KARST GEOMORPHOLOGY AND HYDROGEOLOGY OF THE BEAR ROCK FORMATION – A REMARKABLE DOLOSTONE AND GYPSUM MEGABRECCIA IN THE CONTINUOUS PERMAFROST ZONE OF NORTHWEST TERRITORIES, CANADA

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The Bear Rock Formation (Lower–Middle Devonian) extends >50,000 km^2 in subcrop under the Mackenzie Valley and the Mackenzie and Franklin Mountains in the Northwest Territories of Canada. In its central area (64–66°N, 125–130°W), it rests unconformably on 500 m or more of thick- to massive-bedded dolostones that overlie >100 m of salt and redbeds (Middle Cambrian to Middle Silurian), and it is overlain by 90 m or more of resistant limestones succeeded by thick clastic deposits (Meijer Drees 1993).

Where it has been cored during oil exploration, deep beneath the Valley, the intact formation consists of a regular sequence of dolomite and anhydrite beds (a typical sabkha facies) totaling 250–300 m thick; the formation is disturbed (brecciated) towards the top.

It is widely observed in outcrop on the flanks of the mountain ranges and in outliers east and west of the Valley, where it is always found to be a dissolutional megabreccia, 120–140 m thick. Outcrops are composed of resistant pack breccias (cliff-forming) and regressive float breccias, both consisting of dolomite clasts cemented by secondary calcite (dedolomite). There is also some secondary gypsum. A particularly resistant pack breccia at the top is attributed to near-surface evaporative effects. Evidently, brecciation has been caused by the circulation of meteoric groundwaters, commencing in the Middle Tertiary and continuing to the present.

Outcrops of the Bear Rock Formation occur at elevations of 100 to1,000 m above sea level.

Mean annual temperatures in the mountains are -7 to -9°C (January mean about -28°C), supporting a zone of continuous permafrost calculated to be approximately 50 m deep. Mean annual precipitation ranges from 350–450 mm: most of it

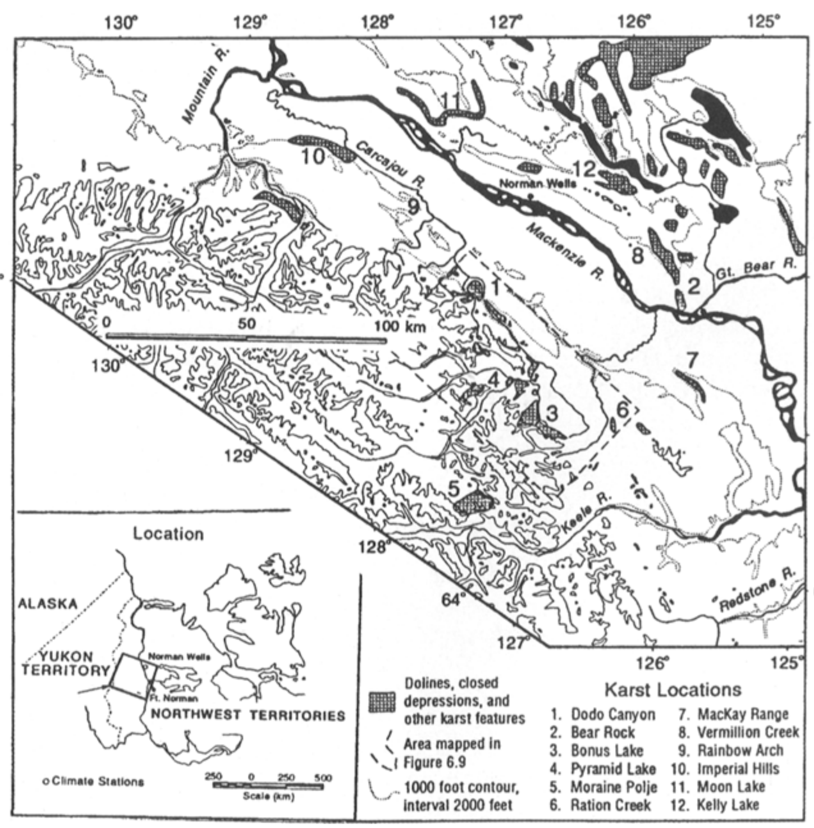

Figure 1. The location of karst terrains developed on the Bear Rock and underlying dolostone formations in the Franklin Mountains and Mackenzie Mountains, Northwest Territories, Canada. Sites 1–3, 6–8 were studied for this paper.

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Figure 2. An aerial view of "dissolution drape" topography on the Bear Rock Formation between Carcajou River and Dodo Creek in the Mackenzie Mountains. The resistant "caprock breccia" in the scene is a stratigraphically transgressive, superficial limestone breccia developed by casehardening processes working on the main Bear Rock breccia underneath. The caprock is 5–8 m thick locally. It dips from right to left (west to east) across the figure, but is seen to be fragmented and draping down into dissolutional depressions of highly irregular form in the main breccia.

falls as snow, but heavy rains (e.g., 74 mm in 24 hours) may occur in summer. The region was covered by the Laurentide icesheet during the last (Wisconsinan) glaciation; the ice was comparatively thin and sluggish, depositing very little till in the mountains.

All outcrops display karst landforms. The principal types are: (1) dolines (sinkholes) and compound dolines of collapse and/or subsidence origin, tens to hundreds of meters in length or diameter; (2) blind valleys where allogenic streams flow into the karst and sink; (3) subsidence troughs, developing along the zero sub-edge of the Bear Rock Formation or following the axial traces of anticlines within it; and (4) small poljes of tectonic origin or created by terminal moraine dams (the polje floors are up to 5 km^2 in area, but the catchments are as great as 90 km^2). There are also small caves formed by seepage and frost action in cliffs ("frost pockets"), and stream caves blocked by detritus or ice. Periglacial processes attack all features, partially filling them with talus, solifluction lobes, or patterned ground. Where the karst development is most intensive, however (in the Canyon Ranges of the Mackenzie Mountains), the dominant appearance is of a dissolution-drape landscape that is unlike any that we have seen elsewhere.

Field studies covering three melt seasons have established that, despite the presence of continuous permafrost, there is effective groundwater circulation through the outcrops and to depths exceeding 500 m (Hamilton 1995). Recharge is chiefly via allogenic waters able to maintain conduit inflow along the upstream margins, or through ponds of melt water that build up in the collapse sinkholes until pressure ruptures the ice and permits rapid drainage. These are "taliks" (leakage routes through permafrost) of distinctive karstic origin. There is also some supra-permafrost flow to shallow springs and seepages in cliff faces. Discharge is via seasonal and some perennial springs: most are located at the lowest points, indicating that the groundwater systems are mature, despite effects of the recent glaciation and modern permafrost.

Early in the melt season, spring waters have a $CaSO_4$ ionic composition representing the dominance of shallow (permafrost active zone) meltwaters. In mid-season, the larger springs change to an $MgSO_4$ composition with water temperatures as great as 4°C, indicating the discharge of deeper waters that are accomplishing dedolomitization. The few perennial springs (which create winter "icings" or naledi) have a significant NaCl component and temperatures up to 9°C. Modelling suggests that there are three-component groundwater-circulation systems involving the Bear Rock Formation, the underlying dolostones and salt, and which are extending the brecciation process today. Analysis of oxygen-isotope patterns in precipitation, sinking streams, and springs indicates that the mean residence times of the central, $MgSO_4$ waters are 40–90 days.

REFERENCES

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