# WHITE ROCKS
# Natural Area Study

Department of Geography / University of Colorado

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# NATURAL AREA STUDY


Donald D. MacPhail
Editor

with

Helen Louise Young
and

Dennis I. Netoff



DEPARTMENT OF GEOGRAPHY
UNIVERSITY OF COLORADO

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## FOREWORD

This report is one of six undertaken this year in the Department of Geography at the University of Colorado. It has become almost a tradition for the graduate seminar in land use to initiate a project in the local area in cooperation with an agency of the Boulder community on either the municipal or county level, sometimes both.

These studies achieve a number of objectives. The participating students undertake a realistic project which they are able to plan, execute, and publish within the brief span of one semester. Also, these studies provide new information for municipal and county officials and citizen groups concerned with planning and guiding the growth and development of the City of Boulder and Boulder County. In short, these are professional training exercises for graduate geographers and are a serious effort in providing new planning perspectives in the interest of public service.

In response to a suggestion by the Natural Areas Committee of the University of Colorado, the land use seminar elected to study and analyze a number of natural sites in the Boulder Valley. The group was also joined in the endeavor by the graduate field seminar of the Department of Geography.

The cooperative base within the Boulder community was wider than usual this year. The sites chosen for study seemed to have potential for a variety of uses beyond their present development. These included instruction of public school and university students, scientific research, recreation, greenbelt, and open space. The graduate students involved worked in cooperation with the resident property owners, the Parks and Recreation Department and the Planning Office of the City of Boulder, the Department of Development and the Parks and Open Space Advisory Committee of Boulder County, the Boulder and Longmont Offices of the Soil Conservation Service, the Science Director of the Boulder Valley RE-2 School District, the Planning Office and the Natural Areas Committee of the University of Colorado, and the Denver Regional Council of Governments.

Sometimes the graduate researchers felt they would have liked to pursue certain themes in greater depth if there had been more time available. Nonetheless, they join me in expressing the hope that this report provides informative insights on a fascinating part of Boulder County.

This particular report on the White Rocks area departs in format and content from the companion studies in this series. The various chapters which appear in this volume are excerpts from two master's theses in geography completed this year at the University of Colorado. The White Rocks is such an interesting and important natural area in the Boulder Valley that everyone concerned felt the need for publishing this information now. The more detailed theses are available in Norlin Library on the Boulder campus of the University. We are grateful to Miss Helen Louise Young and

Mr. Dennis I. Netoff in cooperating with us in this effort and allowing us to combine portions of their fine studies as a rather complete report on the area.[1] The chapters included here represent the endeavors and views of the authors and in no way should be interpreted as the official views of the Department of Geography or any other cooperating agency or organization previously mentioned. Because of this independence from official views, the participants in this project are especially grateful to the Graduate School of the University of Colorado, the City of Boulder, the Boulder County Commissioners, the Boulder Valley RE-2 School District, and the University of Colorado Foundation for sharing the costs of printing this report.

This is the collective and individual effort of a group of dedicated geographers concerned about the quality of the local environment and its attendant stresses. Boulder County residents, students, and local officials may gain understanding from this report that will assist them in their efforts to perpetuate the Boulder area as a pleasant and attractive place to live.

Donald D. MacPhail, Ph.D.
Professor of Geography

Boulder, Colorado
June, 1970

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[1] Netoff, Dennis I., Polygonal Jointing in Sandstone Near Boulder, Colorado, M.A. Thesis in Geography, University of Colorado, Boulder, 1970.

Young, Helen Louise, White Rocks: Social, Cultural and Land Use Changes Affecting A Natural Area, M.A. Thesis in Geography, University of Colorado, Boulder, 1970.

## ACKNOWLEDGEMENTS

Mr. Netoff notes that helpful suggestions and cricicisms have been made by professors and graduate students in geology and geography. He feels especially indebted to Dr. William C. Bradley and Dr. Albert W. Smith for their advice and encouragement, and to Dr. Peter Birkeland for assistance and direction. Appreciation is also expressed to the owner of part of the White Rocks area, Mr. Tel Ertl, for permitting intensive field work to be conducted.

Miss Young mentions her appreciation to many individuals who aided her study efforts. She extends thanks to the following persons: to Professor M. John Loeffler for time spent in direction and guidance throughout the thesis preparation and for the use of the Colorado Piedmont base map; to Dr. Horace F. Quick for helpful suggestions; to many geography graduate students for aid and advice in research, mapping, and photography of the study area; to Mr. Ross Campbell and Mr. Harold Nesbitt for the use of U.S.D.A. aerial photography and soil maps of the area; to Dr. William Weber for supplying records of plants collected at White Rocks; to all individuals who willingly provided information in interviews and to Mr. Tel Ertl, landowner, for allowing access to his portion of the rock outcrop. Special thanks are extended to Mrs. Martha R. Weiser, owner of the western half of the outcrop, for her cooperation in allowing access to the area, providing documents helpful in the thesis preparation and her enthusiastic support and aid throughout the research. Miss Young also wishes to express appreciation to her parents for their support and encouragement.

Finally, our thanks go to Mrs. Nancy Stonington for her creation of the cover design, and to Mrs. Sue Middleton, Secretary of the Department of Geography for typing the report. To Mr. Wilbert J. Ulman, we are indebted for his work with the copy camera and contact printer in the final preparation of the maps for publication.

Donald D. MacPhail

# CHAPTER I. INTRODUCTION

Helen Louise Young

Many planners and private citizens are acutely aware of the change from land in open space to land in urban use. This awareness has, however, been created after urban expansion has already taken place; therefore, a nation-wide information program stressing present needs for more careful consideration of how land should be used is essential.

In order to adequately understand the need for open space, one must understand the meaning of the term. A universally acceptable definition has not been formulated. In the course of a University of California study on open space, Herring (1965) interprets the term as "encompassing any space which allows contact with Nature, though it may serve other utilitarian functions, such as conservation or postponement of urban development." A more precise definition is offered by J. M. Davis (1963). Stressing that open space is not merely vacant space, Davis lists three requirements: 1) the space must be relatively free of man-made structures and give the apperance of a natural landscape; 2) relatively free of vehicular traffic; and 3) must meet acreage requirements that vary in proportion to the intensity of use and the density of development in surrounding areas (U.S.D.A., 1963, p. 337). Open space, then, can be described as land left undeveloped for the purposes of recreation, scientific study, protection of wildlife, watersheds, or a buffer to urban encroachment.

Until the 1960s, Colorado was not acutely aware of the pressing need for open space simply because the problem did not exist in this state. The abundance of a resource, open land, masked the necessity for its conservation at that time. Beginning in the 1960s, an increase in population and industrial expansion has taken place on the eastern slope of the Front Range of the Rocky Mountains. One cannot drive along the Colorado Piedmont from Pueblo to Fort Collins without noticing urban development. Seeing former open space occupied by haphazard suburban and industrial development, planners instigated conservation practices. The trend toward conservation increased in importance during the latter part of the 1960s and now continues into the 1970s.

The growth of the Boulder Metropolitan Area[1] exemplifies the type of urban expansion occurring on the Colorado Piedmont. According to a recent Chamber of Commerce estimate, the population of Boulder has nearly doubled in the past ten years. An 86 per cent increase in population has taken

[1]A term used by the Boulder, Colorado Chamber of Commerce referring to persons living within the City's water and sewer service area.

place from 1960 to 1970 (Boulder Chamber of Commerce, 1970). Much of the growth has been south and east of the city. Two striking examples of suburban, single-family, residential expansion are the Table Mesa subdivision south of Boulder and the Gunbarrel Hill subdivisions northeast of the present city limits. The continued growth of these and similar subdivisions underlines the demand for saving open space.

The awareness of space conservation was not an unheard of idea in Boulder, even years ago. Frederick Law Olstead, Jr. (1910) prepared a report on density and zoning for the City of Boulder, which mentioned the setting aside of publicly-owned land for large parks. However farsighted these concepts might have been, their general idea was virtually ignored until a few years ago. In September, 1964, a City of Boulder publication, "Boulder's Fringe Area Objectives," presented a scheme for preserving Boulder's natural beauty by protecting it from urban encroachment. Suggested as the protective measure was an open-area reserve (greenbelt) to tie together the endangered tracts.

Certainly outdoor laboratories and study sites for the natural sciences would be one type of utilization for the open spaces around Boulder. One function of protected sites, according to Boulder planners, is for scientific use. With the University of Colorado located in Boulder, a need for such areas is critical. The natural sciences, biology, geography, and geology, for example, greatly benefit from the accessibility of suitable study sites, and such sites add to the national stature of these natural sciences. Fortunately, the University has had, and continues to have, an abundance of valuable study area. The continued accessibility to natural study areas cannot be assured, however, unless adequate measures are taken to protect these functional open spaces from the advance of urban sprawl. City and county planners and the University must work as a unit to save and acquire these additional tracts by means of thorough studies of the endangered sites and their problems. The White Rocks is such a study area and is presently used by several departments of the University of Colorado. It is an area facing problems from urban encroachment.

White Rocks, a 60-acre land area of outcropping sandstones, is located approximately 8 miles northeast of Boulder within the Denver-Boulder-Longmont urban triangle (Figure 1). Accessible by four- and two-lane roads from any point on the Colorado Piedmont, the physical environment of White Rocks is unique, is a scientifically valuable area, and is aesthetically attractive. The proximity of White Rocks to population centers makes it vulnerable to urban and highway encroachment, industry, trespassers, vandals, improper use by the scientific community, overgrazing, water and air pollution, all of which threaten its natural state. Increasing the public's awareness of the need for protecting remaining natural areas is essential to the preservation of White Rocks.

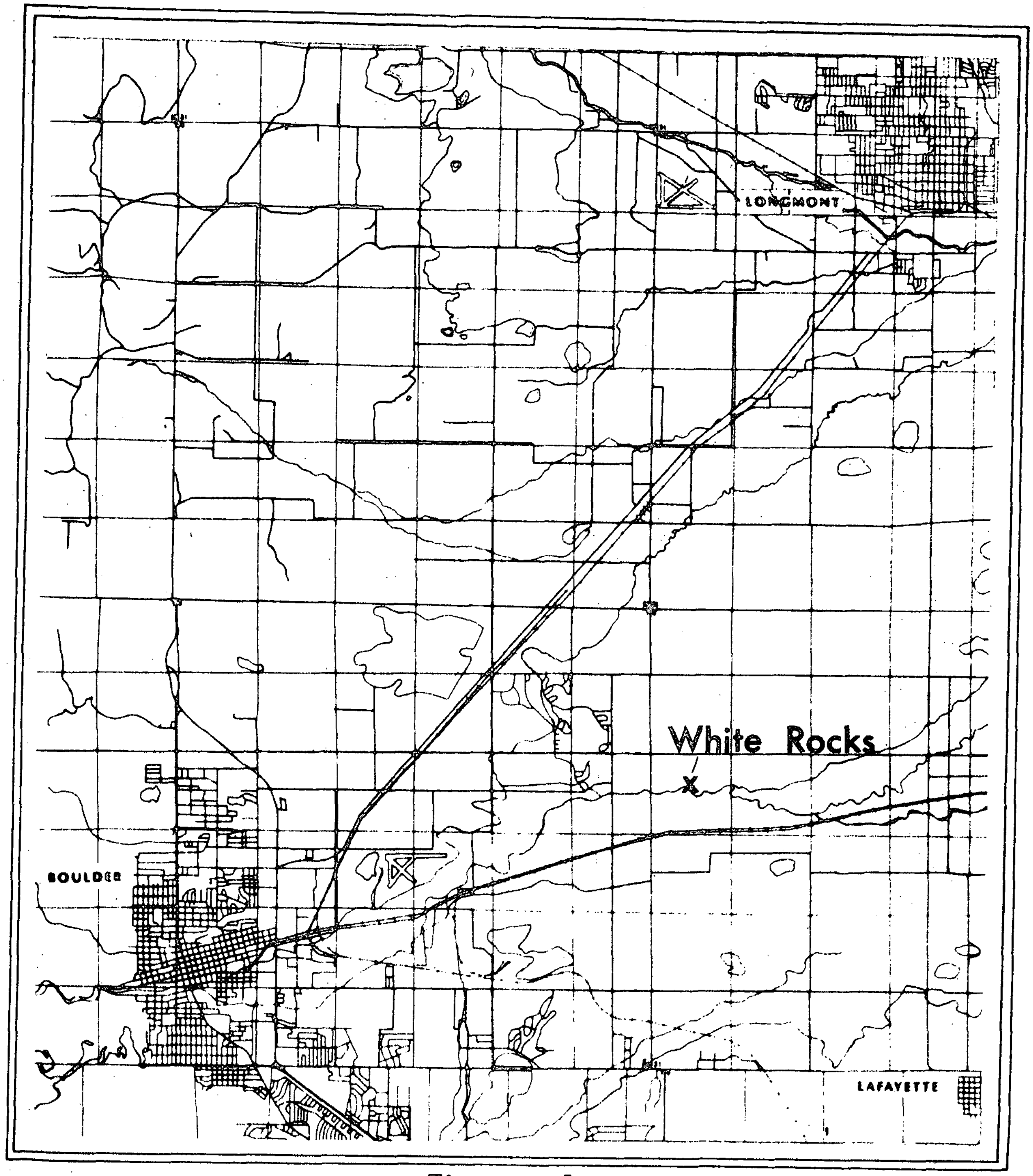


Figure 1

# CHAPTER II. THE ENVIRONMENT

Dennis I. Netoff and Helen Louise Young

The area chosen for analysis lies in the semi-arid section of the Colorado Piedmont near Boulder, Colorado, where several surface outcrops of polygonal jointing occur (Figure 2). Special attention was given to the area known locally as the "White Rocks" (Figure 3), where the polygonal pattern is especially well manifested, and where easy access permitted detailed study.

The conspicuous and somewhat exotic feature that distinguishes many outcrops of the Laramie and Fox Hills sandstones near Boulder results from jointing of a type not usually found in sandstone. The joints intersect to form polygons[1] that differ from those typically developed in sandstone in geometric form and related topographic manifestation.

Two basic polygonal patterns occur. The first is characterized by a preponderance of right-angle intersections and bears close similarity to mud cracks and ice-wedge polygons in plain view (Figure 6). The second, occurring within the first, is composed of hexagonal and pentagonal figures that resemble columnar jointing in horizontal perspective (Figure 6). A hummocky topography that is closely related to joint occurrence gives a unique characteristic to the surface relief and influences the distribution of a variety of local flora and fauna.

## General Geologic Structures

The major structural patterns of the Boulder area are controlled by two regional structural features, the Front Range anticline and the Denver Basin (Hunter, 1947), both formed during the Laramide orogeny. The Front Range anticline has a north-south axis and extends from Canon City, Colorado, north to Laramie, Wyoming. The Denver Basin, along the east flank of the Front Range, is an asymmetric trough and generally parallels the anticlinal axis.

The east-dipping, western limb of the basin is the principal structural feature. The sedimentary beds are steeply dipping near Boulder, then flatten rapidly a few miles to the east. It is within these gently dipping beds that the Upper Cretaceous sandstones under consideration here are found.

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[1]"Polygon" is used here to refer to a closed figure bounded on several sides, some or all of which may be curved.

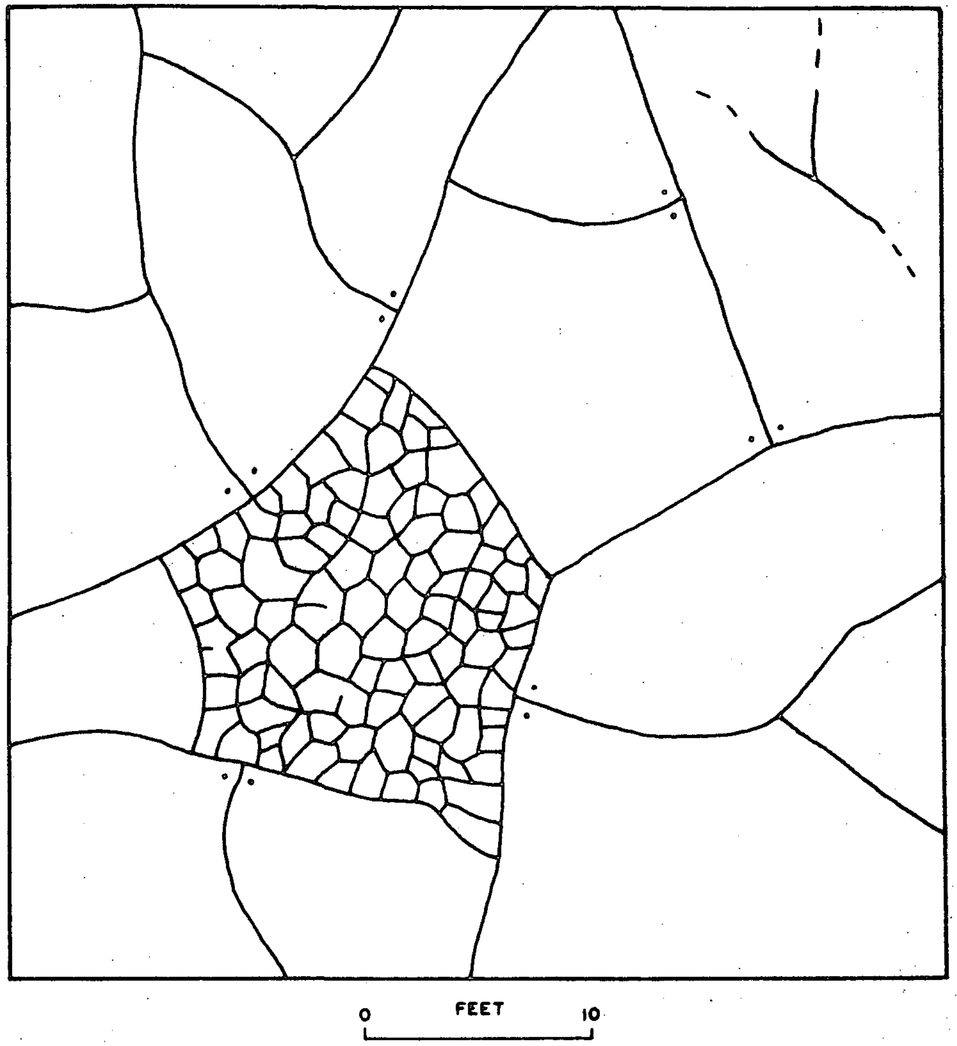
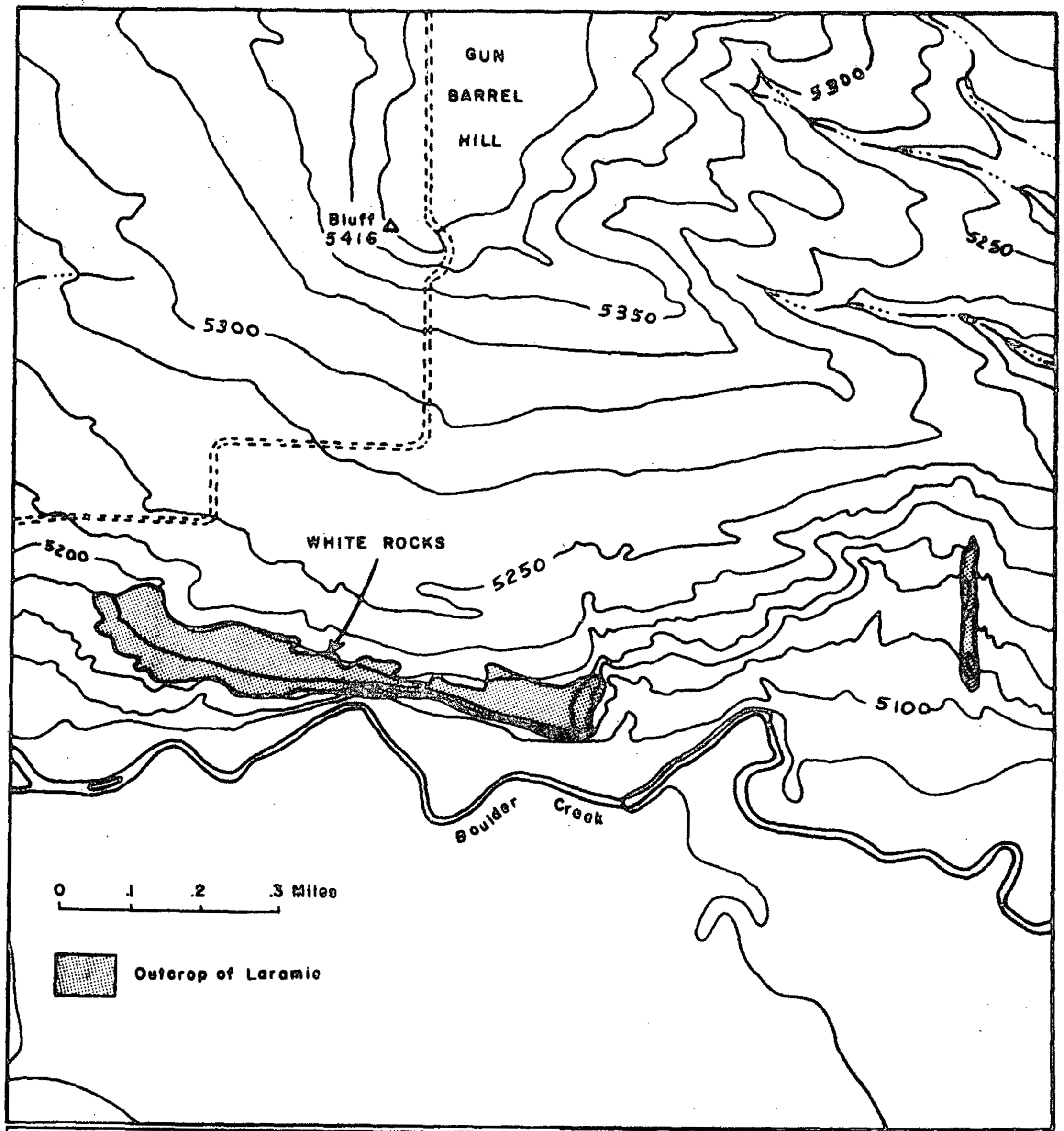



Figure 2. Idealized plan view map of joint systems. A high percentage of right angle intersections occur in the large joint system, while the smaller joints characteristically form hexagons and pentagons (dots denote right-angle intersections).



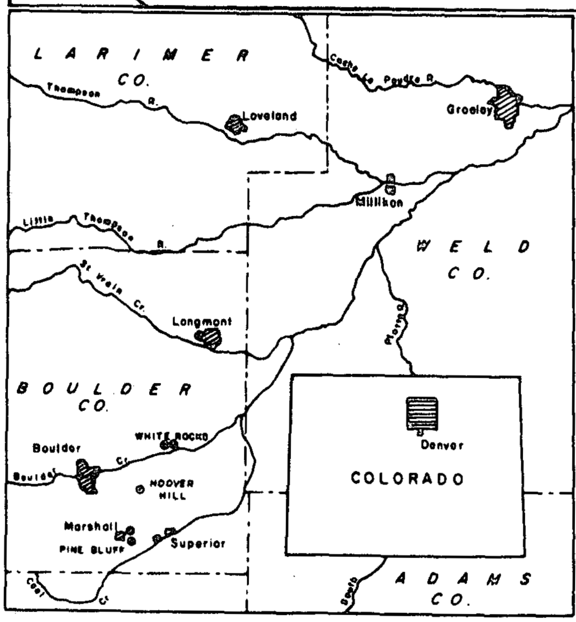




Figure 3. The White Rocks area. Polygonal joint patterns occur in nearly all surface outcrops of the Laramie Sandstone here. The contour interval in the map above is 25 feet.

The distribution of sandstone outcrops with polygonal jointing is shown on the small map at the left. Here the dots indicate the location of such occurrences.

Figure 4. South-facing cliff exposes highly pitted Laramie sandstone. Beneath the lower, undercut part of the Laramie, a thin coal seam separates this formation from the Fox Hills which extends outward toward the floodplain as a bench. (Photo by Dennis Netoff)

Figure 5. Tall grass and scrubby brush vegetation grow at the base of the outcrops along North Boulder Creek. This vegetation cover and the caves created by the wind and solution hollows provide a variety of habitats for small mammals within a short horizontal distance. (Photo by Helen Louise Young)

Figure 4

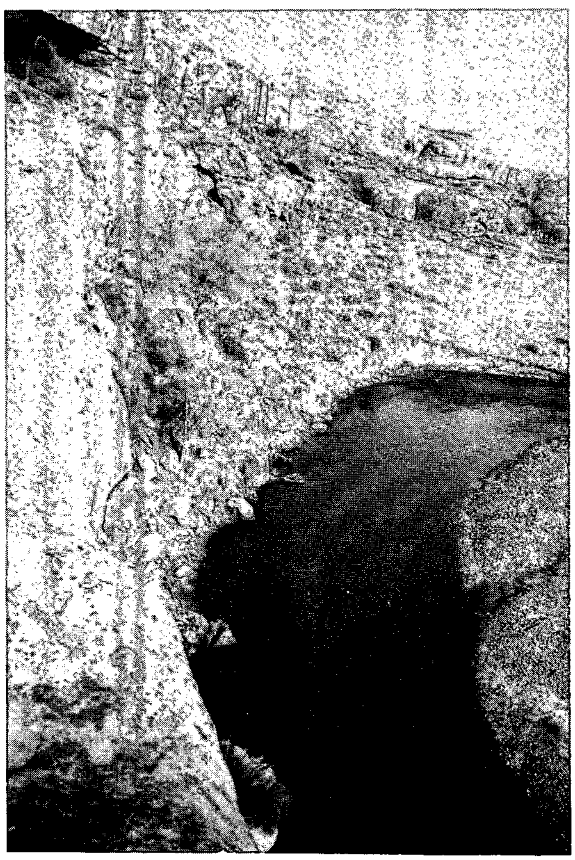


Figure 5

Local structural features are superposed on the regional structure, and are probably of Laramide origin. These include various types of folds and faults that tend to follow one or another of several basic patterns whose trends are predominantly north or northwest (Hunter, 1947). Many of the folds in the area between Marshall and White Rocks are subordinate to faults and are attributed to drag on faults (Parkinson, 1956).

## Upper Cretaceous Stratigraphy

The uppermost Cretaceous sedimentary sequence in the Denver Basin is represented by a series of alternating sandstones, shales, and thin coal beds, all of which were deposited during a general regression of the Cretaceous sea. In this sea, subsidence and sedimentation were generally contemporaneous, but proceeded at different rates, resulting in regression when sedimentation exceeded subsidence and transgression when subsidence exceeded sedimentation (Fenske, 1963, p. 41). The polygonal joint patterns are found in the Fox Hills and Laramie formations, which were deposited during the last major regression of the sea.

### The Fox Hills Formation

The Fox Hills formation is generally a light tan to brown colored, massive, cross-bedded and ripple-marked sandstone that is conformable with the underlying Pierre shale (Spencer, 1961). Grain size varies from coarse to fine, and numerous iron-stained, dark brown, hard, calcareous sandstone concretions are found in many places. Thickness varies from about 90 feet at White Rocks to 131 feet at Marshall (Parkinson, 1956, p. 11).

The upper and lower formation boundaries of the Fox Hills sandstone are difficult to locate exactly because of their transitional nature with the underlying Pierre shale and overlying Laramie formations. The lower boundary is usually accepted as the horizon below which the section is predominantly marine clay shales and sandy shales of Pierre age, and above which the section is buff to brown sandstone containing concretions (Lovering, 1932, p. 702). The upper boundary of the Fox Hills has been described by the same author as the horizon above which the section is composed predominantly of fresh and brackish-water deposits accompanied by coals and lignitic shales and below which it is predominantly marine. The location of this boundary, however, is controversial and several attempts have been made to change it (Gude, 1950; Goldstein, 1950; Horner, 1954). It is noteworthy, however, to recognize that many vertical as well as lateral facies changes exist in the formations and that marine sandstones may be present between the clays and lignites in the "non-marine part of the section."

### The Laramie Formation

The Laramie Formation is a thick series of sandstones and shales, generally considered of fresh and brackish-water origin. The Laramie formation in the Denver Basin can be divided into two parts, a lower one of primarily sandstones and an upper composed mostly of clays. Sandstones of the lower part of the section tend to be white to buff in color, even-bedded, speckled, and medium to fine-grained. Beds are usually soft and easily weathered and exposures are therefore scarce. Sandstone units may be separated by bands of sandy shale, lignitic shale, and intercalated coal seams. The upper part of the section consists mainly of clays, with some small lenticular bodies of sandstone (Horner, 1954, p. 14).

The Laramie overlies the Fox Hills conformably and in most places transitionally. The Laramie is unconformably overlain by the Denver and Arapahoe formations of early Tertiary age according to some authors, but others (Spencer, 1961) assign a late Cretaceous age to the Arapahoe and include it within the Laramie.

Polygonal joint patterns in the White Rocks area are restricted to the Laramie sandstones, and hence a brief discussion of the stratigraphy there seems pertinent. The exposed section consists of 250 feet of sediments which are predominantly sandstone (Fenske, 1963, p. 52). Here the Laramie and Fox Hills can be differentiated on the basis of color and lithology, and are separated by a conspicuous bed of lignitic shale, capped by a thin coal seam. The Laramie is a white, massive, even-bedded sandstone with a "salt and pepper" appearance due to the presence of black chert grains (Horner, 1954, p. 14), and forms a massive vertical cliff that overlooks the floodplain to the south. The Fox Hills is a light tan to brown, strongly cross-bedded sandstone with numerous brown concretions, and makes a step-like bench below the vertical face of the Laramie (Figure 4).

## Occurrence of Polygonal Patterns

Polygonal jointing in sandstone in the Boulder area occurs in only a few places. Outcrops of both the Laramie and Fox Hills formations may display this pattern, but it is better known and commonly better developed on the Laramie, especially at White Rocks. The most extensive outcrop areas of polygonal jointing occur on river bluffs where undercutting by streams has exposed the massive sandstones. Other natural exposures are of minor areal extent and usually occur along the steeper side slopes of terraces or pediments. Sandstone outcrops recently exposed by man are not known to display polygonal jointing.

The presence of polygonal joint patterns appears to be closely related to present-day topography and unrelated to exposure to insolation and wind. Polygonal development is not restricted to any one plane and may be found on slopes varying from horizontal to almost vertical. Exposure to wind and sun does not seem to be an important factor in their distribution, as they have been observed on north-, south-, east-, and west-facing outcrops.

The evidence for polygonal patterns occurring beneath a soil or alluvial cover is inconsistent and inconclusive. Some recently exposed surfaces at White Rocks lack polygonal patterns. Two excavations were made into the overlying soil at White Rocks. Both excavations were marginal to exposed Laramie sandstone that was polygonal jointed. Faint joint patterns persisted over 4 feet back into the soil cover at the first area. The second excavation exposed only a mottled, irregular surface devoid of joints. The explanation of this apparent discrepancy may be that all the joint patterns originated in a subaerial environment, but very recent eolian deposits have covered portions of formerly exposed sandstones. Additional escavations are needed before definite conclusions can be made.

## Types of Polygonal Jointing

Two unique, but distinctively different types of polygonal joint patterns are apparent on almost all areas studied (Figure 6). The patterns can be classified according to whether or not the intersections of the joint are predominantly orthogonal, a classification that was used by Lachenbruch (1962, p. 44-55) to describe ice-wedge polygons in permafrost.

The two systems of jointing are different not only in pattern, but in scale. Orthogonal systems are much larger, and the joints that bound them will be referred to as megajoints. Nonorthogonal systems are smaller in size and give the appearance of being superimposed on the orthogonal systems, and are somewhat controlled in their pattern where they are adjacent to the megajoints. These will be referred to as microjoints.

## The "Turtleback" Form

A unique topographic characteristic related to the combined effects of the orthogonal and nonorthogonal polygonal patterns has given the name "turtlebacks" to many exposed surfaces. Exposures at White Rocks reveal a gently undulating terrain with local relief of up to a few feet. Topographic highs are associated with the centers of polygons, while lows are coincident with joints, the larger joints occupying significant troughs and the microjoints creating a hummocky surface. Thus, the orthogonal polygons, when bounded on all sides by troughs, take on the appearance of a low dome with a hummocky surface created by microjoints, resembling a turtle's back (Figure 7 and Figure 8).

## Origin of Stress

Much of the following discussion is speculative. The proposed theories regarding the origin of stresses that produced the polygonal joint patterns are yet to be proved and await further tests and experimentation.

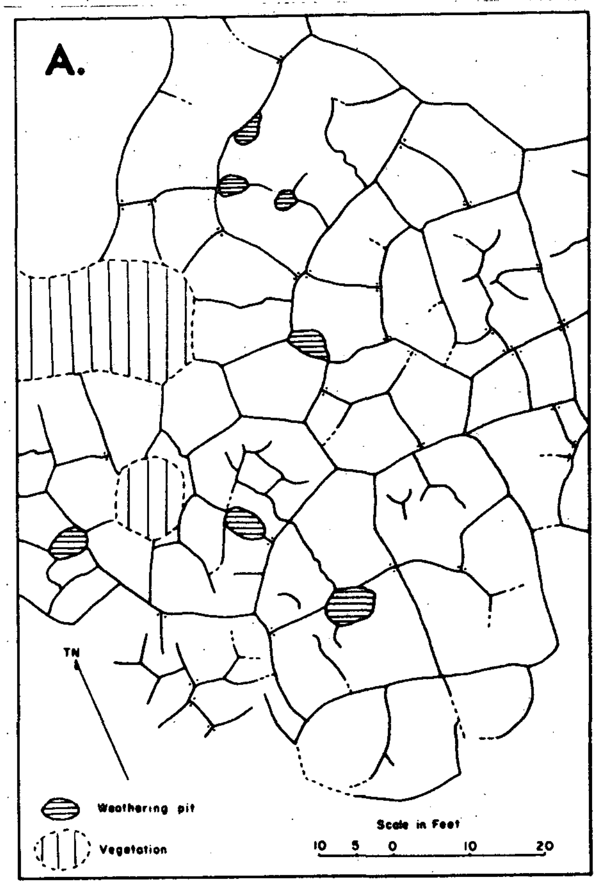
### Thermal Hypothesis

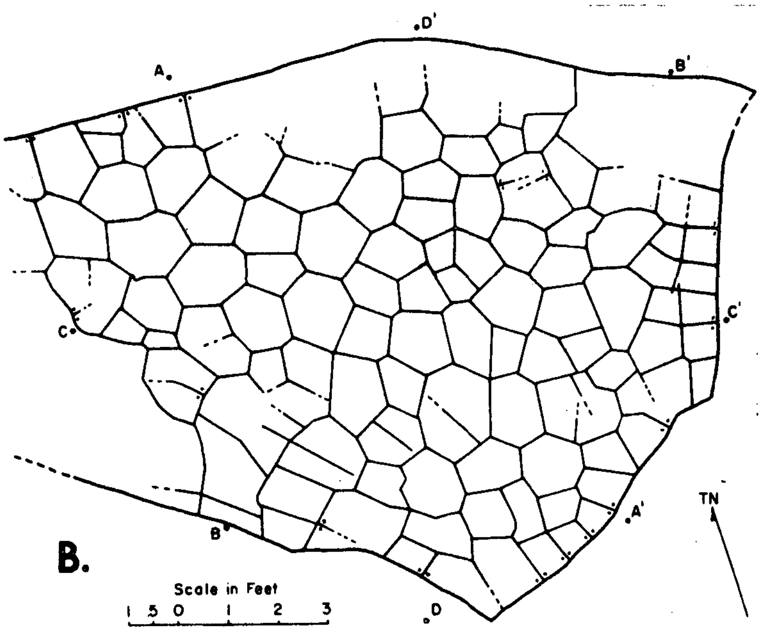
The theory of thermally induced breakage of rock is based on the fact that most materials expand when heated and contract when cooled. Fracture upon heating may occur when heat is rapidly applied to one part of the mass, causing differential expansion and creating shearing stresses that will result in rupture if the elastic strength of the rock is exceeded.

### Desiccation Hypothesis

Volume changes related to clay mineral expansion and contraction are known to cause heaving and cracking in clayey material. Mud cracks and

A. (Right) Orthogonal system of polygons at White Rocks, with dots indicating right-angle intersections.




B. (Left) Nonorthogonal joint patterns in sandstone at White Rocks. Megajoints bound the smaller microjoints except on the eastern side where joints gradually fade. Dots denote right-angle intersections.

Figure 6

Figure 7. The "turtleback" form. The hummocky surface is associated with joint patterns. The diameter of the small polygons is about a foot. (Photo by Dennis Netoff)

Figure 8. Rolling, rocky exposure of the Laramie sandstone at White Rocks. Trees, shrubs, and grasses struggle for a foothold in the depressions where there is a thin veneer of soil and some moisture. (Photo by Helen Louise Young)

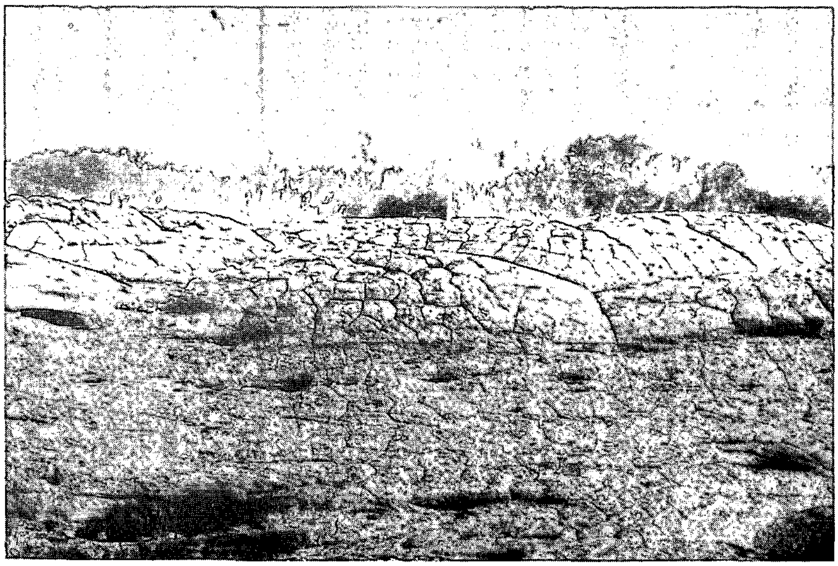


Figure 7

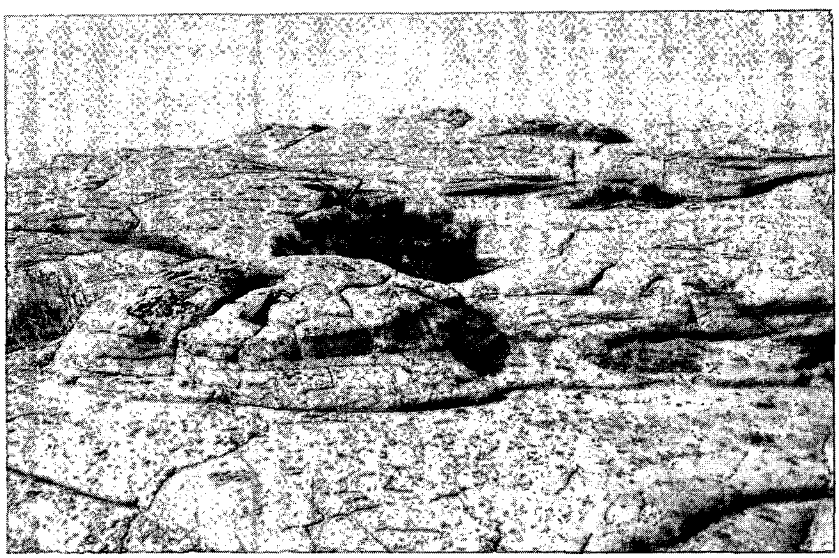


Figure 8

soil cracks, often forming well-developed polygonal patterns, are a common geologic phenomenon and are attributed to desiccation. Voluminous literature in soil mechanics has been dedicated to the effects of expansive clays on road and building construction.

## Moisture Content of Polygons

The moisture content of the jointed sandstone varies vertically, horizontally, and temporally. Moisture characteristics are based primarily on field observation and some quantitative measurements.

The time factor is perhaps of greatest significance in producing local variations in moisture content. Sporadic rainfall is a typical characteristic of the climate, and hence during the course of a year the sandstone is subject to many wet and dry cycles. Following periods of rain or snow, the moisture content of the sandstone is at a maxiuum and may approach saturation, while extended periods of drought result in evaporation and maximum water loss.

Horizontal variations in moisture are especially evident as drying proceeds subsequent to periods of precipitation. While the centers of the polygons take on a dry appearance almost immediately, moisture may linger on for many hours in the troughs near the polygon borders. Moisture content at depth may also reflect this surface pattern. Although no empirical evidence was obtained to verify this, it seems logical for two reasons: first, the joints occupy the lowest point topographically, concentrating surface and subsurface water here by gravity; and second, the joint plane represents a zone of discontinuity and may act as a barrier to moisture migration.

Observation on the vertical distribution of moisture yielded interesting, and somewhat surprising results. Although the surface nearly always appears dry, the sandstone at a very shallow depth is constantly moist to sight and touch. Even after a month without precipitation, damp sandstone was found within 2 inches of the surface. Several samples of sandstone were selected from a vertical section up to a depth of 10 inches and were analyzed for moisture content. Samples were heated to 110 degrees Centigrade for 12 hours and moisture percentages were then calculated on a weight basis. It is interesting to note that a significant change in the slope of the moisture curve occurs at the average depth of microjoints.

A case-hardened surface is typical of most polygonally jointed areas, and is believed to have some influence on moisture characteristics. The thickness of the casehardening is rarely greater than a quarter of an inch and may only be represented by a paper-thin layer in some instances. The composition and origin of the material is unknown, but is probably derived from soluble minerals within the sandstone that have migrated upward by capillarity during dry periods and have been left behind and concentrated as the water evaporates. When wet, the surface may become slightly sticky and behaves similar to clayey material. The presence of the case-hardened surface reduces the infiltration capacity of the sandstone and may also act to retard the upward loss of moisture from the sandstone, acting as an insulating blanket. A possible example of how the material affects the infiltration of water is illustrated by the behavior of water in weathering pits, which are widespread at White Rocks. Following heavy rainfall or snowmelt, the weathering pits fill with water, and the small ponds created may persist for weeks without further precipitation (Figure 9). The permeable sandstone should allow the water to be quickly absorbed, but apparently the case-hardened surface, possibly with the help of swelling clays in the matrix, prevent infiltration.

Once a small depression develops, it becomes a cachement for water, increasing the chemical weathering. In addition, sometimes small rocks are washed down into the solution pits by a heavy runoff. After the water in the solution pit evaporates, the rocks may be moved about in the pits by the wind. Eolian erosion affects both the pits and the rock fragments and continued scouring may polish the faces of the rock fragments until they are quite smooth. These angular, polished rocks are ventifacts called "dreikanters."

## Origin of the "Turtleback" Form

The hummocky topography associated with the polygonal joint patterns is somewhat unique and warrants some discussion (Figures 7 and 8). The troughs that develop along the joints are believed to be a product of more active chemical and physical weathering, initiated by the greater moisture retention capacity in the joint zone. Once an initial depression is created, weathering processes are intensified, and conditions become favorable for the maintenance and further deepening of the grough. The removal of the case-hardened surface may be the initial phase of trough development, allowing granular disintegration of the sandstone and subsequent removal by water or wind.

## Local Anomalies

Tectonic forces have affected the visible statigraphy at White Rocks. A fault has altered the stratigraphic arrangement of the east end of the rocks. Here, a high-angle, reverse fault breaches the sandstone strata. The displaced stratigraphy adds to the aesthetic value of the outcrop by changing the visual relief. West of the fault line, the stratigraphy is not disturbed, but east of the fault line the Fox Hills formation is pushed up to the level of the Laramie. The Pierre shale which underlies the Fox Hills is exposed and, near the fault zone, some of the Pierre beds have been deformed. East of the fault zone, the Laramie, having been uplifted and exposed to weathering and erosion, is not visible (Figure 10).

Concretions[1] are found in varied shapes and sizes in the Fox Hills and Laramie formations at White Rocks. The origin of these concretions begins

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[1]Term refers to an irregular concentration of certain mineral constituents of sedimentary rock.

Figure 9. Weathering pits at White Rocks. Water may linger in these depressions for weeks subsequent to heavy rains. The weathering pit includes the area occupied by water and the adjacent area of unjointed sandstone. The varied topography, created by these and by the turtlebacks, provides a protective habitat for native grasses (note rock hammer for scale on far side of weathering pit. (Photo by Helen Louise Young)

Figure 10. Aerial view of the White Rocks. A high-angle reverse fault line forms a valley at the eastern end of the rock outcrop seen in the upper right part of the photo. Here, the Fox Hills ("F", right of valley) has been pushed to the level of the light-toned Laramie ("L" left of valley). East of the fault, the Laramie outcrop disappears. Note south-facing, pitted cliff face. (Photo by Dennis Netoff)

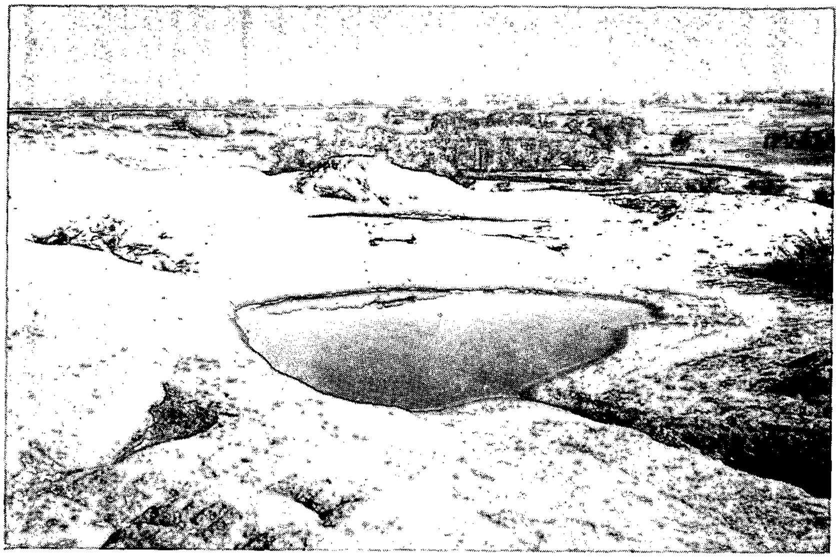

Figure 9

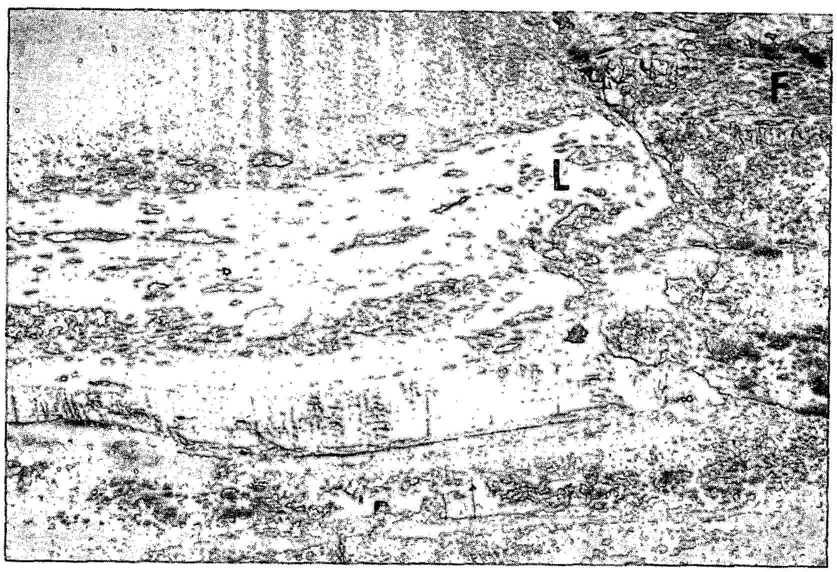


Figure 10

with the dissolving of certain minerals in the sandstone and their suspension in the rock pores. With supersaturation of the pore fluid, precipitation of the mineral occurs around some small nucleus - a fossil or rock fragment. Concretions at White Rocks are of different types depending upon the predominant mineral composition. Size and shape of concretions is determined by the moving groundwater, the alignment of pores in the host sediment and the shape of the nucleus. Fenske (1963, p. 38) listed three major types of concretions at White Rocks: calcareous, sand calcite, and ferruginous.

## Other Geomorphic Features

The genesis of the long, linear, east-west hollow at the base of the cliff is indefinite. The hollow, approximately 5 feet wide, 3 to 4 feet in depth and several hundred feet long is at the base of the Laramie formation on the south-facing cliff (Figures 4 and 10). Because of its prominence, it is not only scientifically interesting, but aesthetically attractive. It is suggested that this linear depression might have been formed by downward percolation of groundwater. An impermeable rock layer just below the present hollow may have forced the water to flow laterally - eroding the hollow as it flowed out of the cliff. Various salt deposits inside and below the long, linear hollow provide further evidence for the role of groundwater. Precipitation of these minerals most likely occurred as evaporites. Disintegration of the sandstone and further accentuation of the hollow may have been facilitated by the growth force of the salt crystals.

Larger, more bowl-shaped depressions into the south-facing bluff were probably carved out by North Boulder Creek when it flowed at a higher level than at present. The creek meandered against the bluff at one spot leaving a depression in the cliff almost a hundred feet long and 50 or 60 feet high.

Other features related to the erosive action of water are the small honeycomb hollows (Figure 4) found on the steep cliff face of the Laramie along with a natural bridge. The hollows may have started as small depressions in the cliff which filled with water dissolving the rock and causing it to crumble after evaporation took place. The natural bridge, about 5 feet high and 15 feet wide at the base, is separated from the cliff by approximately 10 feet.

## Vegetation

Patterns of vegetation vary with altitude, exposure to sun and wind, angle and steepness of slope, available water, soil and influence of man. The varied topography of White Rocks, as determined by chemical composition, structural conditions, and erosional processes, provides a variety of different vegetation habitats within a limited horizontal distance (Figure 5). The steep, 70- to 80-foot drop from the top of the bluff to the floodplain at the southern edge of the outcrop offers a rapid transition from the dry piedmont to the floodplain of North Boulder Creek (Figure 13). Constantly exposed to sunlight, the south-facing, light-colored sandstone provides the warmest and most protected habitat in the immediate area. Local topoggraphic irregularities, such as the "honeycombs" in the cliff, the joints in the sandstone, the weathering pits, and the gulley carved out by the fault provide additional varied habitats for plant life.

White Rocks is a part of the plains grassland region (Rodeck, 1964, p. 36). Typical vegetation on the floodplain is a mixture of blue gramma (Bouteloua gracilis (HBK) Lag.), buffalo grass (Buchloe dactyloides (Nutt.) Engelm.) and yucca (Yucca glauca). Big bluestem (Andropogon geradi Vitm.), needle grass (Stipa comata Trin. and Rupr.) are common on rocky, eroding slopes at White Rocks. Shrubs such as skunkbrush (Rhus trilobata Nutt.) and other scrubby bushes may cling tenaciously to rocks or grow in gullies. Only two or three ponderosa pine (Pinus ponderosa Dougl. ex Laws) grow on the Laramie outcrop (Rodeck, 1964, pp. 36-38).

White Rocks is recognized by biologists in America and abroad as a haven for several species of rare plants. The cliffs support one of only three known colonies in North America of the fern, Asplenium adiantum-nigrum. Extremely rare, this fern has been collected in only three other places in the Western Hemisphere: Zion National Park, Utah; Flagstaff, Arizona; and Marion County, Florida (Weber, 1949). The grass Aristida basiramea and the legume Apios americana, commonly called the ground nut, have been found at White Rocks and are the only recorded Colorado specimens for these species (Weber, 1970). Plants representing 32 different families and over 90 different species have been collected at White Rocks in the past 60 years and are included in the University of Colorado's herbarium (Appendix A).

## Fauna

The varied topography and exposure of White Rocks provide diverse animal habitats. Because of the intimate link between topography, climate, vegetation and animal life, the typical animals found at White Rocks are those associated with the plains grassland vegetation zone. Studies of animal life at White Rocks have been carried on by both the biological scientists and interested residents of the area.

Small rodents, such as mice, squirrels and rabbits are common. These mammals make their homes in the rock hollows at the base of the cliff and in the brush and fallen trees along the floodplain. The predatory mammals, the coyote and red fox, are less common and tend to be more easily frightened by man's presence in the vicinity than the rodents. Landowners fear an overpopulation of herbivores might result if the predators were forced to flee.

The only extensive field inventory of mammals and birds of the area was conducted in 1948 in a cottonwood grove along North Boulder Creek about a mile upstream from White Rocks. Among the observations in this study (Beidleman, 1948) which can be considered typical of the floodplain at the base of White Rocks are: three different genera of snakes and of turtles; 88 different species of birds and 10 different species of mammals.

Many observations by residents of the area have added to Beidleman's list. A composite from Beidleman's thesis and personal interviews lists the most common birds and mammals (Appendix B).[1]

White Rocks is used as a study area by the animal ecologists. Twice yearly, local bird-watchers conduct a bird count along the floodplain near the rocks. Biologists have observed birds at White Rocks and a local resident, Mrs. W. C. Sullivan, banded birds in an effort to check on permanent residents and their migratory patterns.

Several unusual and rare animals have been found at White Rocks. Dr. Robert Gregg, entomologist at the University of Colorado, has collected rare species of ants at White Rocks. Aphaenogaster fulva is common to eastern United States but is rarely found west of the Mississippi River. Three other rare western species have been found at White Rocks (A. huachucana, Formica criniventris and Lasius occidentalis). A mining bee (Perdita opuntiae Cockerell) drills burrows in the sandstone cliff and is unique to the site (Byars, 1936).

The measure of an area's scientific value is in its number, variety and quality of specimens and examples. For a geologist or physical geographer, White Rocks is valuable because of its exposed stratigraphy and its textbook examples of secondary sedimentary structures. As a haven for rare plant and animal life and a variety of ecological habitats, White Rocks has a strong attraction for those interested in biological landscape - topography, climate, vegetation and animal life combine in ecological harmony creating a unique, scientifically valuable and aesthetically attractive study area.

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[1] Only birds and mammals are considered here due to more field observations having been done on these members of the animal kingdom.

# CHAPTER III. EFFECTS OF CHANGING LAND USE

Helen Louise Young

Physical, economic and social factors within a given area determine the land utilization. All must be considered, for each forms an integral component of evolving land use. Man is not entirely at the mercy of nature, yet a certain degree of influence is exerted by the climate, topography and biota in controlling his activities.

The varied topography of White Rocks forms a natural barrier to the plow. Farming the rock outcrop is virtually impossible. Climate also limits agricultural use through the deficiency and unreliability of the rainfall. Adding to the agricultural limitation is a very low groundwater table. Wells permitting large-scale irrigation are not feasible (Longley, 1970). Just as topography and climate are important controls in land use, soil capability may be the major factor in determining land use in the White Rocks area.

## The Soil and Agricultural Potential

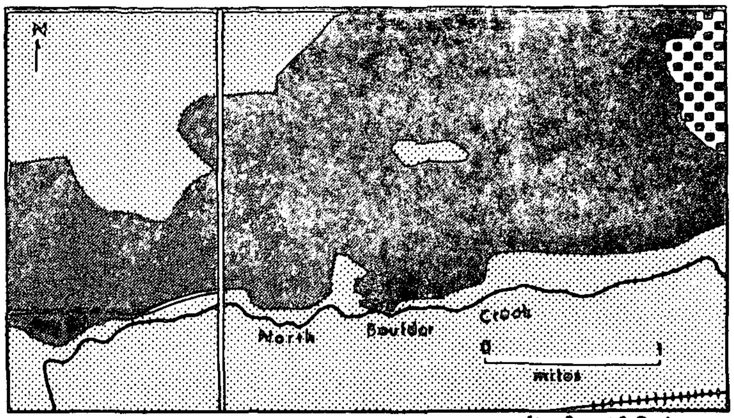
Most soil in a semi-arid climate is potentially fertile; however, lack of rainfall limits the productivity considerably. Sweet and Dodson (1935) and Moreland (1968) have named, described and analyzed the soils in the White Rocks area. Though the reports were compiled more than 30 years apart, the results were quite similar. Different nomenclature was utilized in each report; however, the important consideration is the soil capability rather than the soil name. Only textural description (sand, clay, loam, for example) and land capability classification[1] are used to show the relationship between different soil textures, slope and drainage and different types of land utilization.

The land under dry farming north of the rock outcrop is a sandy loam. These soils are moderately light textured at the surface. The water intake is rapid and the water-holding capacity is medium to moderately low (Moreland, 1966). The lands on the southern fringe of Gunbarrel Hill have a capability classification of Class III and Class IV, depending on the degree of slope (Figure 11). Soils west of 75th Street in the area of highest suburban density are mostly poorly drained clays with a few fine sandy loams. These soils have a capability classification of Class IV and

[1]Classification of lands according to their capability is based on the Land Capability Classification of the Soil Conservation Service, U.S. Department of Agriculture. For definition of classes see Figure 11.

# LAND CAPABILITY

## WHITE ROCKS AND VICINITY




after Sweet & Dodson

### CAPABILITY CLASSIFICATION EXPLANATION

Loams. Class II. Some limitations that reduce the choice of crops or require some conservation measures.

Clay loams. Class III. Severe limitations that reduce the choice of crops or require special conservation practices or both.

Clays and fine sandy loams. Class IV. Very Severe limitations that restrict choice of crops, require very careful management or both.

White Rocks Outcrop. Class VIII. Not suited for cultivation, range, pasture or woodland. Suited only for recreation, wildlife, water supply or aesthetic purposes.

[1]Based on U.S. Department of Agriculture Land Capability Classification.

Figure 11

Figure 12 Aerial view of the White Rocks area looking northwest toward the Continental Divide. The floodplain and meanders of Boulder Creek appear at the left (south) of the sandstone cliffs. In the distance, residences encroach upon agricultural land adjacent to the White Rocks. (Photo by Dennis Netoff)

Figure 13 The vertical cliff at White Rocks presents a striking stratigraphic difference between two sedimentary formations - the white, uppermost Laramie and the Fox Hills below (appears here as the lower, shrub-covered slope). Several different depositional environments are illustrated by the Laramie, the Fox Hills, and the transition zone between them. (Photo by Helen Louise Young)

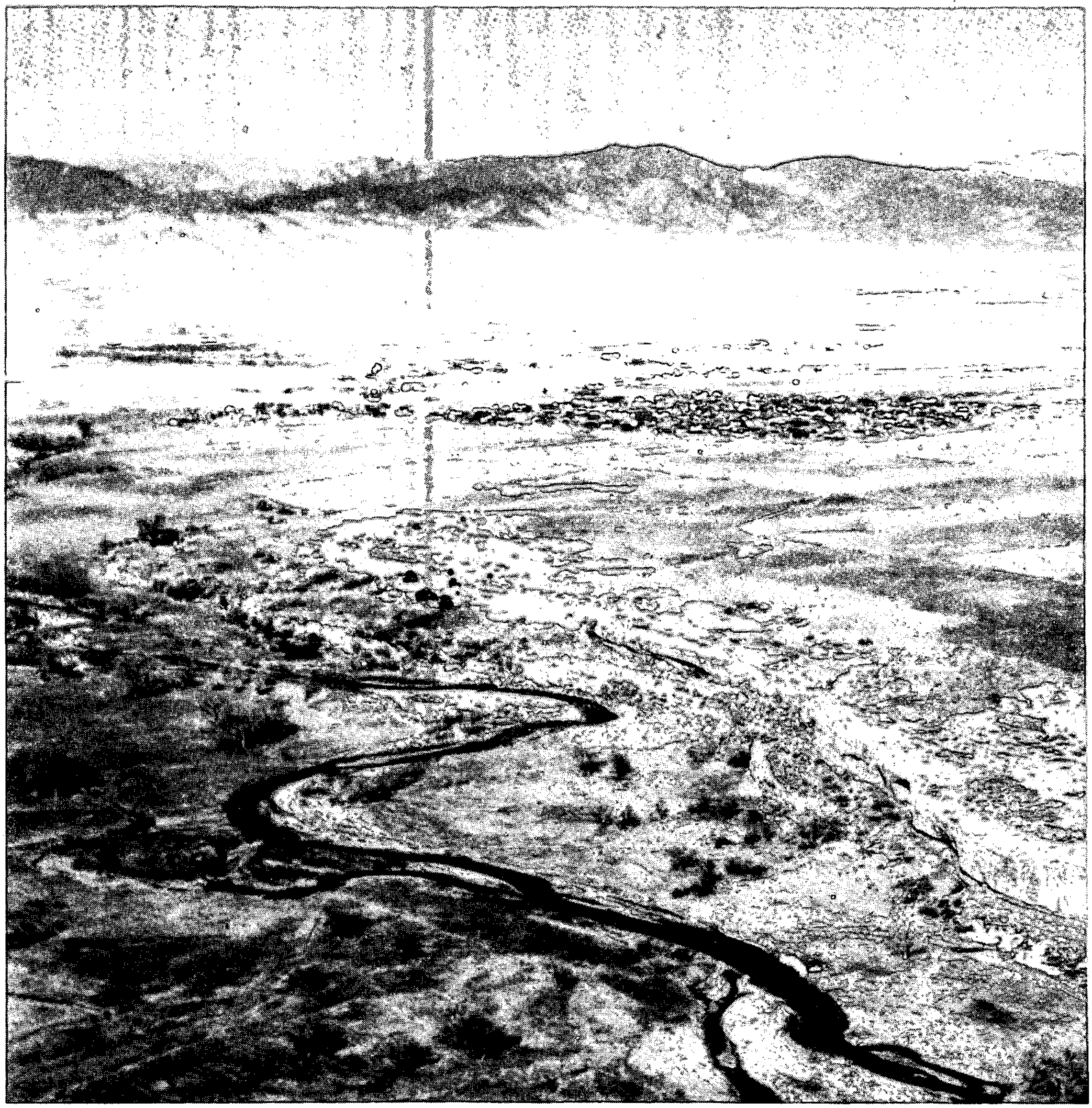


Figure 12

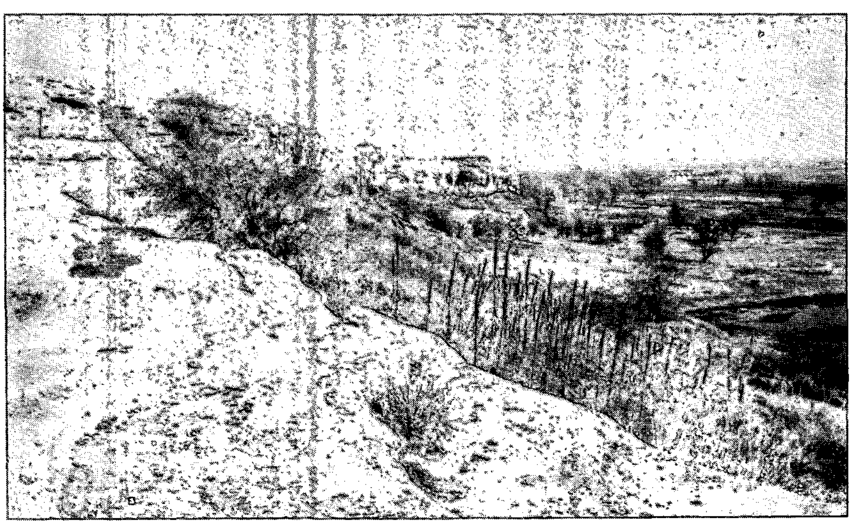


Figure 13

and are less suited for agricultural use than those on Gunbarrel Hill (Sweet and Dodson, 1939, pp. 20-21).

The land on the North Boulder Creek floodplain is a moderately deep, loamy, poorly drained, alluvial soil. The surface has a heavy texture and has a capability of Class IV (Moreland, 1966). In short, all the lands surrounding White Rocks could not be classified as highly agriculturally productive. Care must be taken continually to prevent wind and water erosion. The agricultural land north of White Rocks is utilized for farm-and-fallow wheat, while grazing takes place on the floodplain. The White Rocks outcrop has a capability of Class VIII due to the extremely rugged terrain.

Soil drainage, fertility and slope have a significant effect on agricultural productivity and low agricultural productivity has opened the way for other types of land use in the study area. The first lots to be sold for subdivisions are located west of 75th Street on the flat, poorly drained Class IV land (Figure 11). This land was flat enough to permit houses to be built, yet not agriculturally productive. The land east of 75th Street on Gunbarrel Hill (Class II and Class III) remains under dry farming, but since there is no source of irrigation water on Gunbarrel Hill, the owners of the land might not find it feasible to farm in the near future. Two logical possibilities for the land if it were taken out of farming are: 1) the land becoming part of a greenbelt or 2) it becoming sites for subdivision (Campbell, 1969).

## Urban Growth and Expansion

Presently most of the land east of 75th Street and north of White Rocks on Gunbarrel Hill is zoned for agriculture (Boulder County, 1965). An important exception to agricultural zoning is the Heatherwood Estates subdivision which has been developed within the last 3 years by Wood Brothers Homes, a large building firm based in Denver. The first home in Heatherwood was built in 1967 (O'Laughlin, 1970). Heatherwood subdivision is emphasized to a greater extent than the other suburban developments west of 75th Street (Gunbarrel Greens, Island Greens, Flintlock Estates, for example) because it poses the greatest encroachment threat to White Rocks. Heatherwood is now building houses on most of the Southeast ¼ Section 12, Township 1 North - Range 70 West. This urban expansion may extend to less than one-third of a mile northwest of White Rocks within the next 5 years, for the land (NW¼, NE¼, Section 13) has already been purchased by Wood Brothers Homes. Land so close to White Rocks may be occupied by single-family residences or multi-family apartments (O'Laughlin,1970).

Realistically, within 5 to 10 years, Heatherwood may extend a mile or more to the north and east and, more crucially, south to the very edge of White Rocks. Such a projection may be substantiated inasmuch as the land presently occupied by Heatherwood was farmed as recently as 3 years ago. Subdivisions have expanded over 1 mile eastward toward White Rocks in the past 6 years.[1] The change from dry farming to suburban development

[1]Measurements compiled from U.S. Department of Agriculture aerial photography of the area, 1963 and 1969.

is still occurring. The indication is that a farmer will continue to farm a parcel of land while it is profitable; however, if for some reason (lowering of wheat prices, for example) the farmer can no longer farm, he must seek the best economical use of the land. If a real estate developer offers a handsome price for the land, it is possible that the farmer will sell (Musser, 1970). An additional incentive to sell would be the psychological effect of the suburbs. The encroachment of suburban development near a farm might lead to the leaving of the farm, because of constant disruption of normal farm activities.

Past patterns of land use are significant in understanding present patterns and being able to make future projections. Farming was once the only activity north and south of White Rocks. Industrial growth (IBM, for example) in the proximity and the desire of a person to live away from the city proper have led to the urban expansion near White Rocks today. Essential to the interpretation and the understanding of these rapid and profound changes is the consideration of the expansion and growth of Boulder during the past three decades.

Continued growth and expansion of Boulder is best understood by recognizing its potential as an industrial, research and educational center. An ever-expanding Boulder employer, the University of Colorado, attracts and continues to attract numerous research firms. Examples of the quality of research growth are the following firms: The National Center for Atmospheric Research, the Environmental Science Services Administration, the National Bureau of Standards, Ball Brothers Research Corporation, International Business Machines (IBM), and others.

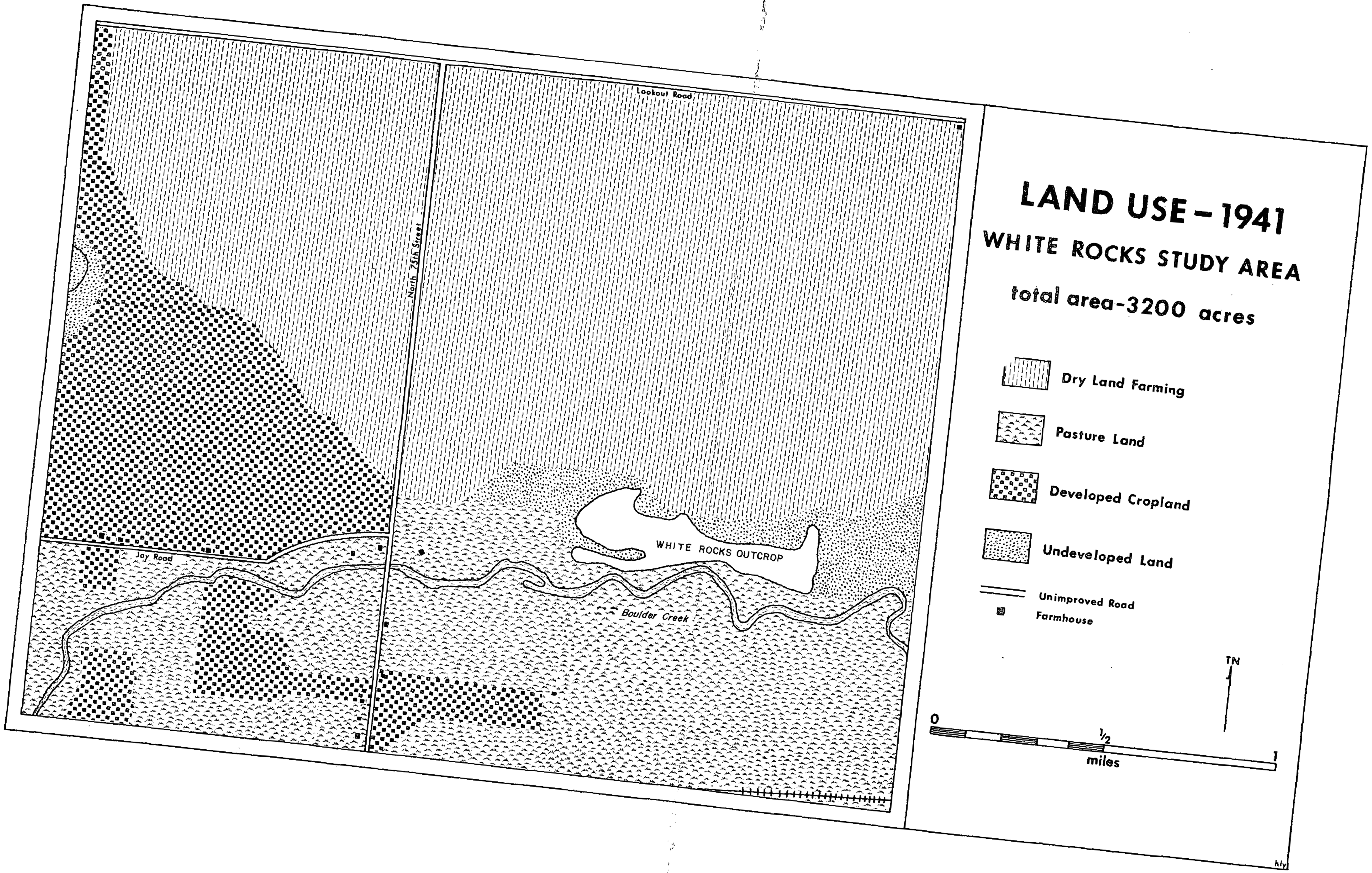
Industrial and commercial growth is mirrored in population growth. The Boulder Chamber of Commerce publishes population figures from the United States Bureau of the Census in addition to their own population projections. Boulder population changes in the last 30 years are noted in Table 1.

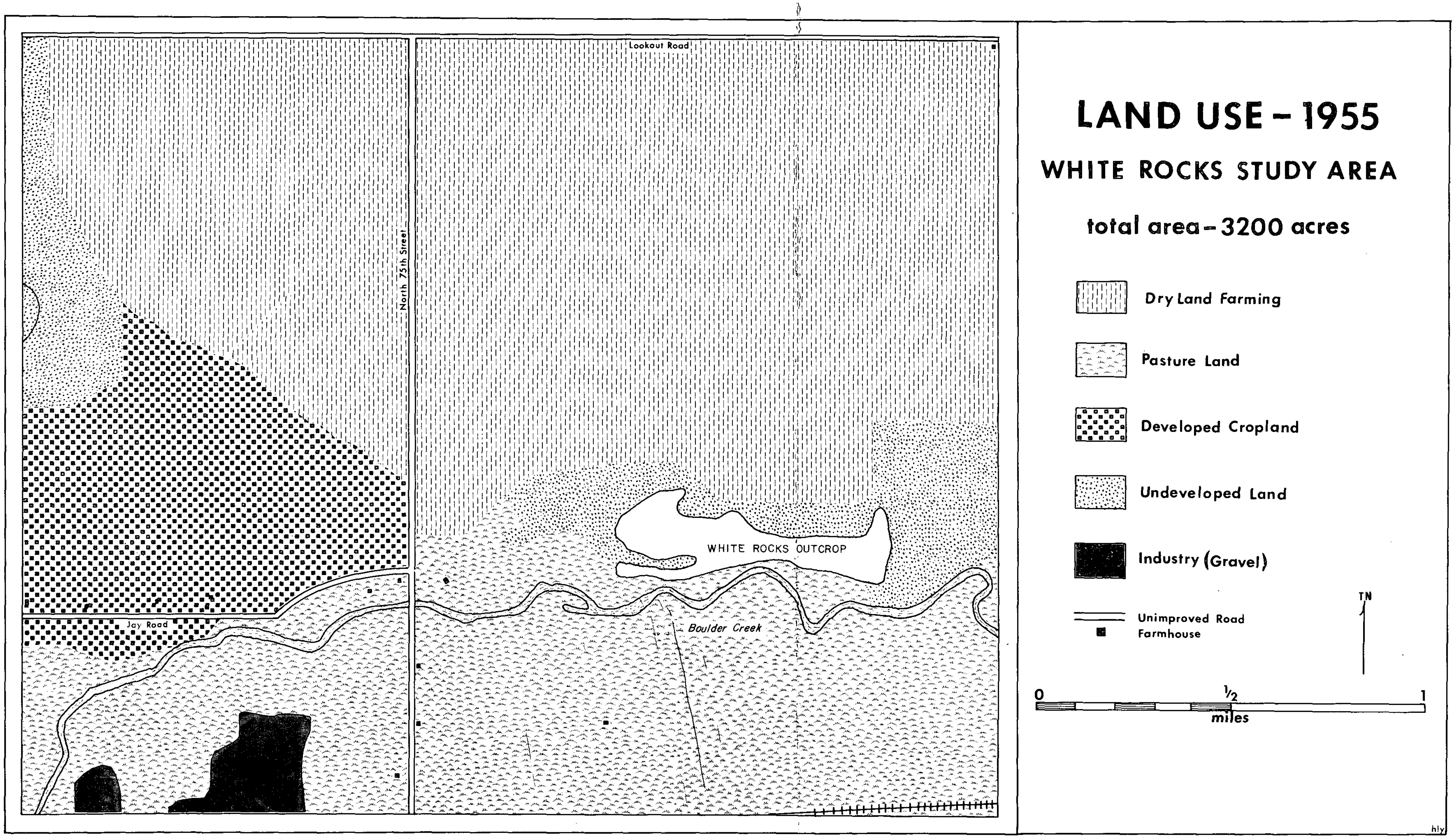
TABLE 1. POPULATION GROWTH, CITY OF BOULDER

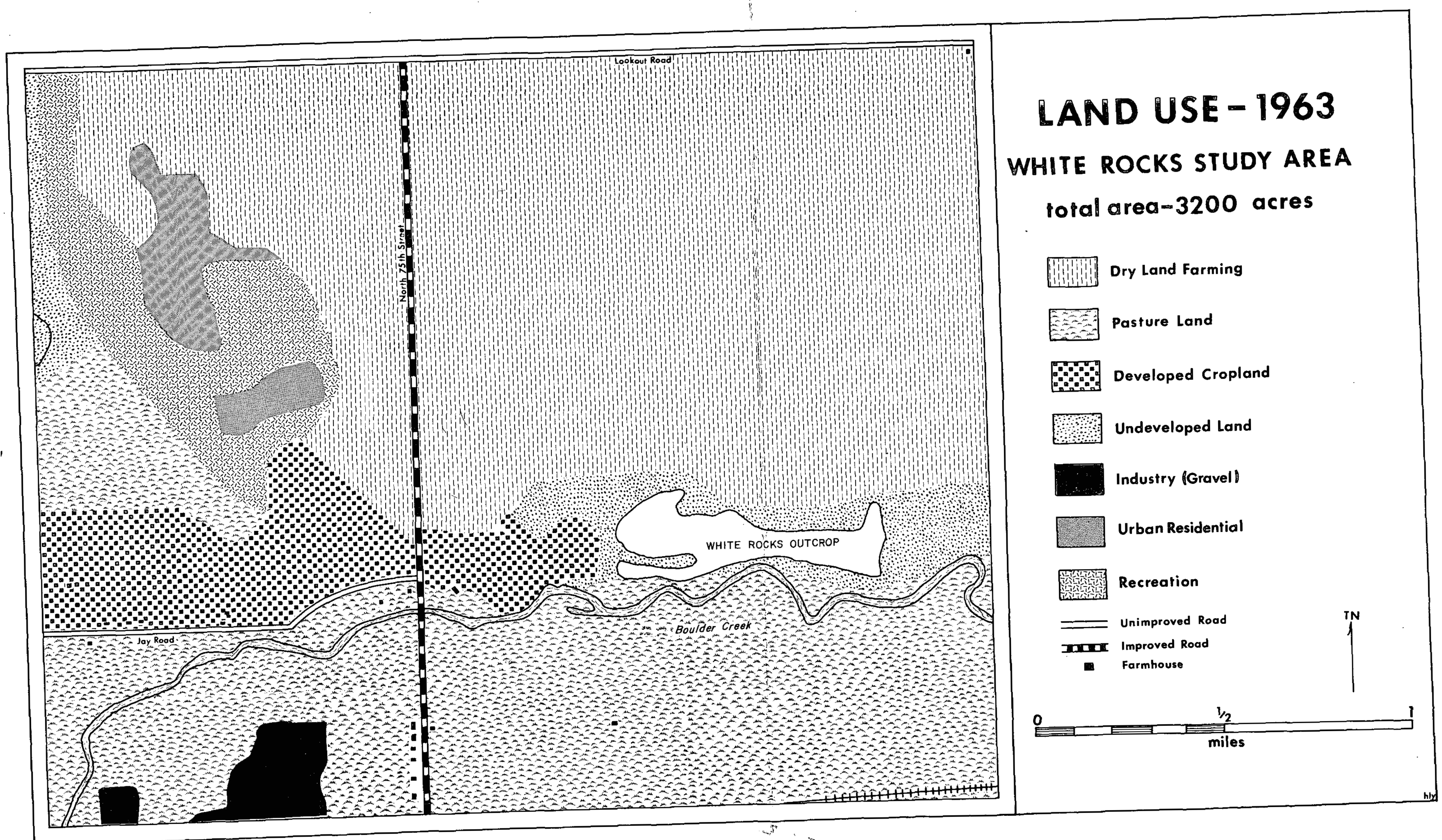
| Year | Population |
|---|---|
| 1940 | 12,958 |
| 1950 | 19,999 |
| 1960 | 37,718 |
| 1970 | 65,977* |

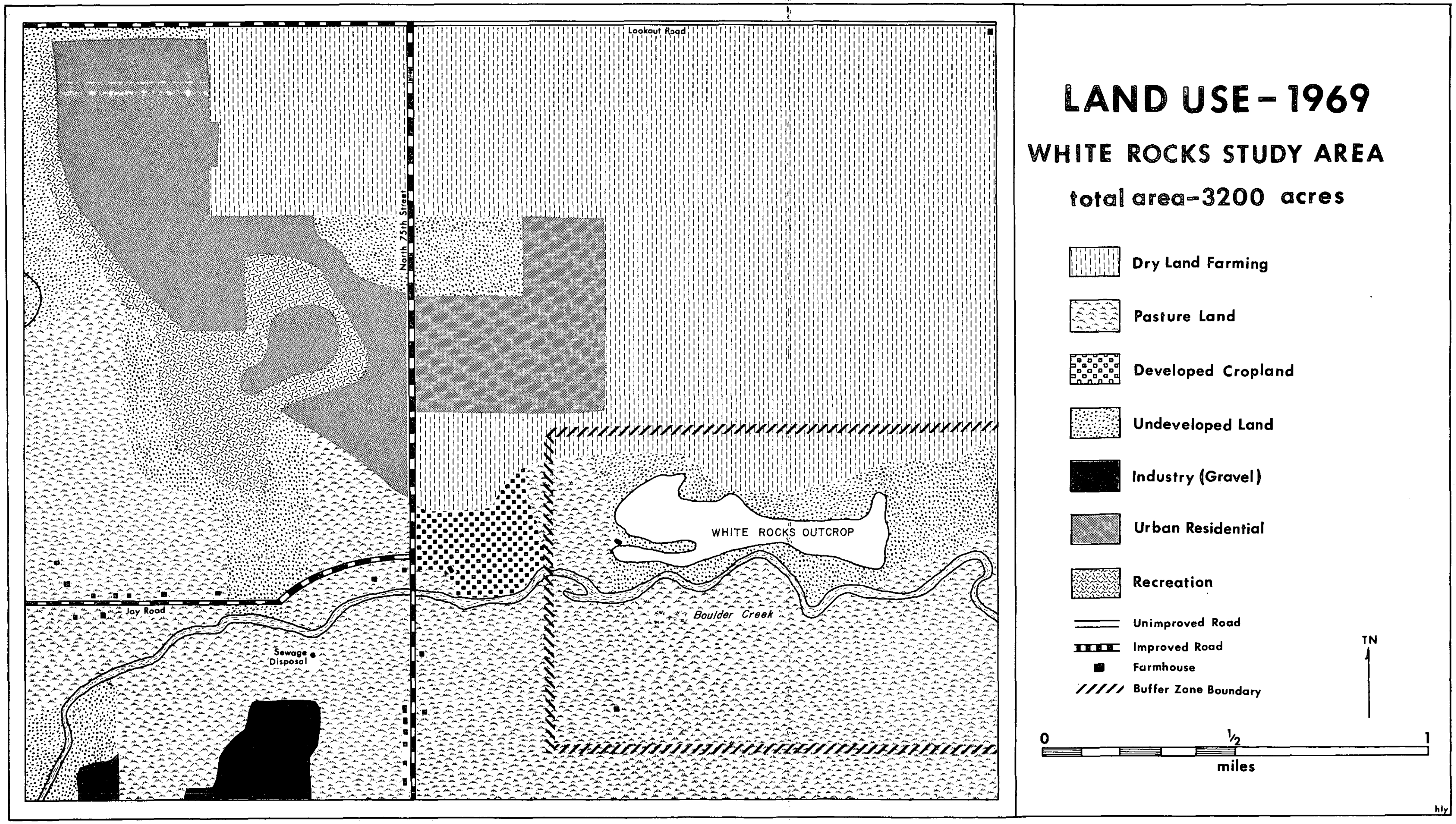
* Preliminary figure, U.S. Bureau of the Census

Source: Boulder Chamber of Commerce


LAND USE – 1941
WHITE ROCKS STUDY AREA
total area-3200 acres
Dry Land Farming
Pasture Land
Developed Cropland
Undeveloped Land
Unimproved Road
Farmhouse
TN
0
½
1
miles
Lookout Road
North 75th Street
Joy Road
WHITE ROCKS OUTCROP
Boulder Creek


LAND USE - 1955
WHITE ROCKS STUDY AREA
total area - 3200 acres
Dry Land Farming
Pasture Land
Developed Cropland
Undeveloped Land
Industry (Gravel)
Unimproved Road
Farmhouse
TN
0
1/2
1
miles
Lookout Road
North 75th Street
Jay Road
WHITE ROCKS OUTCROP
Boulder Creek
hly


LAND USE - 1963
WHITE ROCKS STUDY AREA
total area-3200 acres
Dry Land Farming
Pasture Land
Developed Cropland
Undeveloped Land
Industry (Gravel)
Urban Residential
Recreation
Unimproved Road
Improved Road
Farmhouse
TN
0
1/2
1
miles
Lookout Road
North 75th Street
Jay Road
WHITE ROCKS OUTCROP
Boulder Creek



LAND USE - 1969
WHITE ROCKS STUDY AREA
total area-3200 acres
Dry Land Farming
Pasture Land
Developed Cropland
Undeveloped Land
Industry (Gravel)
Urban Residential
Recreation
Unimproved Road
Improved Road
Farmhouse
Buffer Zone Boundary
TN
0
½
1
miles
hly
Lookout Road
North 75th Street
Jay Road
Sewage Disposal
WHITE ROCKS OUTCROP
Boulder Creek

TABLE 2. CHANGING LAND USE IN THE WHITE ROCKS AREA, 1941-1969

| Category | 1941 | 1955 | 1963 | 1969 |
|---|---|---|---|---|
| Dryland Farming | 51.01 | 50.51 | 46.14 | 32.71 |
| Pasture | 26.09 | 26.88 | 31.76 | 29.40 |
| Developed Cropland | 16.77 | 12.95 | 7.31 | 4.54 |
| Undeveloped Land | 3.43 | 4.73 | 2.25 | 10.10 |
| Urban | --- | --- | 2.19 | 11.82 |
| Recreation | --- | --- | 4.23 | 4.23 |
| Industry | --- | --- | 1.40 | 1.40 |
| White Rocks | 1.84 | 1.84 | 1.84 | 1.84 |
| Percentage subtotal | 99.14 | 98.13 | 97.12 | 96.16 |
| Miscellaneous Uses* | .86 | 1.69 | 2.88 | 3.84 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 |

Note: Percentages of each categorical use are shown for the White Rocks study area of some 3,200 acres surrounding the rock outcrop. Based on information from U.S.D.A. and A.S.C.S. aerial photography.

* Miscellaneous categories include area occupied by roads, railroads, houses and public utility stations.

Although Boulder has undergone tremendous growth in the past 30 years, this growth is not as critical to this study as the suburban expansion east of Boulder in proximity to White Rocks.

Industrial growth east and northeast of Boulder has given impetus to residential expansion in those directions. IBM is the largest employer northeast of Boulder and the growth of IBM has had the greatest single effect on other industrial and rapid suburban expansion northeast of Boulder.

When plans for IBM's construction began in March, 1965 (Town and Country Review, 1970), the land now occupied by IBM was predominately agricultural. In the early 1960s some small-scale platting of subdivisions in the Gunbarrel Hill area had occurred, but there was no substantial urban development until after the location of the IBM plant along the Boulder-Longmont Diagonal Highway (State Highway No. 119). By January, 1969, the number of employees increased by over 2,000 to 4,350 (Town and Country Review, 1970).

In the eastward expansion of Boulder, a sizeable land area zoned for industry under the name of Boulder Industrial Park, is located approximately one and one-half miles east of Boulder. All industries in the industrial park (including Ball Brothers Research Corporation) are accessible from the subdivisions northeast of Boulder via 75th Street. It is clearly obvious not all employees of these industrial areas will eventually move into subdivisions northeast of Boulder; nonetheless, these growing industrial complexes set the stage for further suburban expansion.

Site and situation determine the public's choice to move into subdivisions as Gunbarrel Greens and Heatherwood. For most homeowners, a major consideration is time and distance to work. Additional impetus to suburban expansion northeast of Boulder lies in the aesthetic appeal of the area. The subdivisions are far enough away from Boulder to escape the noise and the traffic problems, in addition to having a spectacular view of the Front Range of the Rockies and the Continental Divide. Thus, a tremendous growth in urban development continues northeast of Boulder.

The most valuable portrayal of changing land use patterns in the past three decades is illustrated by maps of land use changes at selected intervals for historical and geographic perspective (Figures 14, 15, 16, and 17). Data for changing land use is from two sources: aerial photography (1941, 1955, 1963, and 1969)[1] and field reconnaissance.

To understand changing land use patterns, percentages of different uses were determined from each of the four maps based on the air photos for the same years by imposing a grid over each. This method results in acceptable percentages of changing land patterns (Table 2).

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[1]Photographs used were provided by the Boulder County Soil Conservation Service and the Longmont office of the U.S. Agricultural Stabilization Conservation Service.

By comparing land use changes using the four maps and the percentage change table, two particular patterns of change emerge. Most noticeable is the growth of urban areas which occupy former agricultural land. Less striking is the gradual change in agricultural use from less developed agriculture to more grazing. This change may be the result of declining need for agricultural products to be grown in this particular area.

Land used for agricultural purposes and for single-family residences constitutes the main utilization within the study area at the present time. The White Rocks outcrop is neither used for agriculture nor for housing, yet from the scientific and aesthetic viewpoint, White Rocks' most significant utility is as a natural, isolated study area.

## Present Utilization of White Rocks

In keeping with the theme of land use, an inventory of the degree of utility White Rocks provides the scientific and academic communities becomes critical in evaluating the worth of White Rocks as a study area.

Appendix C, an annotated bibliography, lists theses and other scholarly articles written about some interesting geologic feature or biota of White Rocks. Interviews with University of Colorado faculty members having utilized White Rocks or having some special interest in the area were conducted. The interviews provided a measure of the past and present utilization of White Rocks by the University. Undoubtedly, a few interested parties may not have been contacted, but as complete a list of interviews as possible is found in Appendix D. In addition, letters written by scientists and other knowledgeable individuals concerning White Rocks were generously provided (Weiser, 1969, 1970). (See Appendix D for a list of those submitting letters.) These letters were written on request by Mrs. Weiser, who organized efforts to bring the problem of highway encroachment to the attention of the Boulder County Long-Range Planning Commission.

The letters express each individual's estimation of White Rocks' value as a scientific study site. Those in the field of biology emphasized White Rocks as being an isolated habitat for numerous plants and animals, some very rare. Each letter also described White Rocks as a unique study site accessible to the University. Letters dealing more with the geological formations praised the area for its exposed stratigraphy and other interesting geologic features. All the letters stressed the need for preservation of White Rocks. Even though they represent one point of view, they should be noted as knowledgeable opinions of the worth of White Rocks.

Numerous field trips and research projects are conducted at White Rocks. From the Biology Department, a class in insect taxonomy makes an excursion to White Rocks each fall for collection purposes. These trips have been regularly conducted since 1956 (Gregg, 1969). In the spring of 1969, undergraduate classes in physical geography began field trips to White Rocks. The White Rocks field trip, taken by some 500 students since last spring, hopefully will become a permanent part of the class field trip schedule. Prior to spring, 1969, the geography field trips did not involve climbing onto the rocks, but viewed the south-facing cliff from 75th Street.

Until 1964, all undergraduate geology students took a field trip to White Rocks. About 1,000 students per year make this trip. On several occasions, advanced geomorphology classes have visited White Rocks (Bradley, 1969).

Additional activities, whether they be the surrounding land use or the scientific studies at White Rocks, affect the ecological balance of a relatively isolated natural area. Because natural study sites are indeed rare, an analysis of some of the major threats to White Rocks must be investigated.

## Adverse Effects of Encroachment

The analysis of urban encroachment in the White Rocks area has already been discussed. Some additional adverse effects of encroachment are the following: 1) water and air pollution associated with urban and highway expansion; 2) trespassers and casual recreationists; 3) vandals and poachers; 4) overgrazing of the floodplain; 5) increased runoff erosion above the rock outcrop; and 6) negligent use by members of the scientific community.

As additional people come to live in the vicinity of White Rocks, the frequency of unconcerned individuals straying onto the rocks increases. These well-meaning but inconsiderate recreationists leave their marks on the vertical and horizontal rock outcrops by carving their names on and otherwise defacing the rocks. Beer cans, empty gun shells, and other debris are depressing evidence of human carelessness and land pollution. Such trespassing is common and only careful supervision of the rocks prevents major damage. Instances of vandalism include the setting of grass fires, draining an artificial reservoir, cutting of trees and killing wildlife (Weiser, 1969, 1970 and Ertl, 1970).

Explosive growth east of Boulder is accompanied by more intensive use of present transportation facilities and the building of new roads. The most recent threat to White Rocks is McCaslin Boulevard, a proposed high-speed, limited-access, north-south highway. No specific route has been designed as of present; however, two proposed routes actually touch the western (one proposed route) or the eastern (another proposed route) extremity of the rock outcrop. The immediate and long-term effects of this expressway are the following: 1) disturbing the animal life by noise, causing some animals to leave the area thereby changing the ecological balance; 2) filling the air with harmful exhaust (especially if the highway were built west of the rocks due to prevailing winds) with the possible loss of some species of vegetation; and 3) encouraging carelessness, vandalism and demand for public access by making White Rocks more visible from the highway. The impending threat to White Rocks posed by McCaslin Boulevard has been alleviated by a recent decision made by the Boulder County Long-Range Planning Commission on February 27, 1970. The Commission decided that "if and when the boulevard is constructed, the route will by-pass the scenic and valuable natural area known as the White Rocks" (Boulder Daily Camera, 1970).

Soil erosion north of the rock outcrop might ultimately destroy the aesthetically and scientifically valuable topography by greatly speeding up the erosional processes on the rocks. If the natural grass cover above the rocks were to be eliminated by fire, trampling, or suburban development. the Laramie outcrop would be vastly altered from increased erosion. Overgrazing on the floodplain has caused damage to the vegetational habitats along the floodplain by increasing erosion. Through the efforts of landowners who graze their cattle on the floodplain, this overgrazing is being controlled.

Any presence of man on White Rocks alters its natural state: therefore, even those who appreciate the scientific and aesthetic values of the rock outcrop and make field investigations violate its isolated state. The utilization of White Rocks by one scientific discipline may lessen the study potential of the area by another discipline. Those investigating the topography, for example, might inadvertently trample the vegetation or frighten animals. Such incompatable field studies should be carefully avoided. Compared to the other threats facing White Rocks, and considering the utilitarian purpose of such excursions onto White Rocks, damage from the scientific community is the least of the threats. Concerned and knowledgeable individuals are most likely to respect the value of this natural area.

White Rocks is definitely affected by the surrounding land use changes. These changes from agriculture to urbanization pose a threat to its isolated state, its importance as a study area and its scientific and aesthetic value. Scientists, because of the increasing use of White Rocks in recent years, are becoming more aware of its importance - thereby gaining more of an appreciation of the area. Concerned individuals, through an historical perspective of land use change must attempt to formulate steps to preserve White Rocks for future scientific use.

# CHPPTER IV. CONCLUSIONS AND RECOMMENDATIONS

Helen Louise Young

Expansion of urbanization into former agricultural land is not a unique situation, nor is the encroachment of man into isolated natural areas. The dilemma facing White Rocks is mirrored in thousands of other natural sites throughout the country.

The most important decision to be made is whether White Rocks should be preserved in its natural state. On the basis of investigation of pertinent literature, interviews with parties kno wledgeable of its value, and field examinations, the answer to the query must be an unequivocal "Yes." White Rocks is unique geologically and biologically and its loss as an accessible study area would be a tragedy. Not only should White Rocks be preserved as a natural study site, but as an area of extremely limited access even for scientific purposes and aesthetic enjoyment. Ideally, upper-division-course university field laboratory trips and faculty and graduate students should have access to the area for scientific utilization.

The next problem is a geographic delimitation of an adequate buffer zone to protect White Rocks' isolation as it exists today. Bearing in mind the present land patterns (Figure 17), the following buffer zone is presented with its geographical boundaries:

1. Northern buffer zone - suburban development should remain at least one-quarter to one-half mile north or the rocks. A vegetation buffer should remain between housing and the rock outcrop to minimize erosion on the slopes north of White Rocks and the rock outcrop.

2. Southern buffer zone - the floodplain of North Boulder Creek provides an excellent natural buffer. No extensive urban development can be allowed on the floodplain according to county zoning regulations. Gravel pits along the floodplain near the bluffs should be prohibited because of aesthetic damage.

3. Eastern buffer zone - land east of the study area which stops at the prominent fault and the disappearance of the Laramie outcrop is rugged terrain presently used for grazing. No development should come closer than one-half mile to the eastern end of the rocks.

4. Western buffer zone - any residential development should be at least one-quarter mile to one-half mile west of the rocks. Development west of the rocks should be especially discouraged due to the prevailing winds blowing pollutants toward White Rock.

Precise limitation of a buffer zone that protects White Rocks is difficult, for an intimate understanding of the area's delicate ecological balance is necessary. Interwoven with the ecological balance are the social problems and the legalities of changing land use, zoning, and industrial expansion. Realistically, a future projection of what happens to the land surrounding White Rocks and what feasible steps to save it (working within given possibilities) must be considered.

## Recommendations

To provide the most feasible, yet assured method of preserving White Rocks for future generations, the following recommendations should be considered:

1. Continuation of present agricultural zoning for lands immediately north of White Rocks; therefore, the County Commissioner's Zoning Board should not allow residential zoning to the edge of the rock outcrop.

2. Cooperation from real estate developers such as Wood Brothers (developers of Heatherwood) must be sought to prevent extremely close encroachment and to aid in preservation of a buffer between Heatherwood and White Rocks.

3. Industrial development along the floodplain at the base of the cliff must be prohibited if White Rocks is to have its greatest utility. Gravel pits could be restricted by the County's not granting use permits for their location at White Rocks.

4. Close and continuous supervision of White Rocks should be provided to reduce the threat of vandalism. Mrs. Weiser's living near the outcrop presently contributes to the supervision.

5. The wills of the property owners of White Rocks should provide for transfer of their property (after their or their heirs death) to a conservation foundation which could preserve White Rocks in perpetuity. Mrs. Weiser plans to arrange such a provision.

6. Encouraging legislation to deal with legal problems of preserving natural areas. If White Rocks were obtained as part of a green belt program, by an educational institution or a conservation organization, there should be legal means to restrict public access in perpetuity. At present, if White Rocks were in public ownership, there is no legal way to restrict public accessibility.

7. Conservation tax easement, preferential assessment (the valuation of property on the basis of present, instead of potential land use), or other tax advantages should be offered the owners of White Rocks to encourage its preservation as a natural area.

8. Consideration and respect must be given the area by those utilizing White Rocks for any purpose. The value, uniqueness and delicacy of the area should be made known to those entering White Rocks.

An assessment and analysis of the quality of White Rocks as a study area - what it offers in aesthetics and scientific value - and an understanding of the land use changes over time enables a more valid projection of what may happen to White Rocks. White Rocks' physical uniqueness is irreplaceable. Its importance stems from its having been relatively isolated and its having become a haven for seldom-seen plants and animals. Adding to its importance are the geological structures, which merit observation and research. Hopefully, the foresight and cooperative efforts of individuals concerned with protecting the environment will assure the perpetuation of White Rocks as a truly unique natural area.

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# APPENDIX A

## FLORA FOUND AT WHITE ROCKS
## AS RECORDED BY THE
## UNIVERSITY OF COLORADO MUSEUM HERBARIUM

Listing is by family, genus and species.

Alismacaea
- Sagittaria latifolia Willd.

Anacardiaceae
- Rhus glabra L.
- R. trilobata Nutt. ex. T. & G.

Asclepiadaceae
- Asclepias viridiflora Raf.

Betulaceae
- Betula fontinalis Sarg.

Boraginaceae
- Cryptantha minima Rydberg
- C. jamesii (Torr.) Payson
- Lappula redowskii (Hornem.) Greene
- Lithospermum incisum Lehn.

Campanulaceae
- Triodanis leptocarpa (Nutt.) Nieuwl.
- T. perfoliata (L.) Nieuwl.

Chenopodiaceae
- Atriplex canescens (Pursh) Nutt.
- Eurotia lanata (Pursh) Moq.

Commelinaceae
- Tradescantia occidentalis (Britt.) Symth

Compositae
- Artemisia filifolia Torr.
- Erigeron pumulus Nutt.
- Gnaphalium chilense Spreng.
- G. wrightii A. Gray
- Helianthus petiolaris Nutt.
- Hetherotheca villosa (Pursh) Shinners
- Hymenopappus filifolius Hook.
- Kuhnia eupatorioides L.
- Lactuca tatarica (L.) C.A.Mey
- Machaeranthera tanacetifolia (H.B.K.) Ness
- Solidago missouriensis Nutt.

Cruciferae
- Chorispora tenella DC.
- Thlaspi arvense L.

Cyperaceae
- Carex heliophila Mack
- Cyperus acuminatus Torr.&Hook
- C. inflexus Muchl.
- Eleocharis macrostachya Britt.
- Scirpus microcarpus Presl.

Euphorbiaceae
- Chameasyce fendleri (T&G) Small
- C. missurica (Raf.) Shinners
- Euphorbia marginata Pursh

Fumariaceae
- Corydalis aurea Willd.

Gramineae
- Agropyron dasystachum (Hooker) Scribner
- A. gerardii Vitman
- Aristida basiramea Engelmann
- A. fendleriana Steud.
- Buchloe dactyloides (Nutt.) Engelmann
- Calamovilfa longifolia (Hook.) Scribn. in Hack.
- Oryzopsis hymenoides (R.&S.) Ricker
- Poa sandbergii Vassey
- Puccinellia nuttalliana (Schult.) Hitchc.
- Stipa comata Trin. & Rupr.
- Vulpia octoflora (Walt.) Rydb.

Hydrocharitaceae
- Elodea canadensis Michx.

Labiatae
- Monarda pectinata Nutt.

Leguminosae
- Apios americana Medic.
- Astragalus drummondii Dougl. in Hook.

Leguminosae (continued)
- A. sericoleucus A. Gray
- Lathyrus polymorphus Nutt.
- Lupinus pusillus Pursh
- Oxytropis sericea Nutt.
- Sophora nuttalliana B. L. Turner
- Thermopsis rhombifolia Nutt. ex Rich.

Lemnaceae
- Lemma minor L.

Loasaceae
- Mentzelia albicaulis Dougl. ex. Hook.
- M. nuda (Pursh) T.&G.

Onagraceae
- Gaura coccinea Nutt. ex Pursh
- Oenothera albicaulis Pursh
- O. brachycarpa A. Gray

Orobanchaceae
- Orobanche fasciculata Nutt.

Oxalidaceae
- Oxalis stricta L.

Pinaceae
- Pinus ponderosa Dougl. ex Laws.

Polemoniaceae
- Ipomopsis laxiflora (Coulter) V. Grant

Polygonaceae
- Erigonum annuum Nutt.
- Polygonum ramosissimum Michx.

Polypodiaceae
- Asplenium trichomanes L.
- Asplenium adiantum-nigrum L.
- Cheilanthes feei Moore

Nyctaginaceae
- Abronia fragrans Nutt. ex Hook.
- Oxybaphus linearis (Pursh) Robinson

Ranunculaceae
- Ranunculus cymbalaria Pursh

Rosaceae
- Amelanchier utahensis Koehna
- Potentilla anglica Leacharding
- Prunus virginiana L.
- Rosa arkansana Porter

Scrophulariaceae
- Linaria texana Scheele
- Penstemon angustifolius Nutt.
- P. secundiflorus Bentham

Solanaceae
- Physalis virginiana Mill.
- Solanum americanum Mill.
- S. sarachoides Sendt. ex Mart

Ulmaceae
- Celtis occidentalis L.

Umbelliferae
- Cymopterus acaulis (Pirsh) Raf.

Violaceae
- Viola papilionacea Pursh

Urticaceae
- Parietaria pennsylvanica Muhl. ex Willd.

# APPENDIX B

## FAUNA FREQUENTLY SIGHTED AT WHITE ROCKS

### Birds

| Scientific Name | Common Name |
|---|---|
| Ardeidae | |
| *Ardea herodias* | Great blue heron |
| *Nycticorax nycticorax* | Black-crowned night heron |
| Charadriinae | |
| *Oxyechus vociferus* | Killdeer |
| Columbidae | |
| *Columbia livia* | Rock dove |
| *Zenaidura macroura* | Western mourning dove |
| Corvidae | |
| *Pica pica* | American magpie |
| Falconinae | |
| *Falco sparverius* | Sparrow hawk |
| Fringillidae | |
| *Melospiza melodia* | Mountain song sparrow |
| *Passerina amoena* | Lazuli bunting |
| Icteridae | |
| *Agelaius phoeniceus* | Thick-billed redwing |
| *Icterus bullocki* | Bullock's oriole |
| *Sturnella neglecta* | Western meadowlark |
| *Xanthocephalus xanthocephalus* | Yellow-headed blackbird |
| Phasianidae | |
| *Phasianus colchicus* | Ring-necked pheasant |
| Picidae | |
| *Asyndesmus lewis* | Lewis' woodpecker |
| *Colaptes cafer* | Red-shafted flicker |
| Strigidae | |
| *Bulbo virginianus* | Great horned owl |
| Tytonidae | |
| *Tyto alba* | Barn owl |

## Animals

| Scientific Name | Common Name |
|---|---|
| Canidae | |
| *Canis latrans* | Coyote |
| *Vulpes fulva* | Red fox |
| Castoridae | |
| *Castor canadensis* | Beaver |
| Cervidae | |
| *Odocoileus hemionus* | Mule deer |
| Cricetidae | |
| *Ondatra zibethica* | Great Plains muskrat |
| *Peromyscus boylei* | Brush mouse |
| *P. leucopus* | White-footed mouse |
| *P. maniculatus* | Deer mouse |
| Geomyidae | |
| *Geomys bursarius* | Plains pocket gopher |
| Leporidae | |
| *Lepus californicus* | Blacktail jackrabbit |
| *Sylvilagus nuttalli* | Mountain cottontail |
| Sciuridae | |
| *Citellus variegatus* | Rock squirrel |
| *C. tridemlineatus* | Thirteen-lined ground squirrel |
| *Eutamias quadrivittatus* | Colorado chipmunk |
| *Marmota flaviventris* | Rockchuck (Yellow-belly marmot) |

# APPENDIX C

## SELECTED BIBLIOGRAPHY OF WORKS RELATING TO WHITE ROCKS

### Biology

Beidleman, Richard G. "The Vertebrate Ecology of a Colorado Plains Cottonwood River Bottom." Unpublished MA thesis, University of Colorado, 1948.

A field study of a cottonwood river bottom vertebrate habitat along Boulder Creek about two miles upstream from White Rocks. A list of the observed fauna was compiled and the same species are likely to be found along Boulder Creek at the base of White Rocks.

Byars, Loren F. "An Ecological Study of the Ants of the Plains Region of Boulder County, Colorado." Unpublished MA thesis, University of Colorado, 1936.

A description of the correlations between the ant fauna of a compact but ecologically varied area and its topography. White Rocks was one of five study sites for collection of specimens.

Weber, William A. "The Flora of Boulder County Colorado." Unpublished two volume work sponsored by Biology Department and the University of Colorado Museum, 1949.

A two-volume work which includes a key to the flora of Boulder County and a list of all plants collected as part of the University of Colorado Museum collection. White Rocks was a favorite collection site and about 90 different species of plants were found there.

### Geology

Emmons, Samuel F., Whitman Cross and George H. Eldridge. "Geology of the Denver Basin in Colorado," United States Geological Survey Monogram 27, 1896.

An early study of geology in the Denver Basin. Mention is made of the stratigraphy and the coal seam at White Rocks.

Fenneman, N.M. "Geology of the Boulder District, Colorado," United States Geological Survey Bulletin 265, 1905.

A geological study of about a 15-mile radius of Boulder, Colorado. The original purpose of this report was to find petroleum in paying quantities. White Rocks was mentioned as having excellent exposures Fox Hills and Laramie.

Fenske, Paul Roderick. "The Origin and Significance of Concretions." Unpublished PhD dissertation, University of Colorado, 1963.

A description of the Fox Hills and Laramie stratigraphy in the vicinity of Boulder and an investigation of the concretions found in these formations. Special reference is made to concretions found in the White Rocks area.

Hayes, John R. "Cretaceous Stratigraphy of Eastern Colorado." Unpublished PhD dissertation, University of Colorado, 1950.

A report of the Cretacous stratigraphy of part of northeastern Colorado, southeastern Wyoming and the southwestern corner of Nebraska. As part of the overall stratigraphic study, the Fox Hills and Laramie formations were examined at outcrops. White Rocks was one of the sites for study of these formations.

Henderson, Junius. "Cretaceous Formations of the Northeastern Colorado Plains," Colorado Geological Survey Bulletin, XIX, 1920.

Purpose is determination of the stratigraphic position of northeastern Colorado coal beds. A list of fossils found near a fault at White Rocks is included in the work.

Horner, Wesley Pate. "The Fox Hills - Laramie Contact in the Denver Basin." Unpublished MA thesis, University of Colorado, 1954.

A study of the Fox Hills - Laramie contact in six major outcrops in the area east of the Front Range foothills, including White Rocks. This thesis proposes a change in the previously defined contact between the two formations. The study was based on evidence from thin sections, size analysis, measured sections and field observation.

Parkinson, Lucius James Jr. "Geology of an Area East of Boulder, Boulder County, Colorado." Unpublished MA thesis, University of Colorado, 1956.

This thesis maps the structural and areal geology of an area east of Boulder and relates the local structures to regional structure. Special attention was given to faults. Four north-trending faults in the White Rocks area were mapped.

## Geography

Netoff, Dennis Ivan. "Polygonal Jointing in Sandstone Near Boulder, Colorado." Unpublished MA thesis, University of Colorado, 1970.

Master's thesis describing the nature of the polygonal joint patterns found in the upper Laramie sandstone. Through field work done on the turtlebacks, a hypothesis was formulated as to their origin.

Young, Helen Louise, "White Rocks: Social, Cultural, and Land Use Changes Affecting a Natural Area," Unpublished MA thesis, University of Colorado, 1970.

MA thesis describing effect of urban growth on this natural area. Evaluates the potential uses of the area and recommends steps to be taken to preserve its unique quality.

## APPENDIX D.

### LIST OF INDIVIDUALS CONTACTED THROUGH INTERVIEWS AND SUBMITTING LETTERS AS TO THE VALUE OF WHITE ROCKS*

| Individual | Position or Interest |
|---|---|
| Bock, Carl E. (interview) | Assistant Professor of Biology, University of Colorado |
| Bradley, William C. (interview) | Professor of Geology, University of Colorado |
| Crowley, Lawrence D. (letter) | Science Teacher, Boulder Public Schools |
| Gregg, Robert E. (letter and interview) | Professor of Biology, University of Colorado |
| Kroeck, William F. (letter) | Graduate Student, Department of Geography, University of Colorado |
| Longley, Warren W. (letter) | Professor of Geology, University of Colorado |
| MacPhail, Donald D. (letter) | Professor of Geography, University of Colorado |
| Netoff, Dennis I. (letter) | Graduate Student, Department of Geography, University of Colorado |
| Rodeck, Hugo G. (letter) | Professor of Natural History and Director of the Museum, University of Colorado |
| Shushan, Sam (letter) | Associate Professor of Biology, University of Colorado |
| Thorne, Oakleigh II (letter) | President and Director, Thorne Ecological Foundation |
| Weber, William A. (letter and interview) | Professor of Natural History and Curator of Museum Herbarium, University of Colorado |
| Weiser, Martha R. (interview) | Landowner and Resident of White Rocks |
| Willard, Beatrice E. (letter) | Vice-President, Thorne Ecological Foundation |
| Williams, Olwen (letter) | Professor of Biology, University of Colorado |

* Letters are in possession of Mrs. Martha K. Weiser, Boulder, Colorado.