МЕРЗЛОТОВЕДЕНИЕ

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TRADITIONAL ICE CELLARS (LEDNIK, BULUS) IN YAKUTIA: CHARACTERISTICS, TEMPERATURE MONITORING, AND DISTRIBUTION

Ice cellars (Lednik in Russian, Bulus in Sakha) dug into the permafrost layer are a natural form of refrigeration for preserving block ice for drinking water, storing harvested food (fish, game, and livestock such as reindeer), and fermenting food. Ice cellars are traditionally used by indigenous Siberian people, such as Even, Evenk, Chukchi, Yukagir, Dolgan, and Yakut. In cooperation with local stakeholders, we measured the temperature of many ice cellars at each region (Ulus) of Sakha Republic. Though ice cellars are widely used in permafrost regions, these structures and the purpose for their use as well as the methods of maintenance are quite different among communities and due to permafrost temperature conditions. Monitoring ice cellar temperatures and recording descriptions of ice cellars is important in the face of climate change in terms of permafrost studies and archiving traditional techniques of living with permafrost.

Keywords: *Ice cellar, Lednik, Sakha, Permafrost, Thermal regime, Indigenous community.*

Introduction

Permafrost underlies more than one-quarter of Earth's land area. In Siberia, over 90% of the land is underlain by permafrost, a region where most of the indigenous people of Siberia live. The focus of this paper is on ways that traditional families and communities in Sakha Republic use permafrost. Ice cellars (*Lednik* in Russian, *Bulus* in Sakha) are a form of indigenous technology used by Siberian people for refrigeration; ice cellars provide easy access to stored foods. In the Sakha Republic, not only are subsistence foods stored in ice cellars, including caribou, ducks, fish, and marine mammals, which constitute a

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substantial proportion of the local diet, but also ice blocks for drinking water during the summer months, especially in Central Yakutia. Ice cellar infrastructure has both cultural and practical significance. Concern has been expressed recently over the impact of climate change on ice cellars and future sustainability of this resource [1]. This paper reports the results of an ongoing education and outreach project in Russia to understand and accurately report the thermal state of ice cellar temperature regimes and the surrounding permafrost environments [6].

Study Area

Sakha Republic is the largest republic of the Russian Federation; it encompasses most of eastern Siberia and is an area of permafrost terrain. Several residents of the region participated in this study; they were asked to measure and record the temperature in their ice cellars year-round. We visited over 100 schools and communities in Sakha Republic, including Dolgan, Even, Evenk, and Yukagil, where we discussed local ice cellars with residents (figure 1).

Figure 1. Distribution of ice cellars and their structure types overlaying the permafrost map (red dots: vertical cellar, yellow dots: declining slope cellar, blue dots: industrial cellar)

The indigenous people of Sakha Republic have adapted the permafrost environment for their use since they immigrated to the area. Most of Sakha Republic was not glaciated; thus deep permafrost developed during the Last Glaciation. Interest in the thermal condition of permafrost and methods of excavating it were established when valued minerals were discovered in Sakha. Yakutsk, the capital city of Sakha Republic, has one of the richest and oldest permafrost research histories in the world [3]. This long history of interest in permafrost and digging in frozen ground helped develop a variety of ice cellar types in this area. The Soviet Union supported and encouraged the development of community-based or industrial ice cellars associated with mining activities, which encouraged unique ice cellar structures all over Siberia.

Structure of Ice Cellars

People in northern and central Yakutia (another term for the Sakha Republic) have probably used cold storage in permafrost since they immigrated to the area. Before the invention of metal apparatuses or heavy equipment, humans simply dug vertical shafts to store food in or buried food under sphagnum during summer months (*M. Pogodaev,* personal comm. 2016). Contemporary cellars in northern Sakha regions are built primarily for the personal use of one or several families (such as a fishing crew and their dependents), and typically consist of a vertical shaft that leads to a small chamber or horizontal tunnel excavated into permafrost (Figure 2).

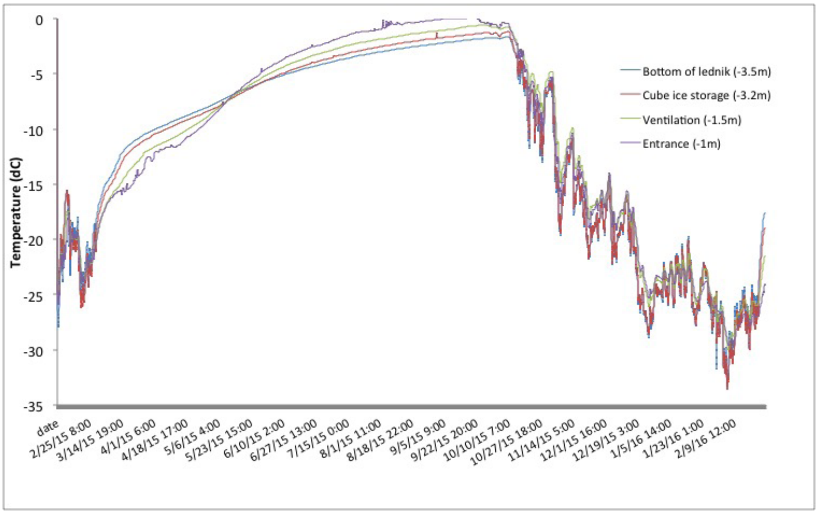

Figure 2. Typical structure of a vertical cellar. Access to the cellar is usually covered with a small shed built over the entrance to prevent snow accumulation and provide convenience for winter cooling

These cellars vary in specific dimensions. The vertical shaft is 1 to 6 m deep and penetrates to a depth such that the ceiling of the chamber is below the permafrost table, which is usually less than 1 m in undisturbed areas but more than 2 m in villages. Older ice cellars or ones in southern permafrost areas are built primarily for personal use, and typically consist of a 15 to 20 degree declining tunnel entrance that leads to a small chamber excavated into permafrost or seasonally frozen soil (Figure 3).

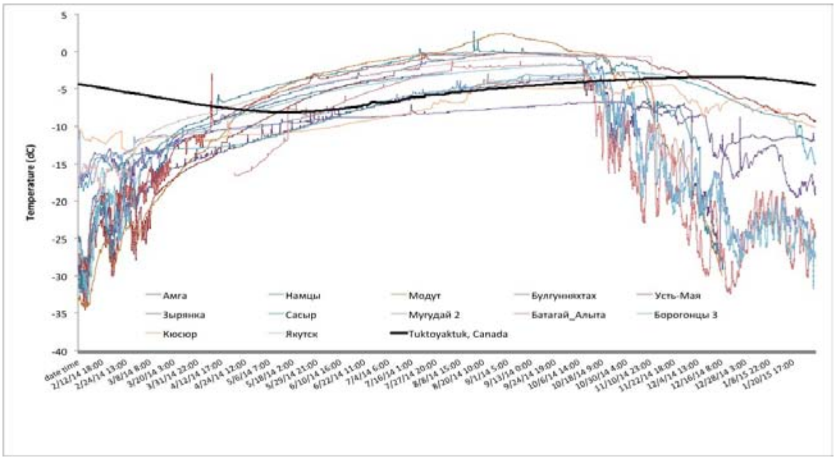

Figure 3. Typical structure of a declining slope cellar. The cellar depth is not far from the ground surface. The cellar is easy for maneuvering and for stringing frozen items in and out, and is especially good for block ice

The depth of the chamber is 1-3 m from the ground surface. This type of cellar is similar in design to European wine and food cellars or icehouses, and provides easy access and maneuvering of what has been stored. In addition to private cellars, there are deeper, longer, and larger-capacity commercial/industrial cellars, most of which were built during the Soviet era for communities in many parts of Sakha Republic. Many of these cellars were dug horizontally a few hundred meters, and even kilometers, into hillsides, and had railroads for managing frozen items. Though abundant, these large-capacity cellars today receive limited use; some have been reestablished as local museums (Figure 4).

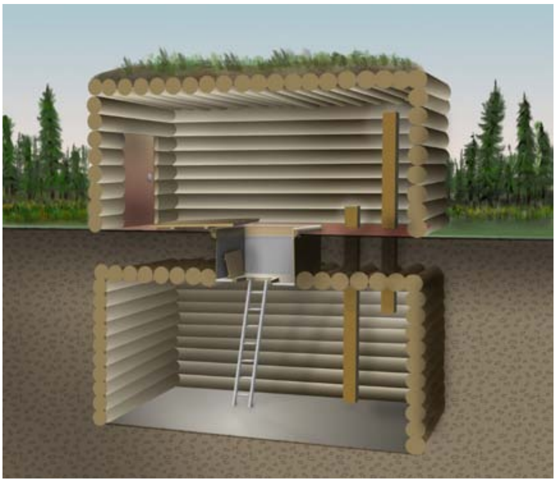

Figure 4. Soviet era deep cellar. Cellars are used for industrial purposes today or sometimes for an entire community

Recently, the media has referred to ice cellar "failures" [1] or has reported that cellars no longer function reliably, because food has thawed while in storage or because an owner cannot safely access a cellar. In our visits to communities in Sakha Republic, we did not observe ice cellar failures; however, several cellars were closed due to a recent fall storm flooding event and filling by ice (e.g., Oymiakon, Verkhoyansk; see Figure 5). Other than these closures, massive numbers of ice cellars were no longer manageable after the Soviet Union collapsed (e.g., Iengra, Tomtor).

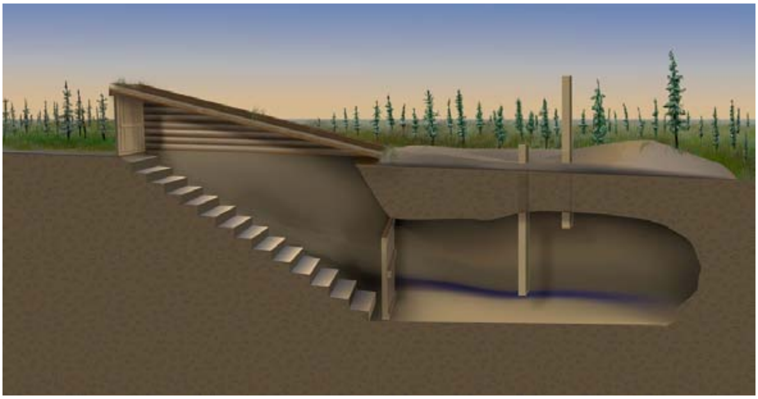

Figure 5. Abundant ice-filled cellar at Oymiakon. The cellar was used for over 100 years, but it is temporarily abandoned for maintenance since a recent flooding event (2012)

Annual Usage and the Maintenance of Ice Cellars

Ice cellars are an efficient solution for storing large volumes of harvested ice, fish, and reindeer meat in Even and Evenki villages. Ice cellars require maintenance and annual cleaning; they are usually cleaned just before using. In northern communities, cleaning occurs in late fall for storage of marine mammals and fish during winter. In central Yakutia, ice cellars that are used mostly for storage of block ice are prepared in middle or late winter. Preparation involves removing all of the meat and fish from the previous year and thoroughly cleaning the cellar, including adding a layer of fresh snow. Pond ice thickness is an important factor in the harvest and storage of block ice. The ice thickness must be 50–60 cm for cutting from a pond. Stored block ice is used for drinking water during the summer months in many part of central Yakutia. Though ice storage in a permafrost cellar is ideal, the temperature inside the cellar does not have to be below zero year-around; it just needs to stay cold enough to delay a rise in temperature due to warmer summer months. Underground storage this far north functions in this way, with a 4- to 5-month delayed response to rising surface temperatures. This method of cold storage is similar to how icehouses were used in the 19th century before electric refrigeration.

Humidity is higher in cellars, and the potential for fungus growth is always present, even in constant negative temperatures. Some cellars used for fermentation purposes take advantage of temperature and relative humidity characteristics. Fermentation is more often practiced by the Chukchi in Chukotka and by North American indigenous cultures than by people living in Yakutia.

Every several years, water is sprayed on the walls of vertical cellars in northern regions and horizontal industrial cellars to develop an icy surface for preventing sublimation of the permafrost. These ice-coated cellar walls prevent sublimation, keep the cellar clean, and help stabilize the walls. Table 1 shows annual cellar usage and maintenance patterns in each area.

Results

The annual temperature cycle of most ice cellars in Yakutia indicates significant cooling during winter months due to opening of doors/leads. The maximum daily temperature observed in the ice cellars ranged from −10.4 to +2.7°C. The temperatures in some cellars in central Yakutia (Modut and Eday) rise above 0°C. The mean annual temperatures ranged from −14.4 to −3.6°C. In contrast, the mean annual air temperature in Yakutsk is around −9°C. The warmest cellar temperatures were observed in fall (September to October), and typically the doors/leads are opened to introduce cold air after November. Thus, the coldest temperatures occurred during winter months, in direct response to air temperature. The temperatures in Ust-Maya and Sasur (Figure 6) suggest when the cellar door/lead was not open during winter monitoring, as the temperature increases until November/December and the winter cellar temperature is 10–20°C warmer than other cellars. The average annual temperature amplitude, i.e., the difference between the warmest and coldest temperatures, range from 9.4 to 36°C in the cellars. This difference results from the depth of the cellar chambers, the original permafrost seasonal amplitude range, and the structure of the cellars.

Figure 6. Mean monthly temperatures in the ice cellars. Approximate cellar locations indicated from Figure 1.

Discussion

Based on public media reports and our own field observations, evidence indicates several major problems related to the maintenance and use of ice cellars in North America [2, 4]. Factors other than climate warming could be negatively affecting cellars, including (1) local soils known to be ice-rich and high in salinity; (2) proximity to flooding rivers or the coast; (3) influence of urban development on local hydrology; and (4) a suite of potential influences related to proximity to other types of infrastructure [4]. However, in Yakutia, these problems of North American cellars were not observed. Descriptions of cellar failures in Yakutia most commonly involve flooding. Typical of rivers in the Arctic, in the Lena, Yana, Indigirka, and Kolyma rivers, flooding occurs during spring breakup due to the snow melting and following the south-to-north stream flow. Springtime floodwater in a cellar would be relatively easy to remove during hot summer months. Though fall flooding does not occur frequently, it has the potential to be a serious problem because there may not be enough time to remove the water before temperatures drop, or it may be too cold to operate draining equipment. If ice fills a cellar completely, it must be abandoned for use, such as with cellars in Oymiakon and Verkhoyansk due to recent fall fooding. During the Soviet era, Kolkhoz or Sovkhoz operated ice cellars that were well-maintained and manageable, overseen by responsible individuals. This kind of intense maintenance helps prevent cellar failure or flooding damage in a community, but has not been economically efficient since the Soviet Union era.

Air convection use in a cellar is a unique design and typically seen in Even and Evenki communities (Figure 7), but not in North American indigenous cellars. A natural cooling system would be a great invention for ice cellars. We observed a similar design in Siberian indigenous communities such as around Baikal and Chukotka. Air convection systems work efficiently during the winter months especially after cold snaps. During March and May, the temperature gradient in ice cellars is reversed. The expected cellar ventilation is blocked by ice crystals.

Figure 7. Thermal characteristics of the air convective cellar

Conclusions

Ice cellars are an important cultural and economic resource for residents of Arctic communities. Climatic conditions could significantly affect the ground thermal regime and, therefore, ice cellars, local soil conditions, flooding events, and factors associated with urban development. These interactions will require further investigation. Soil characteristics and ground ice conditions vary substantially over distances of only a few meters, necessitating detailed surveying. Each community has its own set of factors to consider, and they may vary from the factors discussed here.

In cases where ice cellar degradation is observed, many engineering options are available for maintenance; for example, thermo-siphons could be used to artificially maintain frozen conditions [5]. Thermo-siphons, though having a long history of use in Sakha by Russian engineers, have never been used to maintain ice cellars, but they should be considered for ice cellar maintenance in the future.

Acknowledgments

We thank the owners of the ice cellars for access and information. Local residents, communities, and schools provided detailed information about the maintenance and performance of ice cellars. We are grateful to the North Eastern Federal University for its cooperation on this project. CH2MHill Polar Services and the Russian Academy of Science Melenkov Permafrost Institute provided significant logistical support. This research was supported by grants from the U.S. National Science Foundation (NSF) and by a Fulbright Scholar, U.S. Department of State.

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