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216 Final Project

Using Landsat Imagery to Locate Meteorites: Attempt on Neuschwanstein Meteorite

Introduction

On April 6th, 2002, a meteorite burst in the air 14 miles above Germany, scattering fragments over several miles (Oberst, 2004.) It was called the Neuschwanstein Meteorite due to its proximity to the iconic Neuschwanstein Castle.

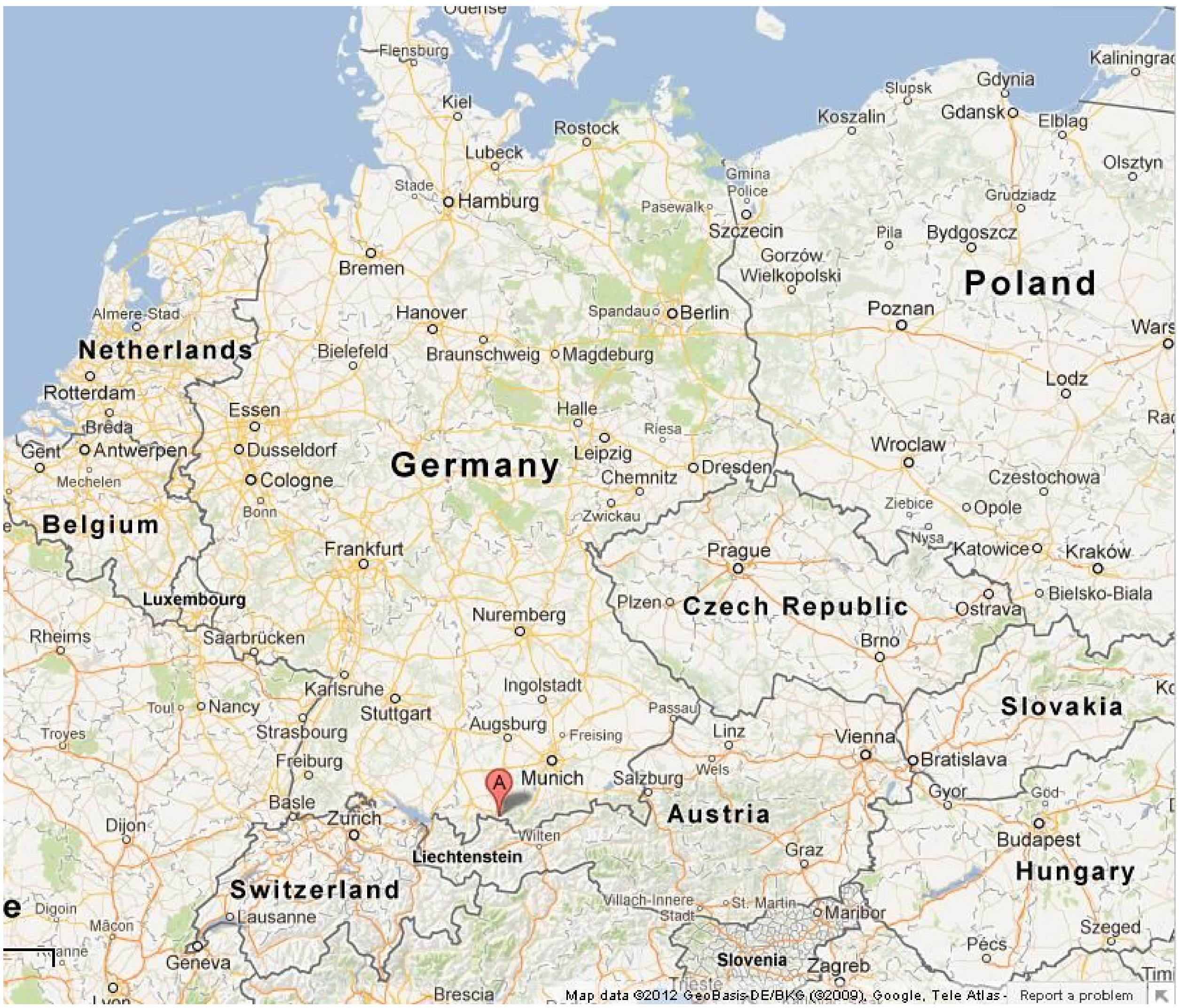

Figure 1: Location of Neuschwanstein Castle. *(World Easy Guides, 2018).*

Currently the most common method of finding meteorites is visually in the field which is expensive for researchers and time consuming. Jürgen Oberst of the German Aerospace Center Institute of Planetary Research launched a field expedition to find the Neuschwanstein Meteorite on May 1st of 2002 which he described the transportation of 29 researchers as simply "costly" (Oberst, 2004.) Ultimately this expedition was unsuccessful and it wasn't until several months and many smaller expiditions later that two amautuer metorite hunters found the first of the fragments (Oberst 2004). As meteorites can be sold remoteness of a meteorite and both be a blessing and a curse for researchers; with more remote impacts the chance of non-researchers getting the meteorite is lessened but the costs of travel and field work go up. If there was some way to know where the impacts were ahead of time costs could be dramatically reduced in that less people would have to go as it would be a recovery rather than a search and less time would need to be spent in the field.

This project intends to test the possibility of using freely available Landsat imagery to find the locations of meteorite fragments in an effort to guide future field researchers. Specifically the well documented 2002 Neuschwanstein Meteorite will be used to test this possibility.

Originally the more recent 2015 Sariçiçek Airburst Event was chosen but after several attempts to get it to read it became clear that there was not a great chance of this project being successful so so I set out to give it the best possible chance at making it work. Most importantly I switched from any meteorite to meteorites with Iron content so the Ferrous Minerals and Iron Oxide Indices might pick them up. Also given a few things I learned from working with Sariçiçek's data I created a set of conditions which would maximize the success rate. I then combed through reported meteorite impacts and recoveries to find the events that best met my set of conditions.

	Omolon	**Neuschwanstein**	**Dong Ujimqin Qi**	**Sterlitamak**
Iron content				
Air Burst				
Large Fragments				
Observed fall				
Time Between Fall and Recovery				
> 1972				
Overland				
Quality PRE Img				
Quality Post Img				

Desert				
No Snow				
Remote				

Table 1: Four Meteorites and Conditions Met. Data derived from The Meteorological Society's Meteoritical Bulletin Database and EarthExplorer.

This gave me four different meteorites which met enough of the criteria to warrant considered. Magadan from Russia in 1981, Neuschwanstein from Germany in 2002, Dong Ujimqin Qi from China in 1995, and Sterlitamak from Russia in 1990. In comparison to the others Magadan was clearly the weakest so that one was ruled out. The remaining three seemed relatively equal but looking into them more I ruled out the Sterlitamak impact as the exact impact site was described simply as "20 Km westward" of Sterlitamak. Ultimately I made a informed guess that Neuschwanstein was the better impact to study given it being more recent and that the recovery period between when the fall occurred and meteorite fragments were recovered.

Methods

A couple of factors made finding the correct data for Neuschwanstein difficult. The meteorite fell April 6, 2002 into a mountainous area meaning that late snow on the slopes remained well into late spring. Fortunately although a search was conducted beginning on May 1st it wasn't until July 14, 2002 that the first of the meteorites found (Oberst, 2004). So using July 14th 2002, the date the first meteorite was found, as the upper limit, I gathered a Post-Impact Landsat 7 imagery data from Earthexplorer. I ended up using imagery for June 17th for the desired area which was snow and cloud free.

Similar reasoning guided the decision to obtain Pre-Impact imagery, but it's procurement ended up being much more difficult. There wasn't both snow and cloud free imagery available August 14th 2000, almost two years prior to the impact. I figured, perhaps incorrectly, that iron levels area would not change much in two years so I used that imagery for my original results. However, unhappy with the results I went back and grabbed imagery closer to the impact in the hopes that snow vs no snow would make less of a difference than two years time. This imagery ended up being from March 29th 2002, very close to the impact date.

To create my ROI I first found coordinates for Neuschwanstein I and II from Juergen Oberst's 2004 paper, "The multiple meteorite fall of Neuschwanstein: Circumstances of the event and meteorite search campaigns."

Fragment	Coordinates
Neuschwanstein I	47°31'26.1"N 10°48'28.9"E

Neuschwanstein II	47°32'01.9"N 10°48'29.4"E
Neuschwanstein III	Unlisted

Table 2: Oberst, 2004 Coordinates.

I used Google Earth to mark those locations and save them to My Places. The coordinates for Neuschwanstein III were not listed so I compared the map Oberst included in his paper, to Google Maps non imagery view to find approximate coordinates for Neuschwanstein III (See Figure 1). These coordinates were marked and saved in Google Earth. This data was then exported as a KML file and then imported into ArcMap using the KML to Layer feature. This data was exported as a point shapefile and then reprojected in WGS_1984_UTM_Zone_32N to match the Landsat data.

Figure 2: *"Map showing the predicted strewn field of the Neuschwanstein meteorites within the Ammergebirge and locations of the first, second, and third (A, B, C) meteorite recoveries" (Oberst, 2004).*

This point shapefile was then imported into ENVI using the import vector option of the ROI tool. Using these points a new ROI was created that encompassed all the meteorite finds as well as an appropriate amount of surrounding area. This new ROI was then used to subset the 6/14/2002, 8/14/2000, and 3/29/2002 Landsat 7 imagery.

I used the Spectral Indices tool to perform a Ferrous Minerals and Iron Oxide analysis on all three data sets. Then using the Band Math tool I compared the Pre-Impact imagery analyses to the Post-Impact imagery analysis. These final Band Math results were opened in ArcMap. The results were each classified similarly to show four levels of change. The original projected Neuschwanstein impacts point shapefile was reopened in ArcMap and overlain over the results for comparison.

To create Figure 6 I used what I felt was the best data, Figure 5: Iron Oxide Using Pre-Imagery from March 29th 2002 as a base in ArcMap but I removed the color from all classifications except for the Most Change category. (I had trouble converting using the Raster to Vector Tool where I had hoped to simply delete the other categories which I have done before but for some reason could not do it using the exported ENVI data either in the geotif or .dat format. This is something I will need to look into in the future.) I overlaid the Neuschwanstein impacts point shapefile. Again using Figure 1 from Oberst, 2004, I create an approximate polygon in Google Earth matching the meteorite trajectory. This polygon was exported as a KML, imported and projected to WGS_1984_UTM_Zone_32N using the KML to Layer and Project tools, and then overalain over the final image.

Results

Figure 3: Ferrous Minerals Change Using Pre-Imagery from August 14th 2000.

Figure 4: Ferrous Minerals Change Using Pre-Imagery from March 29th 2002.

Figure 5: Iron Oxide Change Using Pre-Imagery from August 14th 2000.

Figure 6: Iron Oxide Change Using Pre-Imagery from March 29th 2002.

Figure 7: Possible Locations of Meteorite Fragments By Most Iron Oxide Change Using Pre-Imagery from August 14th 2000.

Discussion

As far as Neuschwanstein I and II I could not see any meaningful correlation between the results of any of the analyses that I performed. If anything Ferrous Minerals Change Using Pre-Imagery from August 14th 2000 and Iron Oxide Change Using Pre-Imagery from March 29th 2002 show a negative correlation.

When performing the final analysis I did not use Neuschwanstein III to make any meaningful decisions as the exact coordinates were not known and its purpose was only to help create an accurate ROI.

Ferrous Minerals Change Using Pre-Imagery from March 29th 2002 does seem to show a slight positive correlation between the coordinates and Ferrous Minerals Change, but because there is so much background change, some of it much more intense than the change at each impact site, that I feel these are not meaning results.

While Figure 5 is hampered by the snow interfering with the results Iron Oxide Change Using Pre-Imagery from August 14th 2000 was not encumbered that way. These results were possible the best in that they showed the least dramatic change overall. They showed a very slight correlation between change and the coordinates, although I wouldn't describe it as meaningful. Given that the results from Figure 6 were the best it was used for Figure 7 in the assumption of IF there was a correlation shown in Figure 6 these would be possible sites for field researchers to look. Given the meteorite trajectory and other fragment locations proximity to these possible site there does exists a small chance that the analysis worked and there are meteorite fragments at these locations, although I doubt it.

Overall I would say that I was unsuccessful in my analysis, although I would not be willing to say that better analyses couldn't possibly work.

There were several problems with study, the most glaring is resolution. 30m Landsat data is just too corse. I suspect that Sentintal 2 10m resolution is still too corse although as all my data preceded it's launch I could not test that theory. As far as resolution goes I think that sub 1 meter might be necessary which given the temporal resolution needs puts the only data in private/commercial hands. While not impossible to obtain, this does make it harder and more expensive to do.

I think if I had to do this exact project again I would have selected the Dong Ujimqin Qi meteorite. Actually I am kicking myself for not having picked this one in the first case. At the time I believed the date difference 2002 vs 1995 would make a bigger difference than the other factors. I think know the trees and shadows from the mountains in the Neuschwanstein data made a bigger difference than using a newer satellite. I think resolution issues would still be a problem but I keep wondering if maybe this would have worked is it wasn't for the vegetation. I may have to do a quick check of this in the future to satisfy my curiosity.

The problem with Iron bearing meteorites is that it only makes up for a fraction of what lands on Earth. The majority don't contain any iron at all. This is especially problematic as often researchers don't know if it's iron bearing or not until that actually recover it so ultimately even if the resolution needs were met and this method could successfully pinpoint meteorite fragments it would still only be successful in a small amount of cases. I don't think that fact necessarily kills the idea though, as it is a relatively easy task to perform and could save money by cutting field time substantially in the cases where it did work.

The more I think about it the more I think Thermal Imagery may be the way to go. I think this would work especially well with with iron bearing meteorite but could still work with rocky meteorites as well. I suspect the emissivity differences between the meteorites and vegetation would pop out if the resolution was good enough. If I was tasked with finding meteorite in Antarctica I would design a high spatial resolution Thermal Imagery UAV.

Conclusion

I would conclude that given the spatial resolution that in most cases it will not be possible to use Landsat data to find meteorite fragments. I would suspect that the new Sentinel 2 data will not be much different.

This, however, does not mean that finding meteorite fragments by means of remote sense rather than expensive field searches is impossible. I would suspect that sensors with very fine spatial resolution imagery and decent temporal resolution will be able to pick up on fragments. Unfortunately this imagery is not freely available so further testing should be done to see if this method is financially worth it.

While ultimately not successful I did learn a lot about ENVI and indices and their limitations. I have a couple of directions and leads to pursue if I ever wanted to try my hand at this project again.

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