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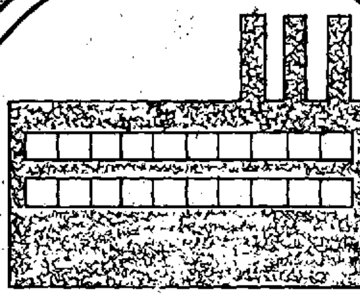

SPECIAL REPORT
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March, 1975
by KENNETH E. KOLM

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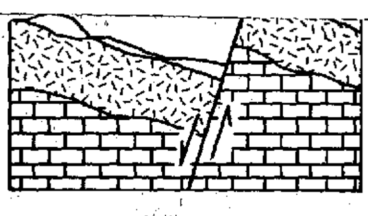

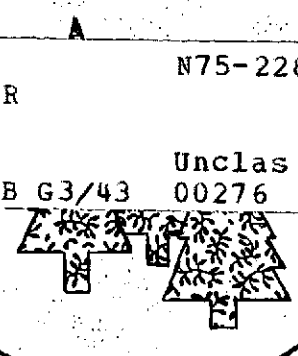

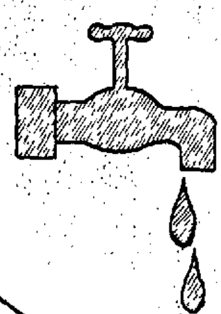

University of Wyoming

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Figure 2. Technical Report Standard Title Page

Special Report:

Mapping of Seleniferous Vegetation and Associated Soils in the Lower Wasatch Formation, Powder River Basin, Wyoming

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March 1975

Prepared For:
Johnson Space Center
Houston, Texas 77058

ABSTRACT

Within the Lower Wasatch Formation, Powder River Basin, Wyoming, light colored soils contain considerable amounts of selenium and support the toxic indicator plant species Astragalus bisulcatus. The principal objective of this investigation was to evaluate Skylab photography for mapping toxic seleniferous plants and their associated soils.

In order to accurately map the seleniferous indicator species, it was first necessary to study for reference an area known to contain these plants. The reference site chosen is located just north of AMAX's South Belle Ayr Mine.

Field work conducted at the AMAX site resulted in 1) identification of toxic selenium indicator plants, 2) soil and rock identification and relationship of these to supported plant communities, and 3) a soils and toxic vegetation map prepared from low-altitude aerial photography.

It was observed that selenium indicator plants generally do not have a high population density, and secondary non-indicator species occupied both the toxic and non-toxic soils. Therefore, it was impossible to map the indicator plants using Skylab photographs because 1) the individual plants are unresolvable, 2) A. bisulcatus interspersed with other non-indicator populations renders the low density toxic population unresolvable, and 3) the reflectances of the continuous grassland and sagebrush communities mask any tonal effect caused by the toxic plants.

However, it was observed that seleniferous indicator plants grow exclusively on both light colored soils and sandstone outcrops. This correlation was confirmed by the results of chemical analyses of soil samples. Therefore, using the techniques of density analysis and photographic enlargement, a seleniferous soils map was prepared for the AMAX mine site using Skylab S190B color photographs, (Track 59, Pass 28).

A regional map of these seleniferous soils and associated plants in the Powder River Basin, Wyoming, is being prepared and field checked. This regional overview displaying the distribution of seleniferous soils should prove to be one of Skylab's most significant applications as a geologic and environmental tool.

A similar regional map will not be prepared from the ERTS-1 data because the seleniferous soil lenses are too small to be resolved at the ERTS scale.

LIST OF FIGURES

Mapping of Seleniferous Vegetation and Associated Soils in the Lower Wasatch Formation, Powder River Basin, Wyoming

Prepared by: Kenneth E. Kolm
Department of Geology
University of Wyoming
1975

INTRODUCTION

The Eocene Wasatch Formation, a series of gently dipping, grayish-yellow sandstones, gray shales, and coal beds (Robinson, Mapel, and Bergendahl, 1964) overlies the coal-bearing, Paleocene Fort Union Formation in the Powder River Basin, Wyoming. Some sandstones and sandy soils within the Wasatch Formation contain considerable amounts of Selenium (Sharp, W. N., and Gibbons, A. B., 1964). These seleniferous soils support the plant indicator species Astragalus (vetch), Xylorrhiza (woody aster), Stanleya (prince's plume), and Oonopsis (goldenweed). The principal objective of this investigation was to determine the utility of Skylab photography in mapping toxic seleniferous indicator plants and associated soils in the Lower Wasatch Formation, Powder River Basin, Wyoming.

THE BIOGEOCHEMICAL NATURE OF SELENIUM

W. N. Sharp and A. B. Gibbons (1964) discovered that certain pink-to-buff sandstones and related soils of northeast Wyoming are highly seleniferous. These sandstone lenses correlate closely to the volcanic tuffs on the western side of the Powder River Basin, thereby implying that the selenium found within them is of volcanic origin (Beath and others, 1935). More specifically, Beath and others (1935) suggest that either the selenium may have been ejected as volatiles from a volcano and then settled in a Cretaceous sea or the selenium compounds may have been derived slowly during erosion of an igneous land mass.

The chemical forms of selenium present in the Wasatch soils and rocks are not definitely known. Trelease and Beath (1949) found that at varying depths within the soil profile, vast differences in water solubility studies exist. These differences indicate the presence of many different chemical forms. Trelease and Beath (1949) concluded that a typical soil profile can be found in Wyoming's semi-arid basins (Table 1).

Table 1. Chemical forms of selenium found in a typical soil profile in the semi-arid Wyoming Basins.

LOCATION	CHEMICAL FORM	CAUSE
Upper Horizon	Organic Selenium Hydrolytic Forms	Plant production and Area of Leaching
Middle Horizon	selenite	Enriched area
Lower Horizon	selenate	Unleached area

Elements found in conjunction with these selenium forms include calcium, iron, and organic molecules (Beath and others, 1935).

Some plant species tolerate the occurance of selenium compounds in the soil. These plants are of two types: indicators and secondary absorbers.

Indicators take selenium compounds which are required for their metabolism from the soils and rocks and chemically convert them to organic compounds (Beath and others, 1939). They absorb selenium as free selenium, selenides, and basic ferric selenites. All absorbed forms are products of hydrolytic action (Trelease and Beath, 1949). Upon their decay or respiration, the indicators release organic selenium into the soil. This organic selenium is then available to other plants called secondary absorbers.

Secondary absorbers are plants whose metabolism does not require selenium for survival. However, they will grow on organic selenium-rich soil and will concentrate significant amounts of the toxic compounds in body tissues. Members of this classification range from the heavy concentrators of genuses Aster, Atriplex, Castilleja, Commandra, Grayia, Oonopsis, Grindelia, Gutierrizia, Machaeranthera, Mentzelia, and Sideranthus, to the occasional users including grasses and economic crops (Trelease and Beath, 1949).

An important key to selenium transport is the interaction of the rocks and soils with the physical environment. The average precipitation of the Powder River Basin is about 12 inches per year (U. S. Dept. of Commerce, 1971-1973). This semi-arid condition favors soil formation in situ (Knight, 1937). Leaching takes place only in the upper few inches of the soils. Therefore, the amounts of selenium present will increase with increasing depth in the soil profile.

Slope is another important factor for determining selenium origin and movement in the soils. In areas of relatively high relief, more rock outcrops are exposed for mechanical disintegration. If selenium is present in the weathered bedrock, the thin soil mantles formed at the base of the outcrops will also contain various amounts of this element (Knight, 1937).

Because of the lack of precipitation in the Powder River Basin, erosion of the thin soil mantles formed on the higher slopes is minimal. However, it is not uncommon to find seleniferous soils that have been carried for short distances and deposited in drainages.

ENVIRONMENTAL IMPLICATIONS

At some critical concentration, selenium is toxic to all organisms (Rothstein, A., 1953; Barnhart, R. A., 1958). This consideration is especially critical in the Powder River Basin where high concentrations of selenium are already present in the rocks, soils, and natural waters (Miller, W. M., 1954). Therefore, a potential environmental hazard exists in the breaking up and removal of the Wasatch Formation; a process which can increase the selenium concentrations in the waters and soils.

Because the Wasatch Formation is overburden to the Fort Union Roland-Smith coal seam, it is inevitable that it will be disturbed. Seleniferous soils will be exposed and, if natural processes are allowed to procede unaltered, there will be an increase in seleniferous vegetation and eventual deterioration of the range quality. Therefore, control of selenium redistribution must be realized in the reclamation of the land. The factors that are important include land slope and drainage, surface exposure of various soils and bedrock, and methods used to re-establish vegetation.

A major goal of this study is to develop a technique for locating the potential problem areas in the Lower Wasatch Formation. A map of these areas would serve as an aid to both ranching and mining interests.

PROCEDURE AND TECHNIQUES

In order to accurately map toxic seleniferous plants found in the Lower Wasatch Formation, it was first necessary to use aerial photography (1:24,000 scale) in a reference study of an area known to contain selenium indicator species. The reference site chosen is located north of AMAX's South Belle Ayr Mine (Fig. 1).

One indicator species, Astragalus <u>bisulcatus</u>, was identified at the AMAX site (Fig. 2). A rough estimate of species abundance revealed that A. <u>bisulcatus</u> has a relatively low population density and grows intermingled with two major vegetation types; grassland and sagebrush (Fig. 3). These plant communities are clearly dominated by grasses which, as a group, are present over the entire mine site. These toxic plants were mapped from aerial photography (Fig. 4 and Plate 1).

It is impossible to identify these seleniferous plants from Skylab photography because: 1) the individual toxic plants are unresolvable, 2) A. <u>bisulcatus</u> is interspersed with other non-indicator populations and 3) the reflectance of the dominant grassland and sagebrush communities masks the reflectance contribution of the indicator species. However, it was observed that seleniferous indicator plants grow exclusively on both light-colored soils and on sandstone outcrops (Figs. 5a and 5b). This correlation was confirmed by the results of chemical analysis of soil samples (Fig. 6 and Table 2). A more intensive chemical analysis and atomic absorption test is presently being conducted to determine the quantity and chemical forms of the selenium present in representative soils.

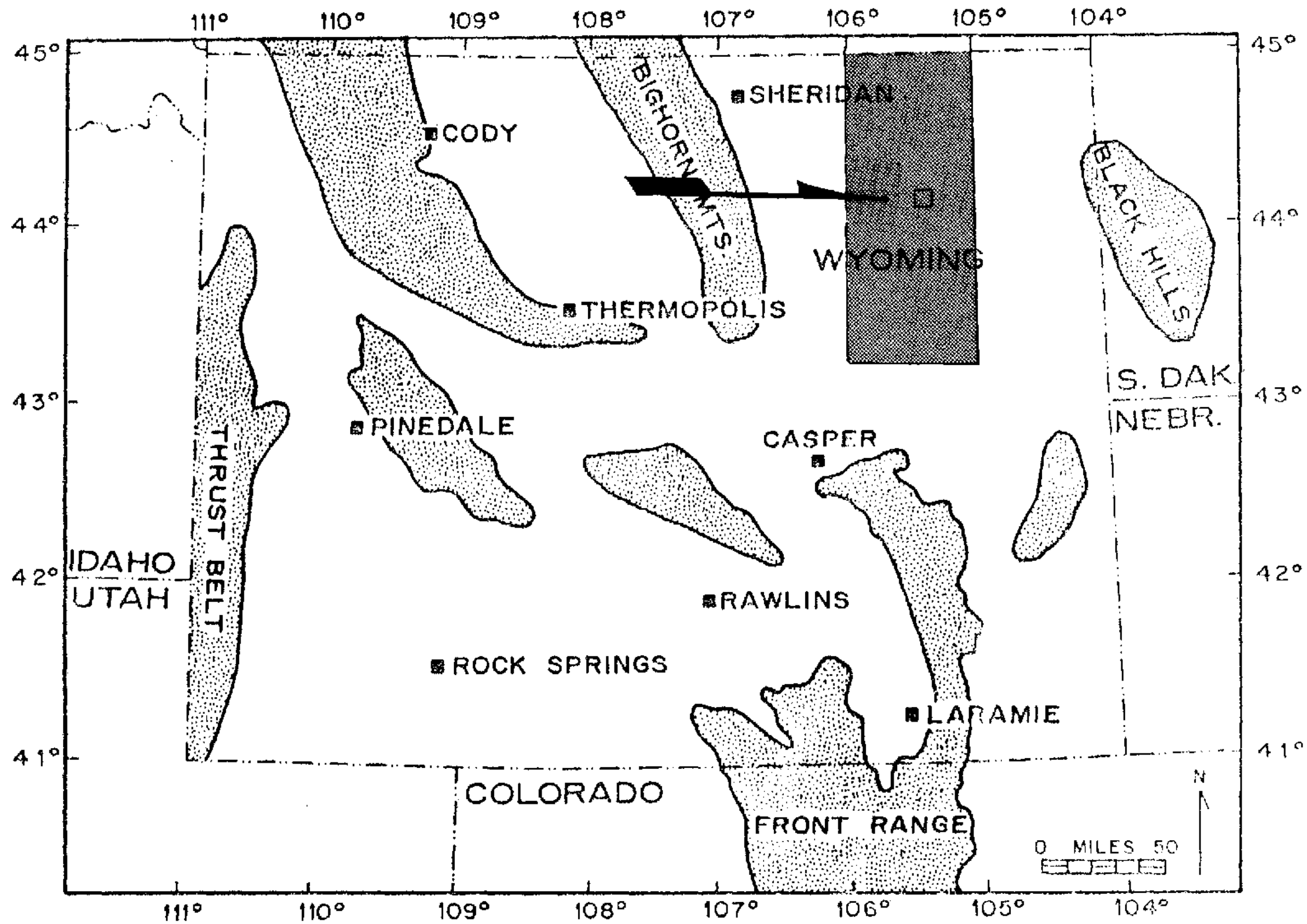


Fig. 1: Index map of Wyoming showing the location of the reference site (arrow) and the area to be mapped from Skylab photography (shaded arrow).

Fig. 2: Astragalus bisulcatus, a selenium indicator species, found at the South Belle Ayr Mine, T 47 N, R 71 W, Wyoming.

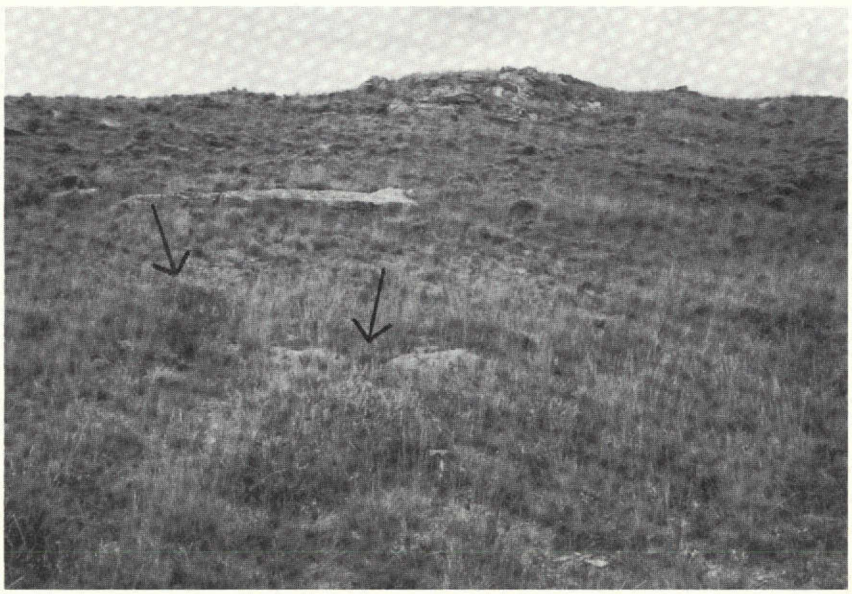


Fig 3: Astragalus bisulcatus,(arrow), is shown growing intermingled with two major vegetation types; grassland and sagebrush.

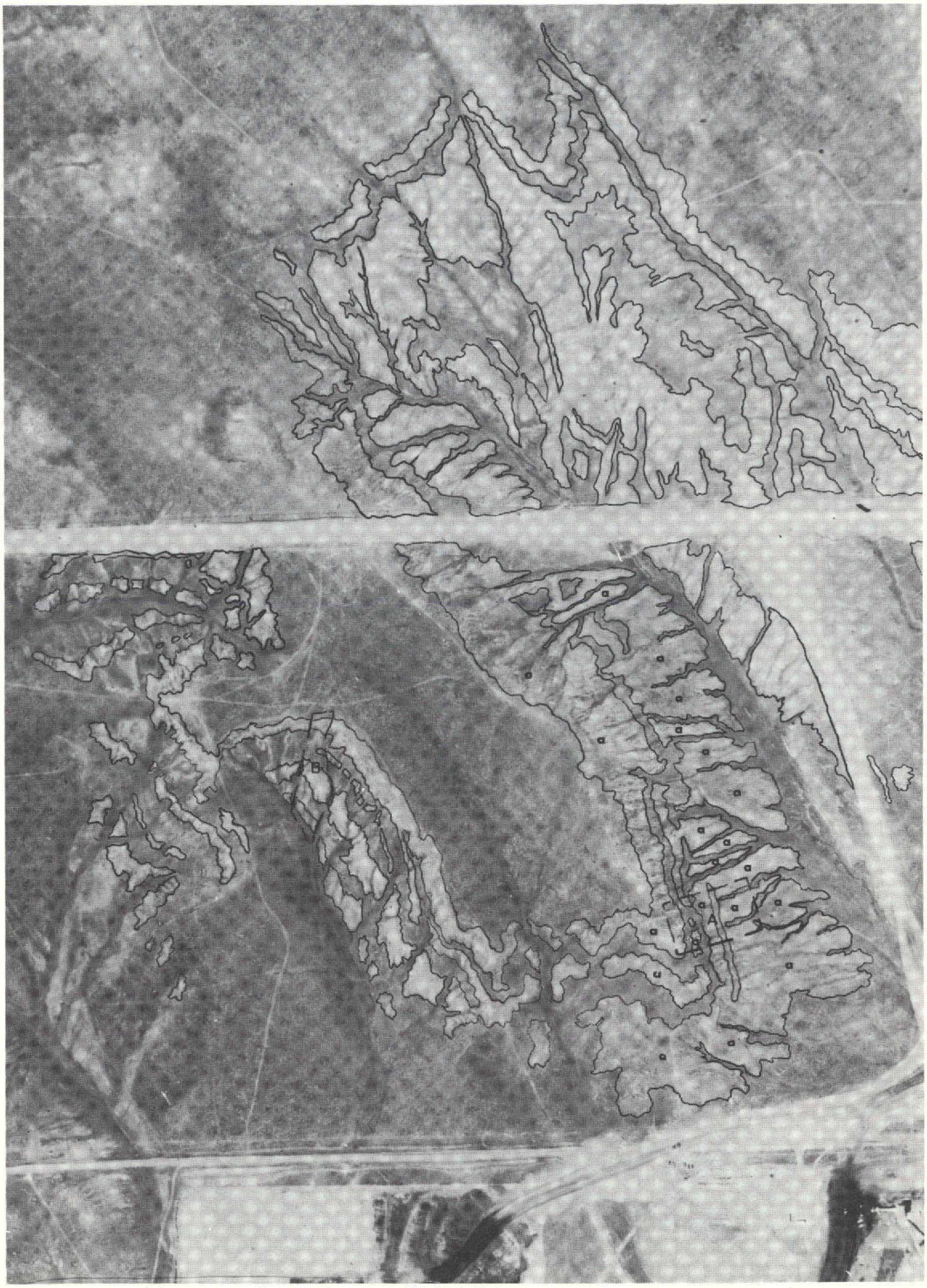


Fig. 4: Seleniferous light-colored soils and sandstone outcrops and the selenium indicator species Astragalus <u>bisulcatus</u> mapped on aerial photography; T 47 N, R 71 W, Wyoming (original scale 1: 24,000).

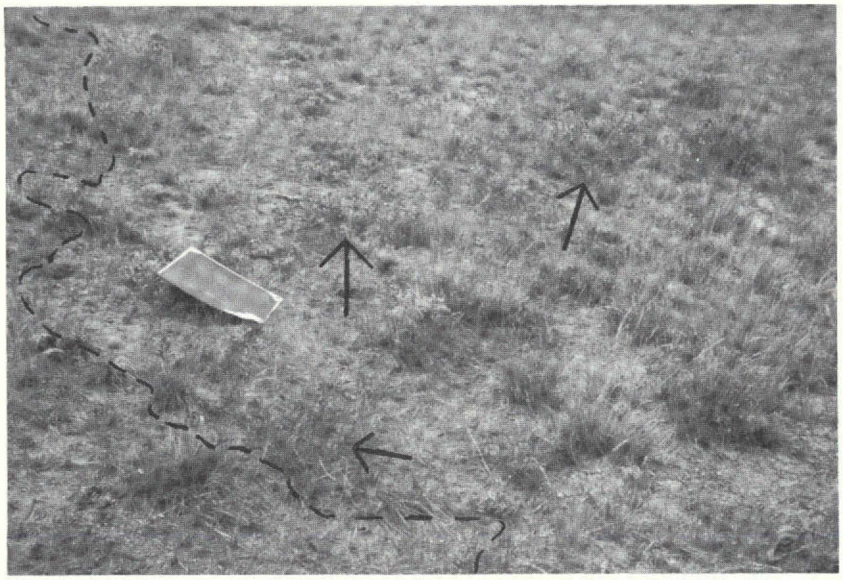


Fig. 5a: Astragalus bisulcatus (arrow) growing exclusively on light-colored soils.

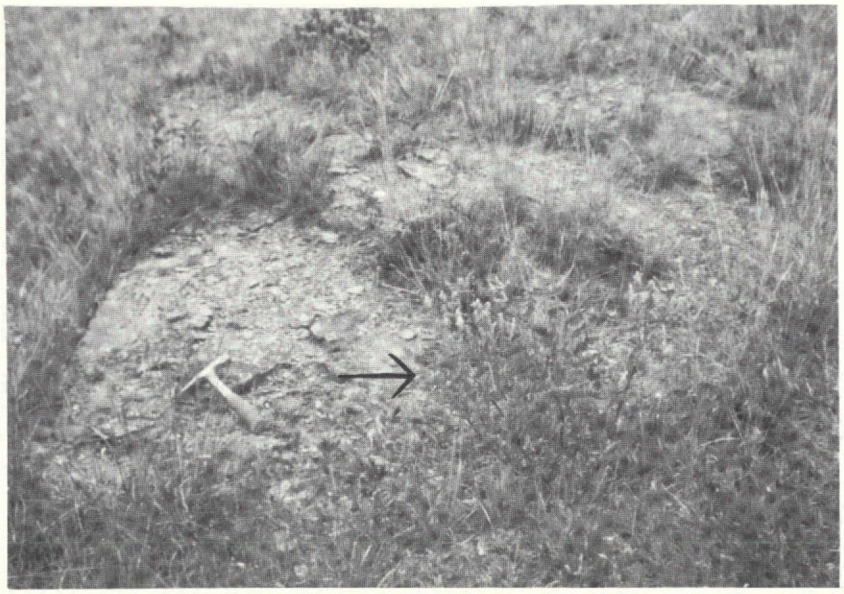
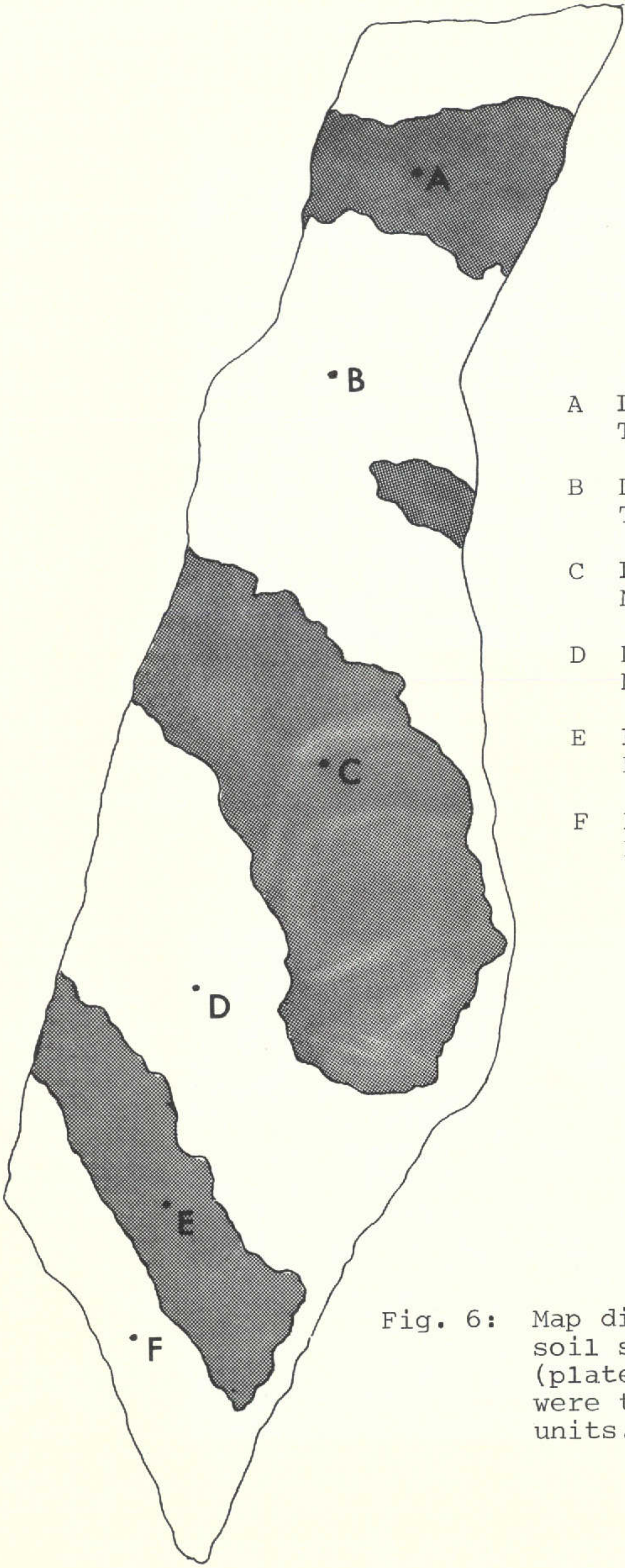


Fig. 5b: Astragalus bisulcatus (arrow) growing exclusively on sandstone outcrops.



Legend

A Light Colored Soil Lens, Top Unit

B Dark Colored Soil Lens, Top Unit

C Light Colored Soil Lens, Mid-Unit

D Dark Colored Soil Lens, Mid-Unit

E Light Colored Soil Lens, Bottom Unit

F Dark Colored Soil Lens, Bottom Unit

Fig. 6: Map displaying the location of six soil samples (A-F), refer to B, (plate 1). Photometer readings were taken for each of six soil units.

TABLE 2

Sample#	Description	Acid Wash	Base Wash	Water Wash
(A)	Light Colored Soils	trace	0.09 ppm	trace
(B)	Dark Soil	trace*	none	none
(C)	Light Colored Soils	0.07 ppm	0.02 ppm	none
(D)	Dark Soil	none	none	none
(E)	Light Colored Soils	none	0.05 ppm	none
(F)	Dark Soils	none	none	none

*Amount tested was too small for accuracy at 0.01 level.

TABLE 3 (Photometer Data)

Sample Description		400-500	480-590	560-1000	590-660	570-660	700-1100
1) Light Colored Soil Lens Top Unit	(A)	9.5	7.0	9.5	7.2	15.0	10.0
2) "	(A)	12.2	8.8	12.0	8.5	18.0	12.2
3) Dark Colored Soil Lens Top Unit	(B)	5.5	3.2	6.0	4.0	8.2	6.8
4) "	(B)	5.0	3.5	5.2	3.8	8.0	6.2
5) Light Colored Soil Lens Top Unit	(C)	7.2	5.0	7.0	5.2	10.8	7.5
6) "	(C)	6.0	4.2	6.0	4.5	10.5	7.2
7) Dark Colored Soil Lens Mid-Unit	(D)	5.0	3.5	5.5	3.7	7.0	5.5
8) "	(D)	5.0	3.5	5.2	3.7	7.8	5.5
9) Light Colored Soil Lens Bottom Unit	(E)	6.5	5.0	8.5	5.5	11.0	8.5
10) "	(E)	7.5	5.5	7.8	5.0	10.8	7.5
11) Dark Colored Soil Lens Bottom Unit	(F)	5.5	3.0	6.5	4.0	7.2	7.2
12) "	(F)	6.2	3.8	6.2	4.5	9.5	8.2
Reference Gray Card		6.8	4.2	6.0	4.3	9.0	6.5

Time: 10:00 - 12:00 a.m.; Day: June 6, 1975; Sun: bright; Sky: cloudless; Temperature: 74.5°F.; Relative Humidity: 20%; Field of View: 110°; photometer was held two feet above the target.

Soils containing selenium usually exist as thin mantles formed by the mechanical disintegration of rocks in situ. Occasionally, the seleniferous material will be transported short distances during erosion. The seleniferous soils of the AMAX South Belle Ayr Site appear to be derived by direct disintegration of sandstone bedrock and are often found downslope from these outcrops due to transportation by erosion. A chemical analysis of bedrock cores is planned to confirm these relationships.

Soils and sandstone outcrops that supported A. bisulcatus had higher reflectances than all other soils and outcrops found within the reference area. Relative reflectance measurements of seleniferous and non-seleniferous soils differed by an average of 2.05 units in the infrared region (Table 3). Therefore, the toxic, light-colored soils and sandstone outcrops were mappable from aerial photography (Plate 1).

Upon completion of the reference map compiled from aerial photography and field studies, the light-colored soils and sandstone outcrops were mapped using Skylab photography (Track 59, Pass 28). S190B color positive transparencies were used because of their superior resolution relative to the S190A photography.

Photographic enlargements (10x) of S190B color positive transparencies provided a base for direct photointerpretation (Fig. 7). The soil lenses and sandstone outcrops are resolved on the enlargements, but, photo-to-map transfer techniques do not preserve this detail. Therefore, the soils and outcrop map compiled using the direct transfer technique does not contain nearly all the information that can be derived from the S190B photograph (Fig. 8).

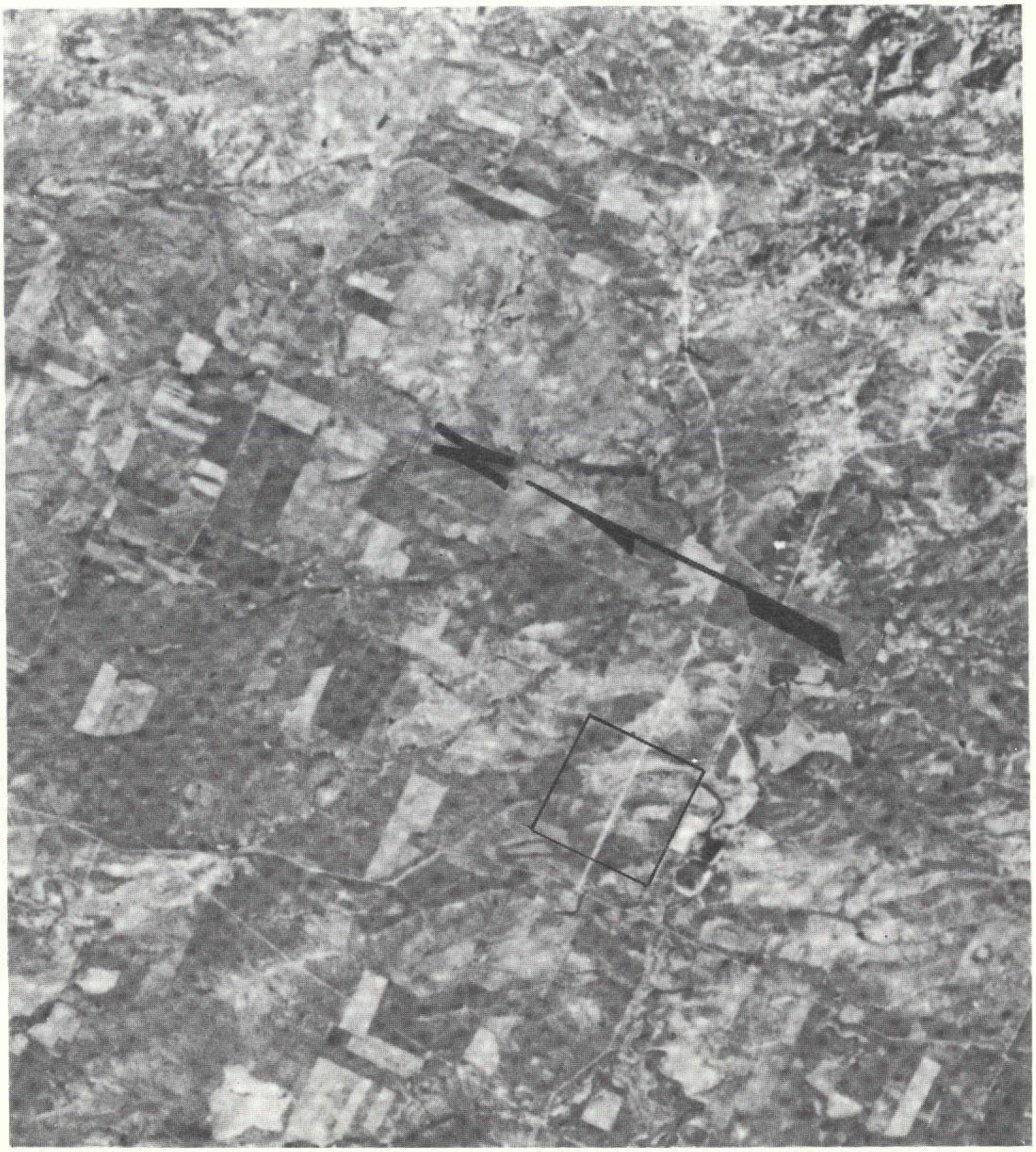


Fig. 7: Enlarged S190B color positive transparency used for direct photointerpretation. The area of study lies within the square.

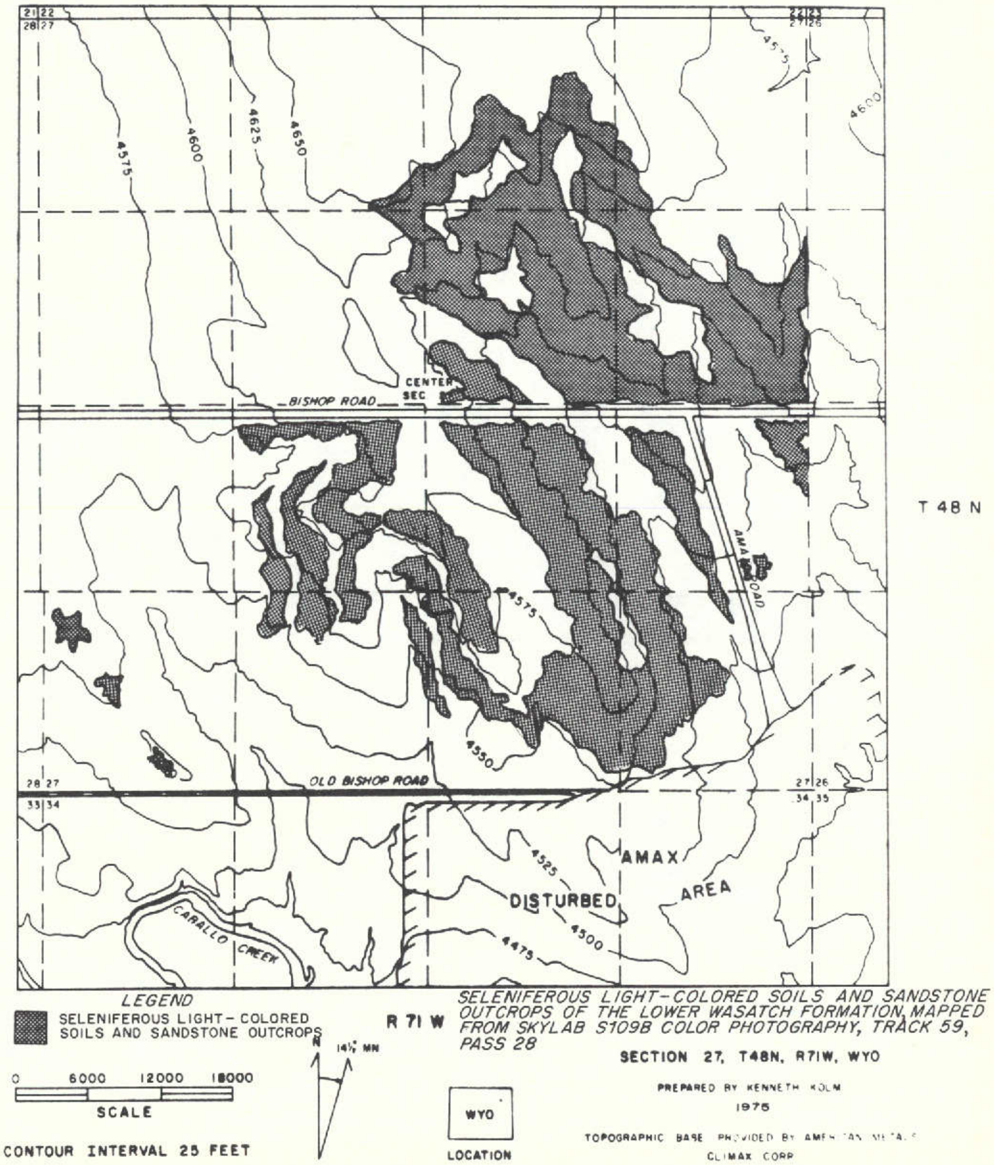


Fig. 8: Seleniferous soils mapped from Skylab S190B photography, T 47 N, R 71 W, Wyoming.

Density contouring was used to objectively define gradational boundaries between the seleniferous and non-seleniferous soils. Because the reflectance values of seleniferous soils and sandstone outcrops are greater that those of most other features present, this technique proved useful in defining the general area where toxic plants are present (Figs. 9 and 10).

Image combination by color addition and/or subtraction using S190A black-and-white photographs has thus far been unsuccessful due to the limited resolution of this photography (particularly in the infrared bands) and the small size of the features being studied. If the four multispectral bands of S190A photography had resolution equivalent to that of the S190B photography, it might have been useful to enlarge all four transparencies (10x) and then combine them together for color-additive or color-subtractive enhancement.

Edge enhancement techniques proved unsuccessful because most of the significant features exhibit little or no relief, displayed gradational contacts, and lack linearity.

Digital ratioing was not used because the Skylab data were not available in digital form.

CONCLUSIONS

To date, the techniques of density contouring and direct photointerpretation from S190B positive transparencies have proven most successful in the mapping of seleniferous soils and related indicator plants. Comparison between the aerial photography and Skylab photography used in this study shows that the Skylab photography is barely capable of recording

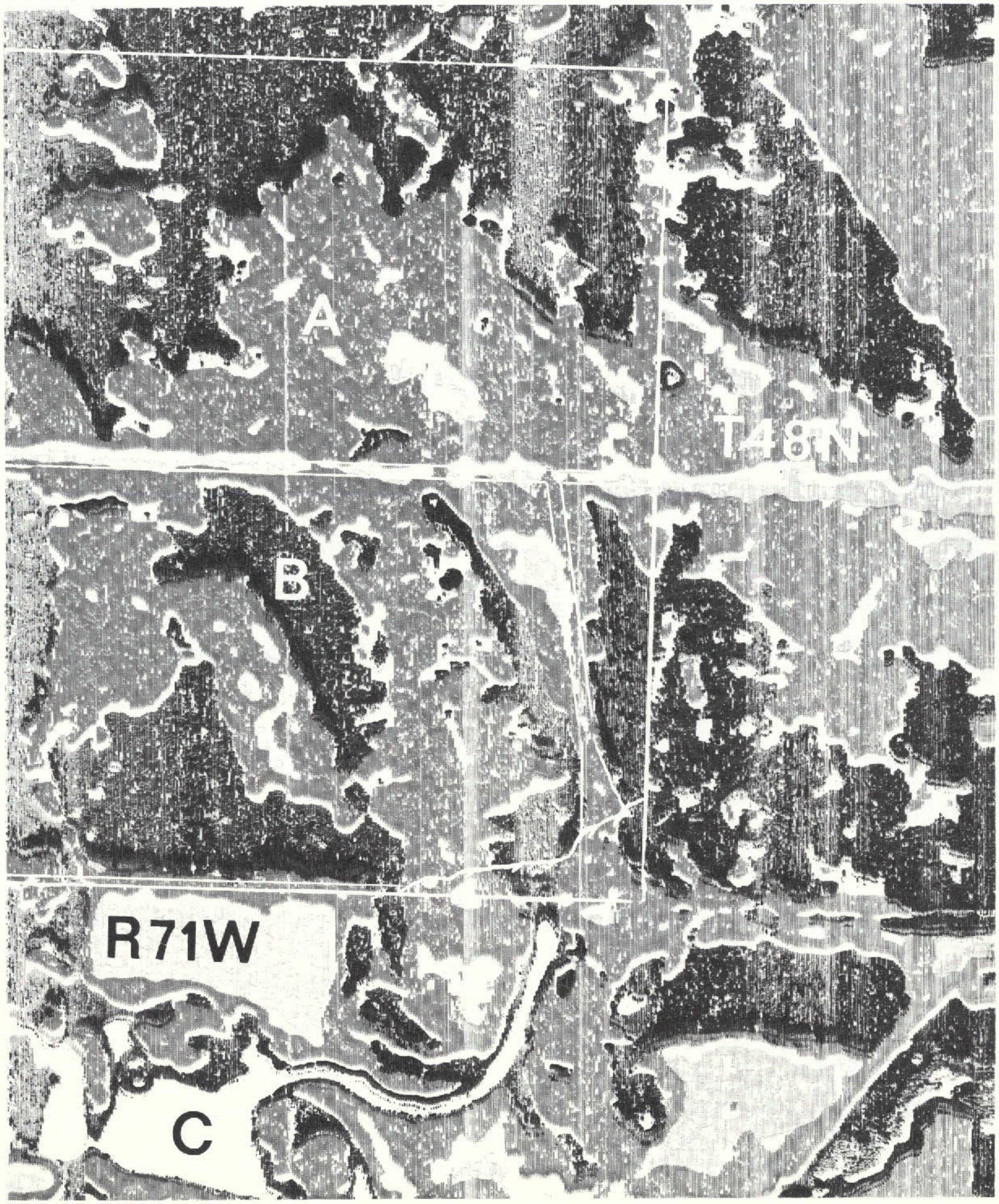


Fig. 9: General area of seleniferous soils location in T 47 N, R 71 W, Wyoming defined by density contouring from S190B photography.

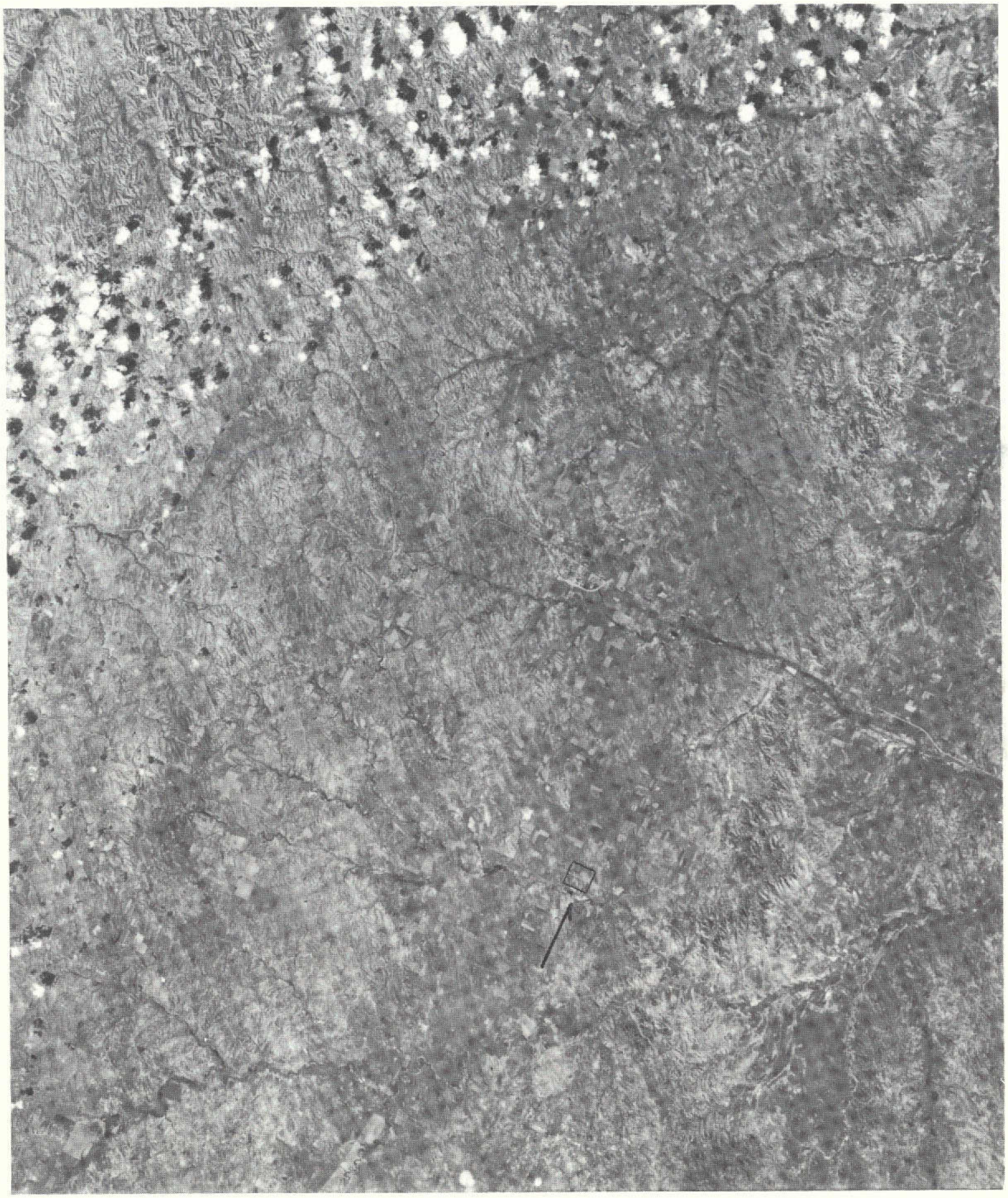


Fig. 10: SE ¼ of S190B photograph from which the density contour map was made. Reference area is outlined.

the detail required in this application, yet the results were judged accurate enough to be useful on a broad scale.

A regional map of these seleniferous soils and associated plants in the Powder River Basin, Wyoming, is now being prepared and will be field checked. Using the techniques of density analysis and photointerpretation, it is hypothesized that the success of Skylab studies concerning toxic soils and vegetation mapping will hinge on the ability of the investigator to produce an accurate map from the regional overview provided by Skylab. Such a map cannot be prepared from ERTS-1 data because the seleniferous soil lenses and outcrops are too small to be resolved at the ERTS scale.

Future studies may also include analyses of the population variations of seleniferous vegetation as the result of revegetation practices. Results of this study should define any problems of range deterioration that must be dealt with in reclamation of mined areas.

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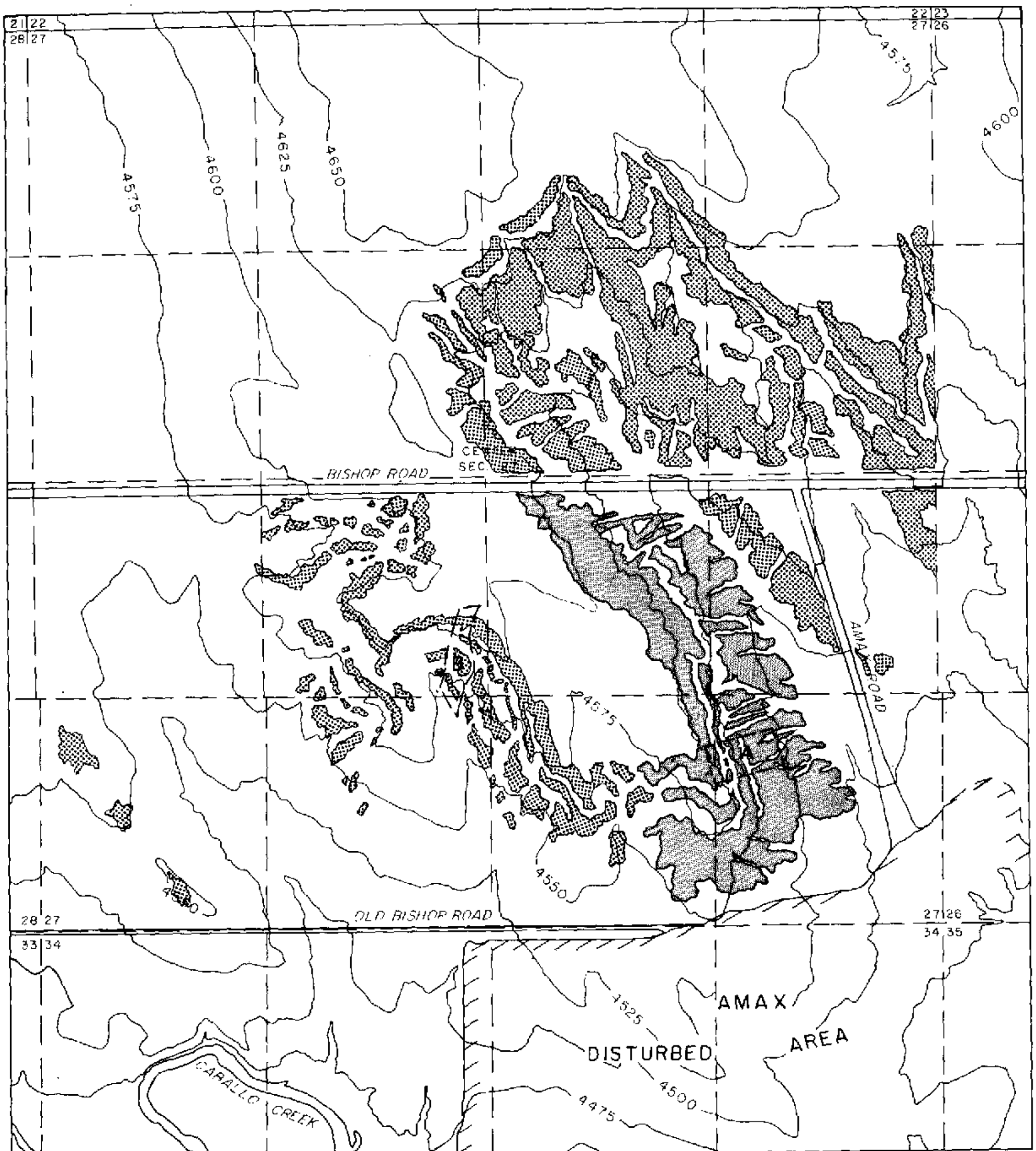


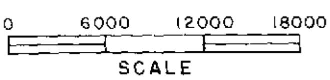
Plate 1: Seleniferous soils, outcrops, and plant indicators in the Lower Tertiary Wasatch Formation, mapped from Field Observation on Aerial Photography

SECTION 27, T48N, R71W, WYO.

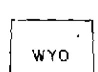
PREPARED BY KENNETH KOLM

1975

TOPOGRAPHIC BASE PROVIDED BY AMERICAN METALS CLIMAX CORP



CONTOUR INTERVAL 25 FEET



LOCATION

LEGEND

Seleniferous light-colored soils and sandstone outcrops supporting the plant indicator species *Astragalus bisulcatus*

Seleniferous light-colored soils and sandstone outcrops; no selenium indicator species observed

Boundary of soil sample study sites

ORIGINAL PAGE IS OF POOR QUALITY