Glacial comminution of mineral grains

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The factors influencing the comminution of separate mineral grains during glacial transport and the applicability of the term 'terminal grade' are discussed.

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In 1965 Dreimanis & Vagners published the results of their studies on mineral modes in basal tills from Ontario, Canada, where they suggested that mineral grains undergo a restricted disintegration during glacial transport. They then named the final product of the glacial comminution 'terminal grades' as the minerals were not crushed or abraded finer than those modes, even after a glacial transport of several hundred kilometres. 'Terminal grades' of the studied mineral types were most commonly found in the finest sand and coarsest silt grades of the tills. For each investigated mineral, the particle-size range of the 'terminal grades' appeared to be relatively constant, and it was suggested that this would apply to tills also from other areas (Dreimanis & Vagners 1965, 1971a). Later, the concept of 'terminal grades' has been widely used (see Lindén 1975, Mulholland 1976, Svantesson 1976, Perttunen 1977, Vorren 1977, Haldorsen 1977a, 1977b).

The following discussion concerns the glacial crushing of separate mineral grains from different bedrock types and the applicability of the term 'terminal grade' as used by Dreimanis & Vagners (1965, 1969, 1971a, 1971b).

The degree of mineral comminution during glacial transport depends on many different factors, of which the properties of the mineral 'inherited' from the parent rocks are the most important ones (Dreimanis & Vagners 1965, 1969, 1971a, 1971b, Haldorsen 1977a). Generally, every factor which influences the brittleness of the minerals is of importance in this connection. Therefore, one single mineral type from different bedrocks may be expected to have 'terminal grades' within many different till grades, depending on its primary properties.

One important factor regarding the glacial comminution is the preglacial history of the mineral grains. During any interglacial cyclus, sediments from the preceding glacial have been exposed to soil weathering, changing the primary mineral composition in at least the upper half metre of the sediments. This weathering may have an influence both upon the primary size of the mineral grains and their resistance to a new glacial transport. Such factors will apparently be of importance for mineral modes in cases where the till contains a large amount of redeposited interglacial sediments. It is for instance, supposed that a significant part of the Scandinavian till deposits may contain such old redeposited material (Gillberg 1977).

However, even when the till material is formed solely by erosion of unweathered bedrock material, there are a lot of factors influencing the glacial comminution of each mineral grain. The following discussion concerns some of these factors.

Generally, there seems to be a great difference between the comminution of grains from unmetamorphic clastic sedimentary rocks such as shales and sandstones on the one hand and grains from crystalline rocks on the other hand (Haldorsen 1977a).

Unmetamorphic clastic sedimentary rocks have mainly been formed by marine and fluvial sedimentation whereby they were enriched by mineral grains resistant to mechanical weathering. During glacial transport, fragments from such sedimentary rocks have mainly been fractured along grain boundaries, giving a till component consisting of separate mineral grains. These mechanically stable mineral grains are usually not reduced in size even by a rather long glacial transport (Haldorsen 1977a). The very great resistance of mineral grains from such sedimentary rocks is further demonstrated by the works of Mangerud (1965) and Sørensen

(1969). Thus, by studying till material from many different unmetamorphic, clastic sedimentary bedrock areas, one may expect to find modes for a single mineral type in every till grade from clay to sand, dependent on the grain size composition of the parent rock.

Crystalline rocks, on the other hand, commonly consist of mineral grains which to a large extent are unstable when subjected to glacial and other mechanical crushing processes. For instance, the high frequency of crystalline rock fragments in the medium to fine sand grades of the tills at Ringsaker, southeastern Norway, indicated that here the crystalline rock fragments were first disintegrated both across and along mineral grain boundaries, the two mechanisms being of about equal importance. During continued glacial transport, the smaller rock fragments and mineral grains have then been further comminuted to the characteristic fine-grained 'terminal grades'. In that way the unstable mineral grains from the crystalline rocks were considerably more reduced in size during glacial transport than the same mineral from the sedimentary rocks (Haldorsen 1977a).

Cleavage, grain size, and grain shape have been found to be very important factors regarding the 'terminal grade' and it was also suggested that hardness is an important factor in this connection (Dreimanis & Vagners 1969, 1971a). However, flakes of biotite, which is a rather soft silicate mineral, have been found to be very resistant to glacial comminution and become enriched in the coarse part of the till matrix even after a glacial transport of more than hundred kilometres (Elverhøi 1977, Haldorsen 1977a). Also muscovite flakes from different bedrock types has been shown to retain their length and breadth very well during glacial transport (Haldorsen 1977a). The resistance of mica flakes probably depends on their great elasticity and their orientation in the basal ice layers during transport. On the other hand, the thickness of the mica grains is rapidly reduced by cleavage, a process which obviously has nothing to do with mineral hardness.

Primary fractures within the mineral grains, which may or may not coincide with the cleavage planes, are in many cases one of the main factors controlling the degree of glacial comminution. Haldorsen (1977a) found that plagioclase grains which within the bedrock were frequently dissected by fractures, were very prone to glacial comminution, and the mode of those plagioclase grains were found in finer till grades than any of the modes observed by Dreimanis & Vagners (1971a).

One factor of importance which has not yet been regarded is the type and degree of cementation of the sedimentary rocks. It should for instance be expected that grains which are cemented by silica material are more easily disintegrated across mineral grains than when they are surrounded by a soft clay matrix.

The type of grain boundary is also a relevant factor in this connection. Rock fragments from the more metamorphosed Late Precambrian sandstones in southern Norway seem to have a greater tendency to be comminuted across mineral grains than the fragments from the unmetamorphic types. During the metamorphosis, the originally, relatively smooth grain boundaries have been modified to more irregular forms, often accompanied by recrystallization of quartz in the pore spaces, giving modes in finer fractions of the till than are observed for the unmetamorphosed sandstone minerals.

On the other hand, metamorphosed sandstones with a clay matrix may have a film of sericite around the grains, which commonly promotes disintegration of rock fragments along grain boundaries, like that for the unmetamorphosed types.

Unweathered mineral grains from unmetamorphosed sedimentary rocks are commonly very resistant to glacial comminution. Their modes in the basal till are 'interited' and closely reflect the primary size distribution within the parent rocks. The term 'terminal grade' should therefore not be applied in connection with mineral modes from such sedimentary rocks in basal till.

For unweathered mineral grains from coarse-grained crystalline rocks, on the other hand, the modes observed in the till were formed by comminution of individual mineral grains during the glacial transport and the term 'terminal grade' may in some cases be applied.

However, the size-class of 'terminal grade' even for minerals from crystalline rocks has been shown to be dependent on many factors, indicating that the range of mineral modes for any one mineral is much greater than suggested by Dreimanis & Vagners (1965, 1969, 1971a, 1971b).

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