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Extending the Late Holocene White River Ash Distribution, Northwestern Canada

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ABSTRACT. Peatlands are a particularly good medium for trapping and preserving tephra, as their surfaces are wet and well vegetated. The extent of tephra-depositing events can often be greatly expanded through the observation of ash in peatlands. This paper uses the presence of the White River tephra layer (1200 B.P.) in peatlands to extend the known distribution of this late Holocene tephra into the Mackenzie Valley, northwestern Canada. The ash has been noted almost to the western shore of Great Slave Lake, over 1300 km from the source in southeastern Alaska. This new distribution covers approximately 540 000 km^2 with a tephra volume of 27 km^3. The short time span and constrained timing of volcanic ash deposition, combined with unique physical and chemical parameters, make tephra layers ideal for use as chronostratigraphic markers.

Key words: chronostratigraphy, Mackenzie Valley, peatlands, White River ash

RÉSUMÉ. Les tourbières constituent un milieu particulièrement approprié au piégeage et à la conservation de téphra, en raison de l'humidité et de l'abondance de végétation qui règnent en surface. L'observation des cendres contenues dans les tourbières permet souvent d'élargir notablement les limites spatiales connues des épisodes de dépôts de téphra. Cet article recourt à la présence de la couche de téphra de la rivière White (1200 BP) dans les tourbières pour agrandir la distribution connue de ce téphra datant de l'Holocène supérieur dans la vallée du Mackenzie, située dans le Nord-Ouest canadien. On a relevé la présence de cette cendre pratiquement jusqu'à la rive occidentale du Grand lac des Esclaves, à plus de 1300 km de son origine dans le sud-est de l'Alaska. Cette nouvelle distribution couvre environ 540 000 km^2, avec un volume de téphra de 27 km^3. Le fait que la cendre volcanique se dépose relativement vite et en des moments précis, et qu'elle possède des paramètres physiques et chimiques bien particuliers, rend les couches de téphra idéales pour servir de marqueurs chronostratigraphiques.

Mots clés: chronostratigraphie, vallée du Mackenzie, tourbières, cendre de la rivière White

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INTRODUCTION

Tephra travels away from the source volcano in plumes determined by the prevailing wind direction at the time of eruption. Fine-grained tephra may travel hundreds of kilometres before being deposited. In distal environments, lake sediments and peat preserve tephra deposits only a few millimetres thick. Such thin deposits, which may represent very powerful eruptions, are normally impossible to trace with certainty in subaerial exposures because of post-depositional mixing and weathering processes. Thus, the known extent of tephra-depositing events can often be greatly expanded through the observation of ash in peatlands (Lowe, 1988; Zoltai, 1988; Holmes et al., 1999). Tephra, or primary fallout debris, typically comprises compact (and occasionally bedded) layers of varying particle size, from fine macroscopic ash to medium lapilli. These pale-coloured, unweathered layers are often visible against darker lake sediments and peat (Fig. 1). The short span and constrained timing of volcanic ash deposition, combined with unique physical and chemical parameters, make tephra layers ideal for use as chronostratigraphic markers in lakes or peatlands (Robinson and Moore, 1999).

Peatlands are a particularly good medium for trapping and preserving tephra, as their surfaces are wet and well vegetated. In distal areas, thin ashfalls do not generally kill the vegetation, and the ash is retained and incorporated into the peat as it grows vertically. Peatlands are generally not subject to the same scale of erosion, rooting, and aeolian processes that may hamper long-term preservation in other environments. Peat-forming mosses grow from their tips and have no roots, removing preservation problems due to bioturbation that may be found in forests or areas with woody or herbaceous vegetation. Zoltai (1988) suggests that peat prevents the settling, or downward translocation, of tephra. The downward percolation of water and runoff in upland soils also tends to prevent preservation where the tephra is thin.

Volcanic ash layers in western Canada have proved to be very important chronostratigraphic markers in providing age control for a variety of geomorphic processes, including alluvial fan growth (Ryder, 1971), slope processes (Osborn and Luckman, 1981; Harris and McDermid, 1998), fluvial aggradation and incision (Dawson, 1889; Fuller, 1986), glacier (Rampton, 1970) and rock glacier fluctuations (Dyke, 1990), lake level fluctuations (Clague,

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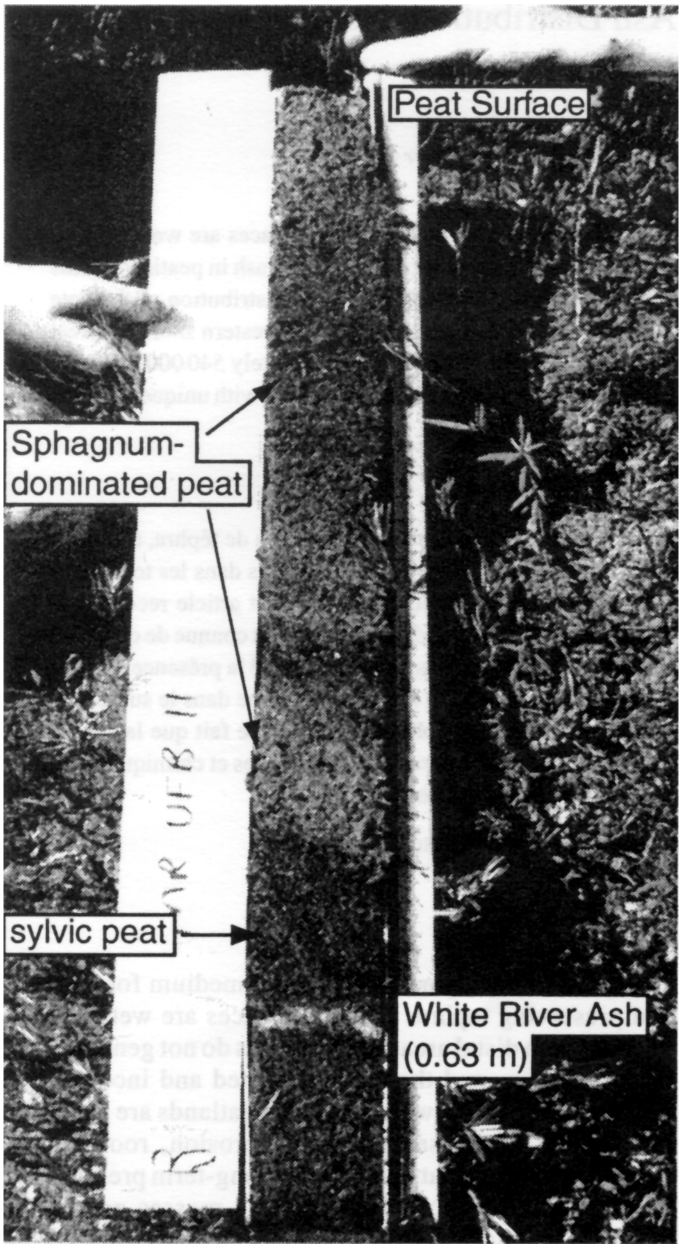

FIG. 1. A peat core from the Fort Simpson, Northwest Territories, area showing the White River volcanic ash as a distinct marker horizon.

1981), and peatland growth (Capps, 1915; Rigg and Gould, 1957; Tarnocai, 1973; Zoltai and Johnson, 1985; Zoltai, 1988; Ovenden, 1990; Robinson and Moore, 1999, 2000). Tephra layers in peat have been used extensively in the past for chronostratigraphic correlations in Canada (Zoltai, 1988), the United States (Rigg and Gould, 1957), Great Britain (Holmes et al., 1999), New Zealand (Lowe, 1988), the former Soviet Union (Braitseva et al., 1997), and Japan (Yabe, 1993).

THE WHITE RIVER ASH

The White River ash layer is one of the more northerly of the Holocene tephras present in western Canada, and was first noted by Schwatka in 1883 (Schwatka, 1898). It is characterized as a Plinian eruption, of explosive power and with a widely dispersed rhyodacite ash (Hanson, 1965) composed of glass, plagioclase, hornblende, hypersthene, and magnetite (Lerbekmo and Campbell, 1969). Two separate lobes (see Fig. 2) were first noted by Bostock (1952), and likely have Mt. Churchill, Alaska, as their source (Richter et al., 1995). The smaller lobe trends northwards along an axis just west of the Alaska-Yukon boundary and is found as far north as the Yukon River. This lobe has been dated at between 1900 and 1500 ^{14}C years ago (Lerbekmo and Campbell, 1969; Hughes et al., 1972; Lerbekmo et al., 1975). A younger, larger lobe trends east from the source. Detailed radiocarbon dating suggests an age of 1147 calendar years before 1950 (a date of A.D. 803) for this lobe (Clague et al., 1995). Workman (1979) and Moodie et al. (1992) suggest that the ashfall from the eastern lobe triggered human population displacements that led to Athapaskan migrations eastward into the Mackenzie Valley and southward into northern British Columbia.

Published maps of the White River ash distribution suggest that the ashfall did not extend as far as the Mackenzie Valley (Bostock, 1952; Hughes et al., 1972; Lerbekmo et al., 1975; Clague et al., 1995), with only the map of Richter et al. (1995) suggesting that the easterly extent might be much greater. However, several researchers have observed the ash in peatlands and lakes at various locations in the Mackenzie Valley (Rowe et al., 1974; Zoltai and Tarnocai, 1975; Rostad et al., 1976; Slater, 1985; Robinson and Moore, 1999; Robinson, unpubl. data; C. Tarnocai, pers. comm. 1998). J.A. Westgate (pers. comm. in Slater, 1985) determined that ash found in a lake near Wrigley, Northwest Territories, was mineralogically consistent with the White River ash. This paper provides a revised distribution of the White River ash, based on field observations of the ash in peatlands. The White River ash is the only documented macroscopic ash in this region during the late Holocene. The author has never seen the ash, nor has it been reported in the Mackenzie Valley except in peatlands and lakes.

EXTENDING THE WHITE RIVER ASH DISTRIBUTION

Data were compiled from published accounts of the ash in the Mackenzie Valley, from unpublished sources, and from field surveys to revise the distribution of the eastern lobe of the White River ash (Fig. 2).

Field surveys showed the presence of the White River ash in the upper metre of peatlands of the upper Mackenzie Valley as far east as 116°16′ W, near the western shore of Great Slave Lake, over 1300 km from the source (Fig. 2). The ash in peatlands at the easternmost sites is less than 5 mm thick and highly discontinuous, suggesting that the true eastern margin may be approached. The ash was not visible in any peatlands investigated farther to the northeast.

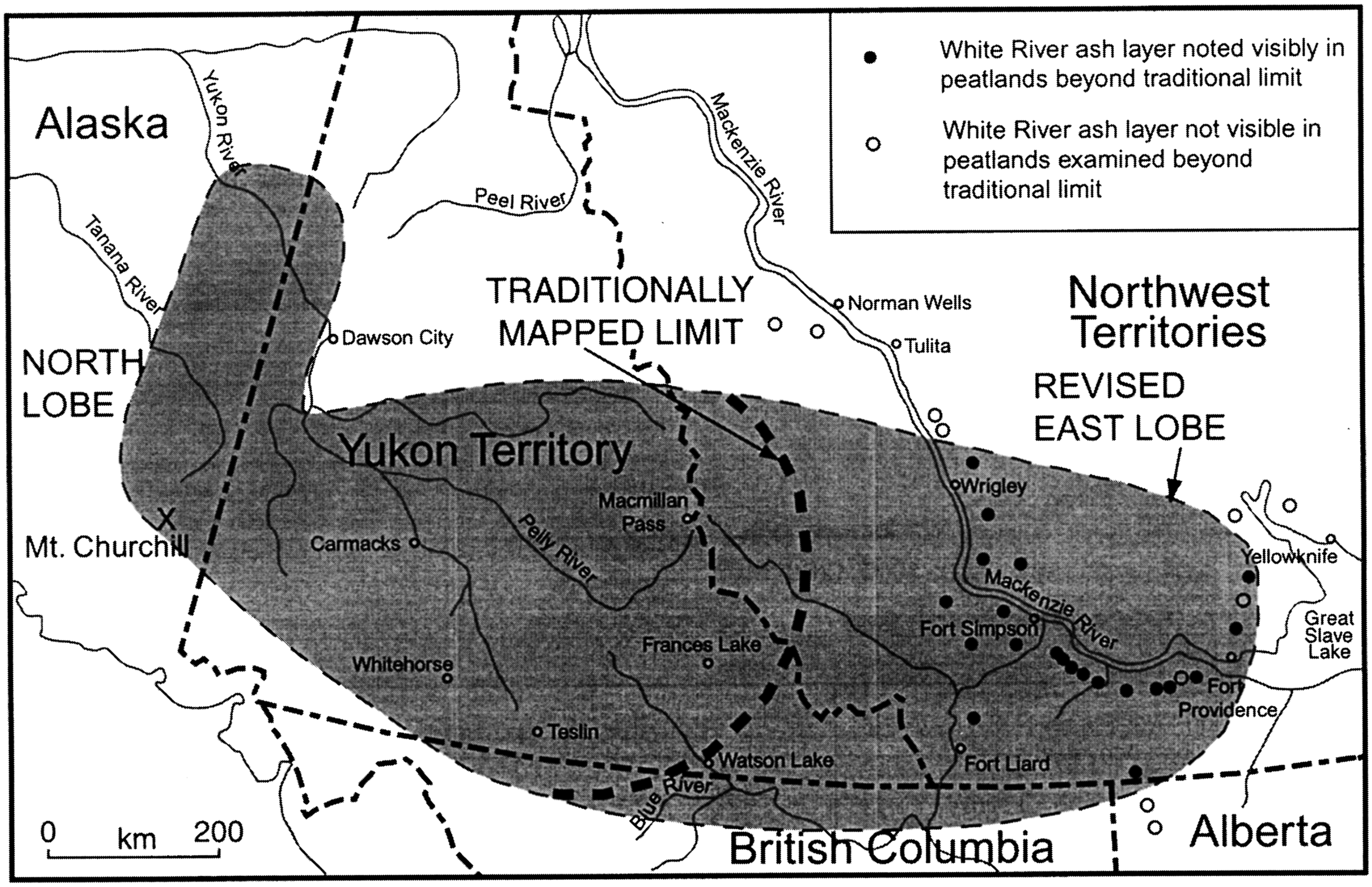

FIG. 2. The White River ash: the traditional limit and a revised distribution based upon occurrence in peatlands (data from Rostad et al., 1973; Rowe et al., 1973; Robinson and Moore, 1999; C. Tarnocai, pers. comm. 1998; and Robinson, unpubl. data).

To the north, the ash has been noted in peatlands and lakes near Wrigley, Northwest Territories (Slater, 1985; Robinson, unpubl. data; C. Tarnocai, pers. comm. 1998), yet field investigations of two peatlands 40 km north of Wrigley failed to yield any visual indications of ash. Detailed investigations of peat cores collected near Norman Wells, Northwest Territories, also failed to reveal visible ash. MacDonald (1983) and Kershaw and Gill (1979) report the White River ash near Macmillan Pass on the Northwest Territories–Yukon border, over 300 km southwest of Norman Wells. Kindle (1945:21) reported that a “white volcanic ash ranging from 2 to 4 inches thick” mantles much of the Teslin-Macmillan Pass area. The ash in that region is reported to be widespread in the valley bottoms, but is not seen on the slopes.

The ash has been noted as a thin, discontinuous layer in a peatland about 17 km north of the Alberta border (60° 10′N, 119° 43′W). Investigations of two peatlands 30 and 50 km further south did not show any visible ash. Similarly, detailed peat investigations in northwestern Alberta did not reveal the presence of tephra (Reid, 1977; L. Halsey, pers. comm. 1999). The ash layer has also been reported near Blue River, northern British Columbia (H. Gabrielse, pers. comm. in Fuller, 1986). Hansen (1950) discovered minor traces of ash of unknown source in the “upper levels” of peat deposits along the Alaska Highway in northeastern British Columbia, but it appears likely that this may be the distal end of the Edziza ash (Souther, 1976).

Lerbekmo and Campbell (1969) suggest that the ash covers 324 000 km^2, and Hanson (1965) calculated a tephra volume of 25 km^3. On the basis of the extension of ash distribution into the Mackenzie Valley, it is possible to revise the distribution of the White River ash layer. This new distribution (Fig. 2) covers approximately 540 000 km^2, with a tephra volume of 27 km^3 based upon an extension of Hanson’s (1965) data. Bostock (1952) presented the first isopach map of the White River ash, and suggested that deposits up to 30 cm thick were found as far away as Carmacks, 330 km from the source. A revised graph showing visible tephra thickness and distance from the source is presented in Figure 3. The use of microscopic techniques (Zoltai, 1988) may serve to extend the distribution further; however, if the ash is not readily visible, its utility as a chronostratigraphic marker is diminished.

THE WHITE RIVER ASH AS A CHRONOSTRATIGRAPHIC MARKER

The short time span and constrained timing of volcanic ash deposition, combined with unique physical and chemical

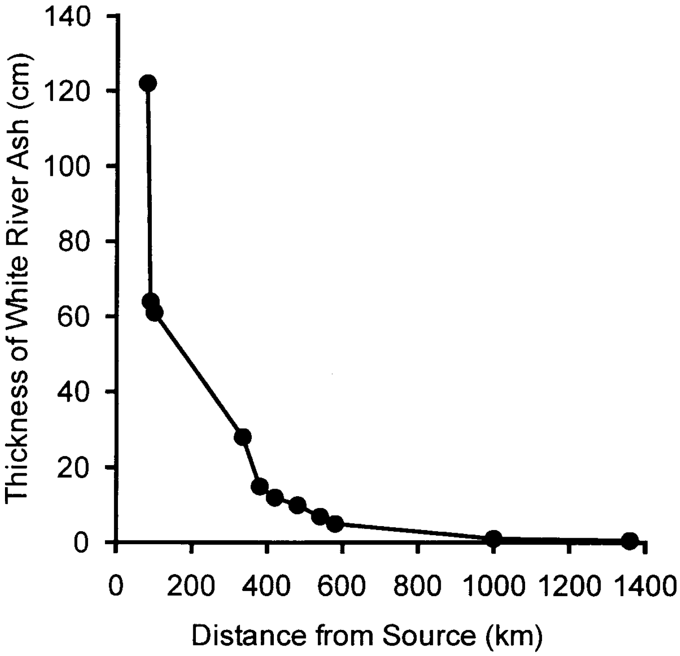

FIG. 3. Tephra thickness and distance from source for the White River ash (data from Bostock, 1952, and Robinson, unpubl. data).

parameters, make tephra layers ideal for use as chronostratigraphic markers. Dawson (1889) used the White River ash layer to infer downcutting of the Yukon River, and Capps (1915) used the thickness of peat over the ash to estimate the timing of the north lobe emplacement. Fuller (1986) was the first to make use of the White River ash as a chronostratigraphic marker in a detailed, process-based study. He used the presence or absence of ash to examine lateral migration, island growth, channel downcutting, and vertical sediment accretion in the channel of the Yukon River over the past 1200 years. In peatlands, where chronological control is always problematic when comparing among sites, the ash has provided a dated base horizon from which to calculate carbon and peat accumulation rates in different peat landforms in the Northwest Territories (Robinson and Moore, 1999) and in the Yukon Territory (Harris and Schmidt, 1994). The ash layer has also been used in process-based studies examining the influence of permafrost aggradation and degradation, fire, microtopography, and water table upon carbon and peat accumulation (Robinson and Moore, 2000). The presence of a visible ash marker allowed a large sample size, impossible to achieve if radiocarbon dating must be relied upon. Dyke (1990) used the White River ash as a marker in studies of rock glaciers and neoglacial moraines near Frances Lake, Yukon Territory. Denton and Karlén (1977) used both lobes of the White River ash to examine the timing of glacier fluctuations and moraine development in southwestern Yukon Territory, although their interpretations resulted in some controversy (Rampton, 1978). The ash has also been used as a marker in several palaeoecological studies (e.g., MacDonald, 1983; Slater, 1985) and in anthropological and archaeological studies (Workman, 1979).

In the southwestern Northwest Territories, the preservation of ash only in peatlands and lakes limits its utility as a marker to locations within these environments. In the Yukon Territory, however, where the ash is preserved in a wider variety of landforms, its potential use as a chronostratigraphic marker extends to fluvial, alluvial, glacial, periglacial, and aeolian landforms and processes.

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REFERENCES

BOSTOCK, H.S. 1952. Geology of northwest Shakwak Valley, Yukon Territory. Geological Survey of Canada Memoir 267.

BRAITSEVA, O.A., PONOMAREVA, V.V., SULERZHITSKY, L.D., MELEKESTSEV, I.V., and BAILEY, J. 1997. Holocene key-marker tephra layers in Kamchatka, Russia. Quaternary Research 47:125–139.

CAPPS, S.R. 1915. An ancient volcanic eruption in the upper Yukon basin. U.S. Geological Survey Professional Paper 95: 59–64.

CLAGUE, J.J. 1981. Landslides at the south end of Kluane Lake, Yukon Territory. Canadian Journal of Earth Sciences 18: 959–971.

CLAGUE, J.J., EVANS, S.G., RAMPTON, V.N., and WOODSWORTH, G.J. 1995. Improved age estimates for the White River and Bridge River tephras, western Canada. Canadian Journal of Earth Sciences 32:1172–1179.

DAWSON, G.M., 1889. Report on an expedition in the Yukon District, N.W.T., and adjacent portions of British Columbia. Geological Survey of Canada, Annual Report v. 3., part 1. 5–277.

DENTON, G.H., and KARLÉN, W. 1977. Holocene glacial and tree-line variations in the White River Valley and Skolai Pass, Alaska and Yukon Territory. Quaternary Research 7:63–111.

DYKE, A.S. 1990. A lichenometric study of Holocene rock glaciers and neoglacial moraines, Frances Lake map area, southeastern Yukon Territory and Northwest Territories. Geological Survey of Canada Bulletin 394. 33 p.

FULLER, E.A. 1986. Yukon River evolution since White River ash. Unpublished M.Sc. thesis, Department of Geography, Simon Fraser University, Burnaby, British Columbia. 181 p.

HANSEN, H.P. 1950. Postglacial forests along the Alaska Highway in British Columbia. Proceedings of the American Philosophical Society 94:411–421.

HANSON, L.W. 1965. Size distribution of the White River ash, Yukon Territory. Unpublished M.Sc. thesis, Department of Geology, University of Alberta, Edmonton. 59 p.

HARRIS, S.A., and McDERMID, G. 1998. Frequency of debris flows on the Sheep Mountain fan, Kluane Lake, Yukon Territory. Zeitschrift für Geomorphologie 42:159–175.

HARRIS, S.A., and SCHMIDT, I. H. 1994. Permafrost aggradation and peat accumulation since 1200 years B.P. in peat plateaus at Tuchitua, Yukon Territory (Canada). Journal of Paleolimnology 12:3–17.

HOLMES, J., HALL, V., and WILSON, P. 1999. Volcanoes and peat bogs. Geology Today 15(2):60–63.

HUGHES, O.L., RAMPTON, V.N., and RUTTER, N.W. 1972. Quaternary geology and geomorphology, southern and central Yukon. 24th International Geological Congress, Montreal, Guidebook A-11. 59 p.

KERSHAW, G.P., and GILL, D. 1979. Growth and decay of palsas and peat plateaus in the Macmillan Pass–Tsichu River area, Northwest Territories, Canada. Canadian Journal of Earth Sciences 16:1362–1374.

KINDLE, E.D. 1945. Geological reconnaissance along the Canol Road, from Teslin River to Macmillan Pass, Yukon. Geological Survey of Canada Paper 45-21. 26 p.

LERBEKMO, J.F., and CAMPBELL, F.A. 1969. Distribution, composition, and source of the White River ash, Yukon Territory. Canadian Journal of Earth Sciences 6:109–116.

LERBEKMO, J.F., WESTGATE, J.A., SMITH, D.G.W., and DENTON, G.H. 1975. New data on the character and history of the White River volcanic eruption, Alaska. In: Suggate, R.P., and Cresswell, M.M., eds. Quaternary Studies. Wellington: The Royal Society of New Zealand. 203–209.

LOWE, D.J. 1988. Late Quaternary volcanism in New Zealand: Towards an integrated record using distal airfall tephras in lakes and bogs. Journal of Quaternary Science 3:111–120.

MacDONALD, G.M. 1983. Holocene vegetation history of the upper Natla River area, Northwest Territories, Canada. Arctic and Alpine Research 15:169–180.

MOODIE, D.W., CATCHPOLE, A.J.W., and ABEL, K. 1992. Northern Athapaskan oral traditions and the White River volcano. Ethnohistory 39:148–171.

OSBORN, G., and LUCKMAN, B.H. 1981. Origin of an unusual Holocene diamicton in Banff National Park, Alberta, Canada. Zeitschrift für Geomorphologie 25:290–299.

OVENDEN, L. 1990. Peat accumulation in northern wetlands. Quaternary Research 33:377–386.

RAMPTON, V.N. 1970. Neoglacial fluctuations of the Natazhat and Klutlan Glaciers, Yukon Territory, Canada. Canadian Journal of Earth Sciences 7:1236–1263.

——. 1978. Holocene glacial and tree-line variations in the White River Valley and Skolai Pass, Alaska and Yukon Territory: A discussion. Quaternary Research 10:130–134.

REID, D.E. 1977. Permafrost in peat landforms in northwestern Alberta. In: Vegetation surveys and disturbance studies along the proposed Arctic Gas Route. Biological Report Series, Volume 37. Calgary, Alberta: Arctic Gas.

RICHTER, D.H., PREECE, S.J., McGIMSEY, R.G., and WESTGATE, J.A. 1995. Mount Churchill, Alaska: The source of the late Holocene White River ash. Canadian Journal of Earth Sciences 32:741–748.

RIGG, G.B., and GOULD, H.R. 1957. Age of Glacier Peak eruption and chronology of post-glacial peat deposits in Washington and surrounding areas. American Journal of Science 255:341–363.

ROBINSON, S.D., and MOORE, T.R. 1999. Carbon and peat accumulation over the past 1200 years in a landscape with discontinuous permafrost, northwestern Canada. Global Biogeochemical Cycles 13:591–601.

———. 2000. The influence of permafrost and fire upon carbon accumulation in High Boreal peatlands, Northwest Territories, Canada. Arctic, Antarctic, and Alpine Research 32:155–166.

ROSTAD, H.P.W., WHITE, R.A., and ACTON, D.F. 1976. Soil survey and land evaluation of the Liard and Mackenzie River area, Northwest Territories. Saskatchewan Institute of Pedology Publication S173. Saskatoon: University of Saskatchewan. 285 p.

ROWE, J.S., BERGSTEINSSON, G.A., PADBURY, G.A., and HERMISH, R. 1974. Fire studies in the Mackenzie Valley. Arctic Land Use Research Program (ALUR) Report 1973–74. Ottawa: Department of Indian Affairs and Northern Development. 123 p.

RYDER, J.M. 1971. The stratigraphy and morphology of para-glacial alluvial fans in south-central British Columbia. Canadian Journal of Earth Sciences 8:279–298.

SCHWATKA, F., 1889. Along Alaska's great river. Chicago, Illinois: G.M. Hill Publishers.

SLATER, D.S. 1985. Pollen analysis of postglacial sediments from Eildun Lake, District of Mackenzie, N.W.T., Canada. Canadian Journal of Earth Sciences 22:663–674.

SOUTHER, J.G. 1976. Geothermal power: The Canadian potential. Geoscience Canada 3:14–20.

TARNOCAI, C. 1973. Soils of the Mackenzie River area. Environmental-Social Committee, Northern Pipelines. Task Force on Northern Oil Development. Report 73-26. Ottawa: Information Canada. 136 p.

WORKMAN, W.B. 1979. The significance of volcanism in the prehistory of subarctic North America. In: Sheets, P.D., and Grayson, D.K., eds. Volcanic activity and human ecology. New York: Academic Press. 339–371.

YABE, K. 1993. Wetlands of Hokkaido. In: Higashi, S., Osawa, A., and Kanagawa, K., eds. Biodiversity and ecology in the northernmost Japan. Sapporo, Japan: University of Hokkaido Press. 38–49.

ZOLTAI, S.C. 1988. Late Quaternary volcanic ash in the peatlands of central Alberta. Canadian Journal of Earth Sciences 26: 207–214.

ZOLTAI, S.C., and JOHNSON, J.D. 1985. Development of a treed bog island in a minerotrophic fen. Canadian Journal of Botany 63:1076–1085.

ZOLTAI, S.C., and TARNOCAI, C. 1975. Perennially frozen peatlands in the western Arctic and Subarctic of Canada. Canadian Journal of Earth Sciences 12:28–43.