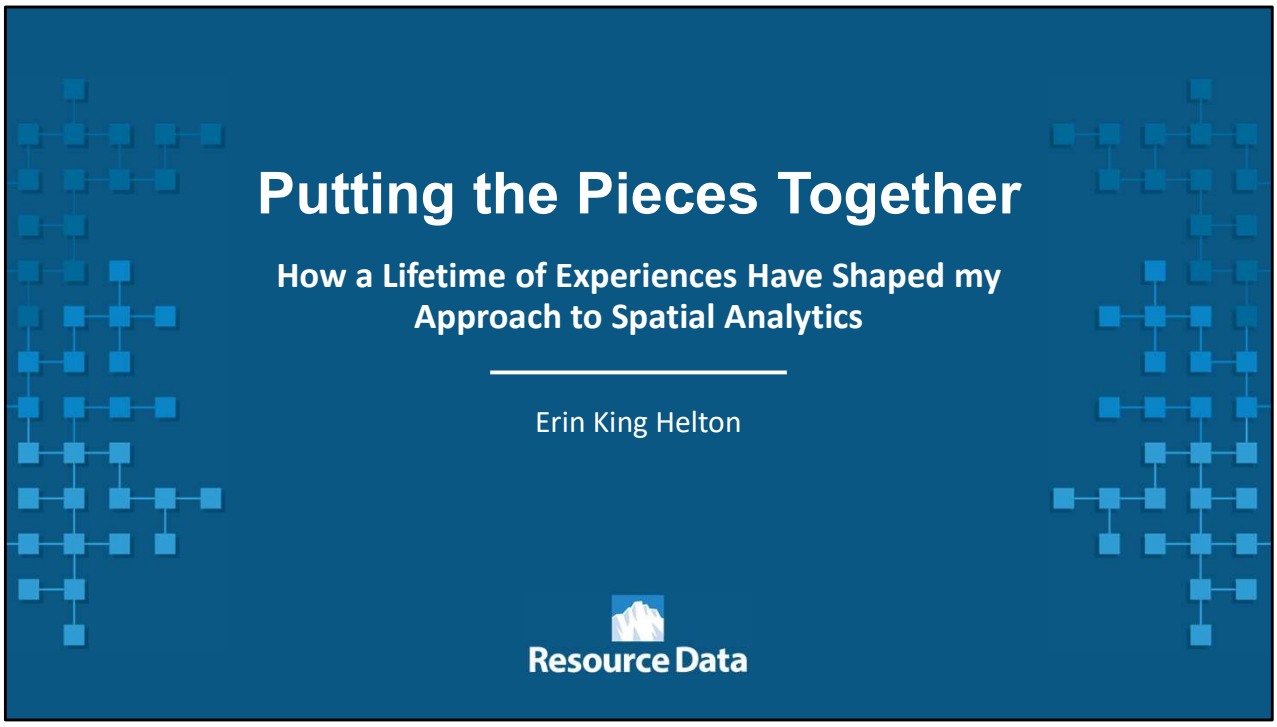

To introduce myself, my name is Erin King Helton. I've been a GIS professional for about 14 years now. If you watch the History Channel you may have caught me on the last season of the Curse of Oak Island. I'm really honored to have been invited to talk to you today about my approach to spatial analytics. I guess one could call it a "wholistic approach", and it's the result of all of my combined professional experiences that have resulted in some outside the box thinking,. And I've tried to apply these ideas to solve some rather interesting problems and mysteries.

How it started…

UNIVERSITY OF TORONTO

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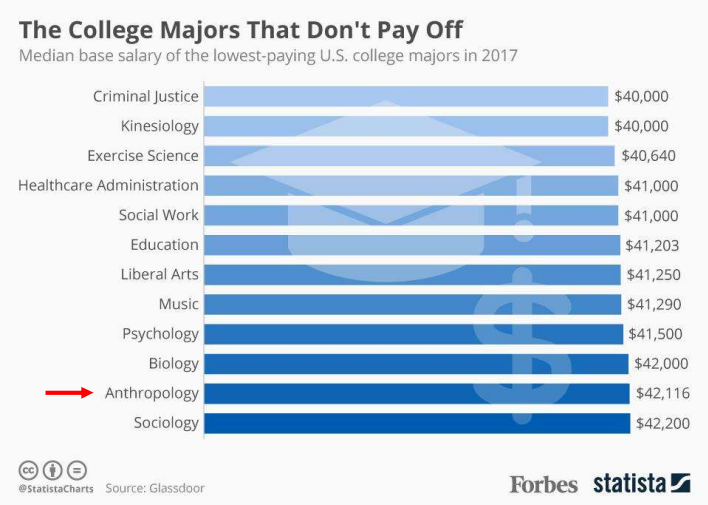
I actually started my undergraduate schooling in archaeology. I was studying at the University of Toronto in Canada, which is where I'm originally from. I was halfway through the four-year bachelor's program and I was starting to become painfully aware of how limited my career prospects were going to be with my degree choice.

How it started…



Archaeology is generally lumped under the “anthropology” field of study, which has repeatedly been recognized as one of the lowest paying majors. So, I remember telling myself halfway through school “you know, I really like archaeology, but I’d also really like to be able to afford to eat…”

How it started…

And that's when I decided to add GIS as a minor. I had been exposed to GIS in a geography course and thought it would both make me more valuable in the field of archaeology, but also provide a fallback plan if a career in archaeology didn't pan out. This turned out to be one of the best decisions I ever made. As soon as I graduated, I immediately found work with a local cultural resources management firm as a GIS technician. However, the Great White North poses some unique challenges in archaeology. The ground freezes in the winter, which means the work is seasonal. So, I decided to move south, here to Texas. Once again having GIS under my belt made finding work easier. I became a GIS Specialist for a CRM firm here and also assisted as a field technician.

Which I have to say as a Canadian in Texas was an interesting experience…
As a GIS Specialist I was also involved in developing survey strategies for upcoming projects. This involved downloading historic maps and aerials, soils data, hydrology, and previously recorded sites to determine areas that had high or low potential for encountering cultural features.

I was also exposed to 3D modeling with LIDAR. These are some pictures of Panther Cave in Seminole Canyon, Val Verde County. I assisted in the short-range lidar capture and mapping of the cave, which was a joint project with the Shumla Archaeological Research & Education Center, National Park Service, and Texas Parks and Wildlife.

Archaeological Prospection
Archaeol. Prospect. **17**, 67–72 (2010)
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(www.interscience.wiley.com) DOI: 10.1002/arp.374

LiDAR-derived Local Relief Models – a new tool for archaeological prospection

RALF HESSE*

State Office for Cultural Heritage Baden-Württemberg, Berliner Strasse 12, 73728 Esslingen am Neckar, Germany

ABSTRACT Local relief models (LRM) are proposed as a new tool for archaeological prospection. A data processing approach is presented which produces LRM from LiDAR-derived high-resolution digital elevation models (DEMs). The LRM represents local, small-scale elevation differences after removing the large-scale landscape forms from the data. The LRM greatly enhances the visibility of small-scale, shallow topographic features irrespective of the illumination angle and allows their relative elevations as well as their volumes to be measured directly. This makes the LRM an improved basis for spatially extensive archaeological prospection over a wide range of landscapes. The LRM raster map of local positive and negative relief variations can be used for the mapping and prospection of archaeological features such as burial mounds, linear and circular earthworks, sunken roads, agricultural terraces, ridge and furrow fields, kiln podia and mining/quarrying sites. This approach is currently being used in a project aimed at the complete archaeological mapping and prospection of the state Baden-Württemberg (Germany), covering an area of 35 751 km². The goal of the project is the verification and extension of the existing archaeological data base. An object-based local relief vector layer is produced as a by-product; however, due to the common amalgamation of natural and anthropogenic features this cannot be used efficiently for archaeological prospection at present. Copyright © 2010 John Wiley & Sons, Ltd.

Key words: LiDAR; airborne laser scanning; archaeological prospection; data processing; local relief model; Baden-Württemberg

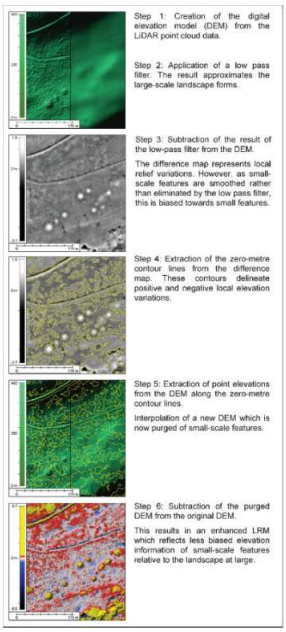


Figure 1. Workflow for the creation of local relief models.

7

I also became familiar with a GIS technique called “Local Relief Modeling” and started playing with the method for both ground surface and stone surface enhancements. This technique was first published in 2010 by Ralph Hesse and consists of a multi-step geoprocessing workflow that purges a Digital Elevation Model or surface model of natural undulations to only leave behind “man-made” scaled features. This made interpreting ground scarring or rock carvings much easier. In some cases, it revealed features that otherwise would have been invisible, obscured by the much more prominent natural topography.

To continue advancing my career, I completed my Masters degree at University of North Texas in Applied Geography (GIS emphasis of course) and I perpetuated my interest in archaeology by making it a minor. I was drawn to the program at UNT because unlike most universities that house the archaeologists in the anthropology department, UNT has them as part of the geography department. However, as I was approaching graduation I made the tough decision to leave cultural resources management and embarked on a new career path more focused on GIS exclusively. This is when I joined my current GIS and IT consulting company Resource Data. While here I began to pick up some new skills, predominantly coding and

automation. I learned how to build custom tools, web map applications, and automate what would otherwise be cumbersome and time consuming workflows.

Mosquito Predictor Tool

ArcMap Toolbox – Python 2.7
Multi-Criteria Decision-Making Analysis
& Weighted Decision Matrix

The BIG Picture

The tool can be used to identify areas of highest risk for Zika carrying mosquito species

Aedes Aegypti

- Only need a small amount of water to lay eggs. Bowls, cups, fountains, tires, barrels, vases, and any other container storing water make a great "nursery."
- *Ae. aegypti* mosquitoes prefer to live near and bite people.
- *Ae. aegypti* don't fly long distances. In its lifetime, these mosquitoes will only fly within a few blocks.

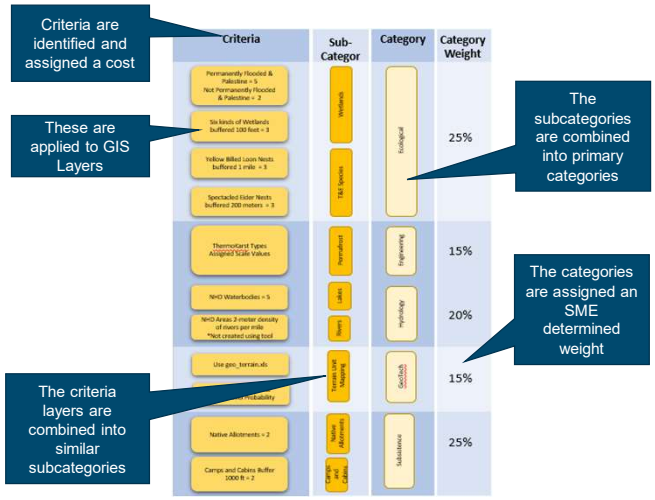
8

For Harris County Public Health
Key Features:

- Change input datasets with ease
- Different weights for different risk factors
- Run multiple times
- Wanted to compare different factors/results with real-life results from their mosquito traps around the county.

Site Selection Tool

ArcGIS Pro Toolbox – Python 3.7
Multi-Criteria Decision-Making Analysis
& Weighted Decision Matrix

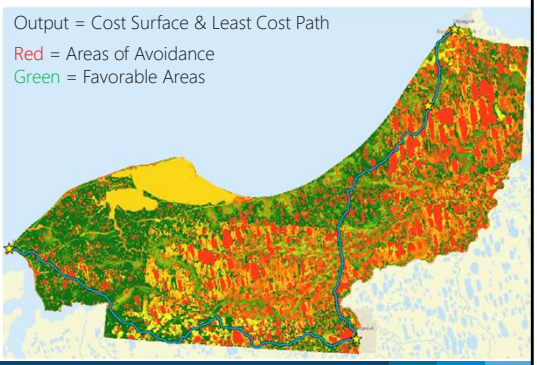


The BIG Picture

The tool can be used to identify the best location for any business need for any location on the globe.

road construction
pipeline right of way
wind turbines
building location
underground utilities
water source
well locations

Output = Cost Surface & Least Cost Path
Red = Areas of Avoidance
Green = Favorable Areas



9

Key Features:

- Change input datasets with ease
- Different weights for different risk factors
- Run multiple times

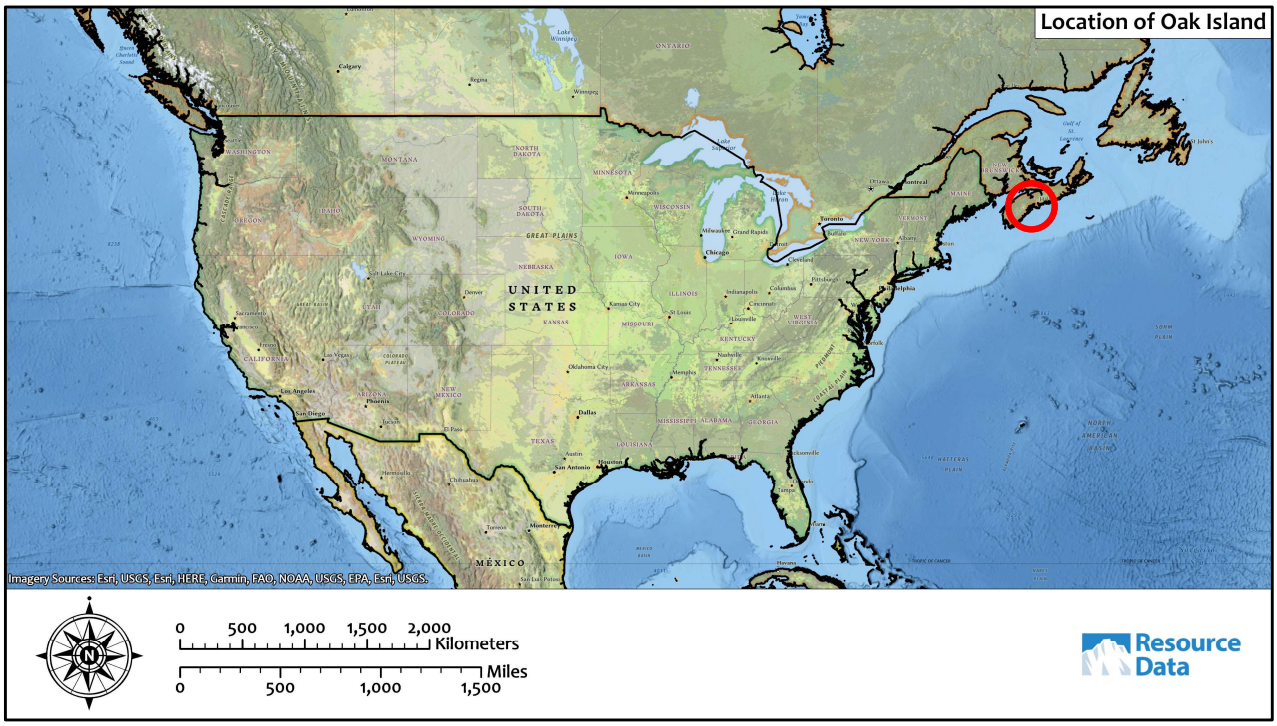
Predictive Modeling = Self-Fulfilling Prophecy?

10

As wonderful and as powerful as these predictive modeling tools can be, I think we have to remember that with great power comes great responsibility. If predictive models are misused, they run the risk of becoming a self-fulfilling prophesy, especially when they are used to guide sampling strategies. This is especially true when it comes to Cultural Resources Management and archaeology. As I was often involved in predictive modeling to determine which areas are more or less likely to contain archaeological sites. However, these models were frequently used to propose more or less surveying in these areas. Regions flagged with higher potential for sites will get surveyed more, and areas flagged with lower potential will be surveyed less. However, this poses a major risk of introducing sample bias. Obviously, if a region is sampled more, more sites will be found. And if a region is sampled less, less sites will be found – perpetuating the self-fulfilling prophesy. However, finding sites in places we don't expect (like a low probability area) means we don't fully understand why they are there. Therefore, sites found in low probability areas have MORE research potential. In fact, a strong case can be made that archaeological sites encountered in low-probability areas should actually be studied more, not less. They have more potential to teach us something new, rather than simply re-affirm what we already know. And I think this is a perfect segue to

my next topic….Oak Island

Oak Island is a perfect example where we should be doing more research. Archaeology that has been conducted on the island has discovered all sorts of features that do not follow the current narrative and challenge our conventional understanding of early North American history.

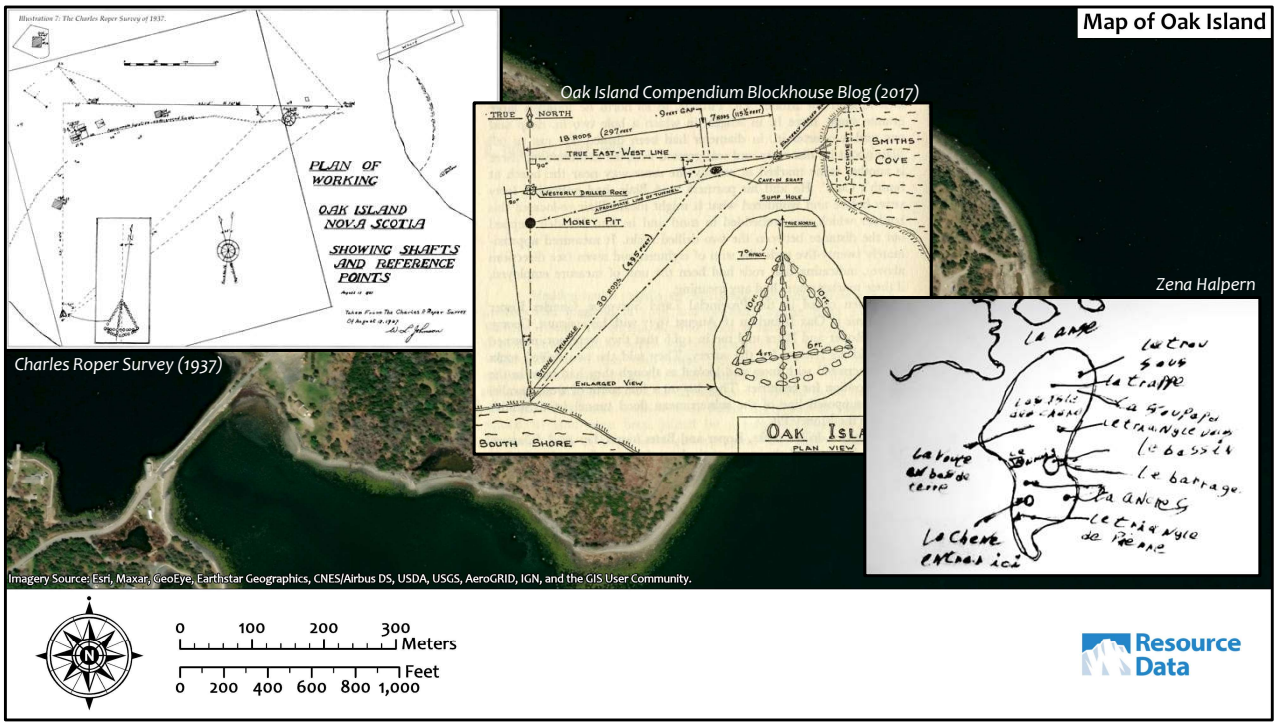


For those who are not familiar, Oak Island is a small island in Mahone Bay of Nova Scotia Canada. It has been subject to over 220 years of investigations, believed to be the location of a massive hidden treasure. Theories about the treasure range from pirate booty, to ancient artifacts hidden by the knights templar. Searchers have even included 32nd President Franklin Roosevelt, who was involved in the searches for decades.

The story begins in 1795 with the discovery of what is called the “Money Pit” that is at least 90 feet deep. This pit appears to have been guarded by a flood tunnel system that was triggered when attempting to dig deeper than the 90-foot threshold.
There are also numerous historic reports of the flood tunnel system being uncovered in Smith’s Cove to the east, with water being drawn in through 5 finger drains covered by mats of coconut fiber. Coconuts, of course, are not native to Nova Scotia. Over the centuries, numerous dig attempts have been made to work around the flooding, all in vain. Some have even died trying.

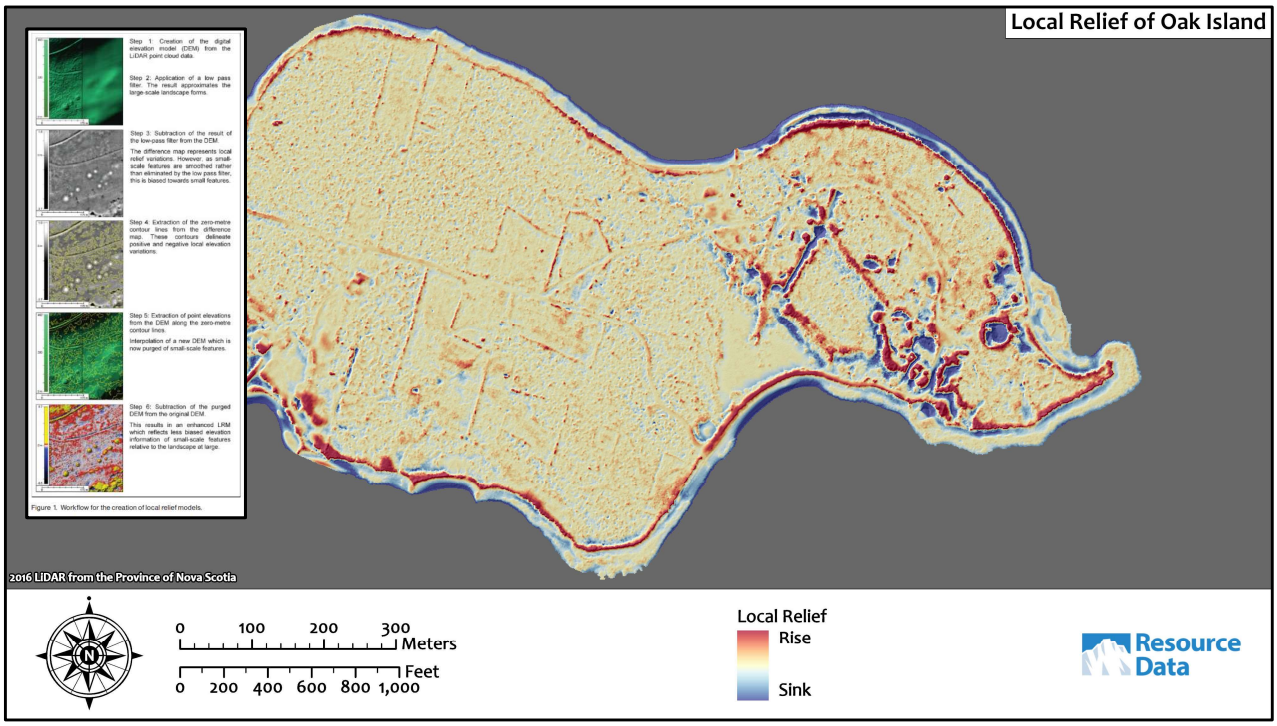
More recently, two brothers Rick and Marty Lagina along with a few other partners have purchased the majority of the island to embark on their own investigations. This is what has become the TV show The Curse of Oak Island on History Channel. I’ve been a huge fan of the show, I’ve been watching it since the beginning. And I was particularly excited when they brought on surveyor Steve Guptill. I thought “YES finally they’re going to start documenting and collecting some real data on the island!” Unfortunately, while they spend a lot of time collecting the data, they didn’t really spend a lot of time analyzing it, putting it all together. I started to reach

out to them suggesting that they needed a dedicated analyst – to which I got little-to-no response. It definitely caused me some frustration. And I finally decided “fine, I’ll just do it myself”.

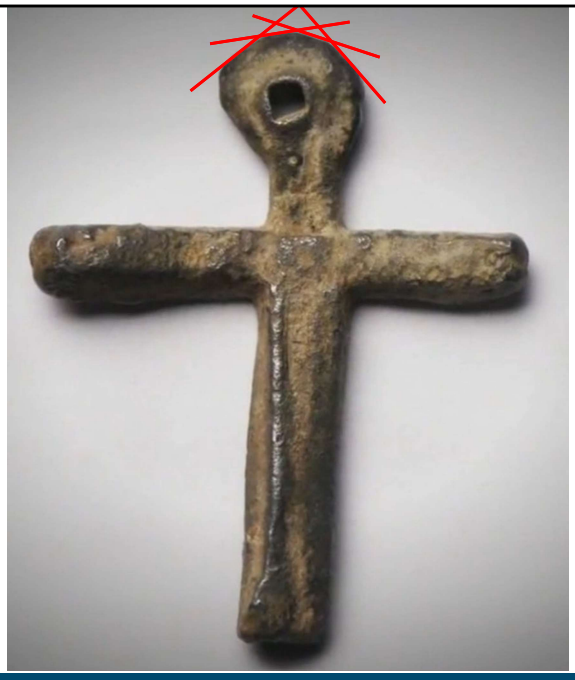


I collected as many datasets as I could, especially LIDAR, historic aerials and maps. I started trying to make sense of it all looking for common elements between what seemed to be inconsistent and incohesive data.
After making some profound discoveries myself….

I finally got their attention.
And now I'm going to share some of my work and discoveries with you.



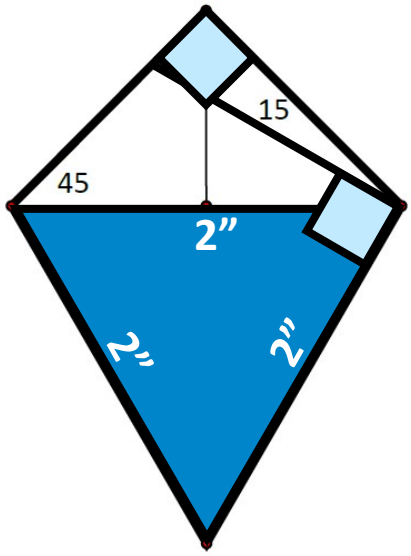
The Province of Nova Scotia offered free 2016 LIDAR that covered the island. So naturally I wanted to apply the Local Relief Modeling techniques that I'd learned about while working in cultural resources management. However, now that I could code, I could turn what was usually a manual 6-step workflow into an automated tool. This allowed me to run the analysis multiple times in a flash, trying out different parameters each time to optimize the results for the island's unique topography. Learning to code and automate had made me a much more powerful and efficient analyst.



17

My background in both archaeology and as a spatial analyst also resulted in some unusual ideas about the significance of one of the most popular artifacts found on Oak Island – the lead cross. This artifact was found in Smith's Cove and laser ablation analysis suggests that the lead derived from a mine in south-central France which was active in the middle ages.

- The first thing that stood out to me about this artifact was that the head is not quite round, has a series of flat edges. Lead is of course softer than most metals, and the rim around the head is the thinnest part of the artifact
- Suggested to me that perhaps a ruler or straight edge had been repeatedly butted up against it.
- Arms and head are bent forward, which gave me a crazy idea….



18

Laid the cross face down so it was resting on its hands, feet and head. Then used a ruler against its four edges. I was shocked to discover that this highly irregular cross with different length arms was actually capable of drawing some very precise angles

- Equilateral triangle on the bottom, exactly 2”
- Square 90 degrees on the top
- Even following the square hole in the head produces a second square angle

- Could this have been used as a protractor? Was this a tool? Not a religious keepsake?

God the Geometer, The Frontispiece of Bible Moralisee, circa 1220-1230

Section of “School of Athens”, Room of Segnatura, Vatican, 1509

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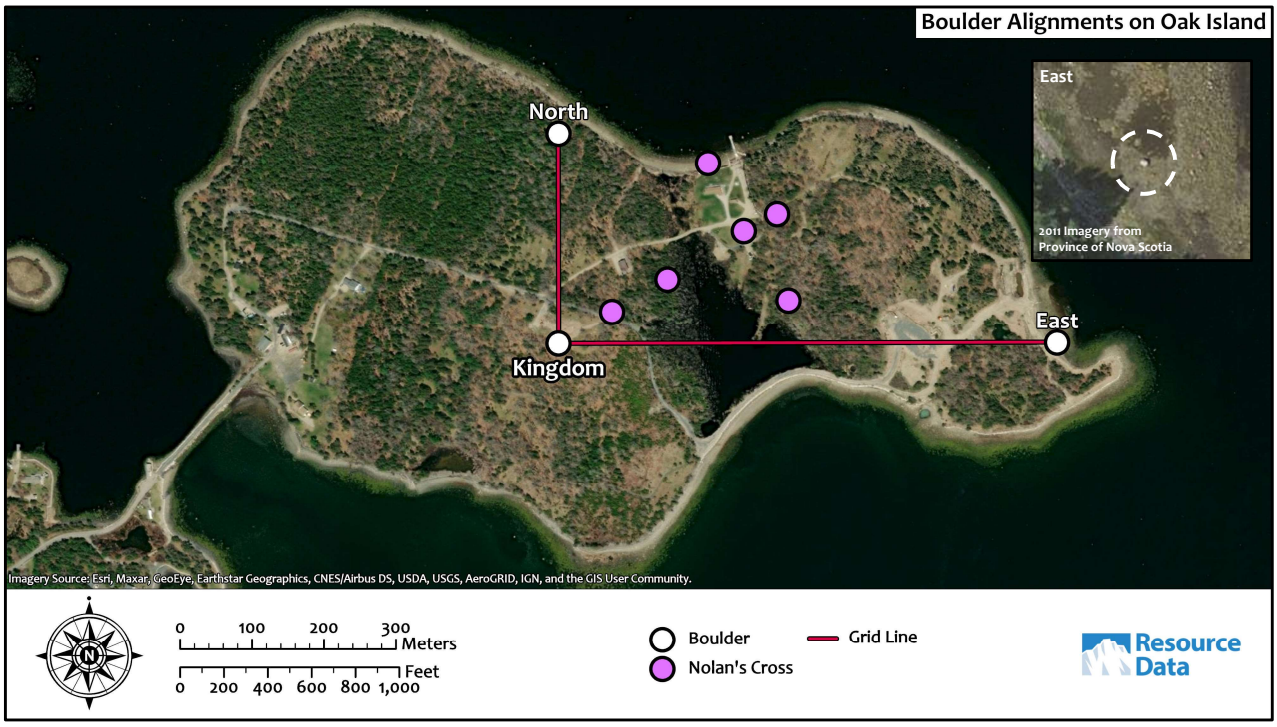
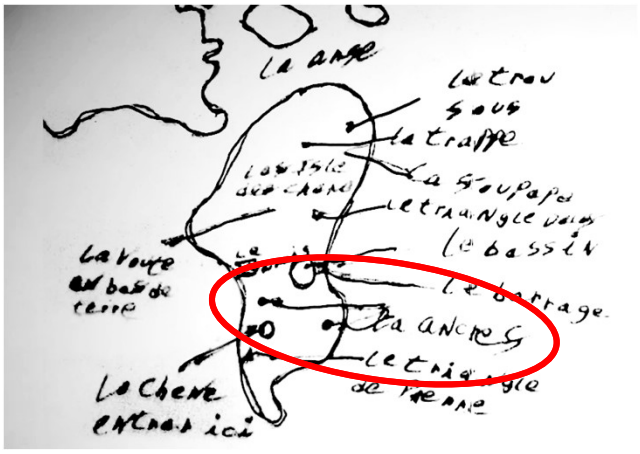
Reminded me of the tools like the square and compass have been used for centuries, their symbols even preserved in brotherhoods like the masons. These aren’t just symbols, these are practical tools that were used in specialized trades – including structural building and cartography.

There is evidence of a square grid across the island


Boulder Alignments on Oak Island
East
2011 Imagery from
Province of Nova Scotia
North
Kingdom
East
Imagery Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.
0 100 200 300 Meters
0 200 400 600 800 1,000 Feet
Boulder
Nolan's Cross
Grid Line
Resource Data

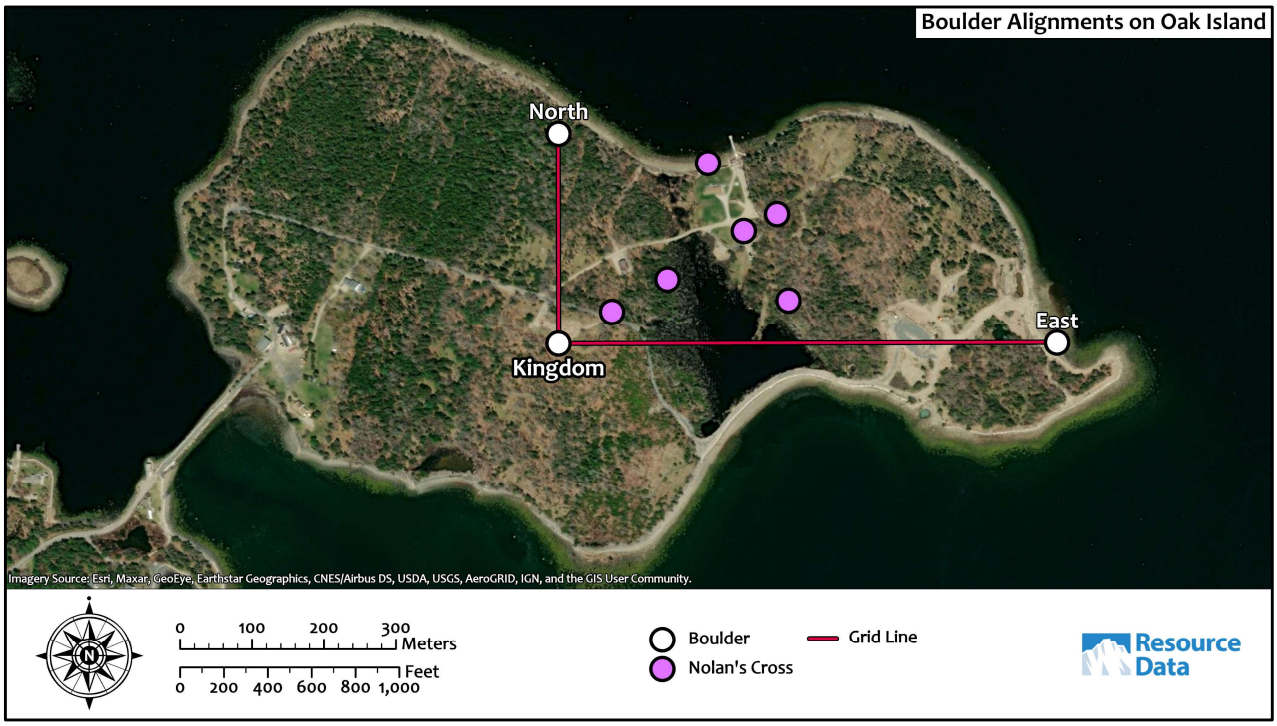


Survey Markers!

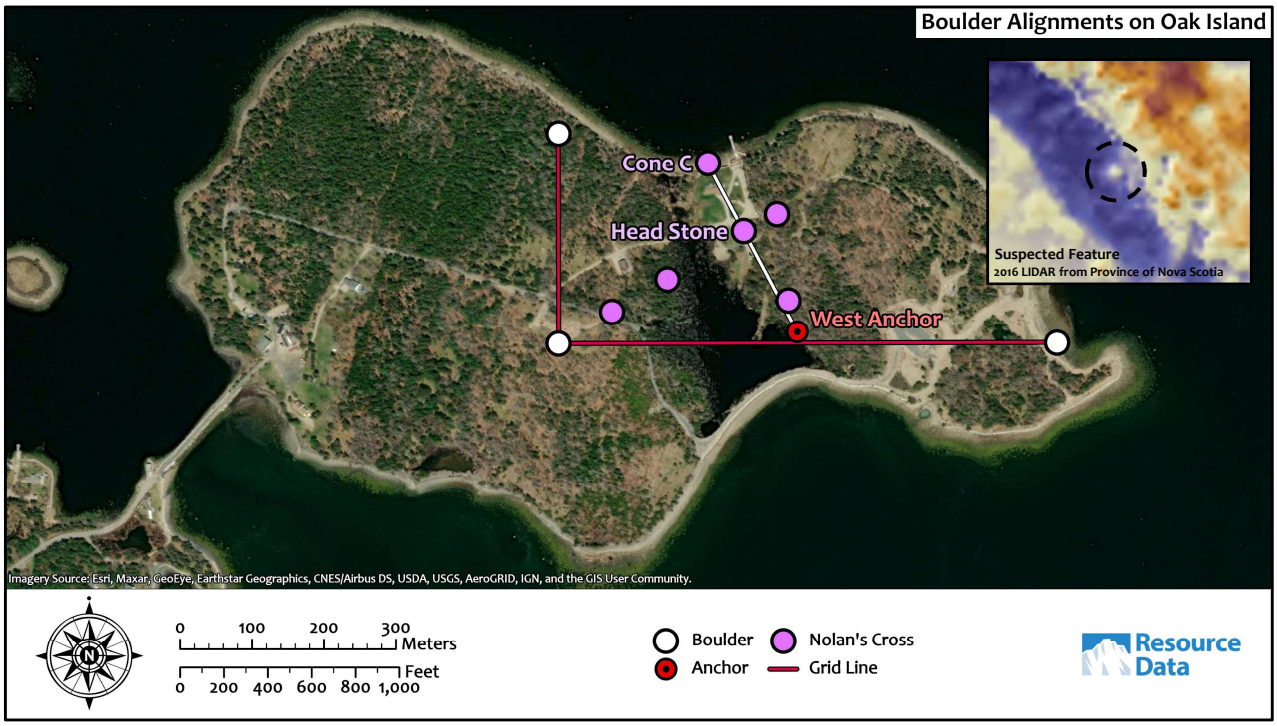
22

From here, I turned to the map that was presented by Zena Halpern. This map is met with a lot of controversy, many believe it is fake and holds no value. I'm not quite so sure. And I was particularly interested in the features that were marked as "the anchors"

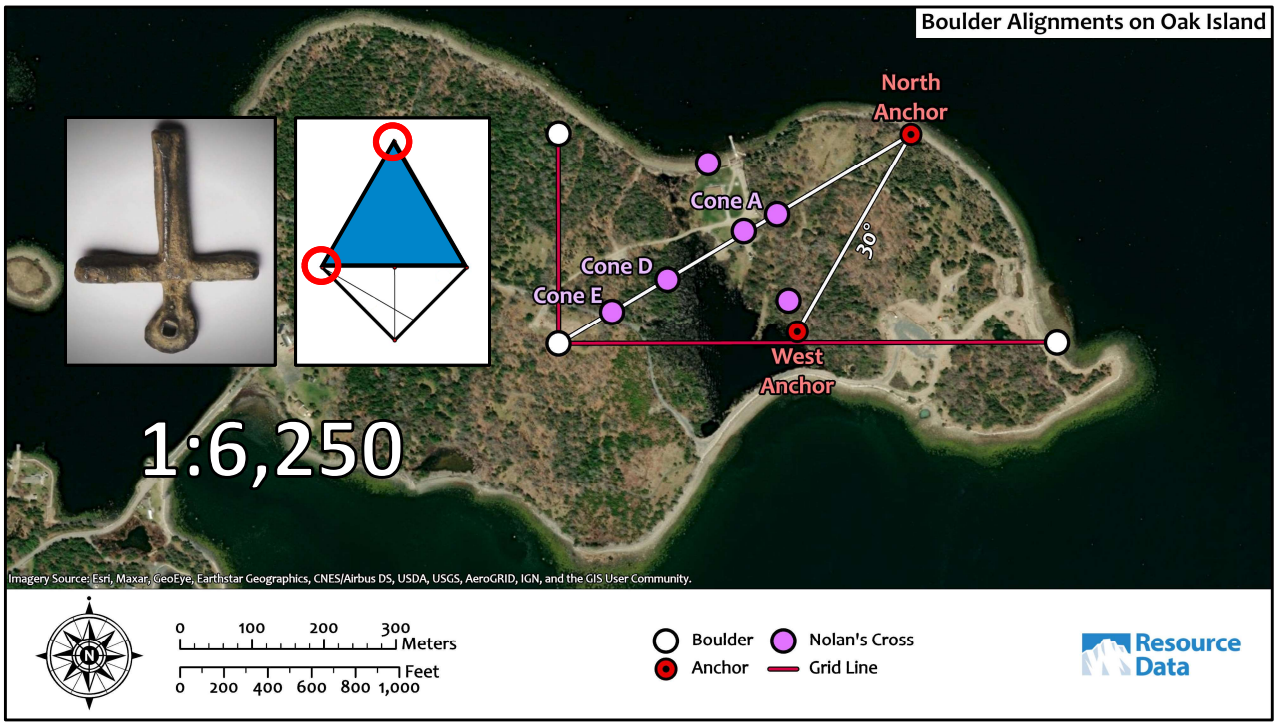
- On land, not in the water. So they probably aren't nautical anchors.
- I think much more likely they are anchoring something on the ground. I suspect that these anchors are actually survey markers. Anchoring alignments and triangulations of other features across the island



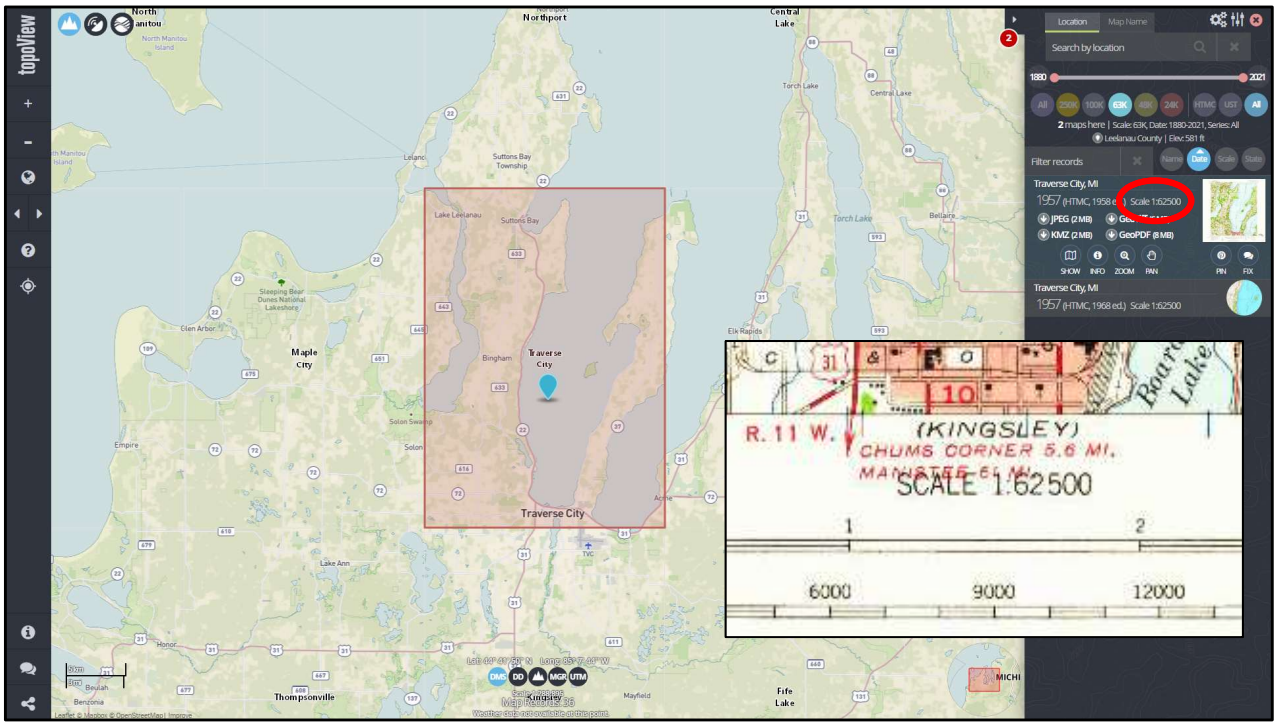
While most alignment theories have focused on the most familiar boulders of Nolan's Cross, I believe that the Anchors are actually the first two stones that other boulder positions derived from. In order to test this theory out, we need to know where the Anchors are. So I attempted to use the Nolan's Cross and LIDAR to help reverse engineer their locations.



I ran a line down from Cone C, through the Headstone, and down towards the grid line. It crossed over an unusual feature that stood out quite prominently in the Local Relief Model on the east side of the swamp. The Oak Island team investigated it and discovered a small boulder with a small pit or hole on the top.



The lidar was less helpful for the North anchor but this is why I chose the spot that I did. I drew a line at 30degrees from the West Anchor, and ran a line from the Kingdom Stone or “grid origin” through the spine of Nolan’s Cross. The intersection is where I placed the proposed North Anchor. Why 30 degrees? Because I suspect these two stones were meant to be used with the Lead Cross to start the map. The lead cross combined with these two anchors appeared to be the starting points for a map of Oak Island with a scale ratio of 1:6250. This scale might not seem very significant, but I’d seen numbers like this before….



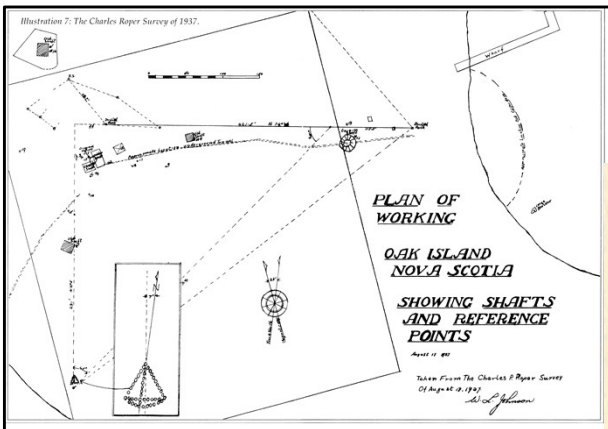
When working in cultural resources management I used to download historic topographic maps for the area that was going to be surveyed. This TopoView website is one that I used regularly. Many historic topos for the United States are in a scale of 1:62,5000, which is a slightly rounded off figure that represents 1 in = 1 mile

1:63,360 → 1 in = 1 mi

1:62,500 → 1 in ≈ 1 mi

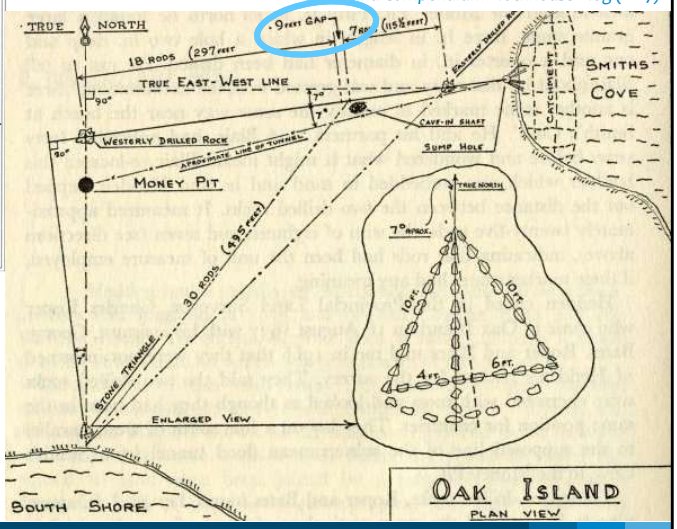
1:6,250 → 1 in ≈ 0.1 mi

Therefore, the combination of the Lead Cross with the two Anchors is starting a map that very closely estimates 1 in = 1/10 of a mile.



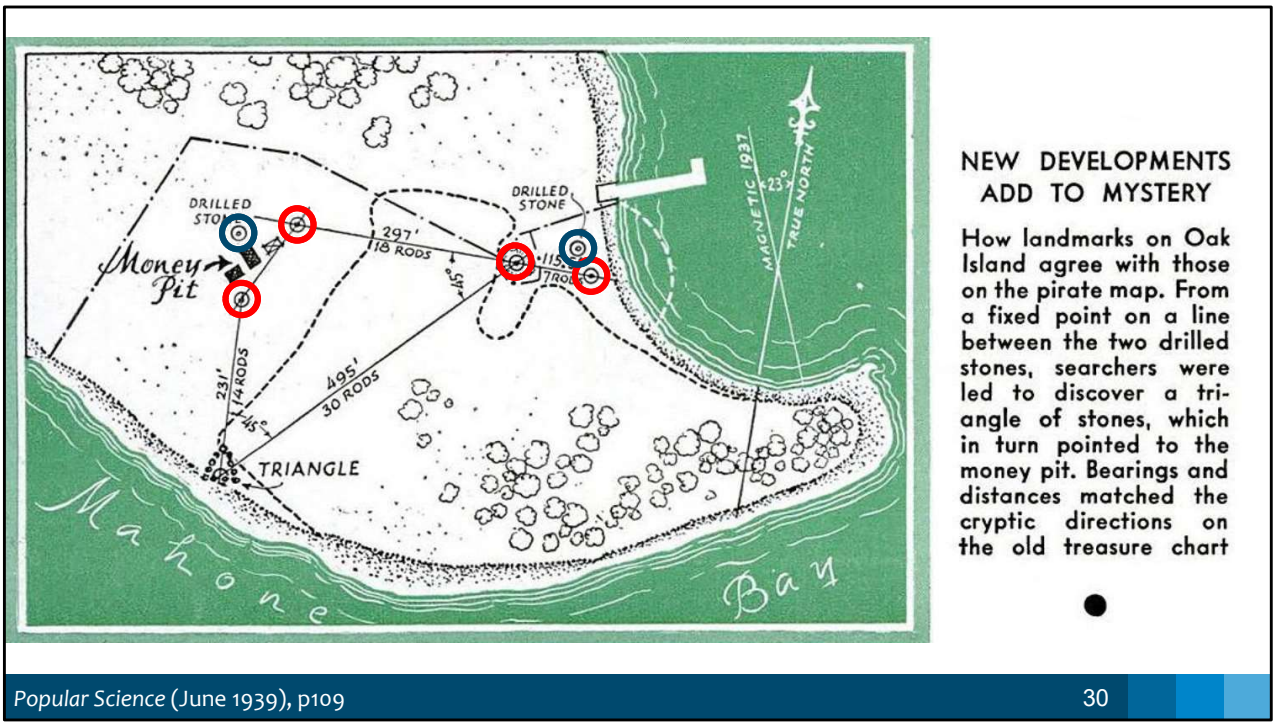
Charles Roper Survey (1937)

Oak Island Compendium Blockhouse Blog (2017)



29

- Next, I turned my attention to the numerous maps that have been made of what is known as the “Money Pit Area”
- Money Pit area has been subject to centuries of searcher activity. Most original features are long gone, destroyed or removed. So these map collections and old search records are all we have.
- A lot of weird measurements between the “West Drilled Rock” and the “East Drilled Rock” features that just don’t make sense
- These maps have scale issues too, they do not georeferenced well and when they are compared to each other their data is inconsistent



NEW DEVELOPMENTS ADD TO MYSTERY

How landmarks on Oak Island agree with those on the pirate map. From a fixed point on a line between the two drilled stones, searchers were led to discover a triangle of stones, which in turn pointed to the money pit. Bearings and distances matched the cryptic directions on the old treasure chart

Popular Science (June 1939), p109

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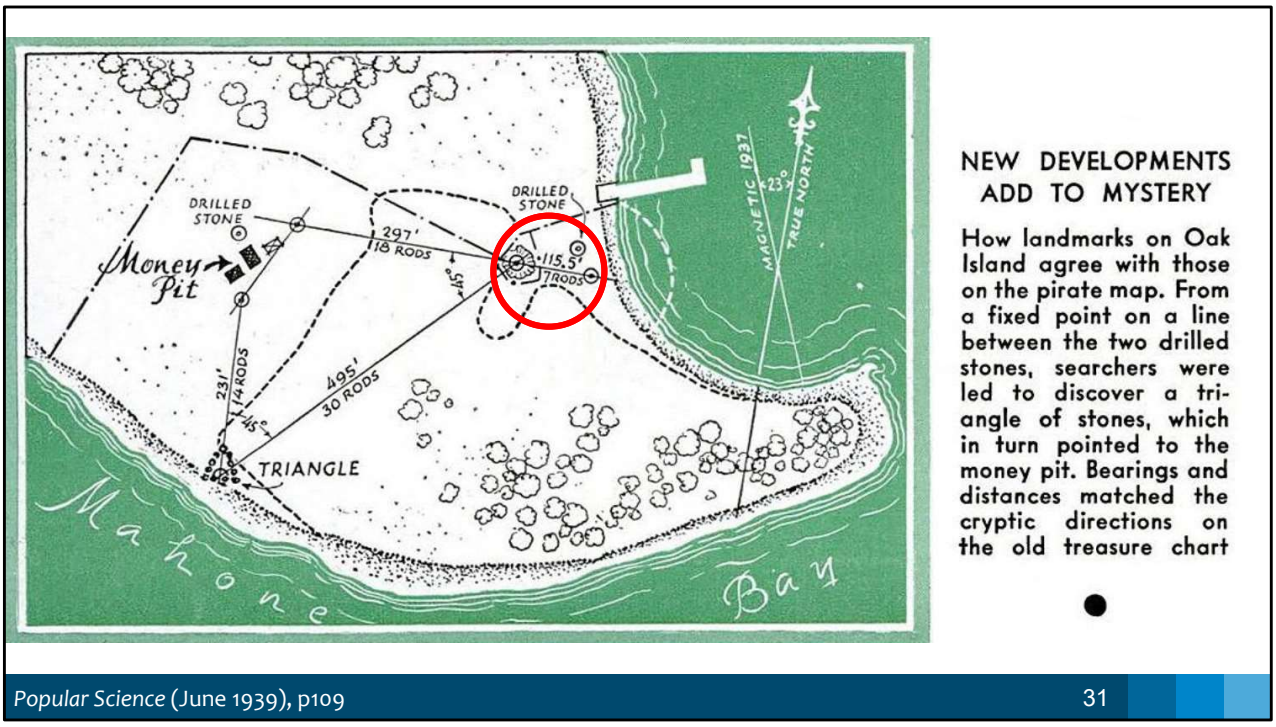
- This map has a series of other boulders, and the measurements have to do with those. Makes much more sense
- Now this map isn't perfect either, but it seemed to have the clearest and most logical depiction how these survey measurements were meant to be interpreted.
- So with this map, I began to piece together where these boulders probably used to stand



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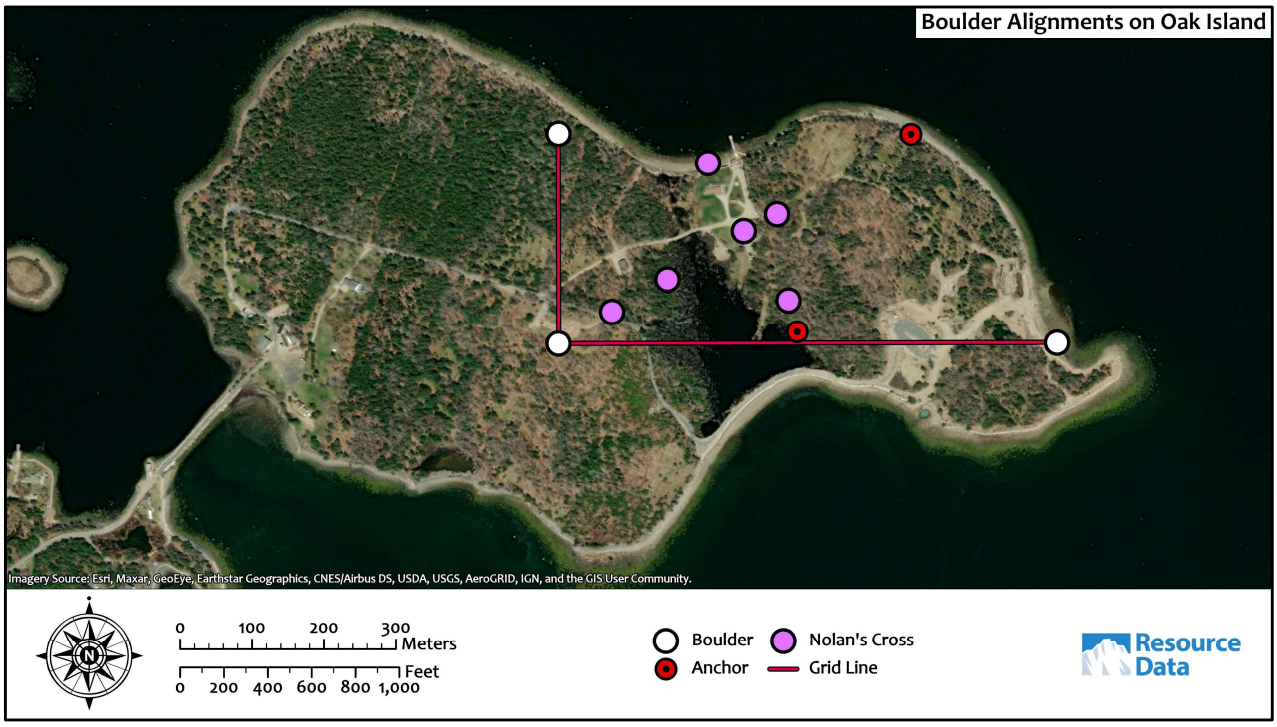
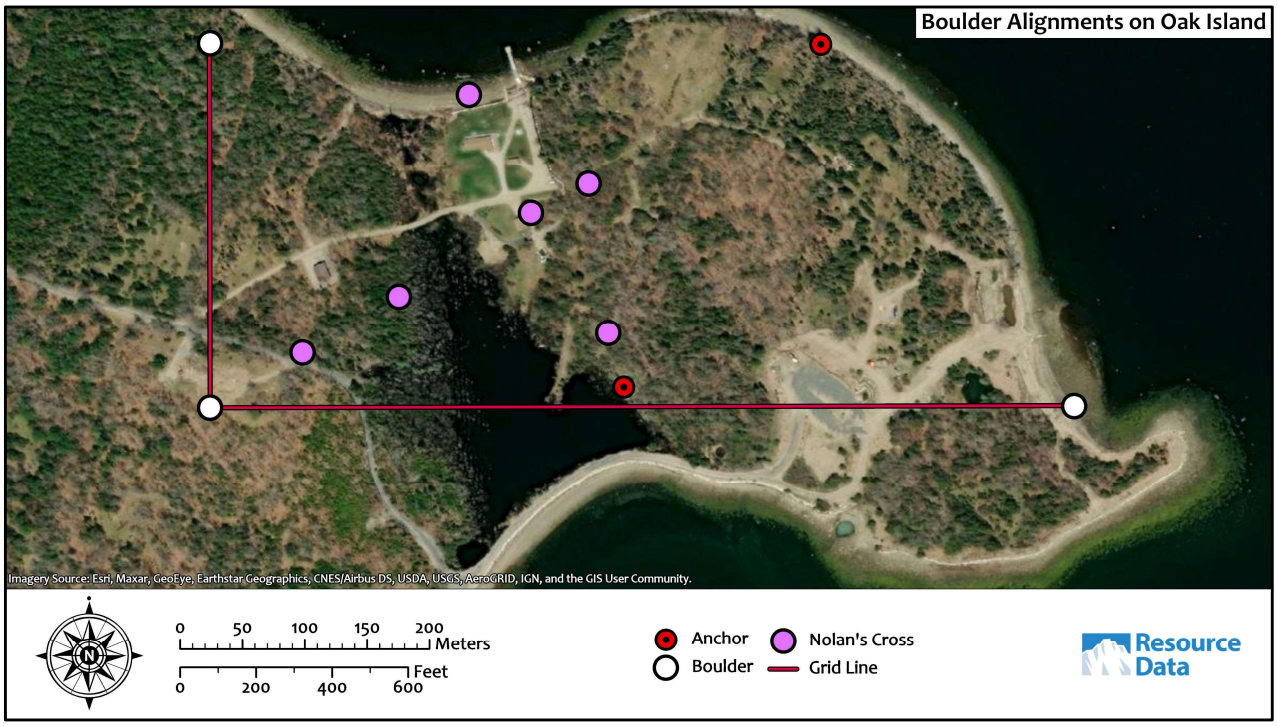
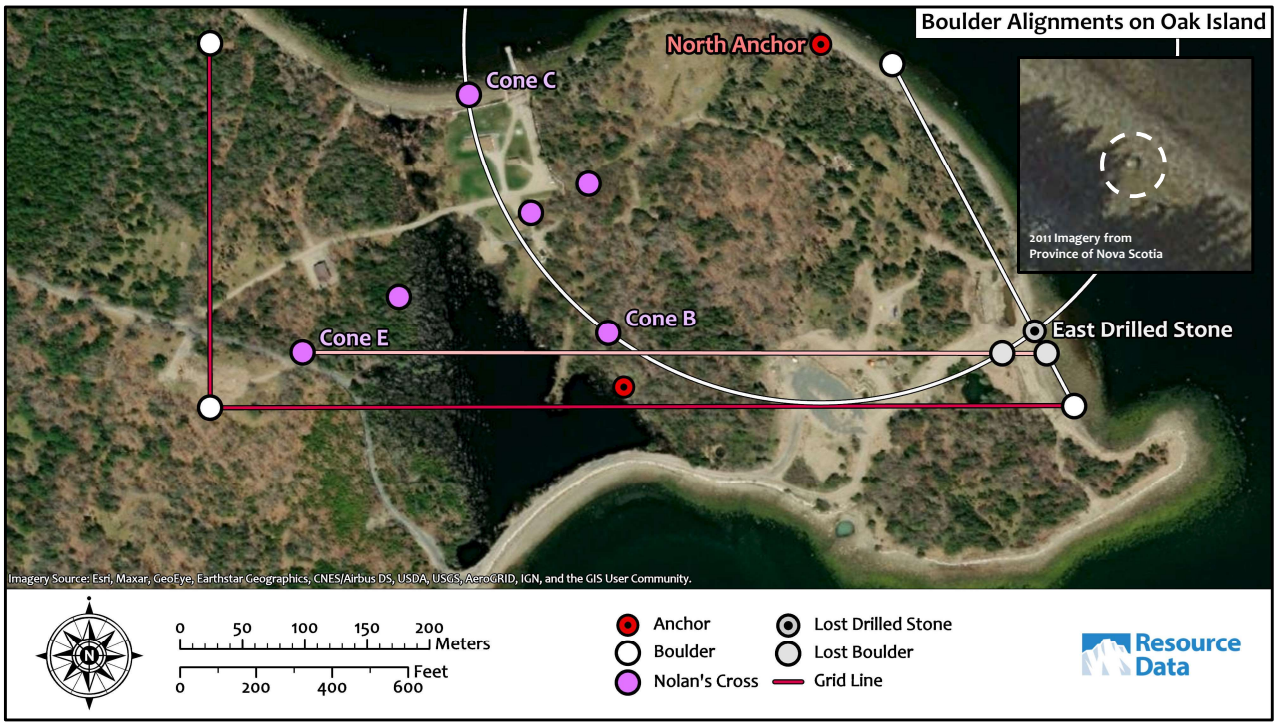
Popular Science (June 1939), p109

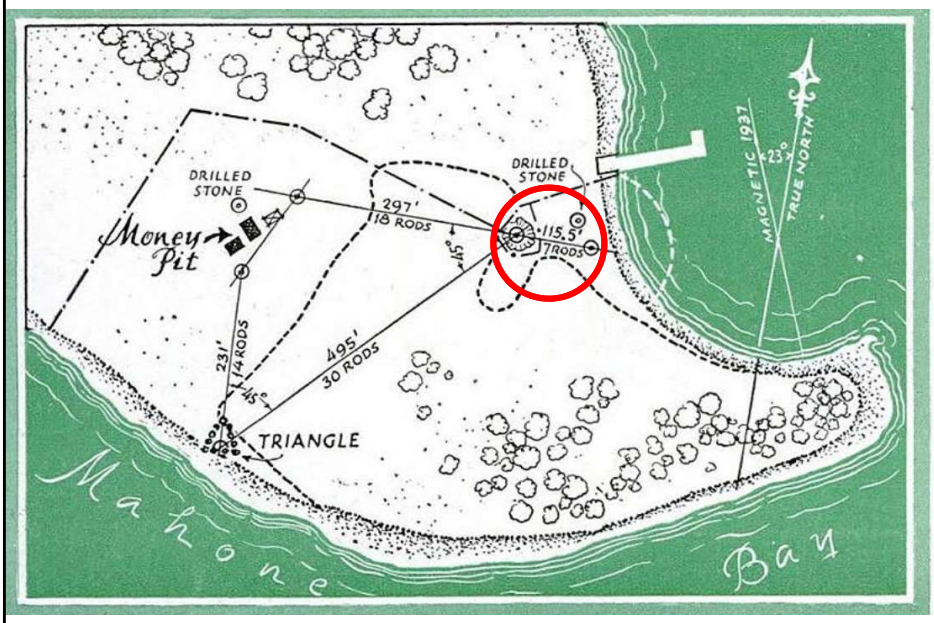
We will start with the two boulders and east drilled stone near Smith's Cove


Boulder Alignments on Oak Island
Imagery Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.
N
0 100 200 300 Meters
0 200 400 600 800 1,000 Feet
Boulder
Nolan's Cross
Anchor
Grid Line
Resource Data



Going to reverse engineer the boulder locations from the 1939 Popular Science map by using boulders that are still in-situ and also square and compass alignment principles.


Boulder Alignments on Oak Island
North Anchor
Cone C
Cone B
Cone E
East Drilled Stone
2011 Imagery from
Province of Nova Scotia
Imagery Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.
0 50 100 150 200 Meters
0 200 400 600 Feet
Anchor
Boulder
Nolan's Cross
Lost Drilled Stone
Lost Boulder
Grid Line
Resource Data



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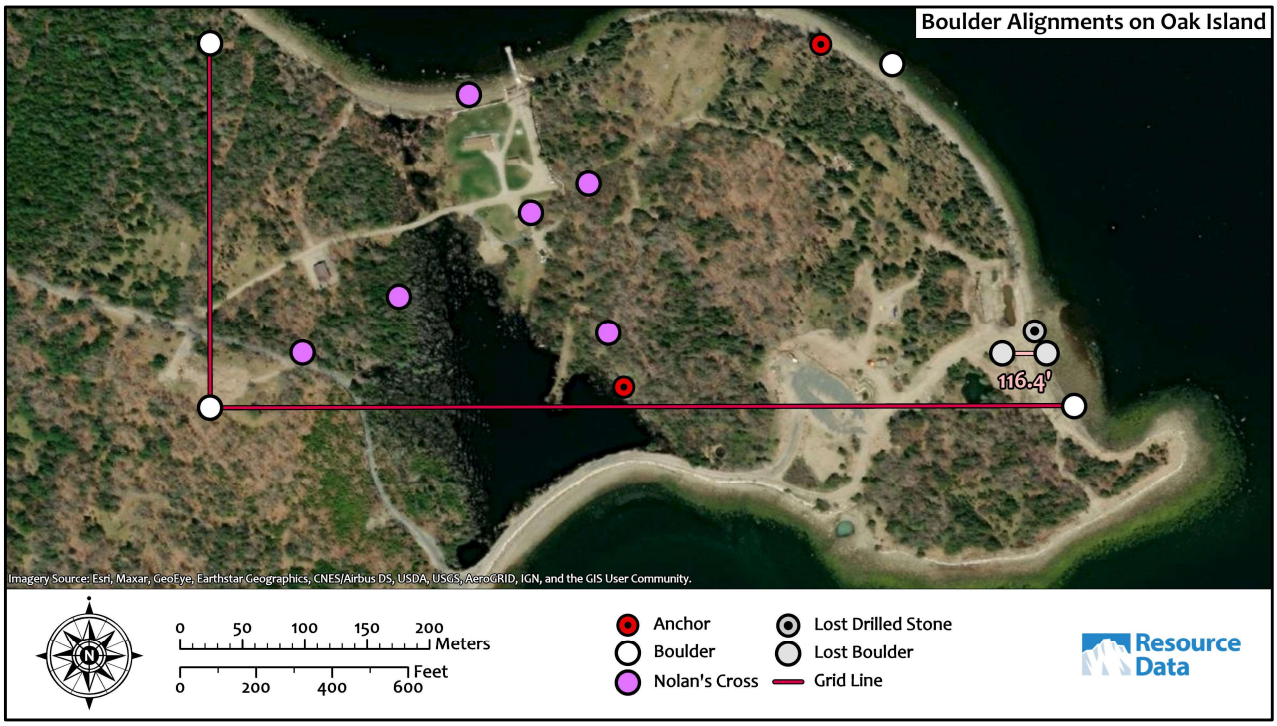
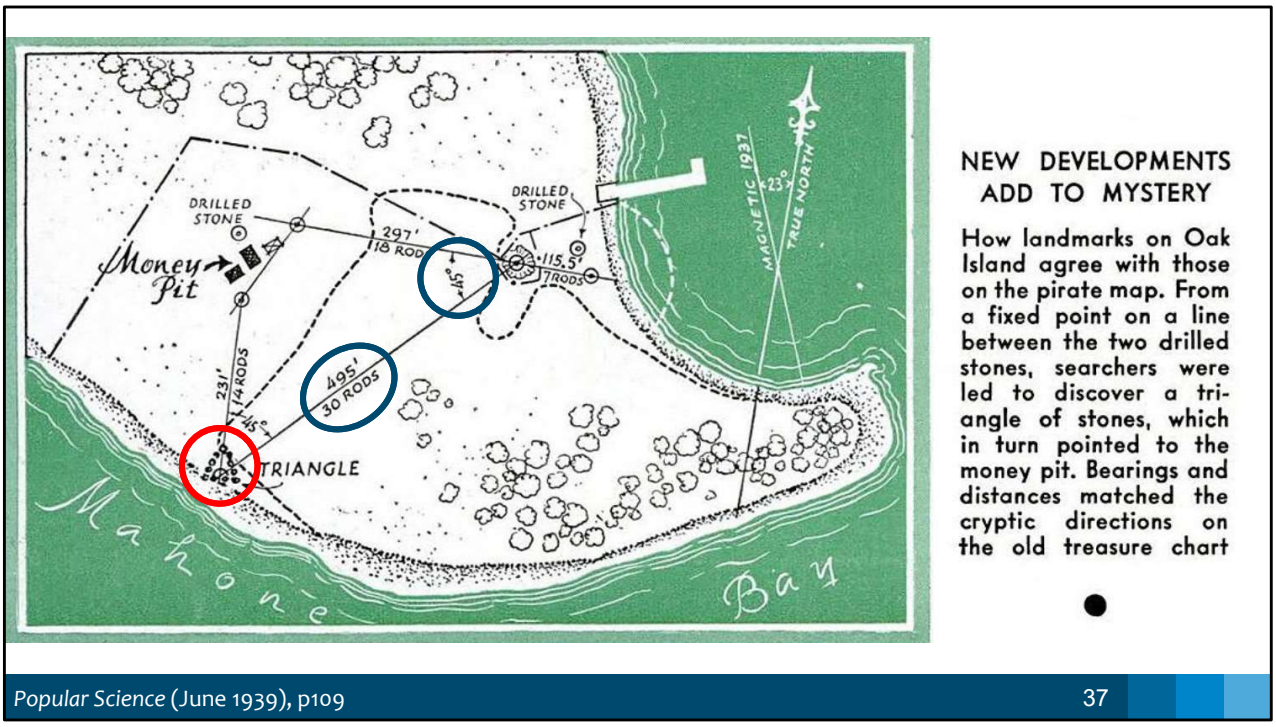
How landmarks on Oak Island agree with those on the pirate map. From a fixed point on a line between the two drilled stones, searchers were led to discover a triangle of stones, which in turn pointed to the money pit. Bearings and distances matched the cryptic directions on the old treasure chart

●

Popular Science (June 1939), p109



Measurements are falling within 1 foot of what is described on the map.



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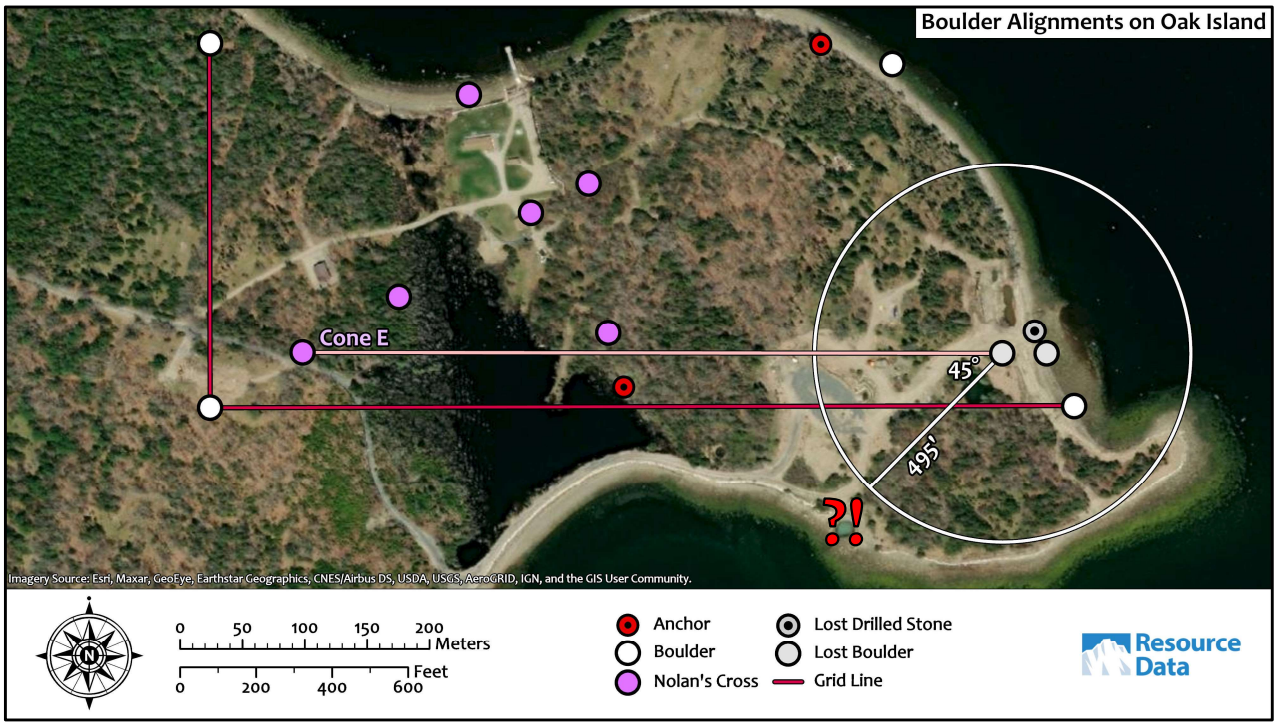
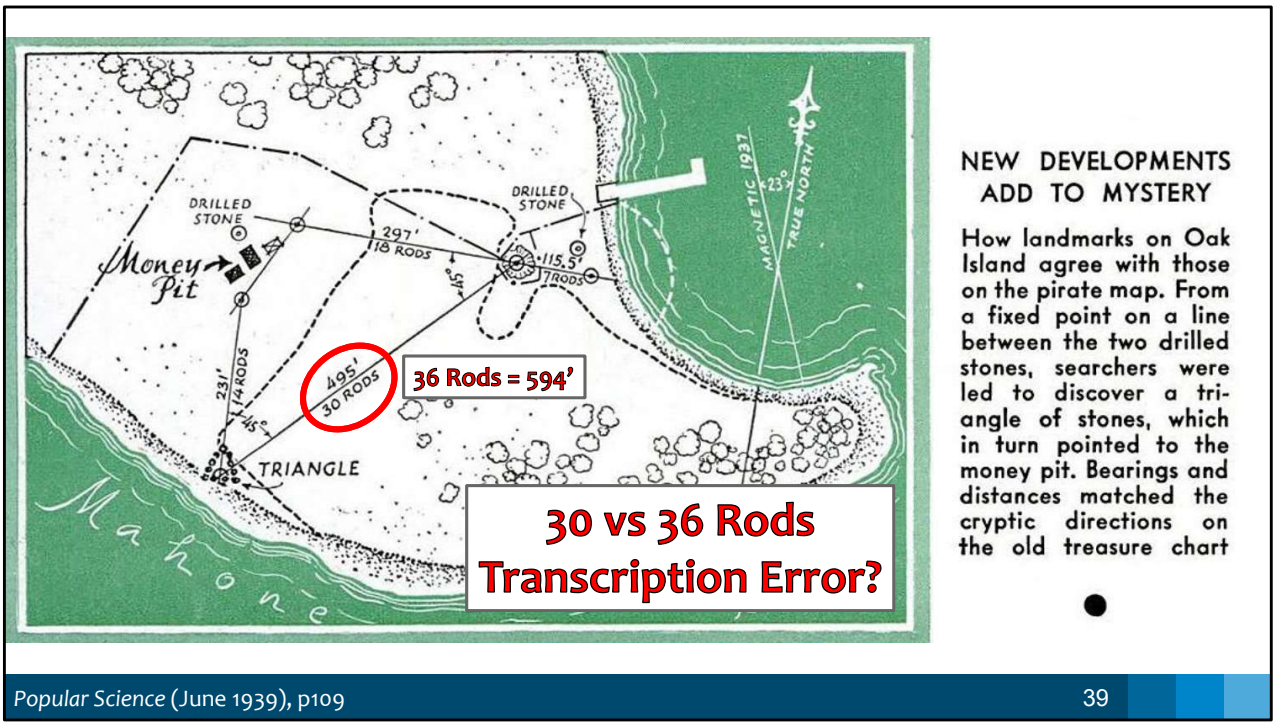
Popular Science (June 1939), p109

37

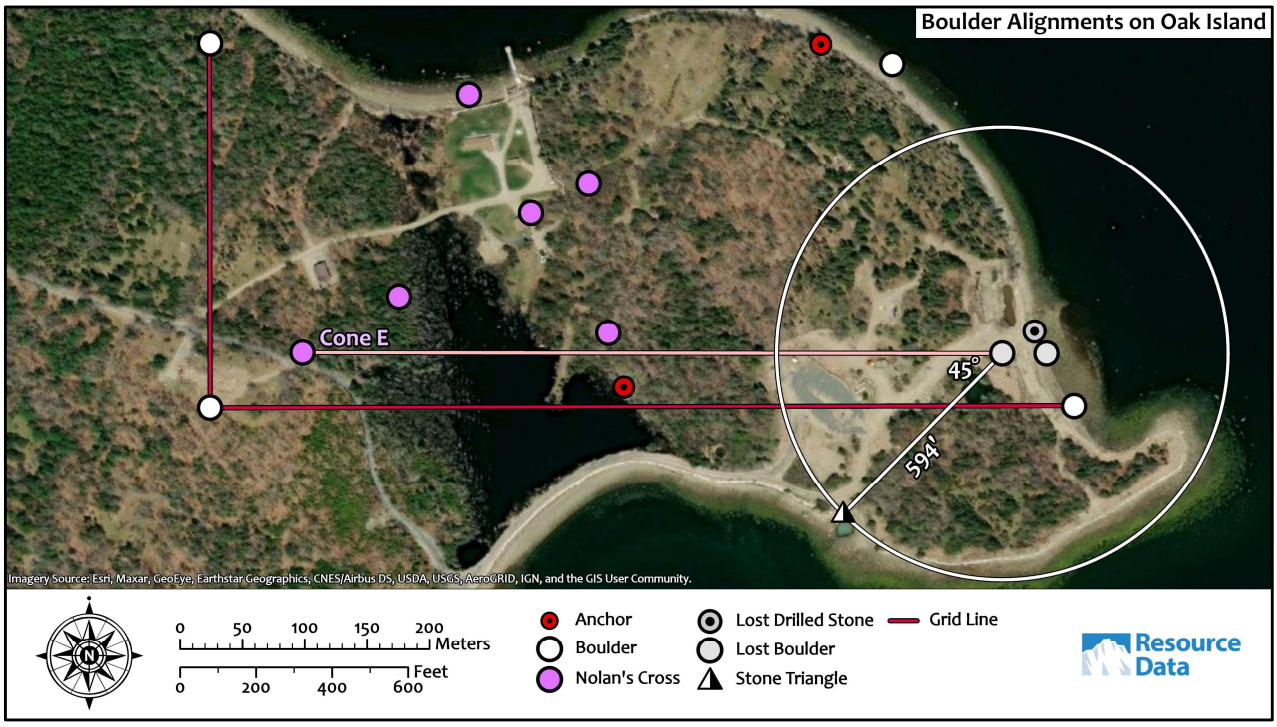
Next let's try to place the stone triangle. We can see on the map that it is drawn near the coast, just above the high tide line. And we have a distance from one of the boulders we just placed, along with a trajectory angle of 45 degrees from the EW line.



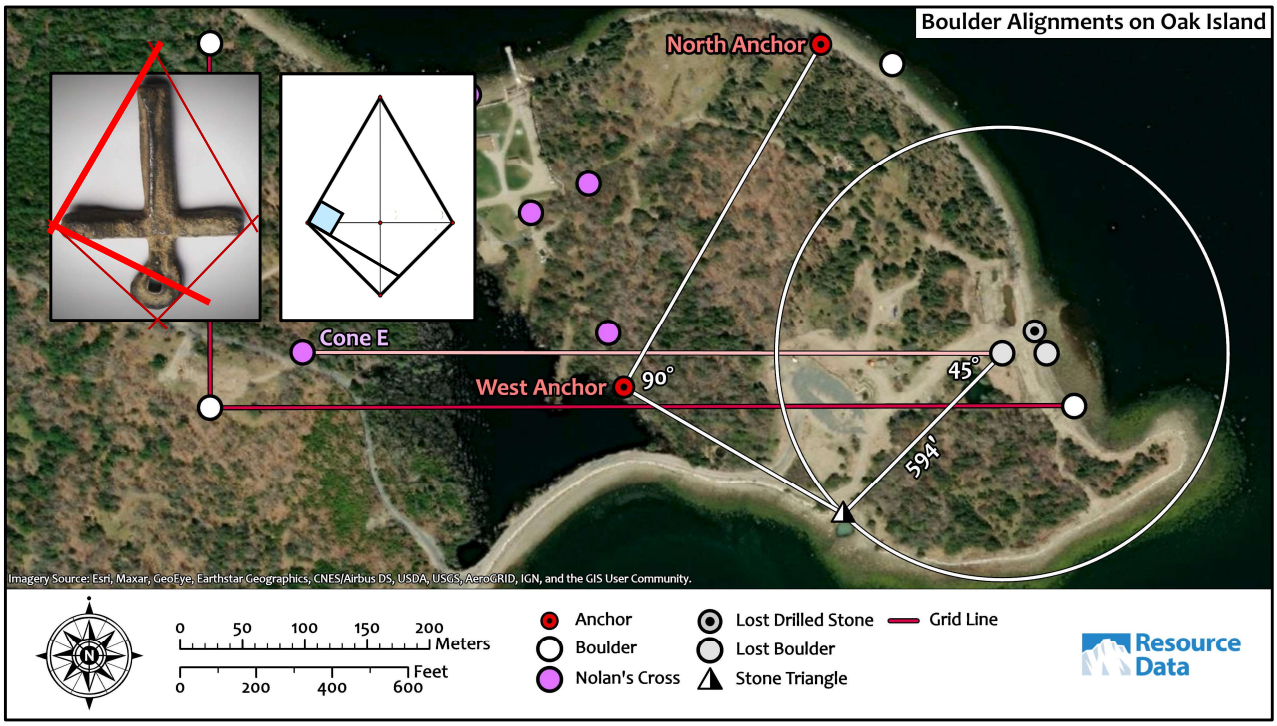
We have a problem. 30 Rods (495 feet) doesn't reach the water's edge like the map depicts



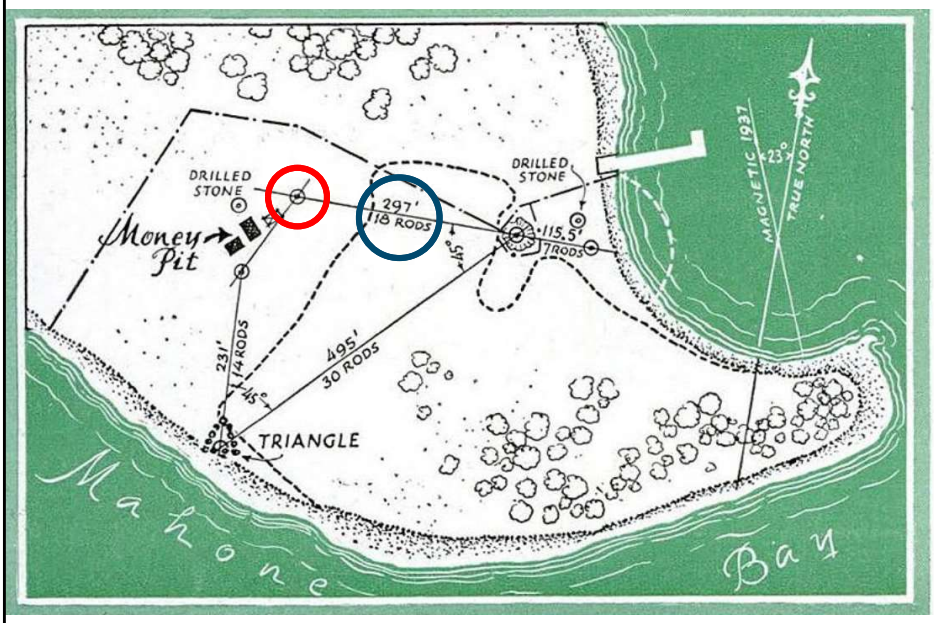
I think this measurement likely contains a transcription error. I think this measurement was meant to be 36 rods, not 30. I seems plausible that at some point, a poorly closed six was misinterpreted as a poorly closed zero. Alternatively, if the measurements were originally in feet, one could also argue that whoever copied the measurements might have been dyslexic. 495’ may have been intended to be 594’



Now we're talkin'



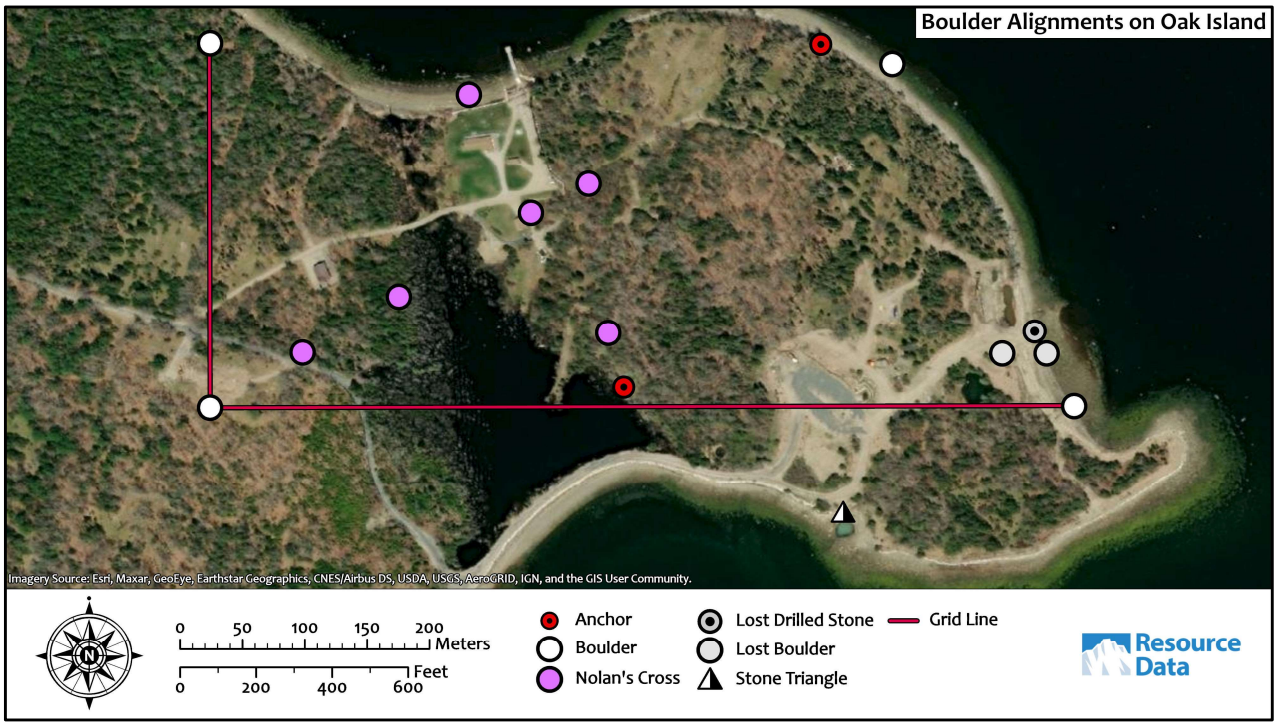
We can also extent a line from the West Anchor as if a square was run along both anchors. This mimics one of the square angles that was found on the lead cross when aligned to the anchors too through the square hole.

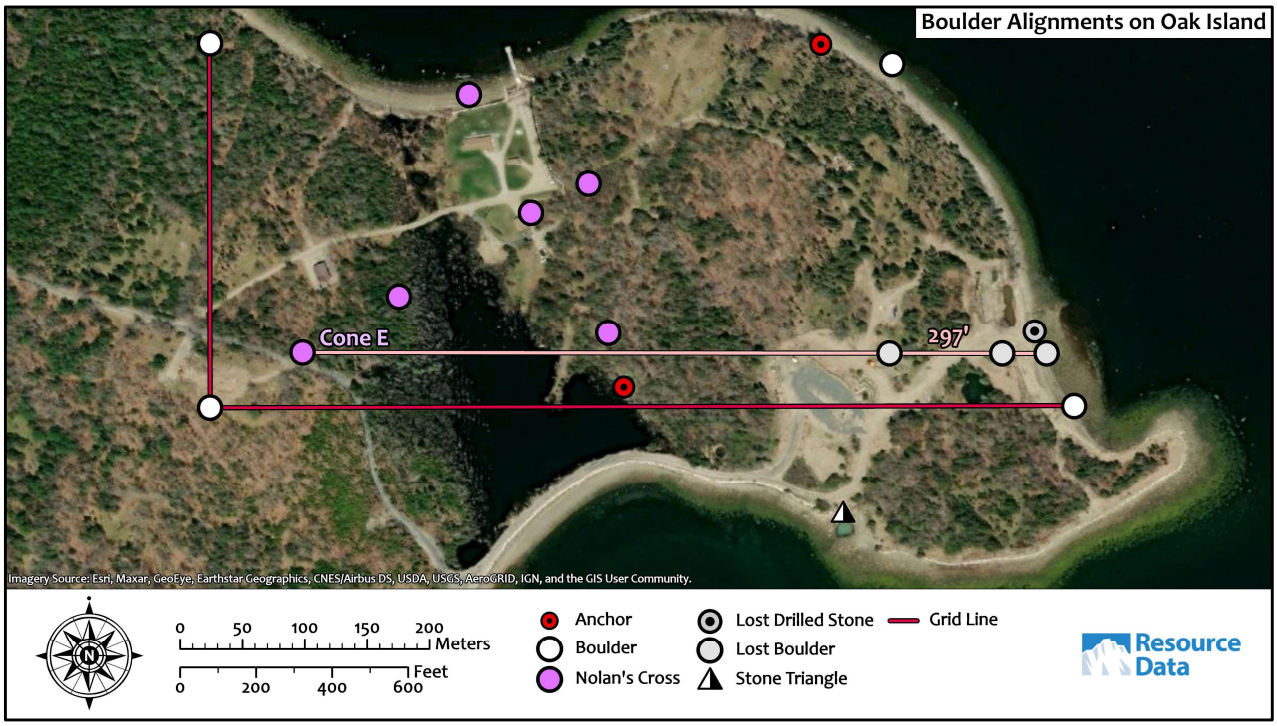


NEW DEVELOPMENTS ADD TO MYSTERY

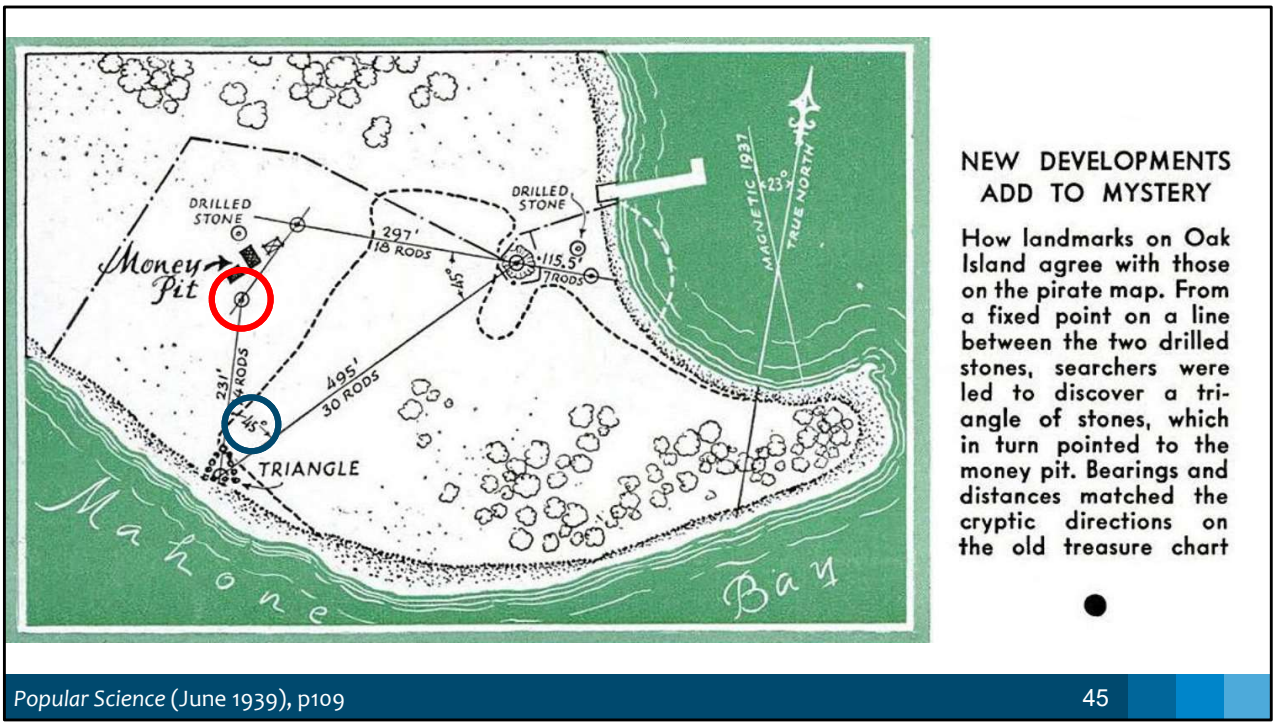
How landmarks on Oak Island agree with those on the pirate map. From a fixed point on a line between the two drilled stones, searchers were led to discover a triangle of stones, which in turn pointed to the money pit. Bearings and distances matched the cryptic directions on the old treasure chart

Popular Science (June 1939), p109


Boulder Alignments on Oak Island
Imagery Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.
0 50 100 150 200 Meters
0 200 400 600 Feet
Anchor
Boulder
Nolan's Cross
Lost Drilled Stone
Lost Boulder
Stone Triangle
Grid Line
Resource Data



This one is easy to place



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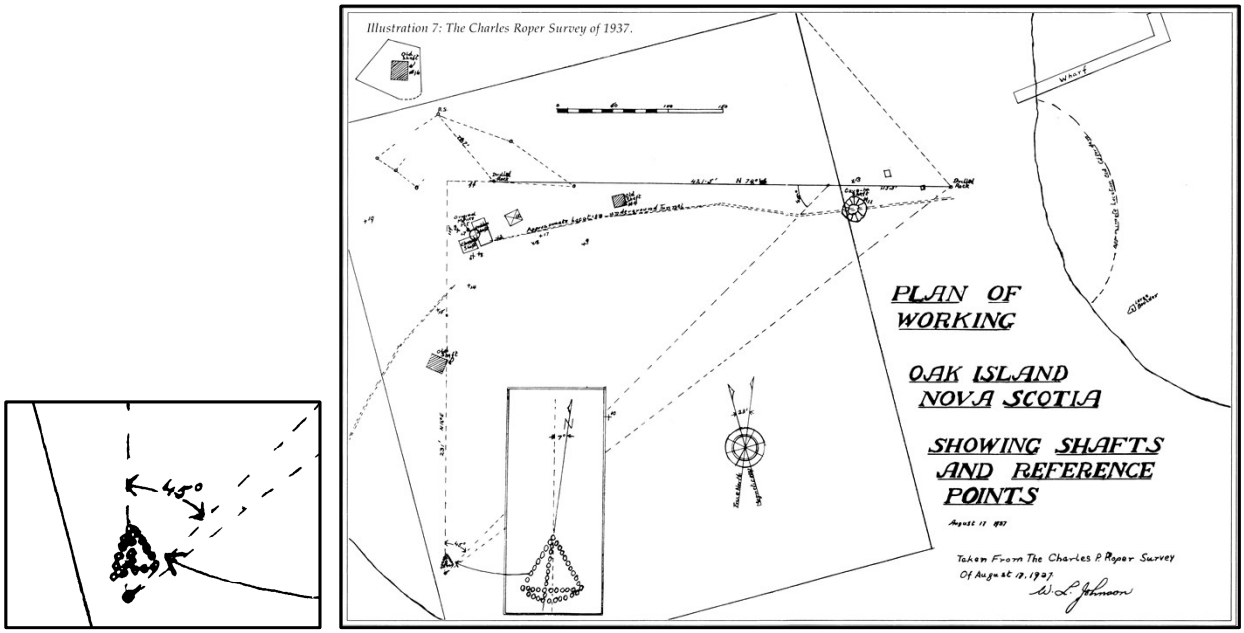
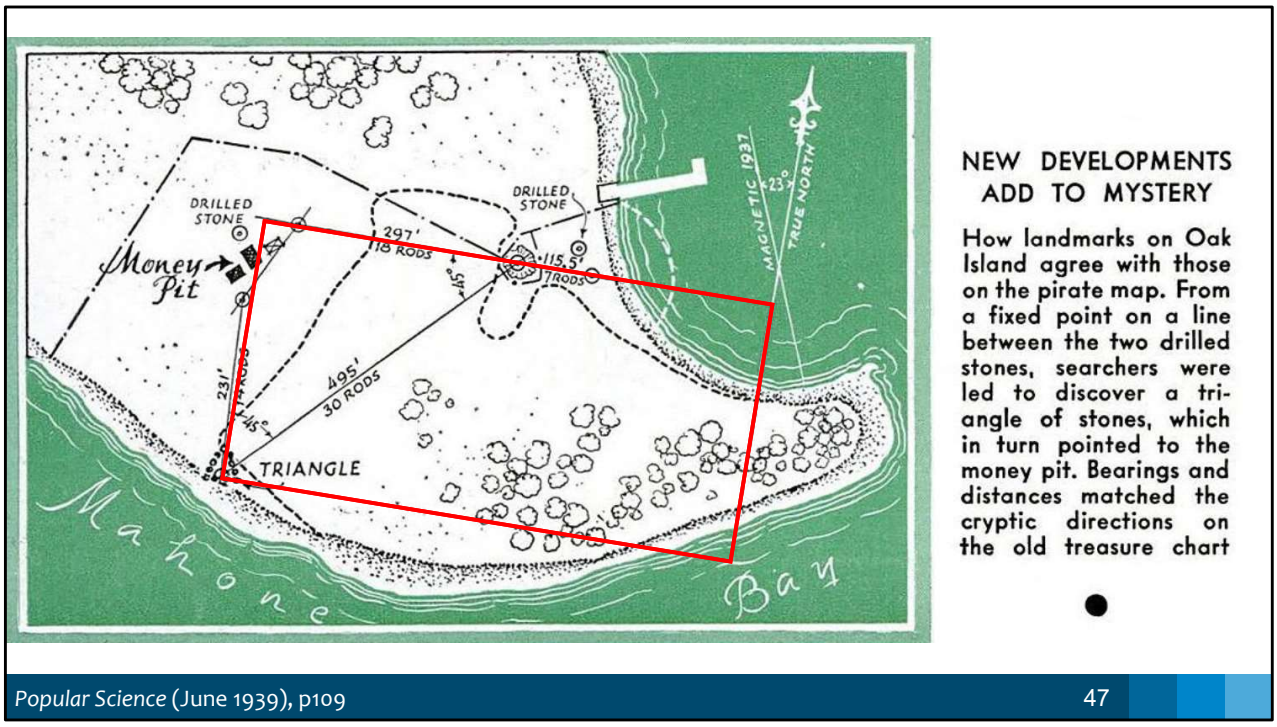
45

Map says 45 degrees from the diagonal line we used to place the Stone Triangle



Charles Roper Survey (1937) 46

45 degree label probably derived from the Roper survey map of 1937



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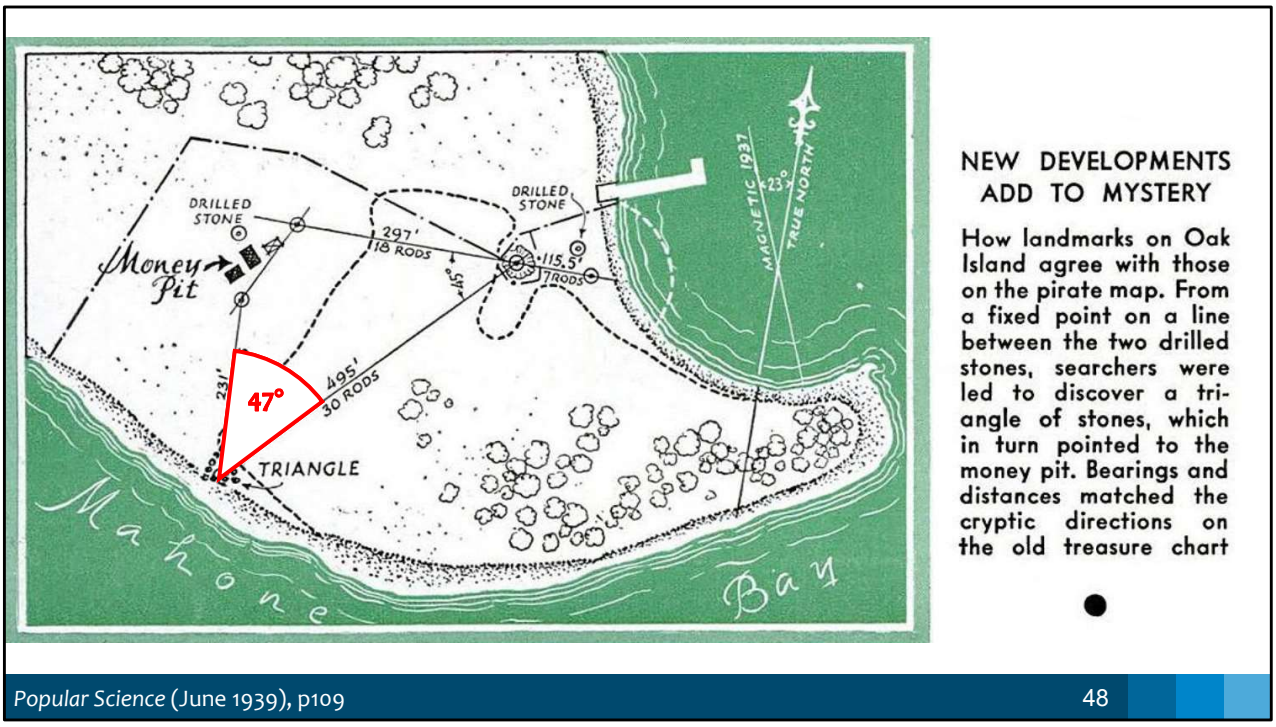
But if we extend a rectangle from True North and along the horizontal line of boulders, you will see that the way this map was drawn does not have the boulder north of the Stone Triangle "true" north. It is a bit more to the northwest.



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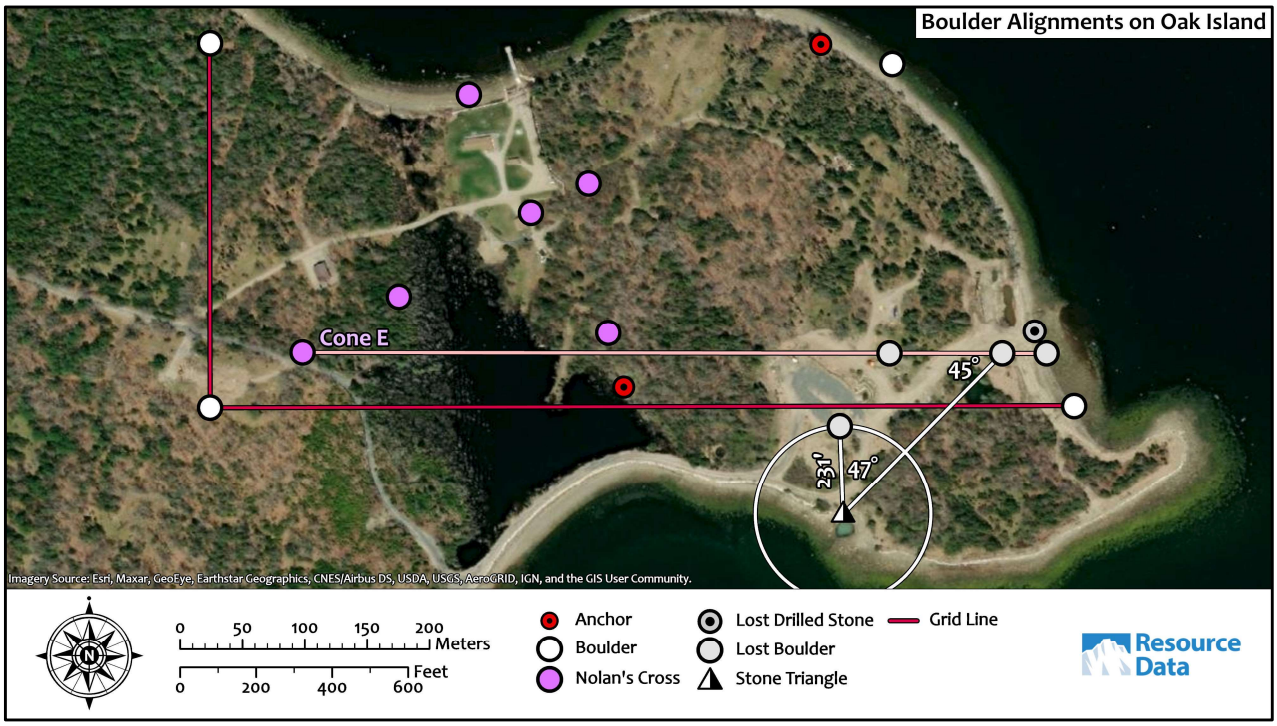
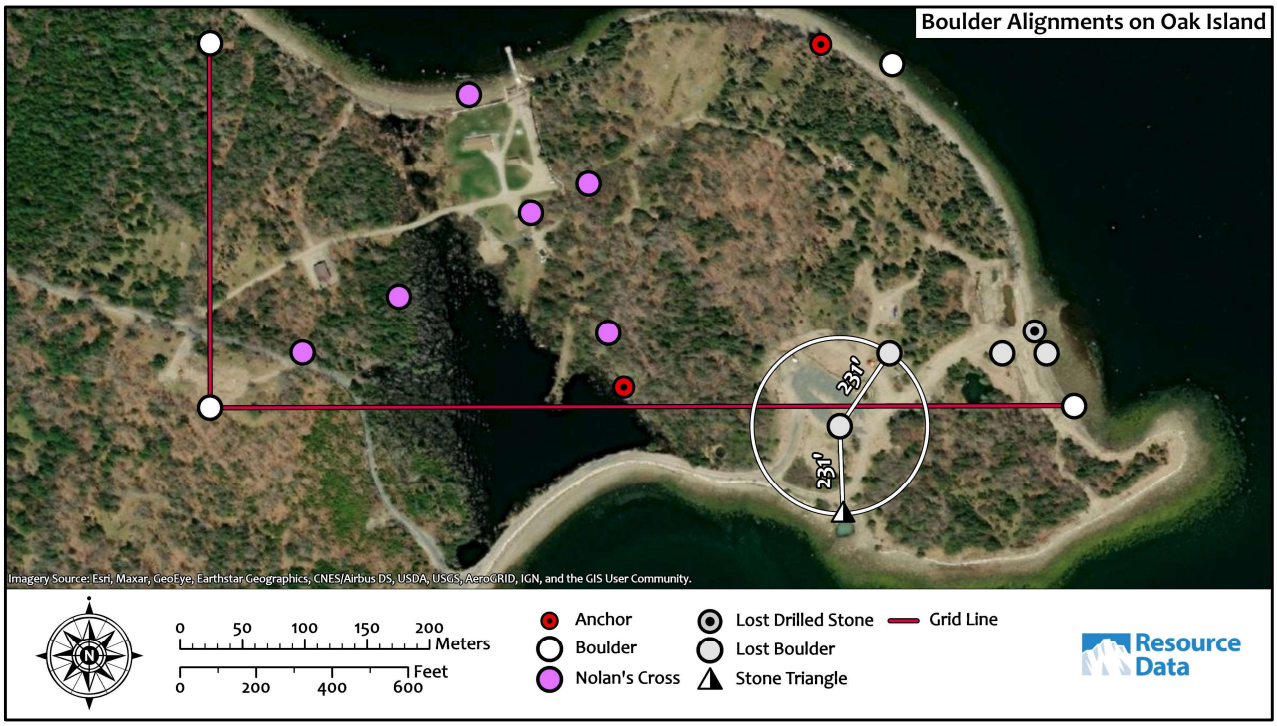
48

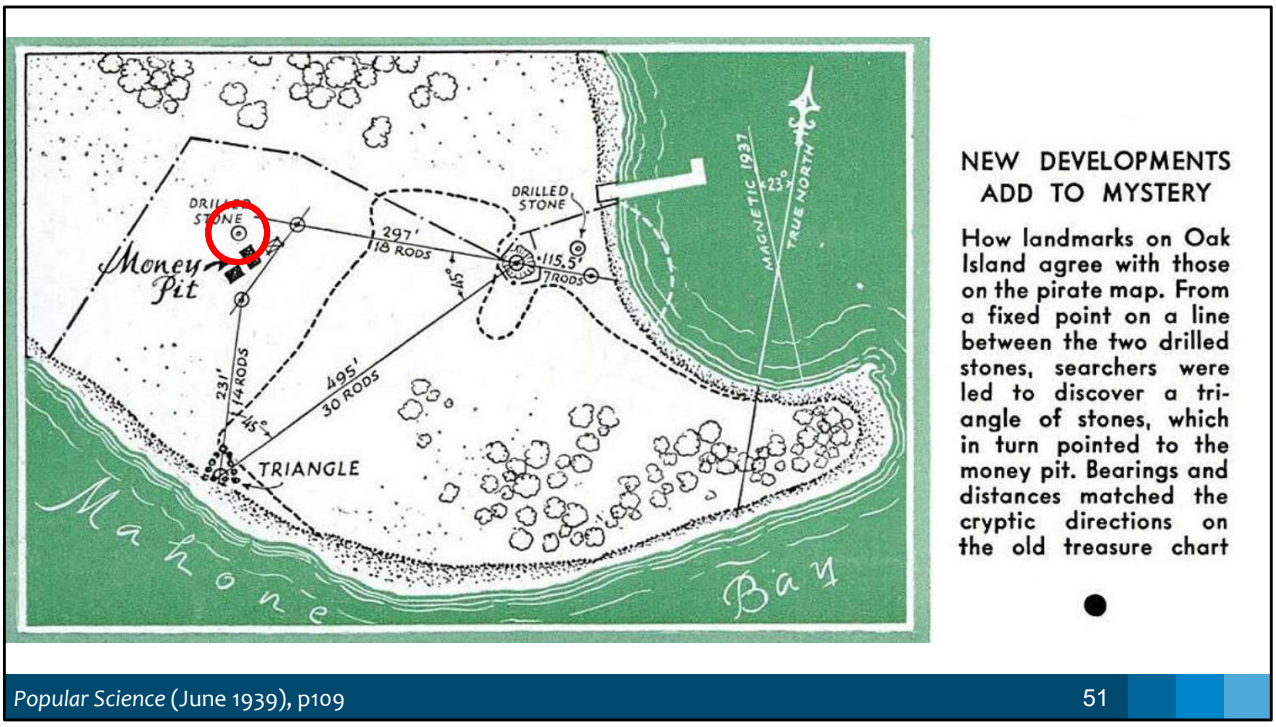
In fact, if we check it with a protractor, the angle is 47 degrees from the diagonal, not 45.



If we place the boulder with a 47-degree angle from the diagonal guideline instead of 45, we get one more validation that this is the true intended location



If you draw a circle around the boulder we just placed with a radius of 231 feet (the distance to the stone triangle, you also hit the boulder along the EW line we just placed too.



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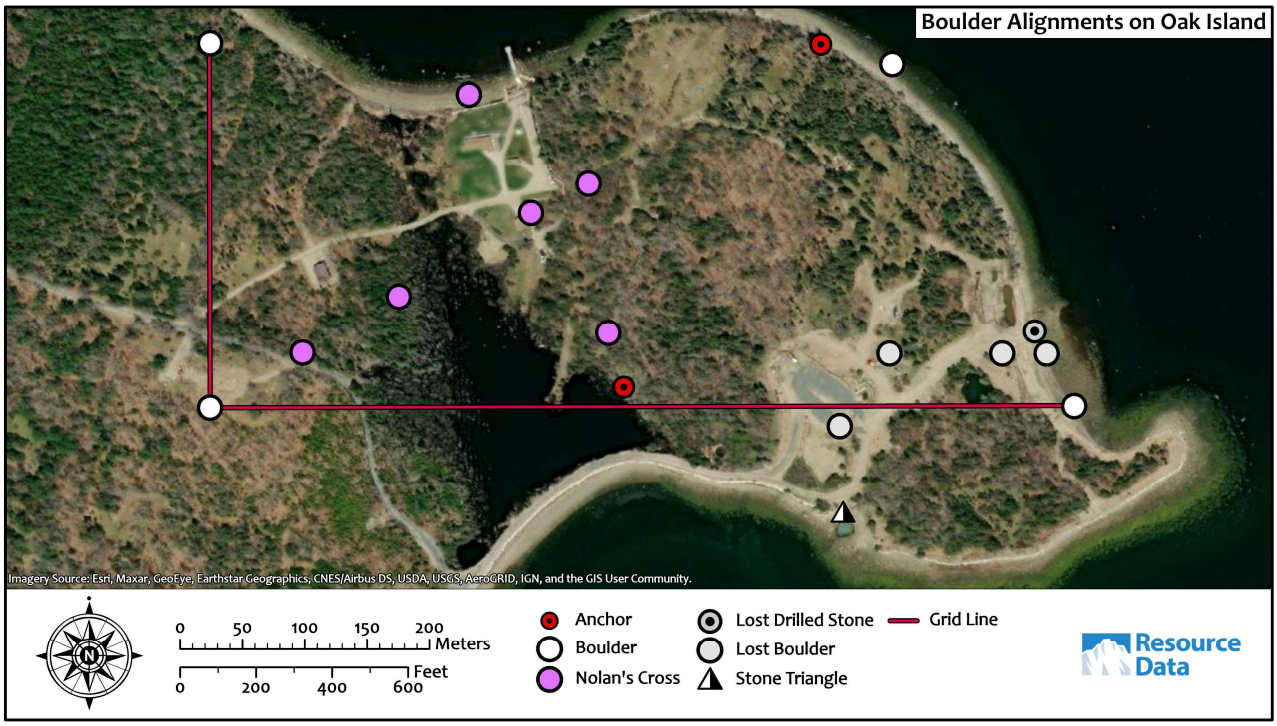
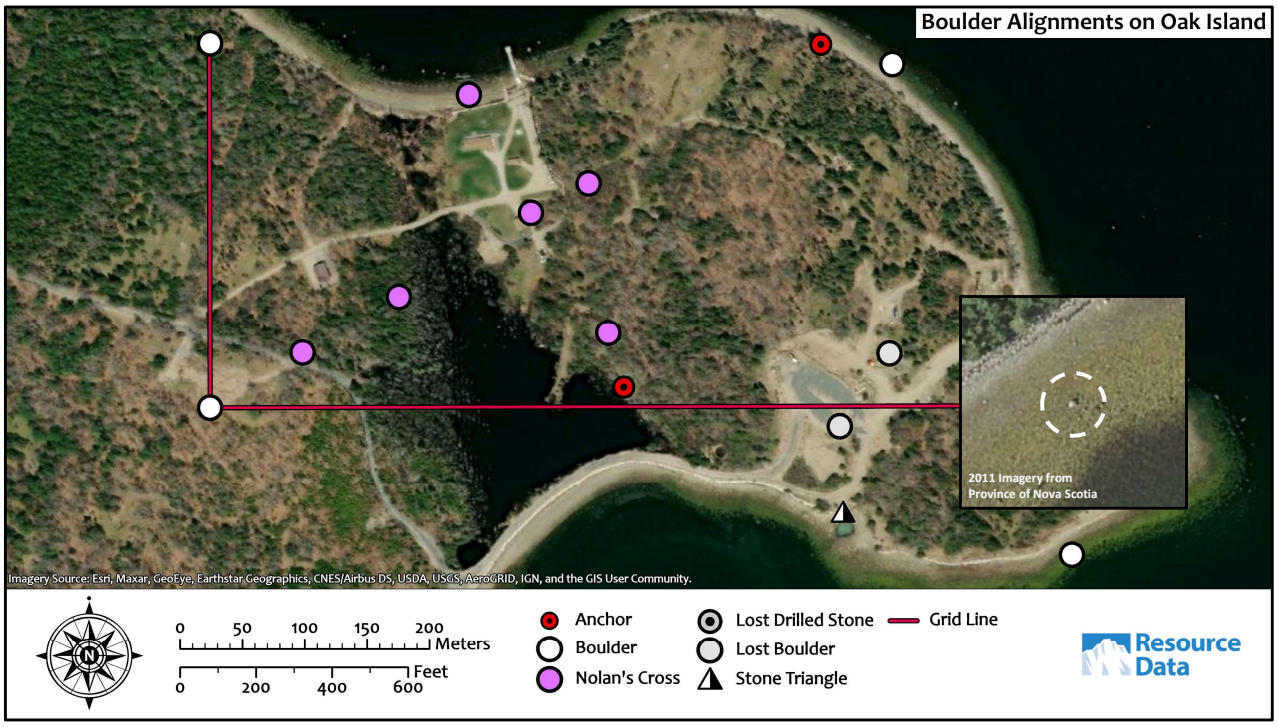
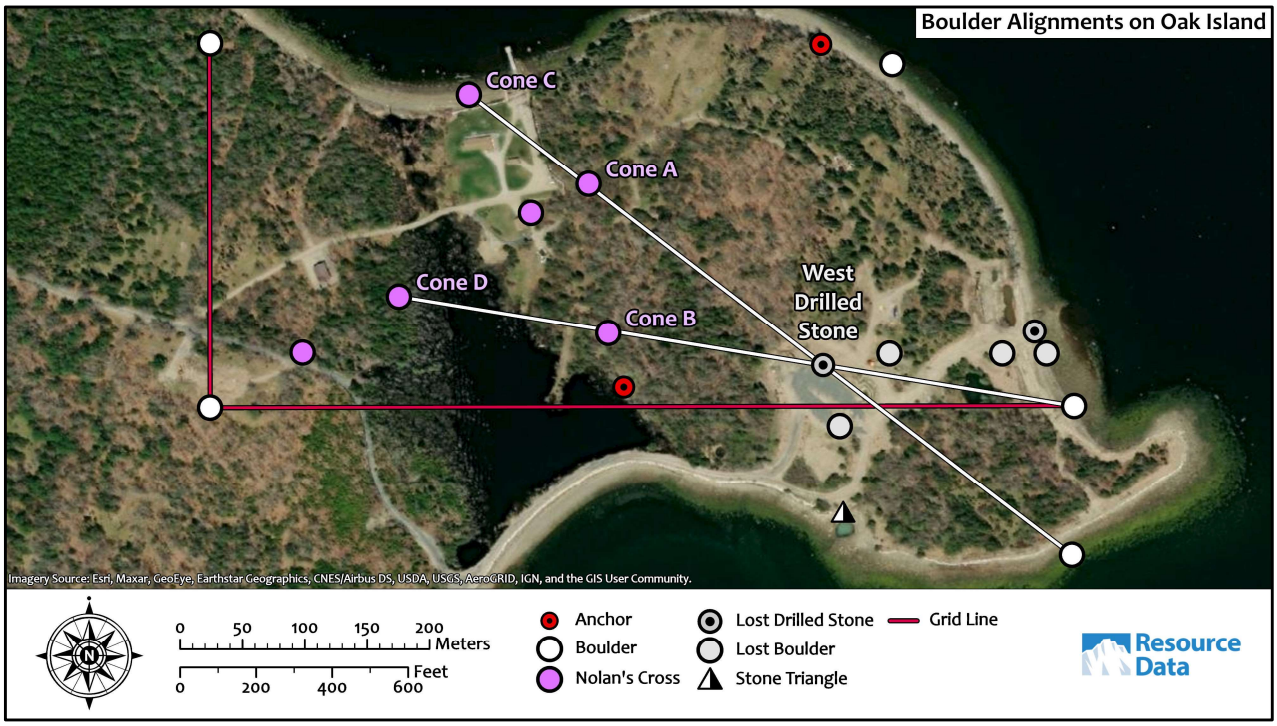
Lastly, we will attempt to place the drilled stone to the west. This stone does not have any measurements so this will be a best guess.



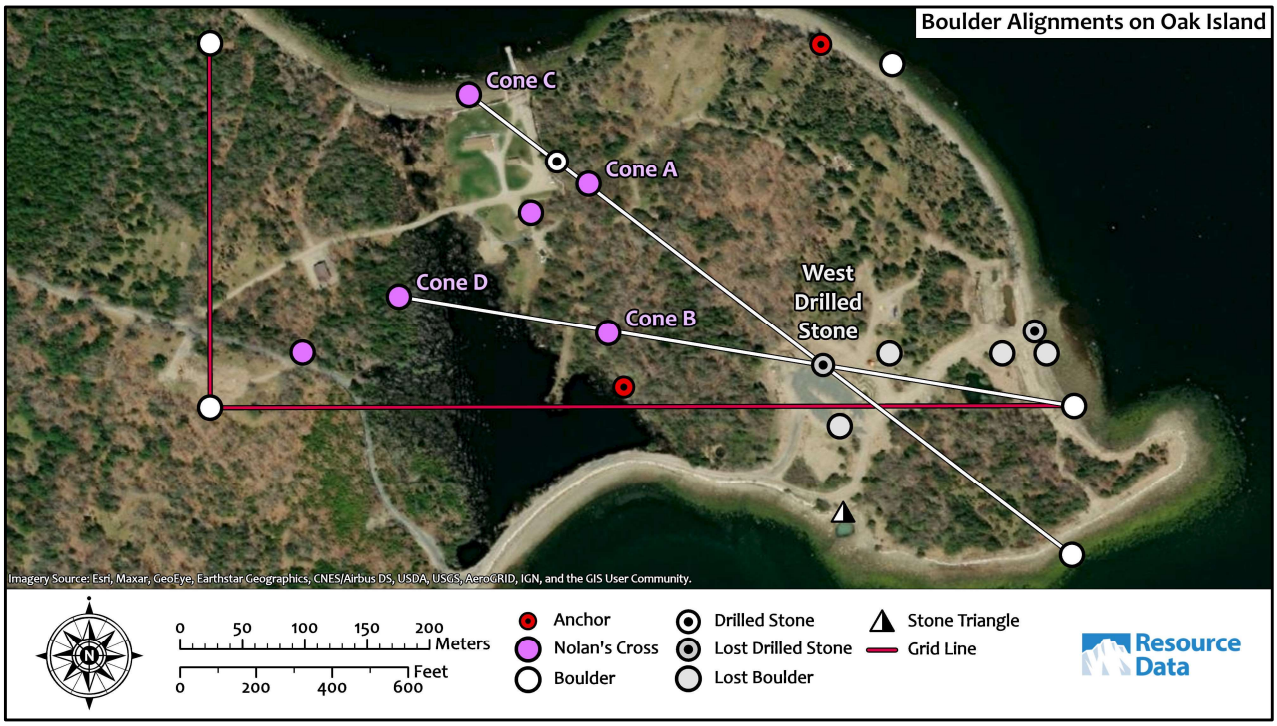
We will do this with the help of another confirmed boulder on the south shore of the island


Boulder Alignments on Oak Island
2011 Imagery from
Province of Nova Scotia
Imagery Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.
0 50 100 150 200 Meters
0 200 400 600 Feet
Anchor
Boulder
Nolan's Cross
Lost Drilled Stone
Lost Boulder
Stone Triangle
Grid Line
Resource Data

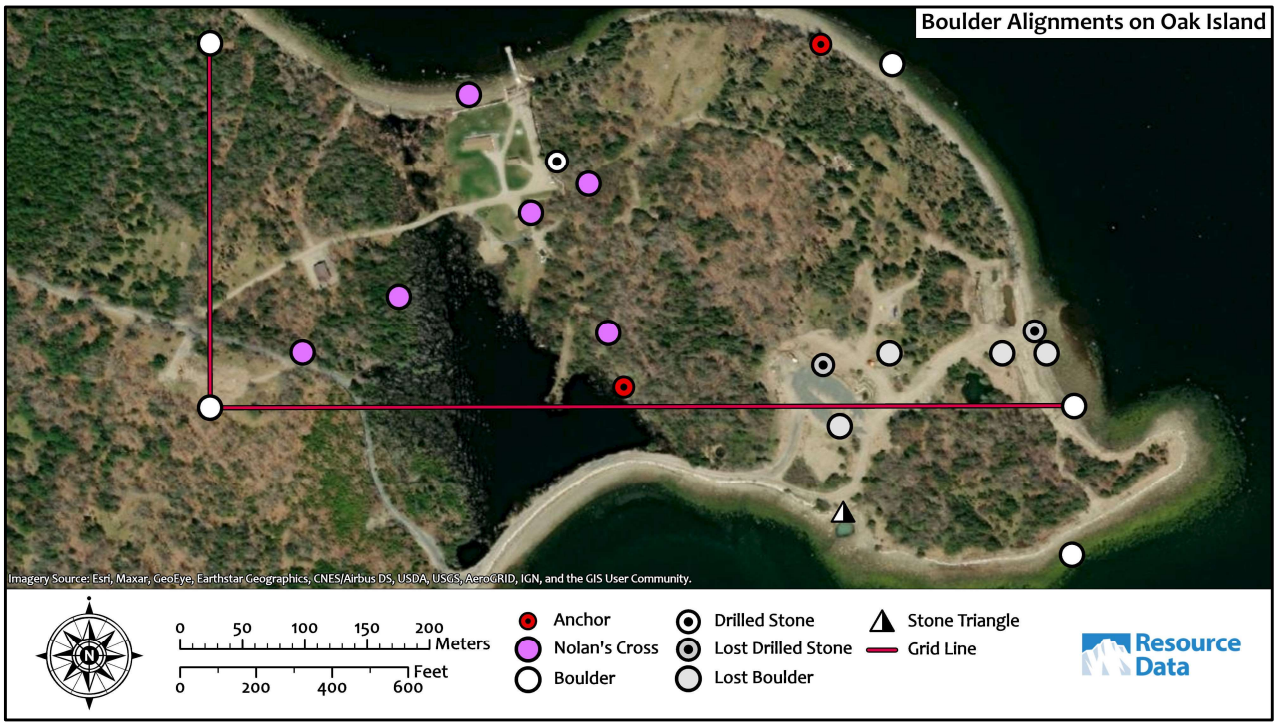


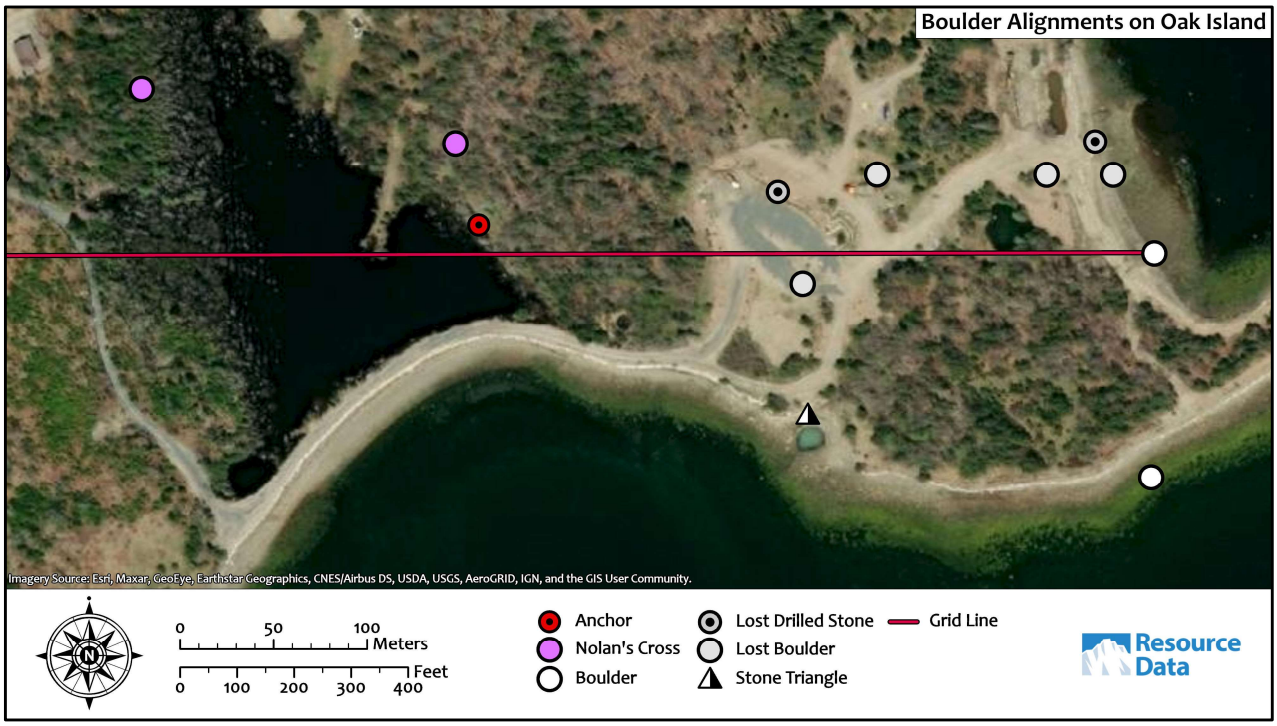
Two lines across the island

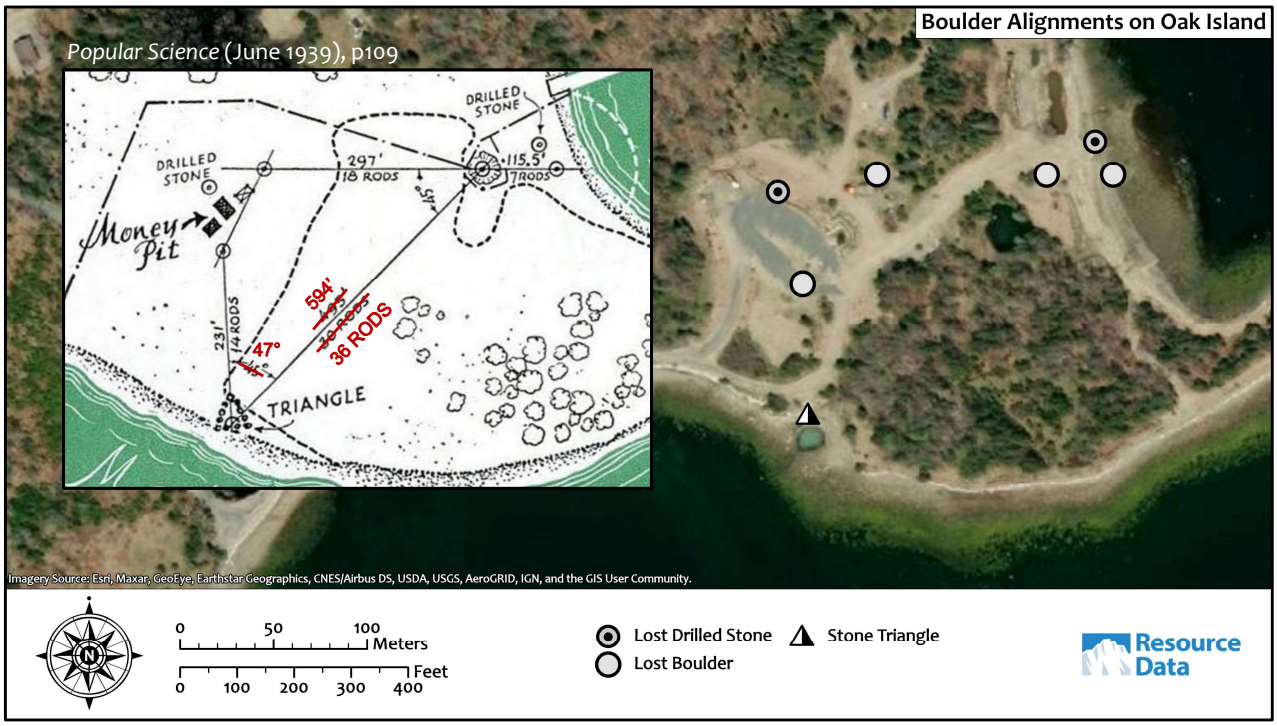
- Cone C, Cone A, and the boulder on the south shore
- Cone D, Cone B, and the east end of the grid line
- Intersection is where I believe the West Drilled stone was originally located



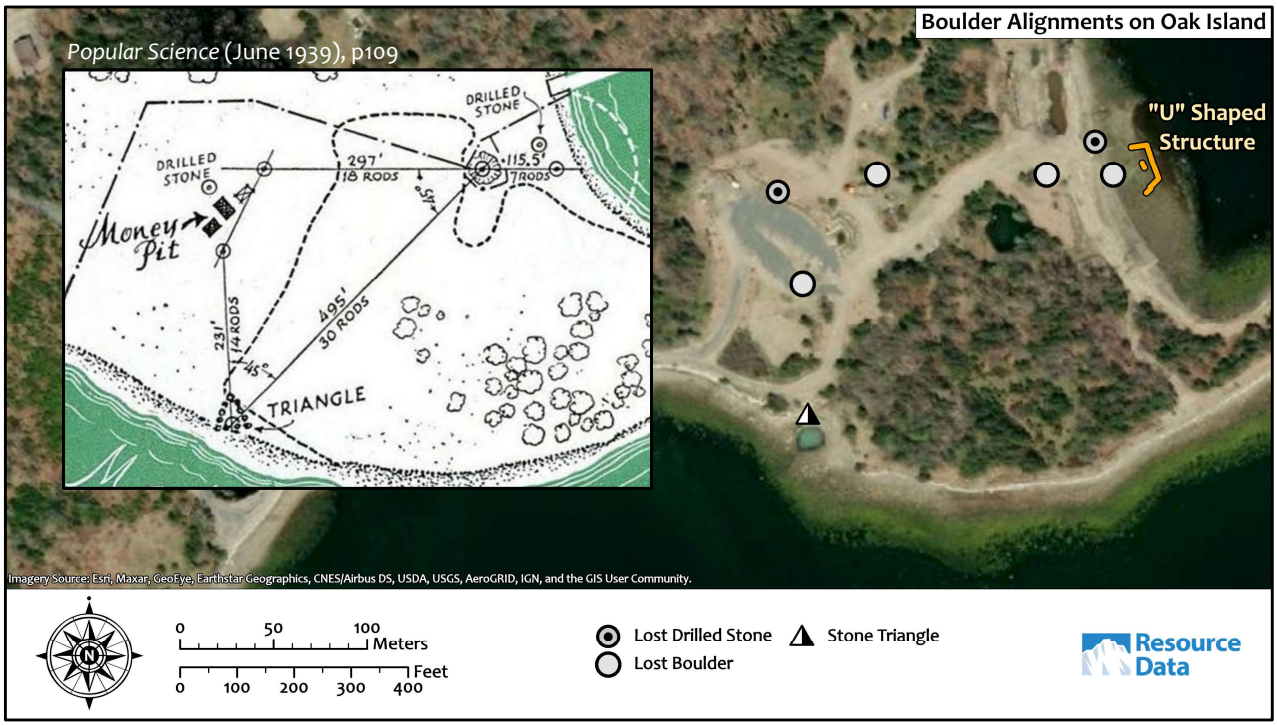
There is another drilled stone on Tom Nolan's property along the line that includes Cone C and Cone A. This one is still in-situ and was GPSd by Steve Guptill with high precision.


Boulder Alignments on Oak Island
Imagery Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.
N
0 50 100 150 200 Meters
0 200 400 600 Feet
Anchor
Nolan's Cross
Boulder
Drilled Stone
Lost Drilled Stone
Lost Boulder
Stone Triangle
Grid Line
Resource Data

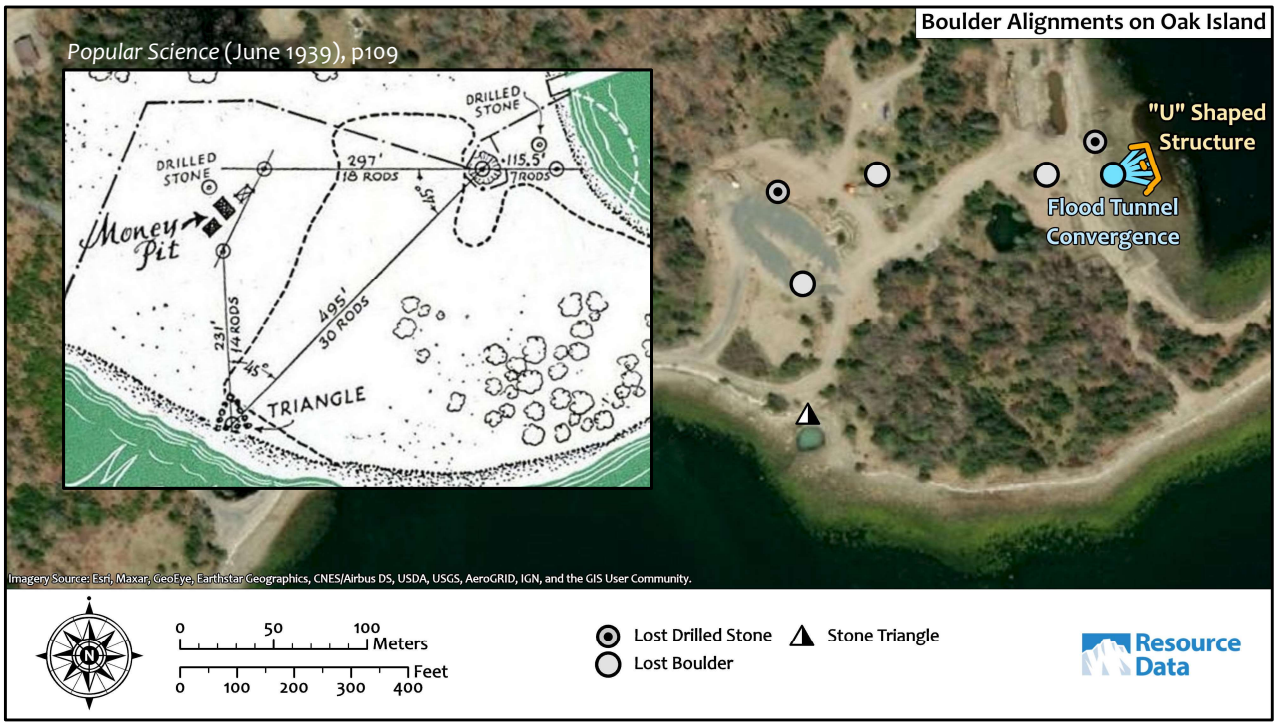

Boulder Alignments on Oak Island
Imagery Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.
N
0 50 100 Meters
0 100 200 300 400 Feet
Anchor
Nolan's Cross
Boulder
Lost Drilled Stone
Lost Boulder
Stone Triangle
Grid Line
Resource Data



We can now compare the 1939 map and the plotted solution side-by side. All measurements being accurate to within a foot as described….with a few justified corrections.



When the team did excavations in Smith's Cove, they uncovered a wooden structure, dubbed the "U" shaped structure.



There are historic records of a series of finger drains that were discovered in the cove by previous searchers. They were described as 66 feet long each and spanned an angle of 60 degrees. These dimensions fit perfectly within the structure if we use the most eastern boulder from this map as the flood tunnel convergence point.

I will not be getting into the Money Pit position today. This map does not offer any precise measurements to place it. If you watch the show you'll see that I made an attempt based on a few other features and by following the instructions of a coded message that was found with the Oak Island map presented by Zena Halpern. However, we were unsuccessful in confirming its location. So, there is more work to be done! I have since revised my work and have proposed some new locations, but they have yet to be confirmed, so I won't get into them today. But by recreating this map using square and compass concepts, I hope it demonstrates a proof of concept that will continue to shed light on other features across the island as we move forward.

The takeaway…

- Never stop developing your GIS skills. You never know how they might come in handy in the future
- Find ways to apply GIS and spatial analytics to personal projects, things you are passionate about


Thank you
Questions?
Find me at booth ##
Resource Data