Analysing Glacial Sediments
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Royal Geographical Society with IBG

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1. Background

The geomorphological processes operating within landscape systems result in the erosion, transport and deposition of significant quantities of sediment that can be preserved within a range of depositional landforms. The processes of sediment transport can result in the material acquiring a series of distinctive characteristics. Material deposited within a beach environment for example is well known for its highly rounded nature. These distinctive characteristics can be used to interpret the processes responsible for the deposition of sediments of unknown origin.

Geographers undertaking fieldwork within different landscape systems can use a variety of different sedimentological techniques to examine and describe the characteristics of the material transported and deposited within different settings. These techniques can include an examination of the morphology of any rocks or “clasts” present (clast shape and roundness analysis), their orientation (clast fabric analysis), and the amount of material of different sizes present (particle size analysis).

The development of clear links between specific geomorphic processes and sediment characteristics are central to the studies of relict landforms and landscapes that are associated with the occurrence of past geomorphic processes that are no longer in operation. This is the case in large parts of the United Kingdom where the landforms and sediments present relate to past glacial activity (Figure 1).

This data analysis exercise will focus on the use of clast shape and roundness data to determine the transport pathway of material in glacial environments. These techniques are routinely used by geographer firstly to help determine whether the material in question has been deposited by a glacier. The process can then be used to determine the transport pathway of the material through the glacier system, more specifically whether the material has been transported on top of the glacier (supraglacially) or below the glacier (subglacially). This can in turn help researchers to infer key aspects of the glacier such as its thermal regime and how active it was.


FIGURE 1: Students working on an exposure of glacial sediments at Glanllynnau in North Wales.

2. Introduction

As part of a field excursion to southern Iceland, you are exploring the foreland of a glacier called Skaftafellsjökull, an outlet glacier in the Vatnajökull National Park that has experienced rapid recession in recent decades. As part of your investigation into the glacier, you decided to use a landsystems approach in which you will examine both the landforms and the sediments to reconstruct the past behaviour of this Icelandic glacier.

Whilst exploring the foreland, you have located an exposure eroded by a former river that provides access to the sediments present in the glacier foreland (Figure 2). This exposure reveals a thick sequence of what you believe on initial inspection to be a glacial till that has been transported beneath the glacier (subglacially). However, in order to test this initial hypothesis, you decide to examine the deposit in more detail using clast shape and roundness analysis.

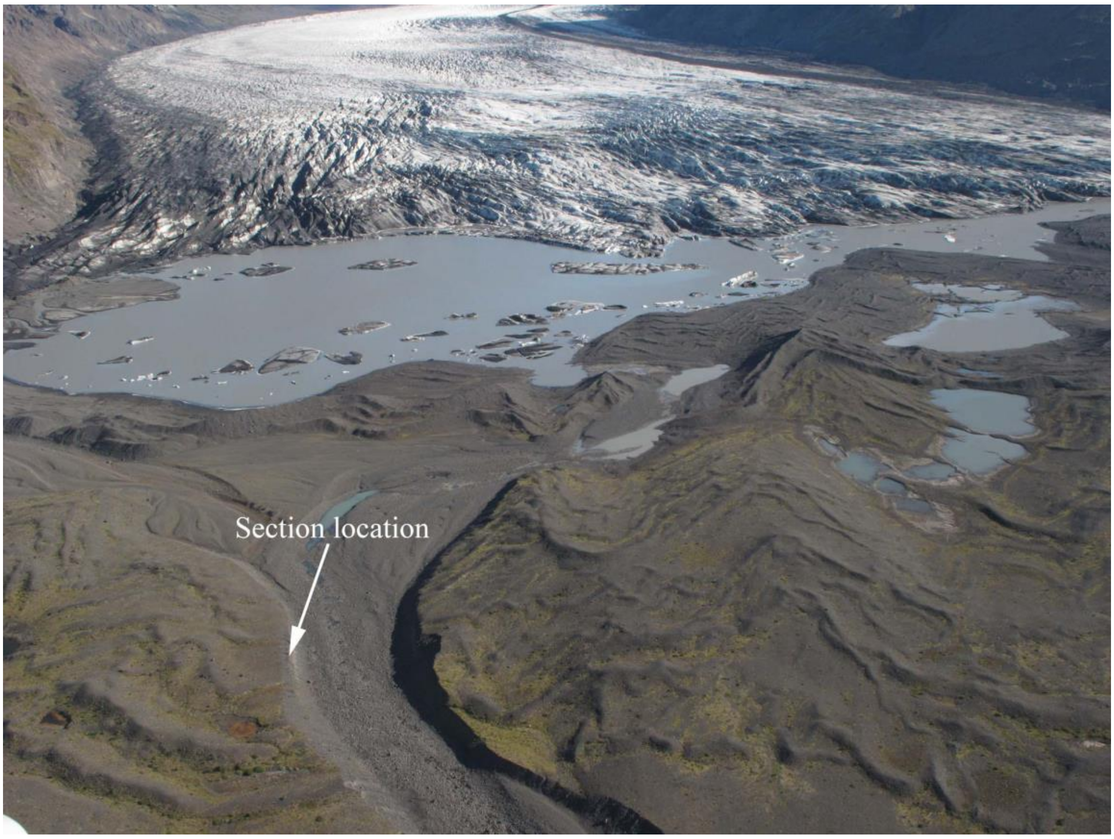

FIGURE 2: Aerial view of part of the margin of Skaftafellsjökull and its foreland indicating the location of the section you have decided to investigate.

3. Describing the Glacial Landystem

Work within landscape systems often starts with a desk-based study that will allow you to familiarize yourself with the study site and its key features. This in turn will allow you to place the results of your field work and related data analysis within their broader geographical context.

Open the Google Earth file provided and examine the foreland of Skaftafellsjokull.

- Make a list of the different glacial landforms you can identify within the foreland (e.g. recessional moraines).
- Which of these landforms provide a record of the recent recession of the glacier margin?

Locate the record of recent retreat (1932-2014) on the Fluctuations of Glaciers browser published by the World Glacier Monitoring Service (http://wgms.ch/fogbrowser/)

- To what extent can you relate the landform record evident at the glacier to these measurements of its recent retreat?

4. Clast Shape & Roundness Analysis

Introduction to the data set

Open the Excel file containing the data relating to the clast shape and roundness analysis undertaken on the deposit exposed in the section. The data set includes measurements taken from a representative sample of 50 clasts and includes two key components:

Shape: Measurements of the three principal axes of the clast – the **a axis** (longest axis), the **b axis** (the intermediate axis) and the **c-axis** (the shortest axis). *Please note that these measurements are recorded at right angles to each other to quantify the shape of the clast.*

The ratios of these measurements can be used to determine whether the clasts are (Figure 3):

- **Blocky** - similar a, b and c axes
- **Platy** - similar a and b axes and low c axes
- **Elongated** – high a axis and low b and c axes

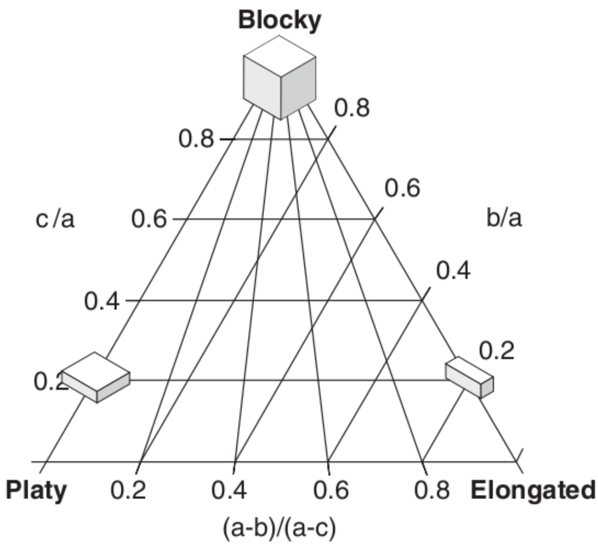

FIGURE 3:
Ternary (triangular) diagram illustrating the three key clast shapes.
(Lukas *et al.*, 2013, p98)

Roundness (categorical): A visual estimation of the "roundness" of the clasts according to the Powers scale (1953) (Figure 4). This involves examining the sharpness of any edges present and then assigning the clast to one of six categories:

- Well rounded (WR) – no discernible edges present
- Rounded (R)
- Sub-rounded (SR)
- Sub-angular (SA)
- Angular (A)
- Very Angular (VA) – edges are very clear and very sharp

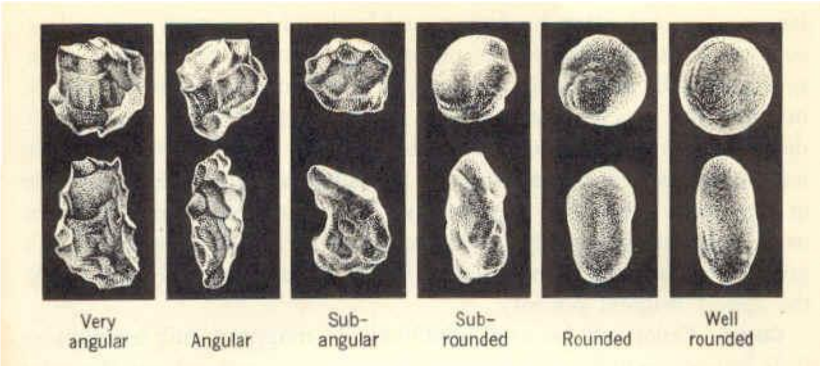

FIGURE 4: Illustration of the Powers roundness scale presented for both sample clasts with both a high sphericity (top) and a low sphericity (bottom) (Powers, 1953, p118).

Nature of the data: It is important to note that whilst shape provides interval data, roundness provides categorical data. This difference has important implications for the data analyses techniques you could apply to the datasets.

Calculating the summary shape and roundness indices

The results of clast shape and roundness are commonly presented in the form of two summary indices:

C_{40} index: Summary index for shape. The percentage of samples with a c:a axis ratio of ≤ 0.4. *Samples with low C40 value are dominated by clasts with higher c:a ratios. In other words they are dominated by "blocky" clasts (see figure 3).*

To calculate:
- Calculate the c:a axis ratio for each measurement (a column has been left for this calculation).
- Identify the number of values ≤ 0.4.
- Express this value as a percentage.

RA index: Summary index for roundness. The percentage of samples that are angular or very angular.
Recently weathered material dominated by angular clasts displays high RA values. Material that has been transported by a glacier or a river for a significant distance generally has fewer angular clasts and therefore has much lower RA values.

To calculate:
- Identify the number of clasts that are angular or very angular.
- Express this value as a percentage.

Data presentation and interpretation

Once you have calculated the two summary indices, you can determine the origin of the sediment investigated at Skaftafellsjokull and test the original hypothesis that the sediment was deposited underneath the glacier as a subglacial till.

Plot your result on a RA-C40 crossplot provided in figure 5 illustrates the distinctive characteristics for deposits of known origins.

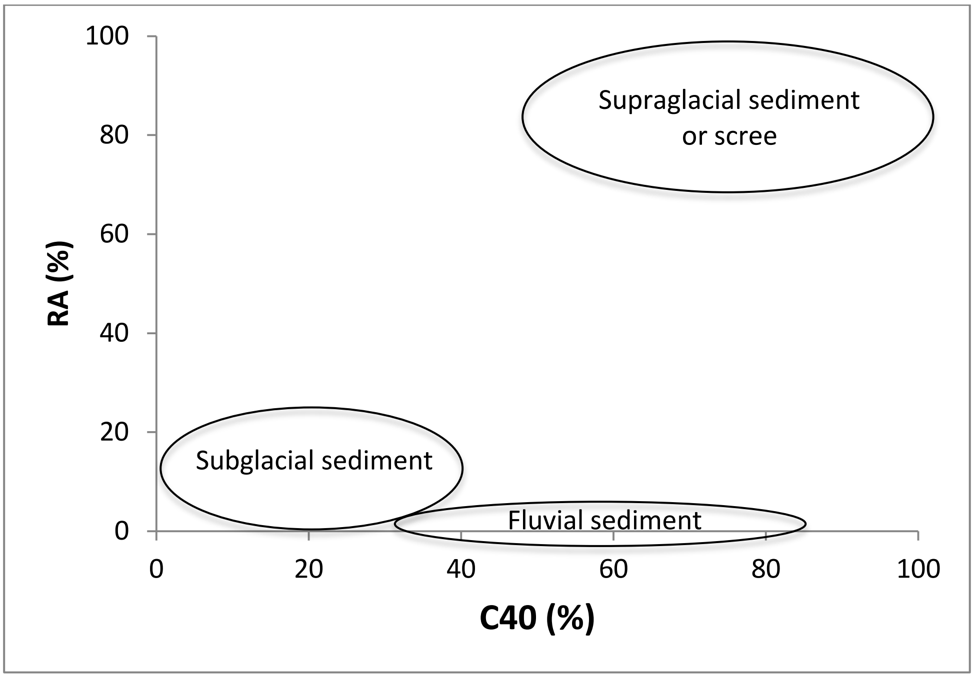

Figure 5: Illustration of the distinctive sample "envelopes" for material transported by rivers (fluvial sediment), on top of glaciers (supraglacial sediment), beneath glaciers (subglacial sediment) and by rockfall (scree).

Where does the sample plot on this crossplot?

Are the results consistent with our original hypothesis that the sediment investigated at Skaftafellsjökull is a subglacial till?

5. Clast Fabric Analysis

As a follow up, you have decided to undertake a clast fabric analysis on the same deposit in order to determine the direction of ice flow when the glacier last covered this area.

The flow of a glacier over areas of soft sediment tends to deform the material, resulting in the reorientation of elongate clasts into positions where they are roughly parallel to the direction of ice flow. As a result, clast fabric analyses involving the measurement of the long (a) axes of elongate clasts can be applied to modern and ancient subglacial sediments to reconstruct the direction of ice flow at the time of deposition.
Open the Excel file containing the clast fabric data. The data set includes measurements of the orientation and dip of the long-axis of elongate clasts taken from a representative sample of 50 clasts within the sediment.

Use these data to create a rose diagram that illustrates the distribution of orientation data and the likely ice flow direction.

Rose diagrams cannot be produced easily using Excel. It is therefore better to produce these figures by hand or to use freely available specialist software such as Georient - http://www.holcombe.net.au/software/georient.html

Plenary discussion

Issues that could be discussed as part of a plenary session include:

1. What additional factors might influence the results obtained from clast shape and roundness analyses?
2. What differences might you expect from investigations of the clast shape and roundness of past glacial sediments deposited within upland and lowland environments?
3. What techniques could you apply to the shape or roundness data in order to determine whether two different samples were statistically different?

References & Further Reading

Powers, M.C., 1953. A new roundness scale for sedimentary particles. *Journal of Sedimentary Petrology*, 23(2), 117-119.

Field Studies Council – Geography Fieldwork (A-level) – Glaciation - https://www.geography-fieldwork.org/a-level/glaciation/

Antarctic Glaciers.org – Clast shape, till fabrics and striae http://www.antarcticglaciers.org/glacial-geology/techniques/clast-shape-till-fabrics-and-striae/