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SAND-WEDGE POLYGONS (TESSELATIONS) IN THE McMURDO SOUND REGION, ANTARCTICA— A PROGRESS REPORT*

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ABSTRACT. A microrelief pattern of polygons 20 to 40 feet in diameter occurs in the perennially frozen ground of the glacier-free lowlands of the McMurdo Sound Region, Antarctica. They are similar to ice-wedge polygons in the Arctic except that they are in ground devoid of vegetation and are outlined by textural changes in the soil between the inter-polygonal furrow and the enclosed polygonal areas. The term "sand wedge" polygon is here proposed for this widespread phenomenon.

The sand wedge polygons occur in all surficial material, even in stagnant glacial ice. A transverse section across the interpolygon trench or furrow reveals a well-formed wedge-shaped mass of structureless fine to medium-grained sand extending 1 to 10 feet below the surface and ¼ to 4 feet wide at the top tapering down to a feather edge at the base. The sediments adjacent to the wedge have been deformed upward and may be vertical or overturned near the top of the wedge. The upwarping decreases downward.

Suggested origin of the polygons and sand wedges is similar to the origin of foliated ice wedges and polygons in the Arctic. Periodic contraction cracks in the perennially frozen ground around McMurdo Sound, cracks produced by the great change in temperature from summer to winter, are gradually filled with clean sand which filters down from above in the spring and summer. Repeated cracking and filling with sand produces a wedge-shaped filling.

Perhaps not all sand wedges reported in temperate latitudes are replacements of ice wedges as generally believed, but may be original structures formed under an arid climate similar to that which exists at McMurdo Sound today.

A ubiquitous physical phenomenon in the ice-free lowlands of the McMurdo Sound Region, Antarctica, is a microrelief pattern of polygons or tesselations (Taylor, 1922) in the perennially frozen ground (fig. 1). The polygons are 20 to 40 feet in diameter and are formed by intersecting shallow furrows or trenches 3 to 18 inches deep. When a small amount of snow accumulates in the furrows the surface of the ground has the appearance of a large mosaic pavement. Such was succinctly stated by Taylor (1916, p. 115):

> The lowlands of loose black rock appear to be rolled by a steam roller, while the surface is broken by gutters from four to eight inches deep. These gutters marked out hexagonal and polygonal areas some twenty or thirty feet across. When a light snowfall had collected in the gutters, the valleys seemed to have been paved with black tiles united by white mortar.

A similar microrelief pattern (polygonal ground, tundra polygons, ice-wedge polygons) is widespread in northern North America, Russia, and other Arctic and subarctic areas but the polygons are outlined, in addition to the relief, by slight differences in the vegetation and by small linear ponds in the polygonal trenches. (Troll, 1944; Frost, 1950; Wiggins, 1951; Black, 1952b;

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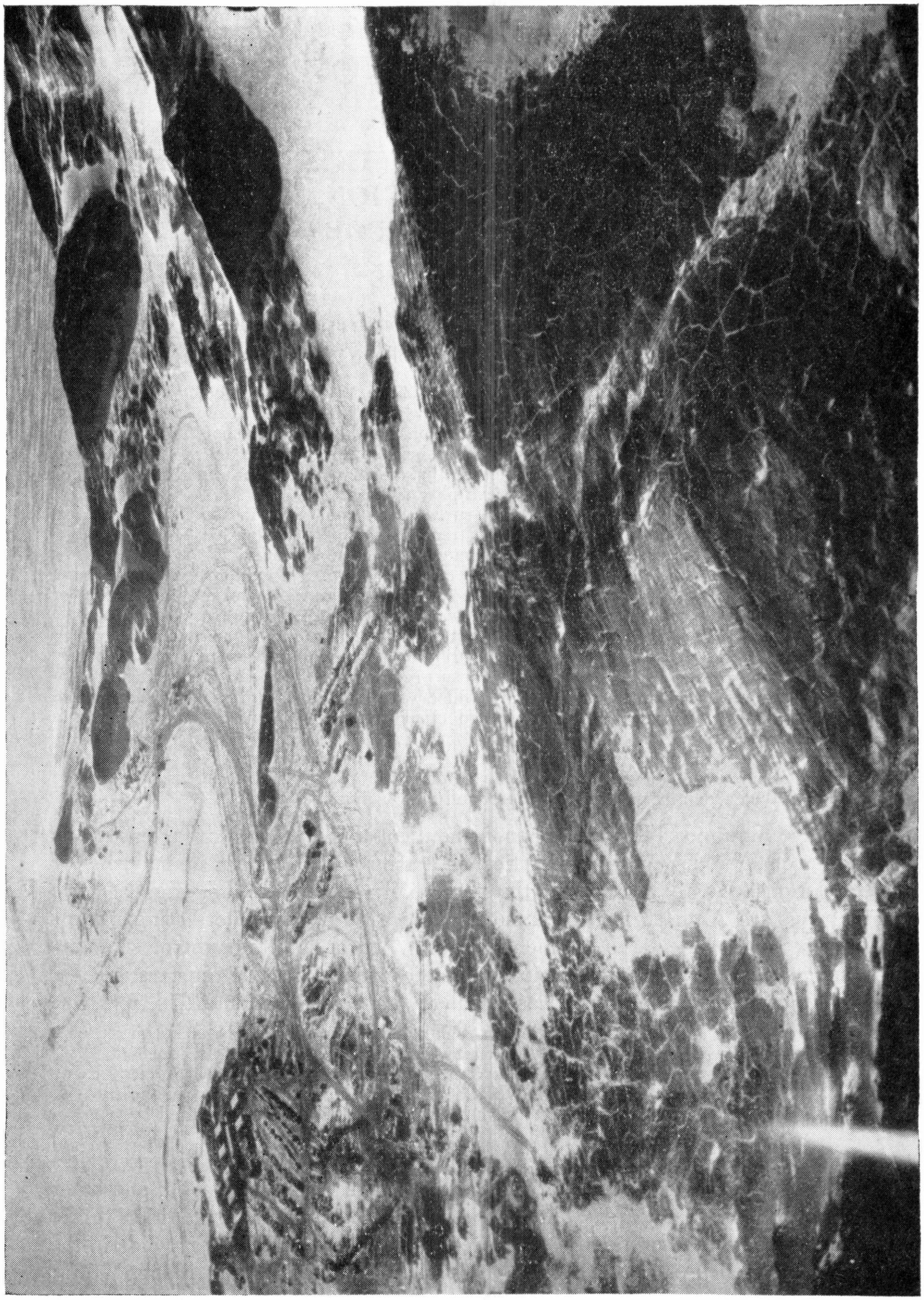

Péwé, 1954; Shumskiy, Shvetzov, and Dustovalov, 1955; Washburn, 1956; Britton, 1958a, 1958b). The pattern in Antarctica is in ground devoid of vegetation and, in the absence of snow-filled furrows, is outlined by textural changes in the soil between the furrows and the enclosed polygonal areas. Taylor (1922) mentioned the polygonal pattern (tesselations) but did not do detailed work or demonstrate a method of origin. The term "sand-wedge polygon" is here proposed for this phenomenon so widespread in the McMurdo Sound Region.

An opportunity to study the polygonal ground in Antarctica was provided by the United States National Committee of the International Geophysical Year and observations were made by the writer, assisted by Norman R. Rivard, in the ice-free areas east, south, and west of McMurdo Sound (fig. 2).

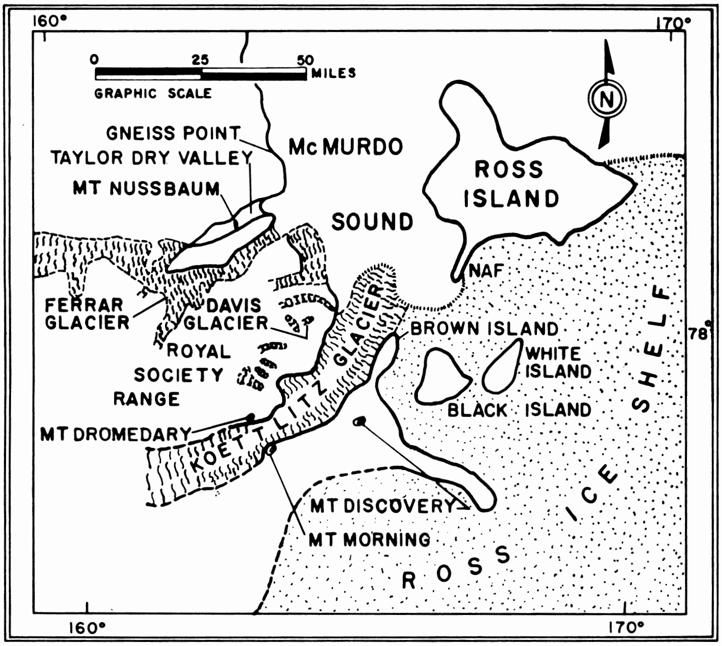

Fig. 2. McMurdo Sound Region, Antarctica.

from December, 1957 until February, 1958. The area around the Sound is composed of volcanic, intrusive, metamorphic, and sedimentary rocks. The lowlands are in large part covered with glacial deposits (Péwé, 1958b) and both alpine and outlet glaciers occur in this region (Péwé and Rivard, 1958).

The climate of the McMurdo Sound Region is rigorous and characterized by low temperatures and aridity. Scattered data from Scott's expeditions and from incomplete IGY observations indicate that the mean annual air temperature near sea level on the east side of McMurdo Sound is approximately 1°F. Data on the mean annual precipitation in the region is difficult to obtain be-

Fig. 1. Aerial view of polygonal ground (tesselations) in basaltic rubble, Hut Point, McMurdo Sound, Antarctica. Williams Naval Air Facility at upper left. U. S. Navy photo, 1956.

cause most of the precipitation is in the form of blowing snow and because the record is very short; however, on the east side of the Sound, the mean annual precipitation in inches of water is probably between 2 and 6. It is the opinion of the writer that the west side of the Sound is drier than the east but no quantitative data are yet available.

The sand-wedge polygons occur in all surficial material such as till, outwash, stream sand and gravel, lake sediments, deltaic sediments, rubble derived from bedrock by frost action, ablation moraine overlying stagnant glacial ice, and even in the stagnant glacial ice. The various types of sediments are firmly cemented by ice and are not dry permafrost. This microrelief pattern occurs on flat lands and on slopes up to 30 to 35 degrees inclination. Most polygons have raised edges 3 to 12 inches high and in many places the furrows are boulder lined. The very young polygons, which are on recent flood plains and the youngest stream terraces, do not have raised edges and the furrows are only 3 or 4 inches deep.

The absence of vegetation permits excellent observation of the structure and configuration of soil in the upturned edge of the polygon, a feature not often seen in the ice-wedge polygons of the Arctic and subarctic regions. A plan view reveals that the ground, which is covered with a deflation lag gravel, is turned up at the edge of the polygon and the linear and plate-like rocks stick out of the ground at steep angles on the ridge adjacent to the furrow (fig. 3). The width of the furrow or distance between raised edges of adjacent polygons ranges from 4 inches to 6 feet. The narrow bottom of the furrow is covered with either clean well-sorted wind-blown sand or cobbles and rock fragments that have rolled down into the furrow from the raised edges. In many places sand can be seen trickling down into a vertical crack that extends into the earth from the bottom of the furrow.

A transverse section (fig. 3) across the trench or furrow reveals a well-formed wedge-shaped mass of structureless fine- to medium-grained sand extending 1 to 10 feet below the surface and ¼ to 4 feet wide at the top tapering down to a feather edge at the base (fig. 3). The sand is cemented by ice and in many places a ¼ inch wide open crack extends downward 1 to 3 feet into the wedge from the upper surface of the permafrost. The sand wedge lies directly under the trench. The sediments adjacent to the wedge have been deformed upward and may be vertical or overturned near the top of the wedge. The upwarping or tilting of the sediments decreases downward and is absent near the base of the wedge. Cobbles or boulders in the parent material adjacent to the wedge crop out in the upturned edges of the sediments and most of the linear or plate-like rocks are oriented with their short axis perpendicular to the dip (fig. 3).

The writer has studied polygonal ground in Alaska for several years and has observed that in the Arctic and subarctic this microrelief pattern is, with rare exceptions (Hopkins and Karlstrom, 1955, pls. 39, 43), directly associated with underlying masses of foliated ground-ice, commonly termed "ice wedges" because of their wedge shape when exposed in transverse section (Leffingwell, 1915, 1919, figs. 16-25; Taber, 1943, pl. 17; Péwé, 1958a, fig. 2). Upon examination of photographs of tesselations in the Antarctic the writer was prepared to find ice wedges and polygons similar to those in the Arctic; however, although the polygonal pattern and microrelief were similar, examination of many sections of the polygons in the McMurdo Sound Region revealed sand wedges in the same position occupied by ice wedges in the North. The sand wedges and the deformed strata adjacent to the wedge duplicate in great detail the features and field relations associated with the foliated ground-ice wedges as described from the North (Leffingwell, 1915, 1919; Black, 1951, 1952a, 1952b, 1954; Popov, 1955; Shumskiy, Shvetzov, and Dostovalov, 1955; Péwé, 1958a). The writer has noted large-scale contraction polygons without ice wedges in outwash gravel near Big Delta, Alaska, and Hopkins and Karlstrom (1955, pls. 39, 43) illustrate such polygons from the Bristol Bay area and Seward Peninsula, Alaska. Such "frost-crack" polygons (Hopkins and Karlstrom, 1955, p. 139) may contain a thin vein of silt or sand generally an inch or less in thickness. The bedding bends downward and extends across the "wedge" instead of bending upward adjacent to the wedges as in the sand wedges of Antarctica.

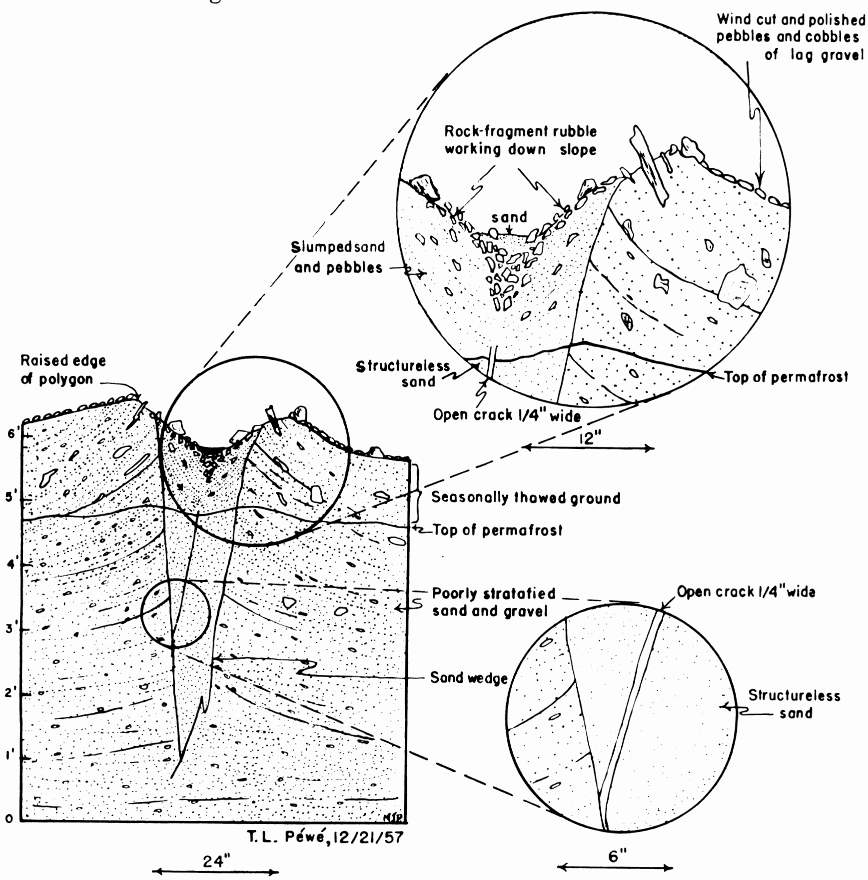

Fig. 3. Diagrammatic sketch of sand wedge, Taylor Dry Valley, McMurdo Sound, Antarctica.

The hypothesis entertained at this time for possible origin of the polygons and sand wedges is similar to the hypothesis for origin of foliated ice wedges and polygons in the North proposed by Leffingwell (1915, 1919) and supported by Black (1952a) and Péwé (1952). Leffingwell postulates (1919, p. 205-212) that foliated ground-ice forms in periodic contraction cracks in the perennially frozen ground—cracks which are produced by the great changes in temperature from summer to winter. The intense stresses generated by a drop in ground temperature result in the formation of a polygonal network of contraction cracks. Hoar-frost, ice crystals, and snow melt water periodically fill or partly fill the cracks to produce a narrow vein of ground-ice in the permafrost. This ice vein is not destroyed by the expansion of the ground in summer and provides a zone of weakness for repeated cracking and ice growth in subsequent winters. Eventually a polygonal network of massive foliated ice masses (wedges) exists in the ground. In the arid ice-free region around McMurdo Sound such contraction cracks are gradually filled with clean sand which filters down from above in the spring and summer. Repeated cracking and filling with sand produces a wedge-shaped filling.

An alternate hypothesis is that ice wedges formerly existed but later disappeared, and that the present sand wedges are "fossil" ice wedges or pseudomorphs after ice wedges. This suggestion can be ruled out because: (1) On many occasions sand was observed trickling down the thermal contraction ground crack in old large wedges and small new wedges. (2) Sand wedges were observed in stagnant glacial ice, a medium which would disappear along with the ice wedges if the later were to melt. (3) The region is so extremely arid, especially on the west side of the Sound, that there is little snow at low levels and most of this disappears by evaporation or sublimation into the atmosphere. (4) No evidence is available to support the suggestion that permafrost and ice wedges disappeared or thawed to produce "fossil" ice wedges.

One conclusion that can be drawn at this early stage of this study is that sand or sediment wedges reported from temperate latitudes in North America (Horberg, 1949; Schafer, 1949; Black, 1957; Wilson, 1958) and Europe (Lotze, 1932; Cailleux, 1948; Dylik, 1951; Dimbleby, 1952; Cailleux and Taylor, 1954; Jahn, 1955; Dutkiewicz, 1956; Dylik, 1956a, 1956b; Dylikowa, 1956; Golab, 1956; Klatka, 1956; Pierzchalko, 1956; Sekyra, 1956) possibly should be reevaluated in the light of discoveries in Antarctica. Perhaps not all the sediment wedges in temperate latitudes, especially if composed of sand, are replacements of ice wedges which formed in a climate such as now exists in the Arctic of Asia and North America but possibly may be original structures formed under an arid climate similar to that which exists at McMurdo Sound today.

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