Discussion and Review of Phillip A. Costaggini's Project on Neahkahnie Mountain, Oregon

Submitted as a Project by
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INTRODUCTION:

As students at Oregon State University, we have put together a project for a CE 406 class. The project was discussed and designed by Peter Seaders, Beth Peutz, and Professor Robert Schultz. The basis for this project was the thesis written by Phillip A. Costaggini in 1985 which included his survey of marked stones found in the Neahkahnie Mountain area. The draft of the thesis that we had access to may not be the final draft. In a book written by Garry D. Gitzen, there exists a draft of Costaggini's paper that is substantially different from the draft that we worked with.

Costaggini's thesis discusses a survey that he did of archaeological monuments on Neahkahnie Mountain on the Oregon coast. Costaggini worked with Wayne Jensen, the curator of the Tillamook County Museum, near where Neahkahnie Mountain is located. The monuments consisted of marked stones and stone mounds called cairns. The origin of these stones is unknown, though several theories exist. Jensen believed that these stones were monuments from a survey done by Sir Francis Drake in the late fourteenth century. Costaggini accepted the job of surveying these monuments, with the help of Jensen, to locate and tie these monuments together.

Phil Costaggini's paper provided the link to his [Jensen's] work that up to this point has been missing. The key for us was to try and recover as much of the data that was reported in his paper as possible, in order to be able to make a search in the field to try to locate some of the monuments that had been surveyed.

DISCUSSION:

Due to the nature of measurement, it is inevitable that errors occur during the survey. There are many sources of error such as systematic errors due to instrument mis-calibration, pointing and reading errors due to the inability of the human eye to sight perfectly on the target, setup errors due to differences in the leveling of the equipment over control points on sequential occupations, and blunders or other sources of error. While systematic errors and blunders can generally be eliminated by good survey practice, other sources of error such as pointing and reading and setup errors cannot. Thus, it is

a well understood fact by surveyors, that no set of measurements, however precise, is ever perfect. Thus, if measurements are taken from a starting point around a set of monuments, and then back to the starting monument, there will always be some difference between the calculated position of the starting and ending point, even though they are obviously in the same position. This error is the accumulation of errors that has occurred through the length of the survey traverse. The longer the distance covered in the traverse, the greater the error is likely to be.

In order to deal with these errors surveyors have developed techniques for minimizing the errors as well as estimating how the errors should be distributed throughout the length of the traverse. First of all specifications have been developed for how to conduct survey's which require high precision. The lowest precision surveys are referred to as "Third Order" surveys. This is typical of property surveys and other types of work that is not intended to be a reference for a large amount of future survey work. The next level of precision is referred to as a "Second Order" survey. Second order surveys are intended to serve as the basis for third order survey work. These specifications require multiple measurements and much smaller closure errors than third order work. Finally, first order surveys are the highest precision and are conducted over very large areas with special equipment. These are intended to serve as the basis for second order control points. Obviously, first order and second order control surveys require a significant amount of time and effort to conduct due to the increased precision and the number of redundant observations that need to be taken. It should be noted that the work done by Phil Costaggini met many of the specifications for a second order survey, and thus can be considered to be very precise overall.

As noted earlier, regardless of the level of precision applied to the survey, some errors will occur. As a result it is necessary to adjust the measurements taken to distribute the errors throughout the length of the survey traverse. In the past many methods have been used to do this which provides a reasonable approximation of how the errors should be distributed. These methods were used because they were less computationally intensive than the statistical method used today, which is known as least

squares adjustment. This method uses statistics and matrix algebra to calculate the solution which minimizes the errors at each observation, and allows the observations to be weighted according to the standard deviation of the measurements taken. If properly applied, this gives the best mathematical solution to the traverse. This can be used to calculate a confidence interval for the position of any particular point.

The survey conducted by Phil Costaggini in the early 1980's was done in three control loops (See Appendix A). The input data and calculated results for these loops are listed in the appendices of his thesis. Fortunately, since the original field data from the survey conducted has not been found, these data contain some of the monuments located in the field survey with Wayne Jensen. These positions, together with the data presented in Phil Costaggini's thesis and estimates from the plat drawing he prepared were adequate to determine positions for many, but not all of the monuments located in his survey. There are, however, a number of monuments that are referenced in his thesis which were not included in the data, nor are they shown in the survey drawings included in the figures of the thesis. These may prove unrecoverable unless the original field notes are found or other sources for there positions are discovered.

Finally, since his survey was tied to two second order control monuments with known coordinates in NAD27, NAD83 and UTM reference systems, it is possible to calculate positions for these monuments that can be found using modern GPS equipment.

Loop 1 of Costaggini's survey is a closed loop which began near the group of cairn's listed in his report as NKA (North Mound 1), NKB (Triangle Stones) and NKC (North Mound 2). This loop went south to the south cairn noted as NKE and then looped back to the starting point. The four monuments noted were included in the traverse loop, while several others were measured by making a short traverse from one of the stations along the closed traverse loop. These traverses were not closed to another station, however, and thus were not included in adjustment calculations. These monuments were listed in his thesis as follows: NKL (Center Rock), RR3 (Ray Rock 3), NKH3 (Triangulation Point), NKER4 (East Rock

Mound), Rock A, and NKP (Wentz Stone).

Loop 2 of the survey was an open traverse beginning and ending at control points on Loop 1. The loop began at a traverse station at the intersection of Highway 101 and the logging road which he followed for a portion of his loop 1 traverse. The loop followed Highway 101 to the north to Augur Rock (NKF), and closed with a single shot from Augur Rock to a traverse station adjacent to the South Mound (NKE). This measurement was 6256 feet and was also used as the basis of bearing for his astronomical observations. This loop together with Loop 1 ties the primary monuments of the triangle of the survey as shown in Mr. Costaggini's survey plat (see Appendix A).

Loop 3 was also an open traverse beginning and ending on stations from the Loop 1 traverse, and was done to tie the survey to United States Coast and Geodetic Survey (USCGS) horizontal control monuments with known state plane coordinates. The records for these control monuments are now owned by the National Geodetic Survey (NGS). The monuments he surveyed to in this loop are station Neahkahnie and station Neahkahnie 2 RM1. This loop allowed the entire survey to be referenced in state plane coordinates, which is what allows us to be able to locate these positions today using GPS positioning technology.

The unadjusted data for each of these loops were entered into software program which performed a least squares adjustment of the data, and provided a printout with the adjusted coordinates, angles, distances and matrix information used for the calculations. These printouts were included in the appendices of the thesis, and give the only data regarding his survey that has been found to date. Unfortunately, these data do not include the measurements for the unadjusted traverses that were done to locate the other monuments not included in the adjusted loops. Due to the age and quality of the printouts available, however, some of the numbers listed were indecipherable. Thus, in order to verify the northing and easting values read from the printouts, a spreadsheet was setup which compared the northing and easting values to the angles and distances which were given in the printouts. By calculating the angles and distances from the northing and easting values, and then conversely

calculating the northings and eastings from the listed angles and distances, it was possible to correct all reading errors which occurred due to illegibility of the data. The results from this spreadsheet are presented in Appendix E.

Once the data were verified, we input the adjusted survey coordinates into AutoCad™. The points from each loop were rotated so that the individual loops fit together at the common survey points for each traverse. Then all of the points were rotated such that the long leg of the Loop 2 traverse was at the azimuth calculated for this line as given in Mr. Costaggini's thesis (See Appendix B). By doing this it made it possible to locate or estimate the position of the remaining monuments shown in the survey plat drawn by Mr. Costaggini as shown in Figure 1.

Figure 1 - Phil Costaginni's Survey Plat (Not to Scale)

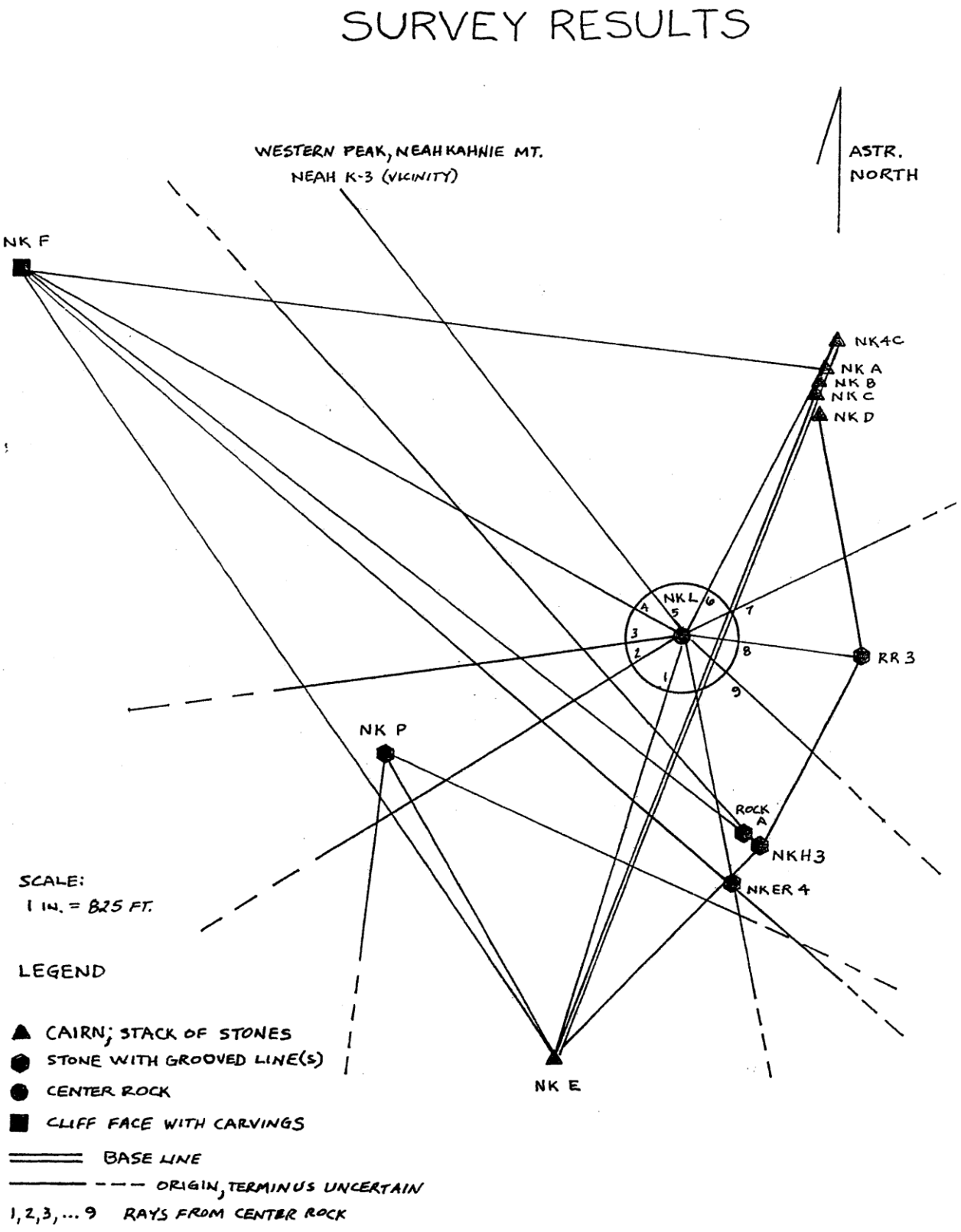

Table 18 from Mr. Costaggini's thesis (see Table 1 below) provided a comparison of the rays on some of the stones at Neahkahnie Mountain to the true azimuths between the various stones. These azimuths were then used to triangulate the position of some of the monuments not included in adjusted traverse loops, or, where only one direction is listed for a stone, to determine the azimuth of a monument and estimate the distance by scaling from the drawings provided in his report.

Table 1 - Azimuth Table of Monuments from Phil Costaggini's Thesis

Line	True Azimuth (from North)			Ray Azimuth (from North)		
	°	'	"	°	'	"
NKH 3–RR 3	25	57	54.6	26	25	43.9
NK E–NK L	16	39	33.8	14	24	00.2
NK E–NK P	331	03	13.0	332	25	38.8
Rock A–NK F	308	35	55.4	311	37	21.2
NK L–HK F	298	37	59.5	296	42	16.2
NK L–NeahK3	322	26	09.7	325	44	35.2
NKER4–NK L	350	17	53.5	353	30	20.2
NKER4–NK F	311	03	35.5	313	56	59.2
NK L–NK 4C	25	48	34.2	27	28	07.2
NK D–NK E	201	10	44.8	201	19	25.6
NK D–RR 3	171	16	22.3	169	19	16.6
NK L–RR 3	109	26	14.4	104	03	19.2

Thus, positions for the remaining monuments were established as follows. Center Rock 1 (NKL) was triangulated from azimuths through the South Mound (NKE) and Augur Rock (NKF). The East Rock Mound (NKER4) was triangulated from azimuths through Augur Rock (NKF) and Center Rock 1 (NKL). Since, these were determined using triangulation from known control points, their locations should be quite accurate.

There were two of the north mounds (i.e. cairns) which were not included in the traverse loop. North Mound 6 (NK4C) was approximated using an azimuth from Center Rock 1 (NKL), and an offset from the survey baseline (see the double line in Figure 1 of 1.57 feet as listed in the conclusions of Mr. Costaggini's thesis. North Mound 3 (NKD) was approximated based on an azimuth through the South Mound (NKE) and scaling the distances from surrounding monuments as shown in Figure 1.

The position of Ray Rock 3 (RR3) was then triangulated from azimuths through North Mound 3

(NKD) and Center Rock 1 (NKL). This position gave reasonable agreement with the distance between NKL and RR3 scaled from Figure 1.

Next the East Rock Mound (NKH3) was triangulated from azimuths through Ray Rock 3 and Augur Rock (NKF). Although this bearing is not specifically tabulated in Table 1, it appears that NKH3 and Rock A are on the same (or very similar) line as the azimuth from Augur Rock (NKF) to Rock A. Thus, the position of Rock A was estimated by scaling from Figure 1 and using this azimuth line.

Finally, the position of the Wentz Stone (NKP) was estimated based on the azimuth given from the South Mound (NKE) and a distance scaled from the survey map.

Based on the results of Mr. Costaggini's survey and the error of closure for the traverse loops that he adjusted, it is reasonable to assume that the positions calculated for the surveyed monuments for which we have data (i.e. NKA, NKB, NKC, NKE and NKF) are within 2 feet of the true positions. Then if we assume a maximum uncertainty in the azimuths given in Table 1 as 10" and a maximum distance of 5000 feet, the additional uncertainty would be approximately 0.34 feet (1.41*5000*sin(10")) which is almost negligible. Thus, the triangulated points NKL and NKER4 should be within 3 feet of their true positions.

The remaining points have a greater uncertainty as they all based (to some degree) on measurements scaled from Figure 1. By comparing the positions determined from multiple methods of estimating their positions, it is likely that these monuments (NKD, RR3, NKH3, Rock A and NKP) are within 50 feet of their true positions. Due to distortions caused by photocopying and the large scale of the hand drawn figures, it is not possible to estimate the distances to any greater precision. It should be noted, however, that when Figure 1 is scaled and rotated such that the triangle formed by NKA, NKE and NKF fits with the coordinate positions, the positions drawn in Figure 1 agree with the plotted positions to the degree that would be reasonable for this type of hand drawn figure.

The coordinates for the stones were calculated in an arbitrary Cartesian coordinate system as

described above. In order to use GPS equipment to locate these positions, it was necessary to transform the survey data to fit with the NGS control monuments which were surveyed in Loop 3.

In his thesis, Mr. Costaggini provides a discussion about how his measurements between Station Neahkahnie and Station Neahkahnie 2 compared to the published values from NGS (i.e. USCGS). Initially, we considered that it would be best to perform the field survey in Oregon State Plane coordinates based on the NAD27 datum. Mr. Costaggini provides both the latitude/longitude values and the state plane coordinates with northing and easting values in his report. Although the lat/long values for both control stations matched the values published by NGS, the state plane coordinates for Station Neahkahnie did not. In fact, although the state plane coordinates for Station Neahkahnie 2 matched exactly with the values in Mr. Costaggini's thesis, there was more than 200 foot difference between the published and reported values for Station Neahkahnie.

Due to this uncertainty, the state plane coordinates based on the NAD83(1991) datum were used to orient the survey. The Cartesian coordinates of the stones were transformed such that the coordinates of Station Neahkahnie were held, and then rotated to match the calculated and published positions of Station Neahkahnie 2 RM1. Once this was done, the error between the published position of Neahkahnie 2 RM1 and the position calculated from Mr. Costaggini's survey was 1.21 feet. This was felt to be adequately precise to serve as the basis of a field search using GPS equipment.

To research the existing conditions near Neahkahnie Mountain where the stones were located, we looked at aerial maps, topographical maps, and existing surveys. Aerial maps showed that the area appeared to be heavily forested. We also scaled and overlaid tax assessor maps on to our recreated survey map (See Appendix D). This allowed us to see existing lots and right of ways in relation to the locations of the stones. The majority of these lots and right of ways have been developed since Costaggini's survey took place. Because of this, we had to assume that many of the stones may have been moved or lost. We attempted to contact the owners of the property where we believed stones may

still be located. We were unable to contact any of these owners because of the fact that these parcels are owned by corporations and partnerships which had no immediate contact information available. We did not contact the owners of the newly developed lots because the location of one stone could have possibly been located on several different lots depending on the scaling and exact locations of our tax assessor maps imposed on our map.

We also contacted the Tillamook County Museum where some of the stones are currently on display. We wanted to know which stones were in the museum so that we would know what not to expect to find in the field. The Collections Technician Lise Zimmerman told us that there are possibly more stones that are currently in the museum archives and not on display. Unfortunately we were not able to meet with Ms. Zimmerman to search their archives because of scheduling.

To test the accuracy of, and become familiar with the GeoXT, we ran a field test on the Oregon State University campus. We inserted the coordinates for stations 'Corvallis Closed Cupola', 'Corvallis Ore. St. Coll. Stack', and 'College' into the GeoXT (See Appendix F). We first attempted to locate station 'Corvallis Closed Cupola'. Once we obtained the required number of satellites and a GPS connection, the GeoXT told us 'Start Moving', which direction to head, and distance in feet. The GeoXT also has the ability to show bearing, distance in meters, elevation distance, among other options. The GeoXT led us to the East side of what is now Benton Hall which had a cupola on the top of the building. The GPS signal would disappear when we got to within about six feet because we could not receive a signal from the required number of satellites. To fix this problem we positioned ourselves as close as possible to the target, while still receiving a GPS signal, and then measured the distance and direction from that location. The result in these measurements was that the target location appeared to be the cupola on top of the building. We repeated this tactic for the station 'Corvallis Ore. St. Coll. Stack'. We had knowledge of where this station was actually located, and the GeoXT led us to that location.

For station 'College' we were able to receive a GPS signal until we reached the target location. This

located us on the West side of 26th Street across from the Dixon Athletic Center. The GEOXP indicated that the target location was about three feet North of a tree, possibly under the dirt surrounding the tree. According to the NGS data sheet station 'College' is located ‘at the intersection of Northwest 26th Street and Adams Ave., on the campus of Oregon State University, 85.0 ft. South of the centerline of the Ave., 58.4 ft. South-Southwest of light pole number 50, 39 ft. West of the centerline of the street, 30.5 ft. East of the center of a track in Coleman Field, and 12.8 ft. West of the West edge of the West sidewalk of the street.

This is consistent with the location given by the GeoXT. During this trial we determined that the GeoXT is able to give distance to the nearest foot. According to the Trimble technical support personnel, using the SBAS (Satellite Based Augmentation System) with the GeoXT allows sub-meter accuracy without using additional real time corrections. We also tested the GeoXT with the locations of stations 'Nary', 'Athena', and 'Mag'. Since we had exact elevations for these stations, we also tested the GeoXT’s ability to read elevation. This was less successful. Readings taken when located on these stations gave an 11 ft. to 12 ft. error.

On November 22, 2008 we traveled to Tillamook County and Neahkahnie Mountain. We began the day at the Tillamook County Museum. We viewed the stones that the museum has on display in a case. The museum had Wendle’s Rock, the Measurement Rock, Angle rock C, and two other stones which are possibly Angle rocks A and B. We were also able to look at several pamphlets and books on the Neahkahnie stones and the history of the area (See Appendix G).

After the museum visit, we made our way to the Neahkahnie Mountain area. We decided to search for the South cairn location first. From the tax assessor maps we were able to locate streets to help with a starting location. Our technique was to follow the GeoXT satellite signal to the target location if possible. If we were not able to receive a satellite signal all the way to the target location, we would get as close as possible to the target location and from that point measure distance and bearing with a compass.

When we had a reading within 200 ft. of the South cairn's location, we parked the van and started to search on foot. We were able to sustain a satellite signal directly to the target location which was in the driveway of a house at 37340 2nd Street. We spoke with the owner of the house (Diane Erickson) who stated that her family had owned the property since 1945 and they had no knowledge of a mound of stones. She did say that prior to the development of the houses across the street, which occurred much later than that of her house, there was mention of stones in 'interesting configurations'. She had never seen these stones herself, but only heard about them. (See Appendix H)

The second monument location that we searched for was the Wentz stone (NKP). We could not find any photographic evidence of the Wentz Stone. We believe that it may be also the same as Treasure Rock 2 or the 'W' Stone due to similar descriptions and locations. We drove to within 200 ft. and then walked to the intersection of Beula Rd. and Kahnie Trail Lp. We took a satellite reading from a manhole close to the intersection of these two roads and then measured the distance and angle with the compass from that point (112 ft., brg. 237° Mag. N). We found that the target location was in a side yard of a house along the beach. We knocked on the door, and the owner was not interested in answering any questions or allowing us access to his property. We were only able to take pictures of the area and move on. (See Appendix I)

The third stone that we searched for was the Augur rock (NKF). We drove in the known direction of the rock and received a GPS satellite signal approximately 2000 ft. away. When we got to within 300 ft., we parked the van at a look out shoulder on the side of the highway. We followed the satellite guidance to within 60 ft. of the target location. This led us to the edge of a cliff wall. We used the compass to determine the bearing, and knew that the distance was approximately 60 ft. At first we were confused because we could not go forward 60 ft. due to the cliff wall. The wall had also been drilled at one point which made us believe that the Augur rock was probably gone. We then began to look up the wall and saw an area at the top of the wall that had not been drilled and could be an estimated distance of 60 ft. This gave us enough hope to set up the total station that we had with us to get an enlarged look at the area. We were not able to determine with certainty that the Augur rock was, or was not there. What we

did see was undisturbed square rock formations. (See Appendix J)

After searching for the Augur rock we drove up Neahkahnie Mountain to search for cairns NKC and NKB. We started with NKC. We drove up the road until we received a signal of within 500 ft. While driving up the gravel road, the signal suddenly directed us off of the road to the East. We parked the van, and decided to walk. We were surprised to find that the exact location where we needed to head East, the brush and blackberries had been somewhat cleared. This was decent evidence that someone had been there before, possibly with the same goal as ours. The area was heavily forested and we could not always receive a signal from the GPS satellites. To fix this problem we would take readings where we could and measure distance with the 200 ft. tape measure and angle with the compass. We did this several times, taking care to double check our distance and line. Once we were within approximately 10 ft., we found a private gravel road, with an opening along the road which enabled us to get a satellite signal and take another distance and angle reading. This reading was consistent with our previous readings. We decided that the target location was approximately 10 ft. East of the private gravel road, next to two large trees. The ground was covered with undergrowth and dense ground cover. We searched the area trying to find the cairn with no luck. We then briefly searched for cairn NKB. We took a reading from along the private gravel road, and then measured off the distance and angle with the compass. Again, the ground was covered with undergrowth and we were not able to find the cairn. We believe that these cairns have a fairly good chance of still being in their original positions because of the fact that the area is not developed and has not been disturbed. Finding these cairns under the ground cover that has accumulated in the area over the last thirty years would be challenging, but with more time devoted to these monuments, we believe evidence of them could be found. (See Appendix K)

The final stone location that we searched for was Center Rock 1 (NKL). We were able to get a satellite signal while on Hwy 101 and followed that reading until the GeoXT directed us West from the highway. We were able to park in a vacated driveway, walk through the property to the back of a lot in a new development. There was a recently constructed road and two new homes on the street. Unfortunately the entire subdivision had been graded. We followed the new road South, until the signal pointed East.

We walked East to the back of a newly graded lot. We were able to obtain a satellite signal to the target location. This location was 6 ft. from the back of the new lot and there was no stone. We were told by Garry Gitzen that the developer of the subdivision was worried about stones being found on his property for fear of the development being stopped. Directly East of the development is undisturbed property. Gitzen also mentioned that Center Rock 1 was quite large, so moving it a great distance would be difficult. It is possible that with more time and searching Center Rock 1 could be found on the undisturbed property East of the new development. (See Appendix L)

CONCLUSION:

Through this project we were able to answer some questions, but not all. What we were able to determine with certainty is that the GeoXT is an instrument that works very well, and is very precise without the need of a secondary real time correction unit. SBAB allows the GPS unit to lead to a waypoint location with sub-meter accuracy. We were actually able to get distance readings under 1 ft. As mentioned previously, the device's accuracy with elevation could be improved, with around a 12 ft. error.

The other fact that we found to be true is that Costaggini performed an accurate traverse survey. Of course surveying 8 ft. wide rock mounds only brings so much accuracy, but his three loops tied together with NGS stations and Polaris shots for bearing produced a good quality survey. Due to his thorough records and procedures we were able to trace back his adjusted loops to recreate his survey for ourselves.

One very interesting question that we have not been able to answer is why there are stone monuments mentioned in Gitzen's recent book, other publications, and from speaking with Gitzen that were not surveyed by Costaggini (See Appendix M). Most significant of the omissions is a second triangulation stone similar to Center Rock 1 mentioned by Gitzen. Another interesting stone that is missing is the Costaggini Rock. Costaggini was able to survey the stones in his traverse with the help of Jensen who showed him where stone monuments were still located, and flagged the location where other stone monuments had previously been located, but had since been removed. This also brings up

the question of where many of the stones are currently located. It is well known that many of the stones have been moved from their original locations. Jensen, as a curator, was interested in protecting the stones as archaeological finds. As mentioned, some of the stones are located in the Tillamook County Museum where Jensen was curator. There are still many more stones whose location is currently unknown. It is believed that many of these stones are in the possession of Jensen's family and friends.

We believe that due to the accuracy of the GeoXT, and our ability to recreate Costaggini's survey and tying it to NGS stations, we were able to find the locations of the stones that we were searching for. If given more time we believe that one could find evidence of at least some of the cairns.

The question of where the stones originally came from is impossible to solve. They could have been placed by Sir Francis Drake as a way to track longitude, they could have been set to mark the location of a wrecked ship filled with treasure, or something completely different. It's possible that the stones were set to track the paths of stars. Costaggini’s conclusion was that the stones were most likely 'to monument or to otherwise symbolically signify possession' by Sir Francis Drake. He also concludes that the stones could not have been used to map treasure. Where ever the stones came from, the truth is that they have grasped the attention of everyone who has every heard the story of Neahkahnie Mountain.