THE ROUNDNESS ANALYSIS OF STONES
A neglected aid in till studies

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Abstract. The degree of roundness of stones is dependent on the mode and length of transport. Therefore genetically different soils, as well as different types of till, often have characteristic roundness morphograms. In eastern central Norway, ordinary tills are dominated by stones with a single-phased roundness and less than 10 % rounded particles. This distinguishes them from tills with a high content of incorporated polycyclic material with multi-phased roundness. Glaciofluvial material contains less than 20 % rounded stones after supra- or en-glacial transport. In sub-glacial and normal fluvial deposits, more than half of the particles are rounded. When erratics are found outside the dominant ice-flow path from their source area, they are very often rounded. The author has applied a method for the classification of the glacial deposits on the basis of their degree of roundness.

Roundness analysis of stones is surprisingly little used in soil studies, perhaps particularly in Scandinavia. Standard reference values for different soils are therefore lacking. If roundness analysis is to be used to any degree, it is necessary to evolve a special classification of the roundness of different soils.

For a number of years, the author has investigated the degree of roundness of the stone fraction (2—6 cm) in various soils. This has promoted the growing conviction that simple roundness analysis is one of the best field methods of soil classification. Some of the data and a few preliminary results are presented in this article.

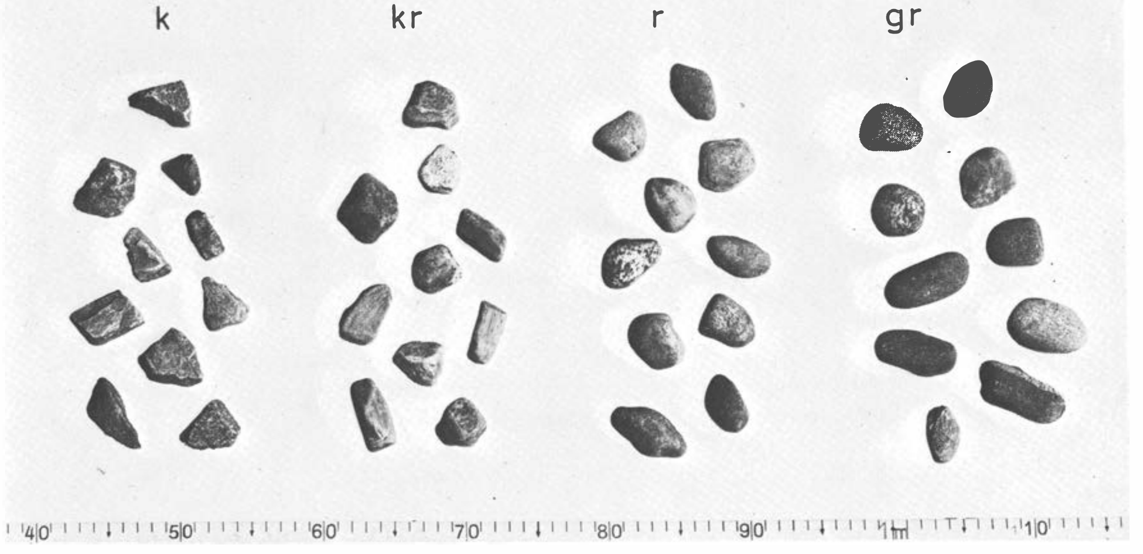

Fig. 1. Standard samples of the four classes of roundness: angular (k), abraded angles (kr), rounded (r), well rounded (gr). *Angular:* More than half of all points and edges are sharp, the surfaces are uneven. *Abraded angles:* More than half of all points and edges are worn but are still well defined. *Rounded:* Few edges are well defined. The particle is convex with oval or circular section along at least one axis. Smooth surface, but not without irregularity. *Well rounded:* Smooth surface. The particle is clearly convex with oval or circular section along at least two axes. After Bergersen (1964).

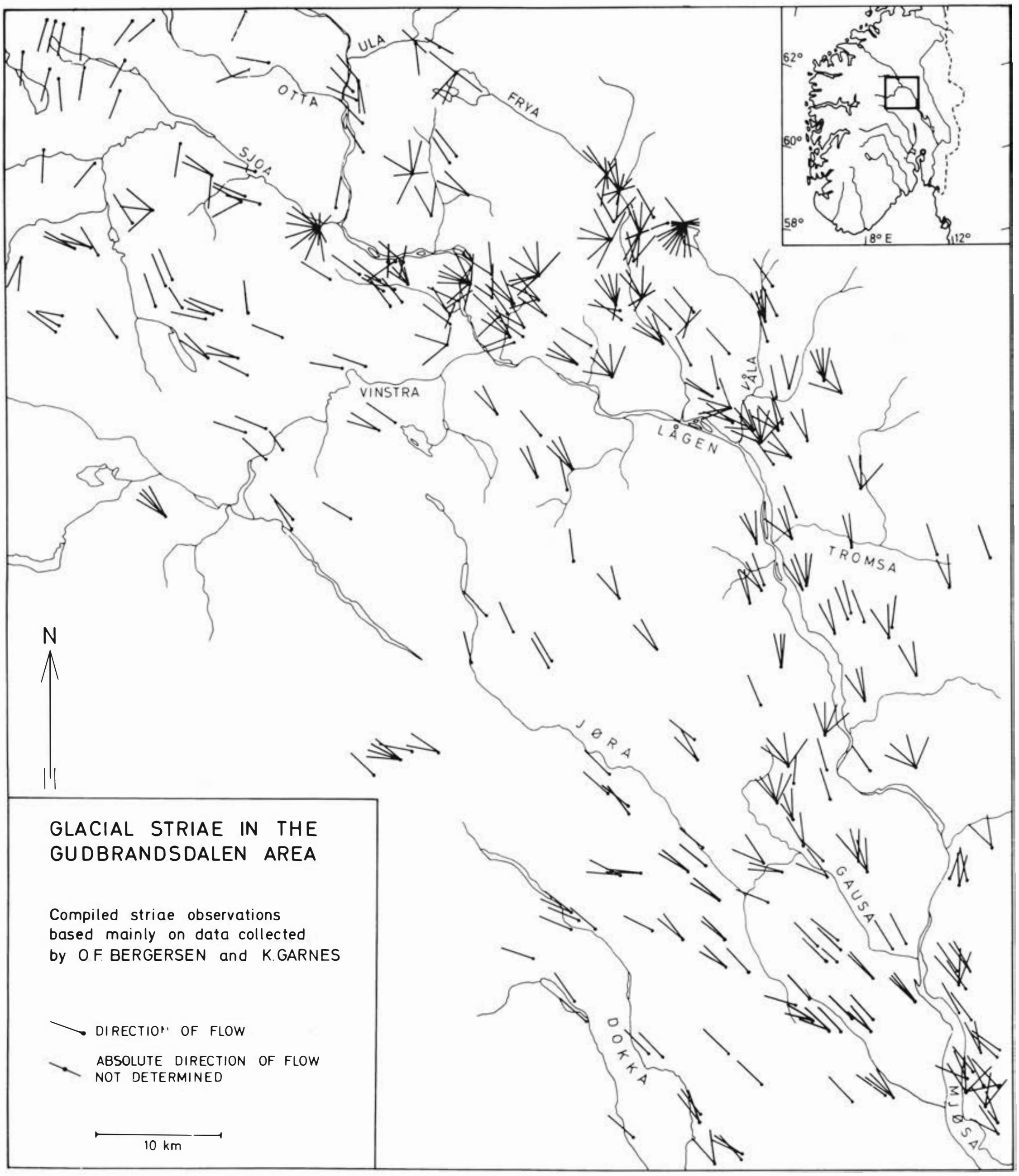

Fig. 2. Glacial striae in the Gudbrandsdalen area. After Bergersen and Garnes (1972).

METHODS

The method used has been described and employed in Germany by Reichelt (1961) and in Norway notably by Bergersen (1964, 1970). A random sample of 100 stones is classified according to visual criteria (Fig. 1). In cases in which a broken stone exhibits preserved surfaces indicating a formerly rounder state, it is grouped according to that state.

The method has been used principally in the Gudbrandsdalen region (key map in Fig. 2), which extends from the high mountains in the north and northwest

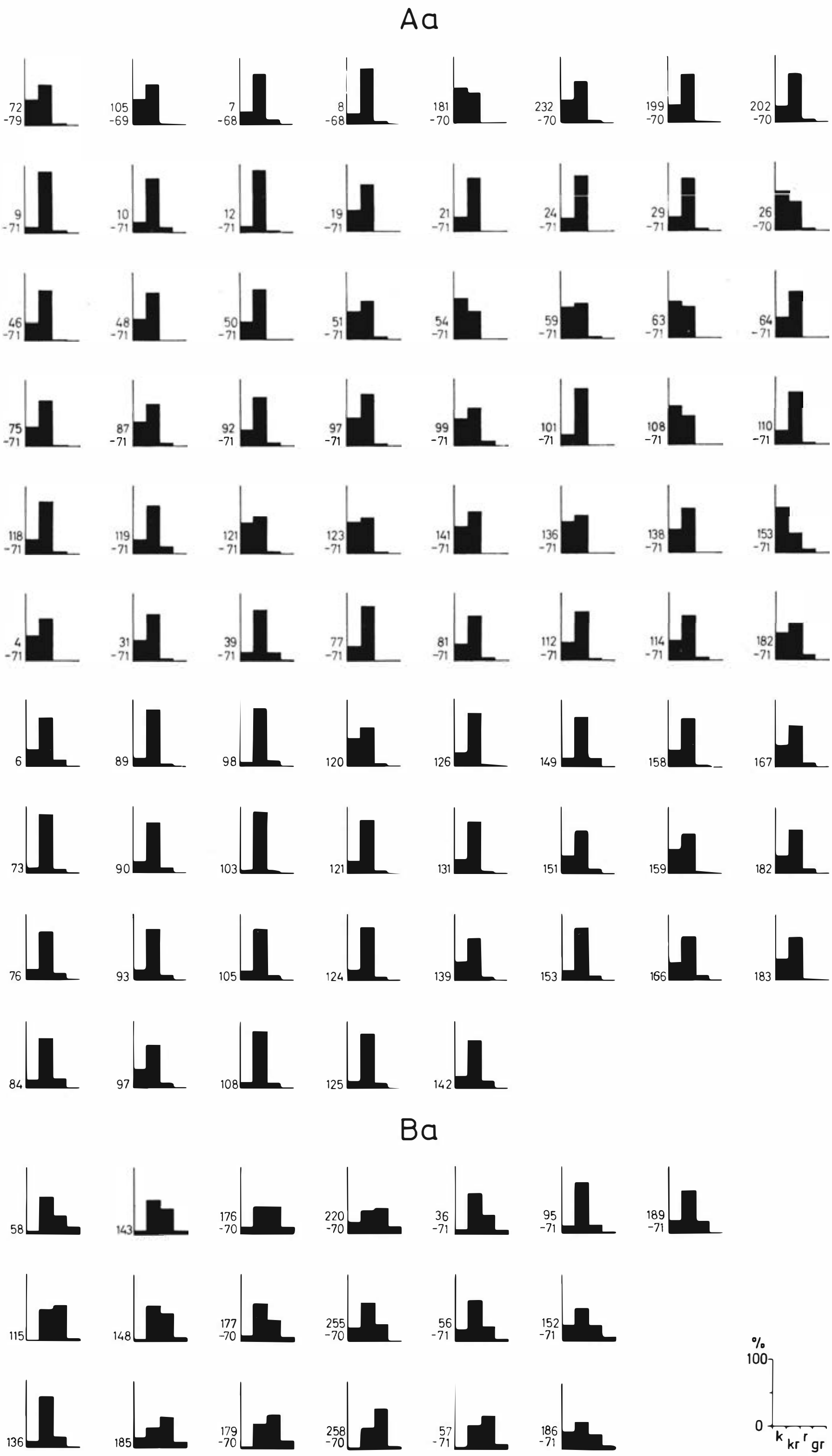

Fig. 3. Combined results of roundness analyses of till in the Gudbrandsdal area, presented as morphograms.

Table 1. Roundness analysis from normal till (type Aa). Selected samples from different bedrock areas. The analysis shows little variation between the rock groups, quartzite (kv), mica-schist and gneiss (sk) and crystalline Jotun rocks (jo).
Rock type, therefore, has little significance for the type of morphogram.

No.	Locality	m a.s.l.	Rocktype	%	k	kr	r	gr
131	Vassbakken, Sjusjöen	900	sk	100	23	74	3	0
53–69	Hole, V. Gausdal	600	sk	93	33	58	2	0
			jo	7	2	3	2	0
				100	35	61	4	0
9–71	Veikledalen	600	kv	3	0	2	1	0
			sk	92	7	84	1	0
			jo	5	0	4	1	0
				100	7	90	3	0
99–71	Skurdal, Harpefoss	260	kv	25	6	17	2	0
			sk	71	32	37	2	0
			jo	4	0	1	2	1
				100	38	55	6	1
21–69	Ulveslåbekken, Ringebu	630	kv	94	26	62	6	0
			sk	6	1	3	2	0
				100	27	65	8	0
202–70	Övre Löyfti, Kvam	420	kv	84	21	63	0	0
			sk	13	2	9	2	0
			jo	3	0	0	2	1
				100	23	72	4	1
259–70	Nordåa, Ringebu	540	kv	82	19	62	1	0
			sk	16	2	14	0	0
			jo	2	0	1	0	1
				100	21	77	1	1
124	Reinåsenseter, V. Gausdal	860	kv	32	4	26	2	0
			sk	8	0	7	1	0
			jo	60	11	46	3	0
				100	15	79	6	0
139	Åmotet Gausa-Dritua	530	kv	3	1	1	1	0
			sk	14	4	10	0	0
			jo	83	22	53	8	0
				100	27	64	9	0
31–71	Sjoa, Åmot	410	kv	21	10	11	0	0
			sk	35	12	30	2	0
			jo	44	8	27	0	0
				100	30	68	2	0

through several valleys to the lowlands in the southeast. The rocks of the area are mainly Eocambrian and Cambro-Silurian sedimentaries. In the northwest lie rocks of the Caledonian thrust sheet (Jotun rocks) which are predominantly gneisses and gabbros. Since these are easily distinguishable in soils from low-metamorphic, sedimentary rocks, they assumed great importance in stone counts (geological key map in Fig. 8).

As shown in Fig. 2, ice movements followed the lower parts of the main valleys toward the southeast. The main transport of both fluvial and glacial material occurred, therefore, along these same lines.

RESULTS

Comparison of all roundness analyses made on *till* clearly shows two main types of morphogram (Fig. 3). Type Aa is completely dominated by stones with abraded angles, but the content of angular material is also high. Rounded stones comprise less than 10 %. This type includes most kinds of till in the region, both lodgement and ablation till. Almost all of the stony material has undergone only one transport phase, and the roundness is thus *single-phased.* Stone counts reveal that the material has, for the most part, been transported over short distances, in only few cases

Table 2. Roundness analysis from till with re-transported sediments (type Ba). Selected samples from different areas. The reason for the clearly different degrees of roundness between the rocks in type Ba is that this type is composed of polycyclic stony material, with greatly varying length and history of transport.

No.	Locality	m a.s.l.	Rocktype	%	k	kr	r	gr
143	Brubakken, Gausdal	190	kv	13	0	5	7	1
			sk	64	6	39	16	3
			jo	23	0	7	15	1
				100	6	51	38	5
148	Skog, Fåberg	230	kv	47	0	14	32	1
			sk	45	2	36	5	2
			jo	8	0	2	4	2
				100	2	52	41	5
115–69	Haugalia, Kvam	360	kv	49	12	27	9	1
			sk	31	2	3	21	5
			jo	20	1	0	16	3
				100	15	30	46	9
2–70	Åretta, Lillehammer	170	kv	21	2	9	10	0
			sk	74	9	57	8	0
			jo	5	0	2	3	0
				100	11	68	21	0
36–71	Bölia, Ringebu	380	kv	58	3	44	11	0
			sk	20	3	11	6	0
			jo	22	0	6	11	5
				100	6	61	28	5
186–71	Fossåa, Sör-Fron	240	kv	35	3	20	10	2
			sk	49	23	18	7	1
			jo	16	1	4	7	4
				100	27	42	24	7

more than 10 km. Rock types have little significance for the morphogram (Table 1).

The second type of till, Ba, has a compound morphogram in which all roundness classes are represented. On the average, about 40 % consists of rounded and well-rounded material. The high content of stones transported over long distances is characteristic of the type. Most of them have been transported considerably farther than 10 km. Local rocks have abraded angles, while those that have travelled long distances are, as a rule, rounded (Table 2).

Within the area of investigation, the distribution of type Ba till is characteristic, in that it occurs exclusively in the main valleys, principally on the valley floor, but also in stoss-side moraines on the outer sides of valley bends. Fig. 4 shows an example from the Kvam-Sjoa area in central Gudbrandsdalen.

Most of the stony material has clearly passed through several transport phases, of which at least one was fluvial or glacio-fluvial. In several localities, large glacio-fluvial deposits are to be found *under* such till. It is natural to conclude that the till was produced by a glacier advance over earlier sediments, some of which became incorporated in it. The material is thus said to contain stones with *multi-phased* roundness.

A characteristic of this kind of sediment is the large number of broken stones. Observations show that almost 50 % of all rounded stones have one or more surfaces with sharp, almost unabraded edges. The lack of wear on the edges indicates that the material fractions were composed during the formation of the till.

While Aa is the predominant till type in a landscape of glacial erosion where very little of the earlier deposits is preserved, type Ba gradually becomes more common in peripheral areas, or towards areas where older deposits are preserved.

Average morphograms for different glacial soils (Fig. 5) have previously been compared by the author (Bergersen, 1970). Glacio-fluvial material also falls characteristically into two groups, Ab and Bb. While the rounded content is about 20 % in type Ab, it comprises half the material in type Bb. The difference is due rather to the mode of transport than to the transportation distance. Type Ab represents deposits by supra-glacial and en-glacial drainage, while Bb is the result of sub-glacial and sub-aerial drainage.

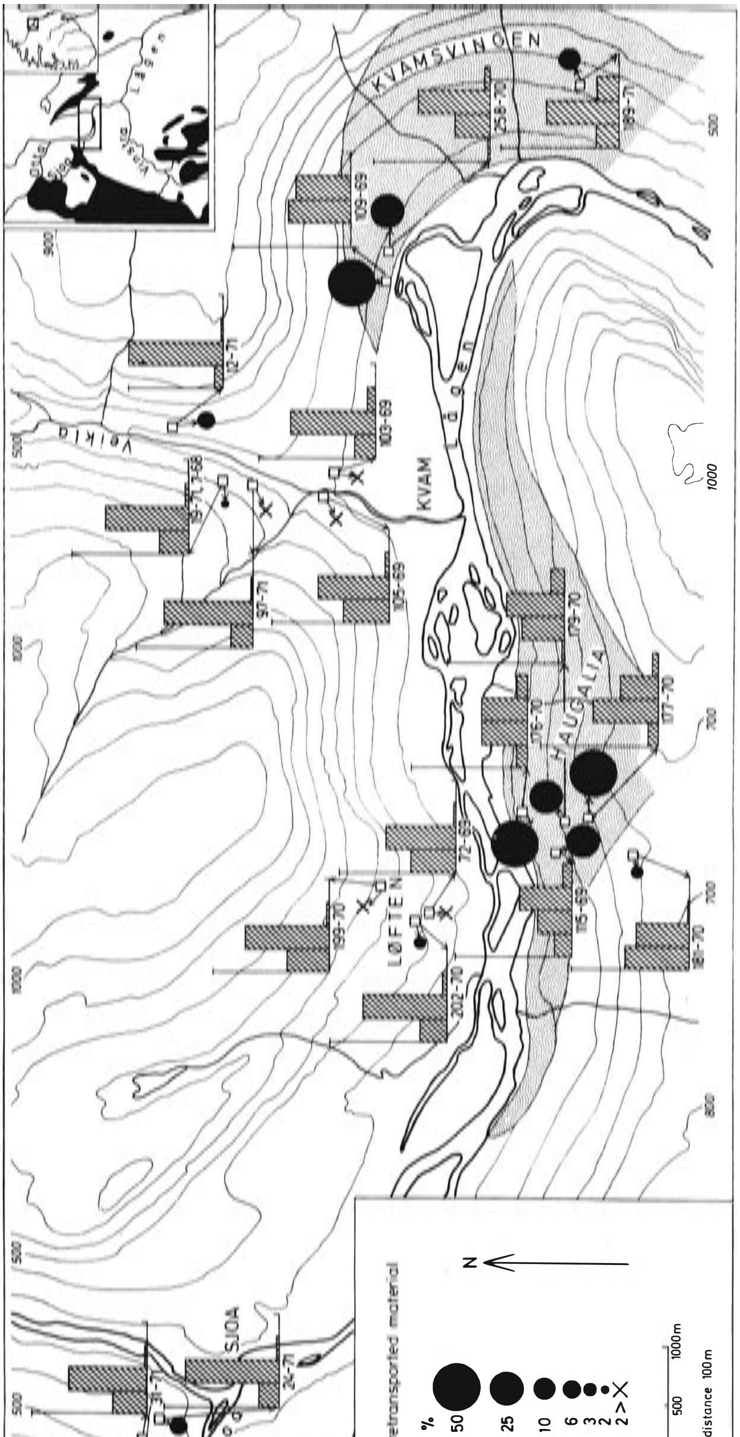

Fig. 4. The distribution of till with a high conent of rounded stones transported for long distances in the Kvam-Sjoa. After Garnes (1973).

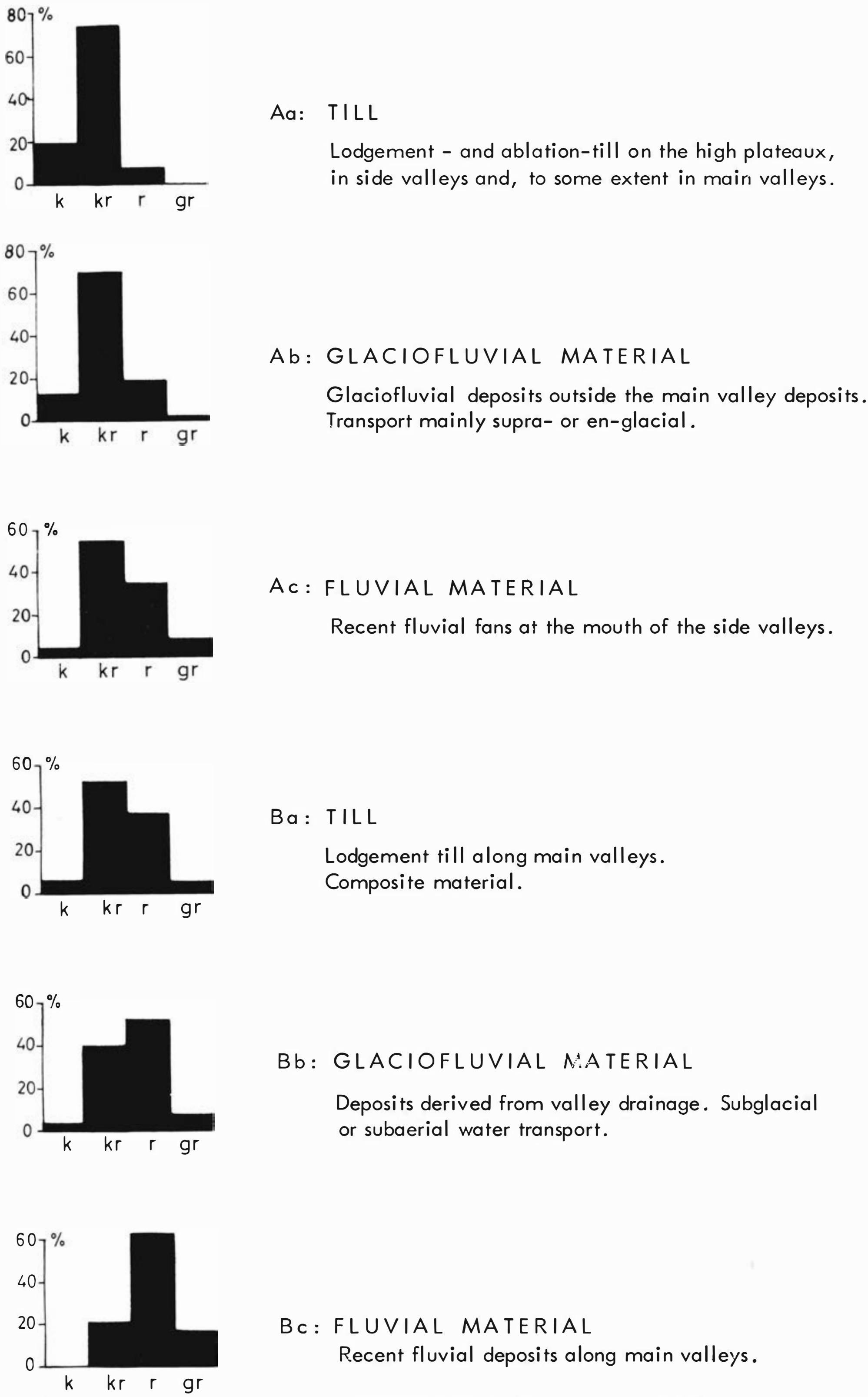

Fig. 5. Average morphograms for different types of soil. After Bergersen (1970).

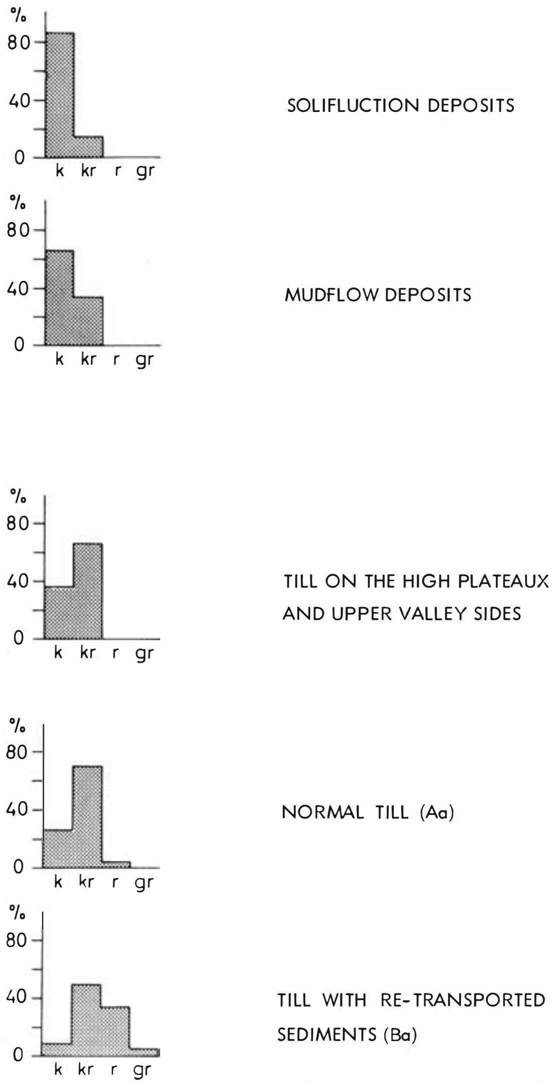

Fig. 6. Average morphogram for different slope deposits, compared with average morphograms for till on the high plateaux (localities higher than 700 m a.s.l.), ordinary till (Aa), and till containing re-transported material (Ba). Slope deposits are predominantly of angular material, showing that the greater part of the original material was not till but weathering products.

Supra-glacial and en-glacial streams can evidently transport stony material over long distances (several tens of kilometers) without its becoming rounded. Considering that material in the basal parts of a glacier, both lodgement till and glacio-fluvial material, is rapidly worn down, it is quite probable that stones transported for a long distance in till have often had a long supra-glacial or englacial meltwater transport, even though they are not rounded. Such stones, besides having undergone long-distance water transport, may also be polycyclic, having been transported in different directions. This must be taken into account in the reconstruction of ice-movement directions on the bases of tracer rocks and stone counts. Particular care must be taken in the case of type Ba.

Closer investigation shows that analysis of roundness can be used as a means of distinguishing between *several different types of till* (Figs. 6 and 7). The average morphogram (Fig. 6) for till on the high plateaux and upper valley sides shows a considerably higher content of angular material than the average for type Aa.

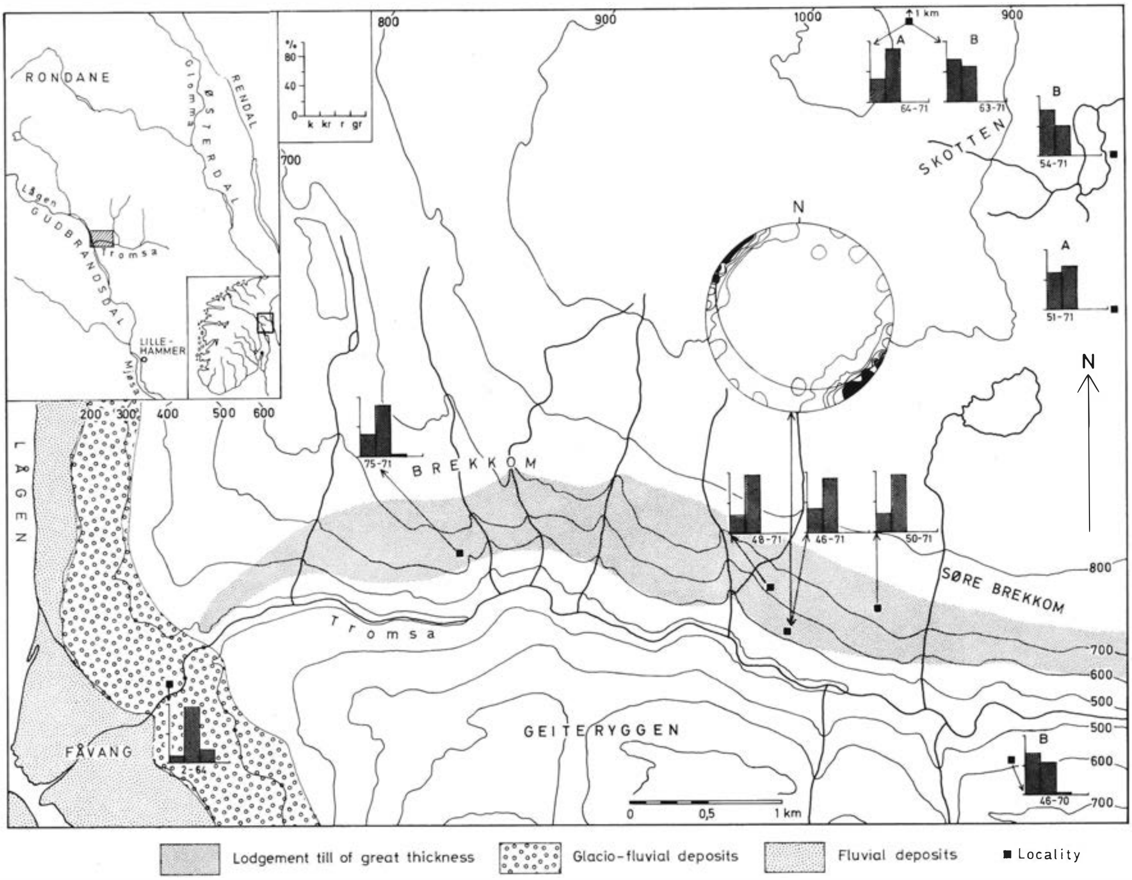

Fig. 7. Sketch map of Tromsdalen. A = ablation till, B = lodgement till. After Garnes (1973).

Roundness analysis often facilitates the identification of and distinction between different slope deposits, which often contain large amounts of Post-Glacial and Recent weathering products. Almost 100 % of the material in block fields, stone stripes and talus is angular material. Mudflow and solifluction soils are also strongly dominated by the angular fraction.

Fig. 7 is an example of the variation in roundness of till in and around a tributary valley. The thick lodgement till on the northern side of the Tromsdalen valley contains relatively little angular material. In the rest of the area, the thickness of the till is usually less than 2 m and often less than 0.5 m, and the contents of angular and round-edged material are roughly equal. Material in the overlying ablation till has obviously been transported farther, as indicated by its greater abrasion, but the content of angular material is also high.

The morphograms hitherto presented are based on averages for the material samples. Further interesting problems arise from studies of roundness in the chosen rock types. It is generally the case, of course, that stones that have been transported the farthest are the most rounded, but there are exceptions. The roundness percentages of Jotun rocks (the percentage of rounded plus well-rounded material) in a number of till and glacio-fluvial deposits in the Gausdal area are shown in Fig. 8. From this, it appears that the Jotun rocks are little affected and remain with abraded edges, provided they were glacially transported in the direction of the ice movement. Where their transport direction is different, for example, in the till in Gudbrandsdalen, more than 80 % are rounded.

Fig. 9 shows this schematically. Material torn from the bedrock is carried through its first phase of trans-

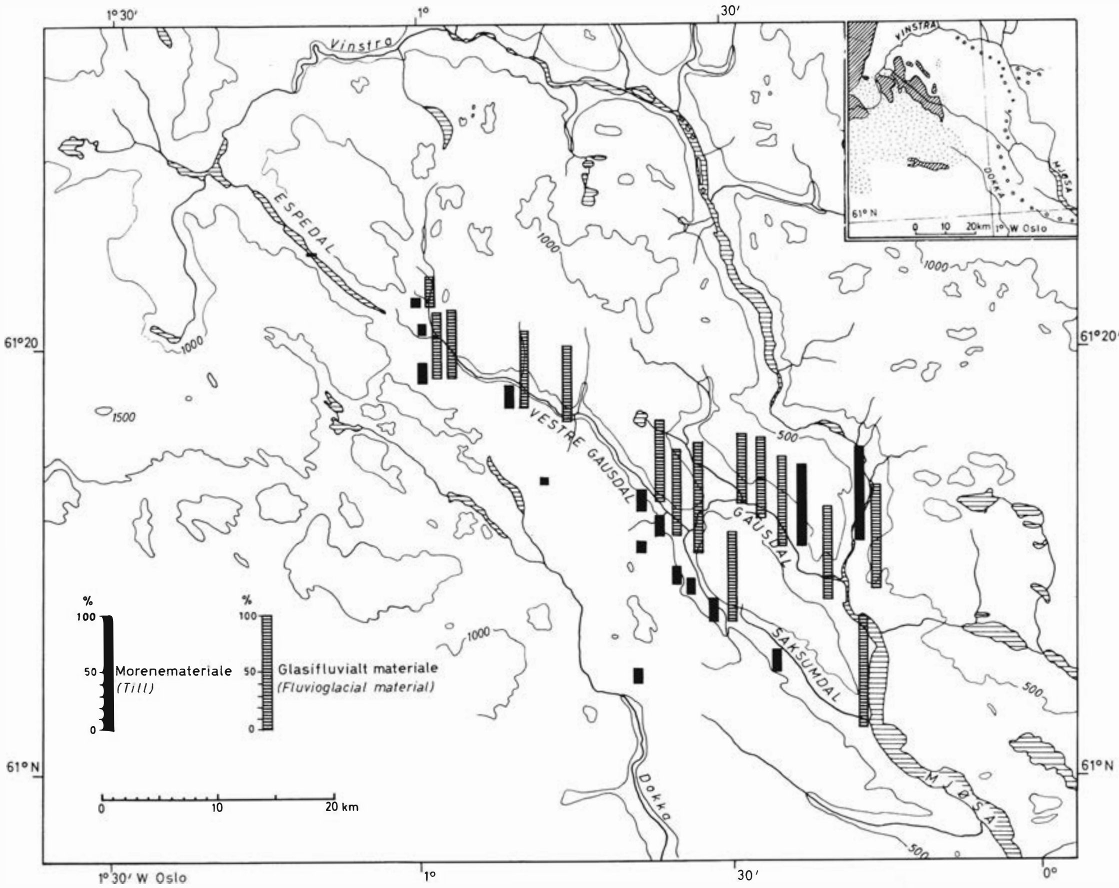

Fig. 8. Percentage of rounded plus well-rounded particles of Jotun rock types in till and glacio-fluvial deposits in the Gausdal valleys. The geological map shows the possible sources of Jotun rock types. Hatched areas: Jotun rock types. Dotted areas: Valdres sparagmite and other sedimentary nappe rocks (may have been mistaken by classified as Jotun rocks). Rings: Biskopås conglomerate with particles of Jotun rock types. In the normal till deposits, the Jotun rock types have a low degree of rounding. Till deposits with a high percentage of rounded Jotun rock particles are interpreted as till with re-transported sediments (type Ba). After Bergersen (1970).

port until it arrives at morphogrammetric stage Aa or Ab. Less than 20 % of the stones become rounded. Transport is effected glacially or by supra-glacial and en-glacial meltwater, which are shown by continuous lines. Short-distance river transport converts the material into type Ac (Fig. 5) or into Bb via the main sub-glacial and sub-aerial drainage routes. In both cases, the contents of rounded material in deposits comprise more than 50 %. Such transport is indicated by stippled lines. When the material is then re-deposited by advancing ice, type Ba till is formed.

The figures also demonstrate why stones from a particular origin are almost always rounded when their location does not agree with the ice direction. They have undergone at least one fluvial phase before being incorporated in till.

CONCLUSION

Genetically different soils, as well as different types of till, often have characteristic roundness morphograms. Even simple roundness analysis rapidly yields important information on the origin and genesis of a soil. Roundness analysis is without doubt a neglected aid in studies of our soils.

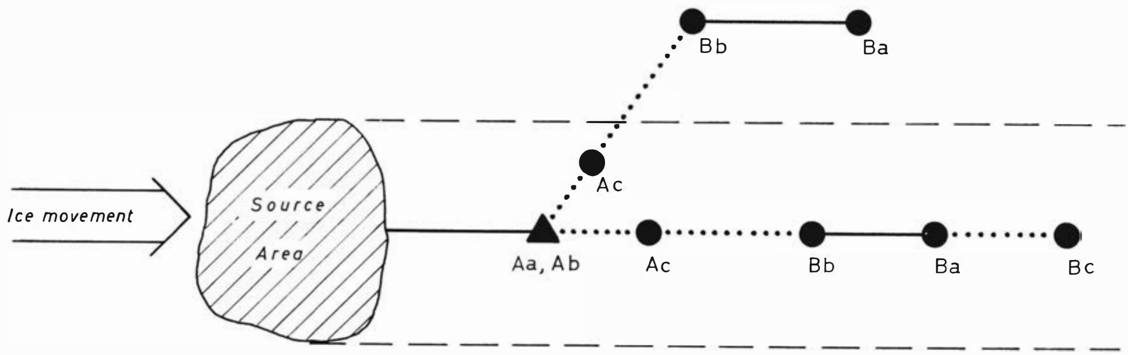

Fig. 9. Schematic presentation of transport history and development of different types of sediments. Freshly eroded debris from the source area yields deposits having morphograms of the type Aa or Ab, showing less than 20 % of rounded particles (see Fig. 5). The transporting agent is ice or en-glacial/supra-glacial meltwater. This transport is shown by unbroken lines. The material will, after short transport by river, yield deposits with morphograms of the type Ac (fluvial material). If the transport is glacio-fluvial along the valley floor (sub-aerial), the result will be deposits of type Bb. Both types yield deposits in which more than 50 % of the material is rounded. This transport is shown by broken lines. Where this material has later been transported by ice, it yields till deposits of type Ba. A later glacio-fluvial or fluvial transport/deposition will yield morphograms of types Bb anc Bc. The figure also illustrates why rocks from a given locality are, in nearly all cases, rounded when found outside the path of ice flow. This material has undergone at least one glaciofluvial or fluvial transport phase before being caught by ice and deposited in till. After Bergersen (1970).

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