Microtextures Studies on Quartz Grains Surface from Mesozoic Silica Sand in Elzafrana area, Eastern Desert, Egypt

Ramag Ahmed Osman

Nuclear Materials Authority, Cairo, Egypt.

ABSTRACT

Scanning electron microscopy (ESEM) analyses of quartz grains from mesozoic silica sand in Elzafrana area, revealed variations in surface textures. The results of this study reveal the existence of distinguished surface features that reflect the effect of mechanical and chemical actions on the quartz grains. This study determines the qualitative microtextural fingerprint of quartz sand grains deposited in Elzafrana, and compares that fingerprint to the fingerprints sediments of uncertain genesis, Aeolian, fluvial, mass-wasting, and other processes all create combinations of microtextures on quartz sand grain surfaces that are unique in the types. These combinations of microtextures record the paleo-environmental history of the study area from which the grains were derived; the various forms of fractures and post-fracture surface alterations found on quartz sand grain surfaces should therefore provide useful evidence of climate and other environmental aspects of the sand grain’s history. Variations in quartz surface textures were detected due to the texture created by mechanical processes was predominating. Abundant abrasion features like V-shaped pits, and linear and curved grooves usually give evidence of transport in a fluvial medium. On levels with intensive reworking and redeposition preliminary relief of grains was smoothed and obliterated. The diagnostic dissolution features were more, where intercalation of dolomites and siliciclastic rocks is common. Possible chemical etching in quartz was observed and fluid effects were responsible for barite precipitation as included in quartz grain. The variability helps to clarify the history of basin evolution and to distinguish different conditions in deposition.

Keywords: Microtextures, Quartz, Silica sand, Eastern desert, Egypt.

1. Introduction

Wadi El-Dakhl area is delineated by latitudes 28°51'45"N. and longitude 32°37'4"E. South of Galala, south of the Elzafrana area, west Gulf of Suez, Eastern Desert, Egypt (Fig. 1). The area is covered by white silica sand which is currently mined for raw glass sand through a number of open cast's quarries.

The reconnaissance silica sand sample investigates the various types of Quartz analyzed in mineral types, study of SEM operation which the study focused on one distinct type of mineral. The inherent hardness of quartz and its chemical resistance combine SEM studies, techniques of heavy liquid separation to isolate quartz. The micromorphological of quartz surface textures indicate the geologic source, transportation process, and depositional environment and geological settings. Aeolian, fluvial, mass-wasting, and other processes create combinations of microtextures on sand grain surfaces. These record combinations of microtextures inferred to the paleoenvironmental history of the area from which the grains were derived; the various forms of fractures and post-fracture surface alterations found on sand grain surfaces should therefore provide useful evidence of climate and other environmental aspects of the sand grain’s history.
The different mechanical and chemical processes effect in quartz sand grains that is apparent in the surface features. These features are described and catalogued according to depositional environment (Krinsley and Doornkamp, 1973). The weathering climate and processes were deciphered (Higgs, 1979). Significant contributions are made by Krinsley and Donahue (1968) and Krinsley and Margolis (1971) about quartz grain surface texture and their transport and depositional environment. The present study aims to characterize the microtextures of quartz grains from Elzafrana.

In order to attain these purposes the following studies conducted. A representative sample of mined silica sand was collected and subjected to sample processing to obtain a small sample of one kilogram size which is subjected to the following investigations.

1- Sieving analysis.
2- Heavy minerals separation and examinations under microscopes.
3- ESEM microscopic investigations.

2. Geology

The white sands at Wadi El-Dakhil are belong to Malha Formation (Early Cretaceous age). Malha Formation was introduced by Abdallah and Adindani (1963). It's type locality is at the southeast corner of the North Galala Plateau. (El-Shazly et al., 1974 and Cherif et al., 1989) adopted the name Malha Formation to a sequence of sandstones that underlies the Cenomanian Galala Formation. Barakat and Tewfik (1966) described Malha Formation, as a Nubia "A" as the Upper part of Nubia sandstone. It is represented by alluvial near shore sandstones with minor clay and siltstone intercalation which rests unconformably over older strata. The sandstones that crop out below the marine Cenomanian beds are represented by stratified beds. Kerdany and Cherif (1990) suggested that the Malha Formation is made up of river deposits which carried clastic materials during a low stand of sea-level from the positive areas.

The Malha Formation in the Wadi El-Dakhil area represented by 100 m. Thickness of the purest white sands. SiO$_2$ is 98.98% in the form of horizontal beds alternate with some intercalation of kaolinite and sandstones. It overlies the Jurassic age and underlies the Raha Formation. It consists of a very white sequence of stratified, cross-bedded and graded bedding sandstones.

3. Methodology

Reconnaissance sample was randomly collected from the surface of silica sand within size were measured using standard sieving and sedimentation technique. Mineral separation was carried on silica sand glass studied sample by using bromoform to exclude heavy minerals. The main physical properties taken into consideration in analyzing the sample are color, shape, roundness, particle of Elwadi Elgedid. The sample was collected from top 5 cm of the surface. Particle morphology, and surface area. Mineral separation is used bromoform in the nuclear material authority lab. to separate heavy mineral from light mineral (mainly quartz).
Investigate and analyses quartz mineral with an environmental scanning electron microscope (ESEM). This instrument is supported by an energy-dispersive spectrometer unit (model Philips XL 30). The applied analytical conditions involved 30 kV as the accelerating voltage, 1–2 mm beam diameter during 60 to 120 s as the counting time, and a minimum detectable weight concentration ranging from 0.1 to 1 wt%, housed in the Nuclear Materials Authority in Qattamiya. Each individual grain was imaged at a magnification level of approximately 100–200X. Quartz microtextures visible at that scale were analyzed in detail at magnification levels between 100-200X.

4. Sieve analysis

The study, one kilogram sample representing the sands from the lithostratigraphical unit at the Elzafrana area was subjected to dry sieve analysis. The two different main fractions were separately weighed and their weights were calculated. The results obtained are given in Table 1. The studied quartz grains are in these two sizes, medium and fine sand. The main quartz grain size is fine sand in ratio 11.20% and the medium sand are 88.8% (fig.2).

Table 1: The grain size of the studied quartz sand fractions.

| Size         | Wt. Value | Wt%  |
|--------------|-----------|------|
| <0.5–0.25    | 634       | 88.8 |
| <0.25–0.125  | 80        | 11.20|

5. Mineralology

The benefit of ESEM microtextural analysis is determining sediment signatures; there are no established a universally accepted, from precise sample size specific to the task of reliably distinguish environmental provenances of samples. In this study analyzed 200 uni-crystalline quartz sand grains selected at random from silica sand samples.

Fig. 2: Grain size distribution of quartz mineral in studying silica sand sample from the Elzafrana area.

The quartz particle surface features to discriminating environment see photomicrographs in figure 3. EDX of quartz grain analysis showed there are two groups of quartz grains one is free from barite inclusion and the other is contained in barite inclusion (fig.4A&B). Quartz sand grain has rounded dish shape concavities, straight scratches and many V-shaped percussion crack and smoothed edges (fig. 3a). The presence two rounded quartz sand grains; the upper grain shows v shaped percussion cracks with different direction and straight cracks the other grain has dish shaped concavities and show the same features like the other one plus pitted v-shape, these pits are formed by chemical dissolution or chemical weathering (fig. 3b). The rounded quartz sand grain shows cracks seem to have an indistinct low relief crescent-shaped cracks, suggesting that the may be related to mechanical action following weathering with possibly some very small v-shaped subaqueous patterns scattered irregularly about (fig.3c). Subrounded quartz sand grain has v-shaped percussion cracks that these resemble chemical features as solution pits and etching (fig.3d). Subrounded quartz sand grain has V-shaped cracks, pits, due to chemical dissolution as fluid flow (fig. 3e). Well formed barite crystal within quartz grain, this quartz sand grain has conchoidal fractures with arcuate steps (fig.3f). Two quartz grains,
which enclosed barite bright crystals that formed in quartz fractures and represent the intersection of a cleavage with the face upon which they are sitting (fig. 3g).

Fig. 3: Photomicrograph SEM of Quartz grains in silica sand in Elzafrana area.
EDX pattern of study quartz grains from silica sand in Elzafrana can be classified into two groups. The one group, EDX chart reflected quartz mineral exists which has a chemical formula SiO2 (fig.4a). The other EDX chart reflected quartz mineral existed and barite mineral is existed too, which has a chemical formula BaS (fig. 4b).

Fig. 4: EDX pattern of Quartz grains from silica sand in Elzafrana area.

6. Discussion

The studied sample contains grains that show several different types of microfeatures. Quartz grains are rounded to subangular and mainly characterized by smoothing edges. These microfeatures are described and catalogued according to depositional environment (Krinsley and Doornkamp, 1973). The weathering climate and processes were deciphered (Higgs 1979). Significant contributions are made by Krinsley and Donahue (1968) and Krinsley and Margolis (1971) about quartz grain surface texture and their transport and depositional environment. The surface textures of quartz grains observed under the SEM refer to various sedimentation environments. The surface textures are mainly characterized by the dish-shaped depressions, and V-shaped pits. One of the most important features that characterize quartz grains is barite precipitation. The V-shaped pits similar to on the present surface of quartz grains of the white sands are also common as a result of chemical processes.

Mechanically formed straight and crescent scratches are followed by impact V-shaped percussion cracks fractures. Rounding of the grains and smoothening of the edges indicates high energy zone. The solution pits are features followed by precipitation as a chemical processes. Evaporation and exposure of quartz as detrital grains pitted surfaces and rounding is indicative of chemical weathering, with partly corroded (Dickinson & Grapes, 1997). Quartz-grain surface showing pits which are formed by solution and a covering of barite particles. This implies diversity in the sediment sources and in the transport agents before the last stage of sedimentation.

Thus, the rounded to sub rounded grain outlines likely resulted from long transport distance and time or a large amount of recycled sediments (Madhavaraju et al., 2009). Alternatively, the rounded to subangular grain outline may reflect the original grain shape generated by the parent rock. As indicated in previous studies, grain outline is related to both the transportation process and the original grain shape of the source rock (Goudie and Watson 1981; Kleesment 2009; Costa et al., 2013).

The microscopic data from the detailed SEM observations of these surface textures, it is revealed that abundant mechanical textures, i.e., conchoidal fractures, step fractures, concavities, and V depressions or marks, are present on the quartz grains. In addition, displays of cracks or fissures and scratched lines are also visible. As the products of rock sheared, the existence of these surface textures provides useful information for understanding the mechanical behavior of rock sheared basal facies fragmentation. Here, it is interpreted these textures as the products of rock sheared instead of as the inheritance of features of in situ rocks or original accumulated deposits.

Hence, chemical dissolution and recrystallization of barite from a little reworking of the sedimentary source rocks adjacent to the silica sand, then precipitated in fractured quartz grains produced in history are unavoidable instead of the irregular surface fractures.
However, these textures, distributed on the surfaces of these samples from the basal facies, are not associated with the surface features indicating chemical dissolution or recrystallization that are commonly observed in a fluvial environment with a relatively longer deposit history (Wang and Deonarine 1985; Madhavaraju et al., 2009; Strand and Immonen 2010).

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Alternatively, this may be due to little reworking of the sedimentary source rocks adjacent to the silica sand. The adjacent sedimentary rocks have an important role on the distinctiveness barite which enclosed in quartz grains.

The scenario of diagnosis Barite and precipitate in quartz pits is similar as the model history of production to deposition and the diversity of grain surface microtextures in an Elwadi Elgedid area (Osman, 2021). The brief of all discussion is represented as the conceptual model. The model depicts the quartz grain history from production to deposition and the diversity of grain surface microtexture (fig. 5).

In this studied area, three characteristic features reflected the sedimentary history: (1) Small holes derived from the remnants of small inclusions in the grains showed parent rock and (2) V-shaped percussion cracks produced by grain-to-grain collisions in the aqueous environment showed transportation process. (3) The relation between the quartz morphological features.

7. Summary

In Elzafra area, four characteristic morphology features were determined for quartz grains. Those features produced by mechanical and chemical processes can be divided into four groups:

1. Rounded aeolian quartz grains dominate in the first micromorphological group showed dish shape concavities, straight scratches and many V-shaped percussion crack which has different directions, pits which formed by chemical dissolution (figs 3a&b) and crescent cracks which they may be related to mechanical action (fig 3c).

2. The second micromorphological group is subrounded fluvial quartz grains have many V-shaped percussion cracks produced by grain-to-grain collisions in the aqueous environment showed the transportation process and pits, due to chemical dissolution (fig d&c). The surface textures on quartz grains (fig 3f), it is revealed that, during the high speed motion of sliding mass, brittle fracturing behavior displays a prominent role in the fragmentation process of basal facies particles. Most brittle fractures are relatively smooth and have evident structurally controlled forms, indicating that the formation of these fractures can result from high-pressure contact between the particles. To generate such high-pressure contact environments, the occurrence of high-velocity collisions or intensive shearing processes may be indispensable (Komorowski et al., 1991; Davies et al., 1999; Crosta et al., 2007; De Blasio 2011; Hogan et al., 2012).

3. The redeposition of barite in the quartz grains cracks and pits (fig 3g). Possible chemical etching in quartz was observed and fluid effects were responsible for barite precipitation as included in quartz grain.

The texture created by mechanical processes was predominating. Abundant abrasion features like V-shaped pits, and linear and curved cracks usually give evidence of transport in a fluvial medium. On levels with intensive reworking and redeposition preliminary relief of grains was smoothed and obliterated. The diagenetic dissolution features were more, where intercalation of dolomitic and siliciclastic rocks is common. The variability of microfeatures in quartz sand grain helps to clarify the history of basin evolution and to distinguish different conditions in deposition.
Fig. 5: Model depicts the quartz grain history from production to deposition and the diversity of grain surface microtexture: a) grains with abundant small inclusion, b) grains with few small inclusion and c) Barite microinclusion in quartz grain (Osman, 2021).
8. Conclusion
1-The studied sample contains grains which show several different types of micro-characteristics. The quartz grains are rounded to subangular and mainly have smooth edges.
2-The surface textures are mainly characterized by the dish-shaped depressions, striations, and V-shaped pits. Deep etching grooves are frequently present as a result of chemical processes.
3-Examination of quartz grain surfaces from studying area in Elzafrana reveals the occurrence of mechanical and chemical surface features.
4-Mechanically formed straight scratches are a predominant feature followed by impact V-shaped percussion cracks fractures and crescent cracks. Rounding of the grains and smoothening of the edges indicates high energy zone.
5-Grooves and solution pits are dominant features followed by precipitation as chemical processes work. Quartz-grain surface showing triangular pits which are formed by solution and a covering of barite particles. This implies diversity in the sediment sources and in the transport agents before the last stage of sedimentation.
6-Thus, the rounded to subangular grain outlines likely resulted from long transport distance and time or a large amount of recycled sediments. Alternatively, the rounded to subangular grain outline may reflect the original grain shape generated by the parent rock. As indicated in previous studies, grain outline is related to both the transportation process and the original grain shape of the source rock.

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