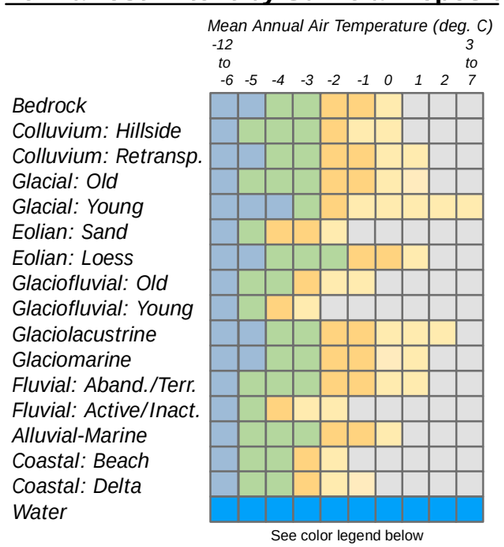
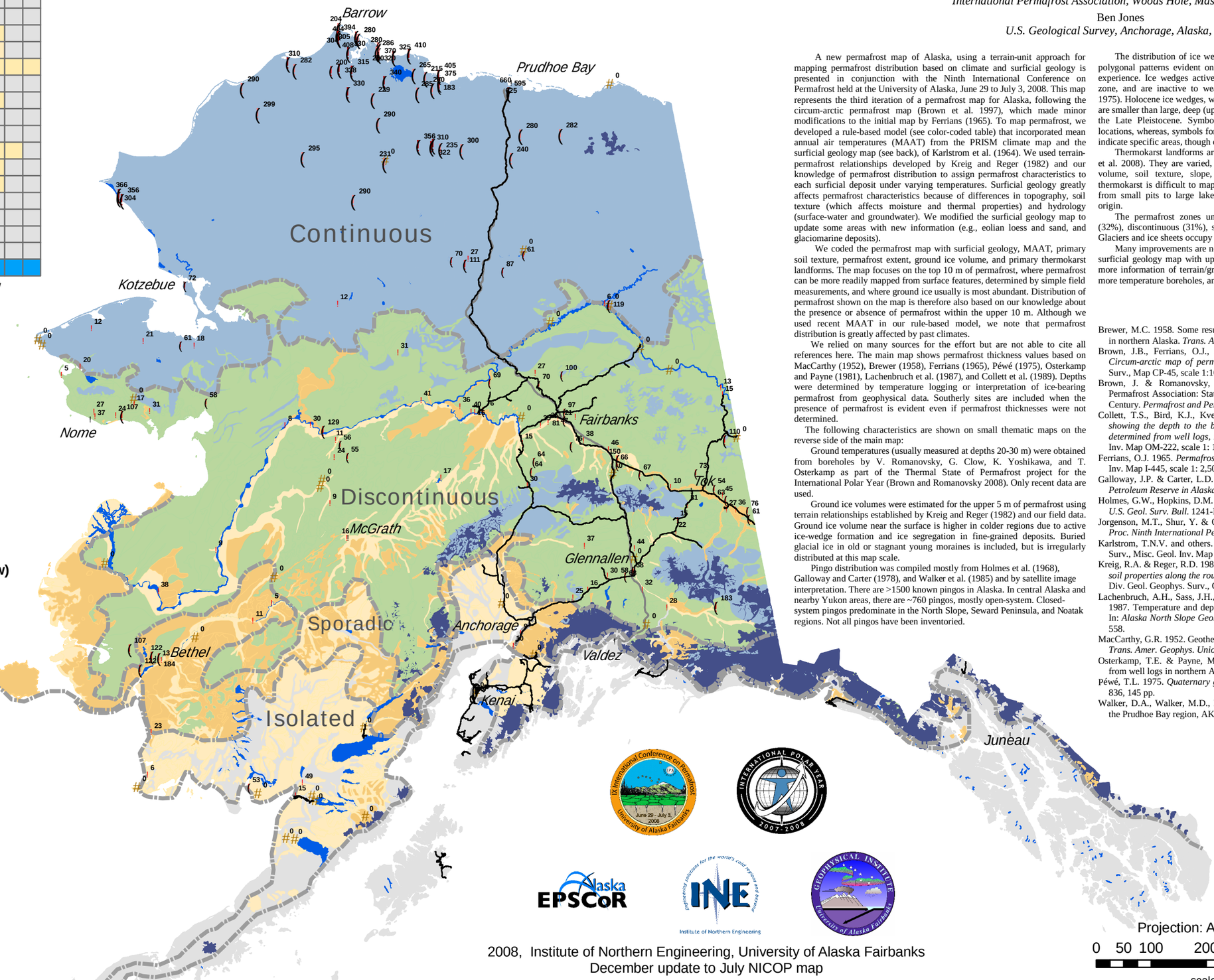
Permafrost Characteristics of Alaska

Torre Jorgenson, Kenji Yoshikawa, Mikhail Kanevskiy, and Yuri Shur
University of Alaska Fairbanks, Institute of Northern Engineering, Fairbanks, Alaska, USA
Vladimir Romanovsky, Sergei Marchenko, and Guido Grosse
University of Alaska Fairbanks, Geophysical Institute, Fairbanks, Alaska, USA
Jerry Brown
International Permafrost Association, Woods Hole, Massachusetts, USA
Ben Jones
U.S. Geological Survey, Anchorage, Alaska, USA

Permafrost Extent by Surficial Deposit



See color legend below



Legend

Permafrost Distribution

- Glacier
- Continuous (>90%)
- Discontinuous (50-90%)
- Sporadic (10-50%)
- Isolated (>0-10%)
- Absent (0%)
- Large Waterbodies (unfrozen below)
- Permafrost_Zones Generalized

Permafrost Depth (m)

- ! 5 - 50
- (51 - 100
- (101 - 200
- (201 - 300
- (301 - 500
- (501 - 600
- # Permafrost present but depth unknown

Other Features

- Major Roads
- Trans-Alaska Pipeline

A new permafrost map of Alaska, using a terrain-unit approach for mapping permafrost distribution based on climate and surficial geology is presented in conjunction with the Ninth International Conference on Permafrost held at the University of Alaska, June 29 to July 3, 2008. This map represents the third iteration of a permafrost map for Alaska, following the circum-arctic permafrost map (Brown et al. 1997), which made minor modifications to the initial map by Ferrians (1965). To map permafrost, we developed a rule-based model (see color-coded table) that incorporated mean annual air temperatures (MAAT) from the PRISM climate map and the surficial geology map (see back), of Karlstrom et al. (1964). We used terrain-permafrost relationships developed by Kreig and Reger (1982) and our knowledge of permafrost distribution to assign permafrost characteristics to each surficial deposit under varying temperatures. Surficial geology greatly affects permafrost characteristics because of differences in topography, soil texture (which affects moisture and thermal properties) and hydrology (surface-water and groundwater). We modified the surficial geology map to update some areas with new information (e.g., eolian loess and sand, and glaciomarine deposits).

We coded the permafrost map with surficial geology, MAAT, primary soil texture, permafrost extent, ground ice volume, and primary thermokarst landforms. The map focuses on the top 10 m of permafrost, where permafrost can be more readily mapped from surface features, determined by simple field measurements, and where ground ice usually is most abundant. Distribution of permafrost shown on the map is therefore also based on our knowledge about the presence or absence of permafrost within the upper 10 m. Although we used recent MAAT in our rule-based model, we note that permafrost distribution is greatly affected by past climates.

We relied on many sources for the effort but are not able to cite all references here. The main map shows permafrost thickness values based on MacCarthy (1952), Brewer (1958), Ferrians (1965), Péwé (1975), Osterkamp and Payne (1981), Lachenbruch et al. (1987), and Collett et al. (1989). Depths were determined by temperature logging or interpretation of ice-bearing permafrost from geophysical data. Southerly sites are included when the presence of permafrost is evident even if permafrost thicknesses were not determined.

The following characteristics are shown on small thematic maps on the reverse side of the main map:

Ground temperatures (usually measured at depths 20-30 m) were obtained from boreholes by V. Romanovsky, G. Clow, K. Yoshikawa, and T. Osterkamp as part of the Thermal State of Permafrost project for the International Polar Year (Brown and Romanovsky 2008). Only recent data are used.

Ground ice volumes were estimated for the upper 5 m of permafrost using terrain relationships established by Kreig and Reger (1982) and our field data. Ground ice volume near the surface is higher in colder regions due to active ice-wedge formation and ice segregation in fine-grained deposits. Buried glacial ice in old or stagnant young moraines is included, but is irregularly distributed at this map scale.

Pingo distribution was compiled mostly from Holmes et al. (1968), Galloway and Carter (1978), and Walker et al. (1985) and by satellite image interpretation. There are >1500 known pingos in Alaska. In central Alaska and nearby Yukon areas, there are ~760 pingos, mostly open-system. Closed-system pingos predominate in the North Slope, Seward Peninsula, and Noatak regions. Not all pingos have been inventoried.

The distribution of ice wedges was determined from the literature, from polygonal patterns evident on remote sensing imagery, and from our field experience. Ice wedges actively form mainly in the continuous permafrost zone, and are inactive to weakly active in the discontinuous zone (Péwé 1975). Holocene ice wedges, which are limited to the top 3-5 m of permafrost, are smaller than large, deep (up to 35 m) syngenetic ice wedges formed during the Late Pleistocene. Symbols for abundant ice wedges denote general locations, whereas, symbols for sparse Holocene and Late Pleistocene wedges indicate specific areas, though distribution remains poorly known.

Thermokarst landforms are abundant in all permafrost zones (Jorgenson et al. 2008). They are varied, due to differences in temperature, ground ice volume, soil texture, slope, and hydrologic conditions. Abundance of thermokarst is difficult to map because of the wide range in size of features from small pits to large lakes, and similar landforms may have different origin.

The permafrost zones underlie 80% of Alaska, including continuous (32%), discontinuous (31%), sporadic (8%), and isolated (10%) permafrost. Glaciers and ice sheets occupy 4% of the area.

Many improvements are needed for a better permafrost map, including: a surficial geology map with updated information and better spatial accuracy; more information of terrain/ground ice/temperature/permafrost relationships, more temperature boreholes, and improved spatial models.

References

Brewer, M.C. 1958. Some results of geothermal investigations of permafrost in northern Alaska. *Trans. Amer. Geophys. Union* 39(1): 19-26.
Brown, J.B., Ferrians, O.J., Heginbottom, J.A. & Melnikov, E.S. 1997. *Circum-arctic map of permafrost and ground-ice conditions.* U.S. Geol. Surv., Map CP-45, scale 1:10,000,000.
Brown, J. & Romanovsky, V.E. 2008. Report from the International Permafrost Association: State of Permafrost in the First Decade of the 21st Century. *Permafrost and Periglacial Processes* 19: 255-260.
Collett, T.S., Bird, K.J., Kvenvolden, K.A. & Magoon, L.B. 1989. *Map showing the depth to the base of the deepest ice-bearing permafrost as determined from well logs, North Slope, Alaska.* U.S. Geol. Surv. Oil Gas Inv. Map OM-222, scale 1: 1,000,000.
Ferrians, O.J. 1965. *Permafrost map of Alaska.* U.S. Geol. Surv. Misc. Geol. Inv. Map I-445, scale 1: 2,500,000.
Galloway, J.P. & Carter, L.D. 1978. *Preliminary map of pingos in National Petroleum Reserve in Alaska.* U.S. Geol. Surv. OF 78-795.
Holmes, G.W., Hopkins, D.M. & Foster, H.L. 1968. Pingos in central Alaska. *U.S. Geol. Surv. Bull.* 1241-H: 1-40.
Jorgenson, M.T., Shur, Y. & Osterkamp, T.E. 2008. Thermokarst in Alaska. *Proc. Ninth International Permafrost Conf., Fairbanks.* In press.
Karlstrom, T.N.V. and others. 1964. *Surficial geology of Alaska.* U.S. Geol. Surv., Misc. Geol. Inv. Map I-357, scale 1:1,584,000.
Kreig, R.A. & Reger, R.D. 1982. *Air-photo analysis and summary of landform soil properties along the route of the Trans-Alaska Pipeline System.* Alaska Div. Geol. Geophys. Surv., Geologic Rep. 66, 149 pp.
Lachenbruch, A.H., Sass, J.H., Lawyer, L.A., Brewer, M.C., and five others. 1987. Temperature and depth of permafrost on the Alaskan Arctic Slope. In: *Alaska North Slope Geology. Alaska Geol. Soc.*, Book 50, Vol. 2: 545-558.
MacCarthy, G.R. 1952. Geothermal investigations on the Arctic Slope Alaska. *Trans. Amer. Geophys. Union* 33(4): 589-593.
Osterkamp, T.E. & Payne, M.W. 1981. Estimates of permafrost thickness from well logs in northern AK. *Cold Reg. Sci Tech.* 5: 13-27.
Péwé, T.L. 1975. *Quaternary geology of Alaska.* U.S. Geol. Surv. Prof. Pap. 836, 145 pp.
Walker, D.A., Walker, M.D., Everett, K.R. & Webber, P.J. 1985. Pingos of the Prudhoe Bay region, AK. *Arctic Alp. Res.* 17: 321-336.

2008, Institute of Northern Engineering, University of Alaska Fairbanks
December update to July NICOP map

Projection: Albers Alaska, NAD 83

0 50 100 200 300 400 500 km

scale 1: 7,200,000