Remote Sensing: Applications in Paleontology

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English 225

Introduction:

Many scientists have attempted to apply remote sensing to different aspects of geology. According to "A Canada Centre for Remote Sensing," remote sensing is defined as, "the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it" (A Canada Center for Remote Sensing). Remote sensing requires an energy source or illumination, which would be something to capture, like a photograph, a sensor to collect the data or record the energy, transmission, processing, and analysis. According to Randall B. Smith, the Earth provides that energy source, by reflecting the electromagnetic radiation from the sun (Smith 2006). Remote sensing is an important study and can be used in many ways, as will be discussed. Applying remote sensing to paleontology could be a low cost evaluation of the geologic terrain. Matching rock types, by using image analysis programs, such as ENVI, and applying processing techniques, known for being fossiliferous, one could potentially narrow possible dig sites prior to entering into the field.

Paleontology:

Humans have been studying fossils since early civilizations. Since the late 1700's, humans have been using paleontology to prove theories, such as Flood geology and catastrophism. Glen Kuban describes the importance of studying fossils as learning about the history of Earth, the biology and ecology of ancient ecosystems, and locating deposits of oil and natural gas (Kuban 1994).

Finding new dig sites is one of the most time consuming parts of paleontology. Dmitry V. Malakhov, Gereth J. Dyke, and Christopher King claim that remote sensing applications will "become more and more prevalent in paleontology, especially in the development of remote field areas" (Malakhov et al. 2009). K.B. Oheim discusses a similar view, in which prospecting land in the field takes significant time and money. Using Geographic Information Systems (GIS) or other remote sensing processing systems could cut the cost and time spent finding new "fossil-producing regions" (Oheim 2007). Other researchers in the remote sensing field have been attempting to apply it to other aspects of geology, such as finding mining areas for gold (Gabr et. al. 2015), creating geologic maps or improving on existing ones (Karnieli et. al. 1996), or even identifying geological issues in remote areas (Frei et. al. 2015).

Remote Sensing:

Continuous research is being done in the relatively new field of remote sensing, and its technologies are constantly being upgraded and changed. Many online databases that store images are free to the public or for students, making access relatively easy. Michaela Frei et. al. discuss different ways to gather remote sensing data through the National Aeronautics and Space Administration (NASA), Advanced Spaceborne Thermal Emissions and Reflection Radiometer (ASTER), and Landsat satellites. This article applies remote sensing to geological issues in Africa. Africa covers a large area and much of it is economically lacking, meaning that there are still areas that do not have basic geologic or topographic maps and infrastructure in rural areas and are not up to par. Frei et. al. used "qualitative and quantitative interpretation of the interaction between electromagnetic waves of various wavelengths and the natural media," using techniques such as principal component analysis, data fusion, spectral angle mapping, spectral feature fitting, and more (Frei et. al. 2015). Some of these techniques and avenues to gather data were used in other research.

Methods:

The research done in Malakhov et al.'s paper "Remote Sensing Applied to Paleontology: Exploration of Upper Cretaceous Sediments in Kazakhstan for Potential Fossil Sites," was followed to find if their data was reproducible, which is a major part of scientific research, and to see if the data could be extrapolated into other areas. Using images found from Earth Explorer and the Landsat 8 satellite, images of the Syrdyra uplift in central Kazakhstan (as shown in Figure 1) were downloaded and studied. This area was chosen for its known Cretaceous fossils, to use as the ground-truthed fossil locations. To use satellite images for analysis of geologic terrain, land cover must be minimal in order maximize the accuracy of the received data. While some electromagnetic waves can penetrate vegetation and water, visible light (red-blue-green), which was used in this case, cannot penetrate vegetation. This area is distinctly lacking vegetation and other land cover, aside from a small lake, which was helpful to distinguish the clay from the ferrous mineral.

After learning about the brief geology of the area, I downloaded a Landsat 8 image from Earthexplorer.usgs.gov. In the paper I was following, they used a Landsat 7 ETM image. I wanted to use Landsat 8 because I thought using band 1 or deep blue visible band would help enhance the image, I found that it did not make that much of a difference. I also wanted to use Landsat 8 for the thermal bands, but I had the same problem, it did not seem to help the image once layer stacked into my image. Since I used the different Landsat image, I had to be careful when they said they used a 3-2-1 image or

7-3-1. Using Landsat 8, the bands are different, so I had to match up the correct wavelengths instead of bands. Their 3-2-1 or true color image was equivalent to my 4-3-2 and 7-3-1 or false color image was equivalent to my 7-4-2 image.

After I downloaded the image, I layer stacked bands 1-7 and also made a layer stack of 1-7 +10, but as mentioned earlier, the thermal band did not make a noticeable difference, so from here on out, when the layer stacked image is mentioned, I will be referring to the 1-7 image. Figure 2 shows the layer stacked image of true color or 4-3-2 (R-G-B respectively). Figure 3 shows the layer stacked image of false color or 7-4-2. In both images, it is easy to see the distinctive two units, the sedimentary basin or the lighter colors (light blue and light pink) and the metasediments/granitoids (dark blue and dark pink). In figure 2, I have shown the ground truthed fossil sites (Malakhov et al, 2009). After playing around with several different band combinations, these two proved to be the best at showing the most detail.

Since this project was geared to show what types of rock units held fossils, I used band ratios to show iron oxide, clay, and ferrous minerals. I created the band ratios and set them to the R-G-B , clay-ferrous-iron oxide, respectively. What I found was that the majority of the fossil sites were in the clay minerals (figure 4), which corresponds to the findings of Malakhov et al. Next I wanted to create a classification. I did an unsupervised classification with 5-15 classes over 3 iterations. Malakhov et al. found that three iterations would allow the pixel classifications to become consistent. After creating 4 different classification images, I found them unuseful.

Since the unsupervised classifications did not work the way I wanted, I decided to create a spectral library using spectral profiles of the original subset image. The classification on the original image worked pretty well, as seen in figure 5. In that classification, it is more clear that the above mentioned sedimentary basin is intermingled with the upper metasediments in the center. I made a couple different spectral libraries with more and less classes, but figure 6 was the only one that really showed the differences in the basin. Because I was trying to see if I could extrapolate the data I found into different areas, I downloaded images in two different areas. In each area, I layered stacked bands 1-7. Then tried to create classifications using the spectral libraries I created from the original subset image. It was found that an atmospheric correction, such as the dark-object subtraction technique described by Pat S. Chavez Jr., must be performed prior to any spectral analysis to allow the spectral libraries I created to be accurate. After the atmospheric correction was done, the classification image of the new area turned out better (Figure 6). I also used band ratios to create the same clay-ferrous-iron oxide image (Figure 7) as the original, since I thought that was the most useful. I have only included the images from the first location I chose because that is the only area that had similar properties as the fossil sites from the original.

Results:

From the results, I found that the experiment was reproducible, but to know if it can be extrapolated into other areas, it would need to be tested by sending a team into the area I have chosen to possibly have fossils. The two areas I chose were okay, but I think I would want to spend more time analysing and studying the areas before sending people into the field.

Findings:

The point of the experiment was to find if remote sensing could be used as a low cost evaluation of the geologic terrain. It was found that it is possible, but more research needs to be done. Creating spectral libraries from the spectral profiles was deemed ineffective and difficult to know the accuracy. I found that it was easier to manually set up the classifications using the profiles rather than using the libraries and produced more accurate results. It was found that the band ratio image was the most informative, but using the classification and band ratio images together helped gain better knowledge of the geology of the area.

Discussion:

This method of ground prospecting isn't widely used in the paleontological world, but from the research, it was found that it could be a beneficial method in terms of saving time and money prior to sending a team into the field. Using similar techniques as those researched, for other geologic reasons, could now also apply to paleontology and prospecting for new dig sites. There were some limitations found such as accuracy of the spectral profiles, distinguishing similar units, and extrapolating the data into other areas. The areas used in the experiment were all in similar locations of Kazakhstan, but in reality, dig sites won't always be in that area. More research and analysing would have to be done in each area to ensure a site would be worthwhile for a dig site.

Conclusion:

It was found to be possible to use remote sensing to find new paleontological dig sites, but there are some complications. I think the accuracy of the spectral profiles needs to be taken into consideration when working on a project like this. It is crucial to recognize the limitations to ensure large mistakes will not be made when trying to apply this data. Another limitation is its ability and accuracy when trying to differentiate similar units. Many of the areas that this would work in have a lot of similar units, like sandstones, clays, and others that are hard to distinguish even with the spectral profiles. I certainly believe the paleontological world could benefit from applying this information for the future. I think this information could be the future of paleontology or even archeology, and it could definitely be used as a low cost evaluation of remote areas.

Figures:

Figure 1:
Taken from ENVI. Blue box represents the ROI

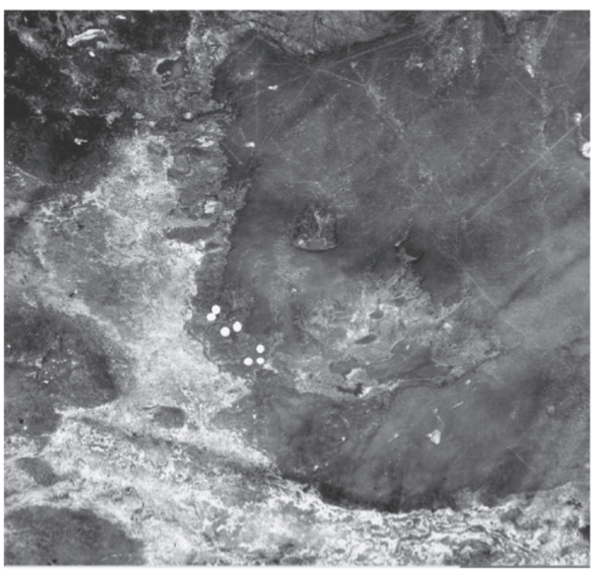

Figure 2:
4-3-2 (white dots represent ground truthed fossil sites)

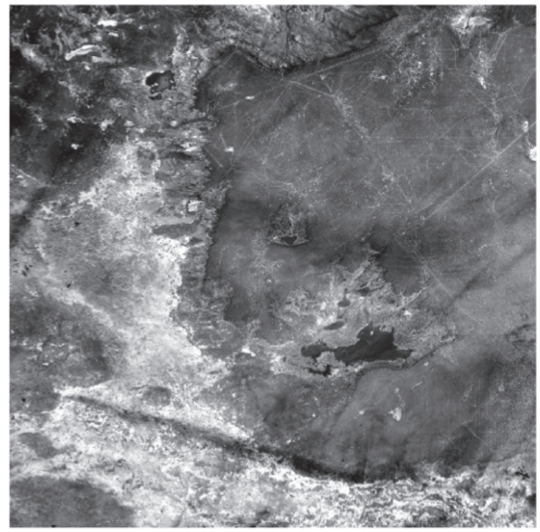

Figure 3: 7-4-2

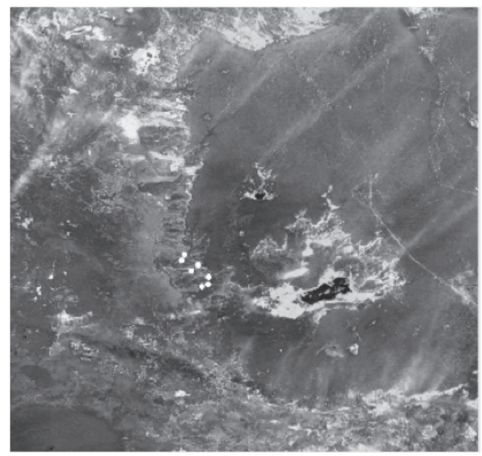

Figure 4: Clay-Ferrous-Iron Oxide

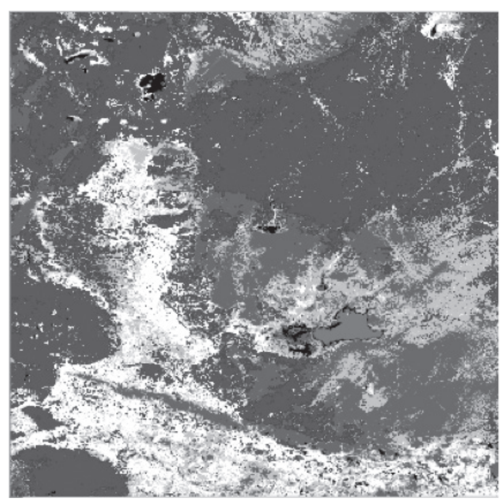

Figure 5: Classification

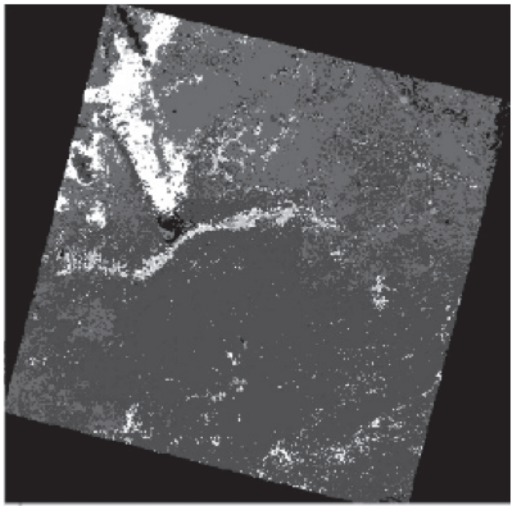

Figure 6:
Classification New Area

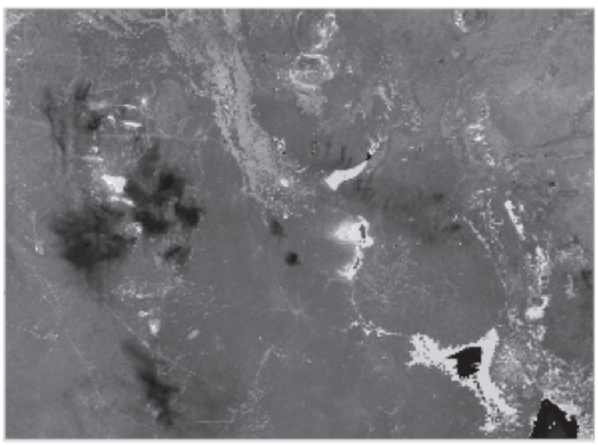

Figure 7:
Band Ratios New Area

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