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Preliminary interpretations of high-resolution airborne radiometric data, Athabasca Basin region

Development of interpretation methodology and value-added products at the Geological Survey of Canada

R. Fortin, B.J.A. Harvey, J.E. Campbell, E.G. Potter, L.E. Sinclair and C.W. Jefferson

Abstract

Airborne gamma-ray spectrometry provides measurements of the surface concentrations of potassium (K), equivalent uranium (eU) and equivalent thorium (eTh). The resulting radiometric maps present intricate spatial variations that are controlled among other things by the complex surface processes and the inherent statistical fluctuations of radioactive decays. To enhance the readability of the radiometric images, radiometric domains, spatially-restricted areas presenting a distinctive signature, can be traced to provide local baselines of the surface concentrations of the natural radioelements. This approach was applied to airborne gamma-ray survey data from the "Eastern Athabasca Basin" survey, in Saskatchewan. Ground spectrometry measurements were conducted in 2013 within the radiometric domains that were identified and compare well with domain averages calculated from the airborne survey data.

Introduction

From 2004 to 2010, through the Secure Canadian Energy (SCE) and Geomapping for Energy and Minerals (GEM) programs of the Geological Survey of Canada (GSC), in partnership with the Saskatchewan Geological Survey (SGS), airborne gamma-ray spectrometric and magnetic surveys were conducted in northern Saskatchewan and completed coverage of the entire Saskatchewan portion of the Athabasca Basin (Buckle et al., 2011) (Figure 2). These surveys followed up-to-date specifications recommended by the International Atomic Energy Agency (IAEA, 1991). Usage of self-stabilizing digital spectrometers, state-of-the-art data processing, and continuous coverage with 125m survey altitude and 400m line-spacing contributed to the high quality of this unique data set. This data set offers many possibilities for understanding regional bedrock and Quaternary geological context and for resource exploration, especially in terms of distinguishing geochemical anomalies of interest from background variations.

Interpretation of gamma-ray data by defining radiometric domains was exemplified by the integration of surficial geological observations, ground gamma-ray spectrometry and geochemical analysis with airborne radiometric data for the NEA/IAEA test area in the northeast corner of the Athabasca Basin (Campbell et al., 2007). Development of an automated imaging technique, a quantitative data reduction methodology and high-level interpretation products is ongoing at the Geological Survey of Canada. This Open File poster summarizes these new development and shows preliminary results from the Eastern Athabasca Basin survey of 2009, in NTS sheet 74H (Buckle et al, 2010).

Figure 1. A geophysical survey aircraft (GSC's Skyvan airborne radiometric survey platform, 1968-1994)

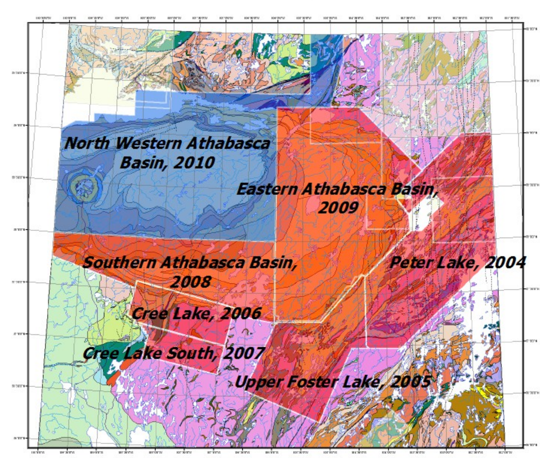

Figure 2. Recent airborne geophysical coverage over the Athabasca Basin.

Radiometric Domains

Airborne gamma-ray spectrometry provides measurements of the surface (0-50 cm depth) concentrations of potassium (K), uranium (U) and thorium (Th). Concentrations in uranium and thorium are usually reported as equivalent uranium (eU) and equivalent thorium (eTh) to emphasize that these measurements are based on the assumptions that these radioactive series are in equilibrium. The concentrations values are usually presented as colour images or contours of the spatial distribution of either single radioelements, ratios, or ternary images (e.g. Figure 4, Broome et al., 1987). The geological and physiographic context, the past and ongoing geochemical processes at the surface, the inherent statistical noise of radioactive decay and other factors result in a complex spatial distribution.

The approach taken here is to reduce the complexity of this spatial distribution into a set of spatially-restricted domains. Such a *radiometric domain* is heuristically defined as an area of finite extent that presents a distinctive radiometric signature. It does not imply that concentrations of the three natural radioelements are uniform within a domain, but rather that their spatial distribution has internally consistent qualities that are distinct from those of surrounding areas.

The main goal pursued by tracing radiometric domains is to enhance the readability of gamma-ray spectrometry maps for end users. A radiometric domain provides a local baseline against which readings can be identified as anomalous. It can also contribute in defining the minimum detectable strength an expected target should have. Interpretation of a domain signature in terms of its physical origin will involve consideration of surficial geology and physiographic context. This knowledge can then feed back and assists in classification and understanding of surficial and bedrock geological processes that affected geochemical dispersion from source materials, including ore bodies.

Data Processing

Data processing consists essentially of the segmentation of the radiometric images. This process must be independent of the colour scale used to present the spatial distribution and must be based on quantitative criteria, as this will facilitate the eventual implementation in an automated process. The primary measurements contained in the flight-line data, as opposed to the spatially interpolated gridded data of the maps, are the preferred input to data processing because they contain the original statistical characteristics of the measurement process. The image segmentation will be based on locating inflection points of the measured profile, along a flight-line. These points, when plotted on a map, will defined the location of domains boundary.

The data reduction scheme consists of the following steps:

Application of a water mask
As water attenuates gamma rays, measurements obtained over water bodies, wetland and areas of high soil moisture must be removed because the relative gamma-ray responses of K, eU and eTh are compromised and can misrepresent the surficial geological materials. Typical K, eU and eTh count rates for water-infested areas are determined from the measurements obtained over water bodies outlined by the CanVec hydrography. These count rates are then applied as threshold values over the entire grid. Grid cells values below these thresholds are nulled and used to create the water mask. Due to the large footprint of the gamma-ray detector, the water mask is dilated by a factor proportional to the flying height to also remove the partial influence of water on airborne measurements.

Filtering of flight-line data
Filtering of data with a low-pass filter or a shape-preserving Savitzky-Golay filter (Savitzky and Golay, 1964) provides some control over the coarseness of the radiometric domains to be traced. In the example presented here (Figure 4), a relatively strong low-pass filter was used to highlight broad regional domains.

Plotting of line data inflection
Inflection points are located by computing the null of the second derivative of the flight-line data and are plotted over the radiometric images. The points are also color-scaled by the value of the first derivative to represent the sharpness of the transition between domains.

Domain Tracing
To trace the domains, the points are connected together and closed as polygons, by inspection of the radiometric images. Loose ends and outstanding points are rejected. This step is conducted manually at present, but partial to full automation of this process is being investigated.

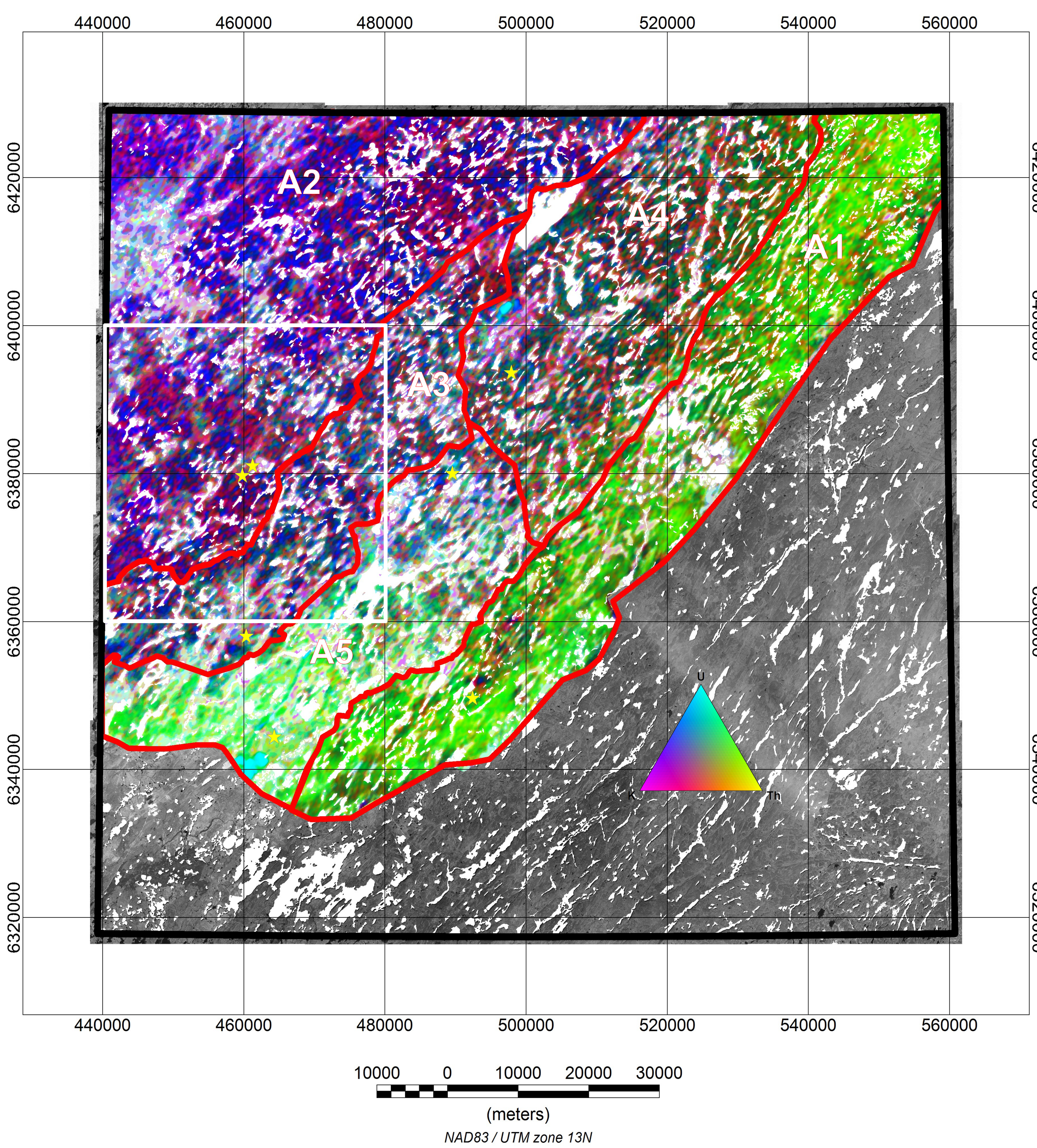

Figure 4. Radiometric ternary image of the region of interest. The radiometric domains defined as a result of this study are labelled A1, A2...A5 and are shown with a red outline. The white outline present the area of domain A2 discussed in the section Validation (see Figure 6.). Yellow stars indicate locations where ground handheld gamma-ray spectrometry measurements were performed.

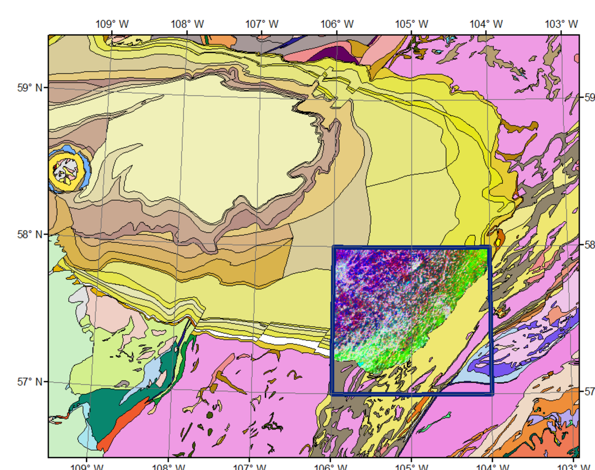

Figure 3. Location map of the region of interest.

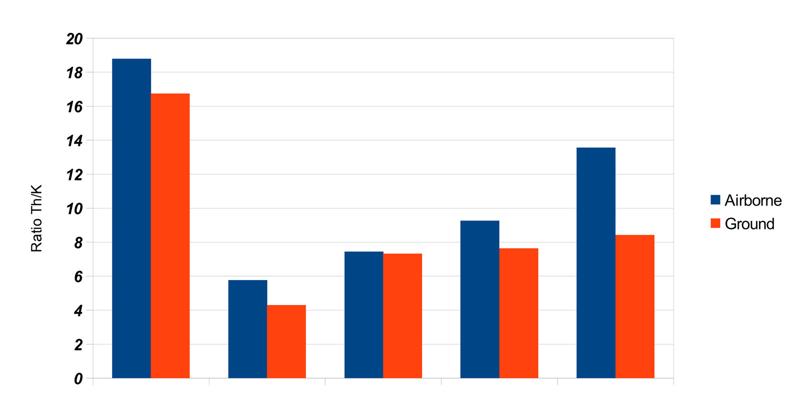

Figure 5. Domain-wide averages of the airborne measurements in comparison with the ground measurements, per radiometric domains (see section Validation).

Validation

The domains were ground-truthed in July and October 2013. In this preliminary analysis, averages of measurements obtained with a hand-held spectrometer are compared with averages calculated from the regional airborne survey of 2009 over the domains (Figure 5). Concentrations measured on the ground are commonly higher than airborne measurements because airborne values are averaged over the relatively large footprint of the airborne detectors, and therefore include the effect of non-optimal locations for gamma-ray spectrometry, whereas ground measurements generally focus on exposed surficial earth materials rather than wet vegetated spots. Ratios of concentrations may thus be more useful parameters for comparison. In the present case, the eTh over K ratio (RTK) values generally compare well between the ground and airborne measurements. High RTK values were obtained on the eastern margin of the basin and appear to represent more locally derived surface material. To the west of sheet 74H, more distally transported drift material is present as shown by the higher concentration of K, typical of basement granitoid rocks that were incorporated in the till.

Whereas domain A2 appears as a distinct area, inspection clearly demonstrates internal variations between higher K and lower K areas (Figure 6). Statistics obtained from the subdivision of domain A2 quantitatively confirm this bimodal distribution. Mapping these concentration differences, which reflect compositional variations in the surficial materials, will assist with the interpretation of the surficial geology, and the paleoglaciological reconstruction for this region.

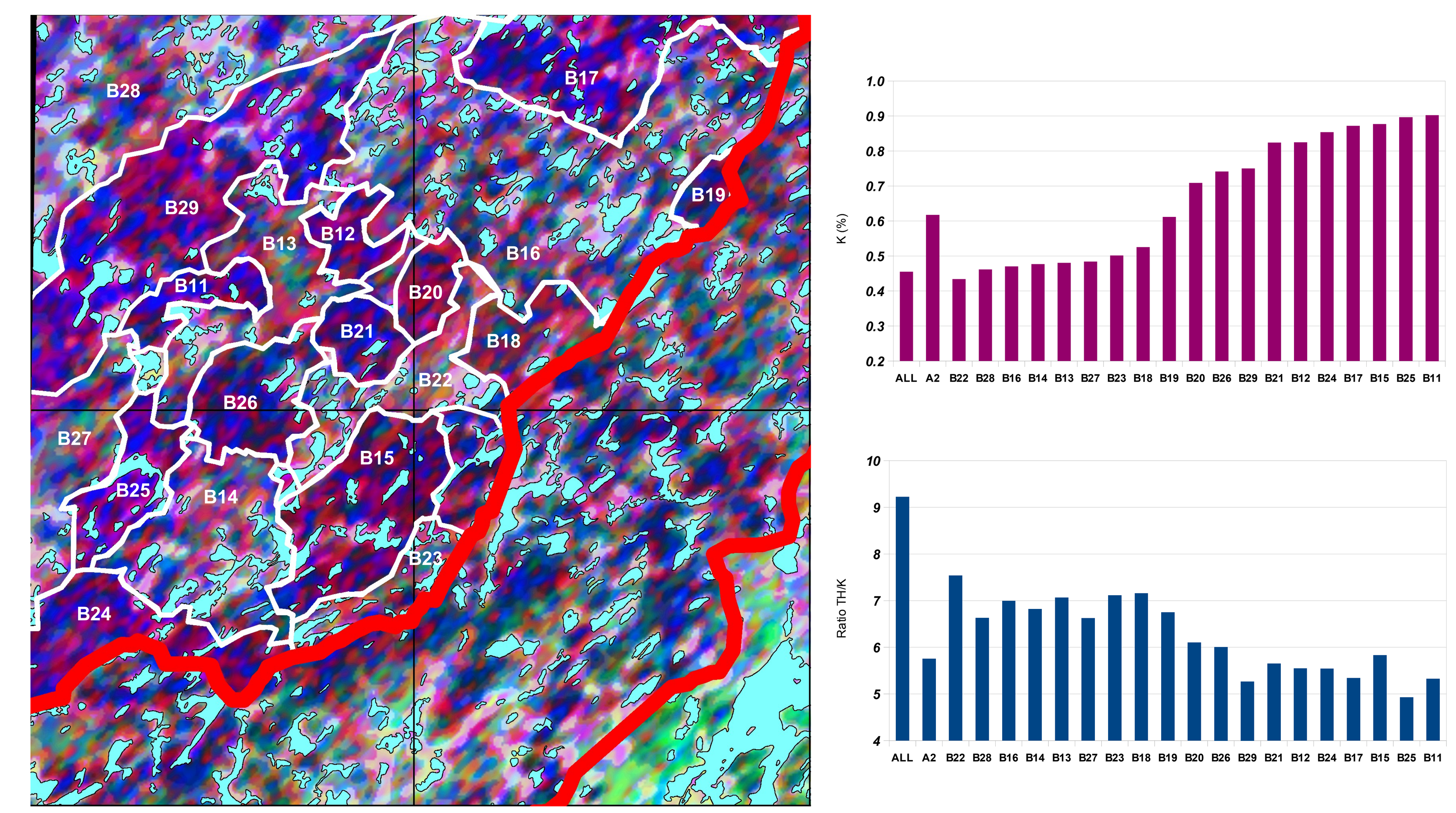

Figure 6. Sub-domains within the A2 domain are traced and labelled B11, B12....B29. The charts present averages for K% and RTK, within each sub-domains. The 'A2' bar presents the average for the A2 domain, and the 'All" bar is the average for the whole region of interest (domains A1 to A5).

Conclusion

Quantitatively assisted heuristic tracing of radiometric domains with internally consistent K, eU and eTh values and ratios is shown to be a feasible first step in the analysis of radiometric highs to distinguish deposit-related anomalies from normal variations related to regional surficial processes. Further work is required to develop a partially to fully automated implementation of the radiometric domain tracing process described here. Integration of surficial geological knowledge will always be indispensable to validate and prioritize potentially economic anomalies. Ground truthing and field follow-up activities are also essential to calibrate remotely defined domains and variations within them, thereby validating and extending the data reduction approach. This includes ground spectrometry measurements and collection of surficial sediment samples for geochemical analysis. Analysis and interpretation are ongoing and final results will be presented later.

Airborne geophysical data from the Athabasca Basin surveys can be obtained free of charge at NRCan's Geoscience Data Repository:
http://gdr.agg.nrcan.gc.ca/gdrdap/dap/search-eng.php

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