

ASSESSING THE USE OF HIGH RESOLUTION SATELLITE IMAGERY TO INVENTORY ABANDONED MINE LAND FEATURES IN VIRGINIA¹

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Abstract: The State of Virginia (VA) Division of Mined Land Reclamation (DMLR) and the Office of Surface Mining (OSM) used high resolution satellite imagery along with other Geographic Information System (GIS) tools to assist in the inventory of abandoned mine land (AML) sites and identification of re-mined areas in southwestern VA. Inventory of AML sites was conducted through feature extraction of QuickBird-2 satellite imagery to identify new AML sites and more precisely locate existing AML sites. The AML features identified as priority for mapping by VA DMLR were dangerous highwalls, apple cores, gob piles, clogged streams, clogged stream lands, portals, subsidence, acid mine drainage, hazardous equipment and facilities, spoil piles containing high coal content for re-mining consideration, and re-mined areas.

The initial results of the image feature extraction included locating acid mine drainage areas, determining linear feet of dangerous highwalls, location of gob piles and spoil piles containing high coal content and areas identified for re-mining consideration, clogged streams and clogged stream lands required acquisition of summer imagery to conduct feature extraction. Additional field data collection is planned to classify portals and subsidence features as well as complete an accuracy assessment of the final classification.

Additional Key Words: DMLR, OSM, AML, remote sensing, classification, QuickBird-2, GIS

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Introduction

The Virginia (VA) Department of Mines, Minerals and Energy's (DMME) Division of Mined Land Reclamation (DMLR) is responsible for ensuring the reclamation of land affected by surface and underground coal mining activity. The DMLR promotes an environmentally sound mining industry throughout Virginia's coalfield counties of Buchanan, Wise, Dickenson, Tazewell, Russell, Lee, and Scott. DMLR also operates an abandoned mine land (AML) reclamation program to reclaim human health, safety, and environmental impacts from mining conducted prior to August 3, 1977.

Abandoned mine land related problems include landslides, stream sedimentation, hazardous structures, dangerous highwalls, subsidence, loss of water, acid mine drainage, and open mine portals.

A common problem facing the AML program in Virginia and nationwide is the limited amount of money and the seemingly limitless amount of land in need of reclamation. DMLR is actively promoting remining as one solution to this dilemma. By taking second cuts on existing highwalls, mining companies have eliminated miles of old pre-law highwalls, covered and revegetated acres of eroding outcrops, and abated acid mine drainage problems.

In the early 1980s, the VA DMME had field teams gathering data on abandoned coal mine features. This effort gradually declined through the mid and late 1980's. Since 1988, updates to abandoned coal mine inventory lists in Virginia have been to add newly discovered features or to categorize known features as "funded" or "completed".

Since the initial collection of inventory data, Virginia has experienced a tremendous amount of remining, wherein coal companies remine lands that were mined prior to SMCRA. It is likely that many features have been remined and reclaimed to current standards and no longer impact human health and safety and the environment. Finally, there is the process of natural succession and aging, wherein geologic processes and vegetative establishment naturally reclaim features. It is apparent that inventory data is old and may not truly represent current conditions. There is also the impact of the dynamics of AML inventory as new features occur or previously unknown features surface. All of these factors result in the need to update Virginia's data, a scenario that is probably the case for many eastern coal states.

To address these issues, the Virginia DMLR took an innovative approach and requested that the Appalachian Regional Technology Transfer (ARTT) team explore advanced technological

methods available to capture AML sites and remaining accomplishments. ARTT contacted OSM's Technical Innovation and Professional Services (TIPS) to initiate a study into the use of high resolution satellite imagery along with other Geographic Information System (GIS) information as tools to assist in the inventory of AML sites and areas for potential re-mining. Evaluating new technologies, such as the use of high resolution satellite imagery for AML inventory will help VA DMME make decisions on how to allocate resources to meet their goals of updating the AML inventory lists.

Materials and Methods

Study Area

The study area is within the coalfields region of southwestern Virginia (Figure 1). The area is 100 square kilometers in size and covers portions of Wise County and the City of Norton.

Satellite Imagery Selection and Preprocessing

QuickBird-2 satellite imagery was selected for this study, being the satellite with the highest spatial and radiometric characteristics available. Two scenes were acquired for the study area. To obtain a leaf-off condition for enhanced visibility of AML sites a scene was acquired on April 5, 2006. The second scene was acquired on August 15, 2007 to obtain a leaf-on condition so that features such as clogged streams and clogged stream lands could be identified. Both images were orthorectified and pan-sharpened to obtain the best spatial resolution possible using ERDAS IMAGINE software (ERDAS Field Guide, 2008).

Field Sampling Methodology

A field sampling strategy was initiated with the goal of obtaining thirty verification and ten validation sites for each of the thirteen AML features (Lowry, et al. 2005). Field sampling was conducted on the ground and by helicopter. Field sampling by helicopter over large areas proves to be the most cost effective and time efficient method to collect the amount of sites required for this verification and validation (Schrupp et al, 1999). Often sites are remote and can be difficult and/or dangerous to get to (Markon, 1995). All sites visited were documented with an AML type description, GPS point or perimeter location and digital photograph (Osborne, et al. 1986). This was used to support the feature extraction process in identification of AML types.

The field sampling work done by aircraft began during the first week of December 2007. In addition, field sites were collected on the ground by VA DMLR. Field verification data were

collected for each of the priority AML sites. TIPS provided a preliminary AMD feature site map and these sites were visited and field verified as well (Fig. 2).

Even though the study area is large and contains many diverse AML sites, there were not enough representative sites in the study area to meet the original field sampling goal of 30 representative verification sites and 10 validation sites for each AML feature. Plans are to search for additional sites within the study area and to extend the study area east to include areas with known features to sample. This field work is planned for the summer of 2009.

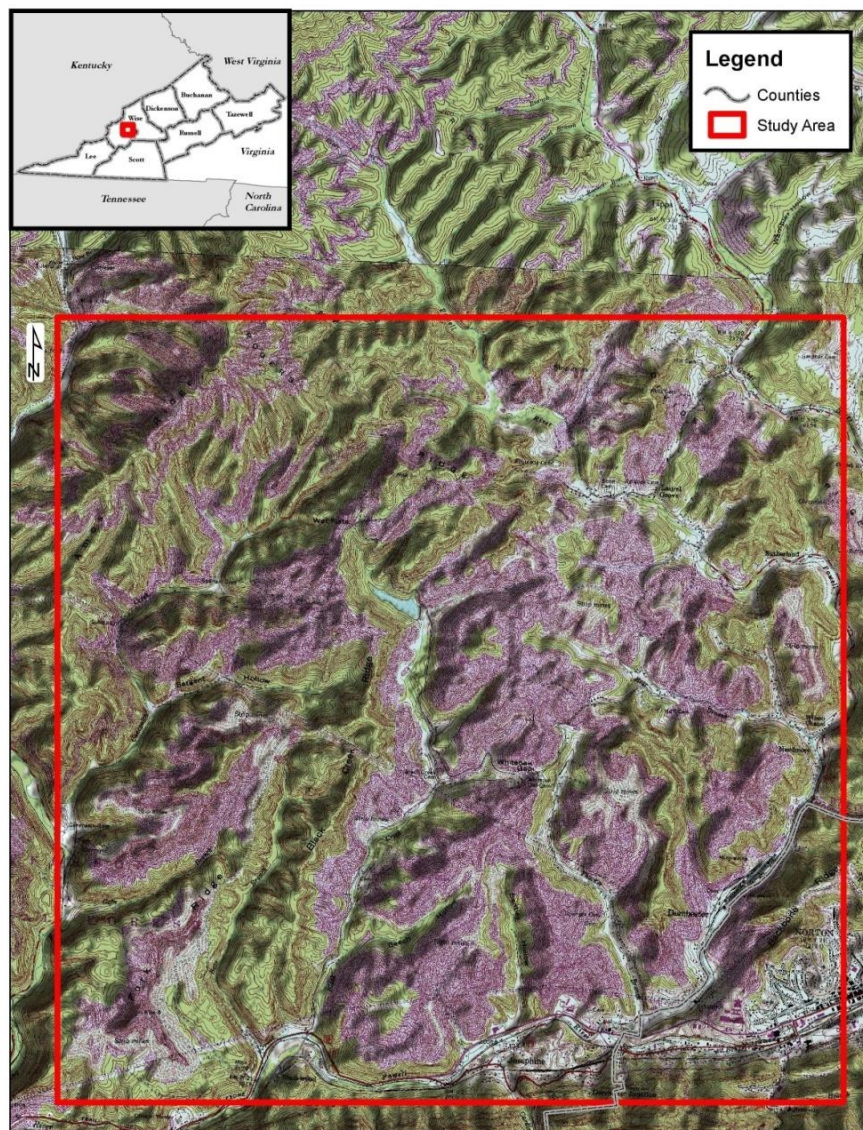


Figure. 1 Study Area Location

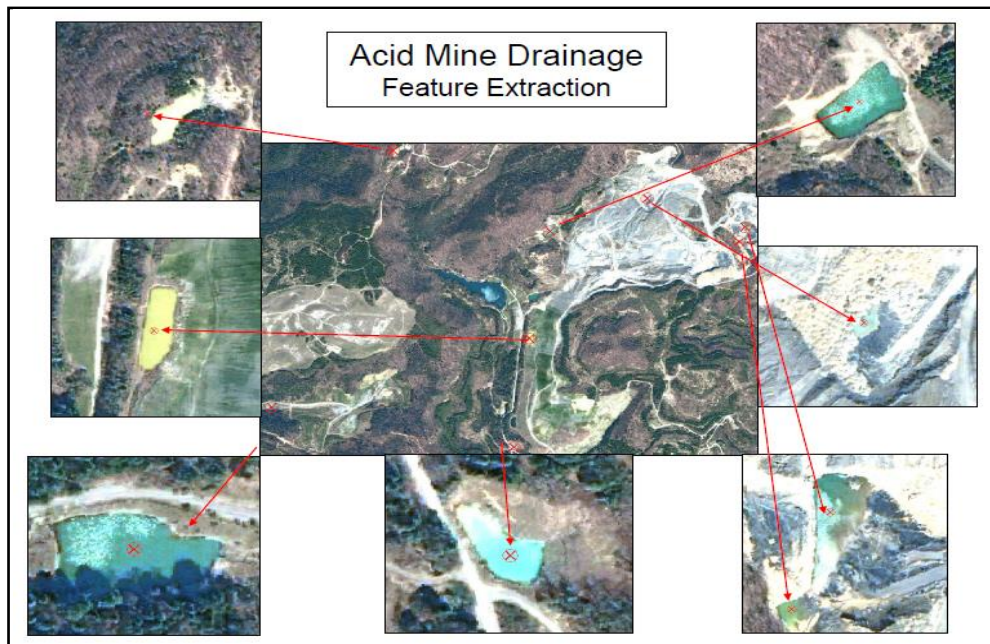


Figure 2. Initial AMD Feature Extraction for Field Verification

Feature Extraction Methodology

Feature Analyst for ArcGIS software (Blundell and Opitz, 2006) was used to extract the AML sites from the QuickBird-2 imagery. Feature extraction methodologies were developed by AFE Advisor, LLC. A feature extraction model was developed for each of the fourteen priority AML types. Table 1 shows the initial results of the fourteen priority AML types identified by DMLR. Examples of the process to extract AML areas for remining consideration , dangerous highwalls, gob piles and spoil piles follow.

Areas for Potential Remining Consideration

The feature “Areas for Potential Remining Consideration” are generally represented on the landscape as highwalls adjacent to between two to four linear rows of conifers, usually spaced approximately 6 feet apart. A forty-meter buffer was placed around the dangerous highwalls (DH) to defining a region of interest. Rows of trees were then extracted using linear training samples of the conifer rows. Larger forested areas that remained in this category were stratified out using clutter removal (misclassified data) processing. All buffered DH’s that have adjacent rows of trees remaining in the buffered area were classified as “Areas for Potential Remining Consideration”.

Table 1. Initial AML Feature Extraction Results

VA DMLR Priority	AMLIS Priority	Feature Mapped	Comments
Remined areas	N/A	No	Historical photography and change detection analysis needed.
Areas for remining consideration	N/A	Yes	
New AML sites	N/A	Yes	VA DMLR to verify
Dangerous highwalls	1 & 2	Yes	
Gob piles & Spoil piles	3	Yes	
Clogged steams	1 & 2	Yes	
Clogged stream lands	1 & 2	Yes	
Subsidence	1 & 2	No	Additional field points needed.
Acid Mine Drainage	1 & 2	Yes	
Dangerous Slides	1 & 2	No	Additional field points needed.
Hazardous equipment & facilities	1 & 2	No	Range of target features is too broad
Portals	1 & 2	No	Additional field points needed
Apple Cores	1 & 2	No	Additional field points needed



Figure 3. Example of QuickBird Image and Areas for Potential Remining Consideration

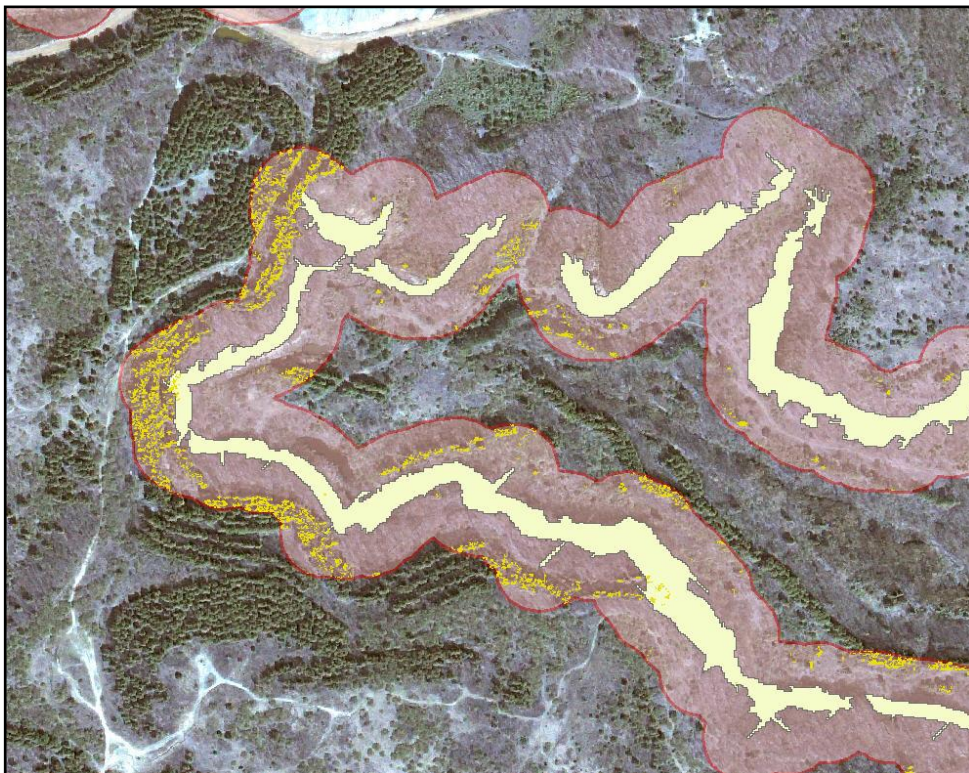


Figure 4. Example of DH, 40 meter DH Buffer and Rows of Trees Highlighted in Yellow.

Dangerous Highwalls

The following is an example of the methodology used for feature extraction of Dangerous Highwalls (DH). Figure 5 shows a portion of the QuickBird image along with field sampling points of a highwall feature. Highwall features appear on the image as dark shadow. In addition to Feature Analyst, ArcGIS Spatial Analyst and ERDAS IMAGINE software was used for DH feature extraction.

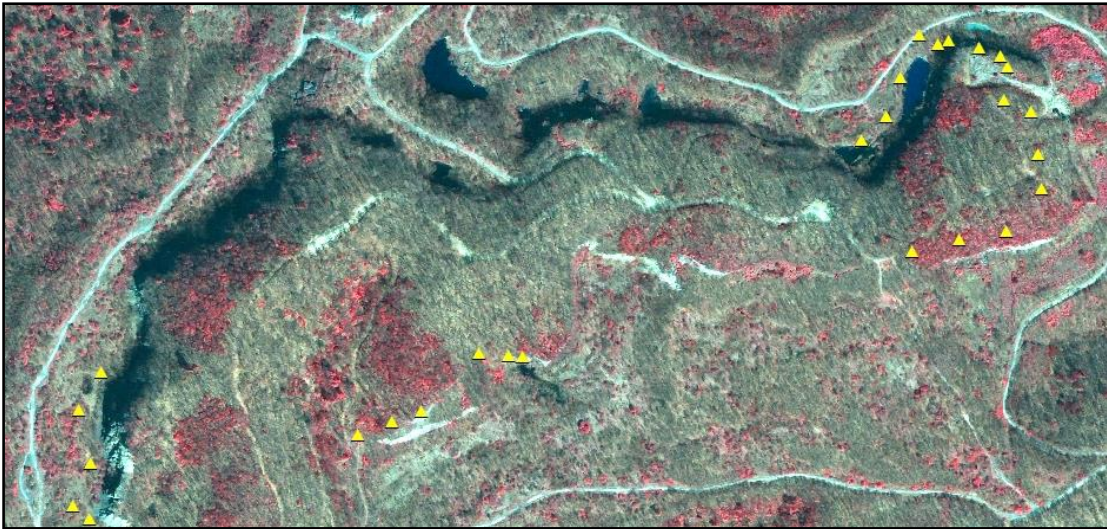


Figure 5. Example of Dangerous Highwall Feature and Field Points

Topographic contour data was required for this process and was provided by VA DMLR from the State of VA 2007 aerial photography program. A Digital Elevation Model (DEM) was derived from the contour data in ERDAS IMAGINE. The DEM cell size was 5 ft., the same as the contour interval. A slope analysis was performed using ArcGIS Spatial Analyst. DH field points were incorporated into the slope analysis, generating a slope category of greater than 60 degrees and a DH designation for this feature.

The red areas in Fig. 6 represent slope angles of greater than 60 degrees. The field sample points were left on the image for comparison purposes.



Figure 6. Dangerous Highwall Features with Field Points

Gob and Spoil Piles

The ability to map Gob and Spoil piles correctly is based on numerous, accurate field sample points and with the understanding that only new piles without overburden are the target. A mask to limit the amount of clutter was used in this model. Given the spectral similarity of this feature to non target features such as urban areas and asphalt roadways, a fair amount of clutter is to be expected (Maloof et al. 1998) (See Fig. 7). Also, a Normalized Difference Vegetation Index (NDVI) band ratio enhancement was performed in ERDAS IMAGINE to create a mask of vegetated and non-vegetated areas. These two masks were applied to the feature extraction model. A training set was created from the imagery using known ground truth points over known gob piles. Figure 8 shows the modeling steps required to extract this feature. Figure 9 shows a Gob pile with the ground truth field sample points. The results of the feature extraction model are shown in Fig. 10. In this feature extraction gob piles and spoil piles are grouped into the same feature class. Both features are so similar in shape and spectral response that it is not possible to separate out the two with QuickBird-2 imagery.



Figure 7. Asphalt roofing spectral signatures mimic gob and spoil piles.

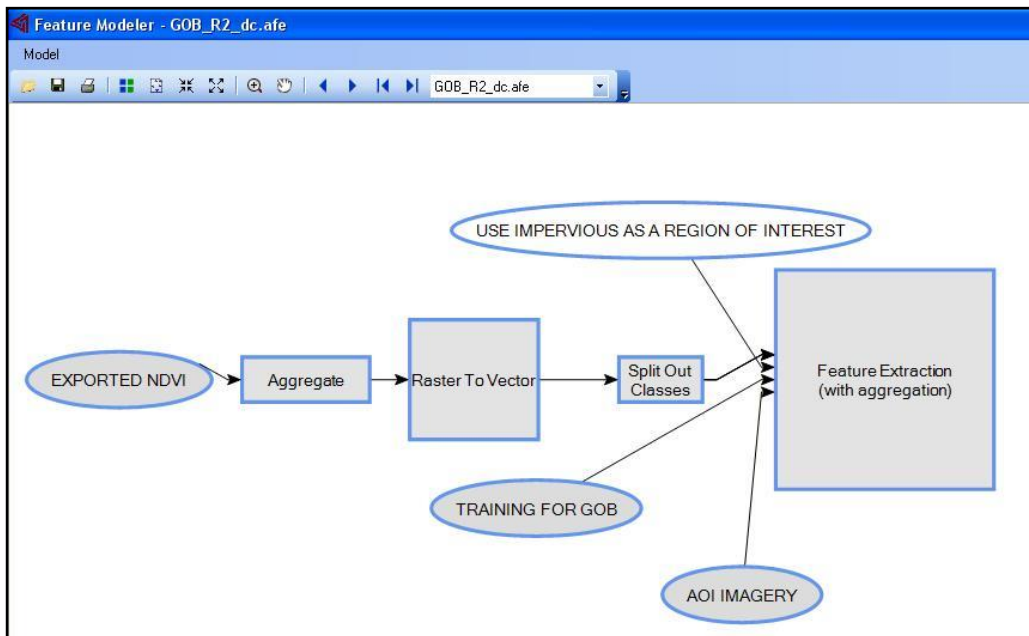


Figure 8. Feature Analyst modeling steps used in creating gob and spoil piles feature class.



Figure 9. A Gob pile feature with field sample points to develop a training set.

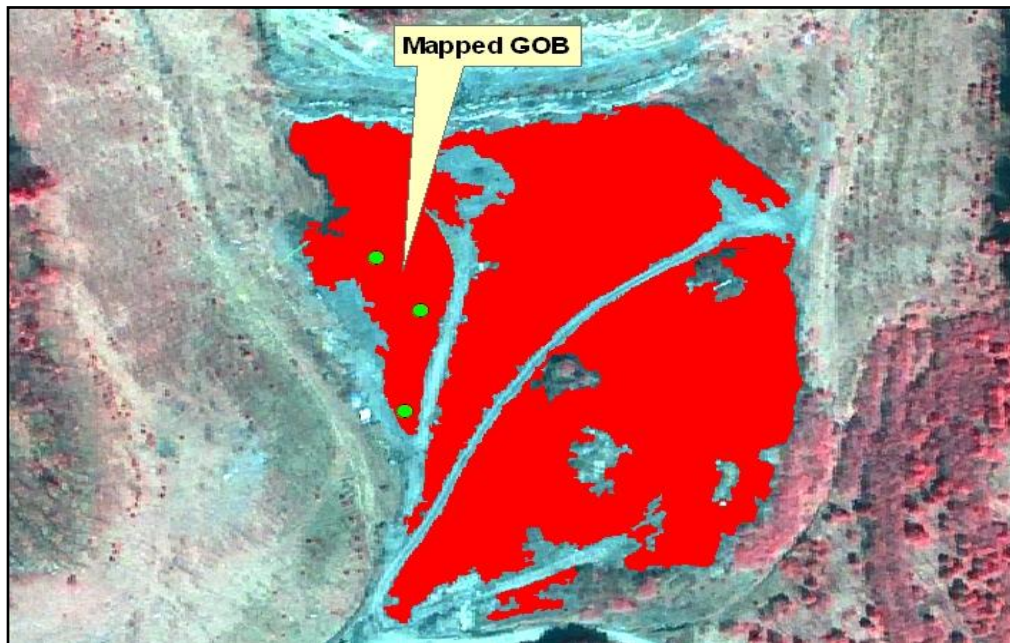


Figure 10. Results from Gob pile feature extraction process.

Results and Discussion

Initial results indicate that a majority of the AML features that DMLR identified can be mapped. Of the fourteen priority sites identified by DMLR, eight AML types have been mapped reliably. These include: 1) Areas for remining consideration, 2) New AML sites, 3) Dangerous highwalls, 4) Gob piles, 5) Spoil piles, 6) Clogged streams, 7) Clogged stream lands, and 8) Acid mine drainage. The three AML features which will require additional field points to conduct a reliable feature extraction are: 1) Subsidence, 2) Dangerous slides, 3) Portals and 4) Apple cores. The features that cannot be mapped reliably at this time with QuickBird-2 imagery are Hazardous Equipment and Facilities and Re-mined areas. As additional satellite's are launched and the associated imagery becomes more spatially resolute and the spectral band width increases, such features as hazardous equipment and facilities may be mapped with more reliability. Re-mined areas could potentially be mapped using historical aerial photography, current satellite imagery and change detection analysis.

Future work will involve additional field sampling for verification of the four remaining AML sites and validation points for the accuracy assessment. Final AML feature extraction and accuracy assessment results are will be reported and the peer review process begun in December of 2009.

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