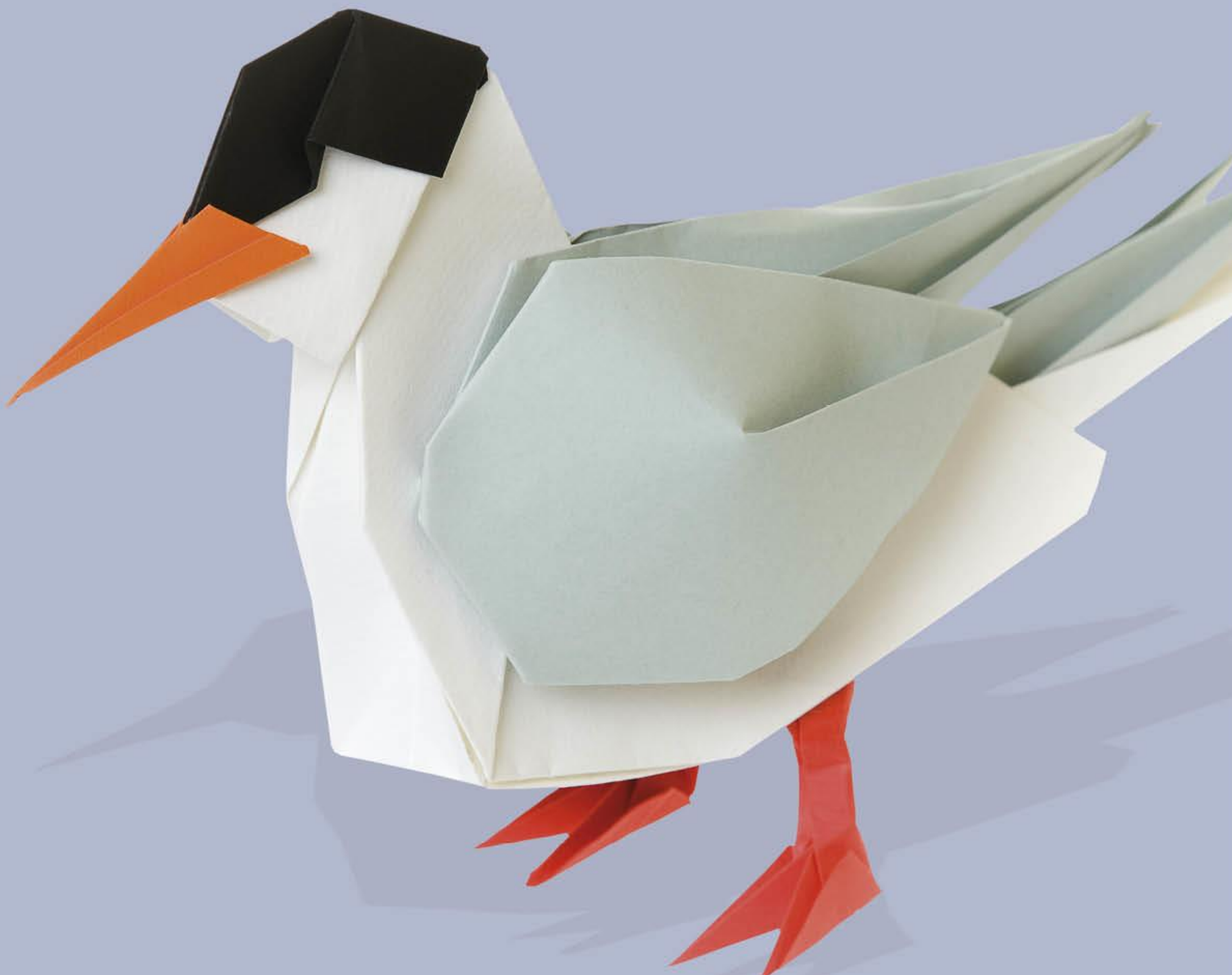
NEA Exemplar 4: An investigation into scree characteristics in the Lake District National Park

Part 1: Candidate write up



A Level Geography

Pearson Edexcel Level 3 Advanced GCE in Geography (9GE0)

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AN INVESTIGATION INTO SCREE CHARACTERISTICS IN THE LAKE DISTRICT NATIONAL PARK

Independent Investigation

ABSTRACT

Investigation undertaken in March 2017 for Geography A Level Coursework May 2018

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Contents

Introduction

Scree is the product of geomorphological processes such as mechanical weathering; and freeze thaw action, this occurs due to extremes of temperature. These sub-aerial processes play a large part in the creation of the glacial landscapes that are visible today, the depositional material is often found in the various forms of moraines and is main cause of micro-features such as chattermarks and striations as a result of subglacial erosion using scree material. It is scree that provides much of the mechanisms that lead to the landscapes seen in upland areas such as the Lake District, Snowdonia and the Scottish Highlands.

Many studies on scree have been carried out (though not many in the Lake District) including Peter Wilson (2005) who considered the impact of scree slopes on Wastwater and its implications for landscape development within the Lake District, whilst (Andrews, 2017) reviewed a paper originally written in the late 1950s that was also based on work done on Wasdale. This concluded conclusively that considerable variations of the angle of 'repose' can occur (Andrews, 2017), he pointed out that much of this was down to size and shape of scree material and how this influenced 'repose' angle. Indeed in Andrew's paper Ward (1945) has shown that the nature of the material is of critical importance in determining the angle of repose of the slope' (Ward, 1945).Other authors had also noted this was like areas within the Alps. This is where I felt there was certainly room to consider whether the areas I have chosen to study contain similar findings.

A diagram of cirque development can be seen below:

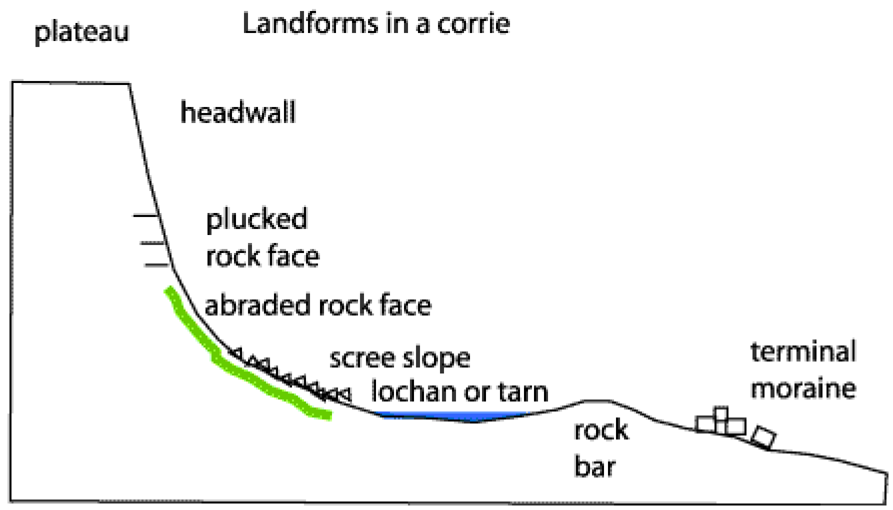


Figure 1: Cirque Development (www.landforms.eu, n.d.)

Having been taught about glaciation I found the subject fascinating and decided to look at scree as I felt it was the most important factor in valley glacier processes. I read several different academic reports (Some of which the teacher had gathered some students uploaded to the VLE) as well as textbooks including Collard (1995) and Small (1989) as part of my secondary. I feel that the study is manageable since many cirques in the Lake District National Park (LDNP) have good access and my choice of areas included the cirques around Easedale tarn as not only was it within easy walking distance, it is also of low altitude in comparison to others and within easy travelling distance from the Blencathra Field Study Centre where I will be based.

I also chose Easedale as it allows me to consider several other cirques close by, all of which had several significant differences. Pavey Ark for instance has a different geology to Easedale. Eagle Crag faces a different aspect and therefore allows me to develop my questions. These three cirques were also within easy reach of each other and therefore it is possible to complete the data collection in one day. The maps below show the location of the chosen sites:

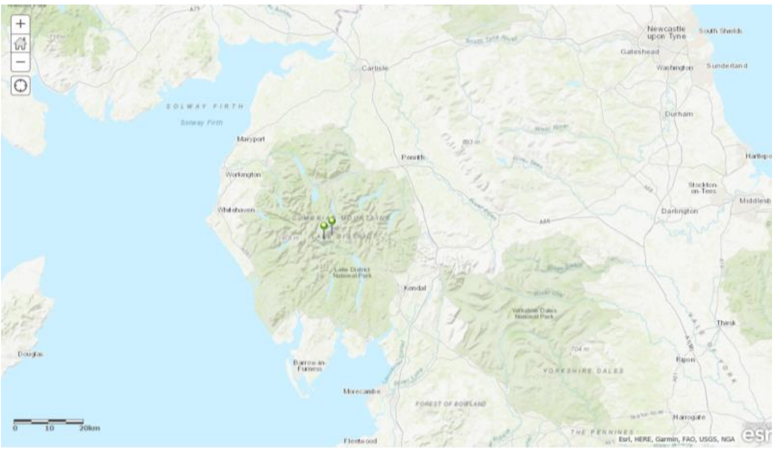


Figure 2: The Lake District National Park Cumbria (Esri, 2017)

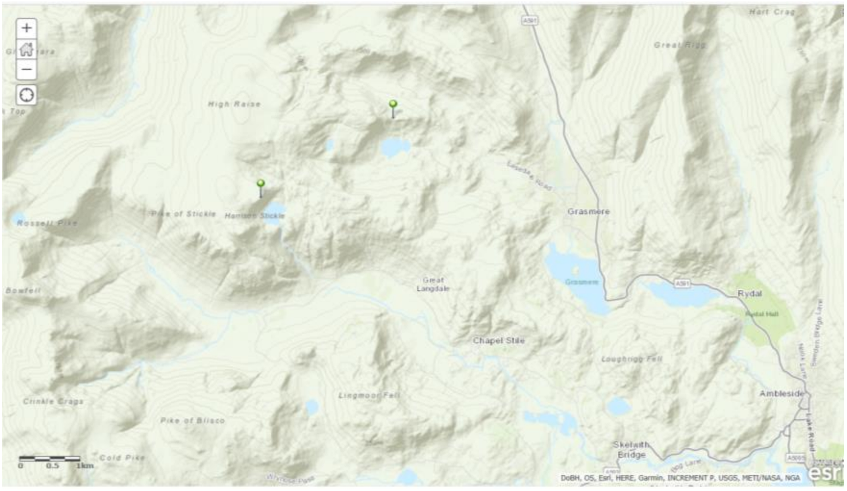


Figure 3: Easedale Tarn in Relation to Pavey Ark (Esri, 2017)

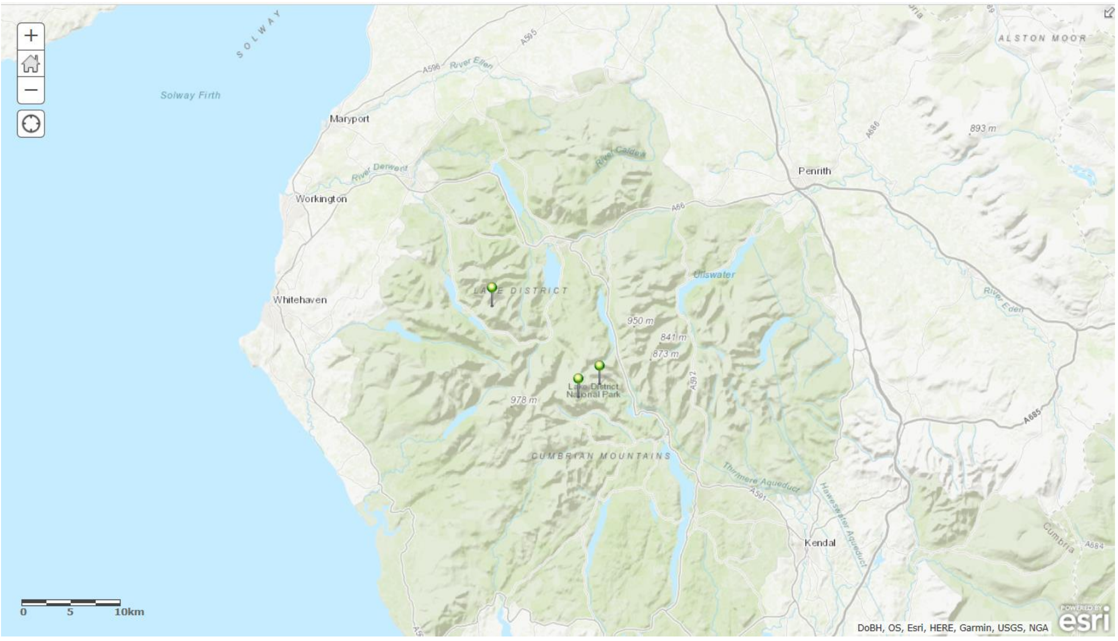


Figure 4: All Chosen sites within the Lake District National Park (Esri, 2017)

According to Collard scree has a model form in so much as there is the steep slope followed by transport slope and finally the talus slope with size sorting as seen below:

Photo 1: Pavey Ark back wall

Scree slopes offer an interesting idea for as Collard suggests there appears to be sorting occurring on the scree slope with smaller more angular material often being found at the top of the slope and larger more rounded material being found at the bottom of the slope.

Furthermore work by Andrews 2017 suggests that there is also variations between different scree slopes with some scree slopes having a higher angle of repose than others. A key factor in determining the size and shape is geology as Sugden and John In their book Glaciers and Landscape: A Geomorphological Approach (1976) Sugden and John have discussed. I anticipate the geological origin of the rock to be important and have a significant effect on why slope angle varies between scree slopes.

The aim of my project is therefore to investigate:

To what extent is the slope of scree slopes influenced by the size and shape of the scree material?

To help achieve my aim, I need to ask several questions the answers to which should help answer the main question in more detail.

Sub- Questions

- To what extent does the does the shape of the scree material influence scree slope angle?
    - I expect to find that that the further down the slope the more rounded the material as more rounded material will be able to roll further. In addition I expect that the angularity of the scree will cause the slope angle to change as there will be more voids with it. According to Collard when discussing the creation of landscapes he makes specific reference to this (Collard, 1995) as does Wilson (2005).
- To what extent does the size of scree material influence scree slope angle?
    - The theory being that the size of the scree will cause the slope angle to change as smaller scree will be able to pack tighter together and so have a lower slope angle. I also expect to find that larger scree size will 'bounce' further down the slope due to momentum and therefore larger material will be found at the bottom of the slope and smaller material will be found at higher levels (Andrews, 2017)
- To what extent does other factors such as the parent geology and aspect influence the scree slope angle?
    - Here I am working on the theory that the type of rock, that being volcanic against sedimentary will also create differences within a cirque and the characteristic of the scree slope. The theory being that harder volcanic rock will be eroded and weathered at a slower rate than those made up of sedimentary rock (Sugden & John

1976). Furthermore the aspect of the cirque is also believed to influence the scree slope as it too influences weathering rates.

Methodology and Fieldwork

We undertook fieldwork as part of a group collecting data for various assignments I worked with 5 other students who were working on titles to do with Cirque size, distribution and scree size, shape and slope. This therefore allowed us to then collect the necessary data we needed for our own investigations.

- To what extent does the does the shape of the scree material influence scree slope angle?

Before we went on the trip it was clear that I was unable to go above 600m due to health and safety risk assessments that had carried out and therefore I would need to get all of data below this level. Any other data that I needed I could obtain from an OS map as well as BGS and ArcGIS all of which offer precise information.

To obtain the data for the scree from the different cirques we divided each cirques into 3 sections via the length of the back wall therefore using a systematic sampling technique. This was to ensure as much spatial coverage of each cirque as possible. Three sites were chosen as it meant that each site could be covered by two members of the group working together.

I then used a systematic sampling technique for obtaining the scree slope material each time going up 60m and at 10m intervals. This was to ensure that we covered all of the scree between 0m and 60m. At each of the transect points (ie 0m ,10m and so on) I threw a 5 by 5 quadrat randomly on the scree and selected one piece of scree material from each of the 25 squares. This is a random sampling strategy and so reduces any bias I might have had in collecting the data.

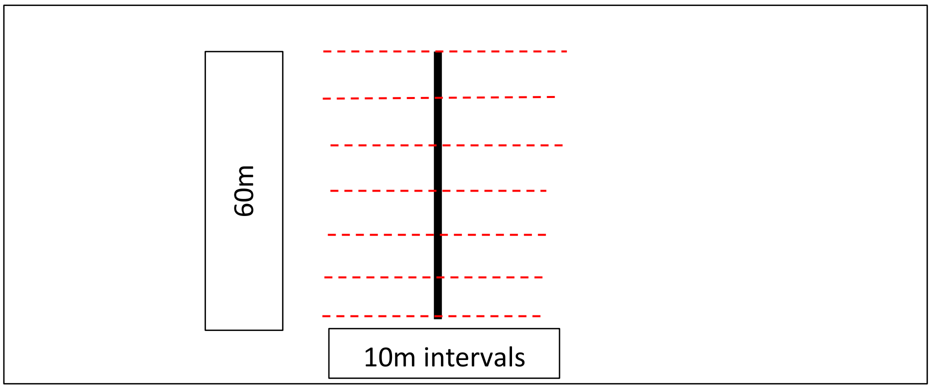


Figure 5 – A diagram showing how I organised the data collection

I used the Cailleux index which I felt was more objective than the Powers Index and therefore better in terms of the accuracy of results which is seen below:

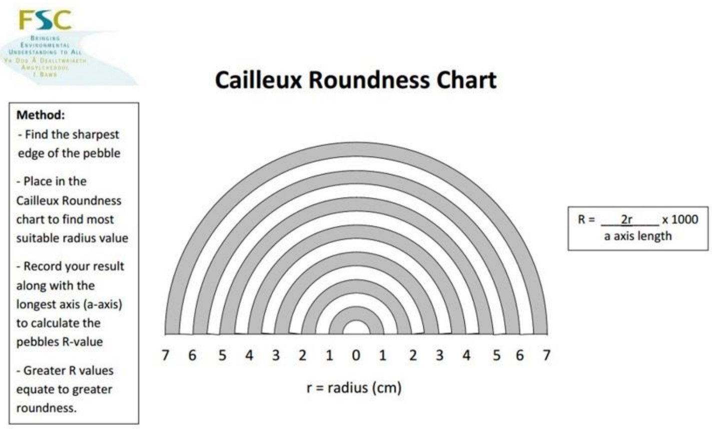


Figure 6: Cailleux roundness Chart (FSC, 2017)

The data was then put through the equation for the Cailleux roundness index

$$Roundness\ index = \frac{2r}{l}\ x\ 1000$$

At the same time, we measured the angle of the slope up the central line at each of the transect points from the edge of the tarn up to 60m. For this we used a Suunto clinometer and two ranging poles similar to the one below:

Figure 7-: Suunto PM-5/360 PC clinometer

We felt that the Suunto clinometer would be far more precise than a plastic gun clinometer.

A key problem that I encountered was in using the Callieux roundness chart. Although I felt it was more accurate than using a bi-polar roundness scale such as Power's Index I still encountered difficulties in ensuring that I was using the radius chart reliably as it was my opinion which was the sharpest edge of the scree material sampled. This was particularly difficult for the more rounded scree that I found at the bottom of the transect. This is therefore a potential inaccuracy of the data collection programme.

In addition another one of the problems that I encountered was that there was often vegetation growing on some of the scree slopes. This would bind the scree slope material together and therefore make the scree slope a steeper slope than if the vegetation was not present. This means that some of the data I collected might not be representative. This is therefore another potential inaccuracy of the data collection programme.

- To what extent does the size of scree material influence scree slope angle?

For this part of the work I measured the size of the scree including the length and width, though this isn't precise it is being used to compare to others and as long as these are measure the same way I feel that this is adequate for the data I need. I obtained this data using callipers which I believe gave therefore gave reliable and precise results.

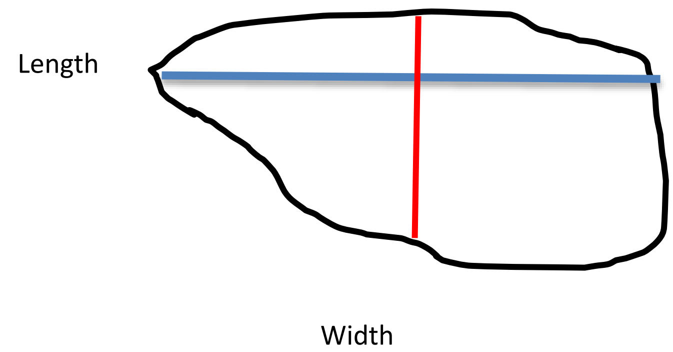


Figure 8: Scree Measurements

The length data was also used in the Cailleux Roundness scores.

One of the problems I faced was in deciding which was the longest axis – this was particularly a problem in the smaller scree material found at the top of the transect. This means that some of the data collection might be reliable. This is another potential inaccuracy of the data collection programme.

There was also the issue of human interference. I noticed that there were several paths amongst the scree at both Easedale and Pavey where Jake's Rake (A graded scramble) can be found and is undertaken by walkers regularly. These walkers can often impact, dislodge and influence scree angles. This would therefore effect the accuracy of the results as the material that I measured might not have been that distance up then transect. This is therefore another potential inaccuracy of the data collection programme.

- To what extent does other factors such as the parent geology and aspect influence the scree slope angle?

This was completed by using secondary resources including geology maps and the British Geological Societies viewer which I found tremendously useful and easy to use giving a clear indication of the geology of the rock and its formation as well as hardness and perfect for the work I was undertaking. I also calculated the aspect of the cirque by locating our three transect points on an OS map and then working out an average aspect from these three sites.

- Ethical Dimensions

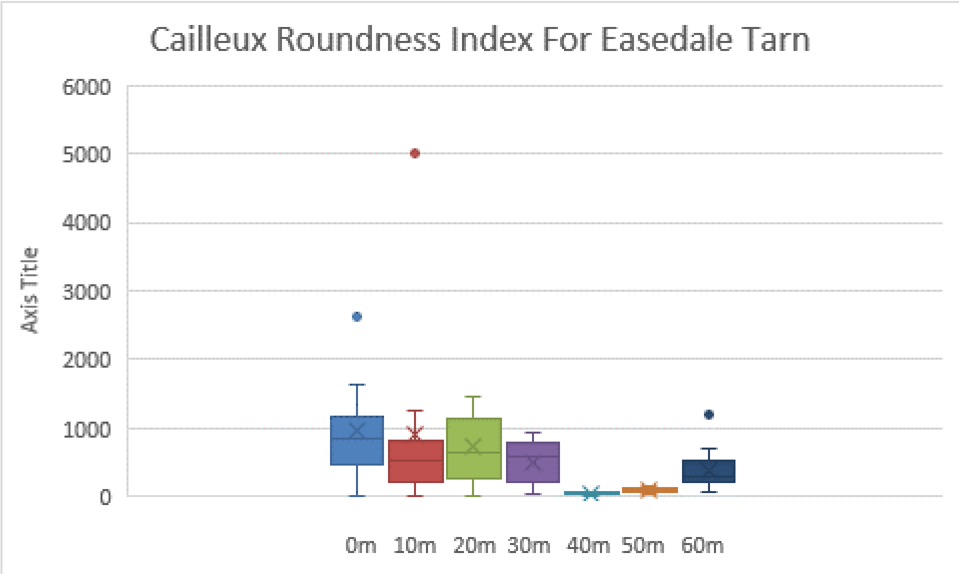
When in the National Park we followed the country code which meant all gates we passed were closed afterwards. We kept quiet in fields where livestock were, and we took all litter down with us. When we met people on the way up to these as they are tourist attractions we were polite and courteous and allowed people to enjoy the countryside as we did.

We also were aware that the scree upon which we walked was an important geomorphological site and therefore we made sure that we replaced stones where we found them, and we kept away from the water's edge.

Our lecturer had decided that the safe upper limit for our study was 60m due to the risk of falls and therefore though we realise our data may be compromised we wanted to make sure that we abided by all codes of practice in completing the work.

- **To what extent does the does the shape of the scree material influence scree slope angle?**

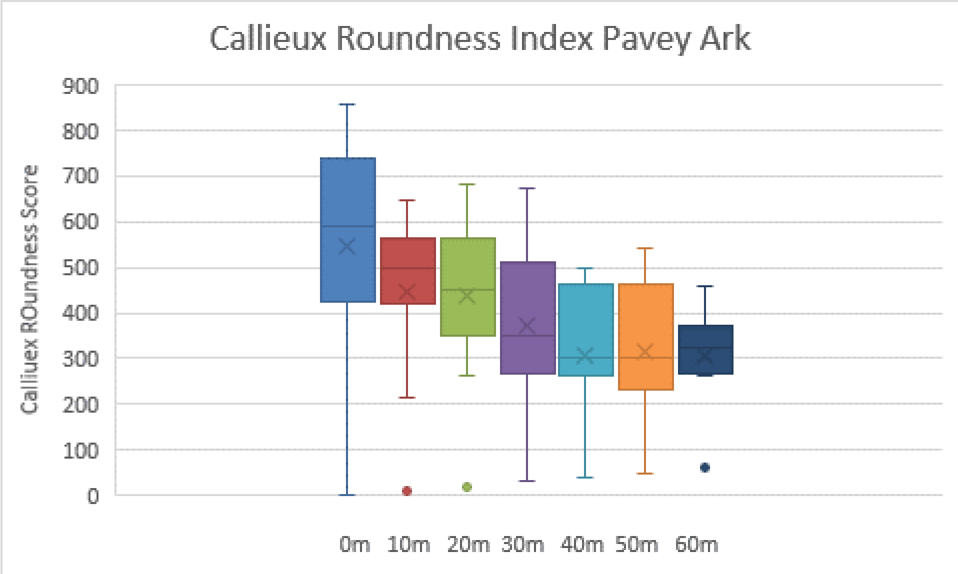
The results are shown below.



Graph 1: Cailleux Roundness Index for Easedale tarn

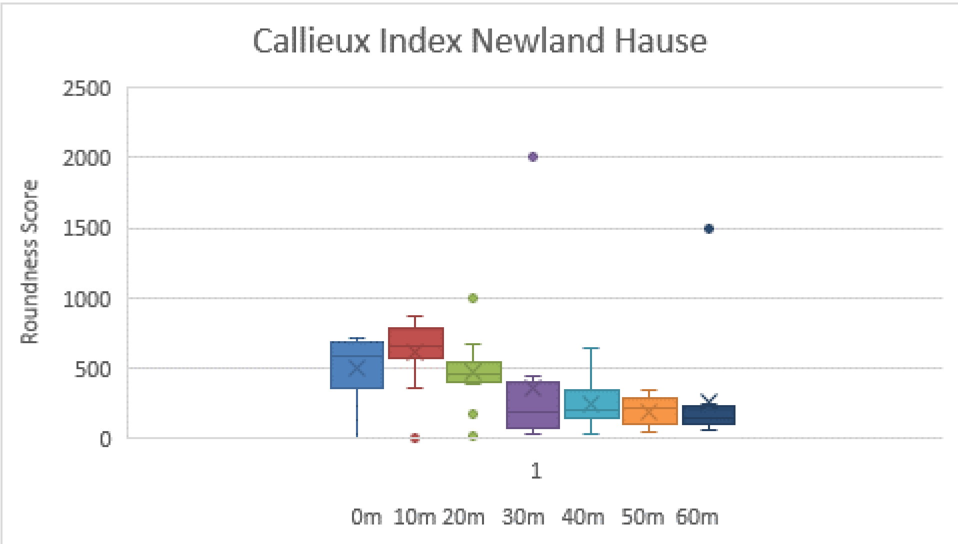
The results show that apart from 60m the angularity decreases with distance up the scree slope decreasing from a roundness value of 832 to 28 at 40m and 74 at 50m which could reflect the fact that the material at the bottom of the slope had abraded and been open to more geomorphological action than the material at the top of the slope as suggested by Andrews. It is also easier for rounded material to roll down the scree slope and this is shown in the diagram.

The same is true for Pavey Ark where the Cailleux Roundness Index (CRI) although the material is far more rounded with values of up to 580 there is still a pattern with the more rounded material found at the bottom of the scree slope (580) and the less rounded material found at the top (325). Yet it is important to note that the scores for the CRI were much lower than those found at Easedale.



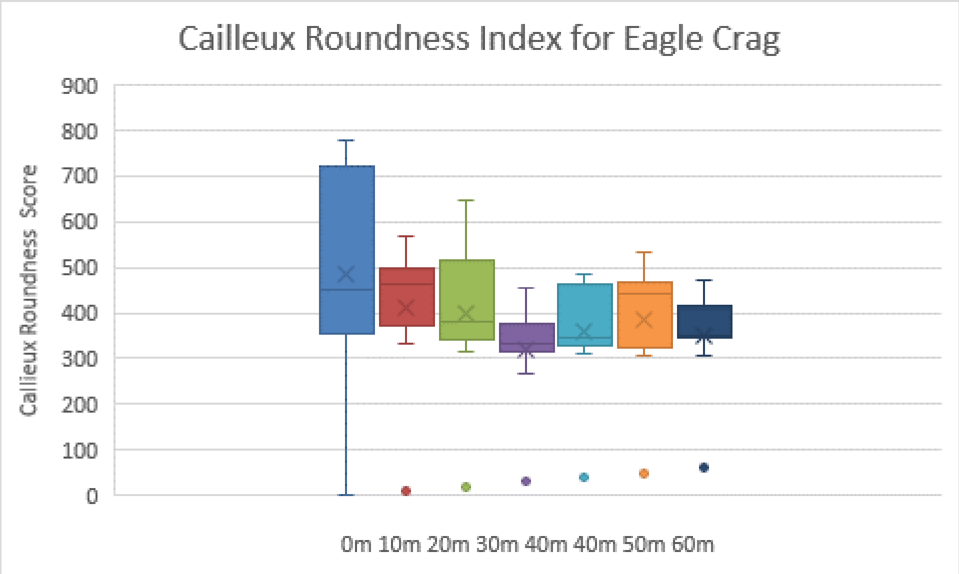
Graph 2: Cailleux Roundness Scores for Pavey Ark

For Newlands again, there were some interesting results as these showed the same kind of relationship as at Pavey Ark and Easedale.



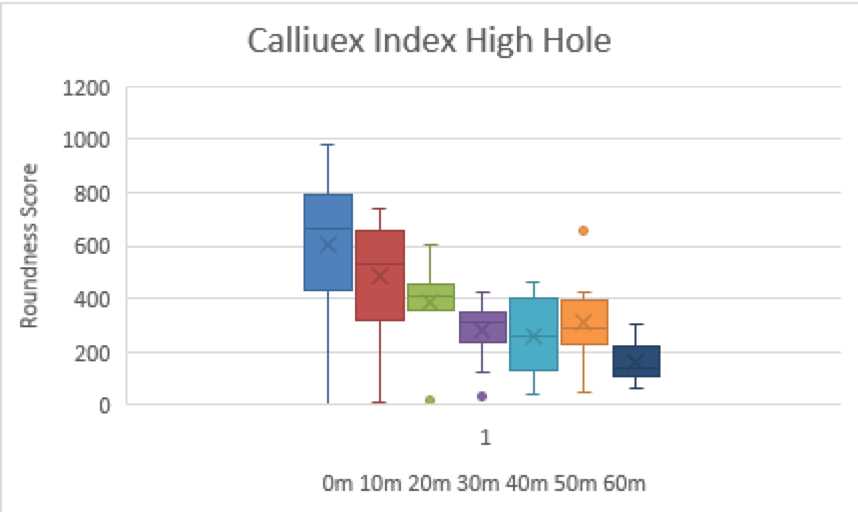
Graph 3: Cailleux Roundness Scores for Newland Hause

For Eagle Crag again the results follow a similar broad relationship as the others where the angularity decreases down the slope:



Graph 4: Cailleux Roundness Scores for Eagle Crag

The same appears to be true for High Hole with an increase in angularity with distance up the slope.



Graph 5: Cailleux Roundness Scores for High Hole

What appears to be the case is that in all circumstances the angularity of the rocks appears to increase up the slope as suggested by theory. This is because the more rounded scree materials are likely to be able to roll further down the scree slope.

I then investigated the extent to which angularity varied between cirques and the impact of this on the slope angles in the different cirques.

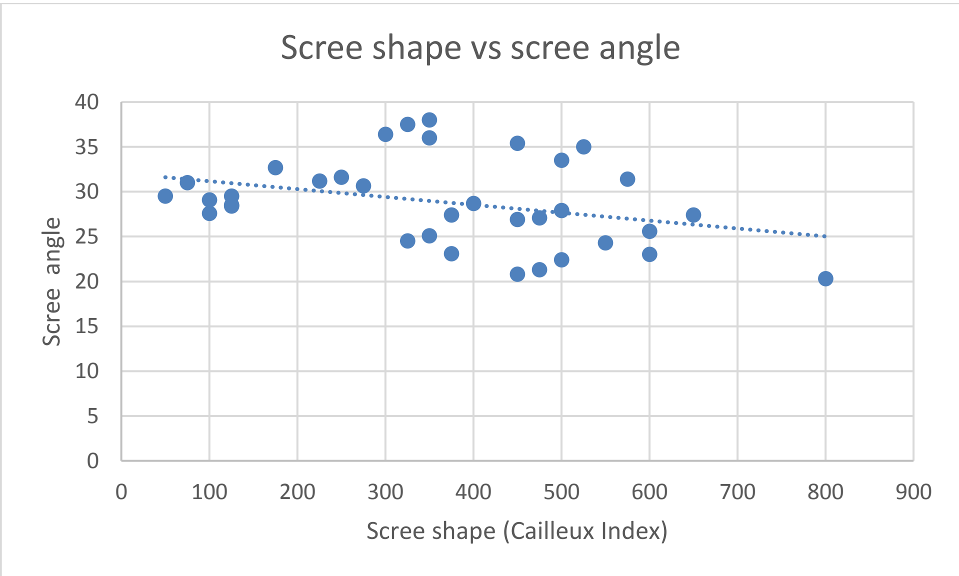
Firstly there is a clear difference in angularity between the different cirques as noted already and so proves my ideas that scree slopes do vary between cirques.

CIRQUE	AVERAGE CI
EASEDALE	742.6
EAGLE CRAG	422.46
PAVEY ARK	426.63
NEWLAND HAUSE	411.96
HIGH HOLE	393.83

Table 1 – Mean values for angularity

Clearly Easedale has the scree material that is the roundest whilst High hole has the material that is the most angular.

I then made a scatterplot of the angle at each one of my transect point and the angularity at that point



Graph 6: Scatterplot of Scree shape and scree angle

This scatterplot shows that there does appear to be a trend where the slope of the scree is higher when there is more angular material and the slope of the scree is more gentle when there is more rounded material. This is because as authors such as Wilson 2017 have suggested the more rounded the scree material the easier it is to pack together and so the more gentle the scree slope.

I then ran a Spearman's Rank test as I felt it was best to show whether there was a relationship between the two variables. This test was done using an online calculator (Social Science Statistics, 2018) and returned the score of -0.39.

I then looked up the critical value from an FCS chart

Table 1 - Critical values for the Spearman's Rank Correlation Coefficient

	Significance level	
Number of pairs of measurements (n)	p = 0.05 (95%) (+ or -)	p = 0.01 (99%) (+ or -)
5	1.000	
6	0.886	1.000
7	0.786	0.929
8	0.738	0.881
9	0.683	0.833
10	0.648	0.818
11	0.623	0.794
12	0.591	0.780
13	0.566	0.745
14	0.545	0.716
15	0.525	0.689
16	0.507	0.666
17	0.490	0.645
18	0.476	0.625
19	0.462	0.608
20	0.450	0.591
25	0.400	0.526
30	0.364	0.478
35	0.336	0.442
40	0.314	0.413

Table 2 – Spearman critical values

Source http://www.field-studies-council.org/media/2594645/spearmans-wksheet.pdf

I was testing the null hypothesis that there is no significant relationship between the angle of the scree and the angularity of the scree. I can reject this hypothesis and accept the hypothesis that there is a relationship at 95% as my value -0.39 is larger than the critical value 0.366 at n= 35. It is not however a significant relationship at 99% level as my value is smaller than the critical value of 0.422. I can therefore say with some certainty (95% certain) that there is a correlation between these and that in the case my study that the angularity of the scree appears to have some influence upon scree angle in different cirques. I cannot, however, say with 99% confidence that there is a relationship.

This might be because of the other factors that influence scree slope angle such as size, geology and orientation having a greater influence than the shape of the scree.

I can therefore conclude that there is a change in scree angularity with distance up the scree slope and that there is a strong but not overwhelming relationship between scree slope angle and scree material shape.

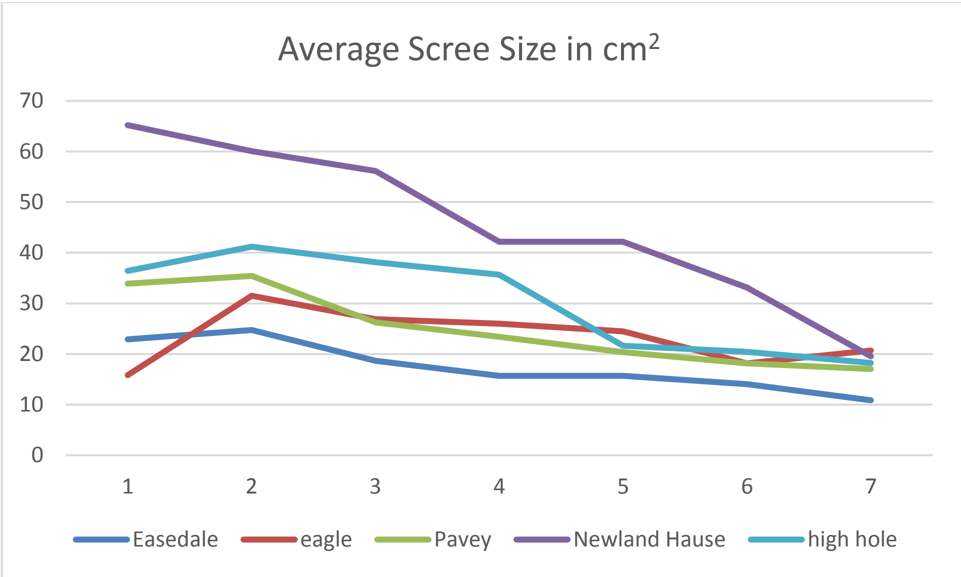
- **To what extent does the size of scree material influence scree slope angle?**

The theory behind this is that the larger scree size will effectively 'bounce' further down the slope due to momentum and therefore larger material will be found at the bottom of the slope and smaller material will be found at higher levels (Andrews, 2017). My results were as follows for this

m	*Easedale*	*eagle*	*Pavey*	*Newland Hause*	*high hole*	***Average***
0	22.9	15.82	33.86	65.21	36.4	**34.838**
10	24.73	31.5	35.42	60.1	41.2	**38.59**
20	18.65	26.87	26.21	56.14	38.1	**33.194**
30	15.68	25.96	23.39	42.16	35.65	**28.568**
40	14.18	24.44	20.35	38.61	21.6	**24.846**
50	14.04	18.17	18.12	33.15	20.4	**20.776**
60	10.85	20.69	17.03	19.54	18.23	**17.268**
AVERAGE	**17.12**	**23.35**	**24.91**	**44.36**	**30.23**	**28.044**

Table 3 - Average Scree size across all 5 Cirques

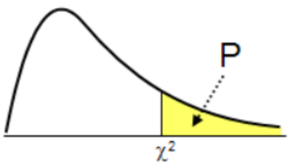
I then made a graph to show this below.



Graph 7: Average Scree Size in cm²

Graph 7 appears to show a solid relationship as it would appear that scree size decreases up the slope which would support my sub question and occurs in all cases at all cirques.

To see if there was a significant relationship between distance up the scree slope and scree size I carried out a Chi square test. This test was done using an online calculator (Social Science Statistics, 2018) and returned the score of 18.62 with 24 degrees of freedom. I then looked up the critical value from a table below



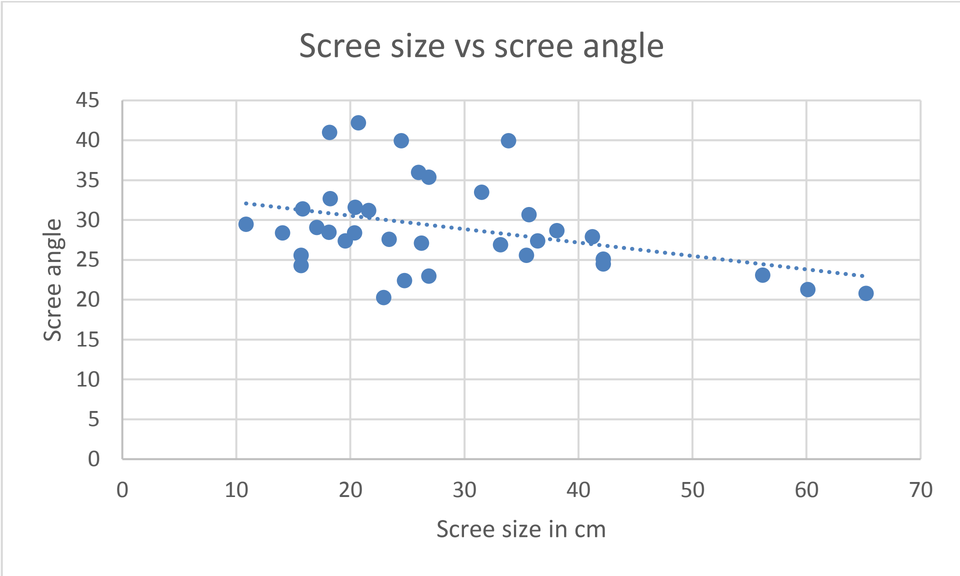
	P										
DF	**0.995**	**0.975**	**0.20**	**0.10**	**0.05**	**0.025**	**0.02**	**0.01**	**0.005**	**0.002**	**0.001**
1	0.0000393	0.000982	1.642	2.706	3.841	5.024	5.412	6.635	7.879	9.550	10.828
2	0.0100	0.0506	3.219	4.605	5.991	7.378	7.824	9.210	10.597	12.429	13.816
3	0.0717	0.216	4.642	6.251	7.815	9.348	9.837	11.345	12.838	14.796	16.266
4	0.207	0.484	5.989	7.779	9.488	11.143	11.668	13.277	14.860	16.924	18.467
5	0.412	0.831	7.289	9.236	11.070	12.833	13.388	15.086	16.750	18.907	20.515
6	0.676	1.237	8.558	10.645	12.592	14.449	15.033	16.812	18.548	20.791	22.458
7	0.989	1.690	9.803	12.017	14.067	16.013	16.622	18.475	20.278	22.601	24.322
8	1.344	2.180	11.030	13.362	15.507	17.535	18.168	20.090	21.955	24.352	26.124
9	1.735	2.700	12.242	14.684	16.919	19.023	19.679	21.666	23.589	26.056	27.877
10	2.156	3.247	13.442	15.987	18.307	20.483	21.161	23.209	25.188	27.722	29.588
11	2.603	3.816	14.631	17.275	19.675	21.920	22.618	24.725	26.757	29.354	31.264
12	3.074	4.404	15.812	18.549	21.026	23.337	24.054	26.217	28.300	30.957	32.909
13	3.565	5.009	16.985	19.812	22.362	24.736	25.472	27.688	29.819	32.535	34.528
14	4.075	5.629	18.151	21.064	23.685	26.119	26.873	29.141	31.319	34.091	36.123
15	4.601	6.262	19.311	22.307	24.996	27.488	28.259	30.578	32.801	35.628	37.697
16	5.142	6.908	20.465	23.542	26.296	28.845	29.633	32.000	34.267	37.146	39.252
17	5.697	7.564	21.615	24.769	27.587	30.191	30.995	33.409	35.718	38.648	40.790
18	6.265	8.231	22.760	25.989	28.869	31.526	32.346	34.805	37.156	40.136	42.312
19	6.844	8.907	23.900	27.204	30.144	32.852	33.687	36.191	38.582	41.610	43.820
20	7.434	9.591	25.038	28.412	31.410	34.170	35.020	37.566	39.997	43.072	45.315
21	8.034	10.283	26.171	29.615	32.671	35.479	36.343	38.932	41.401	44.522	46.797
22	8.643	10.982	27.301	30.813	33.924	36.781	37.659	40.289	42.796	45.962	48.268
23	9.260	11.689	28.429	32.007	35.172	38.076	38.968	41.638	44.181	47.391	49.728
24	9.886	12.401	29.553	33.196	36.415	39.364	40.270	42.980	45.559	48.812	51.179
25	10.520	13.120	30.675	34.382	37.652	40.646	41.566	44.314	46.928	50.223	52.620

Table 4 – Critical values for Chi-Squared

https://www.medcalc.org/manual/chi-square-table.php

I was testing the null hypothesis that there is no significant relationship between the distance up the scree slope and the size of the scree. I cannot reject this hypothesis and accept the hypothesis that there is a relationship at 95% or 99% as my value 18.62 is smaller than the critical value 36.4 and 42.9. I can therefore say with certainty (99% certain) that there is no relationship between the distance up the slope and the size of the scree material.

I then made a scatterplot of the angle at each one of my transect point and the size at that point



Graph 8: Scatterplot of Scree shape and scree angle

This scatterplot does not show what I expected to find. I thought the sites with the larger scree would have a steeper slope as larger material bounces further down slope but there does appear to be a trend where the slope of the scree is higher the material is smaller

As with the relationship between slope and shape I then ran a Spearman's Rank test as I felt it was best to show whether there was a relationship between the two variables. This test was done using an online calculator (Social Science Statistics, 2018) and returned the score of -0.19.

I then looked up the critical value from an FCS chart

I was testing the null hypothesis that there is no significant relationship between the angle of the scree and the size of the scree. I cannot reject this hypothesis and accept the hypothesis that there is a relationship at 95% or 99% as my value -0.19 is smaller than the critical value 0.366 and 0.442. (see Table 2) I can therefore say with certainty (99% certain) that there is no correlation between these and that in the case my study that the size of the scree does not have an influence upon scree angle in different cirques.

This might have been due to errors in my fieldwork. The paths that I had noticed on some of the screes will have the effect of moving material downslope and so smaller material might have been moved further down slope than I had thought.

Because I was aware that other factors might be important (geology and orientation) I decided to carry out a further statistical test to see whether the overall scree size varied significantly between cirques irrespective of which site I gathered the data. To do this I categorized my scree into four quartiles – that is to say for each cirque I have 10 samples from each of 7 sites so 70 for each of the five so 350 in all.

These were sorted from largest to smallest (Excel programme) and then the median value was identified and then the median was calculated for the upper and lower half of the data dividing them four equal groups (Very Large, Large, Medium sized, Small). I then used a second Chi-squared test;

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

O = the frequencies observed
E = the frequencies expected
$\sum$ = the 'sum of'

This was also useful because some of the means were distorted by larger values and I had no overview of the cirques from the individual data collection site means.

The calculations are shown in Appendix 1

Step 1 is to form the hypothesis

The null hypothesis is that size of the scree is independent of the cirques location

The alternative hypothesis is that scree size varies significantly from cirque to cirque

Step Two – Calculating the expected distributions

This is made much simpler by using quartiles so each expected value is the same.

That is Row Total x Column Total /Total

which is; 70x87.5/ 350 = 17.5 which is, of course 70 divided into four equal sizes quartiles

Result

X^2 = 15.17 + 7.95 + 8.68 + 13.79 = **45.59**

With (5-1) x (4-1) = 12 degrees of freedom

Using the Critical Value table this result is > 32.909 which is the critical value at the 99.9% confidence level so we can reject the null hypothesis and accept the alternative hypothesis that the differences in scree size is significantly related to the individual cirques. This would require further research This could be due to the fact the different cirques have different geologies and orientations and so other factors have an influence on scree size and not just distance up the scree slope.

It might also be other factors that influence different cirques such as shape, geology and orientation there are more important factors than scree size in influencing the slope of the scree.

- **To what extent does other factors such as the parent geology and aspect influence the scree slope angle?**

The theory being that harder volcanic rock will be eroded and weathered at a slower rate than those made up of sedimentary rock (Sugden & John 1976), in this case volcanistic rocks were seen at 3 of the five Easedale Tarn, Pavey Ark and Eagle Crag whilst sedimentary rock was found at Newland House and High Hole.

This also might explain why there appears to be only some relationship between scree shape and scree slope and no relationship between size and slope angle between scree slopes.

Cirque	*Bedrock Geology*
Easedale Tarn	Contains both Pavey Ark Breccia and Seathwaite Fell Sandstone Formation - Volcaniclastic-sandstone and volcaniclastic-breccia. Sedimentary bedrock formed between 458.4 and 449 million years ago during the Ordovician period
Pavey Ark	Pavey Ark Breccia Member - Volcaniclastic rocks (both pyroclastic & reworked volcanic rocks). Sedimentary and igneous bedrock formed between 458.4 and 449 million years ago during the Ordovician period.
Eagle Crag	Borrowdale Sill Suite - Andesite. Igneous bedrock formed between 458.4 and 449 million years ago during the Ordovician period
Newland Hause	Robinson Member - Sandstone. Sedimentary bedrock formed between 477.7 and 465.5 million years ago during the Ordovician
High Hole	Buttermere Formation - Mudstone. Sedimentary bedrock formed between 485.4 and 465.5 million years ago during the Ordovician

Table 5 - Rock type of each Cirque (BGS Geology Viewer, 2017)

The rock type though was complex as the geology map of Easedale Tarn shows below and the reality is that this was not going to be as simple as I had originally hoped.

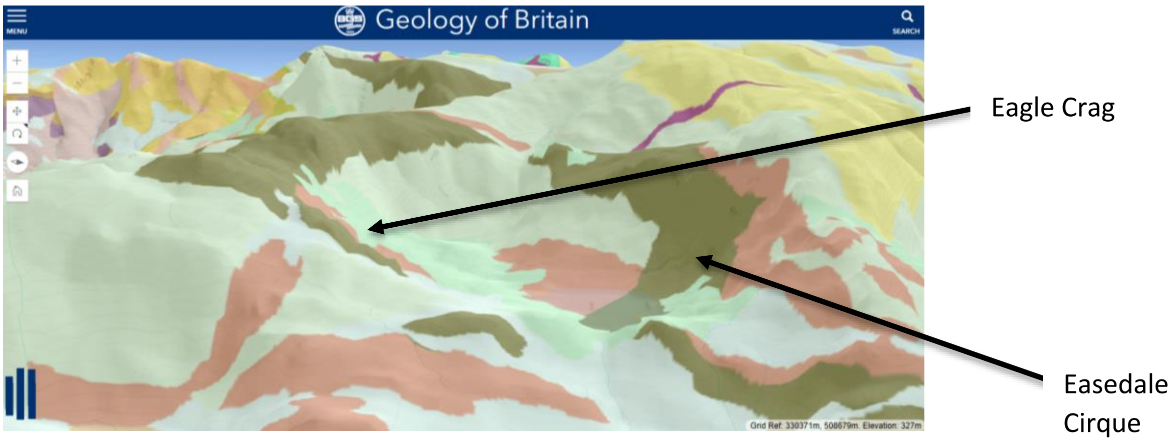


Figure 9 Geology of Easedale/ Eagle Crag (BGS Geology Viewer, 2017)

The angles of the slope for the 5 cirques showed:

Cirque	Angle of Slope	Average for Geology
Easedale Tarn	25.6	
Pavey Ark	27.58	31.05
Eagle Crag	39.96	
Newland Hause	25.21	27.94
High Hole	30.67	

Table 6 : Comparison of Geology

At a very broad level it appears that the volcanistic rocks have a steeper scree slope angle than the sedimentary rocks. This could be that as they are volcanistic they are more resistant to weathering and so create a steeper angle. This might be therefore the reason why I was not able to prove my hypothesis that scree size decreases up the scree slope. This is because as well as the distance up the scree slope influencing the size of the material, geology also seems to be influencing scree size.

There is also aspect. This is the direction that the cirque faces. From the OS map the

angle for the aspect of the scree is shown below.

Cirque	Aspect
Easedale Tarn	41^0 off North.
Pavey Ark	58° from North
Eagle Crag	240^0 off north
Newland Hause	26° off north
High Hole	26° off north

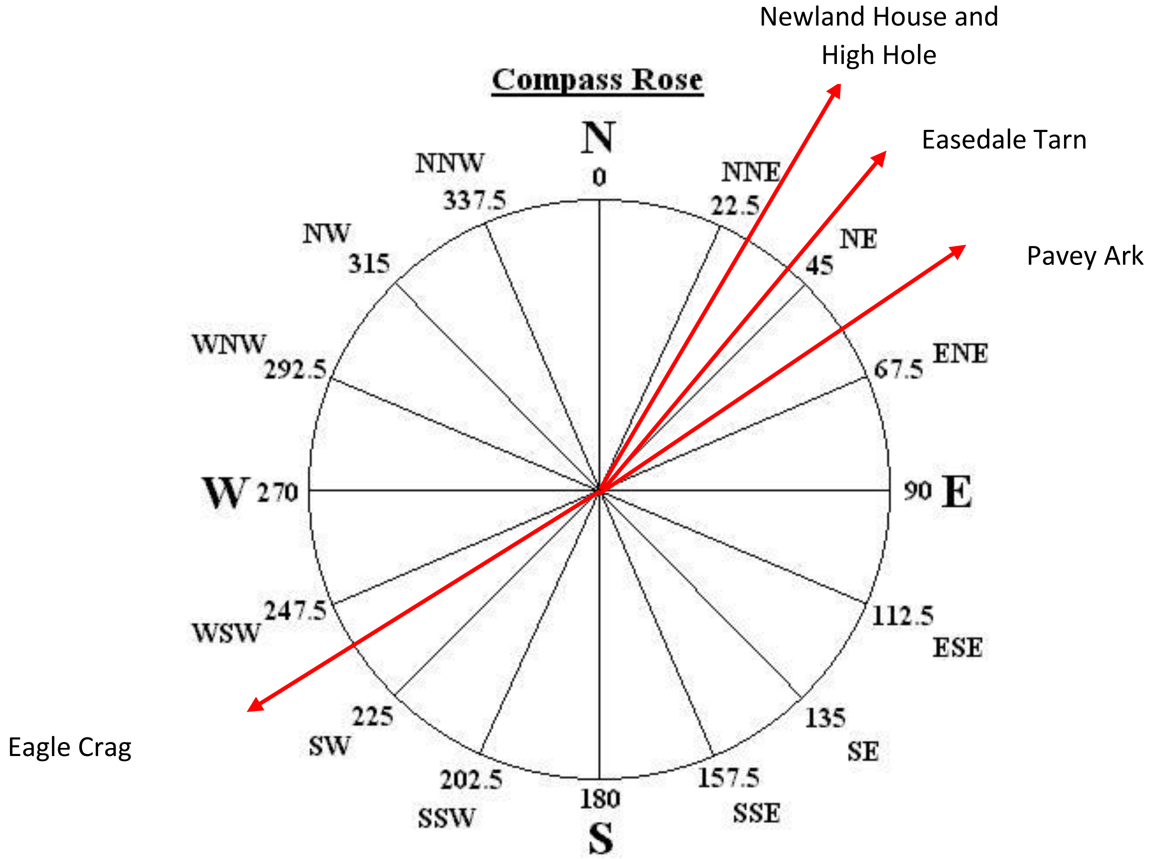


Figure 10: Angles of all Cirques

This might therefore explain the very high slope angle at Eagle Crag as it facing south and not north east and so will have different rates of geomorphological processes working on it. Since the northern areas are suffer the worst conditions (www.landforms.eu, n.d.) the other cirques will erode more and since they all face the same way this might be the reason why the scree slopes differ from cirque to cirque.

The age of the scree slopes might also be important as some such as Eagle Crag were thought to be still active around 11.8 KA (Sissons, 1980).   This is important as if all this cirques are of a similar age then they would have been under similar geomorphological conditions. It is also important to consider the issues of Keskadale the two cirques here were impacted upon by further action from the Younger Dryas period (P. D. Hughes, 2012) whilst no such studies have commented as to the impacts of this period of the others. My assumption here would be they had some impact.

Photo 32: Eagle Crag with Easedale Tarn in front of it (Google Images, 2017)

I can therefore say I have inconclusive evidence as to whether my final sub question is true, and more cirques and different sets of data would need to be studied.

Conclusion

My initial aim was

To what extent is the slope of scree slopes influenced by the size and shape of the scree material?

My sub questions were aimed at helping me answer this:

To what extent does the does the shape of the scree material influence scree slope angle?

To what extent does the size of scree material influence scree slope angle?

To what extent does other factors such as the parent geology and aspect influence the scree slope angle?

For my first sub question **To what extent does the does the shape of the scree material influence scree slope angle?** I expected to find that that the further down the slope the more rounded the material as more rounded material will be able to roll further. In addition I expected that the angularity of the scree will cause the slope angle to change as there will be more voids with it according to the theories of (Collard, 1995) and Wilson (2005).

The results have allowed me to conclude that notwithstanding differences between the angularity of scree slope material in different cirques there is a change in scree angularity with distance up the scree slope. There appears to be a relationship between height up the slope and the angularity of the rock with the higher the distance up the slope the more angular the material. This might be as a result of the more rounded material being able to roll more easily down the slope or it might be due to the fact that the older and so more weathered material is found at the bottom of the slope and so is more rounded. I have therefore proved this part of the sub question.

The results also show that there are definitely differences between the characteristics of the scree slopes between the five cirques. Scree material angularity varied between 393 and 742 degrees showing how scree slope shape and angle differed between cirques. Furthermore the slope angles of the scree slopes varied between 25.21 and 39.96 degrees. The Spearman's Rank correlation coefficient returned a score of -0.39 and highlighted a 95% significant relationship but not a 99% significant relationship which therefore means I can only reject the null hypothesis at 95% confidence level.

Thus I cannot say I have conclusively proved my hypothesis that the shape of the material that makes up the scree slope influences the slope of the scree slope but I can state there is a significant relationship albeit at 95% confidence level.

For my second sub question **To what extent does the size of scree material influence scree slope angle?** I expected to find that the size of the scree will cause the slope angle to change as smaller scree will be able to pack tighter together and so have a lower slope angle. I also expect to find that larger scree size will 'bounce' further down the slope due to momentum and therefore larger material will be found at the bottom of the slope and smaller material will be found at higher levels (Andrews, 2017)

The results showed that there are differences between the sizes of the scree material between the five cirques with Easedale having the smallest material with a value of 17.37 cm and Newland House having the greatest with 44.36cm. Yet my results have allowed not allowed me conclude that there is a significant (according to my Spearman's rank correlation) relationship between scree size and scree slope. This might well be because there are significant differences (obtained from my Chi squared test) in scree size that are related to the individual cirques and so other factors that influence cirques are more important than scree size in influencing scree angle. Thus I cannot say I have proved my hypothesis that the size of the material that makes up the scree slope impact on the slope of the scree slope between cirques.

My final key question, **To what extent does other factors such as the parent geology and aspect influence the scree slope angle?** is based on the theory that the type of rock, that being volcanic against sedimentary will also create differences within a cirque and the characteristic of the scree slope. The theory being that harder volcanic rock will be eroded and weathered at a slower rate than those made up of sedimentary rock (Sugden & John 1976)

The results have allowed me to conclude that at a very broad level it appears that the volcanistic rocks do indeed have a steeper scree slope angle than the sedimentary rocks. This could be that as they are volcanistic they are more resistant to weathering and so create a steeper angle.

The results, however, also showed that there are other factors that have to be considered such as aspect and age.

I can therefore say I have inconclusive evidence as to whether my final sub question is true, and more cirques and different sets of data would need to be studied.

Evaluation of Study

At the beginning of this study I felt that my hypothesis was going to be relatively straightforward to prove as my research suggested this would strongly be the case. This investigation has shown me that often it is not straightforward as there are many facets that influence results and that sampling strategies can create issues such as vegetation interrupting readings and that in relict environments such as the Lake District the evidence of glaciation can be shrouded by nature taking over during interglacial periods and covering much of the evidence and impacting on results.

In terms of the data collection programme a key problem that I encountered was in using the Callieux roundness chart particularly difficult for the more rounded scree that I found at the bottom of the transect. This might have therefore made the results from Easedale which had a far more rounded results than the other four cirques not reliable and in fact they might have been more angular. I do not think, however, that this affects the validity of my conclusion for even if the results are unreliable there is still a big difference between the different cirques. It might have had, however, a bearing in why I could not show a 99% relationship between scree angularity and slope angle and only 95%.

Another reason why there is only a 95% relationship between angularity and slope angle is due to the fact that another one of the problems that I encountered was that there was often vegetation growing on some of the scree slopes. This would bind the scree slope material together and therefore make the scree slope to be a steeper slope than if the vegetation was not present. This means that some of the data I collected was not be representative. It might be that some of the slopes were artificially high such as Eagle Crag and if that slope was lower than the relationship might be stronger and so I could reject the null hypothesis at a 99% level.

Together these might therefore mean that the validity of my conclusion that angularity does influence slope angle might be questionable. Further research ensuring that rounded scree materials were accurately assessed and only samples from non-vegetated scree slopes might be useful in overcoming the issues with this part of my conclusion.

In terms of the validity of my second conclusion there are two issues to be considered. One of the problems I faced in collecting date for this was in deciding which was the longest axis particularly in the smaller scree material found at the top of the transect. This means that this data might be unreliable for instance the very low average size found at Easedale (10.85cm) might not be accurate. This means that my conclusion that scree slope material does not influence scree slope angle might not be valid as scree size might have been greater and therefore the Spearman's rank test might have shown a significant difference between scree size and scree slope.

Another reason why the conclusion might not be valid is that there were several paths amongst the scree at both Easedale and Pavey where walkers could have dislodged and influence scree material. This might be the reason why there seems to be odd results at 10m for the Pavey cirque.

Overall, however, although there are clearly concerns over the reliability and accuracy of this data overall I think my conclusion is still valid as there does not appear to be a direct relationship between scree size and scree slope.

Comparison with other scree slopes

Andrews 2017 was a paper comparing the screes in the Lake District to those in Canada. In Canada the average slope was 35 degrees compared to 29.04 in my study. This might be because of inaccuracies in the way that I measured the slope angle or possibly due to the fact that I could not go above 600m. If I went higher on some screes perhaps I would have found different results. This is another way the project could be extended.

Andrews 2017 paper also gave results for the average size of scree material shown below:

AVERAGE SIZE OF SCREE MATERIAL	
2″ to 6″ 1′ 2″ to 3″ 1′6″	Top of the scree slope.

This is not what I expected as it shows that there does not appear to be grading in the same way that I had observed in my five cirques. This might be caused by the different climatic conditions experienced by Canada and the Lake District with more active weathering quickly reducing the size of the scree material.

Overall, despite my concerns over the validity of the conclusions caused by my worries over the reliability, representativeness and accuracy of the data I can say that the main hypothesis:

To what extent is the slope of scree slopes influenced by the size and shape of the scree material?

Can be broadly accepted because I have proved that scree slopes vary both within and between scree slopes. I have also found a major reason why this is so is due to the shape of the scree material as well as the geology of the cirque and the aspect. I cannot accept, however, that the size of the scree material has a significant influence on the corresponding slope of the scree.

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Appendix 1

Step Two – Record the observed and expected distributions of different categories of scree

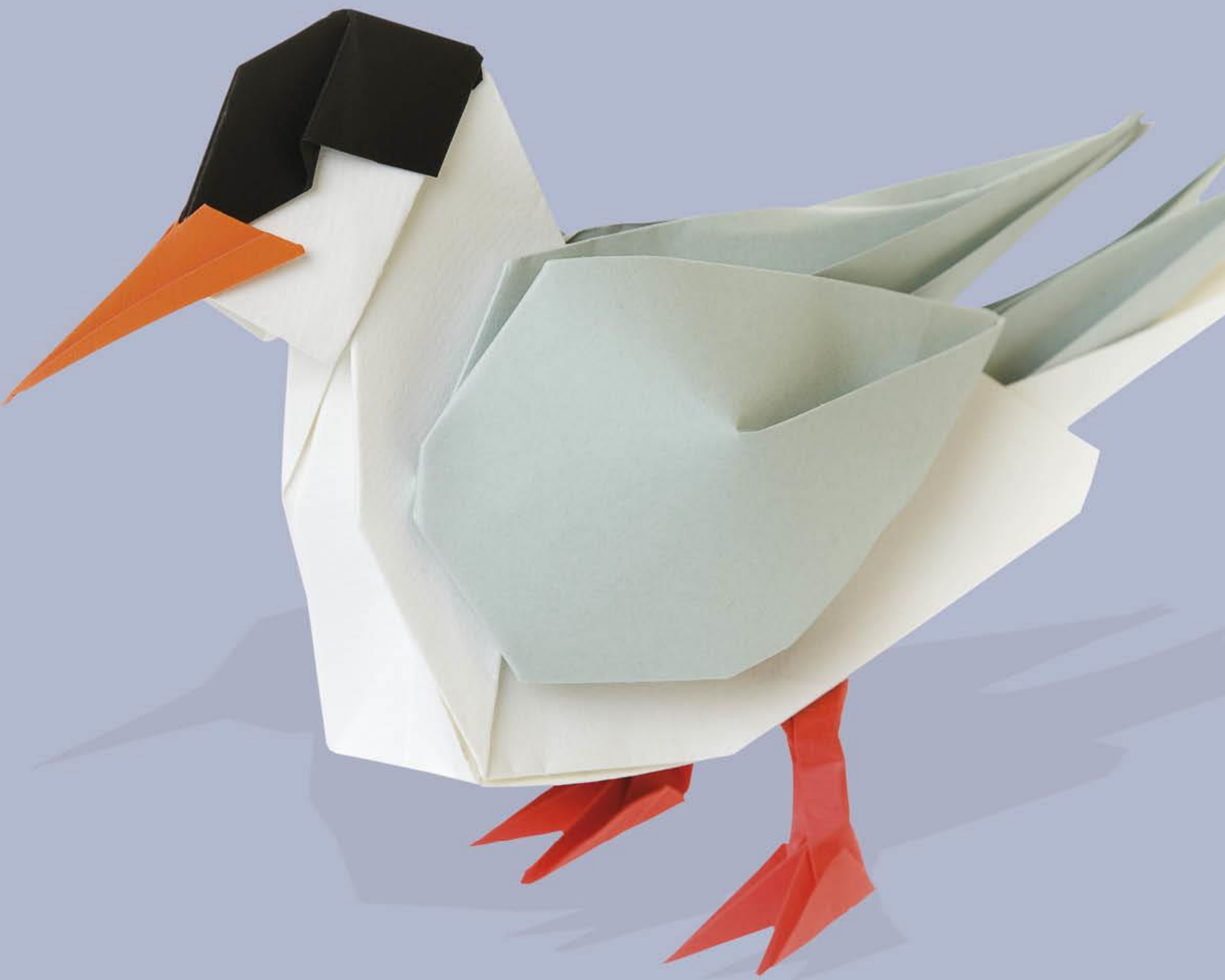
	Very Large		Large		Medium		Small		TOTAL
	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp	
Easedale	8	17.5	13	17.5	28	17.5	21	17.5	**70**
Eagle	13	17.5	10	17.5	22	17.5	25	17.5	**70**
Newlands House	28	17.5	21	17.5	14	17.5	7	17.5	**70**
Pavey	22	17.5	21	17.5	15	17.5	13	17.5	**70**
High Hole	16	17.5	25	17.5	18	17.5	11	17.5	**70**
TOTAL	**87.5**		**87.5**		**87.5**		**87.5**		**350**

Step Three – Calculate the difference between O and E and $(O-E)^2$

	Very Large		Large		Medium		Small	
	O-E	$(O-E)^2$	O-E	$(O-E)^2$	O-E	$(O-E)^2$	O-E	$(O-E)^2$
Easedale	-9.5	90.25	-4.5	2,25	10.5	110.25	3.5	12.25
Eagle	-4.5	20,25	-7.5	56,25	4.5	20.25	7.5	56,25
Newlands House	11.5	132.25	3.5	12,25	-3.5	12.25	-10.5	110.25
Pavey	4.5	20.25	3.5	12.25	-2.5	6.25	-4.5	20.25
High Hole	-1.5	2.25	7.5	56.25	1.5	2.25	-6.5	42.25

Step 4 - Calculate $(O-E)^2$ and sum them to arrive at a value for X^2

	Very Large		Large		Medium		Small	
	$(O-E)^2$	$(O-E)^2 / E$	$(O-E)^2$	$(O-E)^2 / E$	$(O-E)^2$	$(O-E)^2 / E$	$(O-E)^2$	$(O-E)^2 / E$
Easedale	**90.25**	**5.16**	**2,25**	**0.13**	**110.25**	**6.31**	**12.25**	**0.70**
Eagle	**20,25**	**1.16**	**56,25**	**3.21**	**20.25**	**1.16**	**56,25**	**3.21**
Newlands House	**132.25**	**7.57**	**12,25**	**0.70**	**12.25**	**0.70**	**110.25**	**6.31**
Pavey	**20.25**	**1.16**	**12.25**	**0.70**	**6.25**	**0.38**	**20.25**	**1.16**
High Hole	**2.25**	**0.13**	**56.25**	**3.21**	**2.25**	**0.13**	**42.25**	**2.41**
	TOTAL	**15.17**	**TOTAL**	**7.95**	**TOTAL**	**8.68**	**TOTAL**	**13.79**



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