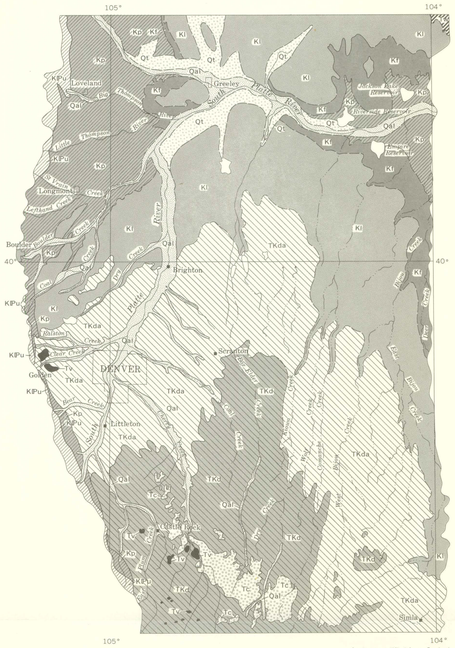
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH
DIVISION OF BIOLOGY AND MEDICINE
U.S. ATOMIC ENERGY COMMISSION

GEOPHYSICAL INVESTIGATIONS
MAP GP-505



GENERALIZED GEOLOGIC MAP OF THE DENVER AREA, COLORADO

EXPLANATION

SEDIMENTARY ROCKS

- Qal — Alluvium
- Qt — Terrace deposits
- Tc — Castle Rock Conglomerate
- Tcr — White River Formation
- Tkd — Dawson Formation, upper part
- Tkda — Dawson Formation (lower part), Denver and Arapahoe Formations
- Kl — Laramie Formation
- Kfh — Fox Hills Sandstone
- Kp — Pierre Shale
- KPu — Niobrara and Benton Formations, Dakota Group, Morrison, Ralston Creek, Lykins, Lyons, and Fountain Formations, undivided

QUATERNARY; TERTIARY; CRETACEOUS TO TERTIARY; CRETACEOUS; PENNSYLVANIAN TO CRETACEOUS

EXTRUSIVE IGNEOUS ROCKS

- Tv — Volcanic rocks (TERTIARY)

Contact
Dashed where approximately located

Lake or reservoir

GENERAL AERORADIOACTIVITY AND RELATED GEOLOGY

The natural gamma aeroradioactivity in the Denver area ranges from 300 to 1550 cps (counts per second) and is generally relatable to the gross composition of the surface material. Certain geologic formations and surficial materials may be delineated by characteristic radioactivity levels. The radioactivity and related geology are discussed more comprehensively in another report (Popenoe, 1965).

The Denver area lies in the Colorado Piedmont section of the Great Plains physiographic province. The area is underlain chiefly by lithified sedimentary rocks of Paleozoic, Mesozoic and Cenozoic age, and by unconsolidated surface deposits of Quaternary age. Shale and sandstone are the most abundant rocks in the northern part of the area but in the southern part of the area arkosic conglomerate predominates. Exposures of bedrock at the surface are small because of a cover of alluvium, eolian sand, and loess. Most of the area lies within the drainage basin of the South Platte River and its tributaries.

Although the survey does not traverse any of the crystalline bedrock of the Front Range, debris from these rocks is the chief cause of the high radioactivity areas on the map. The Front Range immediately west of the surveyed area consists of Precambrian metamorphic and igneous rocks and Tertiary intrusive rocks. Most of the Precambrian rocks have low radioactivity, but the Pikes Peak and Silver Plume Granites, certain varieties of biotite gneiss, and some pegmatites have relatively high radioactivity. One variety of porphyritic quartz bostonite is 15 to 25 times as radioactive as an average granitic rock (Sims and others, 1963). The radioactivity of many of these rocks is due to the accessory minerals monazite, zircon, and apatite. These are particularly stable minerals and persist in the sediments derived from crystalline rocks for long distances from their source areas.

St. Vrain, Lefthand, Boulder, South Boulder, and Clear Creeks drain areas of the Front Range that include the Tertiary igneous rocks, the Silver Plume Granite, pegmatites, and biotite gneiss. The area immediately west of the town of Castle Rock is underlain chiefly by the Pikes Peak Granite.

In the hogback ridges along the Front Range the best exposed rocks are the Lyons Sandstone and Dakota Group, both of which are relatively pure quartz sandstones. These sandstones are the cause of the linear radioactivity lows of 300 to 500 cps that parallel the western border of the surveyed area.

Most of the northern half of the surveyed area is underlain by the Pierre Shale, Fox Hills Sandstone, and Laramie Formation. The radioactivity over mapped exposures of these formations ranges between 400 and 900 cps. Exposures are sparse, however, because these rocks are easily eroded and are covered by eolian deposits on the upland areas and alluvium in the creek bottoms. The loess on the uplands has a uniform radioactivity level ranging between 700 and 900 cps, which is due to a high percentage of feldspar. Dune sand along the South Platte River near Empire and Riverside reservoirs has a lower radioactivity level of 500 to 600 cps.

Along the South Platte River and tributaries that originate in the Front Range, the younger alluvium derived from the crystalline rocks has high radioactivity which contrasts with the surrounding sedimentary rocks. The older alluvium in the upland gravels and the terrace deposits have lower radioactivity, probably due to leaching and weathering which removed or destroyed the radioactive minerals. Caliche deposits with low radioactivity are highly developed in the upper soil horizons of the older alluvium. As the crystalline debris in the alluvium becomes diluted by sand and loess eastward along the South Platte River, its radioactivity diminishes. Alluvium along Kiowa Creek derived from the upper part of the Dawson Formation is also relatively high in radioactivity.

The Denver Formation, an andesitic conglomerate, sandstone, and claystone, and the Arapahoe Formation, a sandstone and conglomerate derived from underlying sedimentary rocks, underlie most of the area surrounding Denver. These formations are exposed at the surface chiefly west of the South Platte River where they are deeply weathered and have relatively low radioactivity of 500 to 700 cps. Deeply weathered ancient alluvial deposits and loess producing radioactivity of 500 to 800 cps overlie bedrock. East of the South Platte River most of the upland surface is sand and loess (Hunt, 1954) and is higher (700 to 1000 cps) in radioactivity.

The Dawson Formation and Castle Rock Conglomerate underlie most of the southern third of the surveyed area. The upper part of the Dawson Formation and the Castle Rock Conglomerate are chiefly coarse clastic rocks derived from the crystalline rocks of the Front Range (Richardson, 1915). The lower part of the Dawson Formation, composed chiefly of claystone and siltstone with some pebble conglomerate and arkosic sandstone (Dane and Pierce, 1936), is transitional between the lagoonal shale, sandstone, and coal of the Laramie Formation and the continental clastics of the upper part of the Dawson. A rhyolitic welded tuff is present in the upper part of the Dawson Formation and remnants of the tuff cap some of the hills south of Castle Rock.

The radioactivity of the upper part of the Dawson Formation and the Castle Rock Conglomerate ranges between 900 and 1450 cps, reflecting the derivation of these rocks from the Pikes Peak Granite and associated crystalline rocks to the west. The radioactivity of these formations is highest where the rocks are well exposed along the ridges and it is lower in the valleys of the creeks where the rocks are probably covered by alluvium and eolian sand and silt. The rhyolitic tuff in the upper part of the Dawson is also relatively high in radioactivity. The radioactivity of the lower part of the Dawson is considerably less than that of the upper part and ranges between 600 and 900 cps. A sharp contrast in radioactivity is seen on the divide between West Bijou and East Bijou Creeks where several outliers of the more highly radioactive upper part are present. The areal extent of high radioactivity on the divide suggests that the upper part is more widespread than has been mapped in this area.

SELECTED REFERENCES

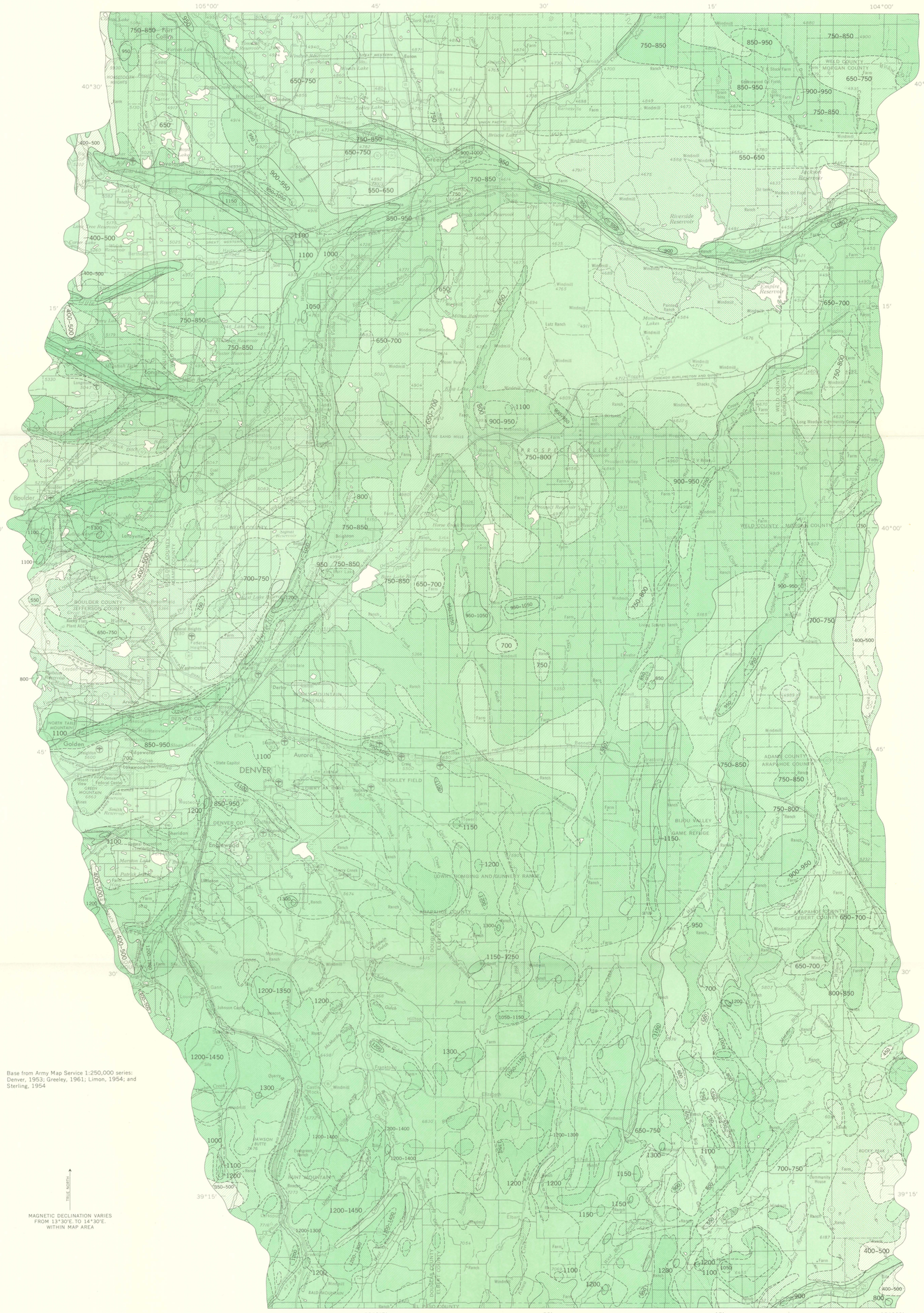
Dane, C. H., and Pierce, W. G., 1936, Dawson and Laramie Formations in the southeastern part of the Denver basin, Colorado: Am. Assoc. Petroleum Geologists Bull., v. 20, no. 10, p. 1308-1328.

Hunt, C. B., 1954, Pleistocene and Recent deposits in the Denver area, Colorado: U. S. Geol. Survey Bull. 996-C, p. 91-137.

Popenoe, Peter, 1965, Aeroradioactivity survey and areal geology of the Denver area, Colorado (ARMS-D: U.S.A.E.C. Report CEX-59.4.26, available from Office of Technical Services, Department of Commerce, Washington 25, D. C.

Richardson, G. B., 1915, Description of the Castle Rock quadrangle [Colorado]: U.S. Geol. Survey Geol. Atlas, Folio 198.

Sims, P. K., and others, 1963, Geology of uranium and associated ore deposits, central part of the Front Range mineral belt, Colorado: U. S. Geol. Survey Prof. Paper 371, 119 p.



EXPLANATION

750–800 — Radioactivity boundary
Solid where well defined, dashed where gradational or inferred. Numbers indicate general range of radioactivity level in counts per second

- 1200–1550
- 1100–1200
- 1000–1100
- 900–1000
- 800–900
- 700–800
- 600–700
- 500–600
- 300–500

Intensity of radioactivity showing general range in counts per second

EXPLANATORY TEXT

The radioactivity data were obtained with scintillation-detection equipment (Davis and Reinhardt, 1957[1]) installed in a twin-engine aircraft. Parallel flight traverses oriented east-west were spaced at one-mile intervals and flown 500 feet above the ground. The radioactivity data were compensated for deviations from the surveying elevation, and for the cosmic-ray component. The flight path of the aircraft was recorded by a gyrostabilized continuous-strip-film camera.

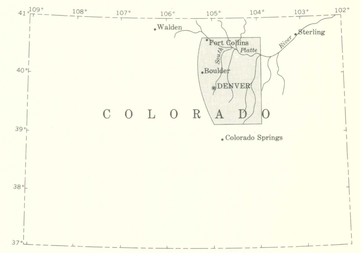
The effective area of response of the scintillation equipment at an elevation of 500 feet is a circle approximately 1,000 feet in diameter, and the radioactivity recorded is an average of the radioactivity received from within the area. The scintillation equipment accepts only pulses originating from gamma radiation with energies greater than 50 kev (thousand electron volts). A cesium-137 source is used during periodic calibrations to assure uniformity of equipment response.

The gamma radiation at 500 feet above the ground has three principal sources: cosmic radiation, radionuclides in the air (mostly radon daughter products), and radionuclides in the surficial layer of the ground. The cosmic component is determined twice daily by calibrations at 2,000 feet above the ground and is removed from the radioactivity data. The component due to radionuclides in the air at 500 feet above the ground is difficult to evaluate. It is affected by meteorological conditions, and a tenfold change in radon concentration is not unusual under conditions of extreme temperature inversion. However, if inversion conditions are avoided, the air component may be considered to be fairly uniform on a given day in a particular area, and will not affect the discrimination of radioactivity levels resulting from changes in the ground component.

The ground component comes from the upper few inches of the ground. It consists of gamma rays from natural radionuclides, principally members of the uranium and thorium radioactive decay series and potassium-40, and fallout from radioactive nuclear fission products. Any fallout present is assumed to be uniformly distributed over the area surveyed. The amount of fallout present must be small as the lowest total radioactivity measured due to both natural radionuclides and fallout is 300 cps.

In compiling the radioactivity data, all radioactivity lows attributable to bodies of water were deleted to facilitate reading of the map. The aeroradioactivity profiles of each flight traverse were examined and significant changes in level were correlated from profile to profile. The changes were then plotted on overlays of the base maps and connected by solid or dashed lines depending on the degree of correlation. The areas between the lines of change were assigned general ranges of radioactivity levels by scanning the records obtained over these specific areas.

[1]Davis, F. J., and Reinhardt, P. W., 1957, Instrumentation in aircraft for radiation measurements: Nuclear Sci. and Eng., v. 2, no. 6, p. 713-727.



INDEX MAP SHOWING AREA OF THIS REPORT

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1965—G65074

Aeroradioactivity survey made at 500 feet above the ground under the direction of G. E. Andreasen and A. J. Petty

NATURAL GAMMA AERORADIOACTIVITY MAP OF THE DENVER AREA, COLORADO

By
Peter Popenoe
1965

For sale by U.S. Geological Survey, price 50 cents