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Grain-Size Distribution of Quartz and Feldspar Extracts and Implications for Flocculation Processes

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Abstract. Quartz and feldspar extracts, obtained by chemical dissolution of the clay minerals, provide insight into the inorganic flocculation and mineralogical influences upon the texture of fine-grained glaciomarine deposits. Glacial comminution in higher latitudes explains the relatively high contents of quartz and feldspars. Quartz and feldspar are better sorted and were apparently less influenced by flocculation than were phyllosilicates, except for particles less than approximately 16 μm, which are poorly sorted due to their inclusion in flocs. The 16-μm boundary is suggested to be useful for approximately separating fines that are usually involved in flocculation and coarse silt and larger grains that are less influenced.

Introduction

It is well known that quartz and feldspar dominate in the sand and silt fractions of most clastic sedimentary deposits (Smalley and others 1979; Blatt and others 1982). This is largely due to their original abundance and the relative mechanical and chemical stability of quartz compared with most other primary minerals derived from bedrock sources. Commonly, the source-rock crystals are of sand size, which limits the supply of silt. At the same time fine-grained quartz and feldspar are more reactive to the sedimentary geochemical environment due to the greater specific surface of fine silt and clay-sized particles. On the other hand, quartz and feldspar can be concentrated in the silt fraction by some geologic processes, for example glacial comminution (Haldorsen 1982; Sharp and Gomez 1986). These factors make the distribution of quartz and feldspar less likely to be simply an extrapolation of the trends within the sand and coarse silt fractions. Furthermore, pelletization and flocculation processes involving fine particles are generally not favorable for well developed size sorting. The electromagnetic differences between framework silicates, such as quartz and feldspars, and the phyllosilicates, may allow different responses to inorganic flocculation. The size distribution of quartz and feldspars has a closer, albeit modified, relation to the original particle distribution and can further illustrate the extent and size selectivity of flocculation.

The samples analyzed were taken from an excavated section 5 km NE of Göteborg, Sweden. These laminated sediments were deposited in a proximal glaciomarine environment during the last Weichselian deglaciation (Stevens 1985). The sands, silts, silty clays and fine clays occur within yearly varves and reflect seasonal variations of discharge, sediment supply, and water stratification. This environment is considered favorable for a study of inorganic flocculation due to the limited disturbance by pelletization, as is suggested by the near absence of preserved faunas (Stevens 1987).

Methods

Quartz and feldspar extracts for 25 samples were obtained by chemical dissolution of the clay minerals (Blatt and others 1982). The samples were dried and fragmented to <0.125 mm. A microsplit, 5 g portion was weighed and then mixed and heated together with 40 g anhydrous sodium bisulfate ($NaHSO_4$) over a Meker burner for 15 min in a covered, platinum crucible. After reaction with 1 M warm HCl, the residue from the crucible and its cover was filtered (Whatman #40 filter paper) and boiled for 20 min in 1 M NaOH and then washed with distilled water. The effectiveness of the extraction technique was evaluated using X-ray diffraction to identify possible surviving clay minerals and atomic-absorption spectroscopy to determine the major elemental composition. Both methods suggested that quartz and feldspar represented 95–99% of the residue.

Both the total samples and the extracts were dispersed in a sodium-oxalate ($C_2Na_2O_4$, 0.65 g/liter) solution by magnetically stirring the sediment suspensions for one half hour. In addition to deflocculation, aggregates from pelletization and moderate sediment consolidation are believed to be dispersed. Some dispersion of inherited aggregates must also be expected but is less predictable. The sediment suspensions were then analyzed during sedimentation using a 5000E Sedigraph (Micrometrics Co., Norcross, Georgia, USA). The sand-sized fractions were separately sieved and recalculated within the total distributions. Calculations for mean and standard deviation were based upon Folk and Ward (1957). The total grain-size distributions were partitioned by the graphical methods of Sinclair (1974), which help identify the common occurrence of possible log-normal subpopulations and their proportions within the observed composite distribution. The fine and coarse subpopulations considered below are those identified by partitioning the total curve into two log-normal components.

Results and Discussion

Typical size distributions for the quartz-feldspar extract and the "dispersed" total sample are shown in Figure 1. Both curves reflect the relatively good sorting of a coarse subpopulation combined with a less sorted, fine-grained portion. The break-point in the fine portions of both curves occurs at about 6 Ø (16 μm). The quartz-feldspar extracts range from 70 to 90 percent by weight of the total sample before dissolution. The relatively high content of quartz and feldspar is consistent with glacial comminution in higher latitudes. The variations of population statistics and subdivisions of the particle-size distribution are plotted in Figure 2 in relation to the content of quartz and feldspar.

Because of the extensive and unavoidable destruction of both flocs and inherited aggregates, the dispersed size distributions produced by peptizing and strong agitation are largely representative of the effectiveness of the dispersion techniques. These distributions cannot be expected to reflect the originally deposited particle populations except in their very coarsest portions where

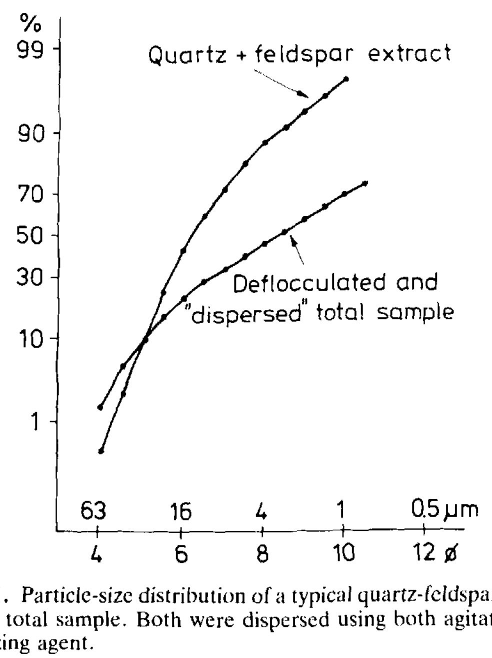

Figure 1. Particle-size distribution of a typical quartz-feldspar extract and the total sample. Both were dispersed using both agitation and a peptizing agent.

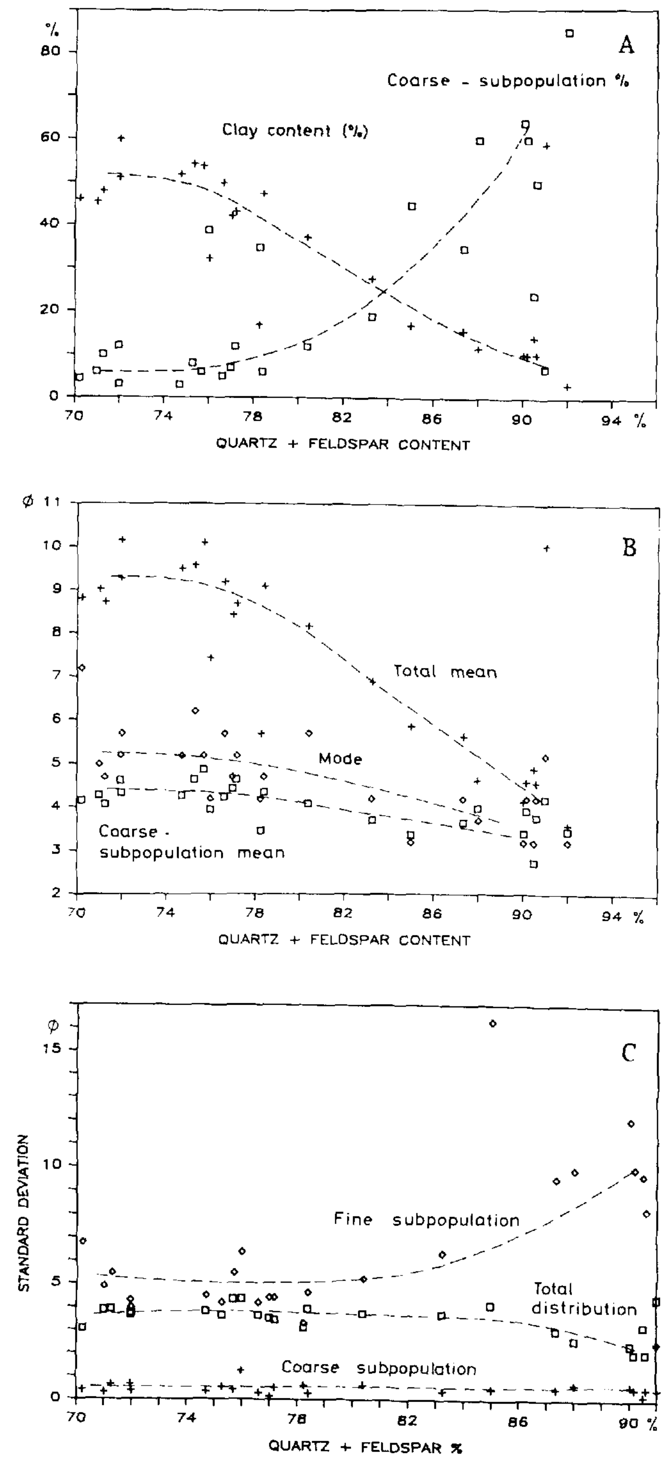

Figure 2. Relationships between the content of quartz and feldspar, determined by chemical extraction, and various descriptive parameters of 25 particle-size distributions. (A) The percentage of the partitioned coarse subpopulation increases with quartz and feldspar content whereas the clay content decreases. (B) The total mean, mode and coarse-subpopulation mean are coarser (lower Ø-values) with increasing quartz and feldspar content due to the relative coarseness of these chemically extracted components. (C) The sorting of the total distributions and the partitioned, fine subpopulation also show trends consistent with the variations in the content of quartz and feldspar, which predominate within the silt and sand fractions. The partitioned coarse subpopulation is consistently well sorted because it consists essentially of quartz and feldspar and is apparently not affected by disaggregation effects during laboratory analysis.

continued floc growth would be limited by similar settling velocities. This suggests that the partitioned coarse subpopulation is a better estimate of the original particle-size distribution. The coarse subpopulation is not always evident as a frequency mode, but in such cases the "grain mode" (Kranck 1975) can be used as an estimate of the original particle-size distribution if consideration is taken for the modal-shift effected by the overlapping portion of the fine subpopulation (Spencer 1963; Stevens 1987).

The quartz and feldspar extracts offer a separate approach to evaluating the effects of flocculation. Theoretical considerations (e.g., Bennett and Hulbert 1986; Singh and Uehara 1986) suggest that quartz and feldspar were not as extensively coagulated, either prior to or during sedimentation, as were the clay minerals. Nevertheless, the electrostatically less active character of fine-grained quartz and feldspar would neither entirely prevent their flocculation nor hinder their entrapment within flocs formed by clay minerals. The extracts, however, are believed to approximate the original particle distribution, at least in the coarsest fractions, because the quartz and feldspar grains are not broken apart by the dispersion technique as would be expected with phyllosilicates, which were presumably more involved in flocculation processes. Approximately 7–10% of the total sample distribution in Figure 1 is well sorted, similar to the range of the partitioned coarse subpopulation for most clayey samples (Fig. 2A). This can be compared with the extracted quartz and feldspar population in Figure 1 where ca. 25 percent is well sorted. This estimate may be high if some aggregate formation occurred during the dissolution techniques. Although this problem has been specifically considered and discounted by earlier workers (Blatt and Schultz 1976; Dauphin 1980), some influence upon the distribution of the particles is suspected and caution is still motivated in interpreting these results. Part of the difference between the distributions of the total sample and the quartz-feldspar extracts in their coarsest portions (Fig. 1) is presumably related to the break up during analysis of pre-flocculation aggregates, such as "domains" (Bennett and others 1981), in addition to the flocs formed during sedimentation. The consistent break in the distributions curves at about 6 Ø (16 μm) suggests, on the other hand, that flocculation has been particularly influential in the finer sizes. This boundary is utilized as a division between coarse and fine silt in a proposed textural classification scheme by Stevens (this issue).

Quartz and feldspar are presumably the dominant components in the well-sorted, coarse subpopulation. Therefore, the extract percentages generally increase together with the coarse-subpopulation percentages (Fig. 2A). Because the quartz-feldspar extracts are relatively coarse the Ø-values for the coarse-population mean, the mode and the total mean all decrease with the quartz and feldspar content (Fig. 2B). The addition of a relatively well sorted quartz-feldspar population improves the total sorting (Fig. 2C), but only slightly since the flocs are also coarser and involve particles over a wider range, thus decreasing the sorting of the fine subpopulation (higher values). This relationship is even more evident when the sorting of the different populations is plotted against the total mean. The sorting of the partitioned coarse subpopulation is very good and essentially constant for all samples. This implies that regardless of the competence of the transporting currents, the effective sorting has been quite selective with respect to the particle sizes transported and allowed to settle from suspension. The standard deviation values of the partitioned coarse subpopulation (Fig. 2C) are not sensitive to the same analytical disturbances that shifted the values of the other populations. This supports the assumption that the quartz and feldspar distribution was not controlled by flocculation in the coarse-silt fractions.

Conclusions

The well sorted, coarse portions of the quartz and feldspar extracts suggest that nearly half of these minerals (ca. one-third of the total sediment) had limited involvement in flocculation (or pelletization if this was significant). Meade (1972) concluded that the role of flocculation in estuary sedimentation had been overestimated in relation to the importance of water circulation and mixing. These factors are also considered important in the present study considering that the samples originated from a proximal glaciomarine setting characterized by meltwater overflow and stratification. The original particles may have been transported further and become better sorted than would have occurred if the meltwater were readily mixed at the marine front (Stevens 1985). This may, in part, explain the textural separation achieved and the formation of varves within a glaciomarine environment where size-sorting processes are often suggested to be inhibited.

The unavoidable breakage of sedimented flocs during laboratory dispersion requires special considerations. Quartz and feldspar extracts and distribution partitioning suggest, however, that flocculation is most important in the fine silt and clay fraction, below approximately 16 μm (6 Ø) in these samples.

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