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Monitoring Natural and Man-made Radiation

by

Airborne Gamma-Ray Spectrometry

Kozlodui Area

BULGARIA

1990

R. Hetu, R. Rangelov, J.A. Grant, R.L. Grasty and D. Graham

Contents : colour maps of gamma ray spectrometric data prepared at the Geological Survey of Canada, Ottawa

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Monitoring Man-Made Radiation By Airborne Gamma-Ray Spectrometry - Bulgaria

R. Hetu, R. Rangelov, J.A. Grant, R.L. Grasty and D. Graham

Introduction

In 1991, Mr. R. Rangelov of the Airborne Geophysics Department of the Enterprise for Geophysical Exploration and Geological Mapping in Sofia, Bulgaria was awarded a 3 month International Atomic Agency Fellowship to study airborne gamma-ray survey techniques for mapping radioactive fallout. His study period was spent working with the Airborne Geophysics Section of the Geological Survey of Canada which has experience in monitoring man-made radiation dating from the fall of the Russian nuclear satellite in northern Canada in the winter of 1978. Since then, studies on separating natural and man-made radiation had been carried out in co-operation with the Finnish Geological Survey.

In 1985, the Bulgarian airborne geophysics group purchased airborne geophysical equipment including a gamma-ray spectrometer and data-processing system from Geoterrex Ltd. of Ottawa. The spectrometer has 50 liters of downward-looking NaI detectors and 4 liters of lead-shielded upward-lookind detectors for monitoring atmospheric background variations. Two 256 channel spectrometers are used to separately monitor the upward and downward looking detectors. The equipment is flown in a Russian MI-8P helicopter with other standard survey equipment such as a radar and barometric altimeter, magnetometer, printer/plotter, magnetic tape for data recording and a video system for track recovery.

On 21 and 22 May, 1990, a detailed survey was flown over a small area in northern Bulgaria in the vicinity of a nuclear reactor near the town of Kozlodui. The survey was flown at a mean altitude of 90 m with a line spacing of 100 m. Analysis of the airborne gamma-ray data in Bulgaria using the Geoterrex data processing system had shown evidence for man-made contamination due to cesium-137 and cobalt-60. More detailed analysis of this data was performed at the GSC using a stripping technique developed in collaboration with the Finnish Geological Survey (Grasty and Multala,1991). This report illustrates the use of airborne gamma-ray spectrometry for mapping man-made radiation by applying this particular technique to the Bulgarian airborne survey data.

Demonstration

Figures 1 and 2 illustrate how the natural gamma-ray component can be removed from a measured spectrum containing both natural and man-made radiation. The average measured spectrum recorded along one particular section of a survey is shown in Figure 1. This spectrum is the average of approximately 1000 individual one second measurements. The main peaks on this spectrum originate from natural gamma-ray emissions from potassium, uranium and thorium. On the side of the 609 keV bismuth-214 peak at channel 51 there is a small bump indicating the presence of cesium-137 at 662 keV. This cesium peak is clearly seen after computer processing of the data (Figure 2). In this spectrum the low energy portion of the natural component has been removed using the stripping technique.

Figures 3 and 4 illustrate how a cobalt-60 spectrum can be extracted from the measured spectrum for a small section of line crossing an area of cobalt-60 contamination. Figure 3 shows the measured average spectrum along this flight section. No clear cobalt-60 peaks can be seen at 1173 and 1332 keV. However, by applying the stripping procedure using coefficients derived from the entire flight, the two peaks can be identified (Figure 4).

Figure 5 illustrates how the stripping procedure can be used to identify the presence of cobalt-60 on the ground. It shows a continuous profile of a single window centered around the cobalt-60 gamma-ray peak at 1173 keV. The natural gamma-ray contribution to this window has been removed by monitoring the potassium, uranium and thorium windows and applying the stripping corrections using coefficients derived from the entire line.

Map Production

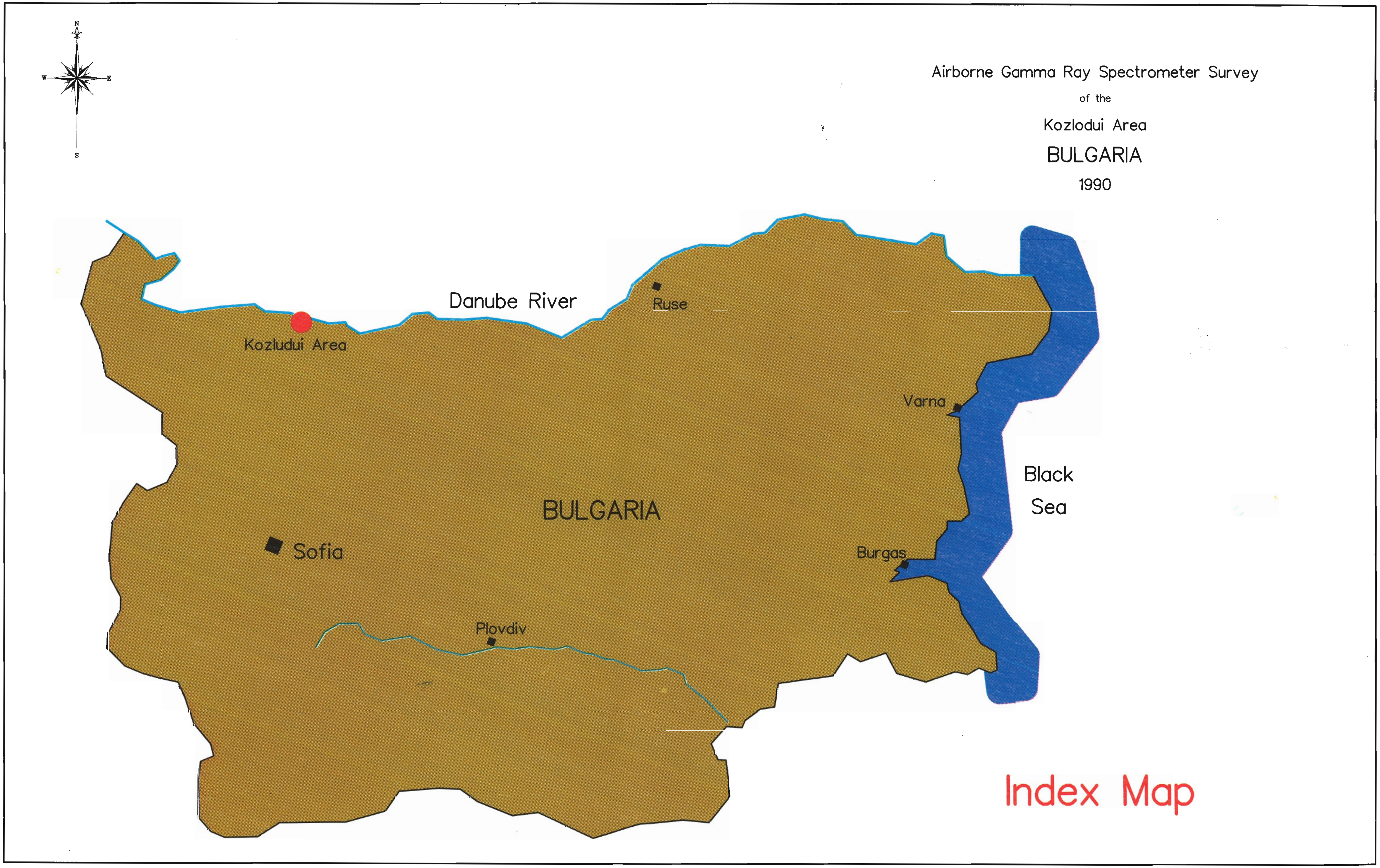
The airborne gamma-ray spectrometry data from the Kozlodui area were processed using calibration constants provided by Geoterrex Ltd to obtain estimated ground concentrations of potassium, uranium and thorium. The first map in this booklet is SPOT Panchromatic Data obtained from Radarsat International Incorporated (CNES copyright 1992) which was recorded digitally and processed using an image analysis system. The second and third maps show the natural exposure rate calculated from the potassium, uranium and thorium concentration of the ground and a total exposure rate map calculated from the total count window (0.40-2.81 MeV) using a calibration constant determined from flights over a calibration range. The total count exposure rate map includes both the natural and man-made components. The low count zone visible on these maps identifies the main river in the area. The fourth map represents the Total Exposure Rate superimposed with the SPOT image using a procedure developed by (Harris et al., 1990). The fifth map is the man-made exposure rate map. The man-made exposure rate was determined by subtracting the exposure rate derived from the potassium, uranium and thorium concentration of the ground from the total exposure rate. Potassium, Uranium and Thorium maps are also included in this booklet.

The final two maps are the cesium-137 and cobalt-60 count rate maps. These two maps were made using stripping coefficients which were obtained using the averages of several flights. The cesium-137 window covered an energy range from 598 keV to 724 keV and the cobalt-60 window was 130 keV wide and centered on the 1173 keV photo-peak. In the case of the cobalt map, no conversion to kBq/m^2 was possible as no ground measurements were available. The cesium-137 conversion from count rate to kBq/m^2 was obtained from data provided by the Finnish Geological survey and the Scottish Universities Research Centre. It should be noted that the higher cesium-137 deposition levels indicated on the map are comparable to those found in large areas of Sweden and Findland due to fallout from Chernobyl.

REFERENCE

Grasty, R.L., and Multala, J.
1991: A correlation technique for separating natural and man-made airborne gamma-ray spectra; Current Research, Part D, Geological Survey of Canada, Paper 90-1D p. 111-116.

Harris, J., Murray, R. and Hirose, T.
1990: IHS Transform for the Integration of Radar Imagery with other Remotely Sensed Data. Photogrammetric Engineering and Remote Sensing, Vol 56, No 12, p. 1631-1641.


N
W
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Airborne Gamma Ray Spectrometer Survey
of the
Kozlodui Area
BULGARIA
1990
Danube River
Ruse
Kozludui Area
Varna
Black
Sea
BULGARIA
Sofia
Burgas
Plovdiv
Index Map

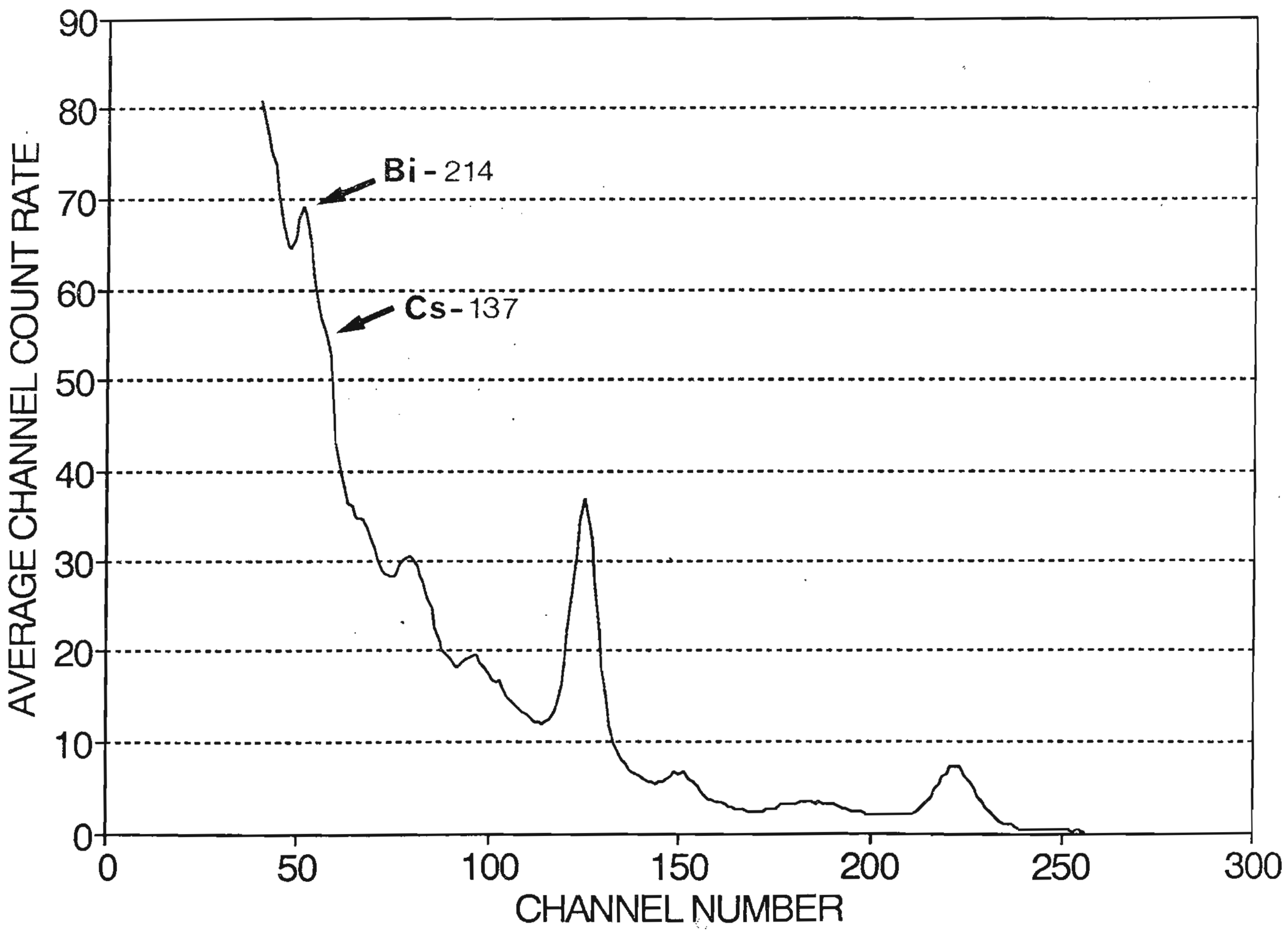

Figure 1. An average spectrum showing very little evidence for the presence of cesium-137.

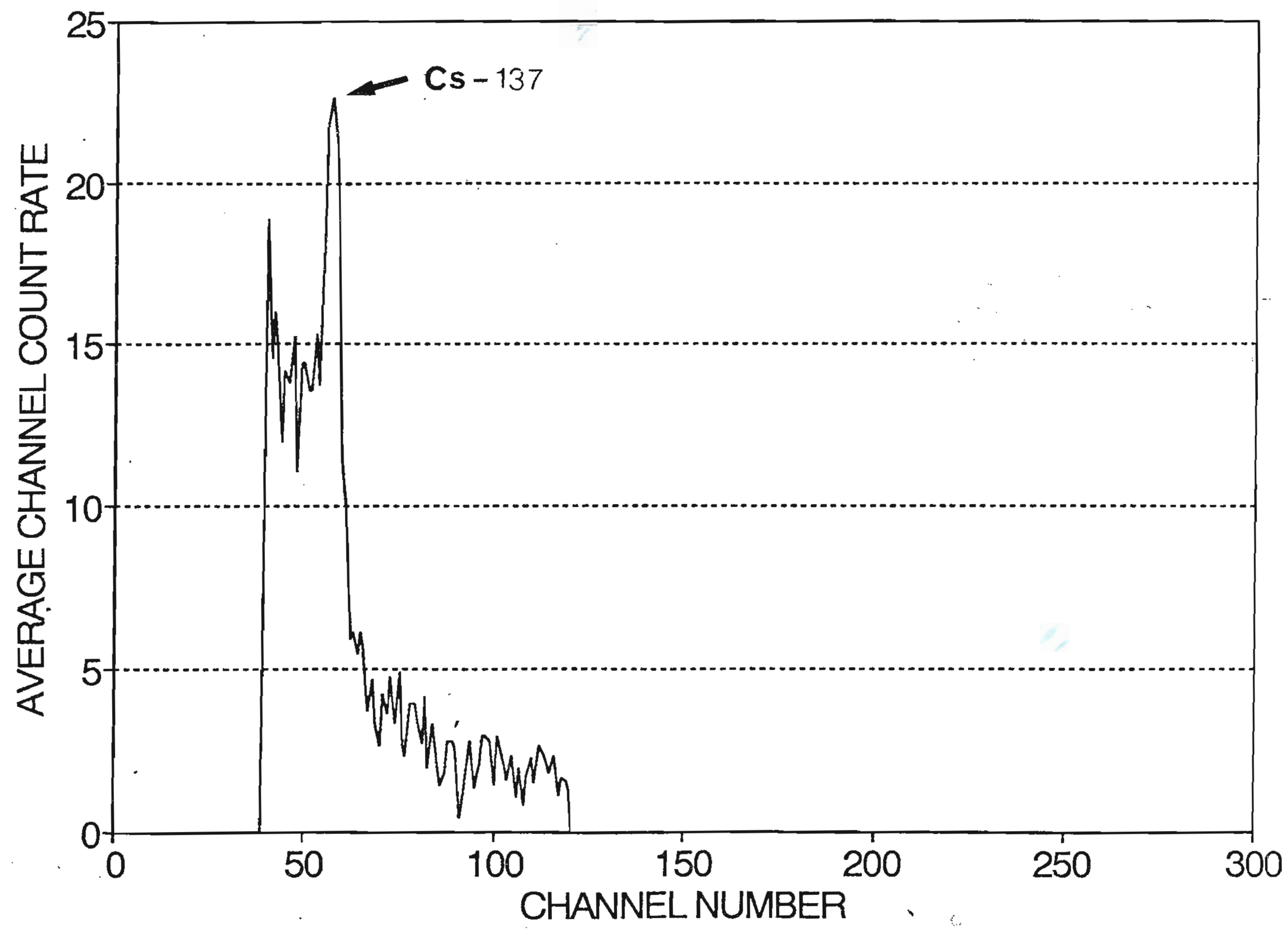

Figure 2. The same spectrum showing the cesium-137 photopeak, after removal of the natural gamma ray components.

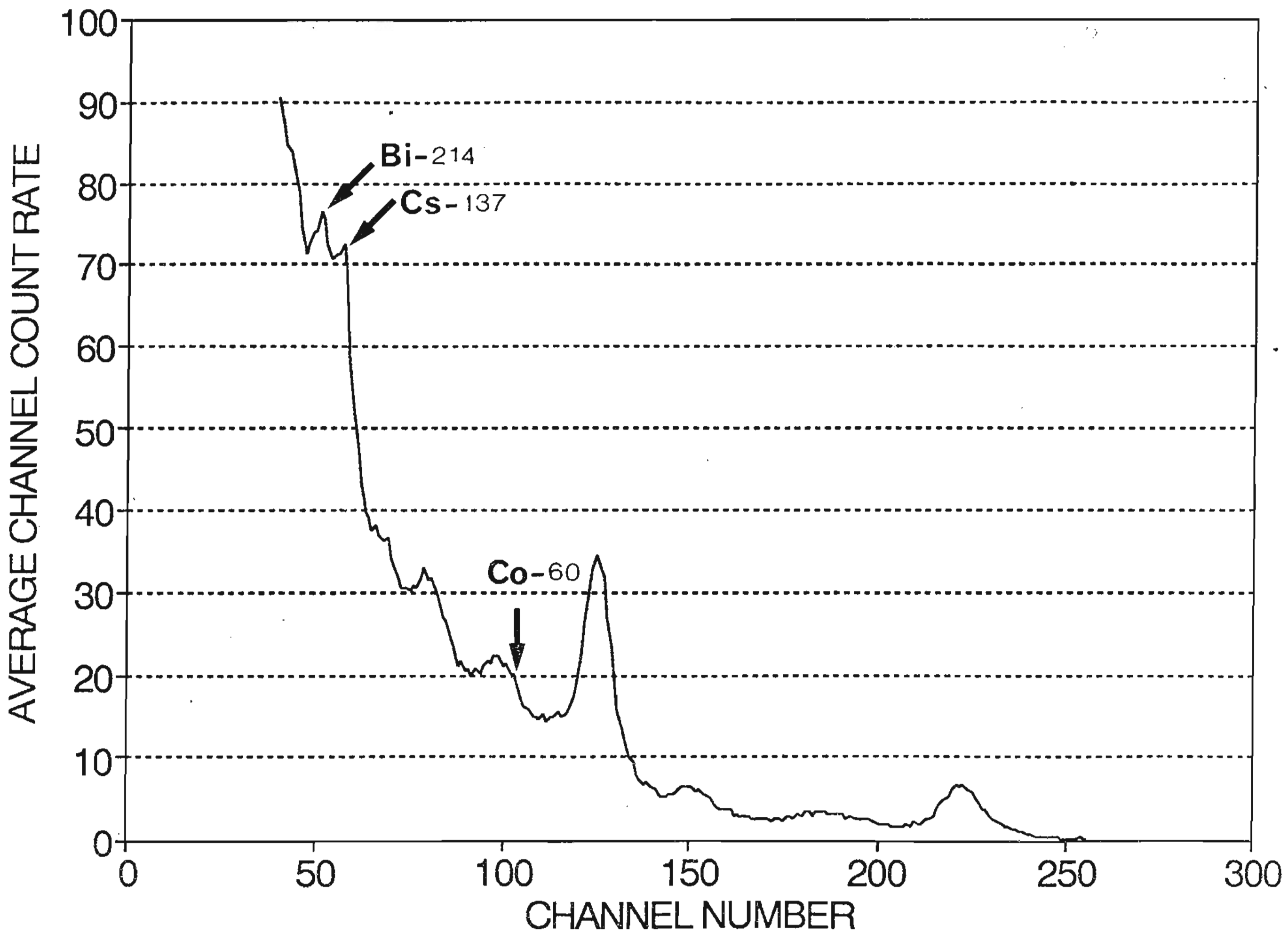

Figure 3. An average spectrum measured over an area contaminated by cobalt-60.

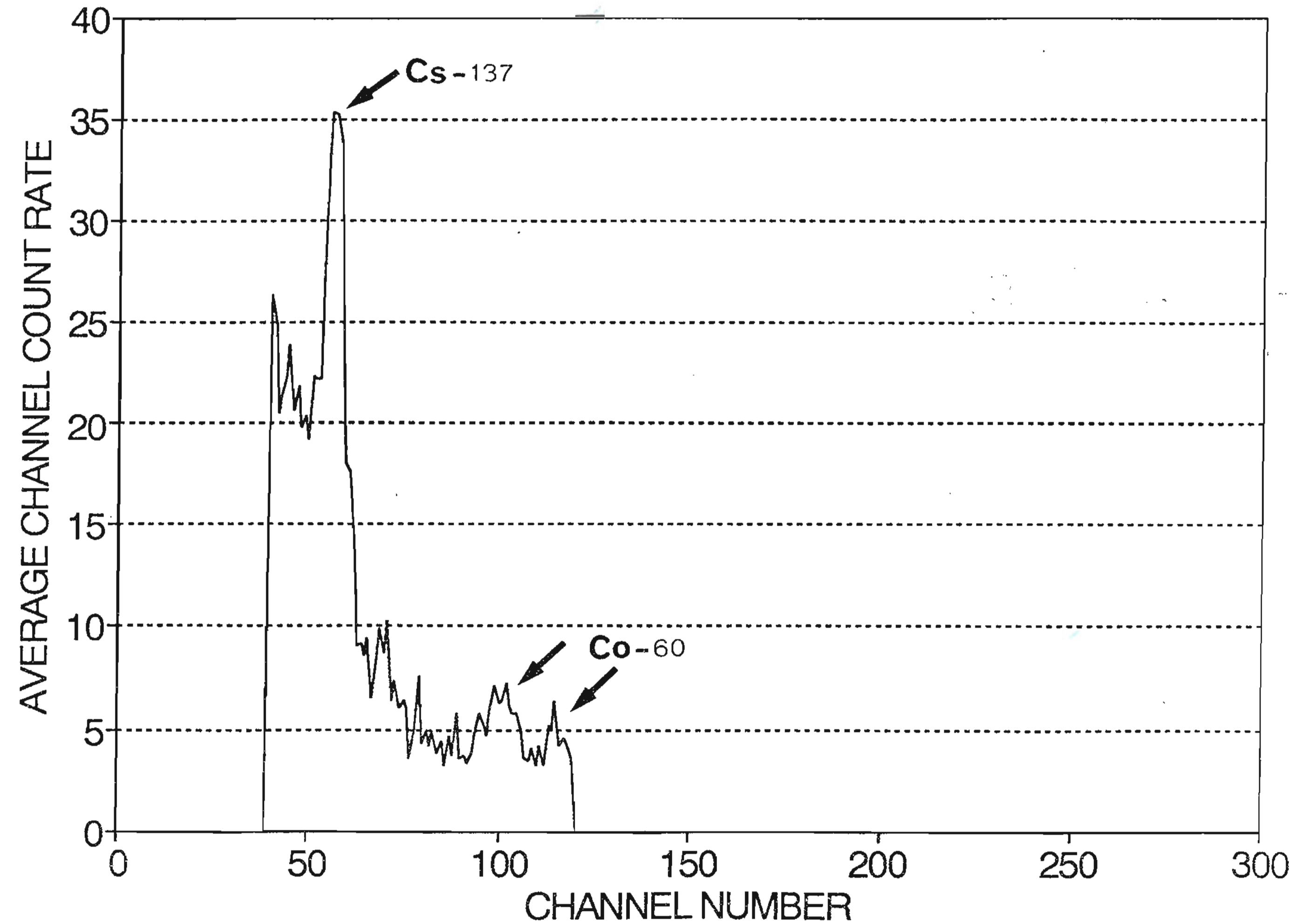

Figure 4. The same spectrum showing the two cobalt-60 photopeaks at 1173 and 1332 keV, after removal of the natural gamma ray components.

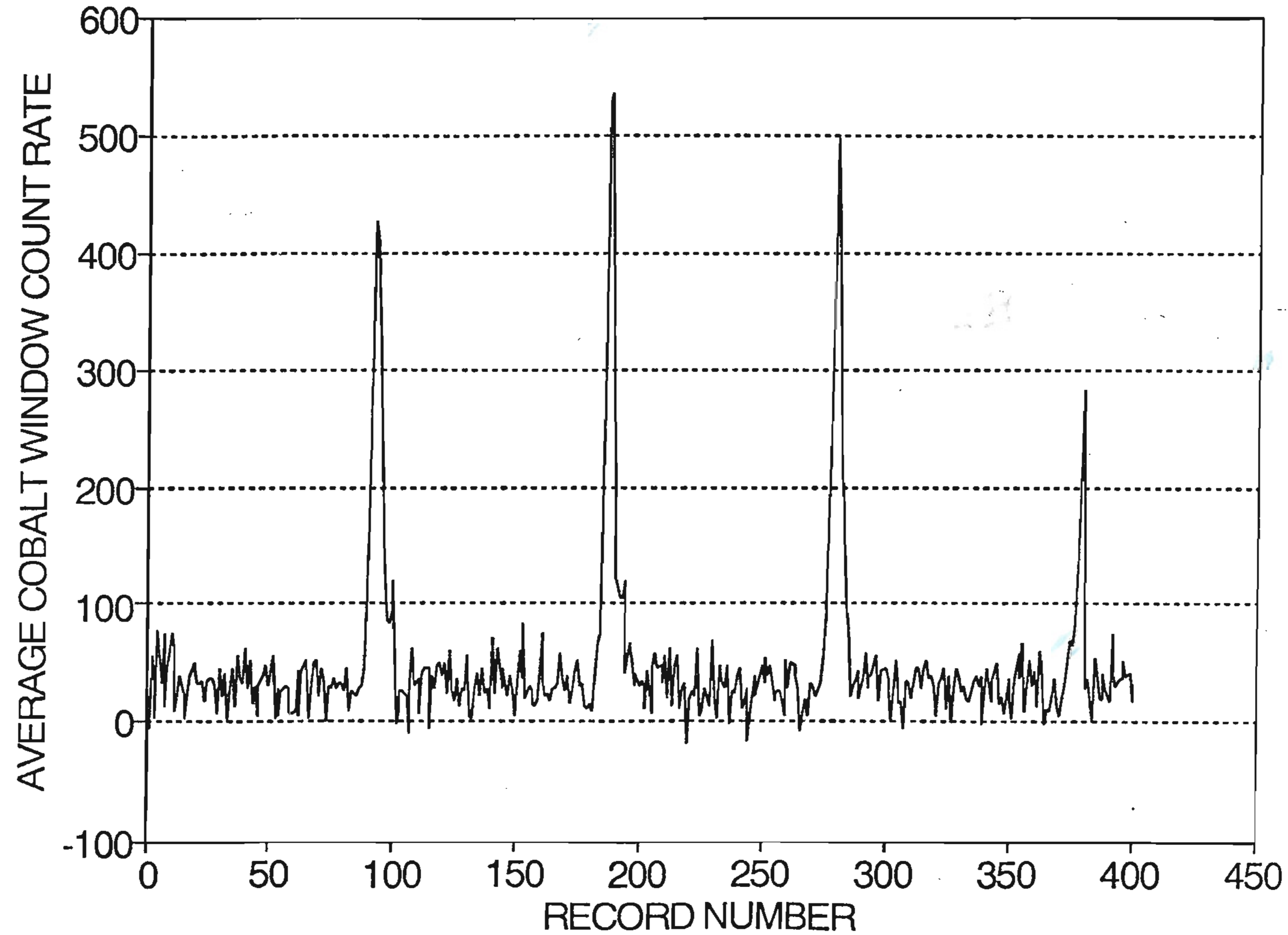

Figure 5. A profile of a single window, centered around the cobalt-60 peak at 1173 keV. The natural gamma ray components have been removed.

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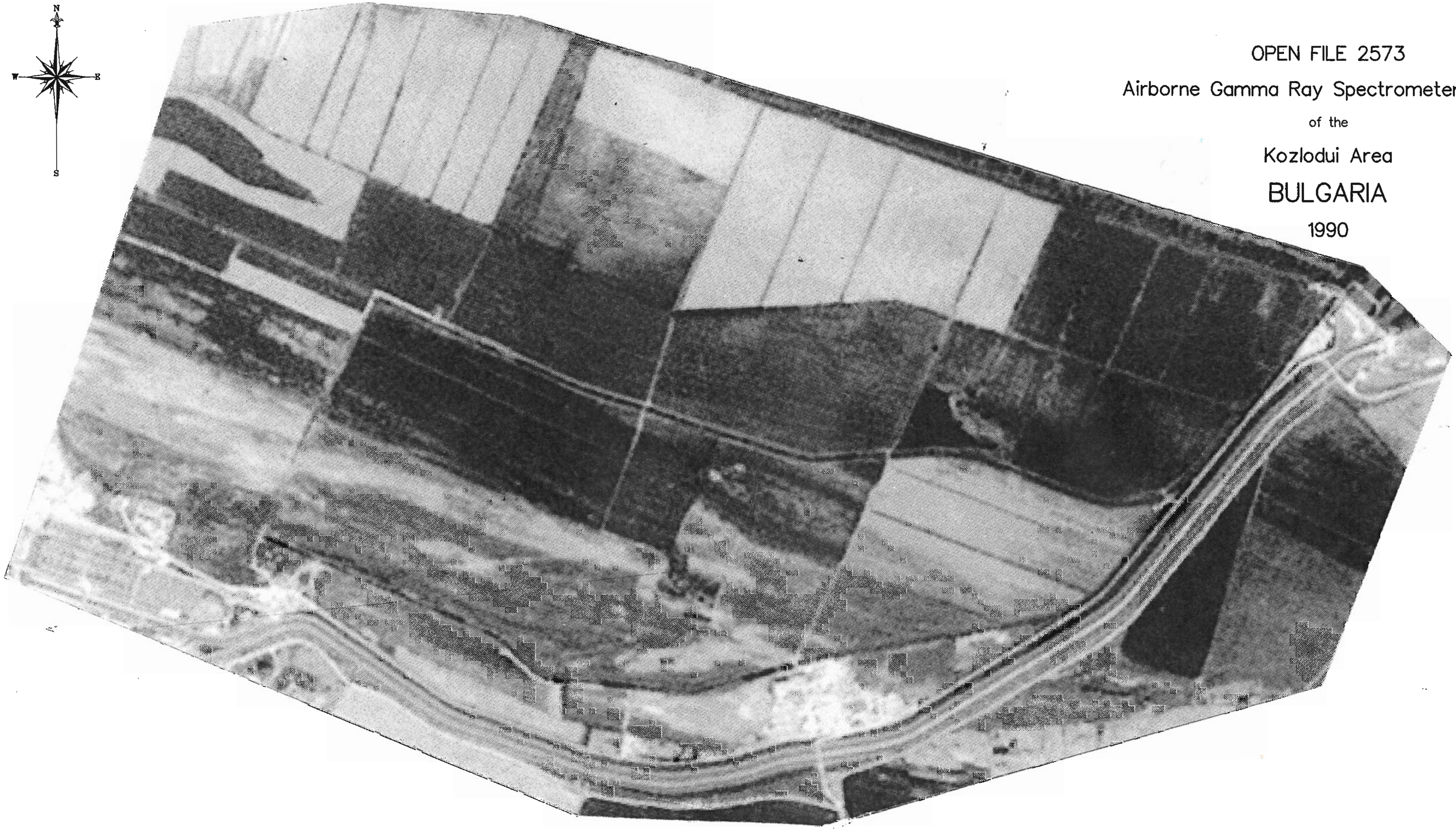
Airborne Gamma Ray Spectrometer Survey

of the

Kozlodui Area

BULGARIA

1990



SPOT Satellite Panchromatic Image

(10 Metre SPOT Pixel Size)

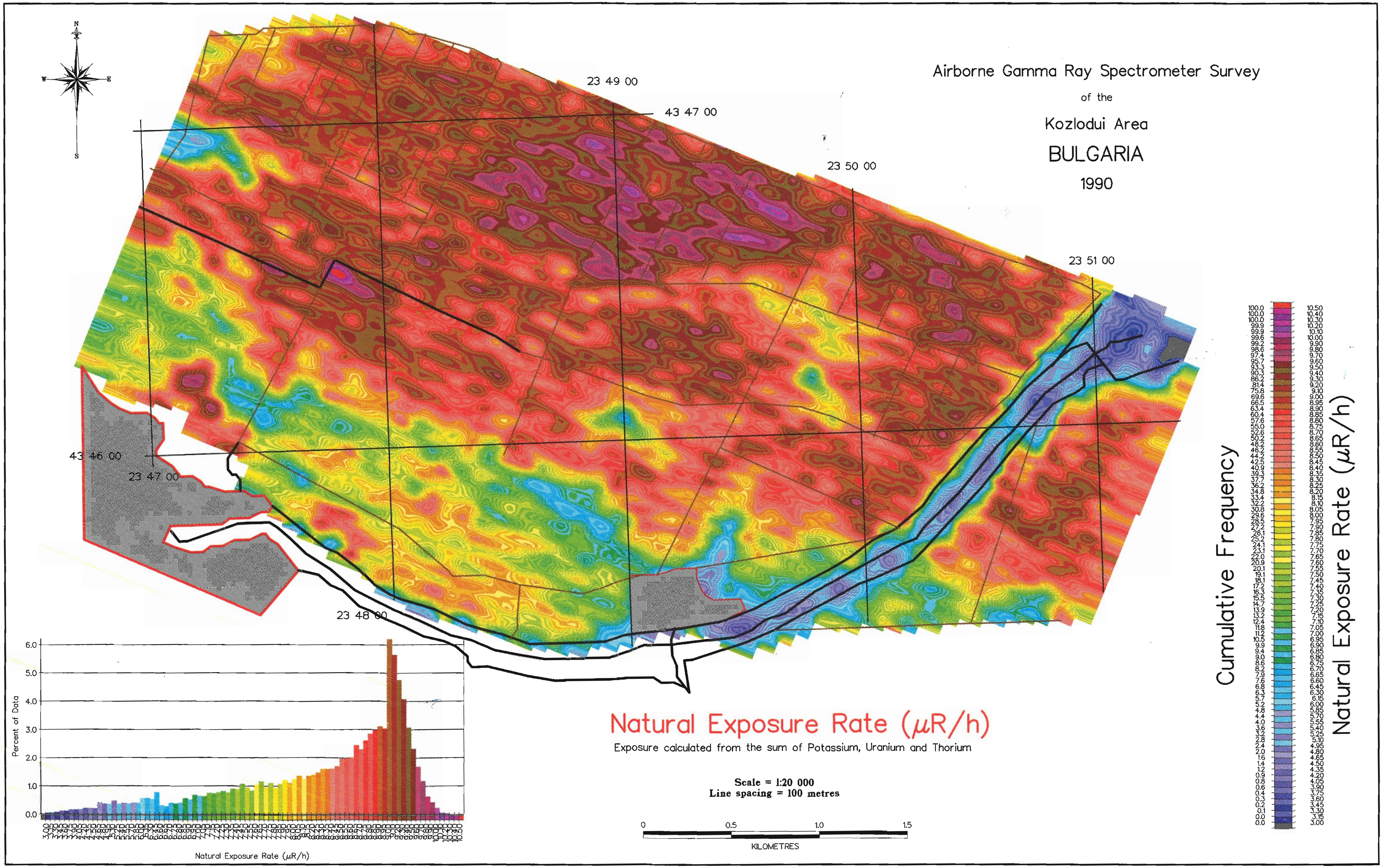
CNES copyright 1992

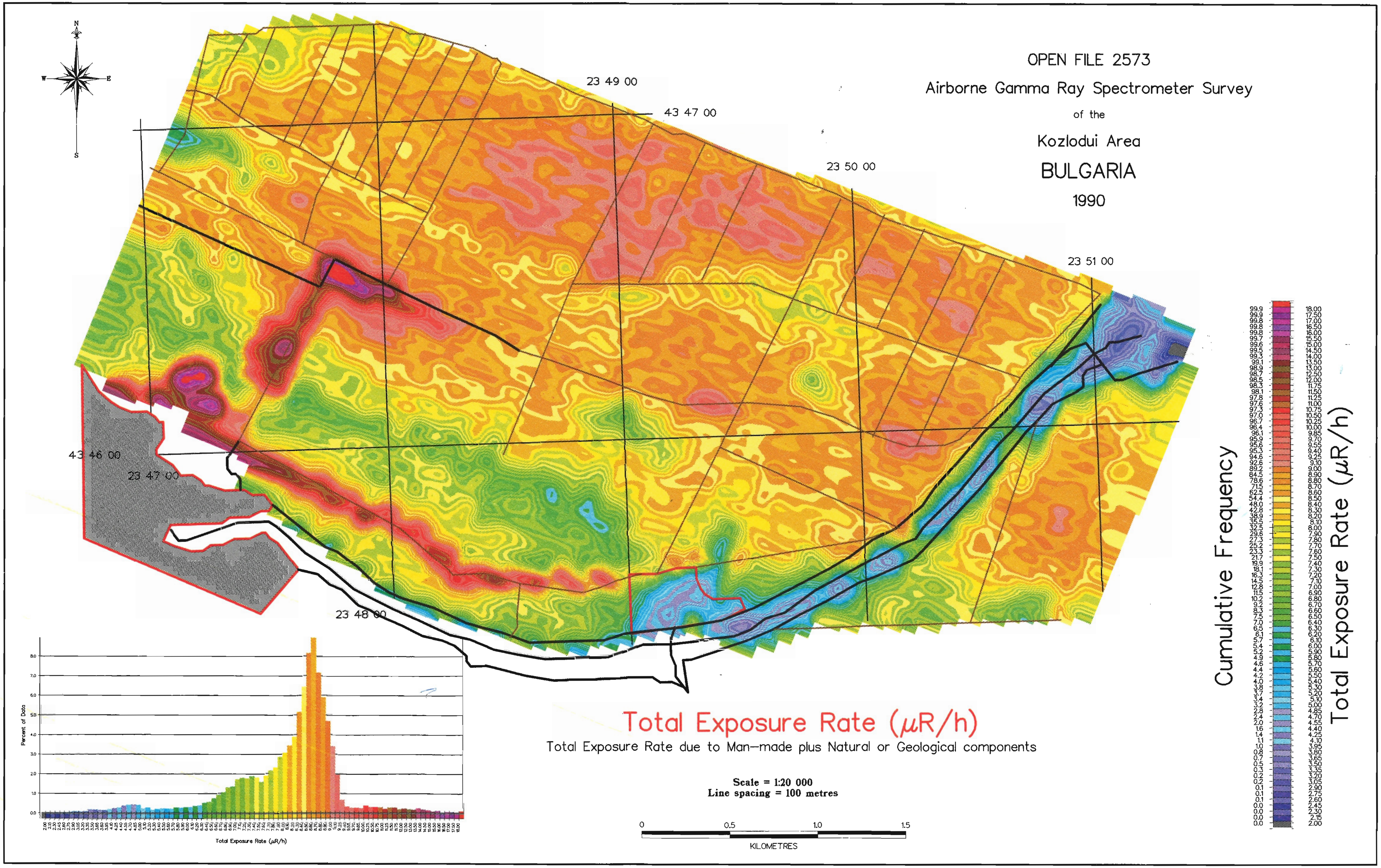
Distributor Radarsat International Inc

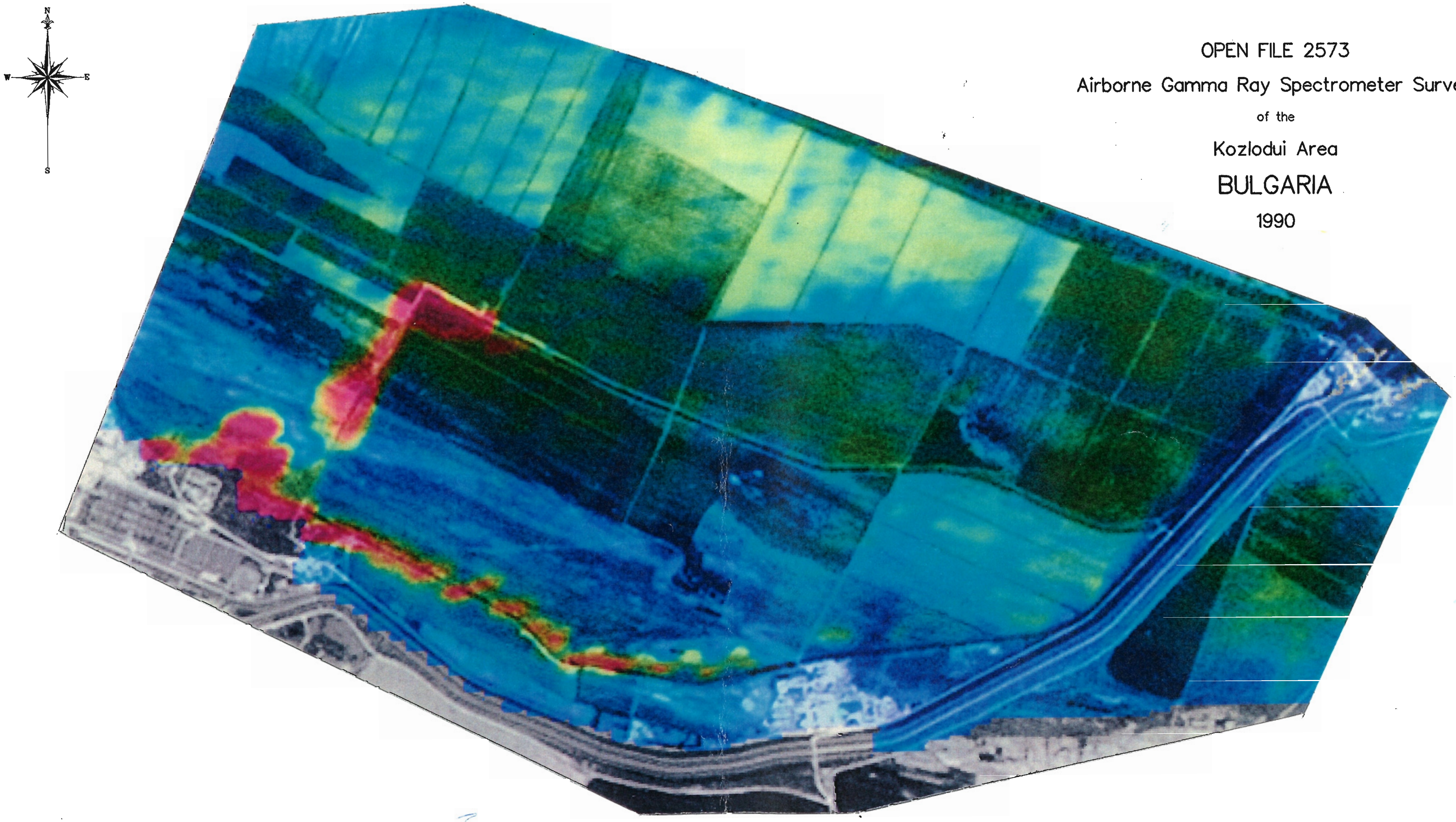
Scale = 1:20 000
Line spacing = 100 metres

0 0.5 1.0 1.5

KILOMETRES


Airborne Gamma Ray Spectrometer Survey
of the
Kozlodui Area
BULGARIA
1990
N
S
W
E
23 49 00
43 47 00
23 50 00
23 51 00
43 46 00
23 47 00
23 48 00
Natural Exposure Rate (μR/h)
Exposure calculated from the sum of Potassium, Uranium and Thorium
Scale = 1:20 000
Line spacing = 100 metres
0
0.5
1.0
1.5
KILOMETRES
Percent of Data
Natural Exposure Rate (μR/h)
Cumulative Frequency
Natural Exposure Rate (μR/h)


OPEN FILE 2573
Airborne Gamma Ray Spectrometer Survey
of the
Kozlodui Area
BULGARIA
1990
23 49 00
43 47 00
23 50 00
23 51 00
43 46 00
23 47 00
23 48 00
N
S
W
E
Cumulative Frequency
Total Exposure Rate (μR/h)
Percent of Data
Total Exposure Rate (μR/h)
Total Exposure Rate (μR/h)
Total Exposure Rate due to Man-made plus Natural or Geological components
Scale = 1:20 000
Line spacing = 100 metres
0
0.5
1.0
1.5
KILOMETRES



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Airborne Gamma Ray Spectrometer Survey

of the

Kozlodui Area

BULGARIA

1990

Total Exposure Rate superimposed on SPOT image

(10 Metre SPOT Pixel Size)

CNES copyright 1992

Distributor Radarsat International Inc

Scale = 1:20 000
Line spacing = 100 metres

0 0.5 1.0 1.5
KILOMETRES

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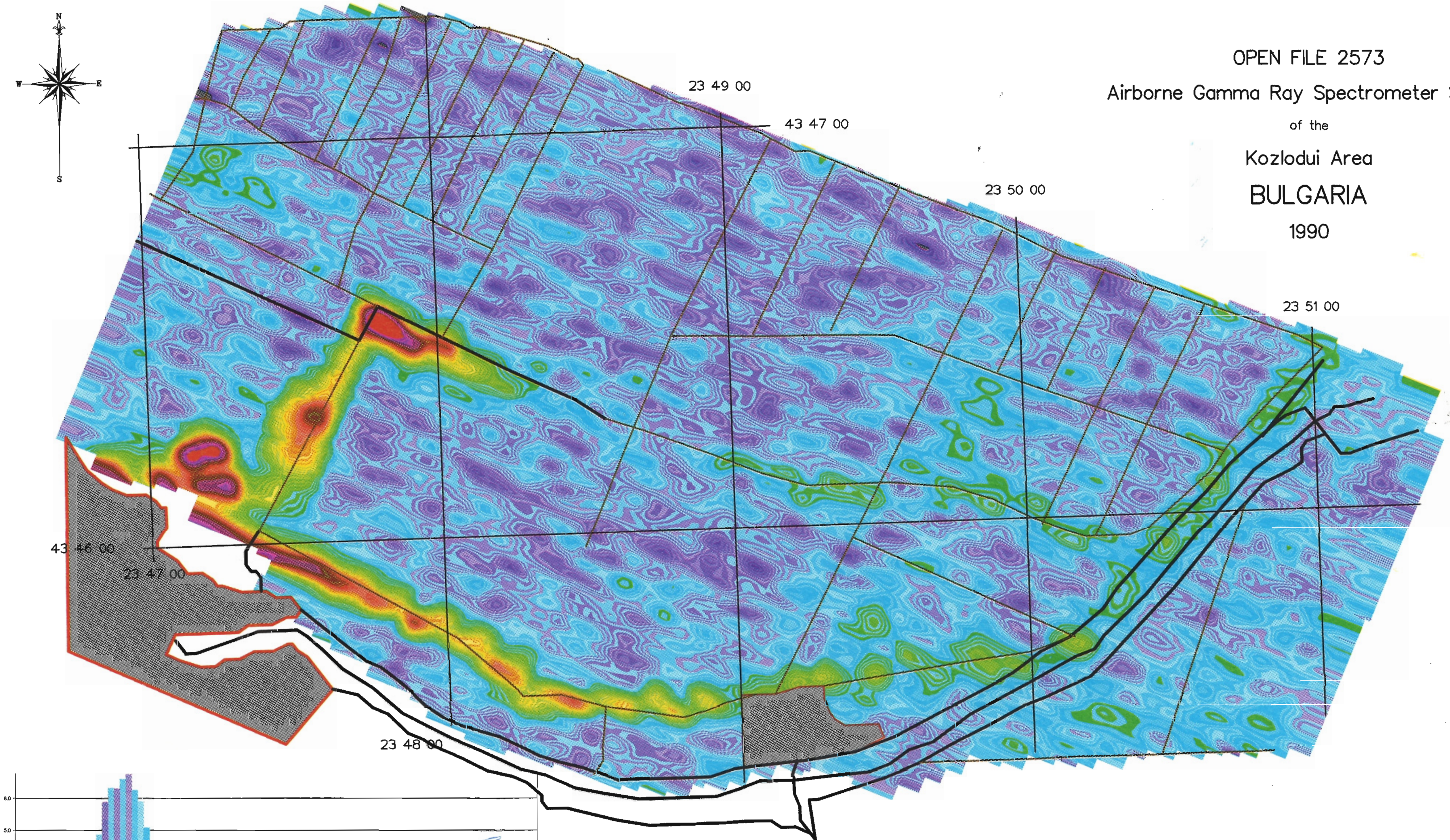
Airborne Gamma Ray Spectrometer Survey

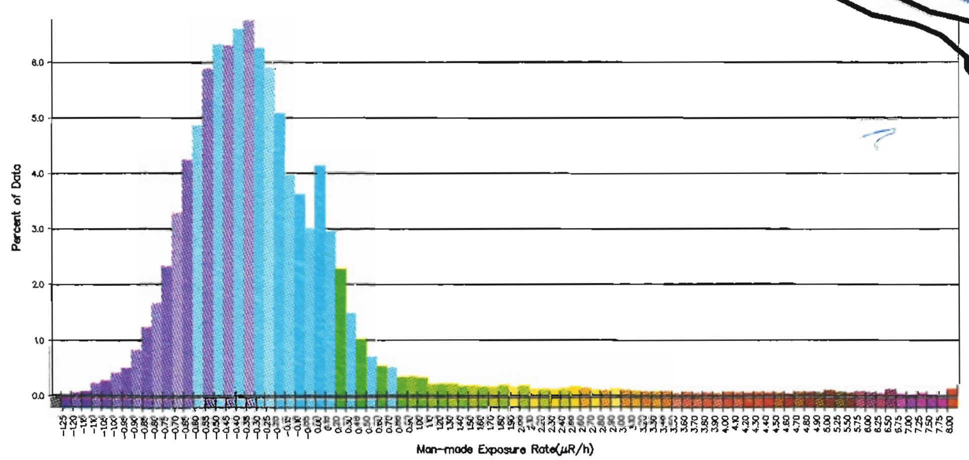
of the

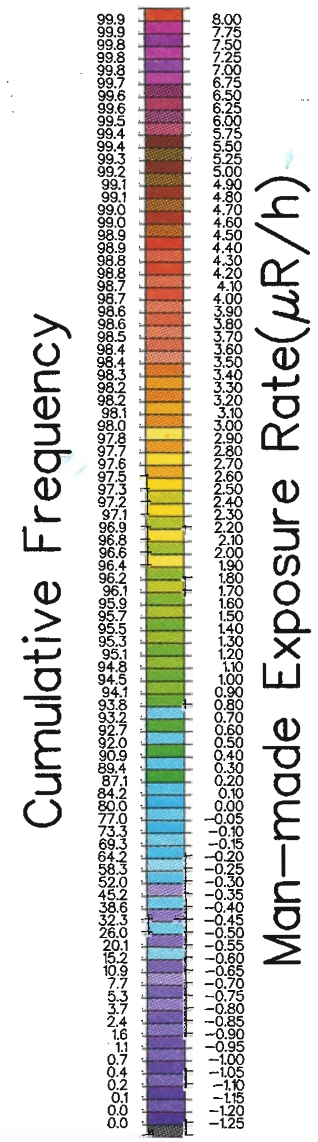
Kozlodui Area

BULGARIA

1990





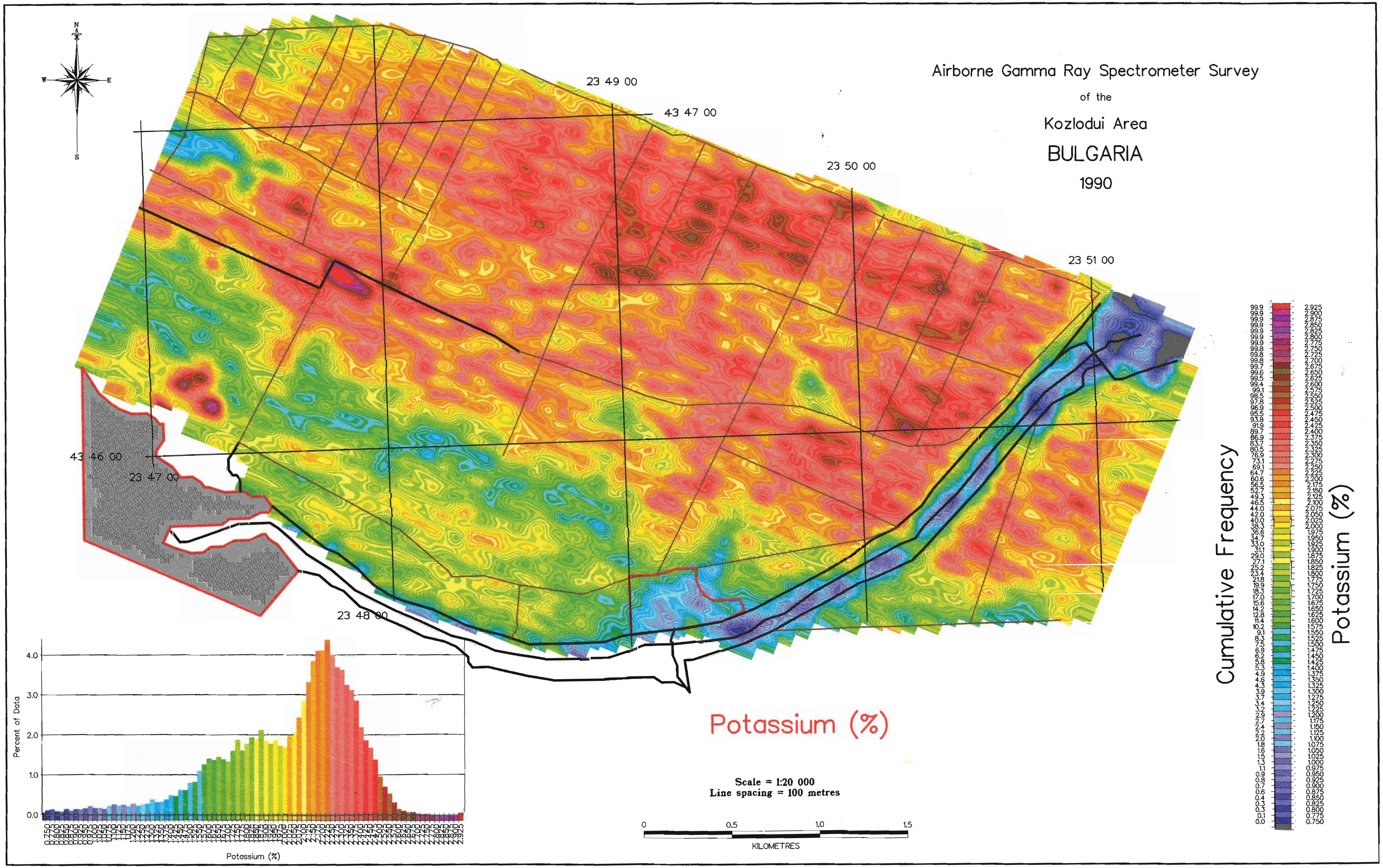


Man-made Exposure Rate(μR/h)

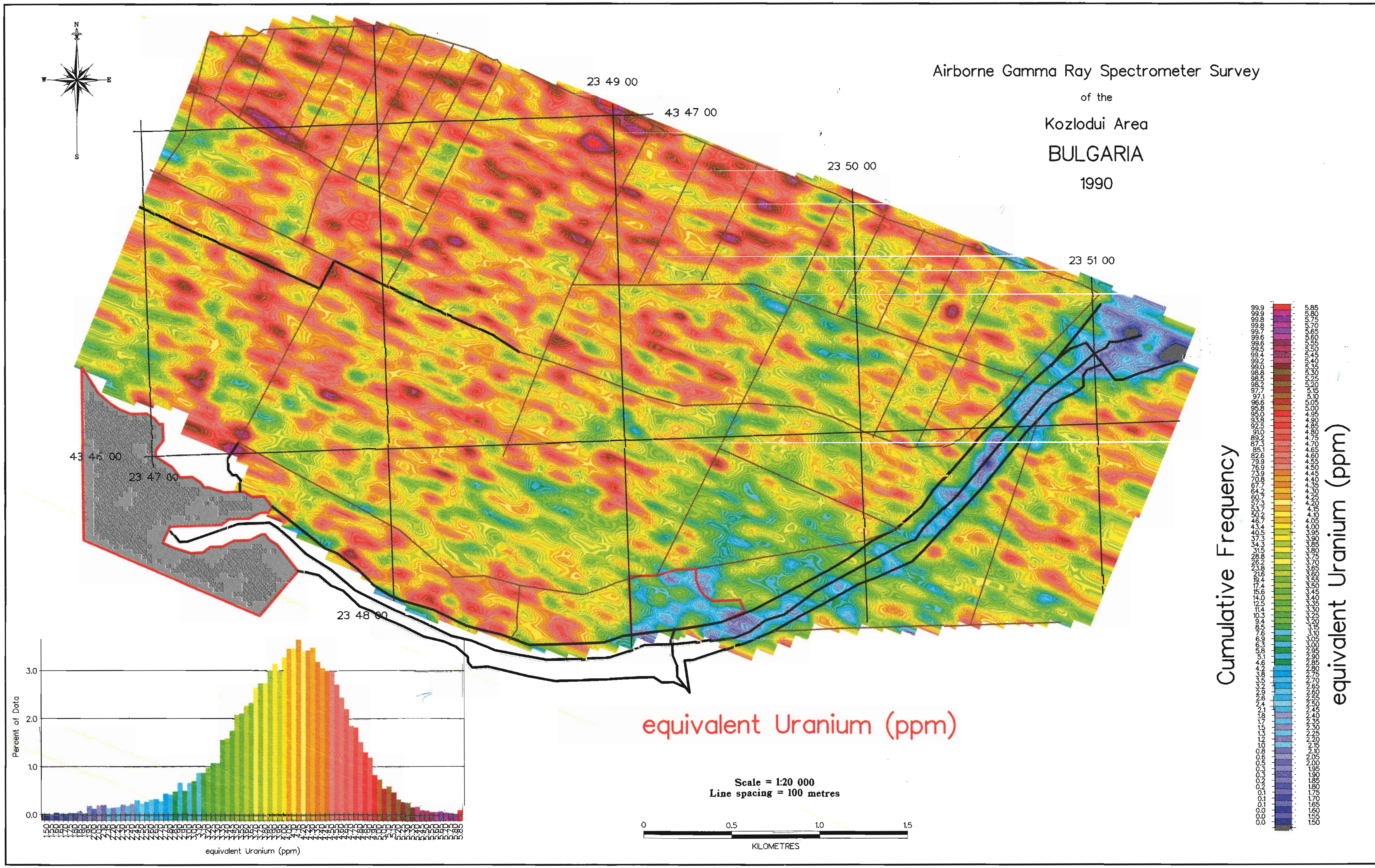
Total Exposure Rate minus Natural or geological component of the Exposure Rate

Scale = 1:20 000
Line spacing = 100 metres

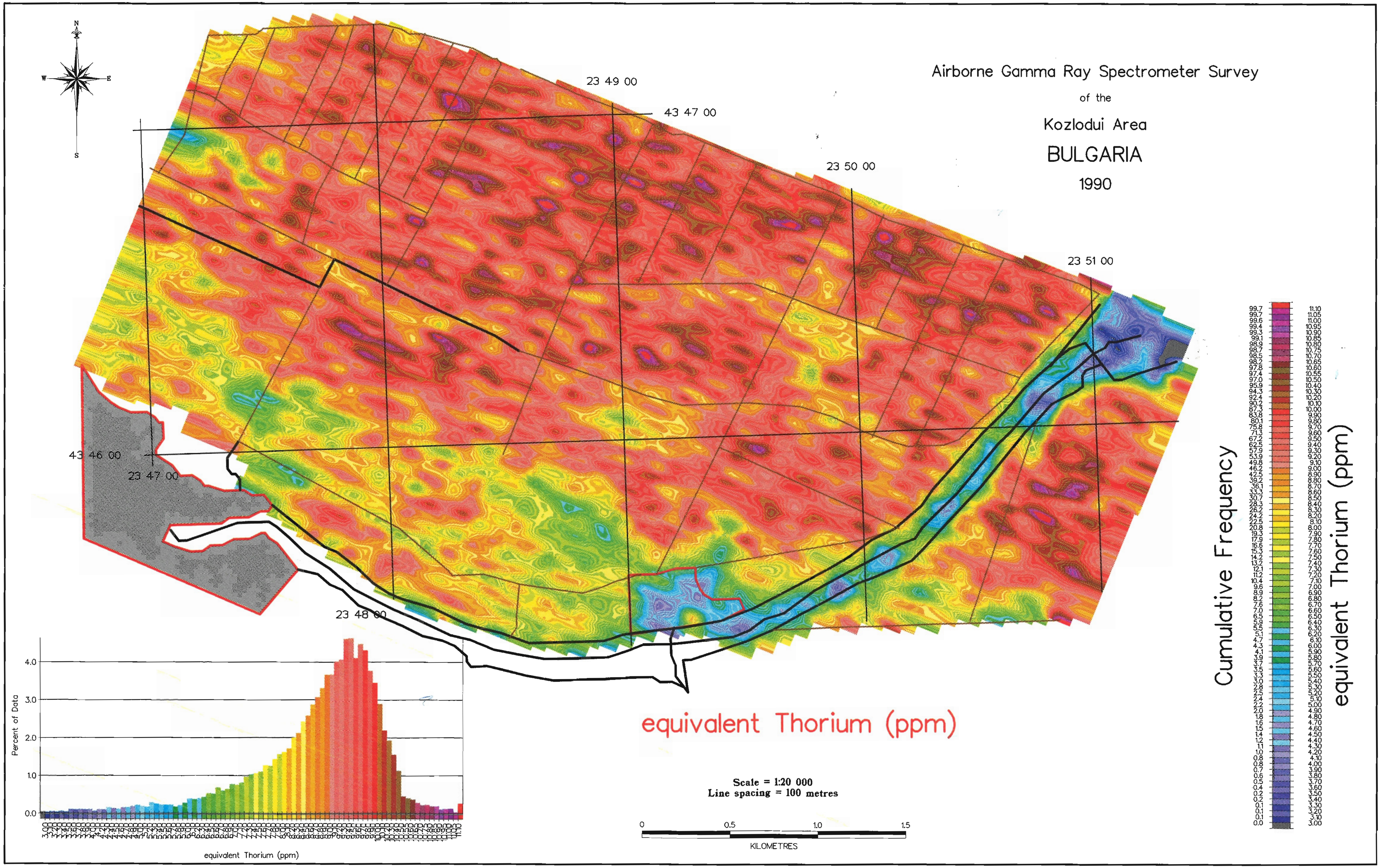
0 0.5 1.0 1.5
KILOMETRES



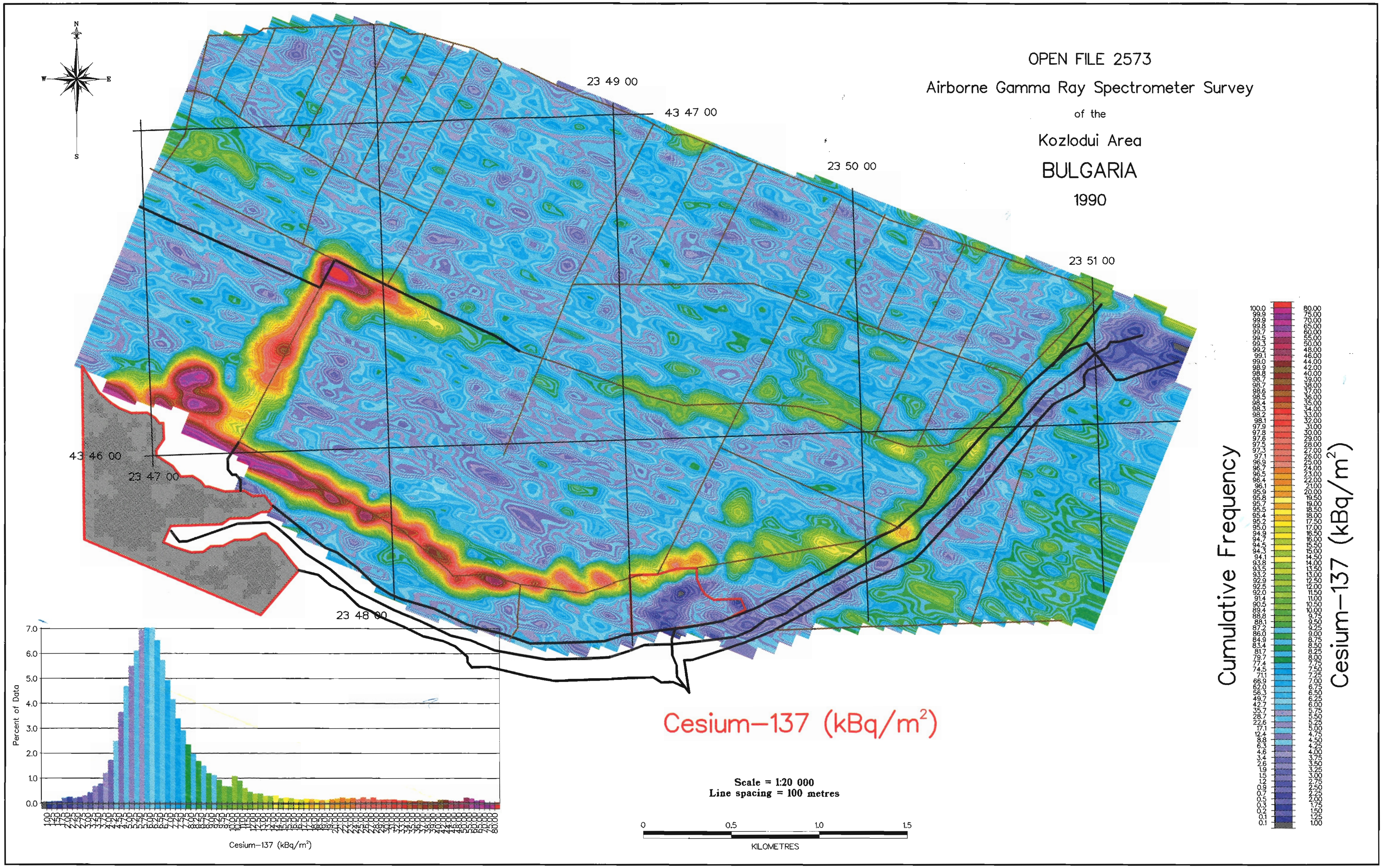
Airborne Gamma Ray Spectrometer Survey
of the
Kozlodui Area
BULGARIA
1990
N
S
W
E
23 49 00
43 47 00
23 50 00
23 51 00
43 46 00
23 47 00
23 48 00
Cumulative Frequency
Potassium (%)
Potassium (%)
Scale = 1:20 000
Line spacing = 100 metres
0
0.5
1.0
1.5
KILOMETRES
Percent of Data
4.0
3.0
2.0
1.0
0.0
Potassium (%)



Airborne Gamma Ray Spectrometer Survey
of the
Kozlodui Area
BULGARIA
1990
N
S
W
E
23 49 00
43 47 00
23 50 00
23 51 00
43 46 00
23 47 00
23 48 00
equivalent Uranium (ppm)
Scale = 1:20 000
Line spacing = 100 metres
0
0.5
1.0
1.5
KILOMETRES
Cumulative Frequency
equivalent Uranium (ppm)
Percent of Data
3.0
2.0
1.0
0.0
equivalent Uranium (ppm)



Airborne Gamma Ray Spectrometer Survey
of the
Kozlodui Area
BULGARIA
1990
N
S
W
E
23 49 00
43 47 00
23 50 00
23 51 00
43 46 00
23 47 00
23 48 00
equivalent Thorium (ppm)
Cumulative Frequency
equivalent Thorium (ppm)
Percent of Data
4.0
3.0
2.0
1.0
0.0
equivalent Thorium (ppm)
Scale = 1:20 000
Line spacing = 100 metres
0
0.5
1.0
1.5
KILOMETRES



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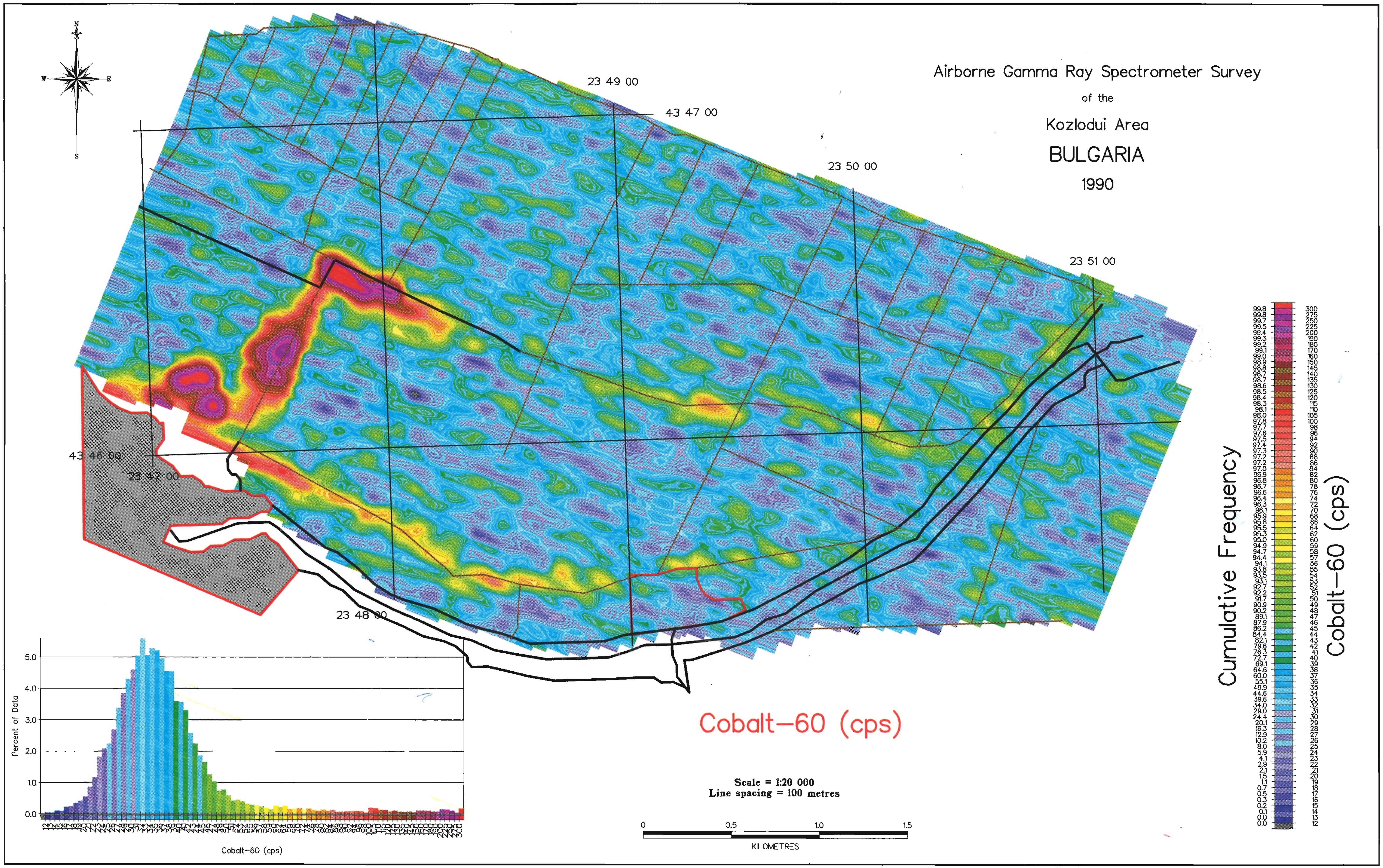
Airborne Gamma Ray Spectrometer Survey
of the
Kozlodui Area
BULGARIA
1990
N
S
W
E
23 49 00
43 47 00
23 50 00
23 51 00
43 46 00
23 47 00
23 48 00
Cumulative Frequency
Cesium–137 (kBq/m²)
Cesium–137 (kBq/m²)
Percent of Data
Cesium–137 (kBq/m²)
Scale = 1:20 000
Line spacing = 100 metres
0
0.5
1.0
1.5
KILOMETRES


Airborne Gamma Ray Spectrometer Survey
of the
Kozlodui Area
BULGARIA
1990
N
S
W
E
23 49 00
43 47 00
23 50 00
23 51 00
43 46 00
23 47 00
23 48 00
Cumulative Frequency
Cobalt-60 (cps)
Percent of Data
Cobalt-60 (cps)
Cobalt-60 (cps)
Scale = 1:20 000
Line spacing = 100 metres
0
0.5
1.0
1.5
KILOMETRES