U.S. DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Remote Sensing Study in Support of Mineral Resource Appraisal of the Black Ridge Canyons and Black Ridge Canyons West Wilderness Study Areas, Mesa County, Colorado, and Grand County, Utah, and the Westwater Canyon Wilderness Study Area, Grand County, Utah

Keenan Lee
Denver, Colorado

Open-File Report 87-435

1987

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards. Any use of trade names is for descriptive purposes only and does not imply endorsement by the U.S. Geological Survey.

REMOTE SENSING STUDY IN SUPPORT OF MINERAL RESOURCE APPRAISAL OF THE BLACK RIDGE CANYONS AND BLACK RIDGE CANYONS WEST WILDERNESS STUDY AREAS, MESA COUNTY, COLORADO, AND GRAND COUNTY, UTAH AND THE WESTWATER CANYON WILDERNESS STUDY AREA, GRAND COUNTY, UTAH

By

Keenan Lee

ABSTRACT

A remote sensing study of the Black Ridge Canyon, Black Ridge Canyon West, and Westwater Canyon Wilderness Study Areas was based on Landsat 2 Multispectral Scanner imagery. These data were processed and analyzed for lineaments and for limonite anomalies that might relate to hydrothermal alteration, migrating hydrocarbons, or uranium.

From the lineament analysis, a major basement fault is interpreted to pass through the eastern part of the Black Ridge Canyon Wilderness Study Area, with probable down-to-the northeast displacement. No limonite anomalies of interest are apparent in the imagery, but the narrow outcrop widths compared with the image resolution suggest that any such anomalies probably would go undetected.

INTRODUCTION

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a remote sensing survey of the Black Ridge Canyon and Black Ridge Canyon West Wilderness Study Areas (CO-070-113/113A), Mesa County, Colorado, and Grand County, Utah, and Westwater Canyon (UT-060-118), Grand County, Utah.

A remote sensing investigation was undertaken in support of a mineral resource appraisal of the Black Ridge Canyon - Westwater Canyon Wilderness Study Area (CO-070-113/113A and UT-060-118). An earlier mineral resource study determined areas of mineral resource potential for copper, lead, silver, and uranium (Toth and others, 1983), and hydrocarbons.

Landsat Multispectral Scanner (MSS) imagery data were acquired and processed to map variations in limonite. The images were used to target hydrothermal alteration associated with mineralization or limonite anomalies associated with either uranium deposition or hydrocarbon seepage.

Landsat MSS images were also used as the basis of a lineament analysis that covered a large area of western Colorado and eastern Utah. Linear features mapped on the images were interpreted to derive longer linear trends of parallel linear features called lineaments. Lineaments were interpreted, along with geophysical surveys and deep drilling data, to determine possible basement structures.

LINEAMENT ANALYSIS

A lineament analysis was conducted in a region covering several U.S. Bureau of Land Management wilderness study areas in western Colorado and eastern Utah. The area incorporated in the analysis is bounded by 107°-111° West Longitude and 37°-40° North Latitude (fig. 1).

METHODS

Linear features were interpreted from Landsat MSS images processed specifically for this purpose. Individual images were processed of single band information, using contrast enhancement and edge enhancement. Gary L. Raines (USGS) interpreted the Utah area and Keenan Lee interpreted the Colorado area. Because several separate Landsat MSS scenes were required to cover this area, the linear-feature data were digitized and compiled onto a single basemap (both Lambert and UTM projections).

This data compilation was then interpreted visually for long trends or strings of aligned linear features, which were combined into lineaments called visual lineaments (VL). Similarly, drainages were inspected for anomalous linear reaches that were mapped as drainage lineaments (DL).

Lineaments were then correlated with published geological and geophysical data. Surface faults were determined from geologic maps at scales of 1:500,000 and 1:250,000. Basement structures were interpreted from the correspondence of lineaments with Bouguer gravity maps at 1:1,000,000, aeromagnetic maps at 1:1,000,000, and deep drilling data.

RESULTS

Correlations with Bouguer gravity maps, aeromagnetic surveys, Precambrian basement structure as determined from deep drilling, and recent geologic maps at a scale of 1:500,000 are listed in Table 1.

The Black Ridge Canyon Wilderness Study Area is on one of the major lineaments of this region, VL11 (coincident with DL3), that lies along the eastern boundary of the modern Uncompahgre Plateau. A basement fault has long been recognized immediately to the southeast, where Precambrian rocks exposed at the surface are offset along high-angle, down-to-the northeast faults, collectively mapped as the Redlands fault by Cashion (1973). This surface faulting appears to diminish toward the study area, as the faults get deeper and pass upward into monoclines. From the lineament analysis, it appears this same fault system continues into the Black Ridge Canyon Wilderness Study area.

The Westwater Canyon Wilderness Study Area is on one of the drainage lineaments, DL1, which follows a very straight reach of the Colorado River. The lineament corresponds to a basement fault, mapped by Case and Joesting (1972), that offsets Precambrian terranes to the southwest, but which becomes less clearly defined in the Westwater Canyon area. The lineament does not extend beyond its intersection with lineament VL11/DL3.

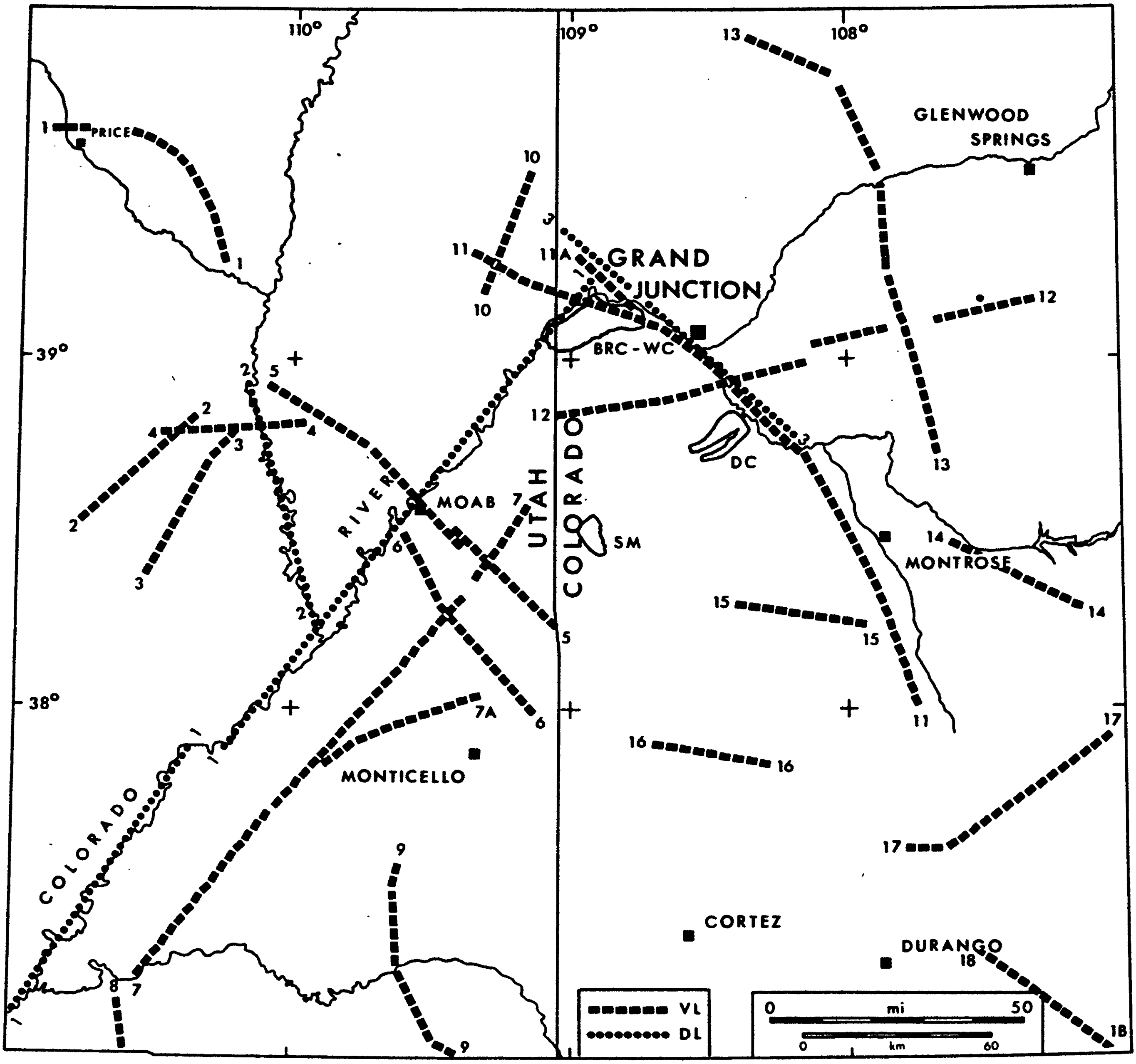

Figure 1. Lineament map of southwestern Colorado and southeastern Utah showing location of Black Ridge Canyon, Black Ridge Canyon West, and Westwater Canyon Wilderness Study Areas (BRC-WC). DC, Dominguez Canyon Wilderness Study Area; DL, drainage lineament; SM, Sewemup Mesa Wilderness Study Area; VL, visual lineament; numbers correspond to Table 1.

Table 1.--Correlation of lineaments in southwestern Colorado and southeastern Utah with geological and geophysical data

Lineament	Correlation with: Gravity[1]	Aeromagnetics[2]	Surface Faults[3] and Precambrian Basement Structures[4]
VL1	WEAK nose of high	WEAK SW flank of high	None apparent
VL2	GOOD gradient on SE flank of high	GOOD gradient on SE flank and in saddles	Reef monocline, fault with >3000 ft offset, down-to-SE
VL3	GOOD (as VL2 above)	GOOD (as VL2 above)	East of and parallel to Reef monocline fault
VL4	None apparent	None apparent	None apparent
VL5	STRONG parallels elongate highs and lows; coincides with low	WEAK subparallel to anomalies	Coincides with Moab-Spanish Valley-Gypsum Valley anticline, faulted
VL6	GOOD parallels elongate lows	WEAK subparallel	NW end coincides w/Kane Springs fault; correlates w/"basement fault"[5]
VL7	GOOD lies on truncations of NW-trending anomalies	WEAK coincides with few small highs	Coincides with three separate surface fault systems; VL7A is Shay Graben, a probable Quaternary fault system[6]
VL8	UNKNOWN (at edge of map)	UNKNOWN (at edge of map)	None apparent
VL9	GOOD along gradient; SE end coincides w/NW-trending high	WEAK along NE flank of several highs	N end coincides with Comb Ridge monocline, basement offset >3000 ft on down-to-east fault; SE end on Boundary Butte anticline
VL10	WEAK subparallel to contours	None apparent	None apparent
VL11	GOOD subparallel to long high; bends along w/bend in high	GOOD parallel to several anomalies	NW end coincides with surface fault; in Colo. Nat'l. Mon. coincides with surface monoclines and basement faults, down-to-NE; coincides with surface fault on Log Hill Mesa near Ridgeway, CO, down-to-west; "Olympic - Wichita Lineament"[5]
VL12	GOOD coincides w/kink in high and w/several flexures	None apparent	None apparent
VL13	GOOD parallels contours, even through a sharp bend, on SW flank of low	GOOD parallels contours on strong gradient, truncates anomalies	Northern bend coincides with down-to-south surface faults along Piceance Creek

Table 1.--Correlation of lineaments in southwestern Colorado and southeastern Utah with geological and geophysical data (continued)

Correlation with:

Lineament	Gravity[1]	Aeromagnetics[2]	Surface Faults[3] and Precambrian Basement Structures[4]
VL14	WEAK complex gravity pattern	WEAK coincides w/high	Coincides exactly with surface Cimarron fault (even where buried), down-to-south offset of basement
VL15	WEAK subparallel to contours	None apparent	Corresponds well to series of down-to-SW normal faults that are part of Laramide Uncompahgre boundary fault system
VL16	None apparent	WEAK subparallel to anomalies	Coincides with long, down-to-SW surface fault along Disappointment Creek
VL17	None apparent	None apparent	Truncates fault in Needle Mtns.; SW end on small Tertiary intrusion
V18	None apparent	None apparent	None apparent
DL1	WEAK NE end lies on truncation of anomalies	WEAK lies on saddles	Coincides with series of long basement faults; numerous basement terranes are truncated along these faults; Colorado Lineament[5]
DL2	WEAK N end parallel contours	WEAK lies on saddles	None apparent
DL3	GOOD subparallel to long high	GOOD parallel to several anomalies	Along surface monoclines and basement faults, parallel to VL11

[1] Behrendt and Bajwa, 1974; Cook and others, 1975
[2] Zeitz and Kirby, 1972, 1976
[3] Williams, 1964; Cashion, 1973; Tweto, 1979; Hintze, 1980
[4] Case and Joesting, 1972
[5] Baars and Stevenson, 1981
[6] Kitcho, 1981

LIMONITE MAPPING FOR HYDROTHERMAL ALTERATION

Landsat Multispectral Scanner (MSS) images are used to map the distribution of limonitic materials, which may act as guides to mineralized areas. The objective is to locate limonitic, hydrothermally altered areas.

"Limonite" is used in this report as defined by Blanchard (1968) "to denote the undifferentiated ferric oxide precipitates as a group. By common consent the word has become accepted as a collective term designating all of the reddish, yellowish, brownish, and blackish-brown supergene ferric oxide or ferric oxide hydrate precipitates...which have not been more specifically identified".

"Limonitic hydrothermal alteration" is used for that hydrothermal alteration that is accompanied by limonite. Areas of hydrothermal alteration lacking the limonite minerals will not be found using this technique, and areas of limonitic rocks not related to hydrothermal alteration often cannot be distinguished from limonitic rocks that are. Limonite cannot be mapped reliably in areas with vegetation cover exceeding about 30 percent, nor in shaded areas.

Exposed sulfide mineral deposits commonly have limonitic surfaces derived from the oxidation of pyrite to goethite, hematite, or jarosite. A gossan may form, or more commonly, a limonite staining occurs. This limonite can be sensed remotely, even in small quantities that incompletely stain grain surfaces (Lee and others, 1983). Limonite minerals have absorption features (low reflectance) in the blue region of the visible and near 0.9 micrometers in the infrared part of the electromagnetic spectrum. Both of these regions are sensed by the Landsat MSS.

METHODS

The Black Ridge Canyon and Westwater Canyon Wilderness Study Areas were imaged by the Landsat 2 MSS on 9 October 1975 (image 2260-17124). Computer-compatible tapes of this image were processed to reformat the images, to destripe them (equalize the six detectors), and to correct them geometrically for skew effect of the earth's rotation (Raines and others, 1978). The image was contrast enhanced using stretch parameters based on statistics of rock surfaces only--that is, the effects of vegetation and shadows were masked out by procedures developed by Knepper and Raines (1985).

Individual bands were ratioed to maximize spectral variations and to minimize illumination differences (very commonly from topography). These band ratio images were combined to produce color-ratio-composite (CRC) images (Rowan and others, 1974) on which limonitic rocks appear green.

RESULTS

The CRC images covering the Black Ridge Canyon and Westwater Canyon Wilderness Study Areas were studied in an attempt to locate anomalous limonitic areas. Only one weak anomaly was found, and comparison with the geologic map showed it to be simply a broad exposure of the Triassic Chinle Formation, a redbed unit characterized by hematite.

LIMONITE MAPPING FOR REDOX ALTERATION RELATED TO HYDROCARBON SEEPAGE

Preliminary studies at the Elaterite Basin, about 130 km south-west of the wilderness study areas, show that migrating hydrocarbons alter the oxidation state of iron in the enclosing redbeds. Suggested changes caused by the alteration process include the development of kaolinite, the introduction of or increase in calcite, and changes in iron oxides. The latter change is the clearest and the most obvious; ferric iron in hematite is reduced to the ferrous state, which allows removal of the iron as aqueous ferrous ion and retention of only trace amounts of hematite. Migrating hydrocarbons may provide sulfur that combines with the reduced iron to form pyrite and marcasite in local concentrations. Thin films of ferrihydrite form on rock surfaces if the altered redbeds are exposed to weathering.

METHODS

Red mudstones have reflectance spectra that show hematite and traces of kaolinite. The altered beds have spectra that show ferrihydrite, kaolinite, illite/smectite, and an overall increase in reflectance, or albedo. These spectral features are capable of being sensed by the Landsat satellite; the MSS can detect changes in iron mineralogy and albedo, whereas the Thematic Mapper (TM) also can sense development of the clay minerals.

RESULTS

For the present study, only MSS images were available. Color-infrared composites of MSS data at the Elaterite Basin show redox alteration as light areas caused by their higher albedo, and MSS CRC's indicate the same altered beds have little limonite compared to unaltered redbeds. The images of the Black Ridge Canyon - Westwater Canyon Wilderness Study Area were examined for areas with these characteristics, but no anomalies were found.

Because the sedimentary rocks in the wilderness study area have very low dips, and because the topography is dominated by mesas and canyons, outcrop widths of most of the formations are very narrow. Resolution of the MSS is about 80 m, so many formations are not adequately resolved on the imagery. The Chinle Formation, a distinctive redbed unit, appears on the images in only a few localities. Any alteration or redox variations within the Chinle Formation, therefore, would not be resolved.

LIMONITE MAPPING FOR REDOX VARIATIONS ASSOCIATED WITH URANIUM DEPOSITS IN SEDIMENTARY ROCKS

Uranium ions in solution frequently precipitate in sedimentary rocks at sites where reductants occur. These sites commonly show limonite variations as well, because the ferric iron in hematite and goethite will be replaced by ferrous iron. The effects will be the same as described above: redbeds will appear limonitic whereas the reduced beds will not.

Uranium in the Triassic Chinle Formation in the Paradox Basin is associated with limonite anomalies. According to Chenowith (1975), in the vicinity of the deposits the color of the sandstone has been altered from reddish purple to greenish gray. Similar effects are associated with uranium deposits in the Permian Cutler Formation (Chenowith, 1975), although some uranium in this formation apparently is concentrated in hematite grain coatings in the absence of reductants (Campbell, 1981).

METHODS

Limonite mapping, as described above, could show these variations in limonite. Both Landsat scanners, the MSS and TM, have the capability to image these differences, especially using CRC's in combination with any single band image or color-infrared composite.

RESULTS

Landsat MSS data of the wilderness study area, in the form of CRC's and color-infrared composites, were examined for limonite variations. Specifically, variations were sought where a lack of limonite occurs within limonitic redbeds. No such anomalies were found, but the narrow width of these outcrops would probably preclude their recognition.

SUMMARY AND CONCLUSIONS

One significant lineament passes through the eastern part of the Black Ridge Canyon Wilderness Study Area. This lineament probably represents a basement fault with down-to-the northeast displacement.

No indication of hydrothermal alteration is apparent. No redox alteration (negative limonite anomaly) is found that can be related to migrating hydrocarbons, nor are any redox variations noted that might be associated with uranium deposition. Most of the outcrops of interest, however, are narrow with respect to the imagery resolution, and such anomalies probably would go undetected.

REFERENCES

Baars, D. L., and Stevenson, G. M., 1981, Tectonic evolution of the Paradox Basin, Utah and Colorado, _in_ Wiegand, D. L., ed., Geology of the Paradox Basin: Rocky Mountain Association of Geologists Guidebook 1981, p. 23-31.

Behrendt, J. C., and Bajwa, L. Y., 1974, Bouguer gravity and generalized elevation maps of Colorado, Sheet 1, Gravity map: U.S. Geological Survey Geophysical Investigations Map GP-896, 2 sheets, scale 1:1,000,000.

Blanchard, Roland, 1968, Interpretation of leached outcrops: Nevada Bureau of Mines Bulletin 66, 196 p.

Campbell, J. A., 1981, Uranium mineralization and depositional facies in the Permian rocks of the northern Paradox Basin, Utah and Colorado, _in_ Wiegand, D. L., ed., Geology of the Paradox Basin: Rocky Mountain Association of Geologists Guidebook 1981, p. 187-194.

Case, J. E., and Joesting, H. R., 1972, Regional geophysical investigations in the central Colorado Plateau: U.S. Geological Survey Professional Paper 736, 31 p.

Cashion, W. B., 1973, Geologic and structure map of the Grand Junction quadrangle, Colorado and Utah: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-736, scale 1:250,000.

Chenowith, W. L., 1975, Uranium deposits of the Canyonlands area, in Fassett, J. E., and Wengerd, S. A., eds., Canyonland Country: Four Corners Geological Society Guidebook, 8th Field Conference, p. 253-260.

Cook, K. L., Montgomery, J. R., Smith, J. T., and Gray, E. F., 1975, Simple Bouguer gravity anomaly map of Utah: Utah Geological and Mineral Survey, scale 1:1,000,000.

Hintze, L. F., 1980, Geologic map of Utah: Utah Geological and Mineral Survey, scale 1:500,000.

Kitcho, C. A., 1981, Characteristics of surface faults in the Paradox Basin, in Wiegand, D. L., ed., Geology of the Paradox Basin: Rocky Mountain Association of Geologists Guidebook 1981, p. 1-21.

Knepper, D. H., Jr., and Raines, G. L., 1985, Determining stretch parameters for lithologic discrimination on Landsat MSS band-ratio images: Photogrammetric Engineering and Remote Sensing, v. 51, p. 63-70.

Lee, Keenan, Cole, D. M., and Kruse, F. A., 1983, Causes of color differences in limonitic areas on Landsat color-ratio-composite images: Colorado School of Mines Remote Sensing Report 83-1, final report NAS7-100/956208, Jet Propulsion Laboratory, 43 p.

Raines, G. L., Offield, T. W., and Santos, E. S., 1978, Remote sensing and subsurface definition of facies and structure related to uranium deposits, Powder River Basin, Wyoming: Economic Geology, v. 73, p. 1706-1726.

Rowan, L. C., Wetlaufer, P. H., Goetz, A. F. H., Billingsley, G. C., and Stewart, J. H., 1974, Discrimination of rock types and detection of hydrothermally altered areas in south-central Nevada by the use of computer enhanced ERTS images: U.S. Geological Survey Professional Paper 883, 35 p.

Toth, M. I., Stoneman, R. J., Patterson, C. G., and Jackson, L. L., 1983, Geology and mineral resource potential of the Black Ridge Canyon Wilderness Study Area, Mesa County, Colorado: U.S. Geological Survey Open-File Report 83-794, 30 p.

Tweto, Ogden, 1979, Geologic map of Colorado: U.S. Geological Survey, scale 1:500,000.

Williams, P. L., 1964, Geology, structures, and uranium deposits of the Moab quadrangle, Colorado and Utah: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-360, scale 1:250,000.

Zeitz, Isidore, and Kirby, J. R., Jr., 1972, Aeromagnetic map of Colorado: U.S. Geological Survey, scale 1:1,000,000.

Zeitz, Isidore, and Kirby, J. R., Jr., 1976, Aeromagnetic map of Utah: U.S. Geological Survey, scale 1:1,000,000.