[EA]Quantifying Reservoir Architecture of the Upper Cretaceous Panther Tongue Sandstone, Star Point Formation, Spring Canyon, UT*

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Abstract

A comprehensive understanding of reservoir architecture, facies distribution, and lateral variability of geobodies is essential to creating accurate reservoir models. Well and seismic data cannot completely characterize these vital factors to reservoir modeling. This study uses a well-exposed delta outcrop of the Panther Tongue in Central Utah as an analog for deltaic reservoirs. Eight kilometers of outcrop in Spring Canyon is modeled utilizing high-resolution unmanned aircraft vehicle (UAV) imagery and virtual outcrop geology software. Four facies exist within these models: prodelta, distal delta front, proximal delta front, and distributary channel. These facies are mapped laterally across the outcrops from proximal to distal regions and off-axis of progradation. Reservoir classification reveals the proximal delta front has the best reservoir quality which degrades in the distal direction. Smaller-scale sand bodies within the interpreted facies are mapped to study reservoir architecture. Measurements of sand beds, which include bed thicknesses, run-out lengths, and dip angle, are compiled into a large dataset. This data set is used to create reservoir models and estimate net sand to gross outcrop exposure ratios (N/G) expressed as sand percentages. Preliminary results reveal that, on average, sand bodies are extensive over 400 m of outcrop. Further, N/G is highest (best reservoir quality) in the proximal delta front and lowest in the prodelta facies. Sand proportions decrease from more proximal areas (nearest the sediment source) to more distal and to outcrops off-axis of progradation. Facies relationships and reservoir architecture impact reservoir quality and fluid flow; a better understanding of both leads to optimized recovery and more informed drilling.

Introduction

The Panther Tongue is a Campanian-aged delta deposit within the Star Point Formation of the Mesaverde Group. The delta prograded southward (Figure 1) and accounts for the first sands deposited into the Western Interior Seaway (Morris et al., 1995). The goal of this research is to characterize variation in deltaic reservoirs using the Panther Tongue outcrop as an analog. In this study, high resolution virtual outcrop models are built and used for measurements.

Methodology

High resolution images of outcrops were collected via UAV photogrammetry to create 3-D virtual outcrop models. Virtual outcrop models maintain spatial relationships and allow for accurate measurements and pseudo measured sections in regions of sheer cliff face. Virtual outcrop models have high enough resolution to trace beds, measure dip angles, and determine sedimentary structures and bed terminations (Enge et al., 2010). Along each outcrop, pseudo wells are placed every 500 ft (~152 m). Beds greater than 0.185 m are measured for bed thickness, lithology, bed dip, and grain size at and 5 meters to the left and right of each the well. These beds are classified into their sub-environment. Additionally, beds are traced along the outcrop to determine their runout lengths and bed terminations (Figure 2). Runout length estimates are minimum runout lengths as many bed terminations are not seen due to outcrop extent. Sand proportion estimates were made at each well.

Results

Analysis of runout lengths and sand proportions show that the average sand bed runout length in the Panther Tongue is 400 m with a median value of 259 m. The distribution of sand bed runout lengths measured from all seven outcrops is reported (Figure 3). However, several outcrops are not extensive enough to see many bed terminations, thus influencing the runout lengths. Because of this, the Access outcrop is also analyzed and reported (Figure 4) because it is the most extensive outcrop. Access outcrop average and median sand bed runout lengths are 430 m and 206 m respectively. A comparison of these values and histograms shows there is strong correlation between the single analyzed outcrop (Access) and all the outcrops. Additionally, histograms show that there is a skew towards less extensive beds (~0-250 m).

Results

Average sand proportions of the mapped and analyzed outcrops are reported in Figure 5. Because local progradation of the Panther Tongue is southward, the northern-most outcrops are considered proximal, and the outcrops to the south are distal (Figure 5). The Access outcrop is a distal expression of the Panther Tongue on the axis of progradation and becomes off-axis to the east. The most proximal outcrop is 86% sand, and sand percentage decreases to 52% at the most distal outcrop and to 37% at the most distal/off-axis outcrop. Generally, reservoir quality decreases in the distal direction (Figure 5). On-axis/off-axis sand percentages in the Access outcrop (Figure 6) decrease from 48% to 23% across outcrop. This supports the idea that reservoir quality decreases in the direction off-axis to progradation.

Discussion

Runout lengths are measured over the entire extent a discrete sand bed is visible in outcrop. These measurements are impacted by outcrop length, prompting the study of the sand bed runout lengths in the most extensive outcrop, Access. The mean runout length for all the outcrops (including Access) and Access outcrop individually are 400 m and 430 m, respectively. Mean runout length measurements are not significantly impacted by outcrop extent of the Panther Tongue outcrops analyzed.

In this study, seven outcrops were mapped and studied in the Spring Canyon area of the Panther Tongue sandstone. Six of the outcrops follow the trend of decreasing sand percentage from north to south (from areas proximal to the sediment source to distal areas).The outcrops on the

western side of the study area (Figure 5) show average sand percentages decreasing from 86% to 70% then increasing to 80%. The outcrop that increases to 80% is an outlier and is a source for future investigation, possibly related to delta lobe-switching.

References Cited

Enge, H.D., J.A. Howell, and S.J. Buckley, 2010, The Geometry and Internal Architecture of Stream Mouth Bars in the Panther Tongue and Ferron Sandstone Members, Utah, U.S.A.: Journal of Sedimentary Research, v. 80, p 1018-1031.

Morris, W.R., Posamentier, H.W., Bhattacharya, J.P., Loomis, K.B., Kupecz, J.A., Wu, C., Lopez, B.M., Thompson, P.R., Spear, D.B. and Kendall, B. 1995, Panther Tongue sandstone outcrop case study; II, Evolution of delta types within a forced regression: American Association of Petroleum Geologists 1995 annual convention, 4, p. 68.

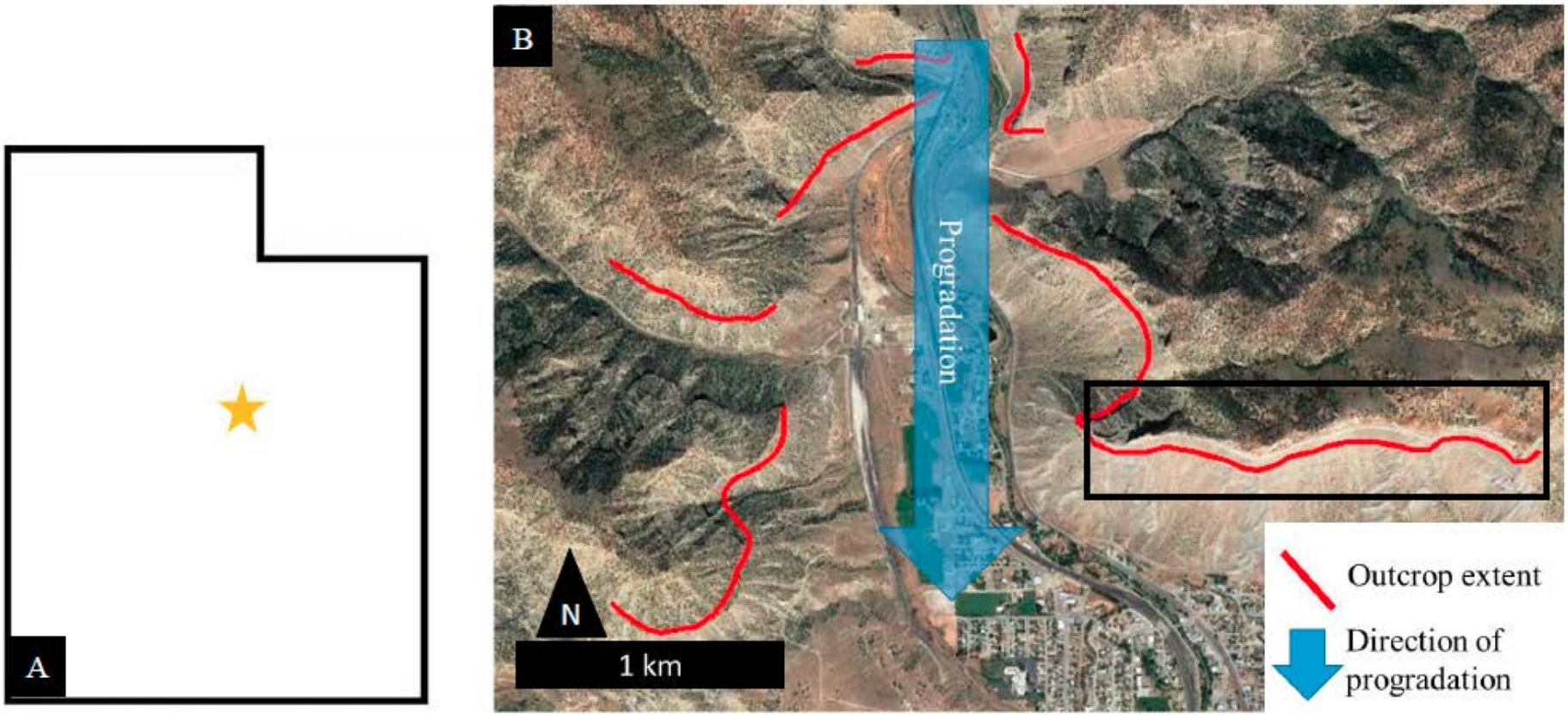

Figure 1. A) geographic context of field site within the state of Utah; and B) Google Earth image of field site with Panther Tongue outcrop extent traced in red, location of Figure 5 outlined (Access outcrop) with black box, and progradation direction denoted with blue arrow.

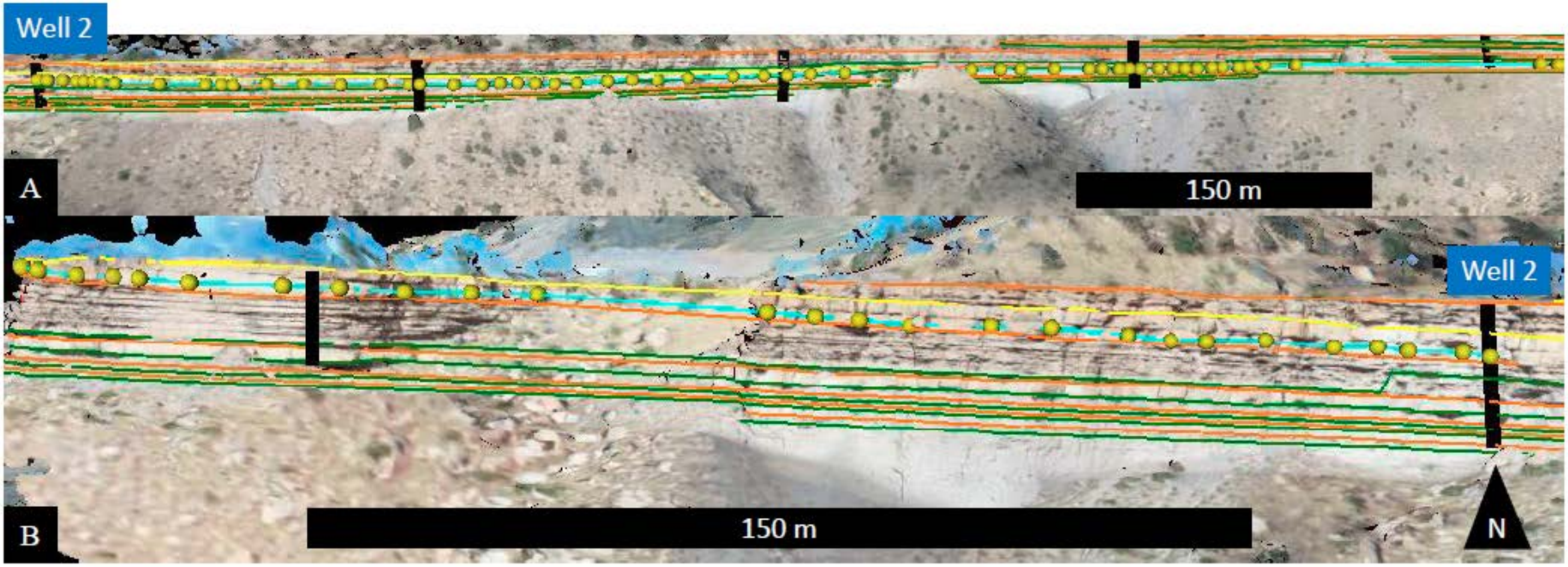

Figure 2. A west-east outcrop panel with one sand bed traced along its extent A) sand bed runout length to measured 686 m to the right B) sand bed runout length measured to 253 m to the left of the well.

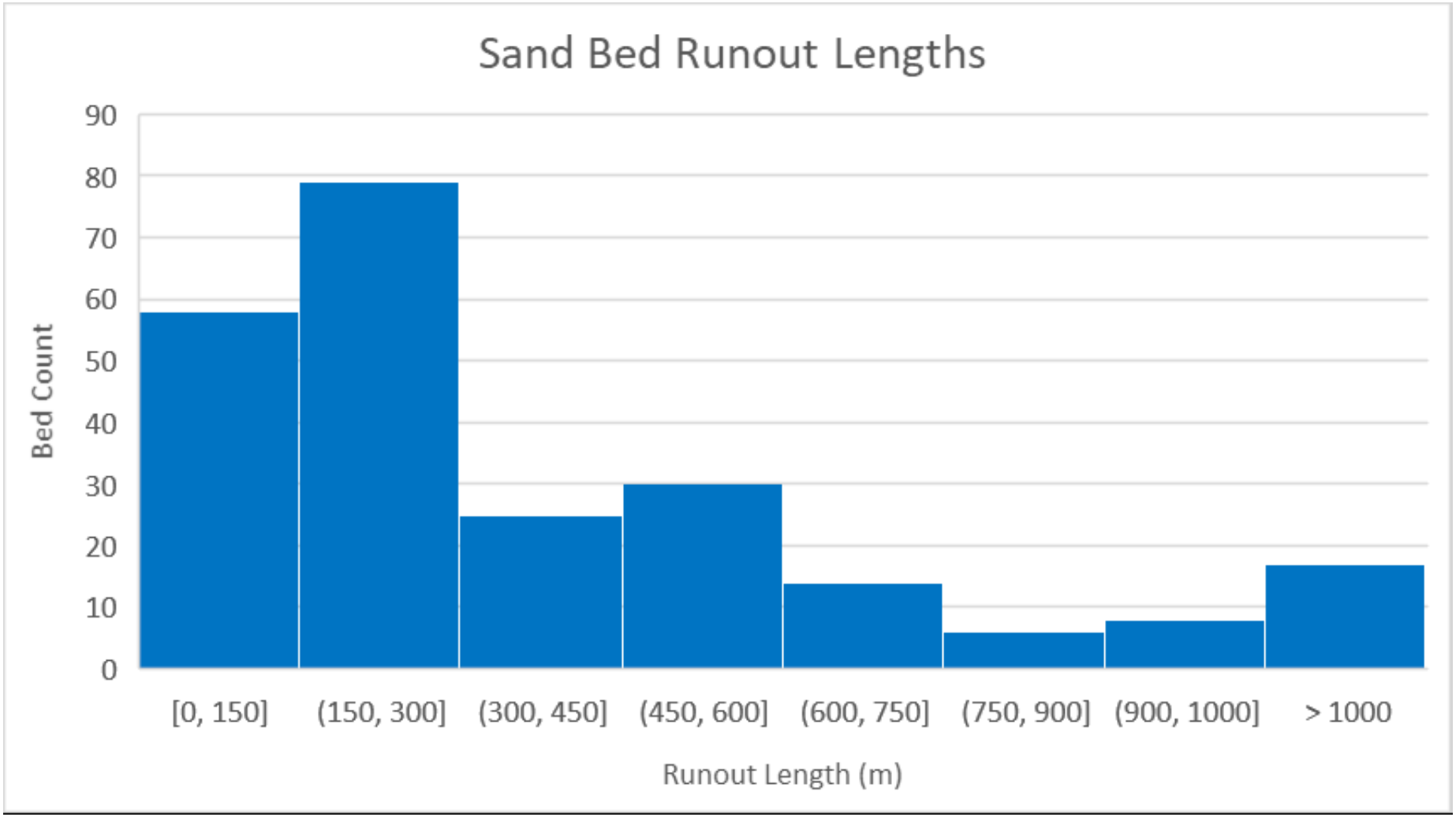

Figure 3. Counts of runout lengths for sand bodies in all outcrops. Histogram shows skew towards shorter runout lengths.

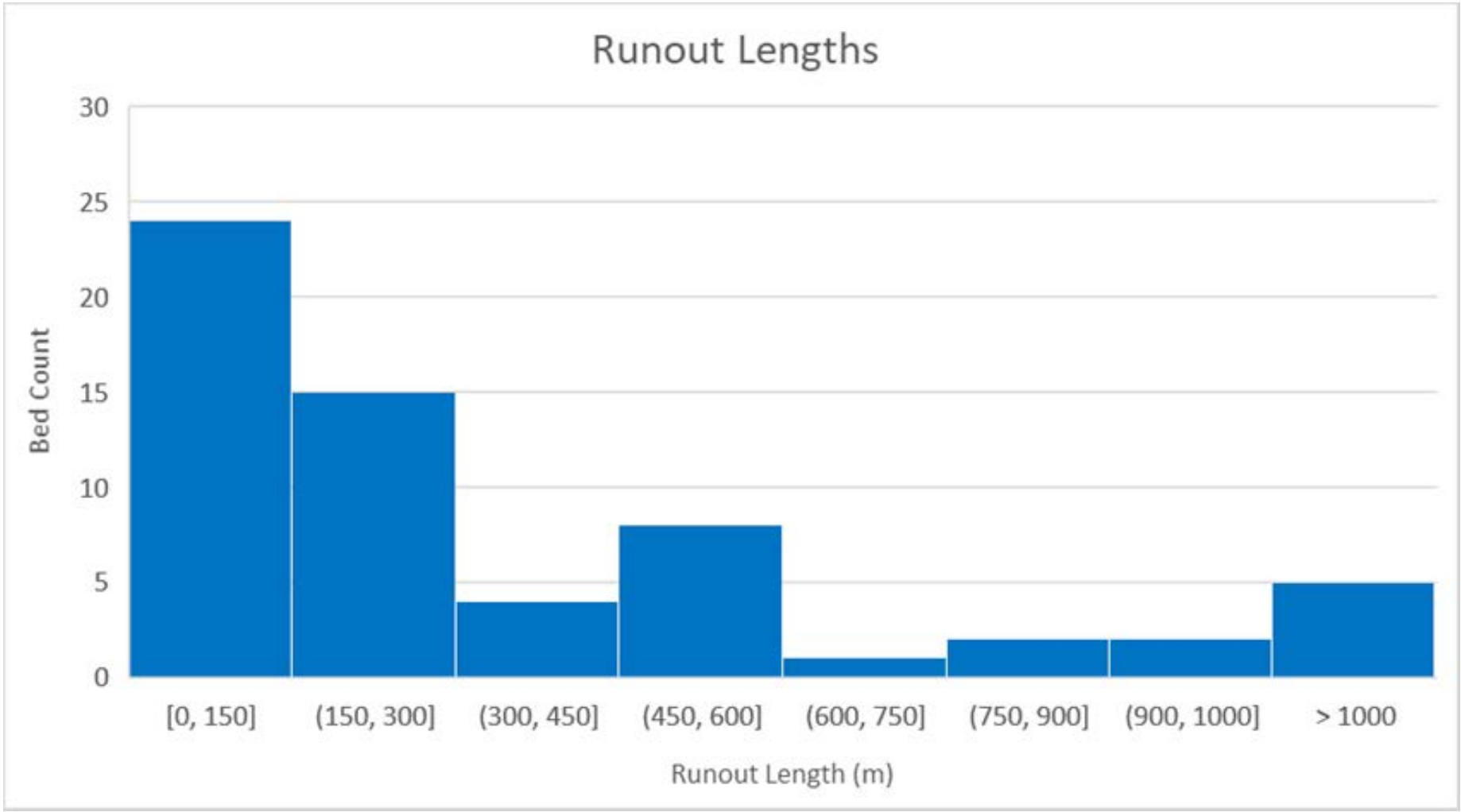

Figure 4. Counts of runout lengths for sand bodies in the Access outcrop. Histogram shows skew towards shorter runout lengths.

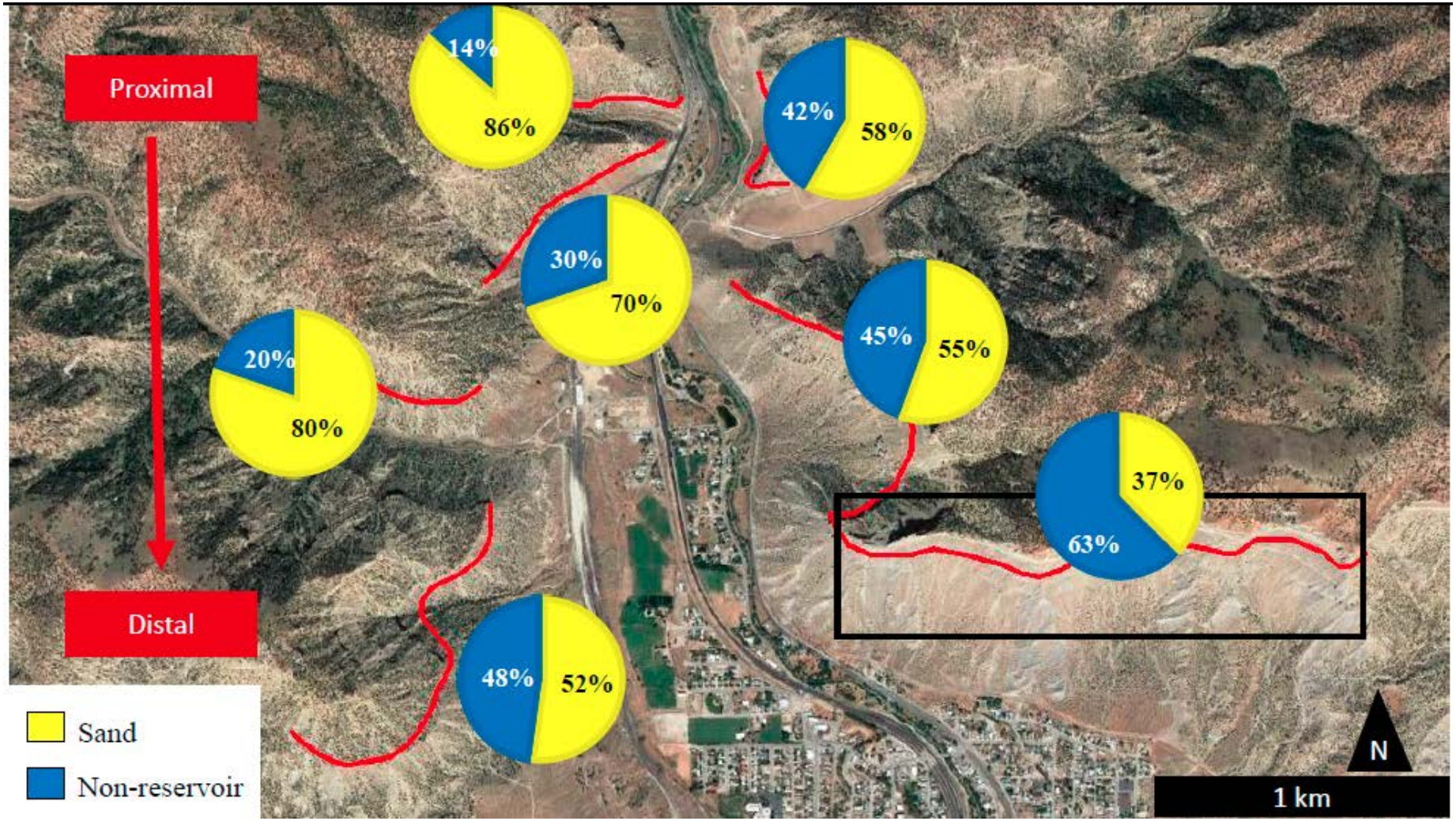

Figure 5. Seven outcrops (red outline) included in this study with their average sand proportions. The ratios show the decrease in sand proportion in the distal direction. Black rectangle outlines location of Figure 5.

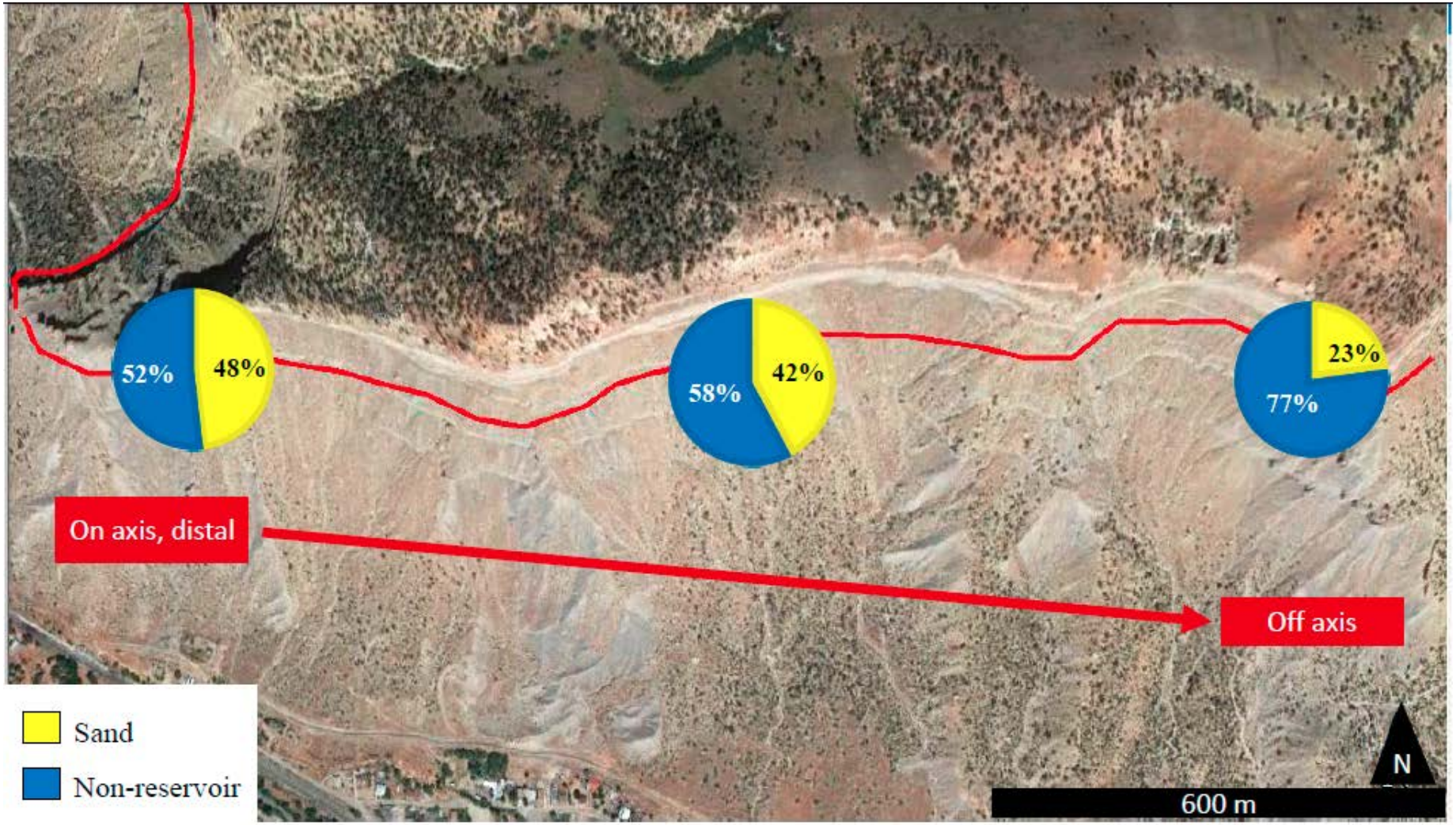

Figure 6. Three locations where sand proportions were measured along the Access outcrop, outlined in red. The ratios show the decrease in sand proportion from west to east (in the direction off-axis of progradation).