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PRELIMINARY GEOLOGIC STUDIES OF COLD CLIMATE DUNES, NORTH PARK, JACKSON COUNTY, COLORADO

by

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This report is preliminary and
has not been edited or reviewed
for conformity with Geological
Survey standards and nomenclature.

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INTRODUCTION

Much of the northeastern margin of North Park is covered with dune sand (fig. 1, 2). The North Sand Hills, 1.11 mi^2 (3.81 km^2), and the East Sand Hills, 1.01 mi^2 (3.46 km^2), are the only major active sand areas in the predominantly dormant 25.3 mi^2 (86.8 km^2) dune field (fig. 2). The dunes occur in a cold, semi-arid climate at a high elevation, 8100-8700 ft (2,468.9 m-2,651.8 m), about 10 mi (16 km) northeast of Walden, Colorado. An average temperature of 37.4°F (3.0°C) and an annual precipitation of 14.3 in. (363.2 mm) were reported at Walden in 1968 (U.S. Department of Commerce, 1968). The area averages only 46 frost-free days annually.

The dunes develop east and northeast of the Canadian River (fig. 2) and along their western margin rest on the Qt_2 terrace as mapped by Kinney (1971) and Kinney, Hail, Stevens and others (1970). Elsewhere, the dune field rests on sedimentary rocks and sediments which in stratigraphic succession include the Goose Egg Formation (Permo-Triassic, Maughan, 1967, p. 147 and E. K. Maughan, oral commun., 1976), the Chugwater Formation (Triassic), the Morrison Formation (Jurassic), the Dakota Sandstone, the Benton, Niobrara and Pierre Shales (Cretaceous), the Coalmont Formation (Paleocene-Eocene), the White River Formation (Oligocene), the North Park Formation (Miocene), and Quaternary, alluvial and colluvial deposits (Beekly, 1915, Hail, 1965).

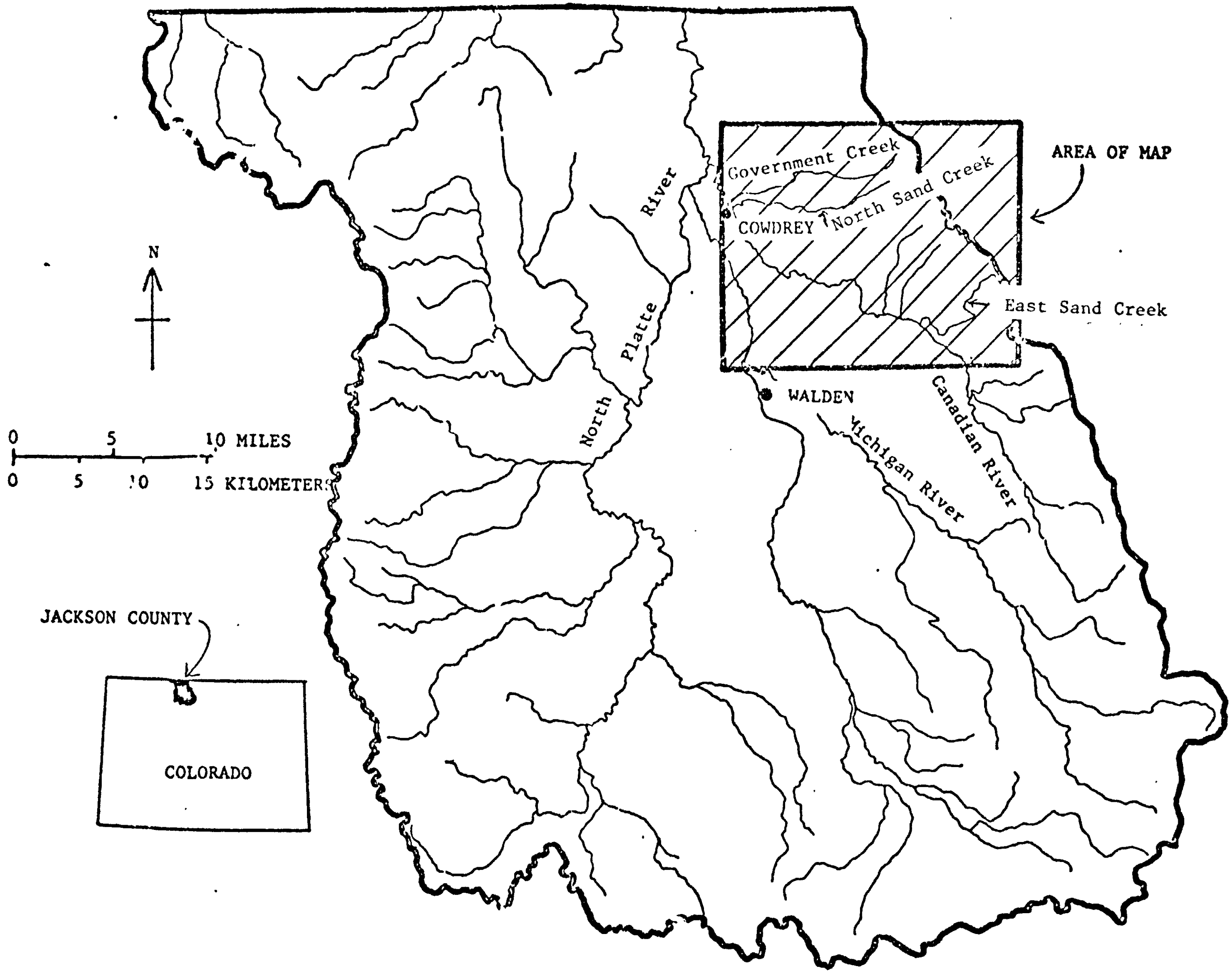

Figure 1.--Location of study area. Hachure area indicates area shown on Figure 2.

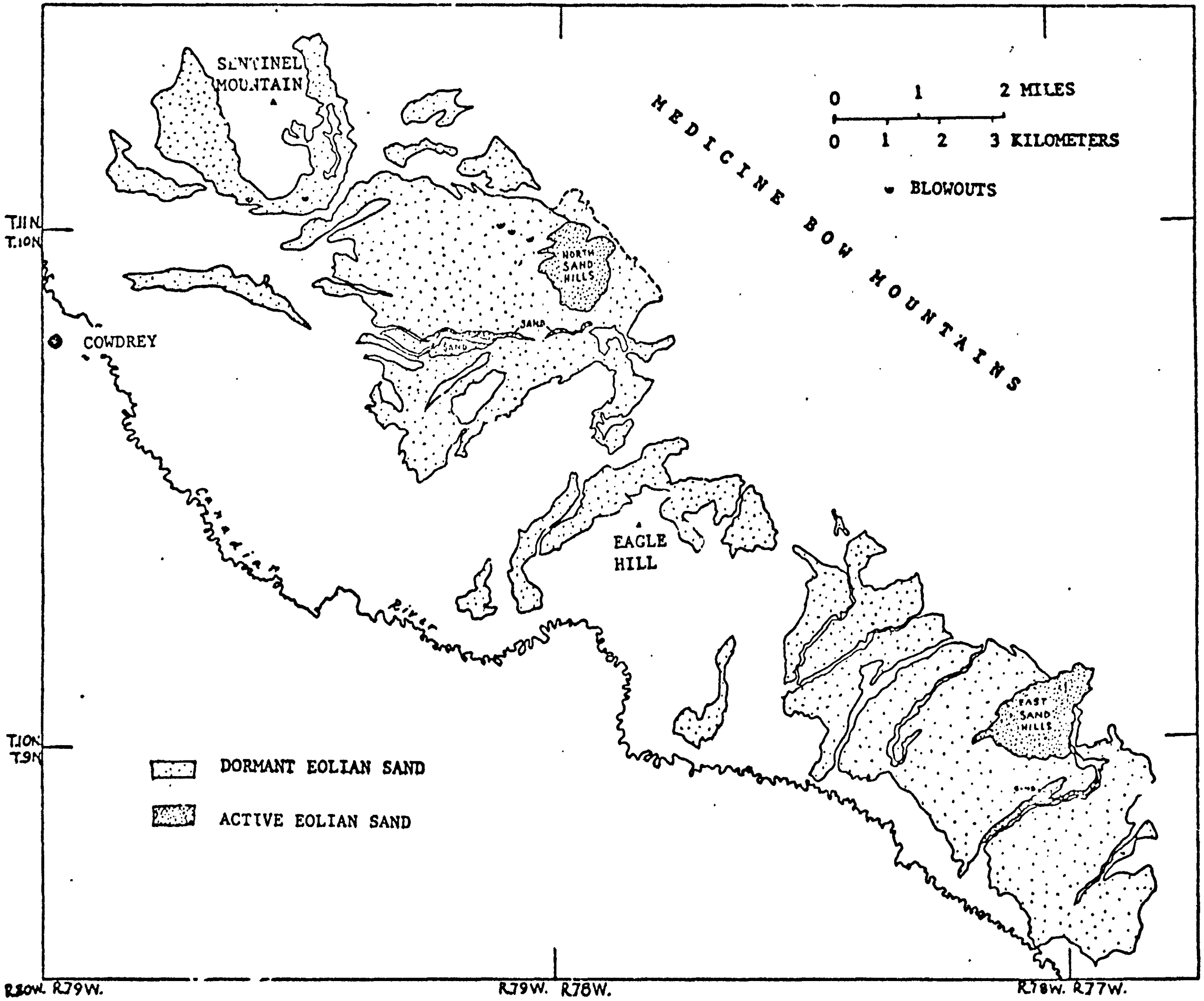

Figure 2.--Map of the North Park dune field showing active and dormant eolian sand. The Bangston fine sand (soil 70-AE) as mapped in the preliminary Jackson County soil survey, U.S. Soil Conservation Survey, 1971, was used as the base for dormant sand distribution.

This report was submitted as an interagency Administrative Report to the Bureau of Land Management and discusses the preliminary findings of the dynamics and morphology of these dunes, particularly the North Sand Hills.

DUNE MORPHOLOGY

The North and East Sand Hills areas are primarily large parabolic dunes which are migrating to the northeast and east (fig. 3). The parabolic dune is a vegetationally controlled type and is U- or V-shaped in plan view, opening upwind. The main components of this dune type include an active nose which has ephemeral, sparse vegetation, and trailing arms which are stabilized by a thicker, perennial vegetation. Disruption of the vegetation causes migration rates to rapidly increase and morphologies to change. The North Sand Hills consist of two large active parabolic dunes with small barchan, barchanoid ridge, transverse ridge, blowout, and parabolic dunes migrating up their windward slopes between their arms. They are, therefore, complex dunes, as different dune forms are superimposed. The northern parabolic dune (fig. 3) in particular is also compound, because smaller en-echelon parabolic dunes have developed within the larger parabolic dune. The active dunes occur upwind of shallow notches either in the hogback formed by the Dakota Formation or in the Medicine Bow Mountains to the east.

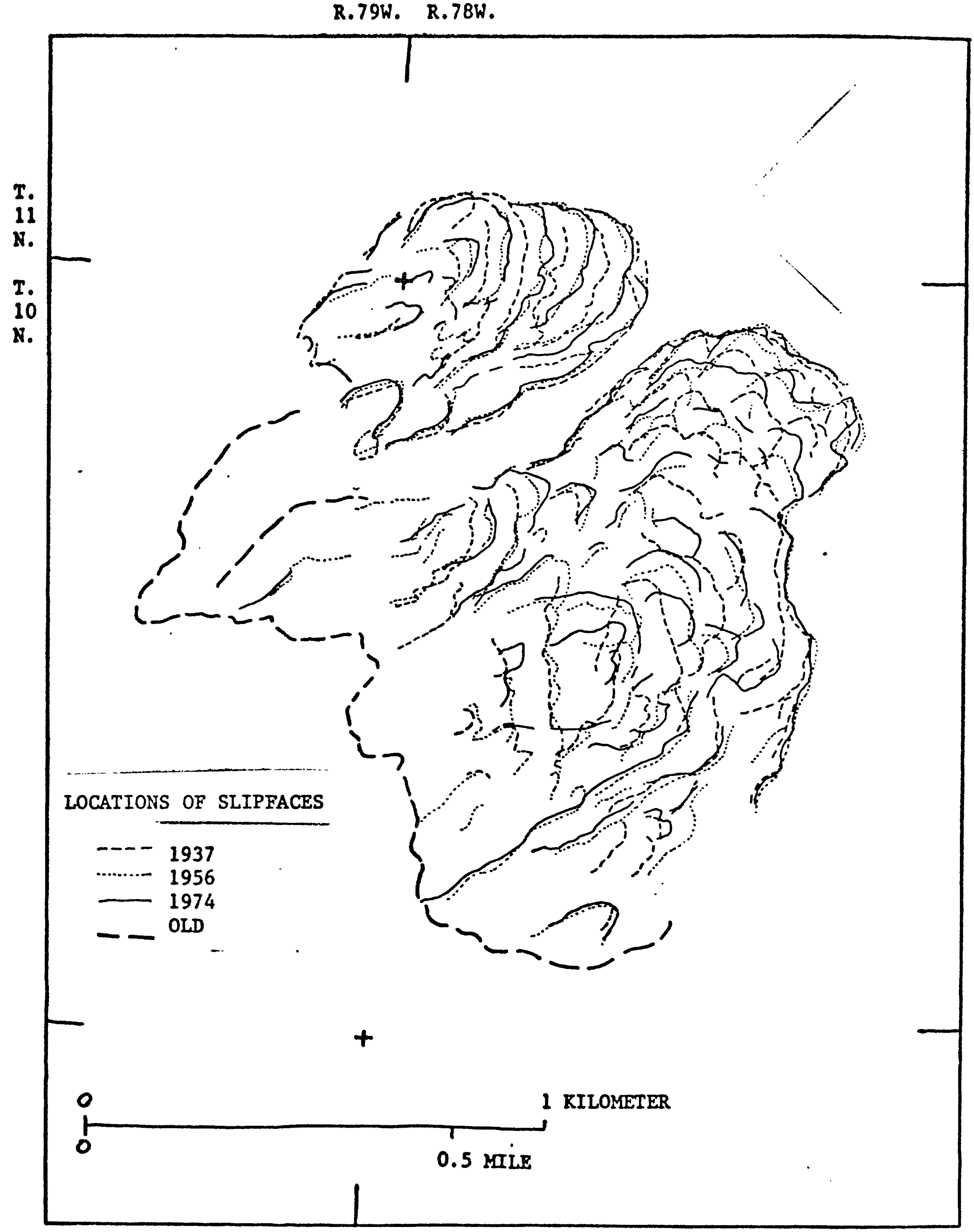

Figure 3.--Movement of the smaller internal dunes in the North Sand Hills as indicated by shifting position of slipfaces. Grouping into two main dunes is visible, a smaller parabolic to the north and a larger one to the south. The noses of these parabolic dunes are to the northeast, and the arms trail to the southwest. The heavy dashed line delineates the old nose (crest) of parabolic dunes which were migrating to the southwest.

The dormant dunes, which comprise the rest of the dune field, are predominantly stabilized parabolic and blowout dunes. They rest on alluvium and colluvium along the western margin of the field. This alluvium is well exposed along drainages throughout the area. A peat layer in the alluvium beneath dune sand along North Sand Creek (fig. 1) was C^{14} dated to 2830 $\pm$ 200 years B.P. (U.S.G.S., W-3655). A peat layer in the alluvium beneath the dune sand along East Sand Creek (fig. 1) was C^{14} dated to 2110 $\pm$ 200 years B.P. (U.S.G.S., W-3656). The dunes do not have a correlatable stratigraphy, and contain only poorly developed interdune deposits. Trees buried by the dunes provide the only dateable material within the region (bison bones found in the dunes will not yield a specific age). The remnants of one such tree, which is now exposed 810 ft (246.8 m) west (upwind) of the present major dune slipface in the North Sand Hills, was C^{14} dated to 1250 $\pm$ 200 years B.P. (U.S.G.S., W-3653).

DEPTH OF THE SAND

The eolian sand is very thin at its western margin near the Canadian River. Records from core holes drilled for the power line project in 1974 show the sand depth increasing gradually eastward to 41 ft (12.5 m) just west of the North Sand Hills. The maximum depth of sand, 100 ft (30.5 m) is reached at the eastern margin of the active dunes in the North Sand Hills.

TEXTURE OF THE SAND

The sand which comprises the dunes is a well to moderately well sorted, fine-grained sand. Textures of 10 samples were analyzed with a Quantimet 720 Automatic Image Analyzer.[1/] Three hundred grains per sample were counted. The mean grain size of these samples ranges from 2.0 to 2.6 ϕ (0.25-0.165 mm), and inclusive graphic sorting values range from 0.45 to 0.64. Sand samples show both positive and negative skewness, as is a characteristic of inland dune fields (Ahlbrandt, 1975). The sand composition is complex, and has abundant feldspar and common volcanic rock fragments. Grains are coated with clay, which was determined by X-ray diffraction to be montmorillonite. Some fluvial deposits, which are overlain by dune sand along North Sand Creek, have manganese coatings (as determined with a scanning electron microscope) due to the presence of manganese bog ores in these deposits.

ANALYSIS OF AIR PHOTO COVERAGE FOR THE NORTH SAND HILLS

Stereo air photo coverage of the North Sand Hills area was available for 1937, 1956, and 1974. Maps of changes in slipface development, vegetation, road usage and spot elevation were made using a Kern PG-2[1/] Stereo-plotter. This instrument is calibrated within one micron, therefore, any computational errors are due to distortion in the photographs, and should be negligible.

[1/]Use of a specific brand name does not necessarily constitute endorsement of the product by the U.S. Geological Survey.

Vegetation

The vegetation of the North Sand Hills area can be grouped into three categories (reflecting its effectiveness to deflect the wind) of high windbreak, low windbreak, and negligible (sparse) windbreak (fig. 4).

The high windbreak vegetation is primarily aspen, with some lodgepole and limber pine, and brush and grasses. The taller trees reach heights of 80 ft (24.4 m). The low windbreak is comprised of sagebrush, bitterbrush, rabbit brush, and various grasses. The low windbreak is generally two to three feet ($\simeq$1 m) high, and forms an effective protection against wind erosion where it is not disturbed by more than random light traffic. The vegetation in areas of negligible (sparse) windbreak is comprised of isolated grasses and brush.

The vegetation pattern as plotted in figure 4 has not varied appreciably from one year to another except in minor blowout areas, and in the low windbreak cover to the west of the dunes. This latter cover showed extensive thinning on the dune crests in the 1956 photos, most likely as a result of the drought that occurred in the first half of the 1950's. Beaver ponds, fallen trees, and other effects of a beaver population can be seen in the 1956 and 1974 photos. The rate of revegetation of a reactivated area is indicated in one location, where a stand of trees and brush visible in 1937 was covered by a slipface in 1956. The area reactivated between 1937 and 1956 was only sparsely revegetated with grass and brush by 1974.

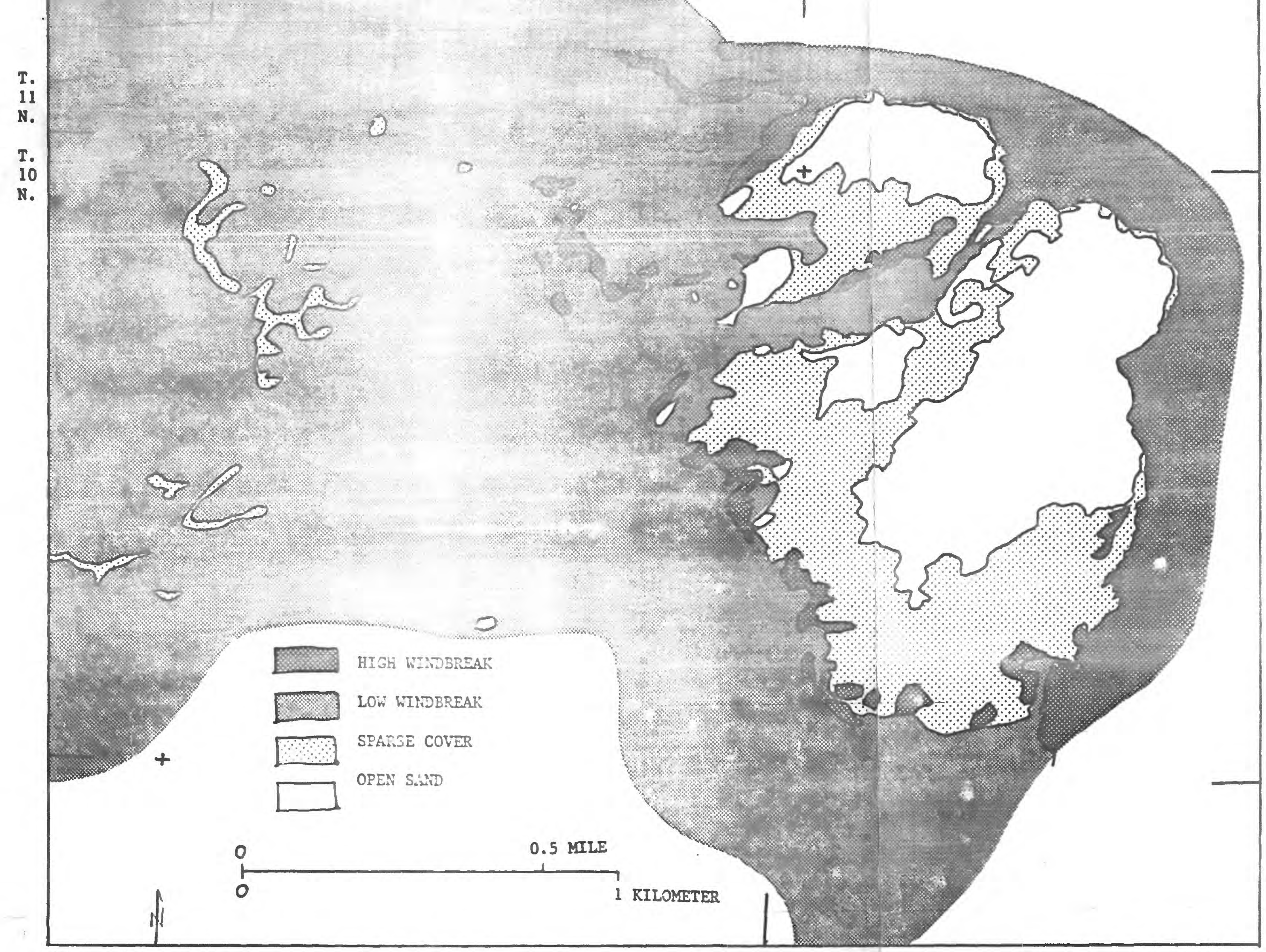

Figure 4.--Vegetation in the North Sand Hills area, as classified by its capability as a windbreak. (Plotted from 1974 air photo coverage.)

Migration of the Dunes

Most of the dune area in North Park is dormant (fig. 2). There is no appreciable net movement of the major dune forms of the active area, as determined from plots of the three sets of air photos. These large parabolic dunes migrate very slowly, as they are undercut and eroded by creeks, and they are impeded along their downwind, eastern margins by tall trees (as much as 80 ft high (24.4 m)) and the foothills of the Medicine Bow Mountains. Analyses of tree rings from 20 aspen and limber pine trees around the margins of these slipfaces indicate that most of the dunes have been relatively stable along these eastern margins for at least a century (F. Martin Brown, written commun., 1976).

There has been a change in the location of certain more active parts of the main outer slipfaces (fig. 3). The outer slipface activity indicates a change in the main dune building direction from eastward in 1937 to northward in 1974 (fig. 3). This sort of change may have occurred many times between those years. Evidence of wind reversal can be seen clearly in the 1956 photos.

However, changes in the shapes and positions of the smaller dunes between the arms of the main active parabolic dunes could be seen in the air photos. These smaller dunes have generally migrated from west to east. Because these smaller dunes migrate at a faster rate than the large parabolic dunes, they eventually overtake the main crest and contribute their sand to the large parabolic dune slipfaces (fig. 3).

The maximum measured rate of dune migration for the smaller dunes is 5.7 ft/yr (1.7 m/yr) to the northeast for the 37-year period of photo coverage. However, most of the smaller dunes migrate at a rate less than 4.5 ft/yr (1.4 m/yr). This is a slow migration rate which supports a similar observation during our field investigations using a sand transportation measuring device, the eolian sand trap, and also on-site meteorological studies during the summer of 1976. Summer winds are weak to moderate in strength, generally less than 25 mph (40 kph), and wind reversals are frequent. Moisture within the dunes freezes during the prolonged cold season and this greatly inhibits dune migration most of the year as evidenced by the slow migration rates.

In Figure 3, the heavy dashed line indicates the location of the crestline of dormant parabolic dunes that were migrating to the southwest. These dunes are now stabilized by vegetation and are partially dissected. This is evidence of wind reversals in the past of longer duration.

Degradation of the Dunes

Agents of dune degradation include animal and vehicular traffic and water erosion. Figure 5 shows the effects of animal and vehicular erosion. What were probably horse trails in 1937 became auto roads in 1956 (the change from single to double tracked roads is visible on the air photos). A fence had been added by 1956 along which cattle formed a path. At one fence corner indicated on Figure 5, a large area of protective vegetation had been destroyed, allowing sand to reactivate.

There is a pronounced increase in roads and their usage marginal to and within the North Sand Hills. The number of road miles increased by 35 percent between 1937 and 1956. By 1974, the number of road miles had increased another 76 percent making a total of 135 percent increase between 1937 and 1974 (fig. 5). A road to service the power lines shows on the 1974 photos, and the cattle trail along the fence shows signs of vehicular traffic. For the first time, roads lead into the dunes, breaching the vegetative cover on the high slipfaces and ridges (fig. 6C). There are places where two, three and four roads connect the same two points. The junctures of these routes are in many places broad, bare patches. Ground inspection shows that many of the new roads run through loose rather than hardpacked sand, facilitating erosion. Increased traffic on these roads and the older roads has broken them down in many places (fig. 5), forming soft, easily eroded stretches which vehicles have then detoured, forming secondary tracks.

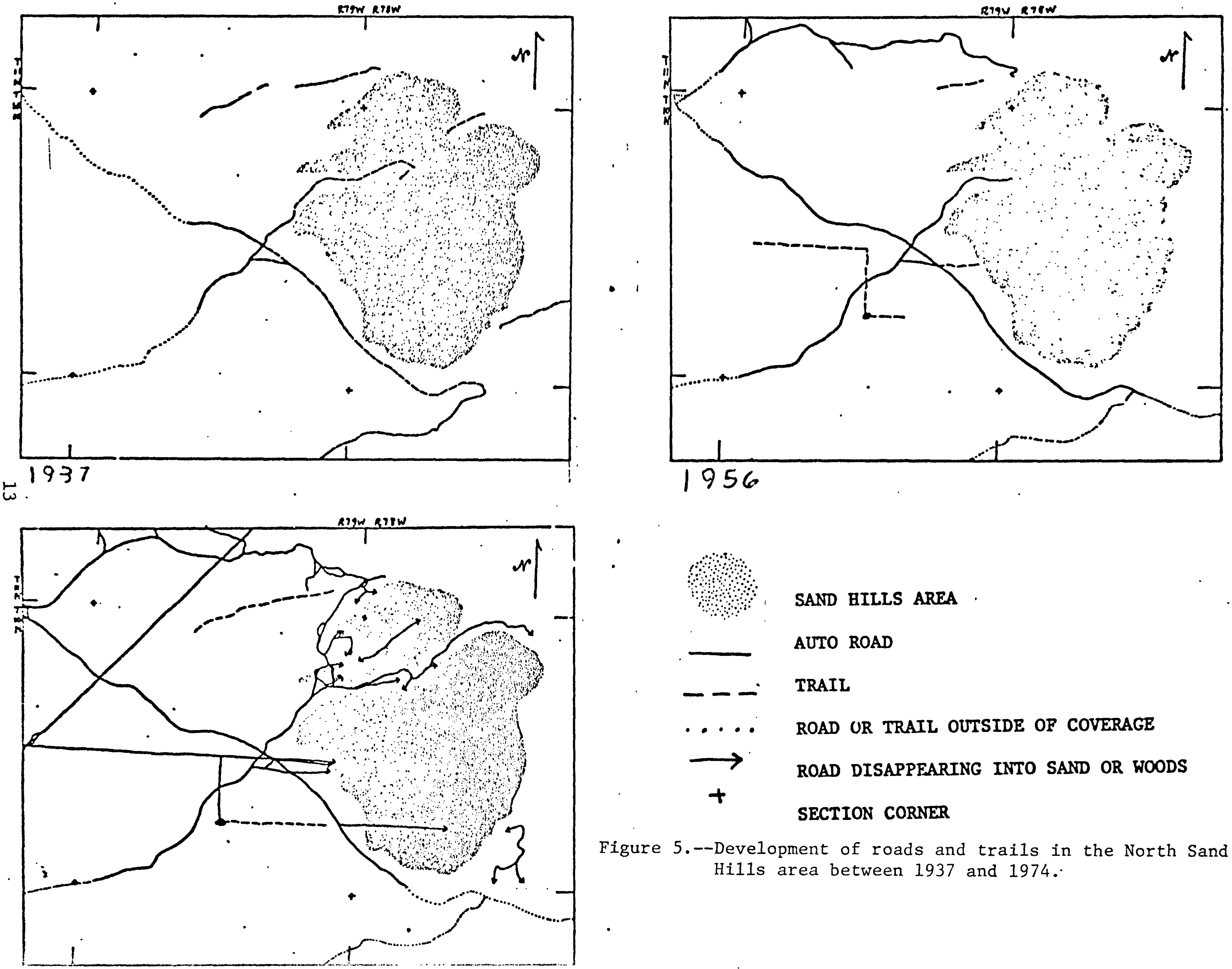

Figure 5.--Development of roads and trails in the North Sand Hills area between 1937 and 1974.

Figure 6.--Sedimentary structures in the dunes of the North Sand Hills. Snow intercalated in the slipface of a barchan dune is shown in the trench in Figure 6A. The flat lower boundary and the convex upward boundary along the snow lense are apparent. Melting of the snow results in tensional and compressional structures. Stairstep faults immediately above the meterstick in Figure 6B are tensional features resulting from snow melting. Compressional structures are seen at the lower left corner of the trench shown in Figure 6B. Extensive vehicular traffic in the North Sand Hills as shown on the arm of the northernmost parabolic dune, Figure 6C, completely eradicate such structures and reactivate stabilized portions of dunes.

a.

b.

c.

Government Creek and Sand Creeks are an effective check to migration of the dunes to the north or east, as they undercut and remove advancing sand. The slipfaces of the parabolic dunes which were migrating to the southwest (fig. 3) have been eroded to some extent by water as well as by vehicles. The result is small alluvial fans covered with low windbreak type vegetation below notches along the western margin of the ridge.

SEDIMENTARY STRUCTURES IN THE DUNES

Diagnostic sedimentary structures indicative of natural deformation of bedding in cool, moist (cold climate) dunes occur in the North Sand Hills dunes. The deformation features described by McKee, Douglass, and Rittenhouse (1971) provide the framework within which such sedimentary structures can be interpreted. When preserved in the rock record, such structures allow identification of the environment of deposition of the rock.

Snow was found buried within the slipfaces of dunes (fig. 6A). As this snow melted, diagnostic tensional and compressional sedimentary structures formed (fig. 6B). Tensional structures form in the overlying sand layers at the uphill margin of the snow lenses as the volume of snow decreased. Compressional features, in contrast, formed on the downslope margins as the sand layers dropped vertically. A detail of stairstep faulting, a tensional feature formed by this process in cohesive sand, is shown in Figure 6B.

Another important feature, incipient dissipation structures, were found in layers of frozen sand which occurred beneath the snow. Dissipation structures were formed of silt- and clay-enriched horizons which modified or destroyed primary bedding.

DOCUMENTING RESEARCH

Experiments conducted in the North Sand Hills area have yielded data for which analyses are still to be completed. These experiments included sample collection for detailed sedimentary petrography, sand trap, and dune migration tests, and C^{14} sampling. Results of further analyses will provide more complete documentation of the preliminary observations of this report.

SUMMARY

The restorative ability of North Park dunes is low because of vegetational influence, effects of the cold climate, short growing season, and the relatively weak summer winds which frequently reverse. Dune migration is inhibited during the winter by freezing of the internal moisture and incorporation of snow within the dunes. These factors explain the inability of blowouts or eroding areas to heal for long periods. Vehicular traffic disrupts both the external morphology of the vegetationally controlled dunes and the internal sedimentary structures of the dunes.

ACKNOWLEDGMENTS

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