Arctic and Subarctic Karst Landforms in North America

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Introduction

Karst in Arctic and Subarctic region in North America contains a wide variety of surficial karst landform characteristics due to not only extensive glacial activities, but also interglacial karst processes during the Pleistocene age.

The purpose of study is to identify how Arctic and Subarctic karst are formed, and what type of glaciokarst landforms are developed in North America. Although most karst landforms can be destroyed during and created after glaciation, currently inactive paleo-karst landform generated postglacially, and may, in fact, yet be active.

Three major climatic regions and vegetation types can be delineated (Fig. 5.21): Polar Desert, High Arctic Tundra, and Low Arctic Tundra. Low Arctic Tundra Region located mainly in the Northwest Territories, the Hudson Bay region, and the western part of Alaska. The Low Arctic Tundra zone is low the northern parts of Saskatchewan, Manitoba, Ontario, Quebec, and New Fundland (Fig. 1, Fig. 5.21) are located in the low arctic tundra zone. The mean annual temperature in High Arctic Tundra region (74-75° N and 95° E) is -16.5° C; the annual precipitation of this area is 143.5 mm (Table 1).

Lithology of North America is mostly Precambrian igneous and Paleozoic sedimentary rocks. Carbonate rocks are widely distributed (>10 %) (Fig. 1, Fig. 1.2) , but generally buried by

Surface karst landforms

Current karst landscapes of Arctic and Subarctic region are mainly related to the process of the ice retreat and outwash of Wisconsinan age (Ford, 1984). Karst landform systems in Arctic and Subarctic regions vary, depending mainly upon the location (latitude), elevation of carbonate rocks, geologic structural control, solubility, and soil and vegetation covers. Karst landforms can be delineated by the following surface limestone morphologies; a coastal limestone landform, a rugged staircase landform, a classical clint-grike landform, a staircase pavement landform (Fig. 9.6), a platformal micritic limestone landform, an argillaceous basinal landform, a cyclic alteration bed landform, a preferential dissolution landform (Fig. 2.7), an ice-scoured landform, a limestone drumlinoid landform (Fig. 10.6), erratic black on pedestal landform, a stream sink landform (Fig. 10.5), karrens (Fig. 9.5), poljes (Fig. 10.4), and dolines (Fig 9.18, Fig. 10.7).

First, a coastal limestone landform (Fig. 9.6; upper left photo) shows flat and linear joint features. This landform is controlled by both contemporary coastal process and deglaciation in front of coast lines along plane limestone bedrock structure. A rugged staircase landform (Fig. 9.6; upper right photo), staircase pavement landform (Fig. 9.6; lower right), and platformal micritic limestone landform (Fig. 2.7; upper photo) is generally located in between the karst plains and uplands or in valleys. Barren limestone surfaces are typical Arctic and Subarctic glaciokarst landforms. These surface landforms are an evidence of an extreme force of ice friction during the glaciation period, because there are cliff faced masses of limestone layers and deep gorges along the fault or joint lines. Advancing and retreating glaciers excavated and carried large pieces of limestone blocks, creating gorges and poljes. Also, contemporary thawing and freezing break and move limestone blocks. (Fig. 9.6; lower left photo).

A classical clint-grike landform represents active limestone surface dissolution along perpendicular joints. All limestone dissolution is moderated by reacting with acids. Karren features (small limestone valleys) with shallow gorges along the structural joints are somewhat common surface karst landforms in Arctic and Subarctic region.

Argillaceous basinal limestone landforms (Fig. 2.7; lower left photo) are generated by ice advances which erode the hillsides. These landscapes are common in stream valley systems and hillslopes of carbonate bedrock. A cliff form of a cyclic alteration of bed landform (Fig 2.7; lower center photo) illustrates thickness of layers, bedding sequences, dip and strike of carbonate bedrock. Bedding form is relatively important to determine local limestone bedding systems. A landform of preferential dissolution (Fig. 2.7; lower right photo) indicates results of dissolution and weathering process between the gypsum and dolomite bedding. Chemical and physical weathering process may act rock dissolution along the weak part of rocks.

A very recent karst landform (retreated ice about 20 years

B.P.) of an ice-scoured surface (Fig. 10.6; upper left photo) presents remnants of an ice receded barren surface which has subglacial calcite precipitates (white mineral). A limestone drumlinoid landform (Fig. 10.6; upper right) is a kind of micro-karst form (< 1 cm width). Around the circular drumlinoid numerous micro-rills with the calcite deposition are developed. These two calcite deposited surface forms develop and decay seasonally, and depend upon calcite concentration of bedrocks.

An erratic block on a pedestal on a molded glacial ridge with a stream sink landform are postglacial landforms (Ford, 1989) (Fig. 10.5). The dissolution under the erratic is characteristic. The sinking stream indicates that subterranean hydro-passages could be connected into the sinkhole where numerous unconsolidated small erratics with debris are accumulated. This hydro-recharge sink also represents either the conjunction of different lithology or transition of faults and joints. Both glacial till and outwash could fill the sinkholes.

Karrens are the most fundamental surficial karst landform in limestone region (Jennings, 1987) (Fig. 9.5). In general, karrens are from one centimeter to ten meters in width, and micro-karren less than one centimeter. The rinnenkarren forms tree or hair shapes is initial dissolution of the surface limestone. They are commonly less than one centimeter in width (Ford, 1989) (Fig. 9.5; upper left photo). Wallkarren is developed vertically, and is disconnected along each limestone layers (Fig. 9.5; lower left photo). Rundkarren has deeper valleys, but flat surfaces. This karren is developed under conditions of deforestation (Fig. 9.5;

upper right photo). The denuded rundkarren will be the last stage of karren development (Fig. 9.5; lower right photo). Its valleys are deeper than any other karrens, and ridges are sharp. A rate of dissolution in Subarctic region is higher than in the Arctic because of the high acidic precipitation influenced by pollution.

Poljes are large enclosed depressions in closed systems of karst terrains (Ford, 1989) (Fig. 10.14). Ford divides these into three basic polje types: border, structural, and baselevel polje. These three polje types are derived from Gams (1973, 1978) who classified five different types of poljes; border, piedmont, peripheral, overflow, and baselevel polje. There are three criteria for poljes according to Gams (1978); a) flat floor in rock or in unconsolidated sediments, b) a closed basin with a steeply rising marginal slope at least on one side, and c) karstic drainage. Most poljes are tropical, but some in cases can be identified in Subarctic areas (Ford and Brook, 1980). Although the origin of polje is not precisely defined, the structural control of polje origin is a dominant theory (Gams, 1978) (Fig. 11.4). It is not explained in the literatures that the origin of polje is caused by cuesta structure, collapsed large cave systems, and tectonic influences. However, it is obvious that poljes are very deep (150 m; Fig. 10.14; upper photo) and big scale (19 km; world widest polje in Livanjsko polje).

Dolines (sinkhole) can be the diagnostic karst landform (Ford, 1989), because they show evidences of subsurface cavities by limestone dissolution process. Most dense spatial depressions are distributed in tropical karst regions. Dolines in Arctic and

Subarctic appear to be low populations, but are very big collapsed (Fig. 9.18) and closed (Fig. 10.11) features. There are three types of dolines: solution doline, collapsed dolines, and subsidence doline.

The solution doline is a common natural process in karst region, is called the karst corrosion. Solution doline requires karren development, numerous cracks and joints, and high water table fluctuations. Figure 9.43 presents an evolution of karst surface landforms according to Cvijic (1918). Figure 9.8 also illustrates the solution process in conjunction of the structure, and the process is called the labyrinth karst or a giant grikeland. The latter is more common in Arctic and Subarctic region, because the process is a combination of dissolution and frost shattering widens along the joints. In Arctic and Subarctic region, there is a long period of permafrost under the ground (French, 1986), so that karst processes are somewhat prevented from the significantly thick permafrost, but a low rate of solution doline may form in the lower part of the Subarctic region.

The collapsed and subsidence dolins in Subarctic region are the most dominant surface karst formation. In the Arctic and Subarctic karst, the evolutional theory could related to or not to be because of extreme cold karst environments affected by glaciers. Three main mechanisms are responsible for collapse dolines (Ford, 1989); 1) dissolution from above that weakens the cave roof, 2) collapse from below that widens and progressively weakens the span of a cave roof, and 3) removal of buoyant support by lowering of water table, effective weight on the span so that its strength is exceeded. The process of Arctic and subarctic karst dolines can be summarized by the author; 1) when a great water table fluctuations occurred during the sea level rising and falling stages, phreatic cave passages were created, 2) Once ice advanced, a weak surface of cavities cracked or collapsed, and 3) collapsed dolines formed when deglaciation outwash dissolved residuals of the surrounding cavities, joint cracks above cave passages, or widening by vadose waters.

Current Arctic and Subarctic dolines vary in size: a great sized doline (Fig. 9.18), deformed rock doline (Fig. 10.7), and till filled doline (Fig. 10.11). These three different types of dolines which are affected by glacial advances and deglaciation. Most dolines are overridden and scoured by warm-based ice, glacial plucking, abrasion and subglacial precipitation. In the Arctic karst region, (Lat. 65^0 N), Fig. 9.18 illustration of Vermilion Creek doline, near Norman Wells, Northwest Territories, Canada shows a spectacular feature measures 180x100 meters and is approximately 40 meters deep to the water line. Figure 2.9 and Figure 2.0 illustrate the till deposition in dolines. Most of dolines was destroyed and filled with glacial tills in Arctic and Subarctic karst. *

Conclusions

Arctic and Subarctic karst landforms were effected by Pleistocene glaciation. Karst development would be active during periods of high water discharge. Subsurface developing during winter between ice and rock interface is active because of geothermal activates. An acidity of rain water is higher than that of ice melting water. Therefore, karstification in Arctic and Subarctic regions is somewhat active so that the hypothesis is rejected. Karren formations may develope by the acid precipitation. Dolines and polije are influenced by geologic structural influences as well as glacial advances and retreat.

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