Known Pleistocene Maximum glacier extents in the 2010 Friends of the Pleistocene field trip area, Alaska

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Modified from: Pleistocene Maximum and Late Wisconsinan glacier extents across Alaska, U.S.A.
Kauffman and Manley, 2004

NOTE

The change in definition of Quaternary time from 1.8 or 2.0 million years to 2.588 million years occurred since the publication of Kauffman and Manley's compilation of paleoglacial limits in Alaska. This adds to the confusion about whether some glacial drifts are Early Pleistocene or Late Tertiary. There is evidence in Alaska (Hamilton et al., 1986) and world-wide (Ruthford & others (1968), Rutford & McIntosh , (2007)), that Tertiary glaciations occurred at least 3 million years ago. Some suggested Tertiary age events or deposits mentioned in the text below may be classified as Early Pleistocene. Table GL1, modified from Cohen & Gibbard, 2010, provides a current correlation of chronostratigraphical subdivisions of late Cenozoic geological time, spanning the last 2.7 million years. The chart illustrates how the Quaternary and Pleistocene were redefined in 2009 and is provided to aid in discussion.

INTRODUCTION

Kauffman and Manley (2004) summarized the results of a collaborative effort among glacial geologists working in Alaska to produce an updated compilation of statewide glacier extents. Their report summarizes evidence used to draw glacial limits in 15 regions across the state and highlights the most significant changes from previous mapping. Their report provides an overview of the glacial-geological record in Alaska, identifies prior efforts to synthesize data on Alaskan glacial geology and briefly discusses the broader implications of the newly mapped glacial extents.

In addition to the digital maps provided with the Kauffman and Manley report, the authors created a website devoted to the palaeoglaciation of Alaska (http://instaar.colorado.edu /QGISL/ak_paleoglacier_atlas). The website serves several purposes including the distribution of Alaska plaeoglacier extents in several Geographic Information System (GIS) formats and includes related digital products and images. Figure GL2in this summary was downloaded directly from the *Alaska PaleoGlacier Atlas*. Figure GL3 was generated in using GIS data acquired from the website showing maximum glacial extents reached during the last 3 million years. Although the atlas is targeted for a scale of 1:1,000,000, figure GL3 was generated at 1:650,000 to emphasize geography of the 2010 Friends of the Pleistocene (FOP) field area. As a result, glacial extent boundaries appear to be coarse and are imperfectly aligned with the map base. All data made accessible through the online *PaleoGlacier Atlas* draws extensively from the statewide compilation by Coulter *et al.* (1965). In addition, many contributors provided previously unpublished information, adding significant value to the compilation.

The digital map and the Kauffman and Manley report focus on the two glacial limits that can most confidently be determined across the state (Figure GL2): (1) the maximum extent of glaciers; and (2) the Late Wisconsinan. The maximum extent of glaciers largely coincides with the outer limit of drift mapped by Coulter *et al.* (1965). It does not represent a single ice advance, but ranges in age from late Tertiary to Middle Pleistocene. The placement of the maximum glacial limit in many places is essentially an educated guess, based on extrapolation of limited data and guided by regional geographical patterns and general geomorphology. The extent of Late Wisconsinan glaciers is delimited more accurately. Generally, Late Wisconsinan deposits are easily recognized by their sharply-defined moraines on which the details of glacial constructional relief are well preserved. There are no Late Wisconsin glacial extents depicted on the *Alaska PaleoGlacier Atlas* in the 2010 FOP area; however, Maximum Pleistocene glacial extents are shown on some high peaks in the vicinity (Figure GL3).

OVERVIEW OF PLEISTOCENE GLACIATION IN ALASKA

In North America, Alaska is unique because the state encompasses the largest contiguous land area at high latitude that was never glaciated (Figure GL2). Even more land was exposed during intervals when eustatic sea level was lower. The regressed shoreline not only exposed a vast area of continental shelf, but it reduced the maritime influence that today penetrates the state. Continentality increased in some areas by as much as 800 km. Lower atmospheric temperature and increased sea-ice cover further reduced the availability of moisture during glacial intervals. Areas beyond the limit of erosion by Pleistocene glaciers preserve an unusually long depositional and geomorphological record of arctic palaeoenvironmental changes (e.g., Hopkins, 1982; Carter *et al*., 1989). Despite their relatively limited extent, glaciers nonetheless influenced these sequences across long distances from the ice margins via fluvial, aeolian, lacustrine and marine systems. Because the glacier fluctuations were driven by the same climatic changes that affected many other geomorphological and biological processes, and because the glaciers themselves influenced an array of interrelated geomorphological processes, the glacial record provides a fundamental stratigraphical framework for the Pleistocene history of much of the state (Hamilton, 1994).

Although most of Alaska and its adjacent continental shelves were never glaciated *(contra* Grosvald & Hughes, 1995; Grosvald, 1998), its vast mountainous terrain generated a mass of glacier ice comparable to that of all the rest of the Western United States combined. The largest expanse of glaciers comprised the coalescent ice caps and piedmont lobes that extended from the Alaska Range to the Gulf of Alaska and from the south-eastern 'panhandle' to the Aleutian Islands. This amalgamation formed the western extension of the North American Cordilleran Ice Sheet and contained most of the glacial ice in Alaska. The ice caps that grew in the Brooks Range, the northern extension of the Rocky Mountain system in northern Alaska, and the Ahklun Mountains in south-western Alaska were the only other major centers of ice accumulation in the state. Lower uplands across the state supported hundreds of smaller valley glaciers; most notable are the small ranges of Seward Peninsula and the Yukon Tanana Upland. In all, glaciers once covered about 1,200,000 km^2 of Alaska and its adjacent continental shelf; during the Late Wisconsinan, the area was 727,800 km^2. At present 74,700 km^2 of Alaska is covered by ice, or 4.9% of the state; most present-day glacier-ice volume is in the coastal ranges proximal to moisture sources around the Gulf of Alaska.

Because most of Alaska was unglaciated, glaciers were free to expand onto adjacent lowlands, where they left a rich record of moraines and morphostratigraphically related glacial-geological features. Evidence for the extent of glaciers around the Gulf of Alaska is now submerged and obscured, but elsewhere, a succession of moraines is preserved along most mountain fronts. Evidence for multiple glacier fluctuations is also preserved in successions of glacially influenced deposits of lacustrine (e.g., Lake Atna, Ferrians, 1963; and Lake Noatak, Hamilton, 2001), marine (e.g., Yakataga Formation, Plafker & Addicott, 1976; Hagemeister Island, Kaufman *et al*., 2001a), fluvial (e.g., Epigurak Bluff, Hamilton *et al*., 1993) and aeolian systems (loess and sandsheets, Lea & Waythomas, 1990; Begét, 2001; and dunes, Carter, 1981; Mann *et al*., 2002). The glacial history is often better-dated in these depositional settings where volcanic products and organic materials are more commonly preserved. The available age control shows that Alaska has experienced glaciations for as long as anywhere else in the Northern Hemisphere. The geochronology also shows that glaciers fluctuated on time scales ranging from tens of thousands of years to decades, consistent with other records of global climatic changes. The ages of Holocene (e.g., Calkin *et al*., 2001) and Late Wisconsinan (e.g., Porter *et al*., 1983) glacial fluctuations are best documented. The ages and correlations of glacial deposits of the next-older (penultimate) ice advance are beyond the range of radiocarbon dating and have remained controversial, as they are in other places in North America. Previous studies generally interpreted the penultimate advance to be younger than the Last Interglacial (Early Wisconsinan *s.l.*) and several new studies have amassed geochronological evidence for an Early Wisconsinan *(s.l.)* age. On the other hand, tephrostratigraphical, palaeoecological, pedogenic and luminescence evidence from the southern and central parts of Alaska suggest that the penultimate drift might predate the Last Interglacial. This discrepancy underlies the map unit classifications of Coulter *et al.* (1965), which included 'Late Pleistocene' (Qg_4) and 'Middle to Late Pleistocene' (Qg_3) units. The penultimate drift was placed into Qg_4 by workers who favored an Early Wisconsinan age and into Qg_3 for those who preferred a pre-Wisconsinan (e.g., Illinoian) age. Kauffman and Manley (2004) agree with Hamilton (1994), who suggested that the penultimate drift might be different ages in different places.

Results of cosmogenic exposure studies suggest early Wisconsin ages for some penultimate glacial surfaces in central Alaska. However, there are many questions about the use of cosmogenic exposure dating methods in the subarctic, such as how assumptions about snow cover and how frost stirring (especially with pebble collections) affects results (PB).

MAXIMUM GLACIATION IN THE 2010 FOP AREA

The 2010 FOP trip travels through part the western tip of the Yukon Tanana Upland (YTU). The YTU is a broad region that encompasses rolling hills punctuated by several rugged peaks scattered between the Yukon and Tanana rivers in east-central Alaska. The glacial history of the Mount Prindle area (east of the FOP area) was discussed by Weber & Hamilton (1984); Weber (1986) provided a summary of the entire region. During the maximum phase of glaciation, more than 20% of the area was glaciated. Ice caps probably developed on all massifs above 900 m altitude, with outlet glaciers radiating as much as 56 km down major troughs. The maximum limit of Pleistocene glaciers shown on the digital map corresponds closely with that of the Charley River Glaciation of Weber (1986; also see Hamilton, 1994, Fig. 7). Glaciers of the Late Wisconsinan were generally restricted to cirques and tributary valleys above 1200 m altitude.

Florence Weber (1986) described evidence for the Charley River glacial episode (named for the subdued morainal landforms and erratic boulders along the Charley River in the vicinity of Ramshorn Creek) at the type locality in the eastern YTU. The type locality differs greatly from the 2010 FOP area in that upland elevations are generally higher. As a result, the environment in the type area supported subsequent glacial episodes and much of the Charley River glacial evidence was modified or erased. Later glacial episodes in the YTU include: Mount Harper (Middle (?) Pleistocene), Eagle (Early Wisconsin (?)), Salcha (Late Wisconsin) and Ramshorn (Holocene). Weber suggests that glaciers of Charley River age left the most extensive glacial record in the YTU and established the basic pattern of modern drainages.

Peaks glaciated during the maximum Pleistocene glaciation in the FOP trip area range from 1009 m in the Elephant Mountains to 1455 m at Cache Mountain (Figure GL3). Roughtop Mountain, appropriately named because tors give it a jagged appearance, has an altitude of 960 m at the summit, within the range of glaciated elevations during Charley River Glaciation or Early(?) Pleistocene time (Figure GL3, See section SG, STOP 11). Roughtop Mountain is not shown on the *Alaska PaleoGlacier Atlas*. However, the high elevation of Roughtop Mountain , evidence of Pleistocene glacial activity at within 40 m elevation to the east in the Elephant Mountains (Figure GL3) suggests that Roughtop Mountain may have been glaciated during Pleistocene maximum although no such evidence has been documented to date. Roughtop mountain may not have had enough mountain mass to support glaciers during the Pleistocene glacial maximum.

One question open for discussion is whether or not tors can be an indicator of Teriary vs. Quaternary glaciation in a given area. This is a difficult question to answer, largely because tor formation rates are not well understood (Yuengling, 1998). Bedrock lithology and weathering characteristics certainly influence tor formation rates. Other influencing factors could include climate and changes in base level. In some areas it is possible to distinguish between old and young glacial events based on the presence or absence of large tors. For example, large granitic tors located in the eastern Alaska Range indicate the limits of early glaciation (R.D. Reger, personal communication, 2010). In addition, Briner and others (2006) suggest that some tors can survive glaciation when overridden by cold-based glaciers. Their results are based on cosmogenic exposure studies and raise additional questions related to tor formation rates in glacial environments.

Sites we will visit may have been influenced by glacial processes. As we travel through the region, let us consider the possible effects of glaciations. Glacially influenced loess and reworked loess deposits will be visible in road and placer cuts. High peaks visible in the 2010 FOP area may have been modified by Charley River and/or older glacial episodes. We can ask ourselves if we see evidence for the Charley River / or older glacial episodes as we look at placer pits and regional geomorphology. Florence Weber (1986) described evidence for Charley River glacial episode at the type locality in the eastern YTU as follows:

- Large erratic boulders at the downvalley limits of U-shaped troughs that radiate from the mountains.
- Possible moraines preserved locally on the sides of valleys as lateral benchlike features and arcuate ridges across a few of the larger drainages.
- Poorly developed cirques and U-shaped valleys on the lower mountains, difficult to distinguish in the field, but evident on aerial photographs.
- Most reliable indicators:
    - Concentrations of large lag boulders in river valleys
    - Erratic boulders on hillsides – consisting of the most durable lithologic type generally granite, gneiss or quartzite.

References Cited:

Briner, J.P., Miller, G.H., Davis, P.T., Finkel, R.C., (2006) Cosmogenic radionuclides from fiord landscapes support differential erosion by overriding ice sheets. *Geologic Society of America Bulletin*, **118/3**, 406-420.

Carter, L.D., Hamilton, T.D. & Galloway, J.P. (1989). Late Cenozoic history of the interior basins of Alaska and the Yukon. *U.S. Geological Survey Circular*, **1026**, 114 pp.

Calkin, P.E., Wiles, G.C. & Barclay, D.J. (2001). Holocene coastal glaciation of Alaska. *Quaternary Science Reviews*, **20**, 449-461.

Cohen, K.M. & Gibbard P.L. (2010). Global chronostratigraphy correlation table for the last 2.7 million years v. 2010. IUGS International Commission on Stratigraphy's (ICS) Subcommission on Quaternary Stratigraphy (SQS) website: http://www.quaternary.stratigraphy.org.uk/charts/

Coulter, H.W., Hopkins, D.M., Karlstrom, T.N.V., Péwé, T.L., Wahrhaftig, C. & Williams, J.R. (1965). Map showing extent of glaciations in Alaska. *U.S. Geological Survey Map*, **I-415**.

Ferrians, O.J., Jr. (1963). Glacolacustrine diamicton deposits in the Copper River Basin, Alaska. Short Papers in Geology and Hydrology 1963, *U.S. Geological Survey Professional Paper*, **475C**, 121-125.

Grosswald, M.G. (1998). Late-Weichselian ice sheets in Arctic and Pacific Siberia. *Quaternary International*, **45/46**, 3-18.

Grosvald, M.G. & Hughes, T.J. (1995). Palaeoglaciology's grand unsolved problem. *Journal of Glaciology*, **41**, 313-332.

Hamilton, T.D., Ashley, G.M., Reed, K.M. & Schweger, C.E. (1993). Late Pleistocene vertebrates and other fossils from Epiguruk, northwestern Alaska. *Quaternary Research*, **39**, 381-389.

Hamilton, T.D. (1994). Late Cenozoic glaciation of Alaska. *In:* Plafker, G. & Berg, H.C. (eds), *The Geology of Alaska, The Geology of North America*, **G-1**. Boulder, Colorado, Geological Society of America, 813-844.

Hamilton, T.D. (2001). Quaternary glacial, lacustrine and fluvial interactions in the western Noatak basin, northwest Alaska. *Quaternary Science Reviews*, **20**, 371-391.

Hamilton, T.D., Reed, K.M. & Thorson, R.M. (eds) (1986), *Glaciation in Alaska - The geologic record*. Anchorage, Alaska Geological Society.

Hopkins, D.M. (1982). Aspects of the palaeogeography of Beringia during the late Pleistocene. *In:* Hopkins, D.M., Matthews, J.V., Jr, Schweger, C.E. & Young, S.B. (eds), *Palaeoecology of Beringia*. New York, Academic Press, 3-28.

Kaufman, D.S., Manley, W.F., Forman, S.L. & Layer, P. (2001a). Pre-late-Wisconsin glacial history, coastal Ahklun Mountains, southwestern Alaska - New amino acid, thermoluminescence and $^{40}Ar/^{39}Ar$ results. *Quaternary Science Reviews*, **20**, 337-352.

Kaufman, D.S., and Manley, W.F., (2004), Pleistocene Maximum and Late Wisconsin glacier extents across Alaska, U.S.A., in Ehlers, J., and Gibbard, P.L., eds., *Quaternary Glaciations - Extent and Chronology, Part II, North America: Developments in Quaternary Science*, **2b**, Elsevier, 9-27. http://notendur.hi.is/~oi/AG-326%202006%20readings/Beringia%20and%20Alaska/D.%20Late_Glacial/Kaufman__Manley_2004.pdf

Lea, P.D. & Waythomas, C.F. (1990). Late-Pleistocene aeolian sand sheets in Alaska. *Quaternary Research*, **34**, 269-281.

Manley, W.F., and Kaufman, D.S., 2002, Alaska PaleoGlacier Atlas: Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, http://instaar.colorado.edu/QGISL/ak_paleoglacier_atlas, v1.

Mann, D.H., Heiser, P.A. & Finney, B.P. (2002). Holocene history of the Great Kobuk sand dunes, northwestern Alaska. *Quaternary Science Reviews*, **21**, 709-731.

Plafker, G. & Addicott, W.O. (1976). Glaciomarine deposits of Miocene through Holocene age in the Yakataga Formation along the Gulf of Alaska margin, Alaska. *In:* Miller, T.P. (ed.), *Recent and Ancient Sedimentary Environments in Alaska*. Anchorage, Alaska Geological Society, Q1- Q23

Porter, S.C., Pierce, K.L. & Hamilton, T.D. (1983). Late Wisconsin mountain glaciation in the western United States. *In:* Porter, S.C. (ed.), *Late Quaternary environments of the United States*, **1**, *The Late Pleistocene*. Minneapolis, University of Minnesota Press, 71-111.

Rutford, R.H. Craddock, C. Bastien, T.W. (1967) Late Tertiary glaciations and sea-level changes in Antarctica, *Paleogeography, Paleoclimatology, Paleoecology*, **5/1**, 15-39

Rutford, R.H., & McIntosh W.C.,(2007), Jones Mountains, Antarctica: Evidence for Tertiary glaciation revisited: in Antarctica: A Keystone in a Changing World – Online Proceedings of the 10th ISAES, edited by A.K. Cooper and C.R. Raymond et al., USGS Open-File Report 2007-1047, Extended Abstract 203, 5 p.

Weber, F.R. (1986). Glacial geology of the Yukon-Tanana Upland. *In:* Hamilton, T.D., Reed, K.M., Thorson, R.M. (eds), *Glaciation in Alaska - The geologic record*. Anchorage, Alaska Geological Society, 79-98.

Weber, F.R. & Hamilton, T.D. (1984). Glacial geology of the Mt. Prindel area, Yukon-Tanana upland, Alaska. *Alaska Division of Geological and Geophysical Surveys Pro-fessional Report*, **86**, 42-48.

Yuengling, K.R., 1998. Cosmogenic ¹?Be/²?Al exposure dating of Alaskan tors. M.Sc. thesis, University of Alask-Fairbanks, 158 p.

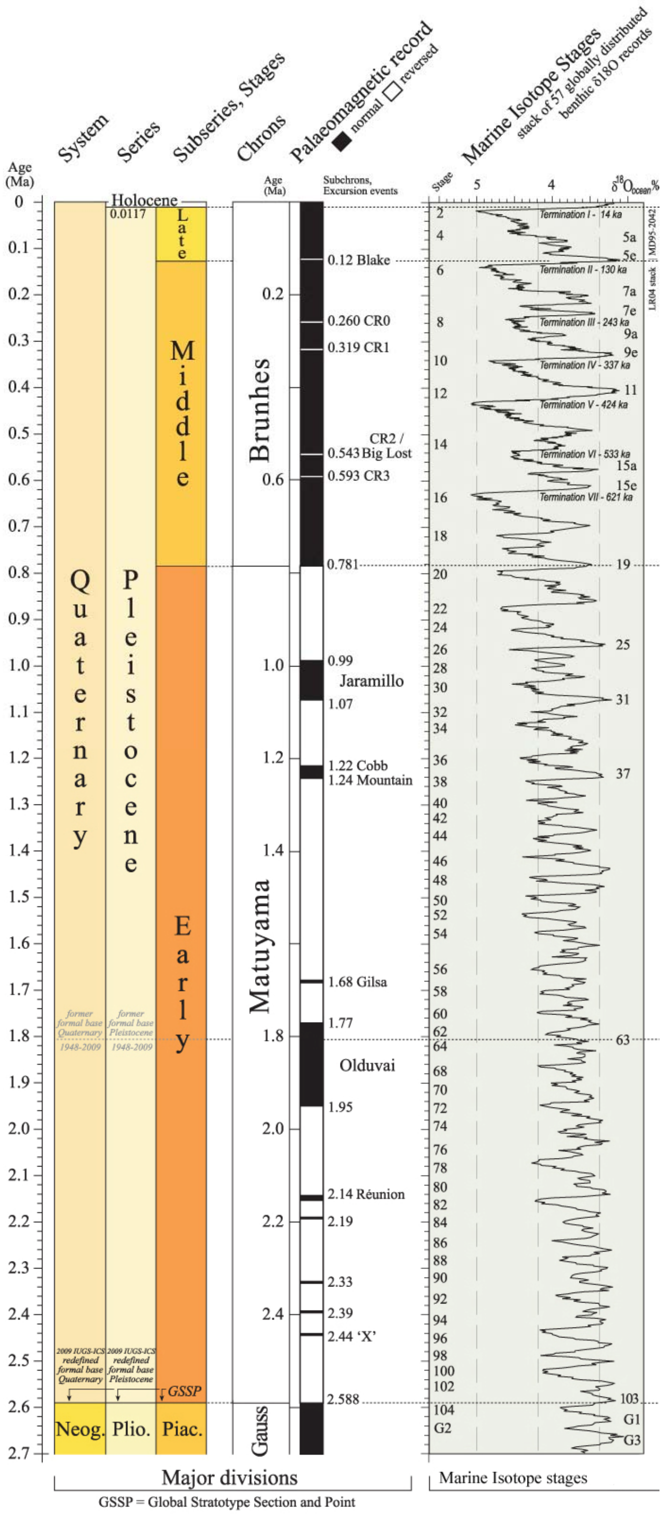
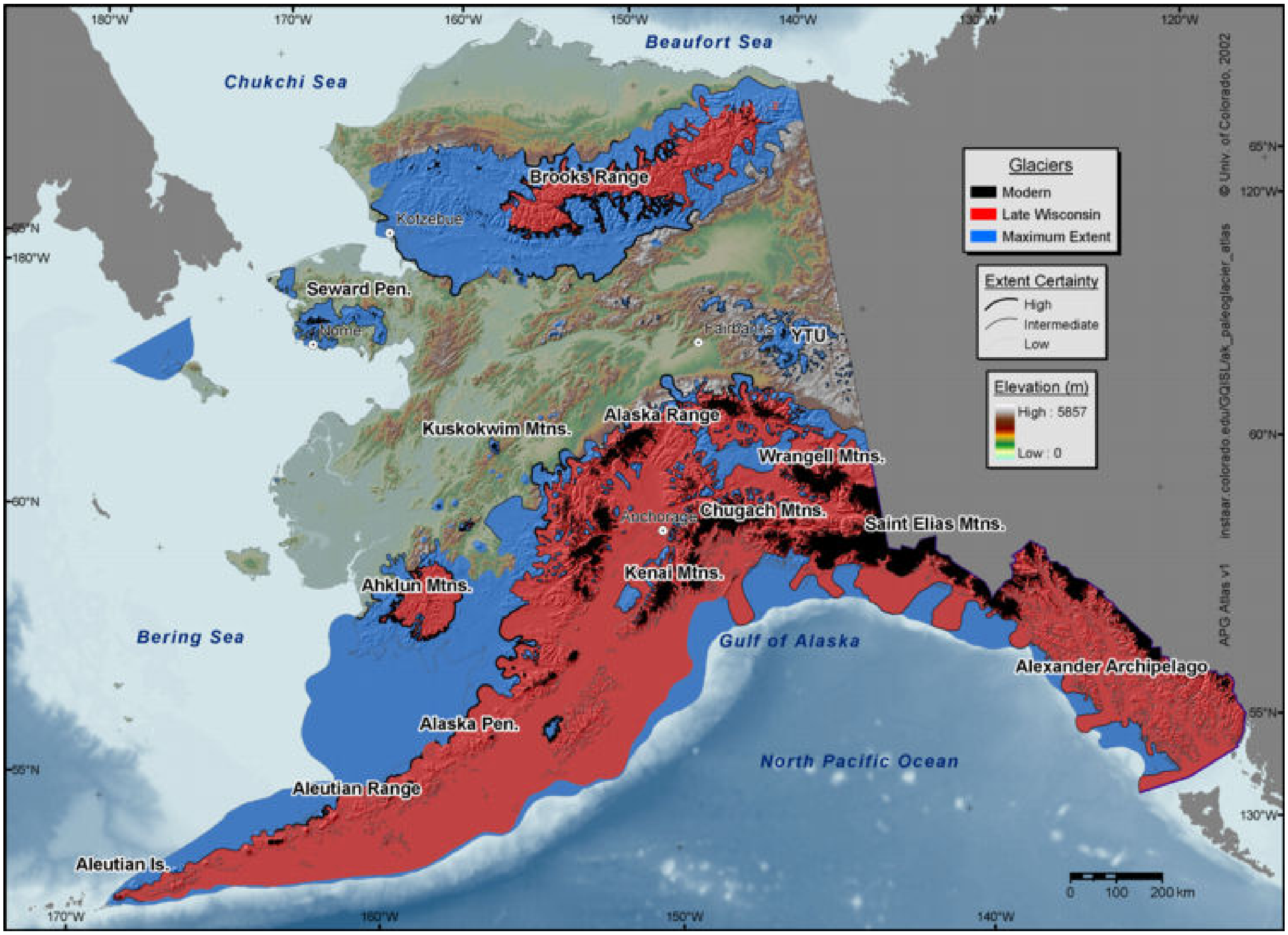


Table GL1 Modified Global Chronostratigraphic Correlation Chart.
http://www.quaternary.stratigraphy.org.uk/charts



Fugure GL2 - Late Wisconsin and maximum (3 milion years or less) glacial extents in Alaska.
University of Colorado, http://instaar.colorado.edu/QGISL/ak_paleoglacier_atlas, v1.

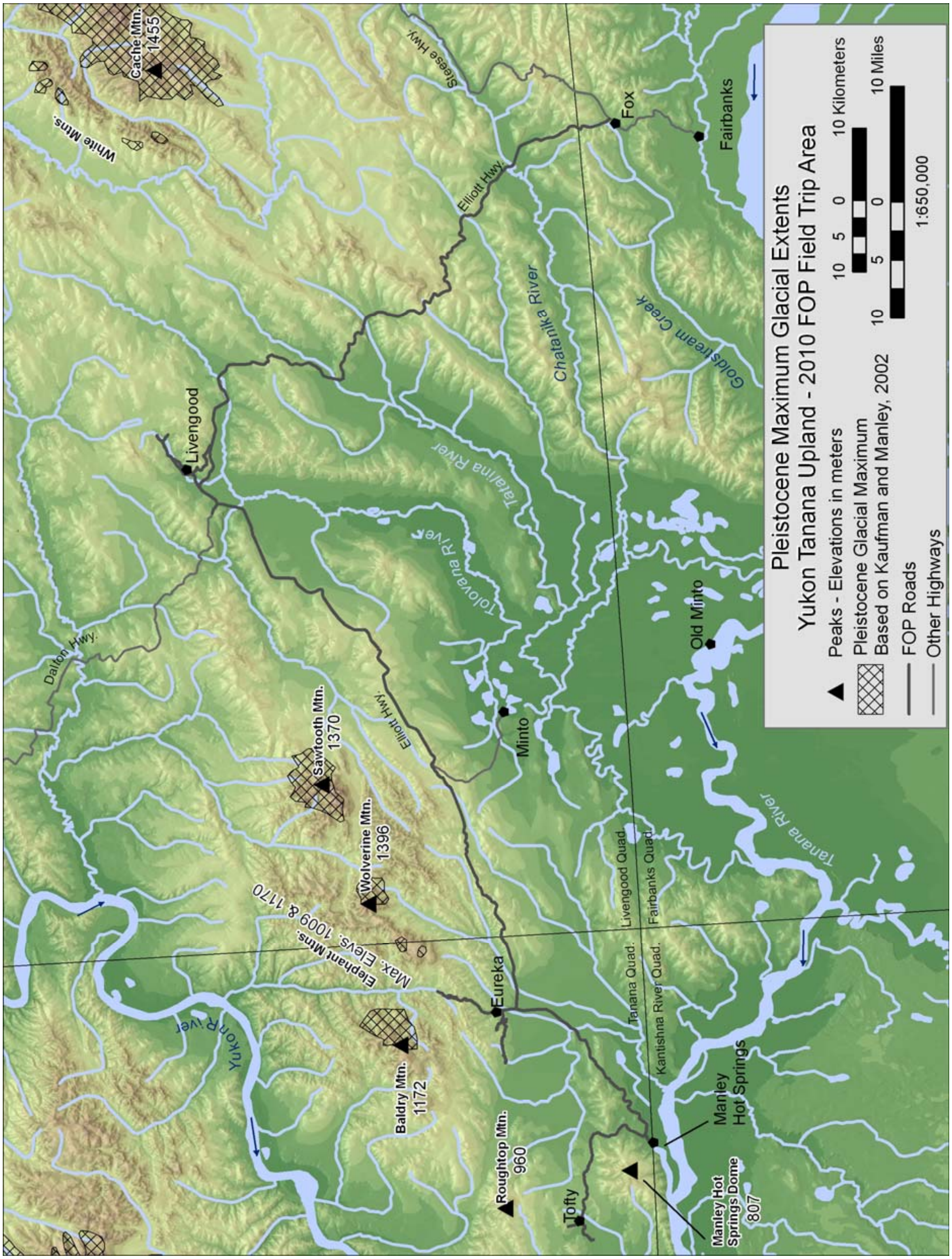


Figure GL3 Pleistocene maximum glacial extents in the 2010 FOP field trip area