UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

New geologic, ground magnetic, E-mode VLF, and radiometric surveys at Phillips Mine-Camp Smith uranium prospect, Westchester and Putnam Counties, New York

by

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Summary

This report updates U.S. Geological Survey Open-File Report 77-780 by including new field data taken in July 1978. A revised geologic map is included, as are new geophysical data from an approximately 0.3-km by 0.5-km area just northeast of and adjoining the area surveyed earlier. The pattern which had been observed to the southwest of spatially coincident radiometric highs, magnetic highs, and resistivity lows deteriorates to the northeast: there the radiometric highs fall on magnetic lows and the correlation with resistivity lows disappears.

Introduction

The Phillips Mine-Camp Smith uranium prospect is located in the Hudson Highlands on the border of Westchester and Putnam Counties, New York. Camp Smith is to the south of the border in Westchester County; the long-abandoned Phillips Mine is north of the border in Putnam County. (See location map, fig. 1.) The Phillips Mine exploited a massive sulfide body at that site, a body consisting chiefly of pyrite and pyrrhotite, during the decade or so just after the Civil War. The moderate- to high-grade metamorphic rocks of the study area display considerable local structure, which was mapped in a preliminary manner by Klemic and others (1959). They described the local geology, some geophysical work, and results of a trenching and coring program performed there in the 1950's. In May-June 1976 and in December 1976, the U.S. Geological Survey made ground total-field magnetic, E-mode VLF apparent-resistivity, and 4-channel spectral radiometric measurements at approximately 400 stations on the Phillips Mine-Camp Smith prospect. A

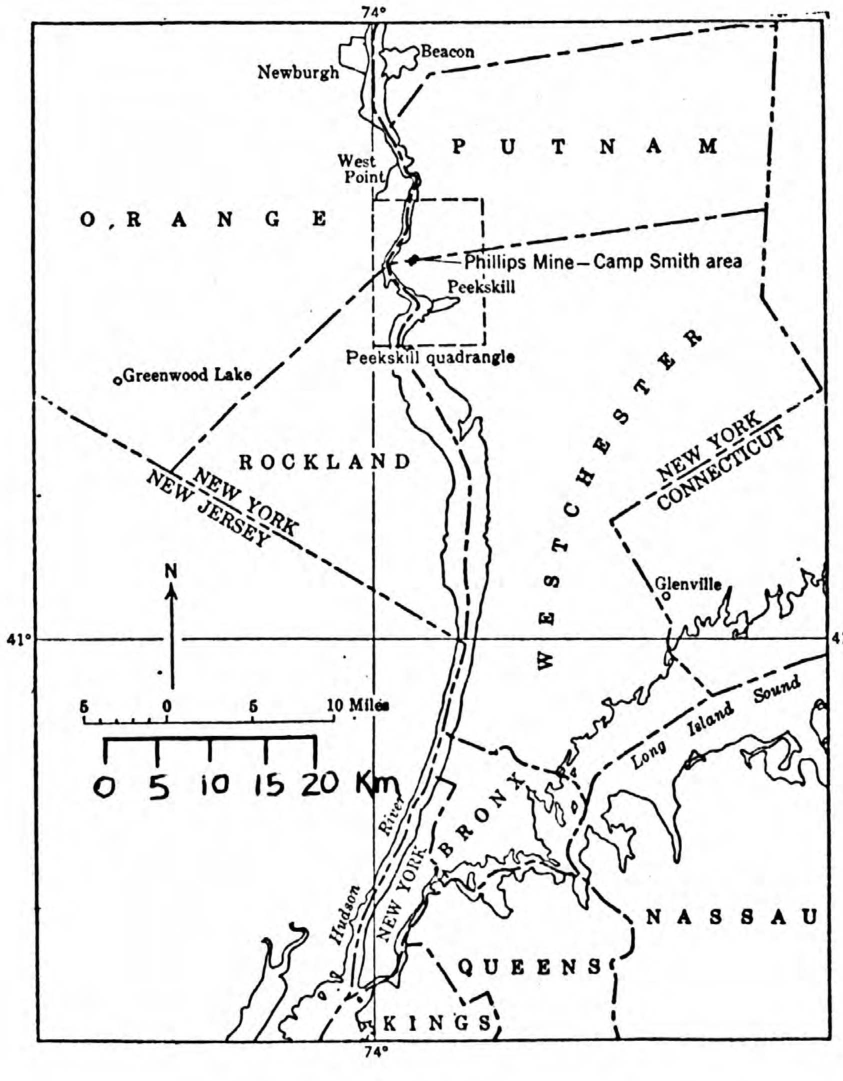


Figure 1.--Index map showing Camp Smith-Phillips Mine location. From Klemic and others (1959).

short abstract of that work was given by Grauch and Campbell (1977), and a record of the data collected then may be found in Campbell and Grauch (1977). Using this data together with preliminary geologic mapping, Grauch (1978) described a possible ore-genetical model for uranium at Phillips Mine-Camp Smith and elsewhere in the Hudson Highlands. In July 1978, the U.S. Geological Survey extended the geophysical work at Phillips Mine-Camp Smith to include approximately 200 more stations in an area northeast of that previously mapped, and performed additional reconnaissance geologic mapping in the area. This report presents the new data, along with that collected and reported earlier.

Geology

The Camp Smith area is underlain by a complexly folded, interlayered sequence of metamorphosed (granulite facies) submarine volcanogenic, carbonate, and pelitic rocks, and minor amounts of granite and pegmatite. This terrain is thought to be of late Proterozoic age, but age relations between the rock units described here are not known. The three major rock units are hornblende gneiss, quartz-feldspar-biotite leucogneiss (biotite leucogneiss of plate 1), and quartz-feldspar-hornblende-(±biotite) leucogneiss (leucogneiss of plate 1). The hornblende gneiss unit is variable in composition and appearance, ranging from massive dark-green amphibolite to banded hornblende-quartz-feldspar gneiss. Minor horizons of magnetite-rich amphibolite gneiss and scapolite-rich amphibolite gneiss are included in that unit. The biotite leucogneiss unit includes minor amounts of marble, graphitic calc-silicate gneiss, graphitic metachert, biotite-garnet-quartz-feldspar gneiss, and amphibole-pyroxene-garnet-graphite skarn. Compositional variations within the hornblende leucogneiss are minor and are reflected by variations from 1:0 to 1:1 in the ratio of hornblende to biotite. In the northeastern part of the area represented on plate 1 the biotite leucogneiss and leucogneiss units are apparently indistinguishable. It may be that the two units are really one with minor primary lateral chemical variations. All three of the major rock units host small amounts of quartz-feldspar pegmatite (leucopegmatite of plate 1) and hornblende-quartz-feldspar (±pyroxene) pegmatite (hornblende pegmatite of plate 1).

Uraninite is found in four different rock types: magnetite-rich layers and scapolite-rich layers in amphibolite gneiss, hornblende pegmatite, and the outer, Cu-Ni-bearing zone of the massive sulfide body. The magnetite-rich and scapolite-rich layers appear to be near the contact between light- and dark-colored gneisses. Hornblende pegmatites, interpreted by us as being anatectic in origin, are also most abundant near that contact. In the massive sulfide body, uraninite is apparently restricted to the Cu-Ni-bearing zone, which in addition contains apatite, pyrrhotite, pyrite, chalcopyrite, marcasite, and magnetite. The core of the sulfide body is apparently massive pyrrhotite with little if any uraninite, pyrite, or chalcopyrite. The uraninite occurrences mentioned above have two features in common: association of uraninite with apatite and proximity to the lithologic break between melanocratic and leucocratic rocks. Minor concentrations of uranium are also found in small, presumably old, fractures near the lithologic break.

Geophysics

Plates 2, 3, 4, and 5 show all geophysical data the U.S. Geological Survey has taken at the Phillips Mine-Camp Smith site. These plates update the corresponding plates in Campbell and Grauch (1977) by including the newer data taken in July 1978.

A general discussion of total-field magnetic methods may be found in Breiner (1973). The 1976 magnetic data were acquired using two Geometrics Model G816 proton-precession magnetometers.[1] One of the magnetometers was used to measure the magnetic field at selected field stations, while the other recorded background magnetic field at a fixed base station. The sensitivity of the instruments was 1 nT (nanoTesla). The base magnetometer recorded one reading per minute on a strip chart recorder. The base-station magnetic field changed each day by less than 40 nT, while measured field anomalies often had amplitudes of several thousand nT. Because of this earlier experience, no fixed base magnetometer was used in collecting the 1978 data; rather, the background field was checked several times a day by reoccupying a base location. All data were taken on days when total daily variation was less than 40 nT. Measurements at a given station site usually repeated to within ±2 nT, but in some zones of steep magnetic gradients successive readings at the same site occasionally differed by more than 200 nT. The magnetic field values shown on plate 2 represent the difference between station value and base value (1976 data) or an equivalent value

[1]Manufacturers and model numbers of equipment used in this report are given for descriptive purposes only. This reference does not imply endorsement by the U.S. Geological Survey.

for 1978 data found by adjusting all measurements so as to make equal the field measured both years at reference station (0,0).

A general discussion of VLF (very-low-frequency) electromagnetic exploration techniques may be found in Paterson and Ronka (1971). Our E-mode VLF data were taken using a Geotronics Model M16 unit with an R100 attachment. The unit was tuned to NBA, a U.S. Navy navigation station at Annapolis, Md., broadcasting at 21.4 kHz. This particular station was chosen to give maximum coupling with local geologic units, since Annapolis is located approximately on an extension of the direction of local strike. At each site a single apparent resistivity value and a phase angle were read directly from the unit. The apparent resistivity value is a combination of the resistivities of those rocks below the site which are shallower than about one skin depth for the 21.4-kHz electromagnetic wave. At that frequency, one skin depth is about 10 m in rocks of 10 ohm-m resistance, and 100 m in rocks of 1000 ohm-m resistance. The measured VLF resistivity values and associated phase angles are shown on plate 3. Very roughly, the phase angle value may be regarded as seeing somewhat deeper than the resistivity value: over a horizontal two-layer earth, phase angles less than 45^{o} result when the deeper layer is more resistive, and greater than 45^{o} less resistive, than the surface layer. Low resistivity values may be indicative, among other things, of massive sulfide mineralization or of wet ground. At Camp Smith, however, very high resistivity values were often measured at stations in marshes and shallow ponds, so that we may discount the latter possibility to an extent.

A general discussion of radiometric techniques may be found in Parasnis (1973). Four-channel radiometric measurements were made using a Geometrics DISA-400 scintillation spectrometer. The four channels were calibrated to measure thallium-208 for thorium, bismuth-214 for uranium, potassium-40 for potassium, and total-count. The total-count channel on the instrument almost always became saturated during the 2-minute sampling period, and so the total-count measurement is not presented here. Readings taken during the summer repeated to within about 10 percent, but winter readings were more scattered, possibly due to frozen ground conditions or to a temperature effect in the instrument. (In winter, daytime temperatures below freezing were common.) Most winter radiometric readings were repeated at least once; of these the warmest-day readings tied best to the summer measurements, and so are reported on plates 4 and 5. The summer 1976 measurements, which are thought to be fairly reliable, include stations 160W through 40E on lines 120N through 160S, and stations 100W through 100E on lines 200S through 400S.[2] Summer 1978 measurements are also thought to be reliable, and include all stations on and north of line 240N. The remaining stations were measured in winter and are probably less reliable.[3]

[2] Station designations are with respect to nominal E-W and N-S directions chosen approximately perpendicular and parallel to local strike, respectively. Nominal west is 40° west of true north. Station ON-S, OE-W is at the intersection of Mine Road and Iron Mountain Road. Station distances are in meters from this origin point.

[3] July 1978 radiometric values measured on line 240N were found to be less than half those measured December 10, 1976, on a parallel line offset only 20 m to the southeast. We now suspect the December 10, 1976, measurements reported in Campbell and Grauch (1977), and have omitted radiometric data taken on that day from plates 4 and 5.

Plates 4 and 5 report C_K, C_U, and C_{Th}, the measured uncorrected count rates at each station during a 120-second counting period, for potassium, uranium, and thorium, respectively.[4] Assuming log C_U and log C_{Th} to be distributed normally, the mean log C_U = 2.417 and mean log C_{Th} = 2.065 for the 597-station suite, with standard deviations of 0.333 and 0.345, respectively. The corresponding mean count rates are C_U = 216 and C_{Th} = 116. An approximate calibration of the instrument used (Joe Duval, written communication, July 30, 1976) is

$$\text{eTh (ppm)} = 0.047\ (C_{Th} - 14)$$

$$\text{eU (ppm)} = 0.0055\ (C_U - 18) - 0.015\ (C_{Th} - 14).$$

Thus, the above means correspond to 4.79 ppm equivalent thorium and 1.18 ppm uranium. Note, however, that the values of eTh and eU given by the above calibration are thought to be correct to no better than ±50 percent. Further, these values would represent surface soil and rock, not necessarily concentrations at depth. Particular caution should be exercised in evaluating data collected along Mine Road, where subsurface material was excavated and scattered on the surface in the course of a trenching operation in the 1950's. (See Klemic and others, 1959.)

[4]In 1978, counts were made for two 30-second intervals at each station. The values reported on plates 4 and 5 are twice the sum of these two measurements, so as to be consistent with the 120-second counting period used earlier.

Changing geophysical character to the northeast

In Campbell and Grauch (1977), we pointed out that a close spatial association of uraninite, magnetite, and sulfides in the region to the southwest of Phillips Mine results in nearly coincident geophysical anomalies there involving high uranium-channel radiometrics, high total-magnetic field, and low VLF apparent resistivity, respectively. In this region, the radiometric and magnetic (and, to a lesser extent, apparent resistivity) patterns are generally narrow and linear, trending along strike. (See figs. 2, 3, and 4.) It now appears that these geophysical correlations deteriorate as one proceeds northeast from Phillips Mine. Northeast of approximately line 0 NS, the continuous linear anomaly patterns become broken into shorter segments, so that contour maps of the data take on a more blotchy aspect.[5] The general trends of the resistivity contours veer a few tens of degrees counter-clockwise from the radiometric and magnetic trends, so that the parallelism which was apparent to the southwest is lost. Finally, the correlation of radiometric with magnetic highs deteriorates over a 100- to 200-meter-wide zone just northeast of Phillips Mine. Northeast of about line 400 N the transition is complete, and the correlation becomes an anti-correlation. Over the remainder of the newly surveyed area, radiometric highs fall consistently on magnetic lows.

[5]Note, however, that the most continuous linear anomalies in the southwestern portion of the study area occur where trenching and drilling were done in the 1950's. (See Klemic and others, 1959.) It may be that the geophysical patterns would have been equally blotchy in these places if measured before surface material was stripped and spoil from the subsurface was exposed.

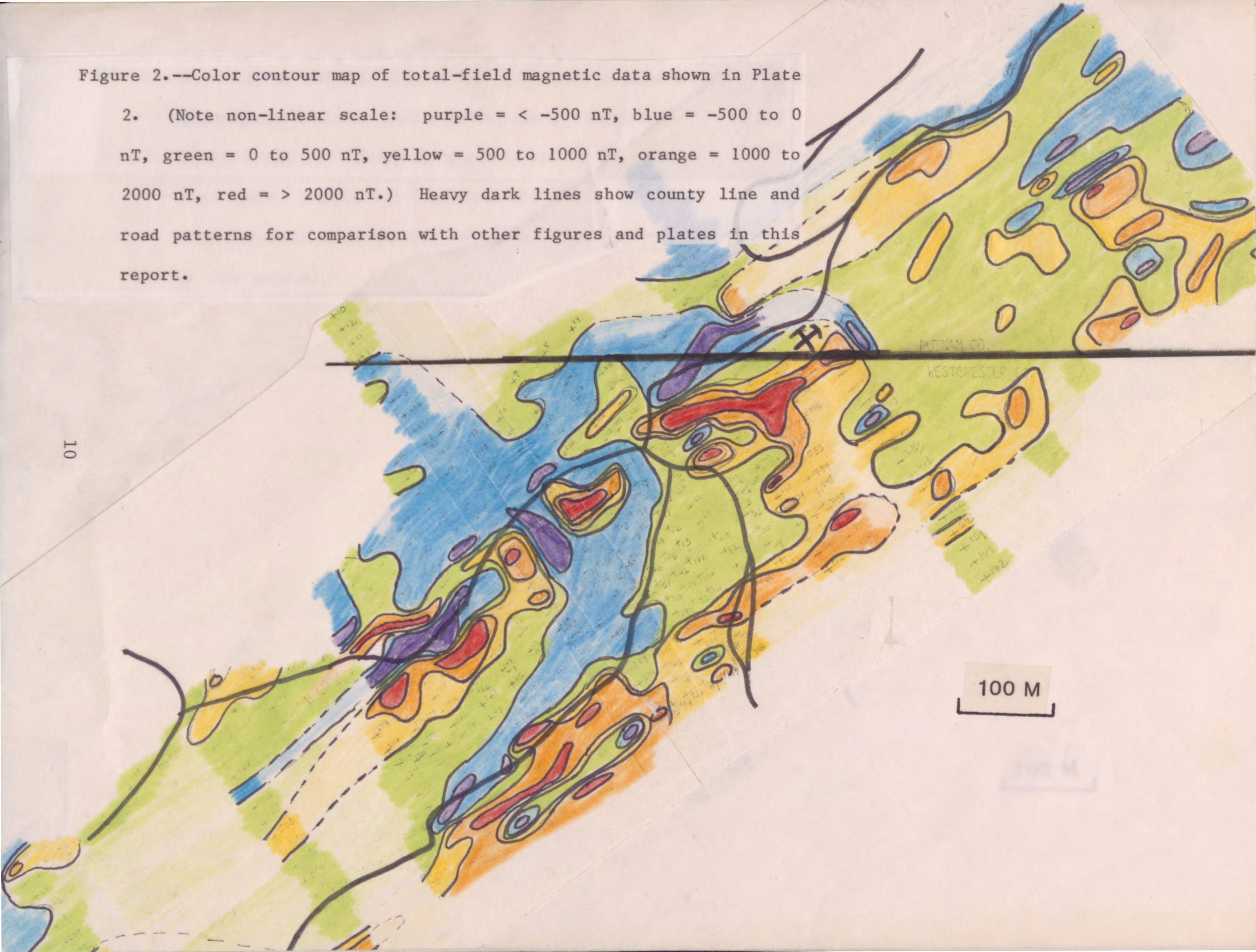


Figure 2.--Color contour map of total-field magnetic data shown in Plate 2. (Note non-linear scale: purple = < -500 nT, blue = -500 to 0 nT, green = 0 to 500 nT, yellow = 500 to 1000 nT, orange = 1000 to 2000 nT, red = > 2000 nT.) Heavy dark lines show county line and road patterns for comparison with other figures and plates in this report.

Figure 3.--Color contour map of VLF resistivity data in Plate 3. (Note logarithmic scale: red = < 30 ohm-m, orange = 30 to 100 ohm-m, yellow = 100 to 300 ohm-m, green = 300 to 1000 ohm-m, blue = 1000 to 3000 ohm-m, purple = > 3000 ohm-m.) Heavy dark lines show county line and road patterns for comparison with other figures and plates in this report.

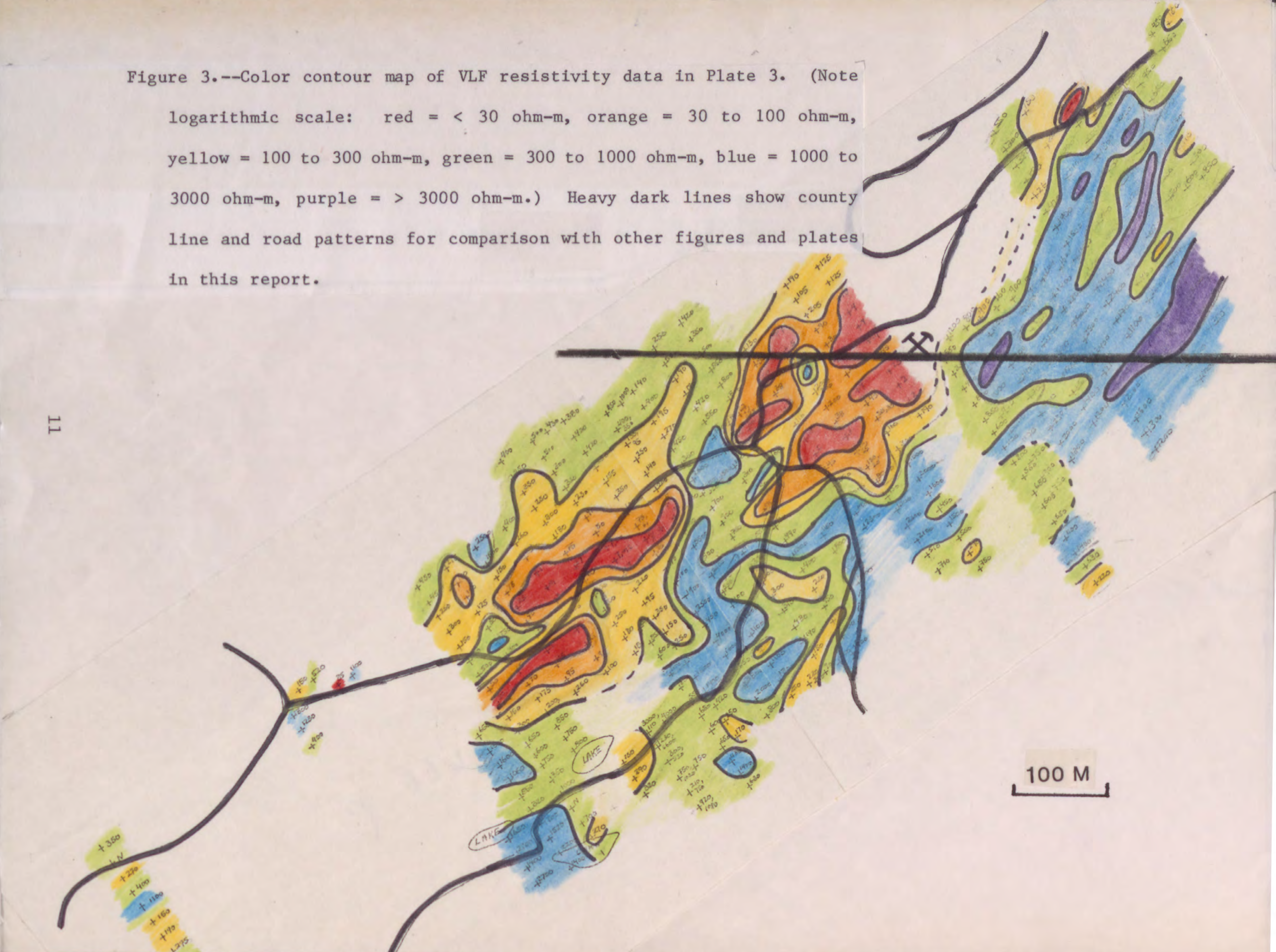
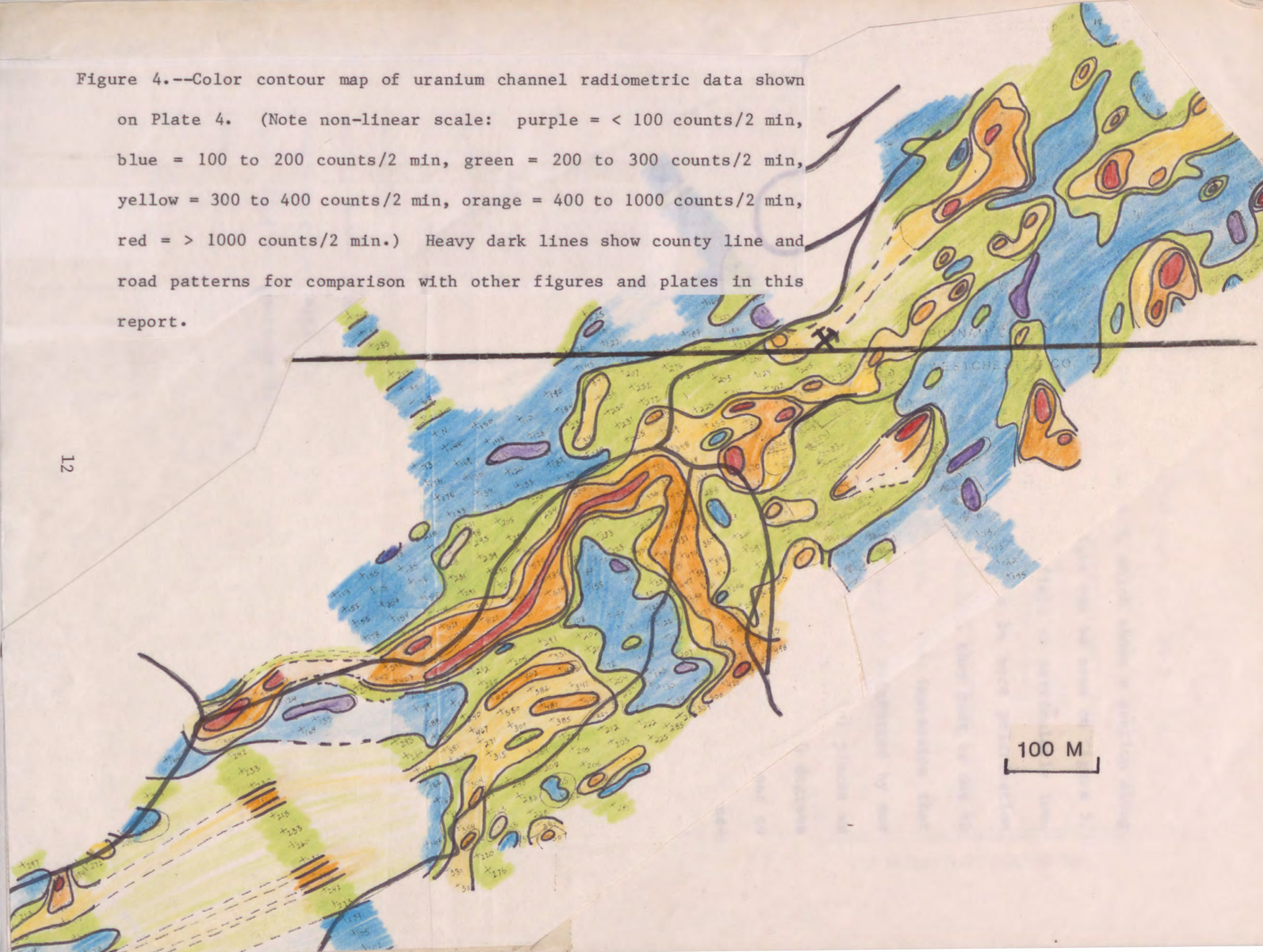


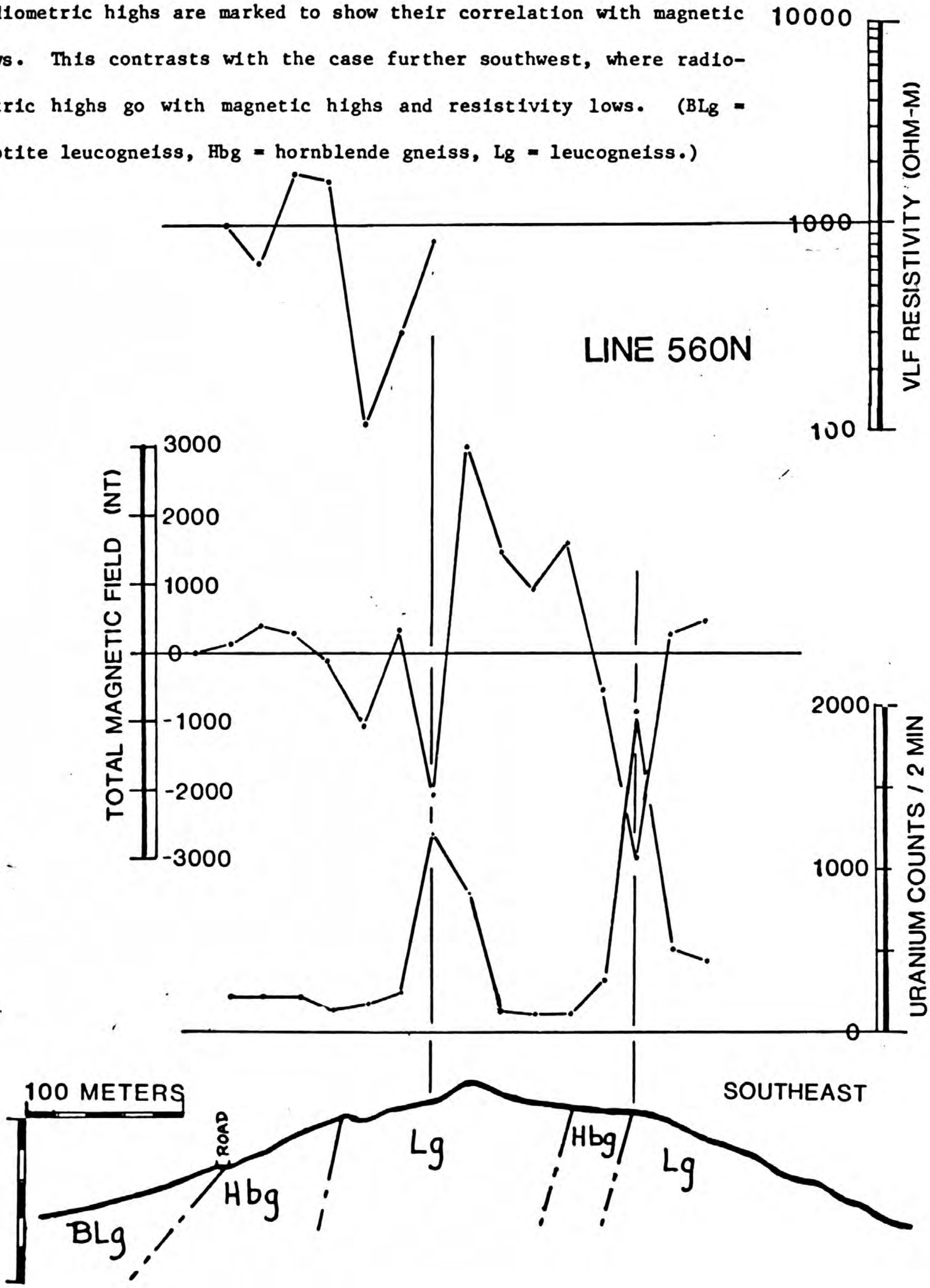
Figure 4.--Color contour map of uranium channel radiometric data shown on Plate 4. (Note non-linear scale: purple = < 100 counts/2 min, blue = 100 to 200 counts/2 min, green = 200 to 300 counts/2 min, yellow = 300 to 400 counts/2 min, orange = 400 to 1000 counts/2 min, red = > 1000 counts/2 min.) Heavy dark lines show county line and road patterns for comparison with other figures and plates in this report.



This point is illustrated in figure 5, which shows a section along line 560 N. Two strong uranium-channel highs can be seen on figure 5, and both occur at sites where the magnetic field is particularly low. These magnetic-field lows appear too strong to be mere polarization shadows to the north of more magnetic units; rather, they must be due to units having permanent reversed magnetization. The impression that strongly permanently magnetized units are present is reinforced by our experience surveying the lines in this area, for in several places we noted that local magnetic compass direction deviated up to 30 degrees from line-of-sight. These local permanently magnetized units appear to be lens-shaped, for they could be followed along strike using the magnetometer for several tens of meters before their magnetic signature would be lost. Like the body causing the southeasternmost of the two anomalies marked on figure 5, such magnetized lenses may occur at the hornblende gneiss-leucogneiss contact.

Although the resistivity survey was not carried as far to the northeast as the other surveys, the resistivity values seen in the newly surveyed area tended to be high and typical of crystalline rock. No additional large, low-resistivity pockets which could represent massive sulfide bodies were seen northeast of Phillips Mine. The correlation of resistivity lows with radiometric highs, which was seen to the southwest, does not continue in the northeastern portion of the surveyed area.

Figure 5.--Geological and geophysical section along line 560 N. Two radiometric highs are marked to show their correlation with magnetic lows. This contrasts with the case further southwest, where radiometric highs go with magnetic highs and resistivity lows. (BLg = biotite leucogneiss, Hbg = hornblende gneiss, Lg = leucogneiss.)



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