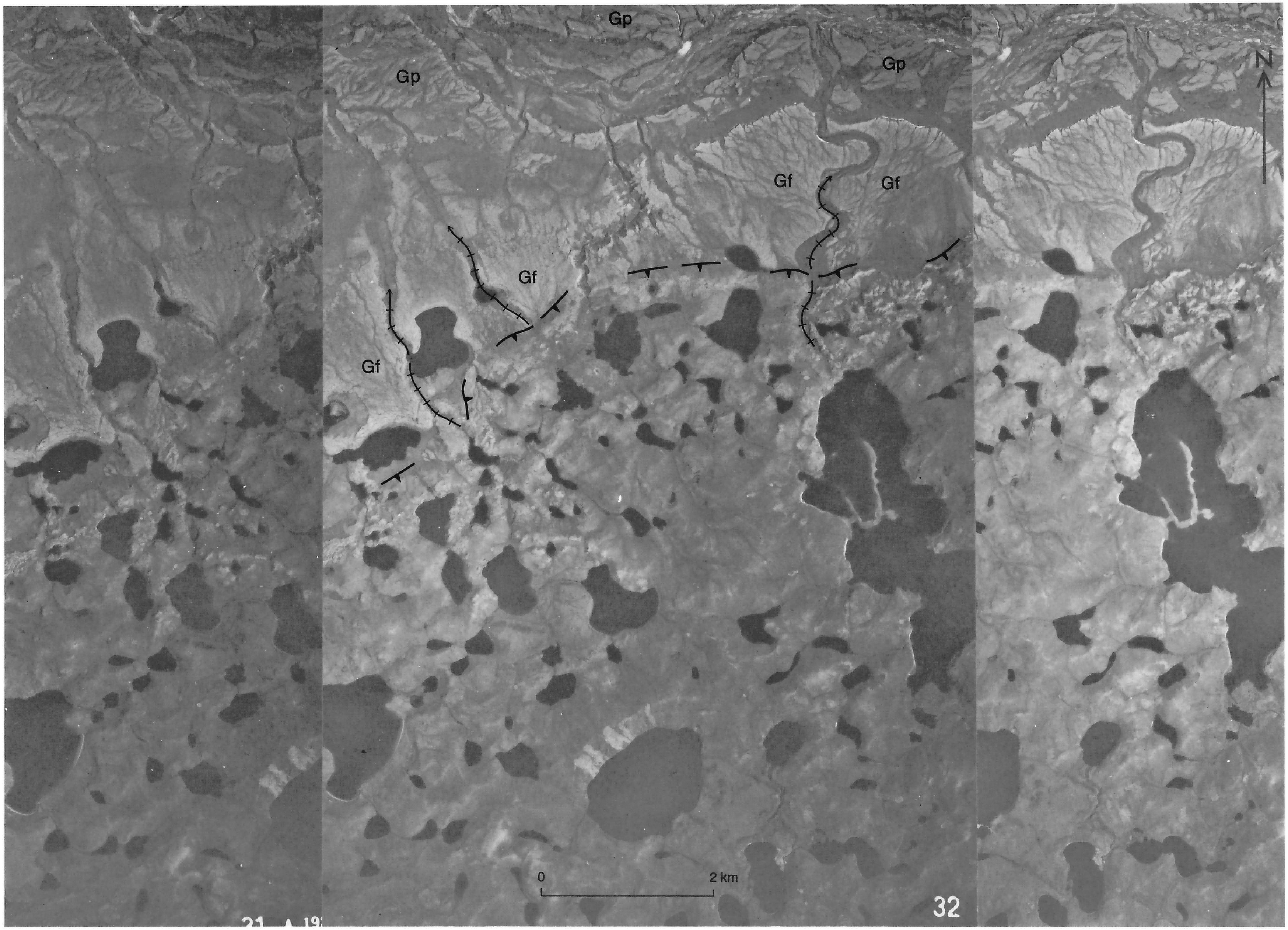

Figure 6. Limit of Tutsieta Lake Phase between Horton River and Binamé Lake, northeastern Anderson Plain (97 C). The glaciofluvial plain was deposited by a major meltwater stream that discharged westward to lower Horton River. NAPL A19210 31-33.

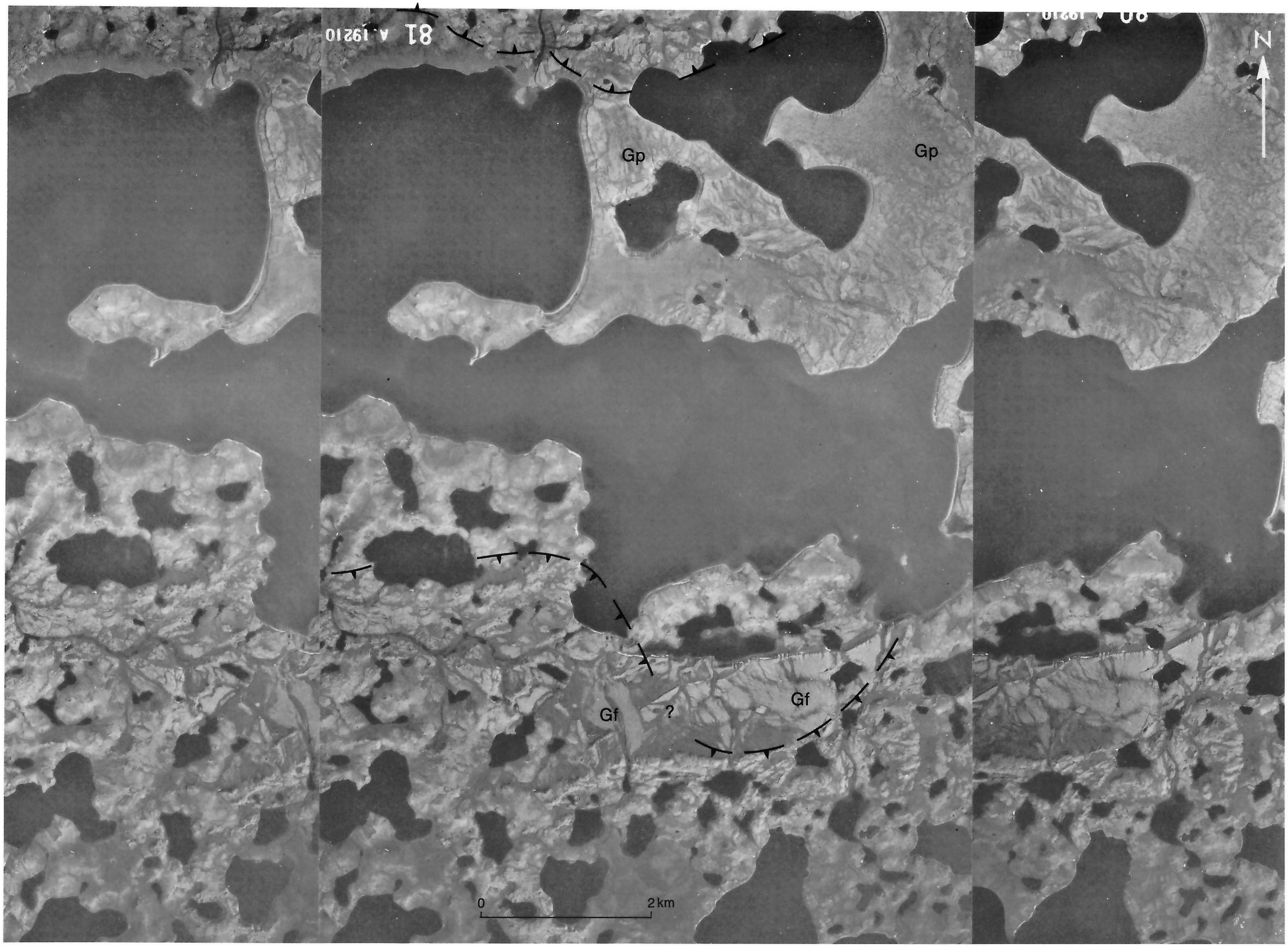

Figure 7. Limit of Tutsieta Lake Phase, north of Binamé Lake, northeastern Anderson Plain (97 C). As interpreted, a moraine at the north (upper) margin of the airphotos marks the limit of an ice lobe in Amundsen Gulf, and a moraine at the south (lower) margin marks the limit of ice that moved northeastward from the upper Anderson River area. Glacial meltwater discharged westward via lower Horton River. NAPL A19210 80-82.

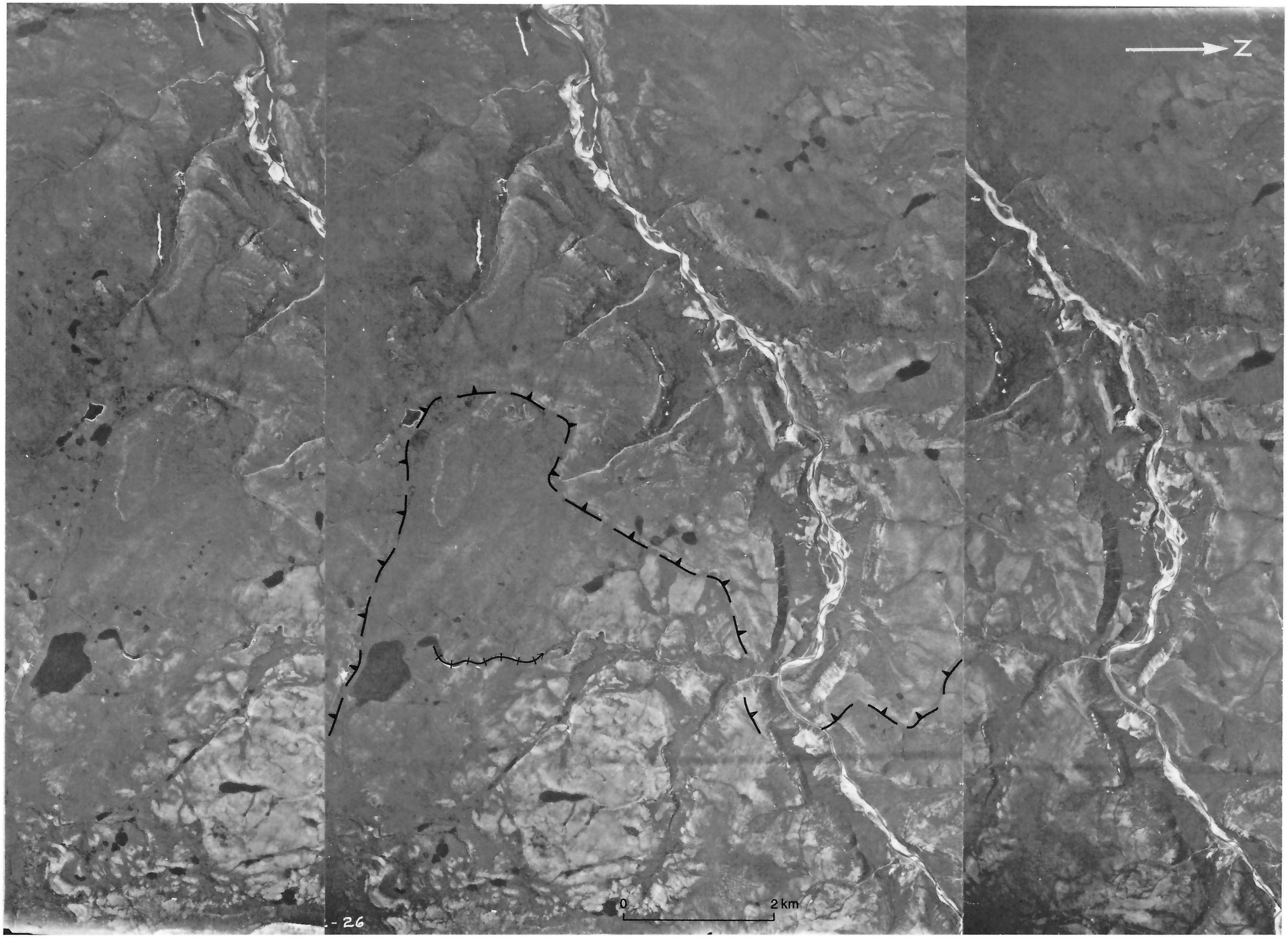

Figure 8. Limit of Tutsieta Lake Phase, east of Hornaday River, Horton Plain (97 A). NAPL A13782 25-27.

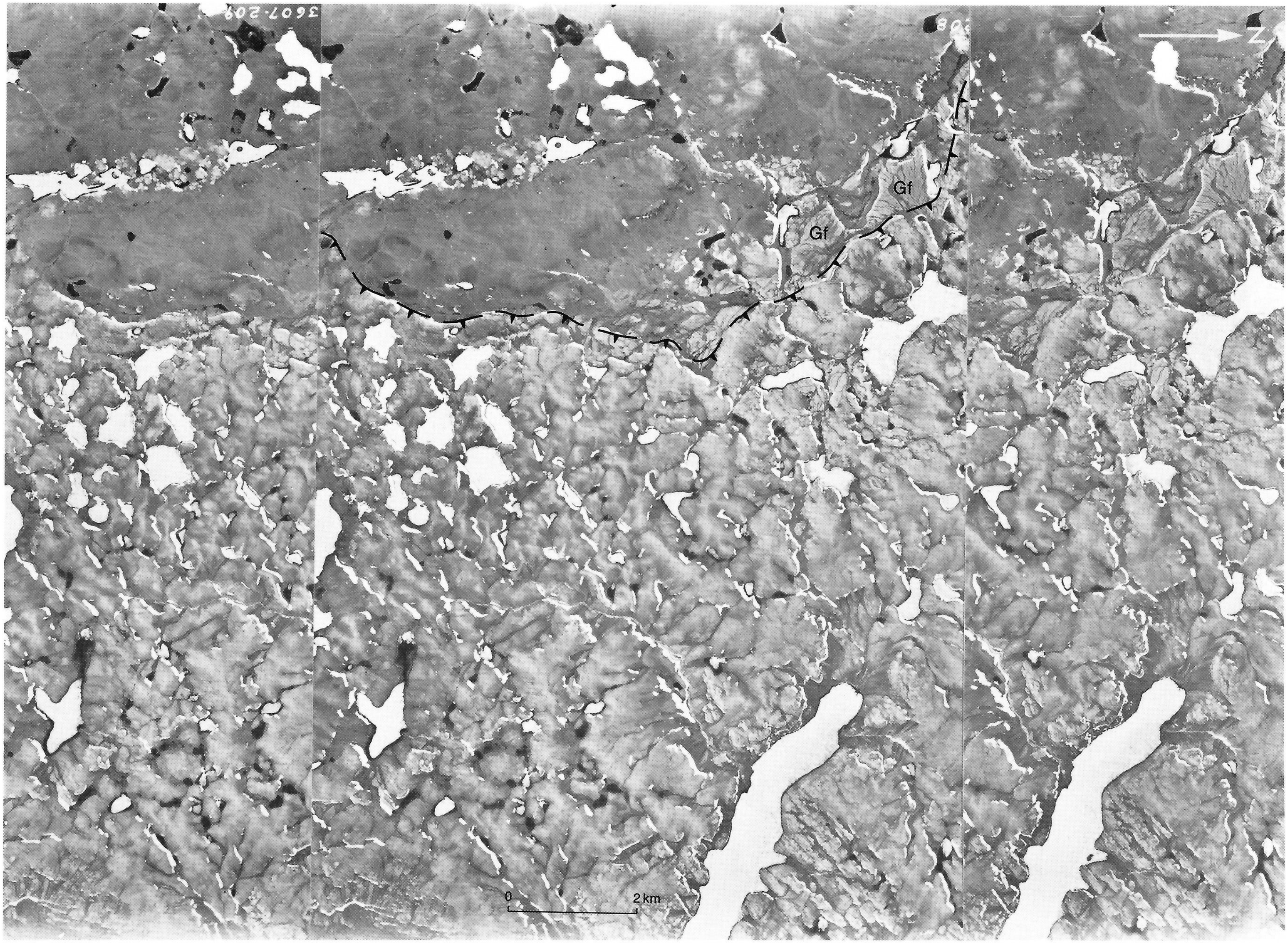

Figure 9. Limit of Tutsieta Lake Phase, west of Hornaday River, Horton Plain (97 A). NAPL A13607 207-209.

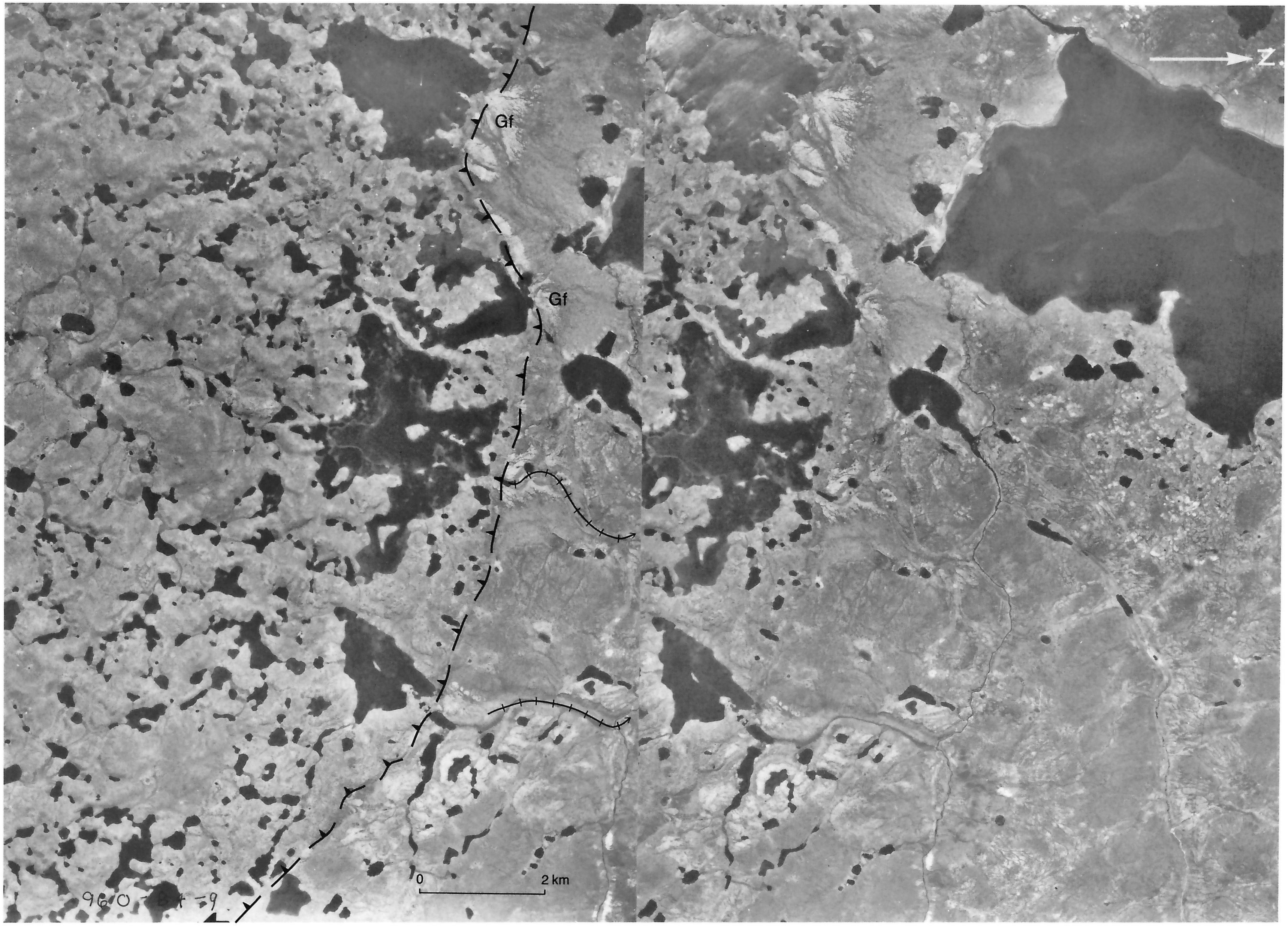

Figure 10. Limit of Tutsieta Lake Phase, south of Estabrook Lake (96 O). Meltwater drained to an ice-free area in upper Horton River valley. NAPL A13633 72, 73.

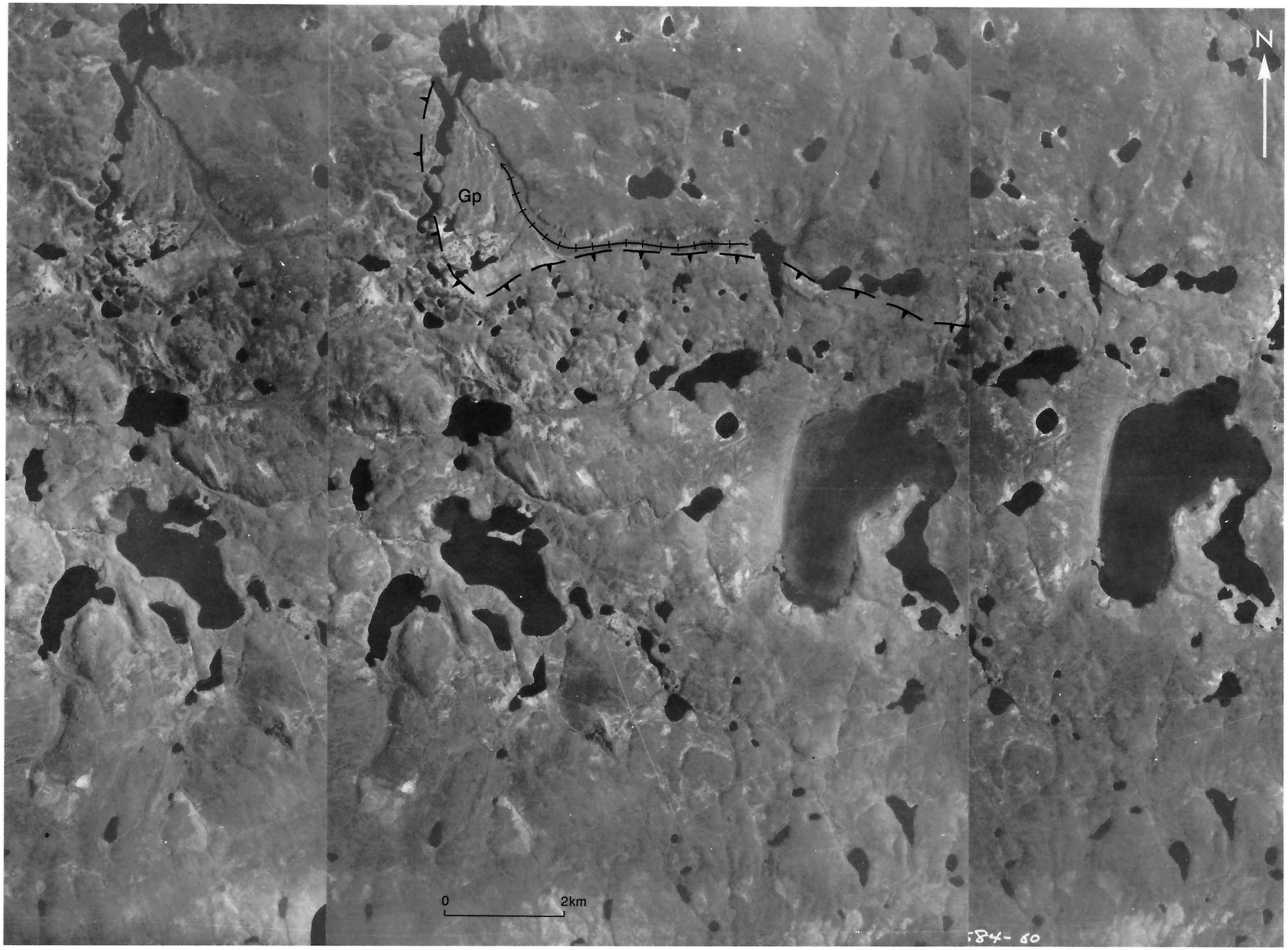

Figure 11. Limit of Tutsieta Lake Phase east of Travaillant Lake, southwestern Anderson Plain (106 O). NAPL A21584 58-60.

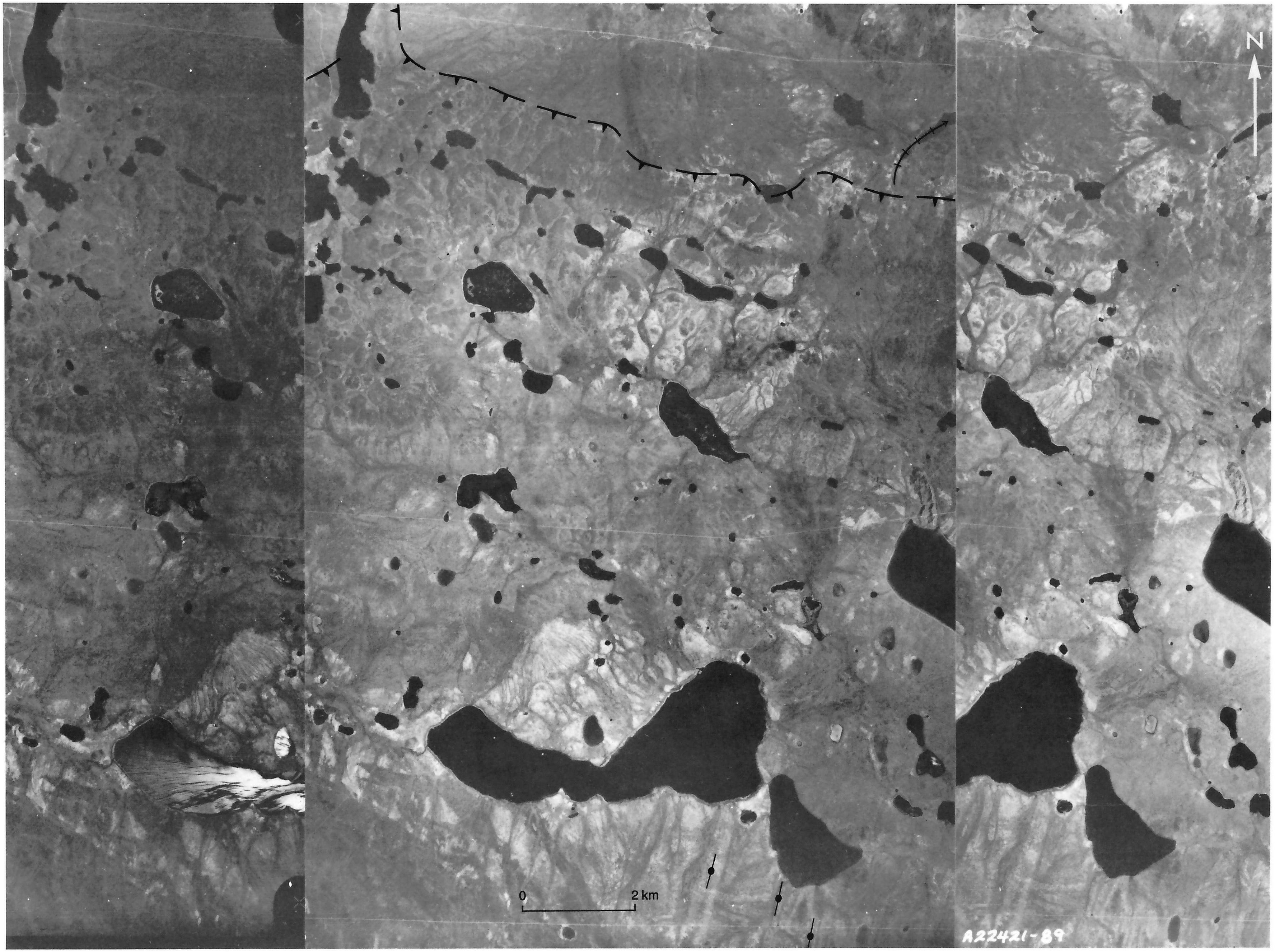

Figure 12. Limit of Tutsieta Lake Phase, southern Grandview Hills, Peel Plain (106 J). NAPL A22421 87-89.

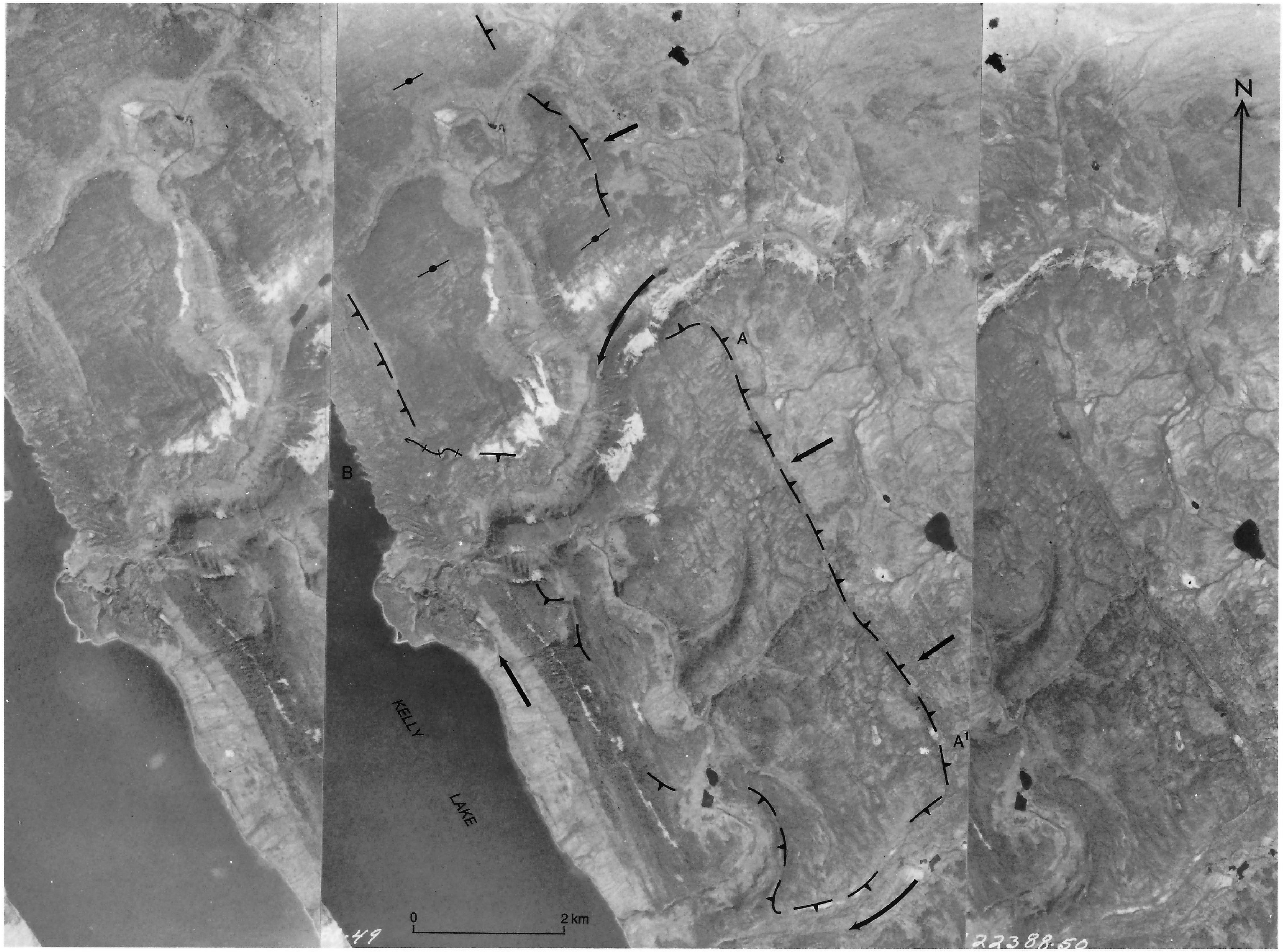

Figure 13. Kelly Lake Moraine, Kelly Lake (96 E). The moraine segment between A and A' is designated as the type locality for the Kelly Lake Phase. Ice abutted against the east side of the upland but moved southwesterly through gaps in the upland and northwesterly along Kelly Lake. Small sharp-crested ridges (De Geer moraines?) at B mark ice retreat positions. NAPL A22388 48-50.

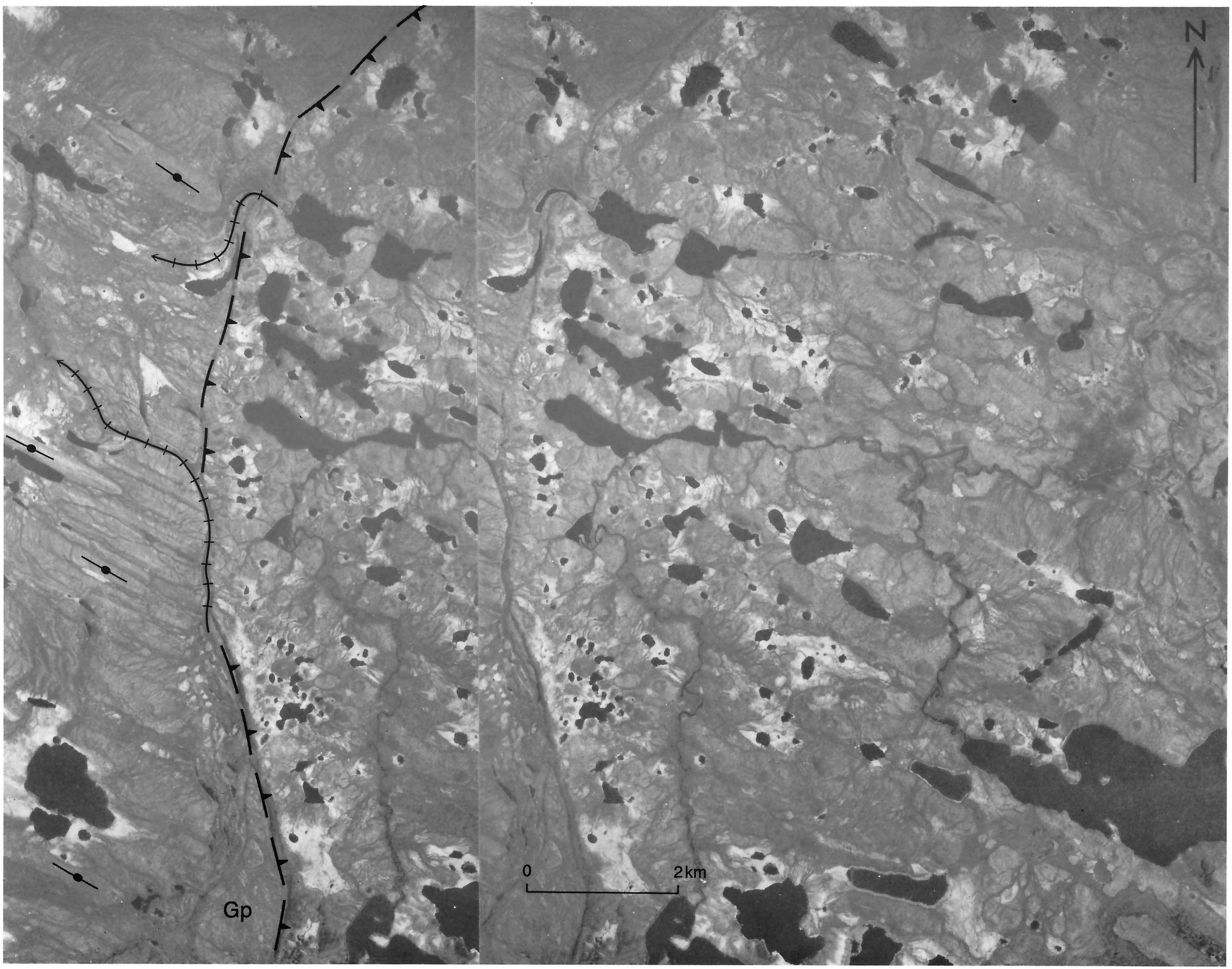

Figure 14. Limit of Kelly Lake Phase, west of upper Hare Indian River (96 L). The western margin of rolling to hummocky moraine is accentuated by sharp ridges (push moraine?). NAPL A21585 6, 7.

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