Applying Remote Sensing to Paleontology Studies in the State of Arizona, USA.

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ABSTRACT. —Advances of remote sensing in the last decade have proven to be quite essential in its widespread use in geology. This research tries to explore and validate the applications of 'remote prospecting' in paleontology studies as stated by a previous investigation. Satellite image data obtained from Landsat 7 ETM+ sensors (date: 2002) were analyzed by using the program ENVI 4.8 with the goal of developing a spectral library for a selected region in the state of Arizona, USA. A first testing phase using the region in where the Chinle Petrified Forest is located (known as the Chinle Formation) displays geologic correlation between spectral profiles generated by ENVI and the geological features previously dated by field observations. Unsupervised ISODATA and supervised Spectral Angle Mapper (SAM) classifications were obtained from the data image processing and evaluated by examining and correlating for potential fossil sites in addition to the geology of the area. Present methodology states viability for a low cost analysis and prospecting tool that could support nearby future field explorations. Improvements and further tests, however, are pending in order to apply such techniques to locations of difficult access and harsh weathering conditions.

Key words: Remote sensing, paleontology, prospecting, Arizona, Landsat, ETM+

INTRODUCTION

Improvements in the acquisition of satellite images from a range of different sensors during the last decade have provide the scientific community with a valuable tool used in many fields. Geological sciences are now more technical-based than before, the increase of modern tools as remote sensing (RS), and global positioning systems (GPS) are not rare in many studies. In fact the use and integration of this field has proven fundamental in the distribution and implementation of new research projects as well in advocating methodologies that until recently were impossible to achieve or even to imagine. Identification and analysis of rocks, minerals and tectonic structures via remote sensing is now a reality due to the development in recent years of specific algorithms and hardware specialization (Malakhov et al. 2009).

Applications derived from satellite images and remote sensing are not limited only to mere observations of the surface, but rather a combination of approaches exist to allow investigators interpolate information about historical geological features (Akhir and Abdullah, 1997) or to determine underground conditions by noticing the aspect of the surface (e.g. as vegetation-soil relation for land growth). More recently, even in fields as anthropology (Anemone et al. 2011) and in paleontology (Malakhov et al. 2009; Oheim 2007) the introduction and combination of remotely sensed (RS) imagery with further analysis by geographic information systems (GIS) and global positioning systems (GPS) has proven the versatility of using such tools for predicting fossil localities for future site exploration.

Based in the previous assumptions, this paper intends to validate a published study (Malakhov et al. 2009) in where the authors claim that by using relatively low-resolution satellite image data, serves as a viable tool for low-cost evaluation of geological terrain in order to locate feasible paleontological sites for field explorations. As the original paper, this recent study will use satellite images derived from Landsat 7 ETM+ but it will apply its same methodology to the region of the Arizona state, USA. As a preliminary test phase, the region of the Chinle Petrified Forest was selected due to its geological features and paleontological records, as well for regional climatic conditions that offer similarities with those found in the original site used in the study of Malakhov (2009).

This study will therefore follow the same methodology established in Malakhov (2009) and will try to minimize modifications to the structure in order to validate the theory and process.

MATERIALS AND METHODS

Terminology and technical data

As any research related to remote sensing (RS) or geographical information systems (GIS) it is important to define specific field terminology, in addition to the software and hardware tools as to avoid any fault in the descriptions. Familiarity and understanding is vital to the proper use of these valuable equipments.

Landsat 7 ETM+ (Landsat Enhanced Thematic Mapper) is primarily the main sensor used and provides imagery at 30 meter spatial resolution. Image processing was develop by using the RSI ENVI software in where different features were used. One of them, the unsupervised ISODATA classification allows the automatic distribution of classes of the pixels data in the image according to an algorithm. The feature separates the detatasets into classes based on statistically significant minimum distances (Malakhov et al. 2009). The Spectral Angle Mapper (SAM) another ENVI classification, however with user input, allows the physical spectral classification by matching pixels in the data to a corresponding and previous validated spectral library.

Area of study

General overview of weather conditions plus the exposure of rock material were primary factors to consider for a viable candidate which similar conditions were comparable to those presented in the site of Kazakhstan by Malakhov (2009). The selection of the state of Arizona as a test target was in addition supported by its long paleontology record as well the accessibility for satellite images of various zones (paths and row identifications) if required in a long term investigation. Focus on a single area primarily was ideal in order to perfect the methodology as well to purge any imperfections in the analyzing process. The region of the Chinle Petrified Forest was therefore selected as by recommendation of Dr. Karl Flessa from the University of Arizona. In addition, the Chinle Formation is well known in the region for its paleontology studies (Heckert and Lucas 2003; Irmis 2005).

As for the exact location in use, the Petrified Forest National Park is quite famous due to the geological history it represents. In short, it compromises a scenario in where in Triassic time tree trunks rafted by flood and then were buried quickly with stream sediments and volcanic ash, later on, infused with silica and preserved (Chromic 1983). Today's remnants of these "painted desert" is a result of lack in rain and the soft, poorly consolidated silt and volcanic ash that characterizes the Chinle Formation, which as a consequence erodes quite easily to weathering conditions. As a result, fast erosion by wind and water prevents plant growth and the development of soil. Ashes residuals have gradually altered into bentonite and must of the petrified logs found in the region are agatized (Chromic 1983).

Image acquisition

Several satellite image sets from the USGS Global Visualization Viewer (GloVis) and from the Arizona Regional Map Archive (Aria) were considered for the research. Observations and geological data derived from the USGS Map of Arizona (USGS) with the aid of Google Earth finally correlated to the selected region of the Chinle Petrified Forest as “path 36 row 35.” Available datasets once obtained from the mentioned sources were then processed by using the RSI ENVI 4.8 software.

Spectral Analysis

Collection of spectral signatures was defined by using the visualization of the band combination 7-3-1 (for R-G-B, red, green, blue respectively) in ENVI from an original Landsat 7 ETM+ image of the quadrant selected in Arizona (Fig. 1). The decision to use these three bands reside that according to the original authors these displayed the greatest image contrast. A subset of the original image was also generated with the basic tools found in the ENVI package for a proper identification of the region in where the Chinle Petrified Forest is located. This was done for both a 3-2-1 (true-color image) and for the previously 7-3-1 (false-color image). An unsupervised ISODATA Classification for the acquired modified image (false-color 7-3-1, subset) was then selected with 5 to 30 classes over three iterations as conditions with the rest of the parameters in their default state.

Selection of most discernible pixel associations allowed the used of the RSI ENVI function Z Profile (Spectrum) for collection of spectra data. Once obtained, the Spectral Angle Mapper (SAM) supervised classification was applied to the entire image in order to compare the spectral results with the geological data obtained from the USGS.

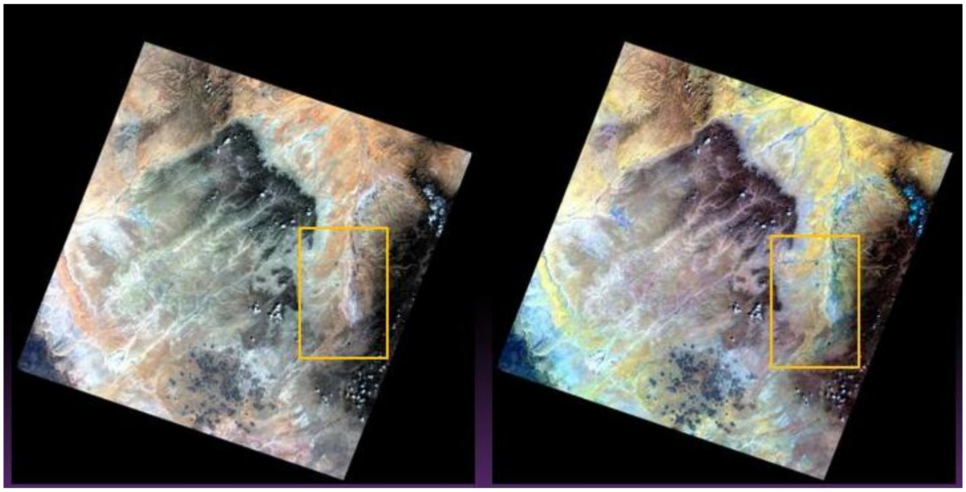


Fig. 1. Image comparison between bands 321 and 731. Box displays region of interest.

RESULTS & DISCUSSION

Results from the spectral analysis indicate an accurate correlation between fossil sites and the processed data. The unsupervised ISODATA classification initially established for 30 classes as a maximum, generated 25 known classifications and 1 unclassified (Fig. 2). This difference could be related to the lack of enough classes given the ISODATA algorithm for the specific section as a bigger image displayed 30 classes without a problem; only by limiting the region, the classification was lowered. Further investigation is required in order to correct this issue. Data comparison with true-color image from the subset in a 3-2-1 band combination proved that classified regions were in agreement with visual confirmation. In addition, comparisons with 7-3-1 band combinations between true-color subset and ISODATA classification resulted in a match that concurred with the general geological observations from the USGS map of the Arizona state. Further analysis of the resultant ISODATA images displayed an overall agreement for topographic features, and although geological classification agrees in overall, ISODATA's classes tend to generate a higher number of classes in comparison to the 10 geological periods of the region. However, selected site location fits into the mixed classes based on the ISODATA result, which also match with the true and false color images.

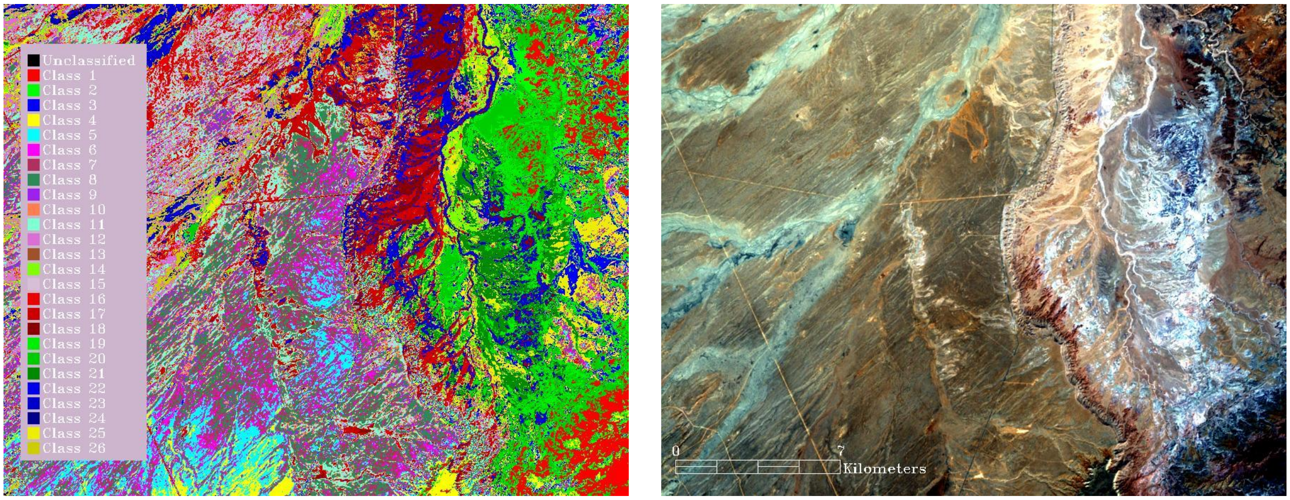
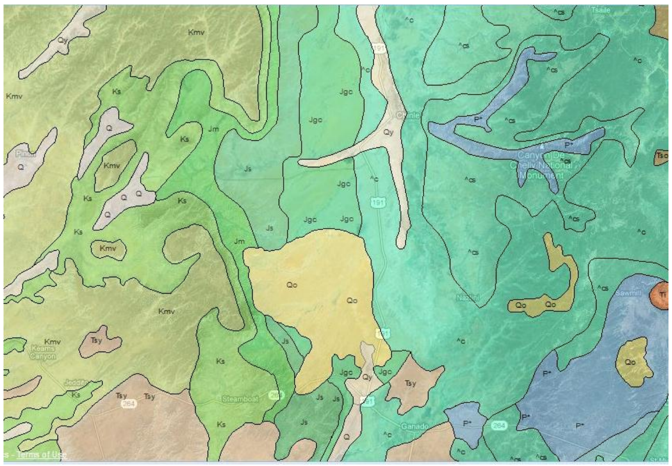


Fig. 2. ISODATA unsupervised classification (left) vs. true-color image with band selection of 3-2-1.

SAM resulting image indicates similarities with the ISODATA classification as spectrum profiles tend to match topographic features and region classification noted by the algorithm. SAM classification also displays correlation of the selected spectrum profiles with the geological information given by the USGS Arizona Map. For the Chinle Formation, the SAM analysis (Fig. 3) suggests spectral classes that match the correlated regions for the Chinle Formation (Late Triassic 210-230 Ma) in blue color, which is partially a combination of mudstone and sandstones with clays prone to shrinking and swelling (USGS). SAM results display also in closed detail that even the Glen Canyon Group (180-210 Ma.) follows the spectral signature (yellow) acquired with little variations. Although validation in the methodology proposed in Malakhov (2009), additional tests are suggested as determining with precise location superficial characteristics and geologic material is still variable and not easy to reproduce with alternate methods. Finally, paleontology has come a long way and this study simply confirms the versatility of using technology in this field in order to accomplish better and low-cost field observations.



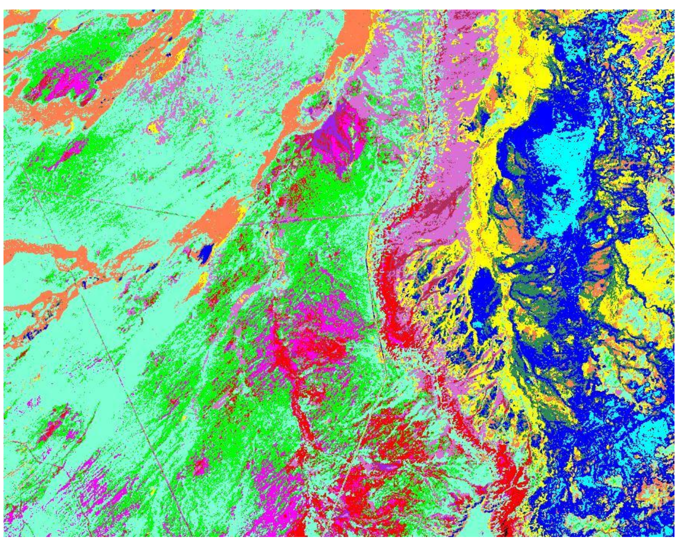


Fig. 3. (Clockwise) An USGS hybrid map for the Chinle formation in Arizona, followed by the same region with a lower transparency and finally the SAM supervised classification created by ENVI 4.8. In SAM image blue marine colors at right indicate correlation with the Chinle Fm. (aqua color) in the USGS maps , while yellow colors tend to indicate the Glen Canyon Group (180-210 Ma) denoted by greener variations in the geological maps.

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Satellite Images provided by:

USGS Geologic Map of Arizona (http://services.usgin.org/azgs/geologic-map-arizona.html)

(Aria) Arizona Regional Map Archive (http://aria.arizona.edu/)

(GloVis) USGS Global Visualization Viewer (http://glovis.usgs.gov/)