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WEATHERED LIMESTONE ACCUMULATIONS IN THE HIGH ARCTIC

Abstract

On some of the dolomitic ridges of Bathurst Island of norhern Canada, rock weathering products percolate downward through the voids of shattered rock as suspensoids and emerge downslope at the surface. The weathered material accumulated as pockets of yellowish-brown silt and clay. X-ray diffraction, SEM and electron microprobe analyses show two distinct classes of material in the accumulation. One is primarily detrital dolomite whereas the other consists largely of a mixture of hydrous ferric hydrolysis precipitates plus illite, kaolinite and other clay-size minerals. Cutan-like features present in the precipitated material do not show any recognizable crystal structure even down to the 100Å size range.

The upper, carbonate-bearing slopes of Bathurst Island (75°45'N, 98°30'W) occasionally have localized accumulations of raw, earthy material resulting from an unusual set of processes. Weathered dolomite products from the ridges move downward through the shattered rock and finally emerge down-slope as surface accumulations. In this report the processes relating to the build up of weathering products and attendent geochemical processes reacting within the accumulated matrix are discussed.

Near the Goodsir River with local relief generally being less than 100 m some of the ridges are mantled continuously with platy, dolomitic limestone resembling conditions of the frost-shattered (*Frostschutt*) zone. The shattered rock matrix is virtually void of sand, silt and clay; rock surfaces are fresh appearing, and there is a paucity of plants (Pl. 1). Downslope conditions change to till-like deposits comprising a stony sandy loam. Between the shattered limestone on the ridges and till-like slopes is a comparatively narrow transition zone in which raw, earthy material accumulates.

It is a common tendency, especially in the High Arctic, for high-purity limestone rock in xeric to mesic sites to be largely free of epipetric lichens as well as vascular plants (CRUICKSHANK, 1971; TEDROW, 1978). On the nearby exposed dolomitic patch reefs (KERR, 1974) small depressions in the rock may, however, have primitive forms of *Rendzina* present (TEDROW and WALTON 1977). On the other hand, silicate rock or a mixture of silicate and carbonate rock have a much greater tendency for some form of plant cover to be present, even under a frigid climate. Not only is there a difference in initial plant colonization of the two rock types (carbonate vs silicate), but differences are also morphologically reflected

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in the soils. On stable, mature sites of silicate or mixtures of silicate and carbonate rock, together with sufficient sand, silt and clay, Polar desert soil generally forms (TEDROW, 1966), but when the rock matrix is high-purity limestone or dolomite, mixed with a prominent component of fines, the derived soils resemble Arctic råmark (KUBIËNA, 1953).

Returning to the problem of initial rock weathering and plant colonization, with *felsenmeer* and other bouldery deposits in which there is a variety of rock types, fresh-appearing surfaces of the limestone boulders are conspicuous in contrast to lichen-covered silicate rock. It is believed that the reason limestone rock in the high arctic and beyond is usually free of plant life is because the exposed rock surfaces are under a relatively intense weathering process. Whereas some of the weathering is from solution processes as evidenced by the presence of cavities and pits in the limestone, there is also physical detachment of the mineral grains from the parent rock surfaces.

There appears to be conclusive evidence that the weathering products of the limestone ridges move down through the shattered rock to the frost table and emerge at lower elevations as mineral suspensoids (Fig. 1). During summer months the frost table under the shattered rock is deep — probably 1 to 2 m with little ground ice. On the other hand the till-like deposits have a summer frost table approximating 30 cm with prominent ground ice present. At the juncture of the shattered limestone and the till-like deposits, conditions favor the accumulation of weathering products from the upper ridges. Accordingly sediments emerge and build up irregular shaped, earthy deposits up to 1 m wide, 6 m long and 30 cm or so deep. Plate 2 shows one of these accumulations. In the photograph the background consists of shattered dolomitic limestone, whereas the foreground is stony sandy loam. When the photograph was taken, a thin sheet of running water covered most of the raw, earthy accumulation. Downslope from the accumulations various soil stripes, stone stripes, and other linear forms of patterned ground are commonly present.

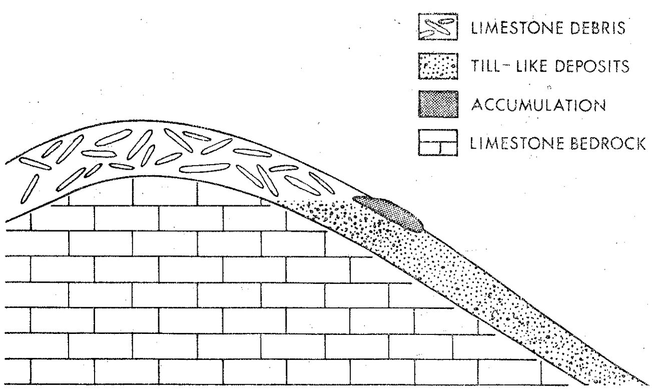

Fig. 1. Diagrammatic sketch showing relation of the weathered limestone accumulation to other surficial material

NATURE OF THE SEDIMENT

The sediment consists of a yellowish-brown (10YR5/8m) mass of silt and clay. Clay-size ($< 2\mu$) material from one of these accumulations was x-rayed and it was found that illite was the major component with kaolinite being prominent. Small quantities of smectite, goethite and clay-size quartz were also present.

Scanning electron microscope (SEM) examination of the total accumulation matrix was carried out over a magnification range of 10× to 20,000×. The matrix could be divided into (1) detrital material from the carbonate rock; consisting of silt and clay which included a considerable quantity of optically identifiable carbonate minerals (Pl. 3), and (2) secondary precipitates of amorphous (?) material and/or concentration zones of finely divided flocs forming crusts and bridges (Pl. 4). No definite organization of the latter was detected even down to the 100 Å size range.

Electron microprobe quantitative estimates show that the morphological classification can also serve as a chemical one (Table I). Whereas the detrital material is primarily calcium and magnesium carbonate, the crusts and bridges are mainly iron flocs and clay minerals. The microprobe analyses were of areas 2 to 3 microns deep. Because of the variation of composition within the field of study we show the data as a range of values rather than an „average" composition.

The preference of the negatively charged clay minerals for these flocs indicate that the flocs are positively charged even in the slightly alkaline waters. Ferric hydrolysis precipitates have isoelectric points (IEPs) approximating pH 9 whereas their aged, crystalline analogs have IEPs approximating pH 7 (Parks, 1965, 1967). It is well known that such precipitates are generally poorly structured, existing as hydrated gels with H_2O occupying sites normally occupied by anions in more crystalline materials. This substitution of water molecules for anions results in elevated IEPs.

That this iron is primarily amorphous or poorly crystalline is also consistent with our SEM and x-ray diffraction studies. The presence of cutan-like features

Table I

Elemental quantitative estimate ranges in various types of sediment within the limestone accumulation using electron microprobe techniques (mole %)

Elemental analysis reported as	Detrital (Range)	Secondary (Range)
$CaCO_3$	42—56	5—6
$MgCO_3$	23—31	6—7
K_2O	3	3—4
FeOOH	5—6	42—47
AlOOH	3—8	13—15
SiO_2	6—12	25—27

within the secondary matrix is of physiochemical coprecipitation of flocs and suspended clay minerals while the carbonate particles are the result of physical settling of detrital particles out of solution.

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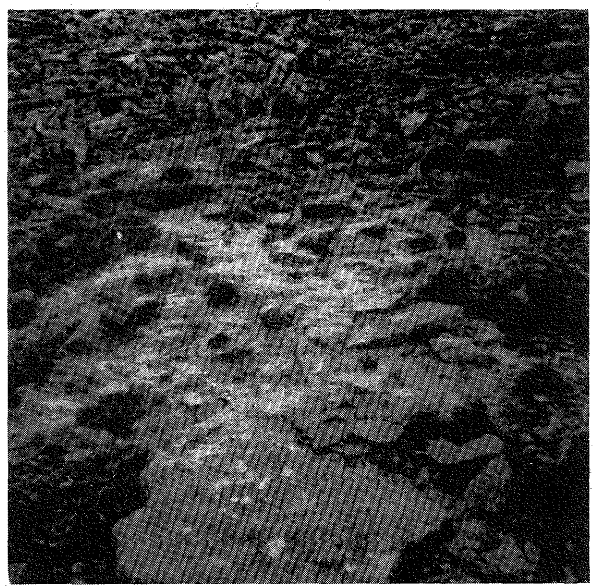
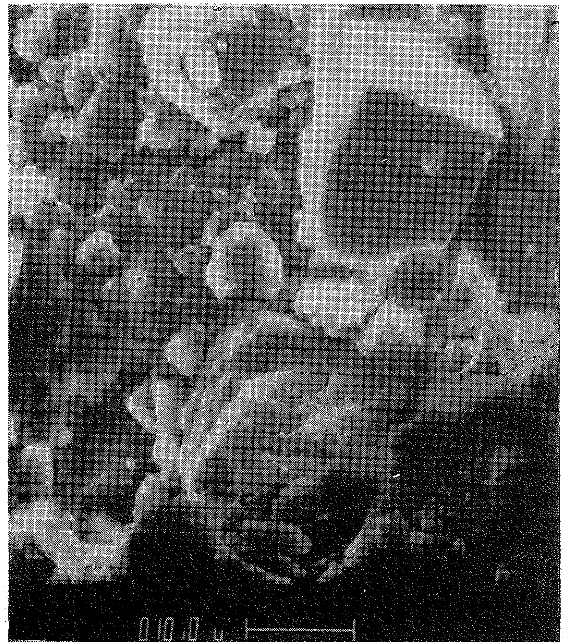
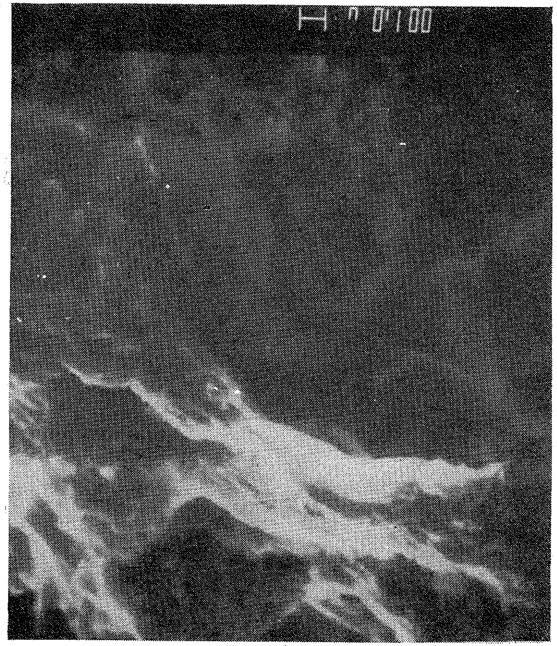
Pl. 1. Frost-shattered limestone ridge on Bathurst Island



Pl. 2. The accumulation of weathered limestone products immediately downslope from a limestone ridge



Pl. 3. SEM micrograph of carbonate-rich, detrital material (secondary electron)



Pl. 4. SEM micrograph of broken iron and silicate-rich crust overlying detrital carbonate material (secondary electron)