# **Rapid Arctic Transitions due to Infrastructure and Climate (RATIC):** Comparison of the geoecological conditions, permafrost hazards, and infrastructure spread in the Bovanenkovo Gas Field, Russia and the Prudhoe Bay Oilfield, Alaska

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## Abstract

Many areas of the Arctic are undergoing rapid permafrost and ecosystem transitions resulting from a combination of industrial development and climate change as summer sea ice retreats and abundant Arctic natural resources become more accessible for extraction. The Bovanenkovo Gas Field (BGF) in Russia and the Prudhoe Bay Oilfield (PBO) in Alaska are among the oldest and most extensive industrial complexes in the Arctic, and both are situated in areas with extensive ice-rich permafrost. Case studies of the two hydrocarbon fields provide an overview of the baseline geoecological conditions, rates of hydrocarbon development, and perceptions of change by local cultures in these two remote Arctic areas.

### **Conclusions**

- Differences in the underlying surficial geology (BGF: hilly, with mainly marine clays overlaid by alluvial sands and peat; PBO: flat alluvial gravel overlaid by loess and peat) have resulted in very different permafrost conditions and hazards (BGF: mainly tabular ground ice in the uplands, with extensive cryogenic landslides and thermocirques on slopes; PBO: ice-rich loess with extensive thaw lakes, and ice-wedge polygons with extensive thermokarst)
- A recent series of warm summers has triggered a major increase in thermokarst in the PBO and themocirques near the BGF.
- Both fields were discovered at about the same time (PBO: 1968: BGF: 1972). The PBO infrastructure network developed rapidly and by 1977 was connected to the rest of Alaska by the Dalton Highway and the Trans-Alaska Pipeline, which permitted additional development of adjacent oilfields, and export of the oil to the ice-free port at Valdez. The BGF development proceeded much slower. Transport of gas out of the region still awaits construction of pipeline linkages to other gas fields on the Yamal and points further south in Russia and Europe.
- The small populations of indigenous people in both areas have benefited economically from resource development, but with major social consequences. Most threatening to both groups is restricted free access by hunters and herders through their traditional lands.
- Future mega-expansion of infrastructure in both areas, combined with climate-induced changes to local landscapes and permafrost present unprecedented challenges to local communities. The shear scale of the proposed hydrocarbon developments in the next few decades could overwhelm the ability of the local communities to adapt to the changing conditions.
- Successful adaptive management will require full engagement of local people and governments with industry and national governing agencies.
- A new initiative called Rapid Arctic Transitions due to Infrastructure and Climate (RATIC) is a forum for developing and sharing new ideas and methods to facilitate the best practices for assessing, responding to, and adaptively managing the cumulative effects of Arctic industrial infrastructure and climate change.

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Bovanenkovo gas field, Yamal Peninsula Russia: Highly erodible sands and the presence of massive tabular ground ice near the surface contributes to landslides and thermo-denudation of slopes. A large set of cryogenic landslides occurred in Bovanenkovo region in Central Yamal peninsula, Arctic Russia in late 1980's. Mega size Bovanenkovo gas field was found in 1970's and in 2012 production began after large infrastructure construction. In central Yamal peninsula both natural and anthropogenic changes has occurred during the past 40 years. These range from physical obstructions, such as roads, railways, and pipelines, to direct and indirect ecological impacts, such as changes in vegetation and hydrology. Analysis summarized from Kumpula et al. (2011), Kumpula et al. (2012), Khomutov & Leibman (2010), Khomutov et al. (2012) and Liebman et al. (2014).



In addition, a significant amount of new permanent infrastructure has been built since 2004.



Pruchoe Bay oilfield, Alaska: Thermokarst in the form ice-wedge degradation, is expanding along ice-wedges adjacent to roads and in areas away from roads. Between 1990 and 2001, coincident with strong atmospheric warming during the 1990s, natural thermokarst resulted in conversion of low-centered ice-wedge polygons, more active lakeshore erosion and increased landscape and habitat heterogeneity. These geoecological changes have local and regional consequences to wildlife habitat, land-use, and infrastructure. Analysis summarized from Raynolds et al. (2014), Walker et al. (1980, 2014), Romanovsky et al. (2012), Kanevskiy et al. (2013).







eld. A. Gas field was found in 1972. In late 1980's gas field construction began. In 1988, direct and indirect impacts of Bovanenkovo ga nmer pastures primarily on the territories used by brigades 4 and 8. Brigade 2 had been relatively unaffected until 2011. As Soviet Union ed in Bovanenkovo. In 2006 Gasprom made new plan to start production and heavy construction phase began. Since ed impacts significantly on lands used by herders south of the Mordy-yakha River. The main gas field no longer functions as ar rtation networks. **B.** Patterns of mechanical surface disturbance and revegetation in the vicinity of Kekh, the denuded of vegetation by heavy off-road vehicle traffic and construction activities. The black polygon circumscribes the extent of disturbance beginning in 1988 and remains consistent across all three images for spatial reference. In the middle scene, VHR Quickbird-2 shows the extent of revegetation after 14 years of natural regeneration. The bottom Landsat TM scene indicates that much of the bare ground has been totally revegetated by 2011

**Examples of typical** cryogenic landslides and thermocirques

Note the tabular ice below the layer of soil in right photo.







he stages of visibly affected area expansion encompassing off-road tracks, roads, quarries and ngs. After only modest development from the mid-1990's to 2009, after that infrastructure expansion has been very rapid, including railroad, pipeline and airfield building. **B.** 2<sup>nd</sup> layered map illustrates the stages of permanent infrastructure development encompassing roads, quarries and residential or other buildings in the core area of Bovanenkovo. C. Nenets camp next to new drill rig. D. Nenets brigade crossing the Se-yakha river in the center of Bovanenkovo gas field. Usually local Bovanenkovo workers help herders by taking children and elders across the river with boats (Photos by Timo Kumpula July 2011).

Reindeer herders have lost many traditional camp sites and they have had to change their traditional routes. Main aim for herders nowadays is to pass the gas field soon as possible to access coastal pastures.